Economic Geology
Vol. 98, 2003, pp. 1449–1462

Deposition, Diagenesis, and Secondary Enrichment of Metals in the Paleoproterozoic Hotazel Iron Formation, Kalahari Manganese Field, South Africa

HARILAOS TSIKOS,[†,*] NICOLAS J. BEUKES,
Geology Department, Rand Afrikaans University, Auckland Park 2006, South Africa

JOHN M. MOORE,
Geology Department, Rhodes University, Grahamstown 6140, South Africa

AND CHRIS HARRIS[**]
Department of Geological Sciences, University of Cape Town, Rondenbosch 7700, South Africa

Abstract

The Kalahari manganese field in the Northern Cape province, South Africa, is a world-class manganese resource (ca. 8 billion tons at 20–48% Mn). It occurs within the Hotazel Formation in the uppermost Paleoproterozoic (2.65–2.05 Ga) Transvaal Supergroup and comprises three laminated Mn ore units interbedded with iron formation. Currently, mining of manganese is concentrated in two areas of the Kalahari manganese field, in the south and in the north of the field, which respectively contain low-grade (<40 wt % Mn) carbonate-rich ore, and high-grade, carbonate-free, oxide-rich ore (generally >44 wt % Mn). In the southern Kalahari manganese field, the iron formation contains quartz, magnetite, and carbonate (calcite, ankerite) as chief mineral constituents, and exhibits bulk chemical and isotopic signatures comparable to other Paleoproterozoic iron formations of the world. Carbonate isotope compositions in the iron formation ($\delta^{13}C$ = –18 to –4‰ vs. PDB; $\delta^{18}O$ = 12–20‰ vs. SMOW) indicate diagenetic processes involving oxidation of organic carbon, and reduction of Fe^{3+} sedimentary precursors. Values from the inter-bedded manganiferous units ($\delta^{13}C$ = –12 to –8‰; $\delta^{18}O$ = 14–22‰) are interpreted to reflect similar processes, with Mn^{4+} acting as the sole electron acceptor.

Over large parts of the northern Kalahari manganese field, pre-1.9 Ga shales of the Olifantshoek Supergroup unconformably overlie the Hotazel Formation. In these areas, three diverse iron formation types were identified across the Hotazel stratigraphy (from bottom to top): (1) least-altered iron formation, which is identical to that seen in the southern Kalahari manganese field; (2) dolomitized iron formation, containing quartz, incipiently oxidized magnetite (to hematite), and Ca-Mn–enriched dolomite; (3) enriched iron formation, comprising exclusively SiO_2 (as quartz) and Fe oxide (as hematite). Mass balance calculations indicate that enriched iron formation formed through carbonate leaching and residual Fe^{3+}-enrichment of least-altered iron formation, accompanied by compaction and mass loss of ca. 20 percent. On the other hand, dolomitized iron formation resulted from partial Fe oxidation and carbonate dissolution-reprecipitation at depth, in the form of Ca-Mn–enriched dolomite. $\delta^{18}O$ values of the latter (20–21‰) are higher than those of earlier diagenetic carbonates by 2 per mil on average, whereas $\delta^{18}O$ values of secondary hematite in enriched iron formation are lower than those of precursor magnetite by approximately the same amount. This suggests the involvement of an isotopically light fluid (either meteoric water or a low-temperature hydrothermal fluid) in the oxidation, leaching, and enrichment of the iron formation. The possibility emerges that extensive fluid flow in the Kalahari manganese field was related to the Hotazel/Olifantshoek unconformity.

[†] Corresponding author: e-mail, harryt@earth.ox.ac.uk
[*]Present address: Department of Earth Sciences, University of Oxford, Parks Road, Oxford, OX1 3PR, UK.
[**]Present address: Departement de Géologie, Université Jean Monnet, Saint-Etienne CEDEX 2, France.

0361-0128/01/3389/1449-14 $6.00