The Merensky Reef at Winnaarshoek, Eastern Bushveld Complex: Insights from a Wide Reef Facies

Roger Scoon[1] and Andrew A. Mitchell[2]
[1]P. O. Box 2461, Rivonia 2128, South Africa
[2]University of Durban-Westville, Private Bag X54001, Durban, 4000, South Africa
e-mail: rnscoon@iafrica.com

Introduction

The Merensky reef is described from the Winnaarshoek property in the eastern limb of the Bushveld Complex, South Africa. The Merensky reef in the western limb of the Complex has been extensively studied, but information on the reef from the eastern limb comes primarily from the original studies of Wagner (1929). Winnaarshoek provides an interesting locale for our study as the Merensky constitutes a wide-reef facies with PGE mineralization distributed over a height of 1.8 m. The Winnaarshoek facies differs from the widely described, and relatively high grade, thin-reef Merensky reef facies at Brakspruit in the Rustenburg area of the western limb. Mineralization at Brakspruit is concentrated into a 0.15-0.25 m thick reef-zone that comprises a layer of pegmatoidal feldspathic pyroxenite bounded by two thin chromitite layers (Viljoen & Hieber, 1986). PGE concentrations in the Merensky reef at Winnaarshoek form two distinct peaks separated by a barren middling. The main peak occurs within the uppermost part of a layer of feldspathic pyroxenite associated with an upper chromitite layer. A secondary peak is associated with a lower chromitite layer. A layer of pegmatoidal feldspathic pyroxenite that occurs below the lower chromitite is only sporadically mineralized. The occurrence of PGE mineralization within a reef-zone defined by two thin layers of chromitite is a feature typical of the Merensky reef throughout the Complex, as is the empirical observation that the wider the reef-zone the lower the mineable grade.

The Merensky reef is a far more complex orebody than may be realized. Cryptic layering of the PGE mineralization presents difficulties with optimizing mining cuts. Mineralization may be developed over several metres, with the highest grades restricted too a narrow part, or parts, of the reef-zone. Cryptic layering is difficult to identify in the thin-reef facies, other than the well-documented association of the highest grades with chromitite layers, but at Winnaarshoek layering is preserved on a more-or-less cm scale. We demonstrate that the PGE mineralization is closely related to compositional variations in the host pyroxenite. This relationship suggests that controls on PGE mineralization are essentially primary magmatic, with minor postcumulus modification by late intercumulus processes. The importance of chromitite layers in the mineralizing process is further advanced (Scoon and Teigler, 1994).

The Merensky Cycle

The Merensky cycle is a sequence of layered cumulates that occurs near the top of the Upper Critical zone. At Winnaarshoek, this cycle comprises a 2-5 m thick layer of feldspathic pyroxenite that is sharply overlain by a sequence of norite-leuconorite, spotted-mottled anorthosite, and mottled anorthosite. This is not a simple differentiation cycle (Scoon & Teigler, 1994). A notable feature is the paucity of norite-leuconorite; the main components of the cycle are feldspathic pyroxenite and anorthosite. Two thin chromitite layers are generally present within the upper part of the pyroxenite. The upper layer of chromitite is typically located 0.4-0.5 m below the contact with the overlying norite-leuconorite. This chromitite is only 8-10 mm thick, but is laterally very persistent. The lower layer of chromitite occurs 1.8 m below the upper chromitite, is 1-25 mm thick and is considerably more erratic. A layer of pegmatoidal feldspathic pyroxenite occurs below the lower chromitite.

Merensky Reef

Winnaarshoek is one of the few sites in the Complex where the Merensky reef is readily identifiable in outcrop; the reef, in fact, crops out for over 1.5 km on the eastern flank of a low ridge and dips gently toward the west. We also mapped the Merensky reef in extensive underground workings that were developed during the platinum "rush" of 1925-9, and logged several hundred drill core intersections. The following description is a synthesis of our interpretation of the "typical" Winnaarshoek facies. The reef-zone is entirely enclosed within the basal ultramafics; no mineralization has been recorded in the norite-anorthosite component of the Merensky cycle.

The feldspathic pyroxenite consists largely of medium-grained (1-30 mm) orthopyroxene crystals with intercumulus plagioclase, and exhibits both poikilitic and porphyritic textures. A prominent characteristic is the presence of scattered, large (10-20 mm) oikocrysts of light green clinopyroxene. These oikocrysts are a feature of most of the pyroxenite layers within the eastern limb, but are absent from the western limb. Diffuse segregations of pegmatoidal pyroxenite occur within the pyroxenite, most notably above the upper chromitite layer.

