Bridging the Gap between Seismicity and Exhumed Faults: Insights from a Seismically Active Strike-Slip Fault Zone in the Rawil Depression (Northern Valais, Switzerland)

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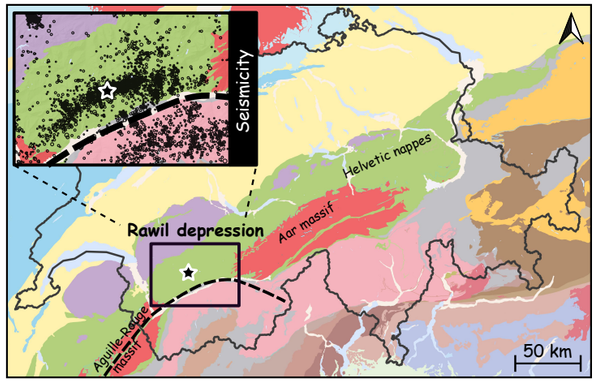
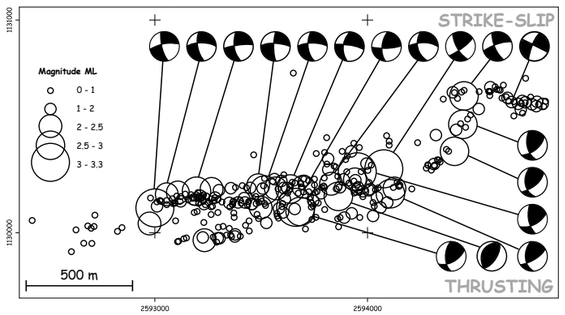
Motivation

- The **SeismoTeCH** project aims to improve the seismotectonic characterisation of Switzerland. The current **pilot study** is investigating the seismotectonics in the Rawil depression (Northern Valais, Switzerland).
- In this study, we **aim** to
  - develop tools to reconstruct seismically active faults from relocated hypocenters with high spatial resolution.
  - link the seismically active fault zones of the Anzère earthquake sequence with the exhumed fault systems in the Rawil depression.
- The **Rawil depression** provides an excellent study area because of its high seismic activity, the well-known geological setting und the unique possibility to obtain profound 3D information with depth owing the remarkable topographic relief.



Geological map of Switzerland (© swisstopo). The most prominent fault system in the Valais, the Rhone-Simplon fault zone, is marked with a dashed line. The black star denotes the location of the Anzère earthquake sequence.

- The **Anzère earthquake (EQ) sequence** consists of 320 earthquake events with magnitudes up to 3.3 that were recorded between 6th to 24th of November 2019.

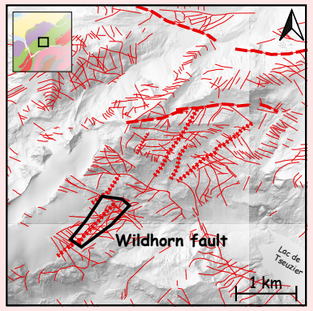


Map view of the relocalised earthquake events and the 17 calculated focal mechanisms of the Anzère EQ sequence.

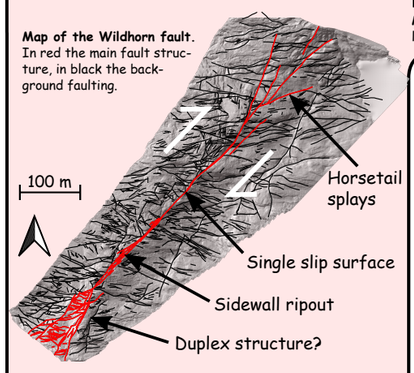
Linking Faults and Earthquakes

Faulting in the Rawil depression

- Mapping of exhumed fault systems, using field observations and remote sensing techniques, reveals two fault systems with suspected late fault activity.
  (in agreement with Cardello & Mancktelow 2015)
  - E-W striking oblique normal faults
  - NE-SW striking strike-slip faults

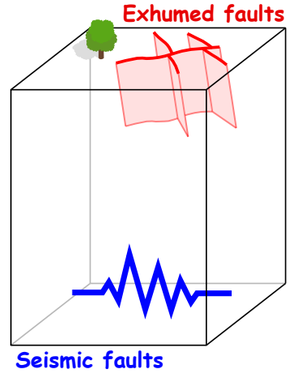


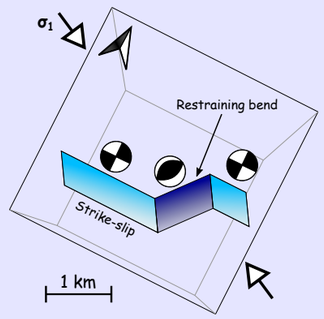
Map of regional faulting. Faults with suspected late activity are drawn bold.



Map of the Wildhorn fault. In red the main fault structure, in black the background faulting.

