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# Formation of Cu–Au porphyry deposits: hydraulic quartz veins, magmatic processes and constraints from chlorine

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**ABSTRACT**

Copper–gold porphyry deposits are the world's main source of copper and a significant source of gold. They consist of vein networks and their surrounding alteration zones. Commonly the deposits are centred on narrow intrusions (stocks), but calling these deposits 'porphyries' is unjustified because the name carries little descriptive or genetic value. Extensional veins were formed by hydraulic fracturing of the stocks, at depths where open spaces could not be maintained and where fluid pressure approaches lithostatic pressure. The post-crystallisation timing of the veins is important because it indicates that the host stocks could not have been the direct sources of either metals or ore-forming fluids. In the traditional magmatic model, precursor batholiths, lying at depth, are *inferred* to be the sources of the Cu and Au in the overlying host stocks. In this model, the batholiths are assumed to have crystallised and produced the mineralising aqueous fluids, Cu and Au. However, in many porphyry deposits, the concept of metal and fluid supply from deeper batholiths is problematic. Neither Cu nor Au is strongly enriched during the crystallisation of silicate magmas, and although hypersaline fluids are a characteristic of Cu–Au porphyry deposits globally, the source of the Cl remains unconstrained. There is little evidence that silicate magmas can release such Cl-rich fluids, and it remains unexplained how elevated levels of Cl may be achieved in a silicate magma. Therefore, the starting assumption that these deposits formed predominantly from magmatic sources and processes is questioned. This study has selectively focused on the roles of rheology, rock mechanics, vein control, metal-enrichment processes and the sources of Cl. Non-magmatic processes may be enough to facilitate strong partitioning of Cu and Au into high-temperature, oxidising, high-salinity, hydrothermal fluids to form Cu–Au porphyry deposits.

**KEY POINTS**

1. Mineralised quartz veins were introduced in fluids during hydraulic fracturing of their host intrusions when these stocks were brittle and had cooled significantly below their solidus temperatures.
2. The porphyry intrusions hosting Cu–Au (copper–gold) mineralisation were not the direct sources of either the fluids or the metals.
3. The sources of Cu and Au included large volumes of surrounding and underlying rocks up to kilometres from the sites of deposition.
4. Cu and Au do not become strongly concentrated during crystal fractionation in evolving silicate magmas.
5. Unaltered igneous rocks have relatively low Cl contents, and experiments suggest low Cl solubilities in granitic to granodioritic magmas.
6. It is highly unlikely that all the Cl required for metal complexing and transport was available from within silicate magmas.

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hydraulic veins; hydraulic fracture; rheology; copper porphyry; gold; magmatic; hypersaline fluids; metamorphism

## Introduction

Porphyry deposits (as they are widely referred to in the literature) comprise stockwork, disseminated and breccia-hosted mineralisation, and are the world's major sources of copper, with important gold, rhenium and molybdenum in addition (Cooke *et al*., 2005; Sillitoe, 2010). These deposits are very large systems that involve up to 3 $km^3$ of ore and can extend to 2 km in depth. For example, El Teniente in

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