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A multi-proxy approach to understanding the origin of Cryogenian iron formations in South Australia and worldwide

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Cryogenian iron formations (CIFs) contain critical insights into the dynamics of Snowball Earth events. However, the source and transport mechanisms of iron remain poorly understood. While a hydrothermal origin for CIFs is widely favored, significant variations in their geological and geochemical characteristics across different locations complicate our understanding. For instance, some CIF deposits exhibit no distinct Europium (Eu) anomalies, while others show positive Eu anomalies that are weaker than those found in Archean iron formations. To better constrain the source of iron in CIFs, we measured Eu anomalies, Co/Zn ratios, MnO contents, and δ56Fe values in two CIFs from the Adelaide Superbasin, South Australia: the Holowilena CIF, formed in a relatively shallow oceanic environment, and the Braemar CIF, which formed in a deeper setting. The Holowilena deposit exhibits pronounced positive Eu anomalies (0.97–1.46 Eu/Eu*), lower Co/Zn ratios (0.05–0.15), lower MnO contents (0.01–0.18 wt%), and higher δ56Fe values (-0.56‰ to 2.36‰), suggesting a stronger hydrothermal signature in the shallower CIF compared to the Braemar deposit. A compilation of global CIF data reveals systematic co-variations between these geochemical parameters, supporting the hypothesis of a local hydrothermal source for CIFs. Our findings suggest that iron was sourced from hydrothermal vents in restricted rift basins and transported to the deeper open ocean. This transport pathway, combined with variations in the redox state at deposition sites, may explain the diverse geochemical characteristics observed in CIFs worldwide.