The oxygen isotope record for the Phanerozoic

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Oxygen isotopic data for the Phanerozoic have been compiled to examine long-term trends in paleotemperature and seawater $\delta^{18}O$ [1]. The $\delta^{18}O$ record is based on calcium carbonate and phosphatic fossils and microfossils – foraminifera for the Cenozoic, belemnites and brachiopods for the Mesozoic, and brachiopods and conodonts for the Paleozoic. The data are derived from recent literature [(e.g. [2]) and compilations by Zachos *et al.* [3] and Prokoph *et al.* [4]. To minimize the effects of diagenesis, this study has emphasized (1) sample-screening of Paleozoic brachiopods by petrographic examination of thin-sections, (2) samples from cratonic regions and localities with unusual fossil preservation, and (3) phosphatic fossils and microfossils.

Veizer *et al.* [5] observed a trend of increasing $\delta^{18}O$ with decreasing age that they attributed to evolution of seawater $\delta^{18}O$. In this study, brachiopod values are low for some intervals in the Devonian, Silurian, and late Ordovician (2 Ma means as low as -5.6‰) that must be explained by warm temperatures (25-40°C assuming seawater $\delta^{18}O$ of an ice-free modern world, -1‰), lower seawater $\delta^{18}O$ (-3‰; either locally or globally), or sample alteration. Conodont $\delta^{18}O$ values yield mean temperatures only as low as ~30°C and suggest alteration of the brachiopod signal or local environmental effects. For samples younger than Devonian, the $\delta^{18}O$ records of carbonates and phosphates yield isotopic paleotemperatures consistent with the modern ocean with no evidence for long-term changes in seawater $\delta^{18}O$.

Some key features in the Phanerozoic $\delta^{18}O$ record include latest Ordovician and late Silurian acmes, Middle Devonian rise, mid-late Devonian decline, and early Carboniferous rise. Conodont $\delta^{18}O$ values increase to a late Mississippian maximum that is not seen in brachiopod data. Jurassic and Early Cretaceous belemnites show a Toarcian decrease, a Callovian-Oxfordian acme, an early Cretaceous increase to a maximum near the Valanginian-Hauterivian boundary, and a decline to a Barremian minimum. The Late Cretaceous and Cenozoic sea-surface record depends on whether 'glassy' or less well-preserved planktonic foraminifera were analyzed. Some glassy foraminifera yield low (warm) values approaching those of some early Paleozoic brachiopods.

[1] Grossman (2010) in *The Geologic Time Scale* (eds Gradstein *et al.*, submitted). [2] Joachimski *et al.* (2009) *EPSL* **284**, 599–609. [3] Zachos *et al.* (2001) *Science* **292**, 686–693. [4] Prokoph, Shields & Veizer (2008) *Earth-Sci. Rev.* **87**, 113–133. [5] Veizer *et al.* (1999) *Chem. Geol.* **161**, 59–88.

Multi-phase fluid flow simulations of Brothers volcano: Application of realistic constraints

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Brothers volcano [1] is an active hydrothermal system located on the Kermadec intra-oceanic arc, northeast of New Zealand, and is one of the best studied submarine arc volcanoes on Earth. It provides insight into the complex subseafloor hydrology of a submarine volcano with evidence for different stages in its magmatic-hydrothermal evolution. Its edifice comprises an elongated caldera surrounding an assymetrically centered cone. While hydrothermal venting at the NW caldera wall is focused, and which dates back to at least 1,200 years, hydrothermal discharge at the cone summit is diffuse and significantly younger. Recent studies of regional seismicity and local harmonic tremor at Brothers volcano [2] imply the existance of a hydrothermal fluid reservoir located underneath the area of the present cone.

We are computing multi-phase mass and heat transport with a process simulation scheme based on realistic fluid properties and correlations discribing phase stability relations in the binary salt-water system [3]. Earlier results of generic fluid flow simulations showed that water depth, seafloor topography, crustal permeability and the relative contributions of seawater and magmatic fluids are first-order physical parameters controlling the style of hydrothermal venting.

In our more recent simulations, we use available data from Brothers volcano, including detailed bathymetry, physical and chemical measurements from different vent sites, and evidence for the size and location of the underlying magma chamber(s). The implementation of two distinct magmatic stages (pre-cone vs. post-cone) with different underlying magma chambers shows that the topography of the volcanic edifice, in combination with the location and size of the magma chamber, play an important role in the style and evolution of the hydrothermal system.

[1] de Ronde *et al.* (2005) *Econ. Geol.* **100**, 1097–1133. [2] Dziak *et al.* (2008) *JGR-Solid Earth* **113**, B08S04. [3] Coumou *et al.* (2009) *JGR-Solid Earth* **114**, B03212.