Fertile magma genesis; a zircon perspective

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INTRODUCTION

Porphyry deposits, a significant source of global copper, molybdenum and gold resources, are associated with hydrous and oxidized (e.g., fertile) primary magmas that commonly occur in multi-stage intrusive complexes (Cooke et al., 2014). Rigorous whole-rock lithogeochemical and isotopic characterization of these primary magmas is invariably affected by related and often pervasive hydrothermal alteration and mineralization. Zircon, ubiquitous in most felsic magmas, is a robust magmatic accessory mineral that is resilient to post-emplacement metamorphism and hydrothermal alteration, and thus their chemistry represents a preserved proxy for primary chemical conditions of porphyry-related magmas (e.g., Ballard et al., 2002; Lu et al., 2016; Lee et al., 2017). Early stage exploration is therefore, focused on identifying fertile intrusions often in areas consisting of poor outcrop exposure, cryptic alteration assemblages with limited mineralization and those lacking a defined regional metallogenic context. Zircon textures and trace element compositions (e.g., REEs) can assist with discriminating intrusions that are fertile and potentially associated with porphyry-related mineralization from those that are not (e.g., Lu et al., 2016).

In this study, we investigate zircon textures and trace element compositions from a series of porphyry-related calc-alkaline to alkaline intrusions in the Cowal District, central New South Wales. The approximately 40 by 15 kilometre Cowal District is underlain by Ordovician volcanic, volcaniclastic and intrusive rocks of the Macquarie Arc. These rocks locally host calc-alkalic porphyry and low sulphidation alkalic-type epithermal prospects and deposits. This district represents a unique study site because porphyry-related mineralization spans >10 million years and is related to, and hosted in, many phases of intrusions with distinct mineralogical and geochemical compositions.

LA ICP-MS TRACE ELEMENT MAPPING APPLIED TO COMPLEX ZIRCONS

Significant new advances in LA ICP-MS trace element mapping of ~50 micron zircons at CODES, University of Tasmania, permits the investigation of intra-grain trace element variability and also to rigorously test zircon as a useful proxy for primary magma conditions. These data, coupled with single grain cathodoluminescence images, are therefore used to fingerprint fertile intrusions and speculate on magmatic processes unique to porphyry related magmas. For this study, we acquired numerous LA ICP-MS maps of zircons from pre-, syn-, and post-mineralization intrusions from throughout the Cowal District. We show that intricate trace element zoning in zircons correlate directly with complex textural zoning (e.g., sector and oscillatory) observed in single grain cathodoluminescence imagery. In fact, zircons from syn-mineral intrusions are often texturally more complex than zircons from pre- or post-mineral intrusions. These complex textures are likely due to a prolonged magmatic history consisting of magma recharge (trace element rejuvenation) and magma recycling (e.g., Lee et al., 2017). Mapping of key fractionation indices (e.g., Th/U, Gd/Yb, and Hf) demonstrate that in many cases, multiple fractionation signatures are evident in one zircon grain supported by complex core to rim relationships, providing temporal evidence of magma recycling. Furthermore, the highest oxidation signature (e.g., high Eu/Eu*, Ce/Nd) recorded in zoned zircons is often concentrated near the crystal rims. These observations imply that magmatic oxidation state cycles during the evolution of porphyry-related magmas that have also endured multiple, pre-crystallization events deemed prerequisites for fertile magma genesis.

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