Structural evolution from porphyry to epithermal conditions recorded by anhydrite veins and cemented breccias at the Lihir Au deposit, PNG*

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The Lihir gold deposit in Papua New Guinea is the largest alkalic gold deposit in the world in terms of contained metal with a 60 Moz resource. Its evolution from early porphyry to late-stage epithermal and modern geothermal stages, and relationships between these transitions and the geomorphological evolution of the host volcanic edifice remains enigmatic. The deposit is located at the base of a 4.5 x 3.5 km amphitheatre, formed by catastrophic sector collapse during the later stages of a protracted magmatic-hydrothermal history. The removal of over 1000 vertical metres from the original volcanic edifice is interpreted to have resulted in overprinting of an early magmatic-hydrothermal porphyry system by a shallow-level auriferous epithermal system.

Anhydrite veins and intergranular disseminations define the ‘anhydrite seal’ at Lihir, a basal unit in the three-layer mining model. The anhydrite seal is overlain by the high-grade, refractory, sulfide-rich ‘boiling zone’ and the mostly barren upper layer, the steam-heated ‘clay blanket’. Ore types roughly define the epithermal (boiling zone) and porphyry (anhydrite seal) alteration domains, however, intense textural destruction associated with clay-rich alteration and primary mineral dissolution has inhibited structural analysis and constraint of the evolving permeability mesh from porphyry to geothermal stages.

Current mining has now uncovered deeper levels in the Lienetz ore zone at Lihir, exposing the three-dimensional geometry of the “anhydrite seal”. Anhydrite vein morphology and kinematics indicate rapid and significant perturbations in stress conditions, and a complex history of polycyclic reactivation. Detailed mapping and kinematic analysis of vein arrays indicate a large portion of massive, barren anhydrite veins and breccias formed early, under sub-horizontal compression. Later sets of anhydrite – quartz – carbonate veins locally overprinted early veins, and formed under sub-vertical to sub-horizontal extension, with internal textures of collapse, dissolution, and shear of the surrounding wallrock. An abundance of open space and cavities largely sit stratigraphically above these anhydrite veins, and correspond to local high-grade zones.

The dynamic, kinematic, and geometric evolution of Lihir most likely involved a complex interplay of far-field tectonic stress, gravitational instability of the volcanic edifice, high fluid pressures, a high ambient geothermal gradient, fluctuating magmatic pressures and strain softening caused by hydrothermal alteration. Anhydrite veins appear to record part of this complex evolution, with the voluminous early veins representing high fluid pressures associated with the early, deep-seated (> 1 km) magmatic-hydrothermal porphyry system, and the late and in some
cases reactivated anhydrite veins representing extension; possibly due to sector collapse events responsible for the telescoping and formation of this giant alkalic Au deposit.