Composition of spring and deep borehole waters in the granitic Ringelbach research catchment (Vosges Mountains, France): contribution of a hydrogeochemical modeling approach

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The Ringelbach catchment is located in the Vosges Mountains (France). It has been equipped with 150-m-deep boreholes, enabling the sampling of both rock and groundwater in the granitic bedrock, and waters of several springs have also been sampled, mainly along a same slope (Figure 1). The data point to very contrasting chemical compositions between spring and borehole waters, but also to some variations within each water type. The hydrogeochemical code KIRMAT combined to the available hydrological and geochemical data sets was used to simulate these differences.

Simulations were performed for the two main groundwater pathways: a shallow subsurface and fast water flow (>2.5 m$_{H2O}$.yr$^{-1}$) in the regolith, which is parallel to the slope, for waters supplying the springs, and a vertical and slower flow (0.5 to 0.1 m$_{H2O}$.yr$^{-1}$) within the granite weathering profile for the borehole waters.

For borehole waters (Figure 2), the model confirms the importance of the dissolution of minor mineralogical phases that are present in the granite (carbonates/dolomites) on the chemical budget of waters. It shows that the chemical differences between the boreholes waters result from differences in the water flow in the granitic bedrock. This result likely highlights the role of geological inheritance on the hydrodynamical rock properties and the chemical compositions of waters circulating within the granitic bedrock.

For spring waters (Figure 3), the model enables to constrain the nature of the regolith, which is neither saprolite nor fresh granite but instead a weathered granite with a weathering age of several tens of thousands of years. Spatial and seasonal variations in the chemical compositions of spring water can be explained within the same circulation pattern as the result of differences in pathway length and water velocity that both control the water-rock interaction times. If this interaction time is long enough, the precipitation of clay phases is enabled, which plays a major role in determining the water chemical composition.

Despite the only one-dimensional approach and the uncertainties linked to the geochemical complexity and the associated kinetic data, the results demonstrate the effectiveness of using such a hydrogeochemical modeling to better understand and quantify the weathering processes and the coupling that exists between water circulation dynamics and water-rock interactions at the catchment scale.

References


Figure 1: Topographic and geologic map of the Ringelbach catchment with the locations of the sandstone spring (SRV), granitic springs (blue circles) and boreholes (F-HUR, F-HEI, F-HEI2). The dotted line indicates the position of the geological section presented below. From Schaffhauser et al. (2014) and Lucas et al. (2017).

Figure 2: Comparison of measured and simulated Mg concentrations of borehole waters after 10,000 years of weathering. From Lucas et al. (2017).

Figure 3: Variations of simulated final water Mg concentration along the sloping regolith layer after 10 years of weathering and comparison with measured granitic spring water samples. From Lucas et al. (2017).