SEG 100 Conference: Celebrating a Century of Discovery

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Porphyry Copper Deposits - from Empirical Models to Mineral Systems

David R. Cooke[1, 2]
1. Centre for Ore Deposit and Earth Sciences (CODES), University of Tasmania, Hobart, TAS, Australia, 2. Transforming the Mining Value Chain (TMVC), an Australian Research Council Industrial Transformation Research Hub, University of Tasmania, Hobart, TAS, Australia

The porphyry copper model is well-established, robust, and long-lived. Its evolution over the past hundred years has occurred through incremental advance of deposit-scale knowledge gained from numerous characterization studies punctuated by "light bulb" moments where step-changes in understanding occurred due to insights from critical thinkers and the application of new technology. Collectively, these advances have facilitated thinking across scales and the development of a porphyry system model.

Deposit-scale characterization studies of porphyry deposits dominated the early 20th Century, providing the foundations for an empirical understanding of the hypogene and supergene characteristics of porphyry deposits. During this period, the recognition of the spatial and temporal association of ores with porphyritic intrusions eventually led to acceptance of an orthomagmatic genetic model for porphyry mineralization in the 1960s.

What many consider to be the classic porphyry deposit model was published in 1970 by David Lowell and John Guilbert. It is based on an exploration model developed by Lowell at San Manuel, Arizona, which led to the discovery of the Kalamazoo orebody. The Lowell and Guilbert model synthesized key deposit features – sulfide and alteration zoning patterns and vein distributions – that could guide explorers towards mineralization. The Lowell and Guilbert model stands as one of the most successful exploration models of the past 50 years – it profoundly influenced porphyry deposit discoveries.

The 1970s was a golden period of porphyry research. The Lowell and Guilbert model was refined by Gustafson and Hunt in 1975, who recognized that overprinting of multiple magmatic and hydrothermal events causes significant "variations on a theme" in the porphyry clan. Pioneering isotopic and fluid inclusion studies, coupled with hydrological and geochemical modelling, led to critical advances in the porphyry genetic model during this period, with Burnham’s 1979 model a landmark advance.

The porphyry system model’s foundations were laid in 1972 when Dick Sillitoe published "A plate tectonic model for the origin of porphyry copper deposits." This step-change in understanding led to a wide acceptance of the critical role of tectonic processes in porphyry mineral systems. Dick Sillitoe, perhaps more than any other individual, has profoundly shaped the porphyry model, effectively working across scales from crustal to regional to district to deposit. His porphyry district exploration model, published in 1989 and refined many times, most notably in 2010, has helped explorers to understand the links between porphyry and other deposit styles (epithermal, skarn, CRD), again leading to significant exploration success.

Generation of high-quality geological, geophysical, and geochemical datasets across all scales has facilitated significant, rapid advances to the porphyry system model over the past three decades. Critical insights have included the recognition of tectonic triggers for mineralization, the ingredients for fertile magma generation, the importance of trans-lithospheric structures, the role of mid-crustal magma chambers, and the influence of brines, vapors, and supercritical fluids on mineralization and alteration. The model continues to be refined, with a priority being to provide explorers with tools to aid discovery in greenfields terrains and under cover so they can meet society’s urgent, ever-growing copper demand.