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The formation of high-grade iron formation-hosted iron ores in the Northern Cape Province of South Africa – insights from iron isotopes and trace elements

ALBERTUS JOHANNES BASSON J.B. SMITH[1] AND STEFAN V. LALONDE[2]

[1]University of Johannesburg

[2]University Brest

Presenting Author: bertuss@uj.ac.za

The Northern Cape Province of South Africa has multiple high-grade iron formation-hosted iron ore deposits occurring in the Neoarchean to Paleoproterozoic Transvaal Supergroup. Larger deposits formed by supergene processes, whereas smaller deposits are hydrothermal. The main ore-forming mechanism was the leaching of quartz, leading to residual iron enrichment, and the oxidation of all iron minerals to hematite. However, petrographic observations, such as specularite veins, suggest that some iron mobilization took place. To gain insight into the post-depositional fluid chemistries that formed these ores, the trace element and iron isotopic composition of three ore deposits (two supergene, one hydrothermal) and host iron formation were assessed.

Two of the deposits (one supergene, one hydrothermal) show $\delta^{56/54}$Fe values that cluster in the middle of the range observed in the host iron formation, suggesting little post-depositional $\delta^{56/54}$Fe fractionation took place, whereas one supergene deposit shows $\delta^{56/54}$Fe values that are more depleted (Figure A). The supergene deposits show positive and negative cerium anomalies, whereas such anomalies are absent from the hydrothermal deposit (Figure B). The host iron formations show no cerium anomalies. One supergene deposit shows an inverse correlation between $\delta^{56/54}$Fe values and cerium anomalies (Figure B).

A highly alkaline fluid would have been required to dissolve and remove the silica (generally >50 wt%) of iron formations. Furthermore, the conversion of all iron minerals to hematite would have required an oxidative fluid. However, for the cerium anomalies to develop, mildly reducing conditions would have been required. In the ore deposit where the $\delta^{56/54}$Fe values are more depleted, it appears that fluids were reducing enough to locally mobilize iron and fractionate $\delta^{56/54}$Fe to more negative values. Where clear petrographic evidence exists for hematite mobilization but a lack of $\delta^{56/54}$Fe fractionation is observed, a highly acidic fluid would have been required for non-redox iron mobilization. The main implication of this study is that no single fluid chemistry can account for the observed data, but that more than one fluid phase, or evolving fluid chemistry, was required. It also indicates that there were differences at a regional scale in iron ore formation processes.