An Eocene analogue for the future oceanic response to increased CO_2 – Existence of a tropical thermostat?

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Future anthropogenic-induced atmospheric greenhouse gas increase is expected to result in a globally warmer Earth. Whilst this will likely result in an increase of high-latitude sea surface temperatures (SST), the future response of the tropical oceans is uncertain. It has been suggested [1] that a tropical 'thermostat' regulates low-latitude surface ocean temperatures. The mid-Eocene was characterised by higher atmospheric greenhouse gas concentrations [2] and therefore may provide a suitable analogue with which to test the thermostat hypothesis. However, there is disagreement between different palaeo-temperature proxies and recent climate models, with some suggesting considerably warmer Eocene SST.

We present new Eocene tropical ocean surface temperature data from central Java, based on a calibration of the relationship between test Mg/Ca and temperature in large benthic foraminifera. This is the first time such material has been used for palaeo-temperature reconstructions, including appropriate corrections for both changes in the ionic composition of seawater over geological time and corresponding D_{Mg} variation. Large benthic foraminifera were chosen over their more routinely studied planktic relatives because they are longer lived and therefore facilitate both annual and seasonal temperature reconstruction. This is important because it is now recognised that seasonality is a key component of climate change [3].

Our results, measured by laser-ablation plasma mass spectrometry, indicate Eocene southeast Asia tropical SST broadly similar to today. These data, backed by a compilation of $\delta^{18}O$-derived temperatures from well-preserved planktic foraminifera, support the existence of a tropical thermostat. Moreover, comparison with higher palaeo-latitude LBF from the Hampshire Basin (UK) provides further evidence that oceanic latitudinal temperature gradients were greatly reduced when compared to the present day.

[1] Kleypas *et al*. (2008) *Geophys. Res. Lett*. **35**. [2] Demicco *et al*. (2003) *Geology* **31**: 793-6. [3] Denton *et al*. (2005) *Quat. Sci. Rev*. **24**: 1159-82.

What can equilibrium thermodynamics tell us about metasomatic alteration?

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In metamorphic petrology, equilibrium thermodynamics is often used to help us interpret metamorphic evolution of rocks that, we can reasonably assume, evolved close to thermodynamic equilibrium, with a relatively fixed bulk composition, except for volatiles, and under conditions where pressure and temperature are controlling intensive variables.

In rocks that have been significantly affected by metasomatic alteration, these assumptions are, in many cases, no longer reasonable. The nature of a metasomatic rock means that chemical potential variables are likely to have been fixed during their formation, rather than bulk composition variables. Metasomatic processes can also happen quickly, so the assumption of thermodynamic equilibrium on all but the shortest length scales might be faulty. Further, the changes in volume may be sufficient that it might be appropriate to consider volume, rather than pressure as a controlling variable.

Such observations are not new, but they are worth revisiting in the light of the massive recent improvements in imaging and analytical techniques that have led to renewed appreciation of the importance of processes such as dissolution-precipitation, and an increased understanding of the mechanics of metasomatic alteration.

Here, methods to improve the conceptual models and quantification of metasomatism, are discussed. These include judicious use of the phase rule, appropriate choices of conjugate variables, and methods to assess the lengthscales over which thermodynamic equilibrium may have applied. These methods are discussed with reference to metasomatic alteration of BIF-derived iron ore and serpentinisation of ultramafic rocks.