

Cyclicality in Earth evolution constrained by time-series analysis of global igneous activity

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Global igneous activity provides a record of crust formation and differentiation, which are, in turn, related to larger-scale geodynamic processes such as plate tectonics and plume activity. Most compilations of igneous activity portray a spectrum of ages compiled by the Gaussian summation of available ages (Gaussian AND summation). Density function distributions constructed in this way describe the probability of an age occurring in the data compilation, which may not be equivalent to the probability distribution for original igneous activity. It has long been recognised that the age of igneous activity may be biased by issues related to selective preservation and sampling. An alternative form of calculation is the Gaussian OR approach, which provides the probability for any igneous activity occurring at a particular age. This approach provides a more robust reflection of the original age distribution.

The DateView geochronology database (available at <http://sil.usask.ca>;) currently contains approximately 60,000 records for all continents, of which ~15,000 reflect igneous crystallisation ages. A Gaussian OR pdf for these latter ages illustrates several intervals of reduced igneous activity since 3.8 Ga. The long-term variations in patterns of igneous activity appear similar for all continents. Interestingly, these 'quiescent' intervals generally coincide with suggested times of supercontinent formation.

Spectral analysis of the probability distribution demonstrates cyclic behaviour at a variety of periodicities. A noticeable feature of the long-term cyclicality is that the period for two of the wavelengths identified increases from ~650 Ma and ~440 Ma at 3.8 Ga to ~860 Ma and ~510 Ma, respectively, at the present. No abrupt changes in cyclicality are evident, suggesting that there have been no dramatic changes in geodynamic processes since 3.8 Ga. Quantification and identification of the cyclicality has important implications for geodynamic processes, including the interplay of plate tectonics and plumes and the styles of mineralisation expected at different stages of earth history.

Carbonate 'clumped isotope' thermometry: A status report

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Carbonate 'clumped isotope' thermometry can determine the growth temperatures of carbonate minerals based on their abundances of ¹³C-¹⁸O bonds, as reflected by the 'Δ₄₇' value of CO₂ extracted by phosphoric acid digestion. This method is precise (as good as ±1 °C), thermodynamically based, and independent of the δ¹⁸O of water from which carbonate grew. However, there are many unresolved questions about the general usefulness of this new and unusual proxy. We review recent developments in its calibration and understanding.

In the last year, we conducted four empirical calibration studies of previously unstudied materials: Foraminifera, Coccolithophores, various lacustrine carbonates, and synthetic dolomites grown through microbial mediation. All of these materials exhibit temperature dependencies of abundances of ¹³C-¹⁸O bonds that are indistinguishable from that previously published for synthetic inorganic calcite. When combined with previous data for various biogenic and inorganic precipitates, these results suggest that the carbonate clumped isotope thermometer is largely free of vital effects and/or structural or crystal-chemical controls. This could be an indication that ¹³C-¹⁸O ordering in carbonate minerals is generally inherited from the DIC pool from which they grow. Furthermore, our results suggest that many calcifying organisms — including those with significant 'vital effects' in bulk stable isotope and trace element composition — grow in local isotopic equilibrium at the site of carbonate precipitation.

Speleothems are a notable exception: they consistently record apparent temperatures ~5-10 °C higher than actual growth temperatures. Theoretical, experimental and empirical evidence suggests that this reflects a kinetic isotope effect during rapid degassing of CO₂ from super-saturated solutions, which depletes the residual DIC pool in ¹³C-¹⁸O bonds. Pedogenic carbonates remain a work in progress: a subset preserve apparent temperatures consistent with their environments of growth, while others appear to be offset to higher temperatures. We speculate that some soil environments experience disequilibrium CO₂ degassing analogous to that influencing speleothems.