

Local hydrothermal sources for Superior-type iron formations: Insights from the Animikie Basin

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Superior-type iron formations (IFs) provide large amounts of iron ore worldwide. Early studies proposed models for Superior-type IFs that involved the delivery of Fe from riverine inputs or from the deep ocean to the outer continental shelf via dynamic upwelling currents. However, the low contents of detritus in IFs and the restricted rate of upwelling in palaeo-oceans do not favour these depositional models for Superior-type IFs. Here, we report major and rare earth element compositions of core samples from Superior-type IFs of late Palaeoproterozoic age from proximal (near-shore) to distal (off-shore) areas of the Animikie Basin in the Lake Superior region, North America. The geochemical characteristics of these IFs, including Eu anomalies and trace element patterns, show that Fe was directly supplied by local hydrothermal exhalative systems rather than by seawater upwelling or continental input. Furthermore, covariation in the Ce anomaly and Fe speciation ratios ($\text{Fe}_{\text{carb}}/\text{Fe}_{\text{T}}$) suggests that most IFs were deposited close to (but below) the Mn redoxcline, where Fe is easily oxidised, which implies that Fe was locally oxidised without long-distance migration. Accordingly, our study proposes a new model for Superior-type IFs whereby ferrous Fe that is discharged from local hydrothermal vents can be locally and partially oxidised in shallow suboxic areas of a redox-stratified ocean. Enhanced hydrothermal fluxes associated with active mantle plume events are presumed to account for this increased delivery of Fe during the late Palaeoproterozoic.