REE Pattern Shape Analysis Using Lambda Coefficients

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Rare earth element (REE: La–Lu) in rocks, minerals, and other terrestrial materials are often normalised to reference baselines such as chondrite asteroids or primitive mantle compositions. Normalised REE concentrations typically appear smooth when plotted with REE along the x axis (either as atomic number or ionic radius). These smooth lines are termed REE patterns and have varying slopes, curvatures (e.g., convex or concave) and other fine scale structures that can provide information about the material the REE pattern is from. The two elements cerium and europium can anomalously deviate from the smooth lines owing to redox effects. Numerical quantification of these shapes, curvatures, and anomalies is traditionally done with element ratios. For example, the La/Lu ratio gives information on whether a pattern is sloping up or down. The Sm/Lu ratio, on the other hand, provides information on curvature concavity. The europium anomaly is typically quantified as Eu/Eu*, with Eu* being the interpolated geometric mean of its neighbouring elements using $\sqrt{(Sm \times Gd)}$. In addition, some REE patterns contain a tetrad effect signature, where four groups of consecutive elements show internal fractionation, for which similar quantification methods, based on element ratios, have been developed. Here, we present an alternative method to quantify these shapes. We use the lambda coefficient method developed by O'Neill (2016) to represent patterns as independent numbers representing REE abundance, slope, quadratic curvature, sinusoidality, and higher order curvature ("W-type"). We also show an accurate method to extract the complete set of tetrad coefficients. Cerium and europium anomalies are calculated relative to the curvature, avoiding potentially erroneous linear interpolations. Lambda coefficients are useful parameters for tracing geochemical evolution, petrological modelling, discrimination efforts, dimension reduction, and many other applications in mineralogy, petrology, and geochemistry.
O'Neill, H. S. C. (2016). Journal of Petrology, 57(8), 1463–1508.