Ore Geology Reviews 144 (2022) 104805

Contents lists available at ScienceDirect

Ore Geology Reviews

journal homepage: www.elsevier.com/locate/oregeorev

Regional and local controls of hydrothermal fluid flow and gold mineralization in the Sheba and Fairview mines, Barberton Greenstone Belt, South Africa

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ARTICLE INFO

Keywords:
Archaean lode-gold mineralization
Barberton Greenstone Belt
Bedding-parallel fluid flow
Flexural-slip folding
Fluid sinks

ABSTRACT

High-grade gold-quartz-sulphide lodes of the Sheba-Fairview Complex (SFC) of gold mines in the Barberton Greenstone Belt of South Africa describe a wide range of geometries, orientations, controls, and a number of different and often contradicting models have been postulated to account for their formation. This paper aims to present a holistic model that describes the focussing of a regional-scale fluid flow into narrower, mineralized structures during the late-stage refolding and tightening of the first-order folds that host the mineralization.

The auriferous reefs of the SFC are hosted by well-bedded, low-grade metamorphic, clastic sedimentary rocks of the Paleoarchaean Fig Tree and Moodies groups that are preserved in two regional-scale, strongly curved and refolded synclinal structures along the northern margin of the belt. The majority (85 %) of presently and historically mined orebodies occur in the broad hinge zone of the refolded synclines. This suggests the regional-scale fluid redistribution from fold limbs into the first-order fold hinge following regional hydraulic gradients during refolding. Ubiquitous bedding-parallel quartz (-carbonate-sulphide) veins and associated alteration underline the significance of bedding anisotropies and bedding-parallel flexural slip for regional-scale fluid flow during refolding. The focussing of these fluids and economic-grade gold mineralization occurs preferentially along contacts between lithologies with pronounced rheological contrasts. Lithological contacts combine the effects of strain localization in weaker units and the formation of fracture permeabilities in competent units across these contacts. Examples include kilometer-scale hinge-parallel ore shoots that are controlled by undulations (jogs) along low-displacement slip horizons between retrogressed ultramafic rocks and competent metasediments. In contrast, low-angle thrusts or steep reverse faults form accommodation structures related to the late-stage tightening of the first-order folds. These structures transect bedding at high angles and are, thus, ideally orientated to collect fluid from the regional system of bedding-parallel fluid flow.

Mineralization in the SFC may be explained by the spatial and temporal coincidence of (1) late-stage NW-SE shortening and refolding, of (2) a well-bedded, anisotropic wall-rock sequence, associated with (3) regional-scale fluid redistribution along bedding planes during flexural slip, leading to (4) fluid focussing into either jog geometries or bedding discordant structures. The combination of these factors is unique to the SFC and accounts for the location of the main Barberton gold mines along the northwestern margin of the greenstone belt.

1. Introduction

The processes of fluid focussing into faults and shear zones are reasonably well understood, highlighting the relationship between deformation, the creation and sealing of transient fracture permeabilities, and associated fluid-pressure cycling (Cox et al., 1987, 1991, 2001; Sibson et al., 1988; Eisenlohr et al., 1989; Hronsky et al., 1990; Groves et al., 1995; Sibson, 2001). Much of this work is based on the analyses of exhumed fault and vein systems of lode-gold deposits. The deposits illustrate the three-dimensional geometry and connectivity of fluid-plumbing structures particularly well (Oliver et al., 1990; Ridley, 1993; Cox, 1995; Sibson, 1996, 2020; Goldfarb et al., 2001). What is less well known, is how the large quantities of fluid required for economic-grade gold mineralization are sourced and channelled from a larger region of fluid production with a more distributed fluid flow (e.g., Cox et al., 2001; Cox 2005). Pervasive fluid flow implies lower volumes of

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https://doi.org/10.1016/j.oregeorev.2022.104805
Received 2 August 2021; Received in revised form 4 January 2022; Accepted 26 February 2022
Available online 1 March 2022