



25

**Abstract**

26 We present the first universal calibration of the clumped isotope thermometer for calcites of  
27 various mineralizing types. These are an eggshell of an ostrich, a tropical bivalve, a  
28 brachiopod shell, cold seep carbonate, and three foraminifera samples that grew between 9 °C  
29 and 38 °C. CaCO<sub>3</sub> was digested at 90 °C using a common acid bath. Considering a difference  
30 in phosphoric acid fractionation factors between reaction at 25 °C and 90 °C of 0.069‰ (Guo  
31 et al., 2009), the function between growth temperature T and the excess of <sup>13</sup>C–<sup>18</sup>O bonds in  
32 the evolved CO<sub>2</sub> is expressed by a linear regression between 1/T<sup>2</sup> and absolute Δ<sub>47</sub> (R<sup>2</sup> =  
33 0.9915):

$$34 \Delta_{47} = 0.0327 (\pm 0.0026) \times 10^6 / T^2 + 0.3030 (\pm 0.0308) \text{ (with } \Delta_{47} \text{ in } \text{‰} \text{ and } T \text{ in K).}$$

35 Both the slope and intercept of our regression line deviate significantly from the first  
36 experimental calibration based on synthetic calcites digested at 25 °C (Ghosh et al., 2006a)  
37 and from several other studies having confirmed this pioneering calibration (i.e., Came et al.,  
38 2007; Tripathi et al., 2010; Thiagarajan et al., 2011; Grauel et al., 2012; Saenger et al., 2012;  
39 Zaarur et al., 2012). However, our relationship between temperature and absolute Δ<sub>47</sub> values is  
40 indistinguishable from that determined by Henkes et al. (2013) if the same difference in  
41 phosphoric acid fractionation factors between 25 °C and 90 °C is applied to both datasets. Our  
42 study and that of Henkes et al. (2013) have in common that data were primarily projected  
43 onto the absolute scale proposed by Dennis et al. (2011) – a reference frame that allows  
44 comparison of clumped isotope data measured in different laboratories. Furthermore, at any  
45 T, our regression line lies within 0.006‰ of the theoretical calcite calibration of Guo et al.  
46 (2009). The observation that both empirical calibrations are indistinguishable from each other  
47 implies that clumped isotope data can be directly compared between laboratories and  
48 referenced to a unique temperature calibration if (1) the phosphoric acid digestion temperature  
49 is set to 90 °C, and (2) raw data are primarily projected to the absolute scale.

50