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Zircon compositions as fertility indicator of Archean granites

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Porphyry Cu deposits are economically significant as they supplied nearly ~70% of the world's Cu, ~50% of its Mo, and ~25% of its Au. They range in age from Archean to present, but mostly are Jurassic and younger. The global peak periods for porphyry deposit development are in the Jurassic, Cretaceous, Eocene, and Miocene. Porphyry deposits in Precambrian terranes are rare, and the reasons for this remain unclear. Low preservation potential is one possible explanation, since porphyry deposits form in topographically elevated arcs which are prone to erosion. Nevertheless, several porphyry-type deposits occur in the Abitibi and Opatica greenstone belts in the Superior Craton, suggesting that the potential for porphyry deposits in Archean cratons might be underexplored.

It was recently proposed by Lu et al. (2016) that zircon compositions can be an excellent pathfinder for porphyry Cu deposits. The best fertility indicators are zircon Eu/Eu* (>0.3) and 10,000*(Eu/Eu*)/Y (>1) ratios, whereas (Ce/Nd)/Y (>0.01) and Dy/Yb (<0.3) ratios are moderately useful. These distinct zircon trace element ratios are interpreted to reflect a specific differentiation trend, e.g. suppression of plagioclase fractionation and enhanced early amphibole fractionation as a result of high magmatic water contents, which is a prerequisite for magmatic-hydrothermal (porphyry) ore formation.

We test the above zircon fertility indicators in Archean granites across the Yilgarn Craton in Western Australia. The studied granites range in age from c. 2930 Ma to c. 2640 Ma, and from high-Al TTG to potassic granite. These Archean granites lie transitionally between Phanerozoic infertile and fertile granite suites, as defined in Lu et al. (2016), on Eu/Eu* vs (Ce/Nd)/Y and (Eu/Eu*)/Y vs (Ce/Nd)/Y plots. On a Eu/Eu* vs Dy/Yb plot, Yilgarn Archean granites have distinctly higher Dy/Yb ratios (>0.3), and define a positive trend, which contrast with the negative trend for Phanerozoic fertile suites. It indicates that Archean granite compositional evolution was strongly influenced by garnet (source retention) whereas Phanerozoic fertile suites are strongly influenced by amphibole fractionation. This in turn suggests Archean granite magmas are typically relatively dry compared to Phanerozoic fertile suites, and is consistent with the absence of amphibole phenocrysts in most granites in the Yilgarn Craton.

The systematic difference in zircon chemistry between Archean granites and Phanerozoic fertile and infertile suites, suggest different processes were involved in forming Archean granites. We argue that Archean granites were mainly formed through lower- or infracrustal partial melting of mafic crust in the garnet stability field, whereas Phanerozoic fertile suites were formed by intracrustal amphibole-dominated fractionation of mafic magmas. Granites formed by the former process have lower potential for porphyry Cu mineralization due to insufficient water and the lack of build-up of copper and sulfur in the melt. Further data is needed from mineralized Archean granites to determine whether they have different genesis from those unmineralized Archean granites.