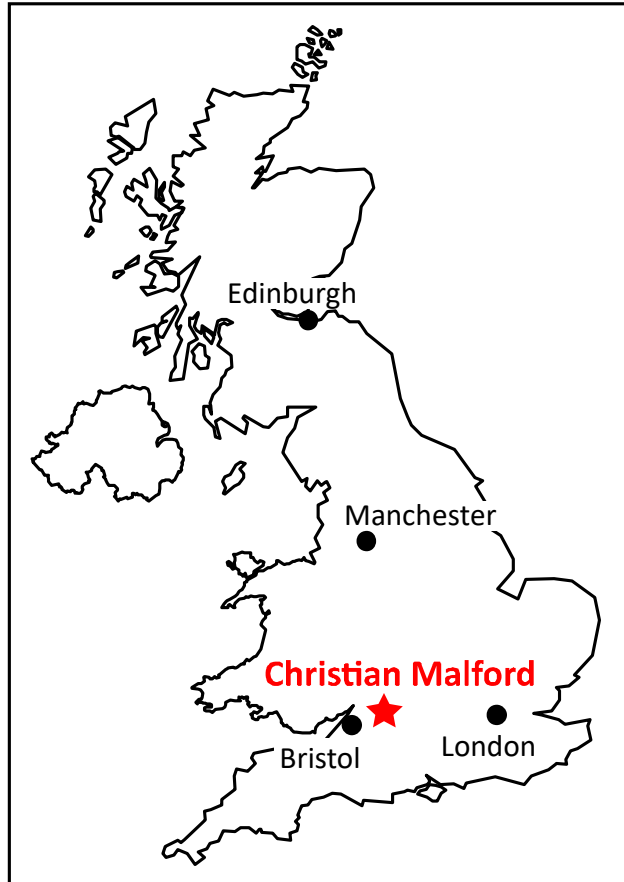


Belemnites, clumped isotopes and oxygen fractionation

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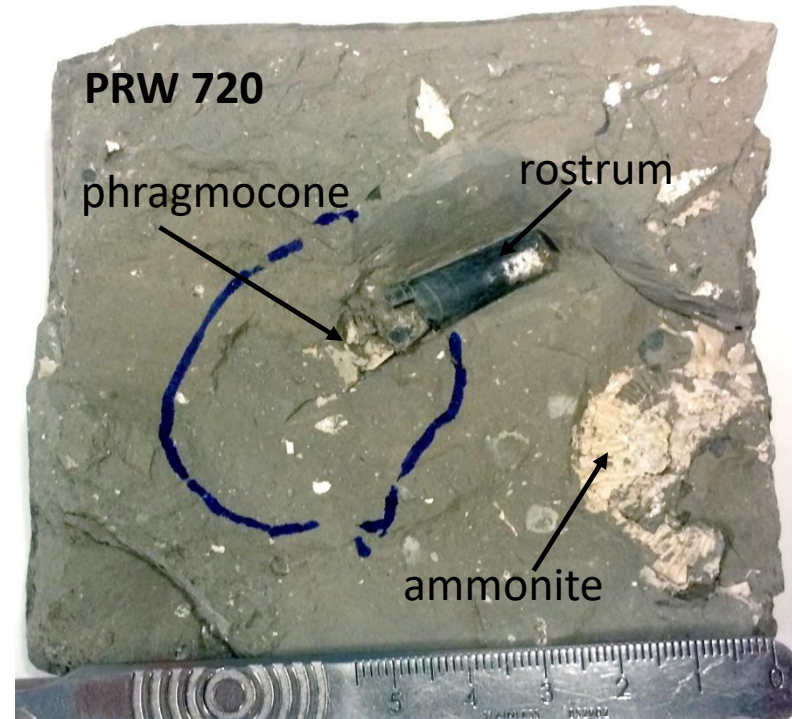
