Strain Localisation, Fracturing and Hydrothermal Mineralisation: Numerical Models of the Mount Isa Copper Deposit, Australia *Vortrag*

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There is substantial need in mineral exploration to understand the structural controls on ore deposition for these types of deposits in order to predict the localities of new ones. Application of basic principles of rock mechanics, and numerical simulations of deformation and fluid flow processes provide fundamental insights to Proterozoic hydrothermal mineralization at Mount Isa, Australia. The rheology of layered meta-sedimentary rocks, and the orientation and position of these layered rocks relative to major fault systems were the key controls on ore deposition. Rock deformation is a crucial requirement for creating fluid pathways and depositional sites in post-metamorphic hydrothermal ore systems, since metamorphism creates a largely impermeable wall rock. Compositional layering in the host rock partitioned mechanical behaviour and strain, leading to selective permeability generation and focussing of fluid flow during separate hydrothermal events. Differences in physical property values between shale and siltstone lead to a significant variation in deformation behaviour and changes in deformation related permeability. From field and mine observations it is reasonable to assume that the shale layers had less cohesion and a lower friction angle, but higher tensile strength than the siltstone layers. A layering of these rock types is thus likely to lead to a partitioning effect known as shear-lag, which occurs when ongoing stretching in the weak phase of a two-layer composite reduces s_3, resulting in a preferential partitioning of tensile stresses into the strong phase. This rheological contrast may be the reason why a number of large copper and lead-zinc-silver deposits in the Mount Isa area are hosted by a single rock unit, the Urquhart shale. According to our model fine-grained carbonaceous shale layers preferentially failed by plastic shearing, whereas meta-siltstones remained elastic or failed in tension, depending on the magnitude of deformation and the pore fluid pressure. If lead-zinc silver mineralization is assumed to have occurred early orogenic or late syngenetic in consolidated and lithified sedimentary rocks, the pelitic layers of the Urquhart shale would have deformed plastically, becoming more permeable than elastically deforming siltstones. A second hydrothermal event occurred after the metamorphic peak of the (ca. 1590–1550 Ma) Isan orogeny. Numerical simulations suggest that during this late orogenic event the orientation of layering and the proximity to major fault systems controlled fracturing and permeability increase in the Urquhart shale. Deformation patterns similar to the observed extent of dilation and brecciation occur in the case of E–W shortening and top-to-E simple shearing. These geometries correspond to the second and third

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deformation events recognized at Mount Isa, during which meta-siltstone layers in the Urquhart shale failed in tension and massive silicification occurred. The fractured siltstones provided pathways for an upward flowing, over-pressured basement fluid, from which quartz was deposited during cooling. An oblique strike-slip strain geometry corresponding to the fourth major deformation event, localized strain in steeply-dipping pre-existing fault zones, and again, in the mechanically anisotropic Urquhart shale. The reactivation of steep structures provided access to surface derived fluids during a third hydrothermal event, causing the precipitation of dolomite followed by chalcopyrite ore. The change from regional contraction and simple-shear to strike-slip changed the hydraulic architecture significantly, favouring upward flow, lithostatic fluid pressures and hydro-fracturing in the former case, and access to surface-derived fluids in the latter. These findings support a sequential model for copper mineralization at Mount Isa, where alteration from a reduced basement fluid preceded introduction of a surface-derived oxidized metal-bearing brine.