- The Wildhorn fault is a vertical, NE-SW trending strike-slip fault that lies within the Helvetic limestone units and around 3km NNE of the Anzère EQ sequence.
- The retreat of the Wildhorn glacier recently exposed this outcrop, which lead to a spectacular fresh outcrop situation and a unique fault rock preservation.
- Detailed fault mapping reveals the internal complexity of the carbonate strike-slip fault in great detail.
- The Wildhorn fault is supposed to have a very young age, however the direct structural relationship with the E-W striking faults and potential paleoseismic activity have to be investigated in more detail.

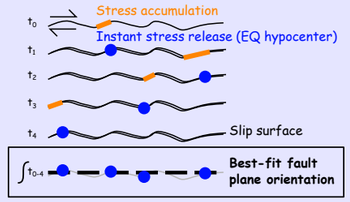




3D sketch that shows the thrusting in the restraining bend, interconnecting two strike-slip faults (Diehl et al. 2020).

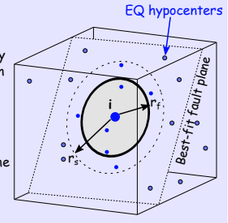
Anzère EQ sequence

- We develop an algorithm to reconstruct seismically active 3D faults from high-precision relocated earthquake hypocenters, combined with a validation procedure based on focal mechanism data, which we apply on the Anzère EQ sequence.



Repeated seismic fault reactivation can be used to reconstruct the fault plane orientation.

- For each EQ event, our algorithm scans the hypocenters for all neighbouring events within the search radius r_s and then calculates a best fit plane through the extracted point cloud, which is rejected if the defined quality criteria for a planar fit are not fullfilled.
- Our approach allows to calculate fault plane orientations and fault areas for each individual EQ event.



r_s Search radius: only hypocenters within r_s are considered for fault plane calculation

r_f Fault plane radius: calculated using the empirical Mag-A scaling law of Leonard (2014)

Schematic reconstruction of the fault plane of master event i (grey disk).

- For the Anzère EQ sequence, we detect a system of seismically active strike-slip faults with an interconnecting restraining bend.
- The spatial variablility in the calculated seismic faults suggests a complex internal structure of the fault zone architecture.

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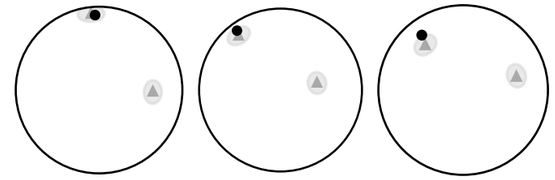
Interactive 3D Model

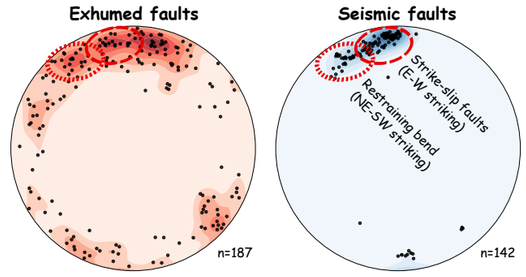
Preliminary Results

- The 3D fault network algorithm developped in this study proofs to be able to reconstruct individual fault planes that match to a great extent with the independent focal mechanism dataset. For most events, our algorithm allows us to explicitly choose one of the two possible focal plane solutions as clearly preferrable.



Comparison of the seismic fault planes (black circle) **and the respective focal plane solutions** (grey triangles) for 3 selected EQ events (stereographic projections of poles to planes, lower hemisphere, equal area).

- Exhumed and seismic faults from the 3D fault network algorithm show **significant similarity in fault plane orientations**, which indicates that
  - the youngest exhumed faults (E-W and NE-SW striking) are potentially paleoseismic structures.
  - the seismicity of the Anzère EQ sequence can be directly linked to a reactivation of pre-existing faults.



Stereographic projections of poles to fault planes (lower hemisphere, equal area). Field data of exhumed faults from within 5km radius of the Anzère EQ sequence.

- A combined approach of studying specific exhumed faults and reconstructing seismically active faults in great detail has the potential to **overcome the current limitations** (e.g. EQ relocation precision, number of EQ in a seismic sequence) to obtain more profound knowledge about the detailed 3D geometries of seismically active faults and the seismic rupturing processes.
- For **future work**, we plan to
  - include hypocenter relocation uncertainties to obtain a probabilistic 3D fault network model with a Monte Carlo approach.
  - also include kinematic constraints to receive more insights into the stress states of the seismically reactivated faults.
  - apply the 3D fault network algorithm on further EQ sequences with high-precision relocated hypocenter datasets.
  - further explore the complexity of seismic fault zone geometries and the consequences for the seismicity of faults.

References: Cardello, L., Mancktelow, N. (2015): Veining and post-nappe transtensional faulting in the SW Helvetic Alps (Switzerland), Swiss Journal of Geosciences Vol. 108.
Leonard, M (2014).: Self-consistent earthquake fault-scaling relations: Update and extension to stable continental strike-slip faults, Bulletion of the Seismological Society of America Vol. 104/6.
Diehl, T., Kissling, E., Lee, T., Schmid, S., Herwegh, M. (2020): New Tomographic Models for High-Resolution Seismotectonic Interpretations in the Central Alps, Swiss Geoscience Meeting.