

# Once upon a time in Maastricht – clumped isotope climate reconstructions from marine macrofaunal assemblages of the Maastrichtian stage

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Towards the end of the Cretaceous a wide portion of the Eurasian plate was covered by a shallow sea with only few landmarks. The climatic conditions towards the end of the Cretaceous are expected to show a cooling trend from the Campanian to the Maastrichtian stage accompanied with several carbon isotope excursions (CIE) detected in the Atlantic, Pacific and Tethyan Oceans. The observation that these CIEs do not correlate with warming as for instance the Paleocene Eocene Thermal Maximum points on different causes that might relate to tectonic activity and/or changes in seawater circulation (e.g. Linnert et al., 2017).

The shallow and still relatively warm water conditions offered a fruitful environment for a wide range of marine organisms of which the fossil remnants are very abundant in the area around Maastricht, defining the type locality of the final Cretaceous stage, the Maastrichtian (72.1-66.0 Ma). Various fossil assemblages containing gastropods, brachiopods, echinoids were recovered from different ecozones of the Maastrichtian. We applied carbonate clumped isotope thermometry to determine ambient temperature changes taking place during the Maastrichtian.

The good preservation of a wide variety of fossils in Southern Netherland with the recent developments in clumped isotope geochemistry (e.g. Bernasconi et al., 2018) allows us to constrain a much better picture of the climatic conditions during which the sedimentary deposits around present-day Maastricht formed.

