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Investigating the diagenetic controls on chert $\delta^{18}O$

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The $^{18}O/^{16}O$ ratio of cherts ($\delta^{18}O_{chert}$) increases by ca. 15 ‰ from the Archean to present. Since oxygen isotope fractionation between solid silica phases and dissolved Si is temperature dependent, this increase has received attention as a potential record of Earth's long term climate evolution. Two endmember explanations - that are not mutually exclusive – have emerged: cooling seawater temperature and increasing $\delta^{18}O$ of seawater. Some recent models invoke Archean seawater $\delta^{18}O$ at near-modern values, which requires either ocean temperatures > 70°C, or pervasive and consistent alteration of all Precambrian cherts. Yet chert is an essentially monomineralic rock that forms as the end point of the silica diagenesis pathway, in which amorphous opal-A is transformed via dissolution-reprecipitation reactions to microcrystalline quartz via an intermediate opal-CT phase. There is now increasing recognition that $\delta^{18}O_{chert}$ reflects the temperature and fluid $\delta^{18}O$ at the endpoint of this diagenetic pathway, which need not reflect seawater conditions. In this contribution, we explicitly investigate how silica diagenesis may have varied, and what implications this has for interpretation of the $\delta^{18}O_{chert}$ record.

We introduce a 1D silica diagenesis model that tracks the transformation of silica polymorphs in the sediment column as they are buried and heated. This model emphasises the importance of reaction kinetics in controlling the depth, temperature and oxygen isotope fractionations associated with chert formation. Our results show that $\delta^{18}O_{chert}$ is a poor archive of seawater temperatures. We also show that $\delta^{18}O_{chert}$ is influenced by heat flow through ocean sediments, such that a large fraction of the Archean-Cenozoic difference in $\delta^{18}O_{chert}$ is explainable simply by accounting for reasonable changes in heat flow over Earth history. This removes the need for extremes in either seawater temperature or $\delta^{18}O$, pointing the way towards a middle-ground interpretation of the $\delta^{18}O_{chert}$ record that satisfies all geochemical, palaeoclimatological and biological constraints.