Testing noble gas temperature systematics in the field with an instrumented monitoring well

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Recent studies have found a significant bias of noble gas temperatures (NGTs) to values below average ground temperatures near the water table [1, 2]. To understand the source of this bias, a new monitoring well was drilled in the Glacial Drift Aquifer, Michigan, near that of a previous study [1]. CO_2 concentrations in the screened region within 0.5 m above the water table as well as dissolved O_2 in groundwater just below the water table are consistent with total CO_2 and O_2 partial pressures of about 0.1 atm at the saturated-unsaturated zone interface, in good agreement with our previous estimate from the oxygen depletion (OD) NGT model [1]. In addition to eliminating the NGT bias to low values, a key feature of the OD model is that the extra noble gas partial pressures reduce the size and importance of the "excess air" component that forms the basis of all standard NGT models. Excess He was previously found [1] and has now been confirmed in samples from eight different levels of the new monitoring well which display an apparent absence of vertical He gradient. He concentrations are above those expected for groundwater in equilibrium with the atmosphere, even assuming the OD model pressure enhancement effect. This implies that groundwater at the water table is not in equilibrium with the overlying air despite likely rapid diffusion through the bulk of the unsaturated zone. Models for gas transport suggest that gas diffusion can have high tortuosity in the capillary zone and this may explain the apparently low vertical He gradient and hence low He flux. To test whether or not transport in the gas phase is a rate limiting step, a new "gas-diffusion relaxation" (GR) NGT model was developed that allows for gradual loss of excess air via diffusion in the gas phase. This model was tested with previously aqcuired data [1] and was not only found to yield correct NGTs, but also to improve the fit over the OD model while still being compatible with measured isotopic ratios.

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Recycling of subducted oceanic crust: Constraints from Nb/U

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Mid-ocean ridge basalt (MORB) and ocean island basalt (OIB) have very similar super-Primitive Mantle (PM) Nb/U (average 47), which, together with sub-PM Nb/U (average ~6) in the continental crust, link the mantle sources of the basalts to the recycling of oceanic crust. Because subduction of oceanic crust is the main means by which Nb/U is fractionated, a well-mixed flux of oceanic crust into the mantle is implied. Two possible mantle scenarios are explored whereby the observed Nb/U fractionation pattern is maintained during the recycling of these trace elements.

(1) Density contrasts suggest that subducted basalt in the lower mantle, converted to its high pressure polymorphs or as total melt, would be permanently trapped at the core-mantle boundary [1-2]. However, rather than completely melting, the basalt, upon reaching solidus temperature, is likely to disaggregate with a lighter fraction of crystals and liquid separating from a heavier perovskite-enhanced residue, as may happen at the margins of Low Shear Wave Provinces [3]. This SiO_2- and incompatible element-enriched fraction, bearing most of the super-PM Nb/U signature, would likely diffuse into the overlying pyrolitic mantle and eventually trigger a new mantle plume. The plume could either itself traverse the entire mantle, or transfer its Nb/U signature to an upper mantle convecting cell at the 660-km boundary layer.

(2) Carbonatites and kimberlites attest to a significant carbonate component in the mantle, which below ~70 km would exist as a melt and has been proposed to explain the upper mantle low velocity zone [4]. Such a melt might scavenge incompatible trace elements from subducting oceanic crust, and become an important storage reservoir for U and Nb. The similarity in Nb/U between subsequent MORB and OIB can be the result of their source's mutual interaction with such CO_2-rich melt zones (but may also produce a bias toward Nb, which is often highly enriched in carbonatites). With decoupling of trace and major elements, MORB and OIB could still have separate upper and lower mantle sources, or reflect heterogeneity in the upper mantle.

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