Goldschmidt 2023 Abstract
https://doi.org/10.7185/gold2023.17925

The evolution of a trans-crustal alkaline magma system and its implications for epithermal Au mineralization: A case study from Lihir Island, Papua New Guinea

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Alkaline magmatism can generate giant epithermal Au deposits. However, the root causes determining ore fertility of alkaline melts remain enigmatic. Silicate melt inclusions (SMIs) that entrapped primitive melts can be used to trace magma evolution and changes in ore-relevant elements. Since alkaline melts are typically assumed to represent small magma volumes produced by low-degree partial melting, their Au content may be decisive for the formation of giant Au deposits such as Ladolam on Lihir Island (>1500 t of Au). We reconstructed the magmatic evolution of Lihir Island, Papua New Guinea, using SMIs, mineral geochemistry and thermobarometry calculations to identify key parameters that influence ore fertility and report the first Au concentrations for alkaline melts determined in-situ by LA-ICP-MS analysis of SMIs.

Our results indicate that alkaline melts were generated in a heterogeneous, metasomatically altered mantle by variable degrees of partial melting of clinopyroxene-rich lithologies. Concentrations of S and Cl are relatively high in SMIs but within ranges typical for alkaline magmas. Interestingly, mean Au contents are also relatively high, with some SMIs showing exceptionally high Au concentrations (10 ng/g to 100 ng/g). Clinopyroxene-melt thermobarometry indicates that melts fractionated at deeper (4-7 kbar) and at shallower (1-2 kbar) crustal levels. Au-rich SMIs stem predominantly from deeper crustal levels, indicating the importance of deep open-system processes in the generation of Au-rich alkaline melts. Fine oscillatory growth zoning of clinopyroxene phenocrysts from melts presumably closest in time to Au mineralization indicate that frequent recharge events of small, variably Au-rich melts at deeper crustal levels might have prepared the ground for subsequent mineralization. Older Au-rich melt batches could have produced concealed, and yet undiscovered, Au deposits or were too small for economic Au enrichment. High oxygen fugacity (approximately FMQ +3) might have helped to obtain high Au contents by supressing sulfide saturation at depth. Mass balance considerations show that as little as a few tens of km^3 of magma could supply the Au present at Ladolam. The SMIs are also Cu-rich, therefore the high Au/Cu ratio in the deposit must be due to higher extraction and/or precipitation efficiency in the case of Au.