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Porphyry copper deposit prospectivity from detrital zircon geochemistry in the Loa River basin, Northern Chile

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The Loa River basin is the most prolific porphyry copper producing region in northern Chile. It hosts the mid-Eocene to early Oligocene Chuquicamata, El Abra and Collahuasi districts; the Paleocene Spence and Sierra Gorda districts; and the Cretaceous Antucoya deposit. We collected heavy mineral concentrates along the Loa River and its tributaries and analysed ~1,600 zircon grains to evaluate their prospecting potential for porphyry copper deposits. We analysed the zircons for trace elements and geochronology, then classified them using the predictive model of Carrasco-Godoy et al. (2024) as fertile or barren. Two high-frequency age peaks were identified, the younger peak is associated with the mid-Eocene to early Oligocene magmatic arc and the older peak with the Paleocene magmatic arc. These peaks in detrital zircon abundance correlate with periods of regional compression, whereas the trough between the peaks coincides with a period of extension. The mid-Eocene to early Oligocene zircons show a systematic increase in the europium anomaly, oxygen fugacity and decrease in phosphorus and titanium over an ~18 Myr period, which ended in the formation of several giant porphyry Cu deposits. In contrast, the Paleocene zircons show no systematic variations over a ~13 Myr period, and the period ended in the formation of fewer and smaller deposits. The machine learning classification shows that the proportion of fertile zircons in samples increases with proximity to ore deposits (up to ~22% close to El Abra) as expected. However, if the data are expressed as a percentage of fertile zircons in each time period, up to 50% of the zircons near the end of a compressive event, when magmatic activity is waning, are fertile. This study shows that a combination of age and space-resolved geochemical analysis of detrital zircons, in combination with predictive modelling, has a high potential for porphyry copper exploration.