

## Paleomagnetic Constraints on Ages of Mineralization in the Kalahari Manganese Field, South Africa

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### Abstract

We report paleomagnetic data from samples spanning several grades of enrichment in the Kalahari manganese field, South Africa, in order to assess mineralogical aspects of the ore-forming stages, and also to date these stages through comparison to previously existing, well dated paleomagnetic results from the Kaapvaal-Kalahari craton. Our paleomagnetic study confirms a multistage evolution for the orebodies, with three distinct, ancient remanent directions preserved. An early diagenetic remanence direction (MAM-1), associated with "dusty" hematite inclusions (1–10  $\mu\text{m}$ ) that are omnipresent in the microcrystalline matrix of low-grade, Mamatwan-type ore, yields a tilt-corrected paleomagnetic pole ( $-08.2^\circ$  N,  $111.1^\circ$  E,  $dp = 5.6^\circ$ ,  $dm = 11.1^\circ$ ;  $n = 6$  specimens) that is similar to previous results from the immediately underlying Ongeluk lavas. A late diagenetic or weak metamorphic overprint (MAM-2), carried by recrystallized hematite (20–250  $\mu\text{m}$ ), within both Mamatwan- and Wessels-type ore, generates a paleomagnetic pole (present coordinates  $12.1^\circ$  N,  $321.8^\circ$  E,  $dp = 3.4^\circ$ ,  $dm = 6.0^\circ$ ; tilt-corrected  $16.1^\circ$  N,  $317.8^\circ$  E,  $dp = 3.4^\circ$ ,  $dm = 6.4^\circ$ ;  $n = 14$  specimens) that resembles those from the ca. 1900 Ma Hartley lavas and Mashonaland sills. The MAM-2 overprint may be related to Kheis thrusting at 1750 to 1800 Ma as previously proposed or to magma-driven fluid migration during rifting as the Hartley-Mashonaland igneous event perforated the Kalahari craton. The third magnetic component observed in our sample suite (WESS) is restricted to high-grade Wessels-type ore, rich in high Fe hausmannite and coarser hematite (0.1–1.0 mm), in the immediate vicinity of north-trending normal faults. It yields a pole ( $54.4^\circ$  N,  $033.7^\circ$  E,  $dp = 4.7^\circ$ ,  $dm = 9.1^\circ$ ;  $n = 7$  specimens) that is similar to both the ca. 1250 and 1100 Ma portions of the Kalahari craton's apparent polar wander path. Either of these ages would be in accordance with previous multigenetic models for the Wessels event and its regional crosscutting relationships. Our WESS paleomagnetic pole, combined with previous paleomagnetic results from the Sishen-Postmasburg region, temporally links Kalahari manganese field hydrothermal upgrading with east vergent thrusting in the Griqualand West foreland, during the early or medial stages of the late Mesoproterozoic Namaqua orogeny.