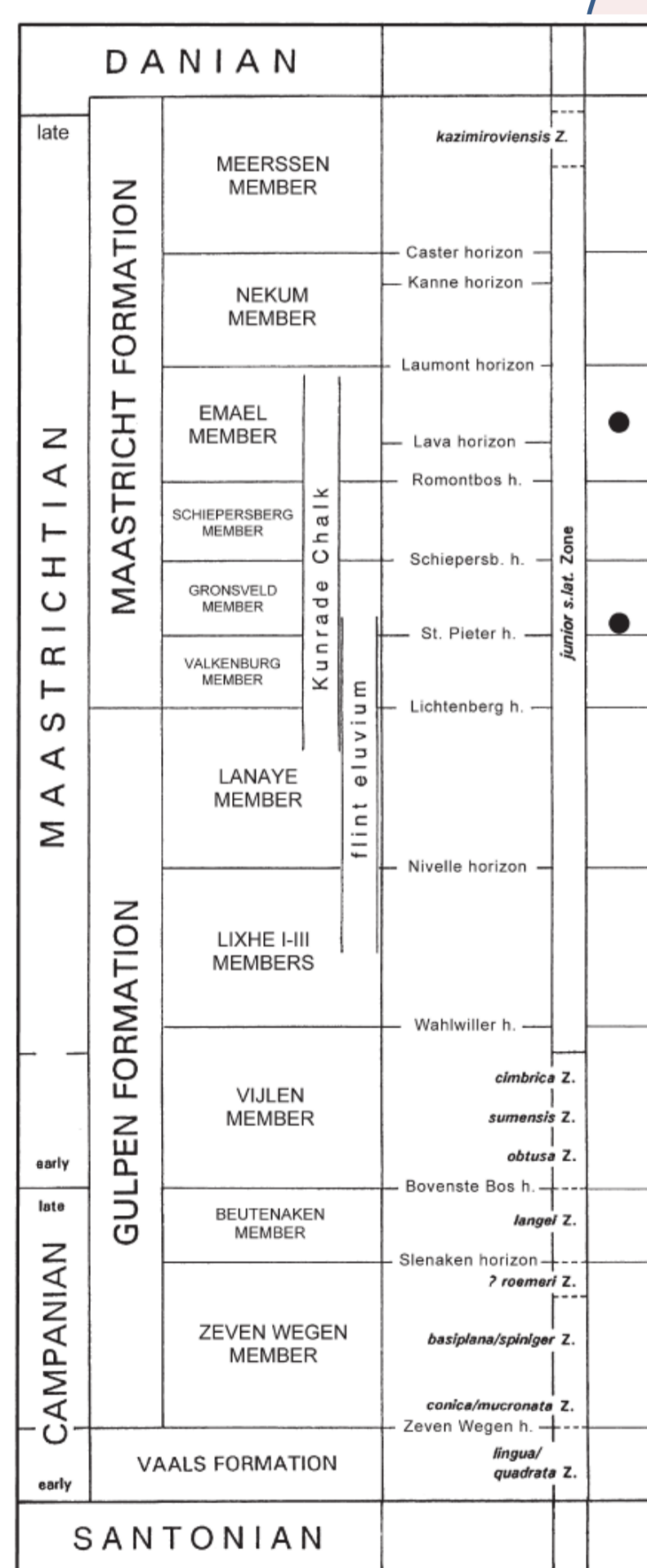
## Conclusions and outlook

- preliminary  $\Delta_{47}$  temperature estimates of Maastrichtian fossil assemblages collected at the type locality near Maastricht reveal seawater T estimates of 11 to 21 °C with variable  $\delta^{18}\text{O}$  estimates -3 to 1 ‰
- macrofossils probably have longer growth season (more annual seawater T estimates) and show potential of high resolution paleo climate snap shots
- These T estimates agree with mid palaeolatitude SST estimates derived of planktonic foraminifera  $\delta^{18}\text{O}$  (compiled in O'Brien et al., 2017) and  $\Delta_{47}$ -T estimates of "US" Atlantic coast (Meyer et al., 2018)

## To do list:

- distinguish primary signals from diagenetic alteration signal (GK3000....mineralogy (XRF+XRD), microscopy, EBSD)
- analyze more replicates (of ~80 µg) to improve precision
- climate variation over Cretaceous-Paleogene (K-Pg) boundary in the sediments around Maastricht?

## Preliminary results on Maastrichtian fossils (uncertainty at 95% CL)



**Trigonosemus pectiniformis**, brachiopod (as GK3109)  
**GK3108-1:**  
 $\delta^{13}\text{C}_{\text{VPDB}}$  2.75±0.03 ‰  
 $\delta^{18}\text{O}_{\text{VPDB}}$  -0.88±0.03 ‰  
 $\Delta_{47}$ -T 12.9±11.5 °C  
 $\delta^{18}\text{O}_{\text{VSMOW}}$  (f) -1.8±2.5 ‰  
 Replicates 4  
**GK3108-2:**  
 $\delta^{13}\text{C}_{\text{VPDB}}$  2.46±0.04 ‰  
 $\delta^{18}\text{O}_{\text{VPDB}}$  -0.40±0.03 ‰  
 $\Delta_{47}$ -T 17.4±7.9 °C  
 $\delta^{18}\text{O}_{\text{VSMOW}}$  (f) -0.8±1.7 ‰  
 Replicates 8



**Thecidea papillata**, brachiopod (Gulpen Fm., Lanaye Mem.)  
**GK3109:**  
 $\delta^{13}\text{C}_{\text{VPDB}}$  1.59±0.02 ‰  
 $\delta^{18}\text{O}_{\text{VPDB}}$  -1.72±0.06 ‰  
 $\Delta_{47}$ -T 11.7±4.3 °C  
 $\delta^{18}\text{O}_{\text{VSMOW}}$  (f) -2.9±0.9 ‰  
 Replicates 8



**Pectinids/spondyliids** (Maastricht Fm., Meersen Mem.)  
**Z734-1:**  
 $\delta^{13}\text{C}_{\text{VPDB}}$  1.49±0.05 ‰  
 $\delta^{18}\text{O}_{\text{VPDB}}$  -1.91±0.08 ‰  
 $\Delta_{47}$ -T 14.0±10.0 °C  
 $\delta^{18}\text{O}_{\text{VSMOW}}$  (f) -2.6±2.2 ‰  
 Replicates 6  
**Z734-2:**  
 $\delta^{13}\text{C}_{\text{VPDB}}$  1.34±0.12 ‰  
 $\delta^{18}\text{O}_{\text{VPDB}}$  -2.08±0.25 ‰  
 $\Delta_{47}$ -T 8.2±7.7 °C  
 $\delta^{18}\text{O}_{\text{VSMOW}}$  (f) -4.0±1.7 ‰  
 Replicates 3

