Zircon rare earth element patterns as an indicator of ore potential

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The chondrite normalised rare earth element (REE) patterns of zircon are usually smoothly varying apart from anomalous abundances of Ce and Eu. The smoothly varying profile is due to the systematic change in ionic radius across the series, while the anomalies arise from the variable oxidation states of Ce and Eu relative to the exclusively trivalent state of all the other REE. The magnitudes of the Ce and Eu anomalies thus relate to the oxygen fugacity of the melt, which correlates with the ore-bearing potential of porphyry-copper deposits in Chile. To calibrate the Ce anomaly for oxygen fugacity and temperature the oxidation state of Ce in a synthetic granitic melt was determined from 800 to 1400 °C.

REE patterns can also exhibit differences in shape, defined by the slope and/or curvature. These differences can be difficult to parameterise, or to discern qualitatively by plotting and comparing large numbers of patterns. A method for parameterising REE patterns using orthogonal polynomials has recently been described [1]. In this approach most patterns can be described by three terms, corresponding to the abundance, slope, and curvature. For ocean floor basalts plots of curvature against slope clearly distinguish MORB and OIB and allow trends that can be attributed to partial melting and fractional crystallisation to be identified. We have applied this approach to REE patterns in zircon. Zircons from I-type granites have REE patterns with a shallower slope, greater curvature and lower abundance than those from S-types. Plots of slope against curvature identify fields for zircons from I-type and S-type granites and discriminate between these with 76% certainty. For zircons from the Chuquicamata-El Abra porphyry copper belt of northern Chile, plots of slope against curvature distinguish between barren and ore-bearing intrusions with 87% certainty. A similar ore-discriminating relationship was observed for intrusions of the Oyu Tolgoi porphyry Cu-Au deposit in Mongolia and the Shaxi porphyry Cu-Au deposit in China. From the available data, the identification of ore-bearing intrusions is accurate for a particular tectonic setting but not necessarily between settings.

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