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Orogenic Au-mineralization during Proterozoic transpression in SW Tanzania: insights from three-dimensional frictional reactivation theory

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Au-mineralization in the western Lupa goldfield, SW Tanzania was associated with transpression and reverse sinistral slip along a network of steeply south-dipping shear zones with non-Andersonian geometries. Slip, synchronous with greenschist facies retrogression, was accommodated by frictional failure and sliding during emplacement of quartz $\pm$ Au-bearing veins, and by crystal plasticity and fluid-assisted diffusive mass transfer. The Kenge ore body is situated along a NW-SE trending shear zone and is characterized by < 10 m thick, Au-bearing fault-fill veins hosted by well-developed phyllosilicate-rich mylonites. The contemporaneous Porcupine ore body is situated along an ENE-WSW to E-W trending shear zone, which is characterized by narrow, discontinuous mylonites within a silicified and non-foliated granitoid protolith. Au-mineralization at Porcupine occurs within steeply-dipping fault-fill and sub-horizontal extension/oblique-extension veins. Three-dimensional frictional reactivation theory explains the different vein styles at Kenge and Porcupine, and extends the classic fault valve model to the general case of oblique slip along multiple, arbitrarily-oriented shear zones. Frictional reactivation of the Kenge shear zone is predicted to have occurred at supra-hydrostatic, but sub-lithostatic pore fluid pressures, whilst frictional reactivation of the shear zone hosting the Porcupine deposit took place at near-lithostatic fluid pressures. Furthermore, analysis of the differential stress required for frictional reactivation suggests that the Kenge shear zone was intrinsically weaker than that hosting the Porcupine ore body, a prediction consistent with the lack of well-developed phyllosilicate-rich shear zones at Porcupine. We hypothesize that near-lithostatic pore fluid pressures at the Porcupine ore body relieved effective normal stresses at grain-grain contacts, helping to preserve intra-granular and fracture porosity associated with partially-altered feldspar grains. This hypothesis is consistent with whole-rock geochemical data that does not preserve evidence for significant volume change despite the potential for volume loss and compaction during greenschist facies hydration (e.g. albite + H+ + K+ $\rightarrow$ muscovite + SiO_2 + Na+). As such, sites of intra-granular and fracture porosity may have been microstructural loci for Au-mineralization, and can also explain the poorly-developed phyllosilicate-rich mylonites and limited degree of shear zone weakening at Porcupine. Our study highlights the importance of understanding the interplay between geomechanics, microstructure and shear zone rheology during mineralization, and suggests that application of three-dimensional frictional reactivation theory can offer new insights into the structural development of other orogenic Au deposits.