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Compositional Change of Meltwater Infiltrating Frozen Ground

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Meltwater reaching the base of the snowpack may infiltrate the underlying stratum, form runoff, or refreeze, forming a basal ice layer. Frozen ground underneath a melting snowpack constrains infiltration, promoting runoff and refreezing. Compositional changes in chemistry take place for each of these flowpaths as a result of phase change, contact between meltwater and soil, and mixing between meltwater and soil water. Meltwater ion concentrations and infiltration rate into frozen soils both decline rapidly as snowmelt progresses. Their temporal association is highly non-linear and the covariance must be compensated for in order to use time-averaged values to calculate chemical infiltration over a melt event. This temporal covariance is termed 'enhanced infiltration' and represents the additional ion load that infiltrates due to the timing of high meltwater ion concentration and infiltration rate. Both theoretical and experimental assessments of the impact of enhanced infiltration have shown that this association causes a greater ion load to infiltrate leading to relative dilute runoff water. Sensitivity analysis showed that the magnitude of this 'enhanced infiltration' is governed by initial snow water equivalent, average melt rate, and meltwater ion concentration factor. Based on alterations in water chemistry due to various effects, including enhanced infiltration, three major flowpaths were hypothesized distinguishable: overland flow, organic interflow, and mineral interflow. Laboratory experiments were carried out in a temperature-controlled environment to identify compositional changes in water from these flowpaths. Samples of meltwater, runoff, and interflow were filtered and analyzed for major anions and cations. Chemical signatures for each flowpath were determined by normalizing runoff and interflow concentrations to meltwater concentrations. Results showed that changes in ion concentrations were most significant for H^+, NO_3^-, NH_4^+, Mg^{2+}, and Ca^{2+}. Repeated flushes of meltwater caused a washout of ions from the flowpaths. In the field, samples of soil water and ponding water were collected daily from a Rocky Mountain hillslope during snowmelt. Their normalized chemical compositions were compared to the laboratory-identified signatures to evaluate the flowpath. The majority of the flowpaths sampled had chemical signatures indicating mineral interflow, only 10% showed unmixed organic interflow; no samples indicated overland flow.