Application of Clumped Isotope Thermometry to Archean Carbonates: Thermal Histories and Potential for Biomarker Preservation

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Introduction

"Clumped" isotope thermometry can allow the determination of formation temperature by carbonate analysis alone, without knowledge of the oxygen isotope composition of the water from which the carbonate grew.1,2

Carbonate Isotope Equilibrium – see schematic pattern above

\[ \text{Ca}^{12}\text{C}^{18}\text{O}_{2} + \text{Ca}^{12}\text{C}^{16}\text{O}_{3} = \text{Ca}^{13}\text{C}^{18}\text{O}_{2} + \text{Ca}^{12}\text{C}^{16}\text{O}_{3} \]

C-18O bonding increases with decreasing temperature.1,2

Study Objectives

◆ Constrain ancient ocean temperature by modeling simultaneous calcite and dolomite \(^{13}\text{C} - ^{18}\text{O}\) reordering kinetics.
◆ Constrain maximum thermal history of an Archean carbonate platform as related to organic biomarker preservation.

Early Earth Habitability & Biomarkers

◆ Organic Biomarkers can provide direct evidence for the metabolic activity of life. However, excessive thermal burial heating can decompose or alter these records.3
◆ Apparent clumped temperatures average 144°C for calcite and 99°C for dolomite. These temperatures require a modeled maximum burial temperature of 163.5°C and a rapid uplift of ~15 million years. Our results support a cool precipitation and Archean ocean temperature.
◆ Low thermal exposure suggests favorable organic biomarker preservation.

Field Investigation

Figure 3 (left) – Campbellrand - Malmani Carbonate Platform Stromatolites. Neoarchean (2.68-2.50 Ga) Kaapvaal Craton, South Africa.10 Early dolomite (brown) has replaced biofilms between calcite (grey) layers; thus the two minerals have the same thermal history.

Results & Thermal Modeling

Figure 4 (below) – Campbellrand-Malmani Carbonate Platform Stromatolites. Thermal Modeling of Dolomite and Calcite formation.1,2 Two thermal histories are presented for dolomite based on formation temperature at 30°C and 80°C.

Conclusions

Additional samples recently collected are expected to better define mineralogical differences and further constrain the thermal history of these ancient carbonates.

References