## High resolution snap shots.

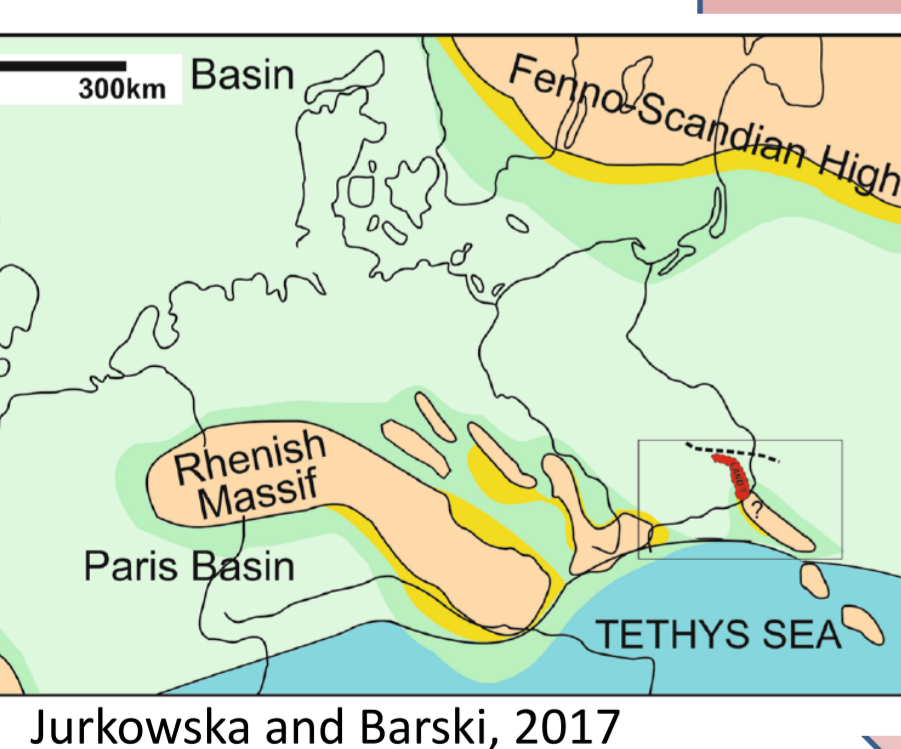
**Magas chitoniformis**, brachiopod (Gulpen Fm., Vijlen Mem.)  
**GK3131-1:**  
 $\delta^{13}\text{C}_{\text{VPDB}}$  2.38±0.03 ‰  
 $\delta^{18}\text{O}_{\text{VPDB}}$  -1.43±0.09 ‰  
 $\Delta_{47}$ -T 17.2±12.7 °C  
 $\delta^{18}\text{O}_{\text{VSMOW}}$  (f) -1.5±2.8 ‰  
 Replicates 6  
**GK3131-2:**  
 $\delta^{13}\text{C}_{\text{VPDB}}$  2.52±0.04 ‰  
 $\delta^{18}\text{O}_{\text{VPDB}}$  -1.62±0.04 ‰  
 $\Delta_{47}$ -T 15.7±4.0 °C  
 $\delta^{18}\text{O}_{\text{VSMOW}}$  (f) -2.0±0.9 ‰  
 Replicates 9



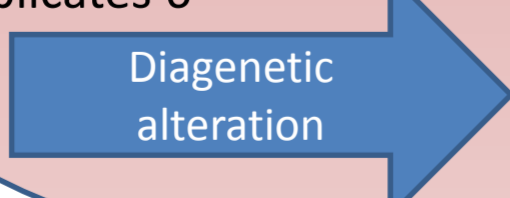
**Nerita rugose**, gastropod  
**Z477-1:**  
 $\delta^{13}\text{C}_{\text{VPDB}}$  2.88±0.01 ‰  
 $\delta^{18}\text{O}_{\text{VPDB}}$  -0.71±0.04 ‰  
 $\Delta_{47}$ -T 18.1±9.0 °C  
 $\delta^{18}\text{O}_{\text{VSMOW}}$  (f) -0.6±1.9 ‰  
 Replicates 7  
**Z477-2:**  
 $\delta^{13}\text{C}_{\text{VPDB}}$  1.88±0.02 ‰  
 $\delta^{18}\text{O}_{\text{VPDB}}$  -0.99±0.03 ‰  
 $\Delta_{47}$ -T 14.7±4.9 °C  
 $\delta^{18}\text{O}_{\text{VSMOW}}$  (f) -1.5±1.1 ‰  
 Replicates 7  
**Z477-3:**  
 $\delta^{13}\text{C}_{\text{VPDB}}$  2.97±0.05 ‰  
 $\delta^{18}\text{O}_{\text{VPDB}}$  0.70±0.06 ‰  
 $\Delta_{47}$ -T 20.3±6.1 °C  
 $\delta^{18}\text{O}_{\text{VSMOW}}$  (f) 0.7±1.3 ‰  
 Replicates 7



**Ototoma retzii**, gastropod (Maastricht Fm., Meersen Mem.)  
**Z735:**  
 $\delta^{13}\text{C}_{\text{VPDB}}$  1.42±0.06 ‰  
 $\delta^{18}\text{O}_{\text{VPDB}}$  -1.34±0.11 ‰  
 $\Delta_{47}$ -T 19.8±13.7 °C  
 $\delta^{18}\text{O}_{\text{VSMOW}}$  (f) -0.9±2.8 ‰  
 Replicates 6



