Water in fractured crystalline rocks, data from the Gotthard railroad tunnel

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The new 53km long Gotthard railroad tunnel currently under construction will be the longest tunnel in the world when completed. It traverses the Alps across strike of the major tectonic units. We present water data from the northern section Amsteg-Sedrun, mostly in steeply dipping granite and gneiss of the Aarmassiv. A large number of water inflow fractures were opened and water samples regularly collected and analyzed. Water temperature was up to 44˚C. The rock column above the sampling point is locally more than 2000m.

The composition of the water varies widely, the total of dissolved solids (TDS) ranges from < 100 to > 5000 mg L^{-1}. High pH and high fluoride is characteristic. Here we present exclusively water from fractured Southern Aar-Granite with TDS = 380 mg L^{-1} and pH = 9.69. Sulfate is the dominant anion; Cl is present in significant amounts. Dissolved solids are essentially mixtures of Na_2SO_4 and $CaSO_4$. Mg is below detection limit. The water is saturated with respect to quartz and calcite, undersaturated with respect to primary granite minerals including microcline and strongly oversaturated with respect to Ca-zeolites leonhardite and laumontite as well as chlorite. Calcite saturation buffers log p_{CO2} to very low values of about -6. Ca-zeolites are the most prominent late stage fracture and fissure minerals coating open cavities, often with impressive mats of laumontite needles.

The water in the tunnel is meteoric recharge water that evolves along the flow path through fractured crystalline basement by reaction with primary minerals of the rocks. We suggest that the cations Ca and most of the Na are released by plagioclase hydrolysis and sulfate originates from sulfide oxydation. On the other hand, some of the Na and most chloride is contributed by crushed fluid inclusions and leached grain boundary salt of gneiss and granite. This is suggested by Cl/Br of ~80 (on a ppm basis). Sulfide oxidation initially consumes dissolved oxygen and produces sulfuric acid that is later utilized in feldspar alteration reactions. The Ca/(Ca+Na) ~ 0.26 (molal) of the fluid suggests that both cations are plagioclase controlled. Feldspar alteration increases pH as reaction progresses and the fluid rapidly reaches saturation with respect to Ca-zeolites. The stable zeolite under present water conditions is stilbite (or stellerite). The currently important reaction in the water-rock system is the conversion of plagioclase to stilbite. Primary biotite of the granite is converted to chlorite, hematite and rutile. The reaction buffers Mg to very low values. The K released by the reaction is insufficient to precipitate adularia, which is a wide spread mineral in Alpine fissures at slightly higher temperatures.