Mantle mixing and the origin and persistence of geochemical reservoirs

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A variety of mechanisms have been proposed for the origin of mantle heterogeneity as observed in mid-ocean ridges and oceanic islands. One source is related to plate motion and recycling: heterogeneity is introduced into the mantle by processes associated with melting, alteration, and subduction, while heterogeneity is destroyed by the stirring action of convection, the stretching and folding common to all kinematic mixing processes. Thus the rate and efficacy of mantle mixing partially constrains the origin and fate of the isotopic heterogeneity seen in mid-ocean ridges and oceanic islands. Mantle mixing is influenced by a variety of factors, including time-varying flow, plate motion, viscosity variations, and phase transitions. Chaotic mixing can be observed in calculations of time-varying 2-D flows, but the rate of mixing in 3-D has been poorly constrained. We present a method for assessing mixing in 3-D, using dispersal and stretching of ellipsoidal tracers, with applications geochemical reservoirs in the mantle. Stirring may be rapid on a regional scale (resulting in fairly uniform mid-ocean ridge basalts on length-scales up to thousands of km) while heterogeneities at the global scale of the Dupal anomaly are retained for billions of years because of isolation across long-wavelength cells. Essentially, the regions that exhibit high rates of stretching and thinning have the most important influence on mixing, and packets of material that are stirred rapidly in regions of high strain rate are carried wholesale into regions of more sluggish convection. The analysis of mixing is complicated by the fact that structures created by passive tracers in 3D exhibit different characteristics than structures observed in 2D models. Nevertheless, it remains difficult to account for mantle isotope systematics and for the Earth's overall heat flow budget without invoking some barriers to flow in the mantle's interior, such as would be provided by mantle layering.

Climate correlations across the MIS 5/4 boundary based on a stalagmite record from Dongge Cave, China

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We present the $\delta^{18}O$ record of stalagmite D11 from Dongge Cave (southern China) on an updated timescale based on twenty-four U/Th ages obtained on a Finnigan-MAT Neptune multi-collector inductively coupled plasma mass spectrometer (MC-ICP-MS). Stalagmite D11 grew between ~97 and 49 ky BP. 2σ errors associated with U/Th ages average ~3‰, and are as small as 1.8‰. The growth rate was moderate, between ~5 to 28 µm/yr. The oxygen isotope record consists of 878 isotope measurements with an average temporal resolution 55 years, ranging from 11 to 115 years. In accordance with previous interpretations [1, 2], the $\delta^{18}O$ record of stalagmite D11 can be considered a reflection of Asian Monsoon intensity.

The D11 oxygen record is punctuated by millennial scale intervals of strong monsoon intensity, which have a one-to-one correspondence with Dansgaard-Oescheger (D/O) warm events 17 through 22, continuing the trend previously seen at Hulu Cave [1]. We can therefore assign absolute ages to these events, with a precision averaging less than ±300 years. The time interval covered by stalagmite D11 is also important in terms of climate because it includes the onset of major glaciation at the MIS 5/4 transition. Previously, we have made critical correlations between Asian Monsoon intensity, atmospheric methane concentration [3], and Heinrich events in the North Atlantic [1, 4], which have enabled us to determine a sequence of events surrounding the last two glacial terminations. By examining the relationships between the Asian Monsoon, sea level, $\delta^{18}O_{atm}$, and atmospheric methane over the timescale recorded by stalagmite D11, we can determine if these different aspects of climate relate to each other in a similar way during major glacial buildup.

[1] Wang *et al.* (2001) *Science* **294**, 2345-2348. [2] Yuan *et al.* (2004) *Science* **304**, 575-578. [3] Kelly *et al.* (2006) *Paleogeography, Palaeoclimatology, Palaeoecology* **236**, 20-38. [4] Cheng *et al.* (2006) *Geology* **34**, 217-220.