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The ^{13}C-^{18}O clumped isotopic composition of Cephalopods: when vital effects turn up the heat

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The stable oxygen isotopic composition of ammonite and belemnite shells has been extensively used to reconstruct Mesozoic seawater temperatures. Temperature reconstruction using stable δ^{18}O however requires an a priori assumption the oxygen composition of seawater, thus researchers now look to the clumped ^{13}C-^{18}O isotopic composition of cephalopod groups to make more accurate temperature reconstructions.

Our measurements of the clumped isotopic composition of modern cephalopods (*Nautilus Pompilus*, *Nautilus Macromphalus* and *Nautilus Belauensis*), made on the IBEX automated clumped isotope sample preparation system, however indicate a significant "vital effects" in clumped isotopic composition corresponding to on average a 10˚C overestimate in shell formation temperature. We show a decrease in $\Delta_{47}$from juvenile to adult septa that does not correspond to changes in surface seawater temperature or vertical migration through the water column during the lifespan of the organism. The clumped isotope composition of most recently formed septa yield growth temperatures 3-8˚C above the upper temperature limit of survival of the organism (27˚C). In contrast Sepia (*Sepia Officianalis*) appear to precipitate shell carbonate *at* or *very near* oxygen and clumped isotope equilibrium. We discuss potential mechanisms, which may produce vital effects observed.

Significant offsets in $\Delta_{47}$of nautili from expected values and associated subtle non-equilbirum δ^{18}O signatures have important implications for paleoclimate reconstruction using the stable isotopic composition of cephalopod carbonate. Non-realistic clumped isotope calculated temperatures of fossil specimens such as ammonites, with minimal evidence of diagenetic alteration, might in part be due to previously un-diagnosed "vital effects".