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Impact of Ferrihydrite Transformation on Heavy Metal Mobility and Fixation in Acid Mine Drainage

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The precipitation of Fe minerals, including ferrihydrite, schwertmannite, and goethite, which play a crucial role in the sequestration of heavy metals. However, ferrihydrite and schwertmannite are metastable phases that undergo transformation to more thermodynamically stable minerals, such as goethite. This mineralogical transformation influences the redistribution, release, and re-adsorption of associated heavy metals, thereby controlling their mobility, bioavailability, and long-term environmental fate in systems impacted by acid mine drainage (AMD). Despite the significance of this process, the mobility of heavy metals during in situ ferrihydrite-goethite transformation remain poorly constrained. This study investigates these transformations by analyzing core samples exhibiting mineralogical transformation with depth. The mineralogical changes and geochemical characterization of Fe and eight heavy metals (As, Cd, Co, Cr, Cu, Ni, Pb, and Zn) were investigated to evaluate the mobility trends during mineral transformation.

As, Co, and Zn exhibited declining concentration ratios relative to Fe with depth, implying preferential association with ferrihydrite. Conversely, Cr demonstrated increasing relative concentrations, suggesting enhanced affinity for goethite. Cd, Cu, Ni, and Pb showed no consistent depth-related trends, highlighting the complexity of their interactions. Sequential extraction analyses revealed Cr and Cd as predominantly exchangeable fractions, indicating high mobility and environmental risk. In contrast, As, Pb, and Zn became more strongly retained, reducing their mobility and potential bioavailability. These findings underscore the critical role of ferrihydrite transformation in controlling heavy metal partitioning and fixation in AMD environments, emphasizing its implications for long-term contaminant stability, geochemical cycling, and remediation strategies.