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The effects of fault-zone architecture, wall-rock competence and fluid pressure variations on hydrothermal veining and gold mineralization along the Sheba Fault, Barberton Greenstone Belt, South Africa

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A B S T R A C T

Hydrothermal vein systems illustrate the spatial and temporal evolution of structural permeabilities along the Sheba Fault, the first-order fault structure in the Sheba-Fairview complex of gold mines in the Archaean Barberton greenstone belt. The fault juxtaposes competent Moodies Group metapsammites against rheologically weaker metaturbidites and intercalated serpentinites of the Fig Tree and Onverwacht groups. Strain localization into the weaker lithologies results in the pronounced asymmetric zonation of the fault into a fault core and a fault-damage zone. The fault core in the weaker Fig Tree and Onverwacht lithologies is characterized by the transposition of earlier bedding and pervasive foliation development. In contrast, hydrothermal veining, alteration and mineralization are confined to competent Moodies Group rocks that form the tens of meter wide damage zone in the immediate footwall of the fault core. Vein systems of the Sheba West ore body disclose the multistage evolution of the fluid flow system along the fault. An early phase of crackle-breccia formation and associated carbonate (dolomite) alteration is regionally widespread and largely pre-dates the main phase of gold mineralization. Crackle breccias are overprinted by successive sets of subhorizontal and subvertical extension (mode I) veins, steeply inclined shear veins and moderately-dipping late-stage cataclasites. The orientation and controls of the vein sets demonstrate their formation during (1) progressive NW-SE directed subhorizontal shortening, and (2) waning fluid pressures from lithostatic values (mode I veins) to sub-lithostatic fluid pressures (mode II shear veins and cataclasites). The economic-grade mineralization of the Sheba West ore body relates to an undulation of the controlling Sheba Fault that corresponds to a releasing bend during top-to-the-NW thrusting. The vein systems along the Sheba Fault illustrate the controls of permeability structures as a result of lithological and rheological contrasts, geometric variations (fault bends) and fluid-pressure fluctuations during faulting.

1. Introduction

Fault zones throughout the crust, from near-surface faults to lower-crustal shear zones, have long been recognized as important fluid conduits (e.g., Fyfe et al., 1978). At crustal depths > 4–5 km and under metamorphic conditions, rock permeabilities are negligible (10^{-15} - 10^{-18} m^2; e.g. Brace, 1980; Clauser, 1992; Manning and Ingebritsen, 1999) and fluid flow along faults is largely fracture controlled, promoted by the presence of transiently lithostatically pressurized fluids (Etheridge et al., 1983). Exhumed hydrothermal vein systems such as those preserved in lode-gold deposits provide insights into the internal geometry and connectivity of vein networks that constitute these paleo fluid-plumbing systems at depth (Cox, 1995, 2020; Cox et al., 1991, 2001; Sibson, 1986, 1996, 2001, 2009, 2020; Sibson and Scott, 1998).

The permeability structure of exhumed faults depends on a number of factors such as the fault geometry, displacement (magnitude and kinematics), fault-rock composition and competence contrasts between faulted strata, the predominant deformation processes at the given P-T conditions and/or strain rates and fluid pressure variations during deformation (Caine et al., 1996; Cassidy et al., 1998; Chauvet, 2019; Cox, 1995; Cox et al., 1991, 2001; Groves et al., 1998, 2018; McCuaig and Kerrich, 1998; Ojala et al., 1993; Robert and Poulsen, 2001; Sibson, 1996, 2001, 2020; Sibson and Scott, 1998; Tarasewicz et al., 2005). Fault slip at depth of a few kilometres is assisted by suprahydrostatic

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