Goldschmidt 2026 Abstract
https://doi.org/10.46427/gold2026.34508

Arctic Rusting: Understanding Iron Release from Thawing Permafrost at Multiple Scales

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Permafrost thaw is reshaping northern landscapes by altering hydrological flow paths, soil moisture and thermal regimes, and mobilizing iron (Fe). Recent arctic Fe stream rusting signals subsurface changes to permafrost conditions and impacts the vitality of local streams and vegetation. While many sampling locations in the arctic are difficult to access, the oxidation-reduction (redox) reactions of Fe can be observed from space via satellite as their products absorb/reflect electromagnetic radiation in the ultraviolet/visible spectrum. However, knowledge gaps exist in linking the quantitative spectral qualities (i.e., band index) of the water column to a quantitative chemical composition, and further comparisons to subsurface terrain features, vegetation vitality, and ecosystem resiliency. This study combines bulk and micro-scale geochemical tools with spatial data (satellite and unmanned aerial systems; UAS) to track arctic rusting over landscapes and link numerical, spectral Fe-index values with chemical composition of stream water. The study sites range from high gradient mountain bedrock streams to low gradient tundra streams in arctic Alaska. The highest concentrations of total aqueous Fe (nearly 80 mg/L) were found near a mountain seep in a primarily weathered bedrock regolith area. Concentrations of Fe adjacent to stressed vegetation reached elevated levels of 35 mg/L total Fe. While upstream concentrations of Fe were elevated, stream stabilization did occur at the mountain study site approximately 2500 meters downstream from the seep, coinciding with an increase in pH values and 1000-fold decrease in total Fe. Cumulative results from UAS and satellite imagery analysis show general agreement between platforms with UAS exhibiting higher Fe-index values, reflecting differing spatial resolutions. However, clear distinctions in water-column Fe distributions may convolute the remote interpretation of Fe concentrations. Overall, combining quantitative spatial characterizations of Fe with micro-scale chemical measurements provides an integral link to understanding subsurface terrain processes derived from permafrost thaw and aids efforts to scale numerical riverine Fe estimations across broad landscapes.