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Petrogenesis of Discordant Magnesian Dunite Pipes from the Central Sector of the Eastern Bushveld Complex with Emphasis on the Winnaarshoek Pipe and Disruption of the Merensky Reef

ROGER N. SCOON†

P.O. Box 2461, Rivonia 2128, South Africa

AND ANDREW A. MITCHELL

School of Geology, University of KwaZulu-Natal, Private Bag 54001, Durban 4000, South Africa

Abstract

Discordant ultramafic bodies are a significant feature of the Bushveld Complex, South Africa. Many of these bodies form subvertical, cylindrical pipes oriented more or less at right angles to gently dipping layered rocks. Three main types of discordant ultramafic body have been identified: the (unmineralized) magnesian dunite pipes, the iron-rich ultramafic pegmatite, and the platiniferous dunite pipes. The magnesian dunite pipes, such as the Winnaarshoek occurrence, are most prominent in the central sector of the eastern limb. The Winnaarshoek pipe consists of two cores of magnesian dunite (a fine- to medium-grained assemblage of forsteritic olivine with accessory Cr spinel), together with an extensive rim of clinopyroxenite pegmatite. We emphasize that the mineralogy and chemistry of the magnesian dunite pipes is quite different from those of the iron-rich ultramafic pegmatite (coarsely crystalline rocks composed largely of fayalitic olivine, augite, and Fe-Ti oxides). The platiniferous dunite pipes constitute a third category of discordant ultramafic body because, in addition to Pt-rich core zones, they consist of both magnesian dunite and iron-rich ultramafic pegmatite. In determining the possibility of locating pipe-type platinum ores in other layered intrusions, the spatial association of primitive and differentiated lithologies within the Bushveld occurrences should be recognized.

Mining operations exploiting layered reefs in the Bushveld Complex are adversely affected by discordant ultramafic bodies, and identification of the different types has important consequences. Both the unmineralized magnesian dunite and platiniferous dunite pipes may be associated with catastrophic downwarping of the layered cumulate wall rocks, whereas the discordant iron-rich ultramafic pegmatite bodies are considerably less disruptive as they exhibit evidence of passive volume-for-volume replacement. Ultramafic and mafic cumulate layers, including the Merensky reef, are cut out from the downwarped envelope associated with the Winnaarshoek pipe as well as from a juxtaposed megapothole structure. A transitional facies of the Merensky reef is developed on the margins of the megapothole and a localized thick reef facies occurs on the margins of the downwarped envelope.

Field relationships demonstrate that the different types of discordant ultramafic body in the Bushveld Complex are unlikely to be consanguineous. The iron-rich ultramafic pegmatite is ascribed to magmatic replacement of layered cumulate wall rocks in response to the downward-draining of differentiated melts derived from within the intrusion, but the magnesian dunite pipes are a product of primary magmatic processes. Mineralogical and chemical similarities between the magnesian dunite pipes and layered olivine cumulates located in the lowermost part of the intrusion are unlikely to be coincidental. The olivine layers accumulated as a result of fractional crystallization of ultramafic magmas episodically injected into the intrusion as basal flows; the magnesian dunite pipes formed by flowage differentiation of similar magma batches within vertical conduits. The only liquidus phases during formation of the olivine layers and magnesian dunite pipes were forsteritic olivine and Cr spinel. Crystallization of orthopyroxene and plagioclase in the vertical conduits was suppressed as a high temperature was maintained by forced upward convection, such that the differentiated residue was ejected upward into the resident magma. Vertical conduits developed in response to syn-Bushveld tectonism that included diapirism, triggered by the anomalously high heat flux associated with the central sector of the eastern limb. The clinopyroxenite pegmatite rim, as well as the downwarping and absence of ultramafic and mafic layers proximal to the Winnaarshoek pipe, is attributed to selective partial melting of ferromagnesian components within noritic wall rocks. Facies changes on the margins of the downwarped structure, as well as within the megapothole, may indicate the nearly synchronous formation of all three features at Winnaarshoek: Merensky reef, megapothole, and magnesian dunite pipe.

† Corresponding author: e-mail: rnscoon@iafrica.com

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