

## Clumped Isotope Paleothermometry: Interpreting Lacustrine Climate Records

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“Clumped Isotope” measurements of carbonate offer a powerful tool for reconstructing the paleotemperature of past environments. One of the key challenges to interpreting clumped isotope measurements is to understand both the temperature-dependent relationship of the system, and how carbonate formation temperatures relate to broader climatic conditions. We examine timescales of carbonate formation in terrestrial systems to determine how clumped isotope temperature measurements relate to climate. Specifically, we use surface temperature records from lakes spanning a wide range of latitudes and elevation to develop transfer functions that relate seasonal temperature to mean annual air temperature. These functions enable determination of mean annual climate from proxies that record a seasonal signal. Transfer function relationships are applied to an example from the Isle of Wight, UK, to constrain the magnitude of temperature change during the Eocene-Oligocene transition using freshwater biotic carbonate.  $\Delta_{47}$  measurements of pristine, aragonitic gastropod carbonate produce unreasonably high Eocene and Oligocene paleotemperature estimates using established temperature-dependent relationships. However, transfer functions that account for timing of carbonate formation produce reasonable measures of mean annual temperature and the overall change in MAT during the Eocene-Oligocene transition. These data show that the  $\Delta_{47}$  paleotemperature proxy provides a powerful and accurate measure of paleoclimate when appropriate transfer functions that relate timescales of carbonate formation are employed. Such an approach must be considered in the application of this proxy to terrestrial systems for problems ranging from paleoclimate to paleoelevation studies.

## Evaporite assimilation ‘window’ triggers sulfide immiscibility

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The assimilation of sulfur from sedimentary evaporites by mafic and ultramafic intrusions may trigger the formation of Noril'sk-Type Ni-Cu-PGE (platinum group element) deposits. The Neoproterozoic Minto Inlier on Victoria Island of the western Canadian Arctic exposes dikes, sills and flood basalts from the Franklin Large Igneous Province and sedimentary rocks of the Shaler Supergroup. The Franklin intrusives have many features in common with those in the Noril'sk region of Russia. Both intrude a sequence of carbonates, shales, evaporites and sandstones and are sill-dominated with fault-controlled conduit systems. The excellent exposure on Victoria Island enables intrusive-host rock interactions to be studied directly.

In order to investigate the process of evaporite assimilation, we collected samples through a 5m thick evaporite-hosted sill and the underlying 5m of sedimentary rocks. The host evaporites are part of the Minto Inlet Formation and consist of interbedded carbonate, gypsum and anhydrite. The host sulfate evaporites have  $\delta^{34}\text{S}$  values between +15.9 and +16.2‰ and the sill has elevated  $\delta^{34}\text{S}$  values between +11.4 and +12.9‰ in the core and upper sill that imply contamination from crustal sulfate source. However, the lower chilled margin has a  $\delta^{34}\text{S}$  value of only +1.9‰, within the range of primary igneous values from other sills in the area.

The sulfur isotope value of the chill margin indicates that sulfur was not directly introduced into the sill from the sedimentary rocks below. Possible explanations for elevated S-isotope values within the sill include stoping and mechanical assimilation along the upper sill contact; or the delivery of sulfate contamination from upstream in a later magma pulse. Using simple mixing calculations, we estimate that the sill has assimilated up to 0.4 to 0.7 wt% anhydrite. Based on calibrated relationships between evaporite assimilation, sulfur solubility and oxidation state, this range of evaporite assimilation is within a favourable ‘window’ for ore deposits. It is enough to generate sulfide immiscibility, while being low enough to avoid oxidation of the magma and resorption of the sulfur.