

Baseline geochemical characterization of trace elements in stream sediments in mineralized watersheds of the Duluth Complex, northeastern Minnesota

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Abstract Characterizing baseline conditions in mineralized watersheds of the Mesoproterozoic Duluth Complex, northeastern Minnesota, is essential to establishing the scientific context needed to responsibly extract minerals in one of the most prospective mining areas in the United States. Future mining could potentially release metals into watersheds that already naturally contain significant amounts of some elements.

Stream-sediment samples were collected from 19 sites in three watersheds that span a diversity of geologic settings and mineralization styles in the Duluth Complex to help characterize baseline stream sediment geochemistry prior to mining. The geochemistry of the sediments reflects underlying rock types, glacially transported unconsolidated materials, and the mineralization style within each watershed. The watersheds are located: 1) where Cu-Ni-PGM mineralization occurs in near-surface boulders and outcrops along the basal Duluth Complex (Filson Creek); 2) where Cu-Ni-PGM mineralization occurs only at great depth (Keeley Creek), and 3) in the vicinity of Fe-Ti oxide ultramafic intrusions that occur at the subcrop beneath glacial cover (St. Louis River).

In Filson Creek, with mineralization near the surface, stream sediments generally contain higher Cu than where mineralization occurs only in the deep subsurface (Keeley Creek). In the St. Louis River, concentrations of Fe, Cr, Mg, and Ti increase downstream near the basal section of the Duluth Complex, and Cr, Cu, Ni, and Pb are highest where the river flows across exposed rocks of the Virginia Formation, a Paleoproterozoic shale/greywacke unit. The influence of trace element concentrations on the aquatic ecosystem also was evaluated. Total Cr concentrations in stream sediments in the lower part of the St. Louis River and total Cu and Ni concentrations at some sites in Filson Creek exceed concentrations at which harmful effects to sediment-dwelling organisms are likely to be observed (probable effects concentrations). Nearly all of the Cd, Cu, Pb, and Zn, and most of the As, likely occur in bioaccessible forms, based on an extraction method that solubilizes metals not tightly bound to silicates and sulfides. In addition, an excess of labile metals that are not bound to metal sulfides (based on AVS/SEM) suggest potential toxicity; however, the high organic carbon of some sediments (up to 5 wt. %) could sequester significant amounts of trace elements.

Characterizing sediment trace element content and bioaccessibility, and assessing impacts on the current ecosystem health in these watersheds, may help to develop successful strategies that can minimize and mitigate future impacts of mining and develop appropriate restoration goals.

Keywords Cu-Ni-PGE deposits, Fe-Ti oxide deposits, St. Louis River, organic carbon, AVS/SEM

