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# Multi-stage alteration, rheological switches and high-grade gold mineralization at Sheba Mine, Barberton Greenstone Belt, South Africa

Lucas Pintos Cerda *, Caitlin Jones, Alexander Kisters

*Department of Earth Sciences, University of Stellenbosch, Matieland 7602, Stellenbosch, South Africa*

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ABSTRACT

Structural, petrographic and geochemical data from Sheba Gold Mine in the Barberton Greenstone Belt of South Africa indicate that gold mineralization formed at the end, and as the result of a multi-stage structural, fluid flow and alteration history. This multi-stage evolution is a prerequisite for the formation of high-grade (>40 g/t Au) ore bodies. The Sheba Mine is situated in well-bedded metaturbidites of the Mesoarchaean Fig Tree Group and structurally infolded ultramafic lavas in the first-order, refolded Ulundi syncline in the northern parts of the belt. Original komatiitic lava flows are pervasively altered to talc-carbonate greyschist. This regionally widespread alteration relates to an early phase of deformation and associated fluid flow. The reaction softening associated with this alteration accentuates rheological anisotropies within the heterogeneous wall-rock sequence. This results in the localization of strain along the contact between talc-carbonate greyschist and overlying, massive greywacke and chert units during later-stage refolding and associated flexural slip. Pervasive quartz veining, silicification, K-enrichment and the progressive replacement of the earlier talc-carbonate assemblages by a high-variance quartz-fuchsite green schist alteration testify to the localized fluid flow along this contact. The newly formed, finely intergrown green schist assemblage leads, in turn, to a reaction hardening and embrittlement of the former greyschist-chert contact. High-grade gold mineralization is hosted by brittle quartz-carbonate vein networks and breccias developed along brittle-ductile structures that cross-cut the competent green schist at high angles. The siting of gold and predominance of free gold suggest that gold precipitation is related to extreme fluid pressure cycling and phase separation of the mineralizing fluid during the formation of the brittle fracture networks. The thrust kinematics of the late-stage controlling structure studied here indicate that the mineralized structure accommodated regional NW-SE subhorizontal shortening when further tightening of the Ulundi syncline passed the lock-up stage could no longer be accommodated by flexural slip. The results highlight that the formation of favourable conditions for high grade mineralization, such as those at Sheba Mine, may be the result of the interaction of temporally distinct fluid flow and alteration events and lithological heterogeneities during the progressive structural evolution of a region.

## 1. Introduction

A common observation in orogenic lode gold deposits worldwide is the introduction of gold late in the paragenetic sequence or structural evolution of individual deposits (e.g., Bohlke and Kistler, 1986; Cox et al., 2001; Forde, 1991; Forde and Bell, 1994; Goldfarb et al., 2001; Groves et al., 2000; Groveset al., 1998; Powell et al., 1991; Robert and Poulsen, 2001; Willman, 2007). Reasons for this have variably been discussed as changes in the physicochemical conditions of mineralizing fluids (e.g., Craw et al., 2006; MacKenzie and Craw, 2007), progressive changes in the kinematics or geometries of the hosting structures and/or stress fields (e.g., Forde, 1991; Forde and Bell, 1994; Willman, 2007), changes in particular rheological properties of rocks due to newly formed alteration parageneses or the reactivation and reutilization of pre-existing structures, lithological contacts or earlier phases of mineralization (Craw et al., 2006; Forde and Bell, 1994; Koegelenberg et al., 2016; Zhang et al., 2020). In most cases, the late-stage introduction of gold is commonly interpreted to occur towards the end of a protracted fluid history and progressive structural evolution (e.g., Cox, 1995; Groves et al., 2000), but there is also evidence for gold being introduced in temporally unrelated mineralization events (e.g., Chauvet, 2019; Thébaud et al., 2018).

* Corresponding author.
*E-mail addresses:* lucasromanpintos@hotmail.com (L. Pintos Cerda), caitlinjones.geo@gmail.com (C. Jones), akisters@sun.ac.za (A. Kisters).

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