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Assessment of groundwater origin and discharge in crystalline basement using hydrochemistry and strontium isotope ratios

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In order to make reliable prognoses on water leakage in hard rock tunnels and to prevent large-scale water inflow into such tunnel systems a detailed knowledge of groundwater discharge is of high significance. Groundwater discharge is affected by the geological, tectonic and lithological conditions in the catchment area. Because crystalline rocks are generally less permeable, the occurrence of deep circulating groundwater is limited to fractures, lineaments, joints and cleavages. However, layers of highly soluble rocks, e.g. carbonate rocks may be intercalated in crystalline sequences resulting in local karst formation that may not be recognizable on the surface. Therefore, the main goal of this investigation is the assessment of the usability of various tracer methods including hydrochemical and isotope tracers to find indications of such layers. In this study, we employ 87Sr/86Sr isotope ratios as a natural tracer to distinguish groundwater that has been influenced by carbonates dissolution from groundwater that is solely affected by silicate weathering in crystalline catchment areas.

The investigated area, the Koralm massif, is situated in Carinthia (Austria) and consists of a polymetamorphic crystalline basement. The crystalline basement is constrained by major fault zones, which have generated Tertiary basins on both sides of the mountain range. Mylonitic gneisses and micaschists are the predominant lithologies. Occasionally, marbles, amphibolites, and eclogites are intercalated. Because of the low permeability of the crystalline schists, the Koralm massif is mainly characterized by surface runoff and numerous small springs. However, fractures in the marble layers represent very important pathways for fluids in the crystalline basement. Large-scale water inflow into the tunnel can occur when the tunnel excavation progresses in short distance from low permeable crystalline layers to high permeable zones (e.g. fault structures which are connected to karstified marbles). To investigate the genesis of the water, spring water samples were collected at representative sites across the mountain range and analyzed for major solute concentrations, environmental isotopes, and 87Sr/86Sr ratios.

Based on saturation indices for calcite and 87Sr/86Sr ratios, the influence of dissolving calcium carbonate and mixtures between crystalline and carbonate waters can easily be identified. 87Sr/86Sr ratios vary from 0.7098 to 0.7200 with lowest values reflecting carbonate dissolution and highest values associated with the weathering of silicate minerals. 87Sr/86Sr ratios support the results from other hydrochemical parameters analyzed in this study. The results of this study clearly demonstrate that the combination of hydrochemical investigations and 87Sr/86Sr ratios provide very useful information about the geochemical evolution of groundwater in crystalline basements. Moreover, it is possible to distinguish between different lithologic settings in the crystalline recharge areas.