Copper isotopes in surface- and groundwater as indicators of hydrothermally altered crystalline bedrock in Handcart Gulch, Colorado, USA

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Handcart Gulch is an unmined alpine watershed that drains mineralized and hydrothermally altered crystalline rocks. The stream water is naturally acidic, with pH between 3 and 4 most of the year. The waters have high concentrations of metals and sulfate, typical of streams draining rocks rich in sulfide minerals. Low stream pH values (pH 3 to 3.7) inhibit adsorption of Cu, so its behaviour should be nearly conservative. Conservative behaviour implies that variations in both Cu concentrations and isotopic ratios should be controlled by distinct inputs from surface and groundwater sources, rather than in-stream processes such as adsorption. Stream-water samples were collected in 2014 along a 1.5-km reach of the stream. Groundwater was collected from 5 shallow (<50 m) wells along the same reach and 2 deep (>150 m) wells located near the top of the watershed. Copper concentrations and δ^{65}Cu values in well waters peaked at the same location but there was a slight lag in the stream, so that the highest Cu concentrations and δ^{65}Cu values in stream water were seen 100-200 m further downstream. Based on these results, we resampled along a 5.4 km reach of Handcart Gulch in 2017 and installed 19 shallow (≤2 m) piezometers. The concentrations of Cu and other metals and SO_4^{2-} in stream- and groundwater change in the same areas as previously observed, with a similar lag between groundwater and stream water. The pH of groundwater in this reach is generally <3, but the stream pH remains >3. At the groundwater Cu peak, the input of high concentrations (>2 mg/L) of isotopically heavy Cu (7‰ relative to SRM-976) may reflect a different source of Cu compared to other parts of the watershed, such as weathering of a different style of bedrock mineralization or alteration associated with a concealed mineralized zone in the rock.