**Oolopygus gr. Pyriformis**, echinoid (Gulpen Fm., Lanaye Mem.)  
**GK3000-1:**  
 $\delta^{13}\text{C}_{\text{VPDB}}$  1.03±0.19 ‰  
 $\delta^{18}\text{O}_{\text{VPDB}}$  -2.94±1.62 ‰  
 $\Delta_{47}$ -T 29.5±a lot °C  
 $\delta^{18}\text{O}_{\text{VSMOW}}$  (f) 0.3±8.6 ‰  
 Replicates 2  
**GK3000-2:**  
 $\delta^{13}\text{C}_{\text{VPDB}}$  -0.06±0.06 ‰  
 $\delta^{18}\text{O}_{\text{VPDB}}$  -7.24±0.08 ‰  
 $\Delta_{47}$ -T 36.0±8.7 °C  
 $\delta^{18}\text{O}_{\text{VSMOW}}$  (f) -2.8±1.7 ‰  
 Replicates 6

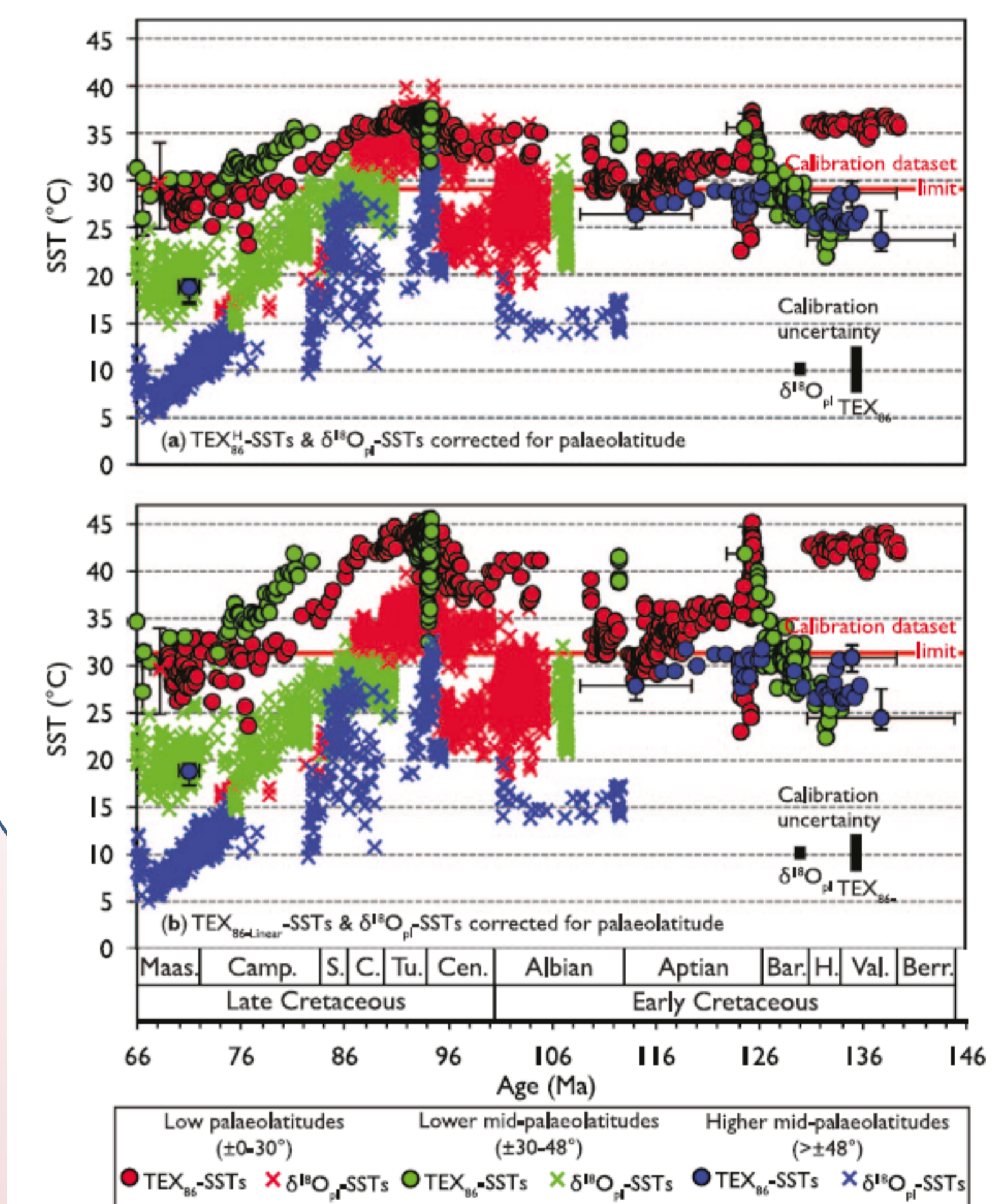


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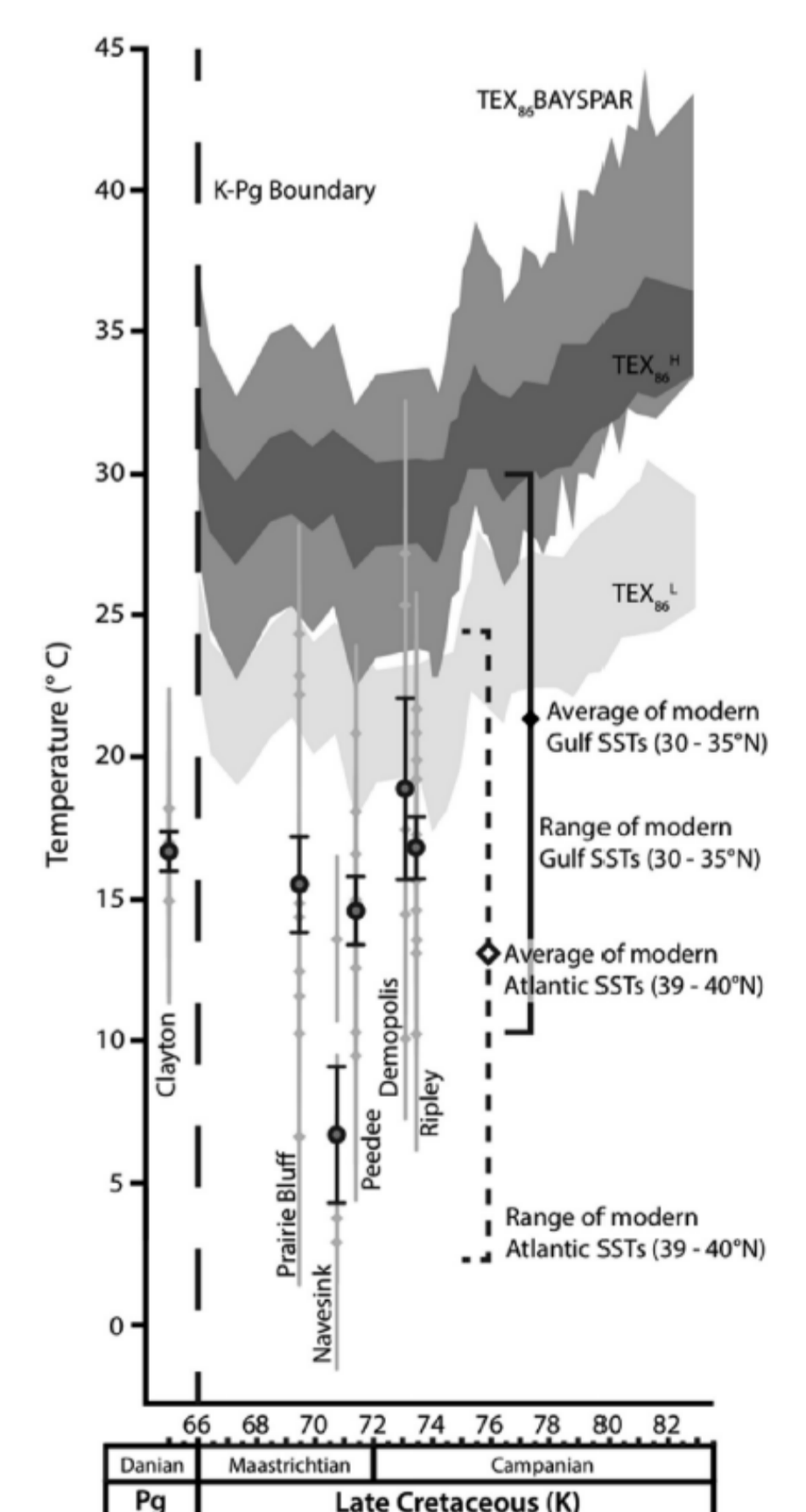
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Global TEX<sub>86</sub> and  $\delta^{18}\text{O}$  of planktonic foraminifera compilation by O'Brien et al., 2017



$\Delta_{47}$ -T reconstructions on bivalves and gastropods from the Atlantic coast of modern US (from Meyer et al., 2018)