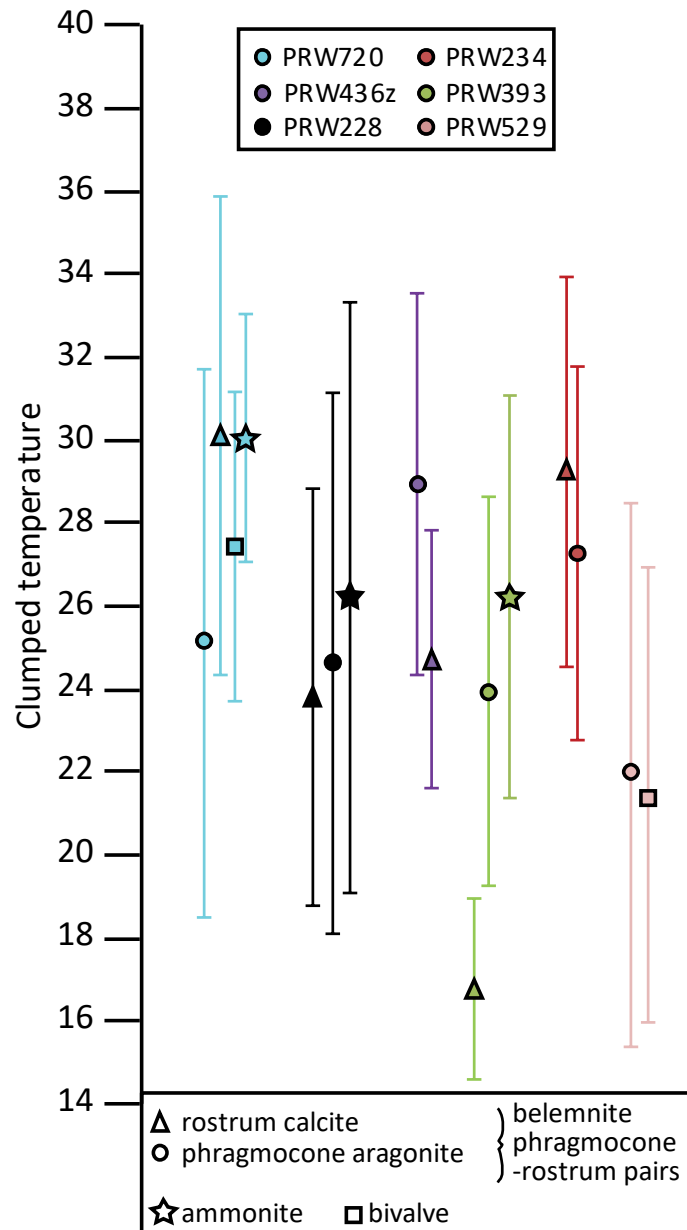
All samples are derived from the Middle Jurassic Peterborough Member of the Oxford Clay Formation, outcropping at Christian Malford.



