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3D visualization of deformation structures and potential fluid pathways at the Grimsel Test Site

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Knowledge on the ability of fluids to infiltrate subsurface rocks is of major importance for underground constructions, geothermal or radioactive waste disposal projects. In this study, we focus on the characterization of water infiltration pathways, their 3D geometries and origins. Based on surface and subsurface mapping in combination with drill core data, we developed by the use of MoveTM (Midland Valley Exploration Ltd.) a 3D structural model of the Grimsel Test Site (GTS). GTS is an underground laboratory operated by NAGRA, the Swiss organisation responsible for the management of nuclear waste. It is located within a suite of post-Variscan magmatic bodies comprising former granitic and granodioritic melts, which are dissected by mafic and aplitic dikes. During Alpine orogeny, the suite was tectonically overprinted within two stages of ductile deformation (Wehrens et al., in prep.) followed by brittle overprint of some of the shear zones during the retrograde exhumation history. It is this brittle deformation, which controls today's water infiltration network. However, the associated fractures, cataclasites and fault gouges are controlled themselves by aforementioned pre-existing mechanical discontinuities, whose origin ranges back as far as to the magmatic stage. For example, two sets of vertically oriented mafic dikes (E-W and NW-SE striking) and compositional heterogeneities induced by magmatic segregation processes in the plutonic host rocks served as nucleation sites for Alpine strain localization. Subsequently, NE-SW, E-W and NW-SE striking ductile shear zones were formed, in combination with high temperature fracturing while dissecting the host rocks in a complex 3D pattern (Wehrens et al, in prep.). Whether the ductile shear zones have been subjected to brittle reactivation and can serve as infiltration pathways or not, depends strongly on their orientations with respect to the principal stress field. Especially where deformation structures intersect each other, water flow is high. Our 3D structural model allows the recognition of such intersections in 3D space and the prediction of their spatial extent. The structural model developed with the introduction of the locally known hydraulic permeabilities and in combination with the results of on-going hydrochemical investigations will allow to estimate the location of the recently active water pathways.

References

Wehrens, P., Baumberger, R., Berger, A., & Herwegh, M. (in prep.). How is strain localized in a mid-crustal basement section? Spatial distribution of deformation in the Aar massif (Switzerland).