Two mineralization peaks are identified, the Upper reef and the Lower reef (Fig. 1). The richest mineralization is found in the Upper reef (colloquially referred to as "top-loading", a characteristic feature of the Merensky reef, including the thin-reef facies). The Upper reef is typically 0.5-1 m thick and is rich in disseminated base-metal sulfides. The main peak of PGE mineralization is sharply cut-off by the upper chromitite layer. The pyroxenite above the upper chromitite, which characteristically includes diffuse segregations of pegmatoid, is only poorly mineralized, but does contain abundant base-metal sulfides. The Lower reef is typically restricted to the lower chromitite layer but may include the underlying sporadically mineralized pegmatoid. The 0.8-1.3 m of pyroxenite between the Lower reef and the Upper reef is generally barren, as is the 2-3 m of pyroxenite below the pegmatoid. Locally the entire sequence between the upper and lower chromitite layers is mineralized, thus forming a much thicker, composite reef. Locally, the Lower reef may be richer than the Upper reef. Variations from the norm may be due to proximity to potholes, particularly in sections where the pyroxenite is considerably thinned. A regional facies change also occurs proximal to a large dunite pipe in the northern part of Winnaarshoek.

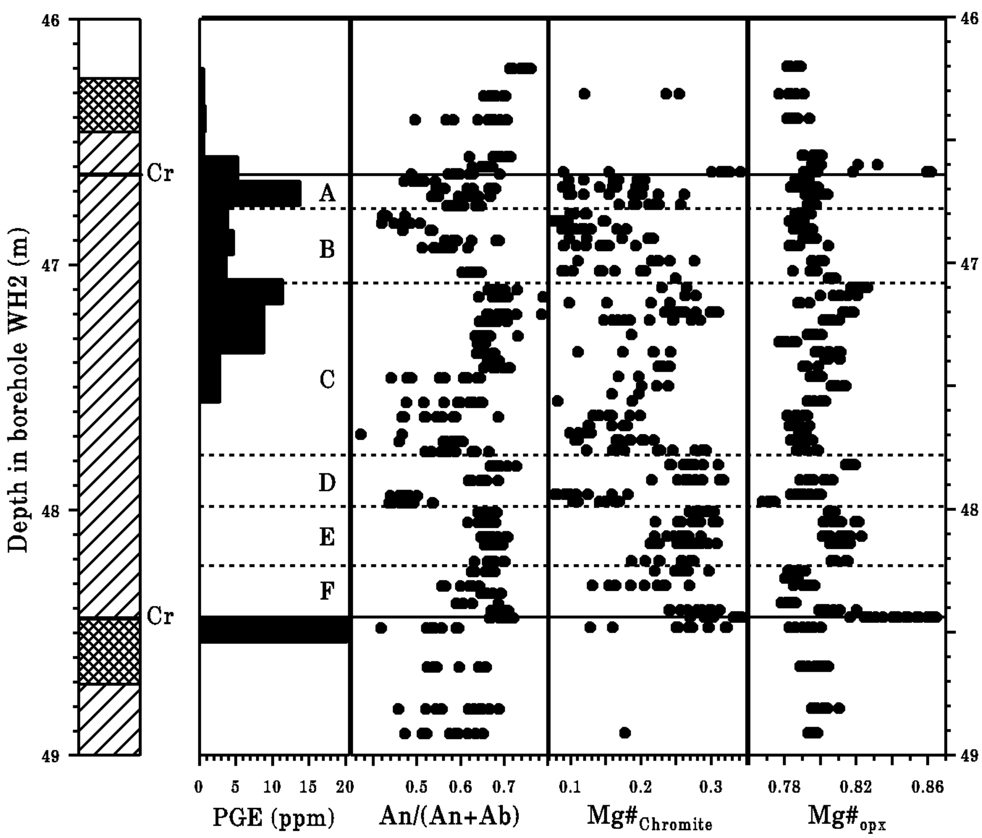

Figure 1. *Whole-rock PGE values and mineral chemistry of plagioclase, chromite and orthopyroxene in the Merensky Reef in borehole WH2. Diagonal hatching on stratigraphic column indicates medium-grained feldspathic pyroxenite, fine cross-hatching pegmatoidal feldspathic pyroxenite, and no ornamentation leuconorite. The lower layer of pegmatoid is laterally contiguous, but the upper layer is patchy and discontinuous. Position of chromitite layers indicated by "Cr". PGE values are the sum of Pt, Pd, Rh and Au, and Mg# is the Mg-number (Mg/(Mg+Fe^{2+})).*

Principal differences between the Merensky reef-zone at Winnaarshoek and that at Brakspruit are as follows: (a) the relatively wide separation of the chromitites results in the PGE mineralization forming two discrete layers. (b) PGE mineralization is situated some several metres above the base of the Merensky cycle, whereas at Brakspruit it occurs at the base. (c) PGEs occur in a medium-grained pyroxenite and the pegmatoidal pyroxenite is only sporadically mineralized.

