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Hydrogeological properties of fault zones in a karstified carbonate aquifer and their impact on groundwater circulation (Northern Calcareous Alps, Austria)

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This study presents a comparative, field-based hydrogeological characterization of exhumed, inactive fault zones in low porosity Triassic dolostones and limestones of the Hochschwab massif, a carbonate unit of high economic importance supplying 60% of the drinking water of Austria‘s capital Vienna. The hydrogeology (groundwater storage and flow) of the massif has been reported to be essentially governed by karstified, large-scale faults. Previous work has shown that faults that formed during the Oligocene to Miocene lateral extrusion of the Eastern Alps act as groundwater pathways draining the karst massif preferably in E-W-direction. We present hydrogeological relevant data from these types of fault zones and a conceptual model, which supports the idea that fault-zone networks also have the potential to contribute significantly to the storage capacity of the aquifer.
With respect to fault zone architecture and rock content, four types of faults are presented: (1) faults with single stranded, minor fault cores, (2) faults with single stranded, permeable fault cores, (3) faults with single stranded, impermeable fault cores, and (4) faults with multiple stranded, permeable fault cores. Within these faults cataclastic rocks and strongly cemented cataclastic breccias form low-permeability (< 1 mD) domains. Fractured rocks with fracture densities varying by a factor of 10 show significantly elevated porosities (> 3%) with respect to the country rock (< 1%). Dilation breccias with average porosities > 3% and permeabilities > 1000 mD form high-permeability domains. Our data illustrates significant differences in the architectural build-up of fault zones in dolostone (multiple-stranded cataclastic fault cores of weak lateral continuity, high volumes of intensely fractured rock) and limestone (laterally distinct, single-stranded fault cores, Riedel-shear fractures dominating fracture patterns). Karstic carbonate dissolution occurs preferentially along faults cores in limestones and, to a lesser degree, dolostones creating superposed high-permeability conduits.
All faults contain domains of brecciated and highly fractured rocks along their lateral and vertical extension and are therefore considered as conduits on both the outcrop and the regional scale. The abundance of low- to medium-displacement faults suggests that connected fault-zone networks exist throughout the Hochschwab plateau. Such fault networks are assumed representative for the entire watershed.
Based on fault zone architecture and quantitative hydrogeological data of fault zones in the catchment of the Kläffer spring, a Monte Carlo simulation of a conceptual fault-zone network was done to clarify whether faults with porosity characteristics established in this study are able to contribute significantly to the winter base flow of the spring, or significant additional storage volume has to be taken into account. Simulations account for the uncertainties of the size of the catchment area, average fault porosity, and total fault zone volume. It is shown that a minimum of around 5% of fault-zone volume over the whole catchment area is required to deliver the base discharge of the main spring system.