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A $\delta^{44/40}$Ca, Mg/Ca and δ^{18}O multi-proxy approach reveals a two phase calcification process in *N. pachyderma* (sin.)

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A reassessment of the temperature sensitivity of the Mg/Ca and $\delta^{44/40}$Ca signal in the planktonic foraminifera *N. pachyderma* (sin.) from Holocene Nordic Seas sediment surface samples covering an SST-range in between 0˚C to 8˚C reveals that lowest Mg/Ca and $\delta^{44/40}$Ca ratios are recorded in water temperatures of about 3.5˚C. Based on this new set of calibration data, we found that tests of *N. pachyderma* (sin.) can be subdivided into two groups which differ significantly in their suitability as temperature proxy recorder. Mg/Ca and $\delta^{44/40}$Ca ratios of *N. pachyderma* (sin.) from the Norwegian Sea reflecting water temperatures above about 3.5˚C are positively correlated ($\delta^{44/40}$Ca = 1.32 ($\pm$0.40)*Mg/Ca [mmol/mol] – 0.70 ($\pm$0.37); R^2 = 0.75, n = 20) and match existing Mg/Ca temperature calibrations. In contrast, Mg/Ca and $\delta^{44/40}$Ca proxy data of *N. pachyderma* (sin.) originating from the cold ($<$3.5˚C), low saline Arctic Domain and polar waters tend to be inversely related to temperature and are decoupled from each other, forming an almost parabolic Mg/Ca temperature relation. This highly non-passive character of *N. pachyderma* (sin.) at the 'cold end' of existing proxy-temperature calibrations can be reconciled by a model assuming that the final foraminiferal test composition of *N. pachyderma* (sin.) is defined by temperature dependent proportions of two different calcite phases present in the foraminiferal species. In fact, a binary mixing process of two distinctively different calcite endmembers is clearly visible in our data by identical temperature dependent slopes of $\delta^{44/40}$Ca and Mg/Ca data. Above about 3.5˚C, the mixing process between the two calcite endmembers follows a positive correlation with temperature and may represent part of the trace metal homeostasis during moderate temperatures. However, the inverse Mg/Ca-temperature response of in specimens from below about 3.5˚C may

then be interpreted to reflect different biomineralization pathways meant to inhibit the decrease of the Mg-content below a certain threshold value with decreasing temperatures. Both mixing processes may then be alternating tools to compensate for the influence of the temperature in order to keep the Mg/Ca ratio within narrow limits set by the foraminiferal physiology. These observation challenges earlier assumptions that the van´t Hoff equation can be unambiguously transferred to biological systems to explain the temperature sensitivity of foraminiferal Mg/Ca ratios. Rather we have to assume that the foraminiferal physiology actively controls their trace element incorporation within narrow limits.