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Zircon trace element analyses as records of magmatic processes: Insights into the petrogenetic evolution of porphyry systems

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Over the last half century, a great deal of research has been dedicated to understanding Porphyry Copper Deposit (PCD) formation. Multiple models of mineralisation have been developed, centred on fundamental observations common across these systems. These models have several ideas in common: (1) requisite regional, calc -alkaline magmatism produces highly fractionated, hydrous magmas; (2) oxidised conditions allow for the transport of sufficient S, Cl and metals to the upper crust within the magma; (3) a shallow, exsolved magmatic-hydrothermal fluid is responsible for concentrating metals from within the magma; (4) a mechanism of fixing the metals into the observed reduced, sulphide-hosted hypogene mineralisation is required. However, quantification of these conditions is generally poor due the pervasive nature of the hydrothermal alteration associated with mineralisation. Zircon, which is ubiquitous in mineralised and un-mineralised intrusions, offers a solution to this problem, providing the opportunity to study the chemistry of the original, unaltered ore metal-bearing magmas.

Zircon is a common accessory mineral in igneous lithologies. It incorporates significant concentrations of trace elements, particularly the Rare Earth Elements (REEs), during crystallisation. As it is a geologically robust mineral phase with negligible diffusion of ions through the crystal lattice even during intense hydrothermal events, zircon geochemistry reflects that of the parental magmatic system and the crystal provides armouring for melt inclusions from hydrothermal alteration. We use zircons from a single magmatic lineament to examine the magmatic evolution of a mineralised system. Our study area is the Maronia Magmatic Corridor of Northeastern Greece. It is a NE – SW trending belt of Oligocene high-K to shoshonitic, calc-alkaline plutons hosting porphyry – epithermal style mineralisation with significant by-product metal mineralisation including Re and Au-Ag tellurides. In addition to the Sappes, Kassiteres and Maronia deposits, unmineralised outcrops from other plutons fall along the same magmatic trend allowing for comparison between fertile and potentially unproductive systems. Whole rock geochemical analyses of unaltered host plutons from along the Corridor indicate varying degrees of crustal assimilation during early magmatism. Late, metal-bearing porphyritic intrusions closely follow the emplacement of the host plutons, however, intense argillic to advanced argillic alteration has completely destroyed the original mineralogy and igneous texture of the porphyries leaving few clues as to their petrogenesis.

The zircons serve as a high-precision U-Pb geochronometer, as a tape recorder of magmatic processes, and as a host to melt inclusions. Zircon analyses chronicle the evolving geochemistry, both in time and space, of intrusions and eruptions of intermediate to felsic magmas from a single magmatic centre. Our study allows for integrated interpretations of magma petrogenesis, the conditions necessary to transport and fix metals in porphyry systems and the timescales over which these processes operate. Early results indicate pulsed magma accumulation and rapid crystallisation and cooling of these systems. We will present strong evidence of inheritance in the porphyry intrusions and potential for sulphide saturation prior to emplacement. We will use geochemical signatures, e.g. REE patterns and V/Sc fractionation, to illuminate the lower crustal processes controlling petrogenesis and magma metal fertility.