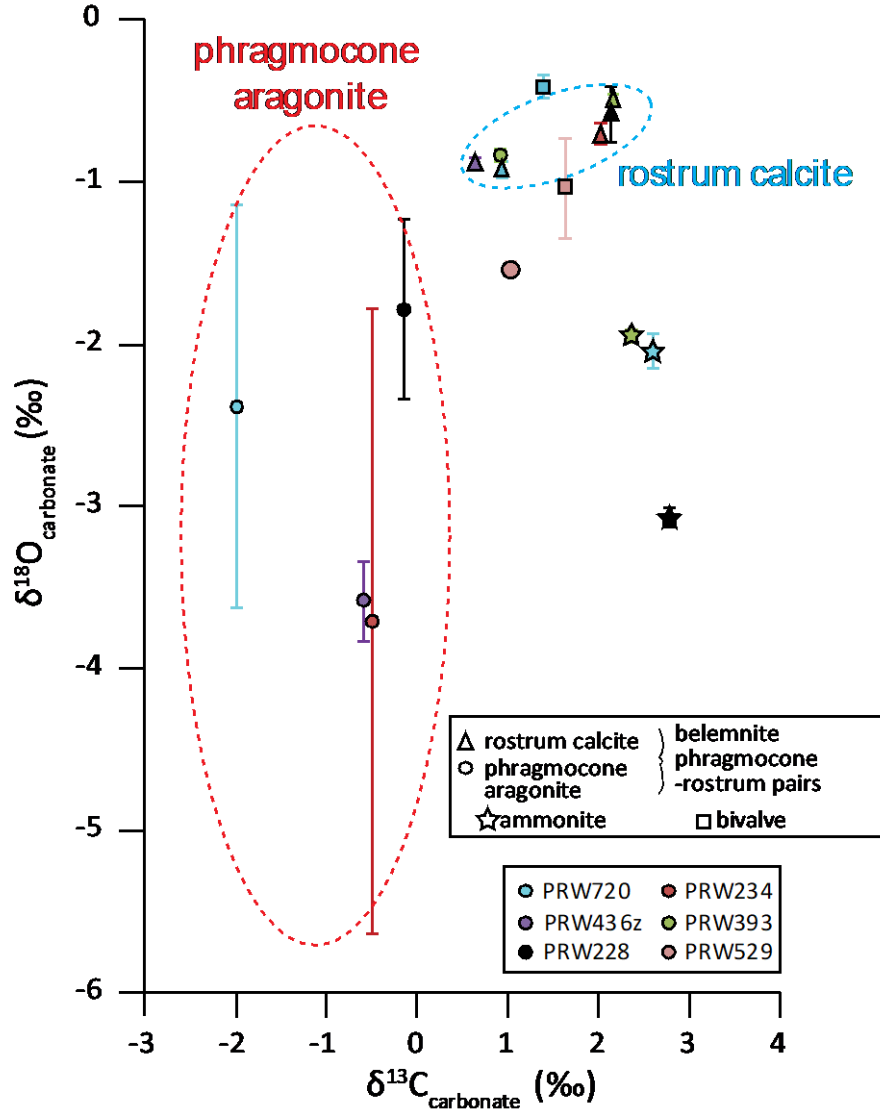
- Preservation exceptional: immature sedimentary organic material with $T_{\max}$ values of 411 °C and HI 694 mg HC/g TOC (Glass et al., 2012).
- All samples are from the Callovian Athleta Zone (Phaeinum subzone).
- All belemnites analysed are from the genus *Cylindroteuthis*.
- Original aragonitic belemnite phragmocones preserved.
- Ammonite (*Kosmoceras*) and bivalve (*Mesosacella*) aragonite present too.

Clumped isotope temperature reconstructions

- Belemnite rostrum-phragmocone pairs give clumped isotope temperatures within error of each other (one exception, PRW393).