Mineral Chemistry and PGE Distribution

All samples discussed here were taken from borehole WH2. The reef was intersected at a depth of 50 m proximal to the old underground workings in an area where we have good geological control. Compositional variations in chromite, orthopyroxene and plagioclase, determined by electron microprobe analysis, are compared with whole-rock PGE contents (Fig. 1). The most primitive chromite compositions occur in the upper and lower chromitite layers, but the highest Cr_2O_3 contents are encountered in disseminated chromite grains within the pyroxenite. Orthopyroxene and plagioclase compositions, particularly as regard the Mg-number and An/(An+Ab) ratios, respectively, display cyclicity. Based on a combination of PGE, chromite, orthopyroxene and plagioclase compositional systematics, the pyroxenite between the upper and lower chromitites has been divided into a series of units. These divisions are not rigid, and should be viewed specifically as an aid to the description of the Merensky reef succession in borehole WH2. The uppermost three units, together with the upper chromitite, form the Upper reef. The lowermost three units form the barren lower part of the pyroxenite between the Upper and Lower reefs.

The uppermost unit (A) carries high PGE values and chromite and plagioclase compositions are demonstrably more primitive here than in the upper part of the underlying unit (B). Units B and C carry significant PGE values, with the latter being particularly richly mineralized, and report the most primitive compositions of chromite, orthopyroxene and plagioclase in the succession between the chromitite layers. An upward differentiation trend is identified in unit B, but unit C reports a reversal with the Mg-number of the orthopyroxene increasing upward. These cycles are superimposed on otherwise relatively uniform orthopyroxene compositions in the overlying and underlying units.

The most conspicuous difference between units A-C and the underlying units D-F is the absence of PGE values from the latter. There is a slight inflection in the Mg-number of the orthopyroxene across the boundary between units C and D, but wide within-sample compositional ranges prohibits identification of an equivalent inflection in plagioclase and chromite. There is an apparent trend of reversed fractionation in all three minerals in unit D. Unit F has relatively fractionated orthopyroxene compositions, comparable with those below the lower chromitite rather than with the overlying units.

Discussion

There is no consensus on the origin of the Merensky reef. Data presented here are compatible with a magmatic origin for the PGE mineralization. Scoon & Teigler (1994) interpreted height-related trends in the PGE-bearing, sulfide-poor, chromitites of the Bushveld Complex (LG1 through UG1) as evidence of repeated replenishment of a differentiating magma chamber. The UG2 and Merensky reefs are thought to be a continuum of this process, with the higher concentrations of PGE attributed to episodic triggering of S-saturation.

Cm-scale layering in the Merensky reef-zone at Winnaarshoek suggests recognition of multiple replenishment and magma mixing processes. Differentiation trends within the pyroxenite suggest replenishment occurred as sequential intrusions of small batches of magma. PGEs were primarily concentrated into two layers, the lower chromitite, and the upper chromitite together with units A-C of the pyroxenite. Sulfur saturation and PGE mineralization were triggered relatively high in the Merensky reef-zone, as compared with the thin-reef facies at Brakspruit. Formation of both chromitite layers and/or PGE mineralization is ascribed to magma mixing due to repeated replenishment.

Downward percolation of dense PGE-rich sulfide melts within the reef-zone has in part obliterated primary trends. Remobilization of PGE-rich sulfide melts may have in part been caused by additional heat due to repeated replenishment. The distinction between thin-reef and wide-reef facies is dependent on separation of the chromitite layers (timing of magma replenishment). The width of the Lower and Upper reefs in a wide-reef facies is in part related to the degree of remobilization.

Summary

Cm-scale layering within the Merensky reef-zone in the WH2 borehole succession has a complex origin and some 11 different layers or units are recognized.

(a) The pyroxenite above the upper chromitite layer, although poorly mineralized, contains abundant base-metal sulfides and segregations of pegmatoidal feldspathic pyroxenite.
(b) The upper chromitite layer is laterally contiguous and contains moderate PGE values.
(c) The pyroxenite between the two chromitite layers is subdivided into six units:
    (i) Unit A, with high PGE values, can be distinguished from the underlying unit B in terms of chromite and plagioclase compositions.
    (ii) Unit B has moderate PGE values that are accompanied by an upward differentiation trend in the Mg-number of orthopyroxene.
    (iii) Unit C contains high PGE values that are accompanied by a reversed differentiation trend in the Mg-number of orthopyroxene.
    (iv) Units D-F carry no PGEs.
(d) The lower chromitite layer is typically richly mineralized.
(e) The layer of pegmatoidal feldspathic pyroxenite is sporadically mineralized.
(f) The footwall pyroxenite is generally barren.

References

Scoon, R. N. and Teigler, B., 1994, Platinum-group element mineralization in the Critical Zone of the western Bushveld Complex: I. Sulfide-poor chromitites below the UG-2: ECONOMIC GEOLOGY, v. 89, p. 1094-1121.

Viljoen, M.J. and Hieber, R., 1986, The Rustenburg Section of Rustenburg Platinum Mines Limited, with reference to the Merensky Reef. in: Anhaeusser, C. R. and Maske, S. (eds.), Mineral Deposits of Southern Africa, v. II, Geological Society of South Africa, p. 1107-1134.

Wagner, P.A., 1929. The Platinum Deposits and Mines of South Africa: Edinburgh, Oliver & Boyd, 326p.