Geophysical Research Abstracts
Vol. 20, EGU2018-13766-1, 2018
EGU General Assembly 2018

High-resolution earthquake catalog and seismic velocity models to image the structure of seismogenic faults zones in the Valais (Switzerland)

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The seismicity in the Valais (southwest Switzerland) is mainly concentrated in the Rawil region, forming an E-W lineament, sub-parallel to the Rhone-Simplon line (RSL), but offset by 5-10 km to the north of it. The RSL forms the tectonic boundary between the Penninic and the Helvetic nappes and is characterized by dextral deformation. The apparent offset between seismicity and the RSL raises the question where current deformation is localized along the EW striking section of the RSL. Considering the uncertainty of routine earthquake locations reported in the bulletin of the Swiss Seismological Service (SED), it is currently unclear whether the seismicity lineament indicates the existence of a 20-km single long fault or several small fault segments. In the former case, the structure would have the potential to host magnitude 6-7 earthquakes. On the other hand, hypocenters reported in the routine SED bulletin range from very shallow (surface) to about 10 km depth, which suggests brittle deformation across the basement-cover contact. Whether or not the earthquakes penetrate into the basement can indicate if deformation is thick- or thin-skinned. Such conclusions, however, crucially depend on uncertainties associated with bulletin focal depths. In addition, information on the 3-D velocity structure could constrain the geometry of the major tectonic units and their boundaries, e.g. the Helvetic nappes, the Penninic nappes, the Aar massif, and the RSL. High-precision hypocenters combined with the 3D velocity structure can therefore clarify the relationship between seismicity, tectonic units, and fault zones in a regional context.

In this study, we first aim to minimize the uncertainties of bulletin hypocenters in the Valais region. Bulletin hypocenter locations reported in earthquake catalogues are determined with an a priori (often suboptimal) 1-D or 3-D velocity model. However, travel times depend on hypocentral parameters as well as seismic velocities (the coupled hypocenter-velocity problem). The so-called minimum 1-D model calculation, which involves simultaneous inversion of arrival time data from local earthquakes, is a well-established approach to solve the coupled-problem for a region and therefore provides robust and accurate absolute locations. To better understand the spatio-temporal distribution of the seismicity and its connection to mapped fault zones, we establish a high-precision earthquake catalog by first relocating absolute hypocenter locations of the last 33 years with the minimum 1-D model approach for the Valais region. These hypocenters are further improved by relative double-difference relocation, including waveform cross-correlation techniques.

Finally, we aim for a local 3-D earthquake tomography image with a spatial resolution of 5x5x5 km to measure lateral and vertical velocity variations and to determine the dominant tectonic units. This model will benefit from the significantly improved ray coverage in the Valais compared to models computed e.g. a decade ago. Previous 3-D models of this region had resolution of 15x15 and 25x25 km, which are insufficient to resolve the tectonic units targeted in our study. The derived high-precision earthquake catalog together with the high-quality tomographic image and available focal mechanisms will then improve the understanding of upper-crustal structures and seismotectonics of this region.