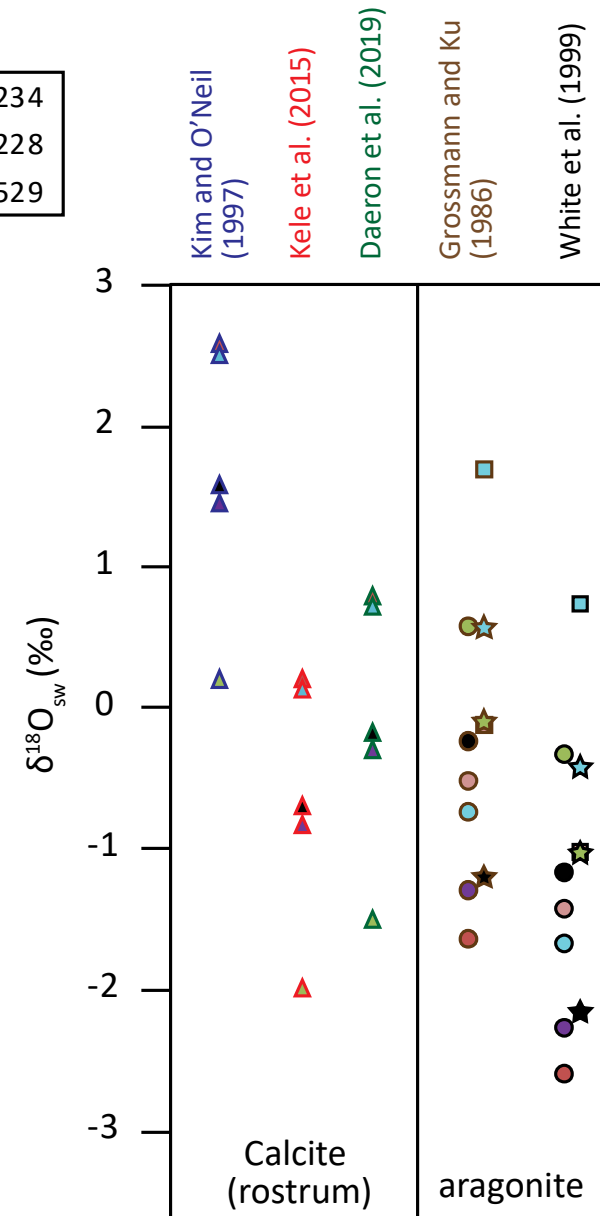
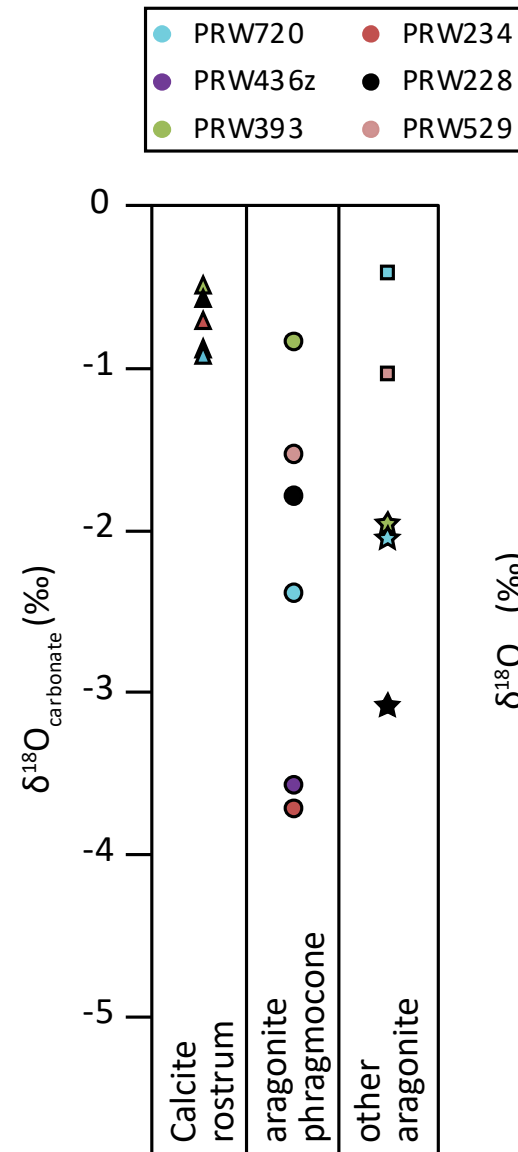
Stable isotopes



- Rostrum calcite has higher $\delta^{13}\text{C}$ and $\delta^{18}\text{O}$ than phragmocone aragonite exception: PRW 393 (also anomalous T)
- Rostrum calcite has much smaller spread for both $\delta^{13}\text{C}$ and $\delta^{18}\text{O}$ than aragonite (phragmocone and non-belemnite aragonite).
- Rostrum calcite generally higher $\delta^{18}\text{O}$ than phragmocone and other aragonite
- Rostrum calcite higher $\delta^{13}\text{C}$ than phragmocone, though within range similar range to other aragonite.

Reconstructed $\delta^{18}\text{O}_{\text{sw}}$

- Kim and O'Neil (1997) calcite thermometry equation returns more positive $\delta^{18}\text{O}_{\text{sw}}$ than the aragonite equations give for the same belemnite.
- Our data therefore suggests that the fractionation factor for oxygen isotopes in belemnite calcite from seawater is closer to that of slow-growing abiogenic calcites (e.g. Kele et al., 2015; Daëron et al., 2019) than rapidly-grown synthetic calcite (e.g. Kim and O'Neil, 1997) or other biogenic calcites (e.g. Craig, 1965; Brand et al., 2013).



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