

The mid-depth $\Delta^{14}\text{C}$ anomaly during termination 1, Do hydrothermal vents play a role?

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The $\sim 190\%$ drop in surface ocean and atmosphere $\Delta^{14}\text{C}$ during the last glacial termination cannot be explained entirely by ^{14}C production change and thus appears to require a flux of ^{14}C -depleted carbon into the upper ocean/atmosphere or a repartitioning of carbon in the ocean. A deglacial $\Delta^{14}\text{C}$ stratigraphy from deep Pacific cores does not exhibit a -190% decline as observed in upper ocean records during the 'Mystery Interval' [1]. There are large benthic ^{14}C -age excursions in several deglacial records from intermediate water depth cores at low latitudes but not in higher latitude cores [2]. These observations lead us to consider whether the flux of ^{14}C -depleted carbon from hydrothermal sites in the Pacific played a role in the Mystery Interval $\Delta^{14}\text{C}$ changes. Recent studies document liquid CO_2 and CO_2 -rich fluids accumulation in sediments that blanket active vents. The storage and net flux of CO_2 from the sediments is regulated by a CO_2 -hydrate cap at the sediment/water interface. The temperature dependence of CO_2 hydrate stability is a possible mechanism for affecting storage and release of CO_2 and CO_2 -rich fluids from sediments. We explore a hypothesis where hydrothermal systems act as a 'capacitor' for CO_2 storage-release. CO_2 -hydrate stability expands upward to shallower depths during glaciation, reducing the net flux of ^{14}C -depleted CO_2 to the ocean. During deglaciation, CO_2 -hydrate stability deepens, releasing ^{14}C -depleted CO_2 from sediment reservoirs. A $\sim 3^\circ\text{C}$ temperature increase at intermediate depths in the Pacific during T1 would have lowered the hydrate stability horizon several hundred meters and released ^{14}C -depleted carbon to the upper ocean/atmosphere. This would explain why abyssal water masses were not anomalously old during the last glacial and why the -190% decrease in $\Delta^{14}\text{C}$ during the Mystery Interval is not observed at deep water sites.

[1] Broecker, W. & S. Barker (2007) *Earth & Planetary Science Letters* **256**(1-2), 90–99. [2] Stott, L & Timmerman, A (2011) *Hypothesised link between glacial/interglacial atmospheric CO_2 cycles and storage/release CO_2 – rich fluids from the deep sea*. AGU Geophysical monograph series: Understanding the causes, mechanisms and extent of abrupt climate change.

Sampling the Earth's mantle

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The Earth's mantle is isotopically highly heterogeneous, certainly on the kilometer scale of the melting region, but perhaps even on a smaller scale. During partial mantle melting and melt extraction, instantaneous melts from a range of depths are mixed to different extents, eventually forming the melts sampled by oceanic volcanism. Mixing of partial melts from a range of different source components has an averaging effect that biases the isotopic composition of the melts compared to those of their mantle sources. The isotopic composition of oceanic basalts hence reflects only a limited extent of the isotopic heterogeneity present in the mantle.

The relative amount of melt mixing is reflected in the correlations between isotope ratios and different trace element parameters. For OIB, where melt extraction occurs over a short depth interval underneath a thick oceanic lithosphere, little melting of refractory, depleted mantle components occurs. Consequently, melts from the enriched mantle components do not become significantly diluted, resulting in few correlations between isotope and trace element ratios, but also a close correspondence of enriched melt and average enriched source signatures. In ridge-related settings, in the absence of a thick oceanic lithosphere, the depleted mantle components melt to a large extent, and the enriched melts are diluted significantly during partial melting and melt extraction. Melts from the enriched source components, however, still dominate the final erupted melt and obscure the true extent of mantle depletion in mid ocean ridge basalts (MORB). Hence the depleted components of the Earth's mantle are expected to be isotopically more extreme than even the most depleted MORB.

Care must be taken, therefore, to extrapolate the isotopic variation observed in oceanic basalts directly to mantle heterogeneity. Before attributing the isotopic signatures of the basalts directly to those of the mantle, it needs to be understood how partial melting samples and averages heterogeneous source components. Only then can we infer the distribution of heterogeneous source components, their size, mineralogical, chemical and isotopic composition, which is a prerequisite for inferring the origin of the various heterogeneous materials in the Earth's mantle.