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Origin of solutes in surface waters from high Alpine catchments, Zermatt area (Swiss Alps)

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Research on water-rock interaction quantitatively models geochemical reactions and transport of solutes as coupled phenomena. We studied the chemical evolution of surface waters in Zermatt-Matterhorn area, Switzerland. The chemical characteristics of the surface water have been used to infer the mechanisms of solute acquisition in open system in geologically diverse Alpine catchments. The surface water in study area is predominantly controlled by the interaction of meteoric water with the exposed rocks. Dissolving primary minerals of the predominantly metamorphic rocks contribute to the observed total dissolved solids with leaving behind a residue of newly formed insoluble minerals.

A total of 102 water samples were collected mainly from small water bodies located in Zermatt-Matterhorn area representing the geographical and lithological diversity. Altitudes of sampling locations range from 1600m to 3200m. Since water samples were from water bodies at high elevation, water-rock interaction was little affected by anthropogenic or biologic contributions.

Temperature, pH, and electric conductivity were measured on site. Total dissolved solids was relatively low and varies from 6 to 244 mg/l. Dominant solutes are Ca, Mg, HCO3, SO4 and minor components are Na, K, NO3, Cl and Si, while F and B occur in traces only. The calculation of saturation states with PHREEQC shows that all surface waters are undersaturated with respect to all relevant minerals. Statistical analysis of the composition data shows that Ca-HCO3-SO4 and Na-K-SiO2 are strongly correlated. Three chemical types of water can be distinguished: Ca-HCO3, Mg-HCO3 and Ca-SO4.

A hydro-geochemical inverse model has been set up for interpreting the water-rock interaction that estimated the contributions of the various rock-forming minerals to the composition of the waters. It shows that: 1) Ca-HCO3 water result from interaction of precipitation with mafic schist or calcareous micaschist, the reaction can be summarized as: 1) Meteoric water + CO2 + O2 + pyrite + epidote + chlorite + albite + phengite + “halite” = “quartz” + goethite + kaolinite + Ca-HCO3 water and 2) Meteoric water + CO2 + O2 + calcite + pyrite + albite + phengite + chlorite ± “halite” = ±“quartz” + goethite + kaolinite + Ca-HCO3 water. Magnesium-rich Mg-HCO3 water is produced from reaction of precipitation with serpentinite: 3) Meteoric water + CO2 + O2 + antigorite + diopside + phengite + pyrite = magnesite + talc + goethite + Mg-HCO3 water. Sulphate-rich Ca-SO4 water occur mainly in gneiss and granite catchments, where the precipitation interacted with pyrite-baring rocks according to the reaction: 4) Initial water ± CO2 + O2 + pyrite + plagioclase + K-feldspar + chlorite ± halite = goethite + kaolinite + albite ± quartz + Ca-SO4 water.