Hydrous phases in the lower mantle

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Dehydration of subducting lithospheric slabs to less than 200 ppmw H_2O in the upper mantle is virtually impossible given the stability of nominally hydrous phases such as serpentine, 10Å phase, phase A, chondrodite, and clinohumite. Velocity models of the transition zone are consistent with significant hydration (> 1000 ppmw H_2O), but not with a dry pyrolite composition. It seems likely then that transition zone is relatively hydrous and that slabs penetrating the TZ are also hydrous. Where slabs push through 660 km into the lower mantle the fate of the water depends on the H solubility in $MgSiO_3$-perovskite, periclase, akimotoite, and majoritic garnet as well as the nominally hydrous phase D.

FTIR studies indicate relatively low solubility of H in perovskite and periclase [1]. However, we have synthesized $MgSiO_3$-perovskite with up to 2000 ppmw H_2O as measured by SIMS. It is, however, as yet unclear if the H is in the structure or as inclusions. We have measured up to 3000 ppmw H_2O in majoritic garnet where hydration may be associated with Mg octahedral vacancies. Phase D ($MgSi_2H_2O_6$) is a nominally hydrous phase stable to depths up to 1500km. We have synthesized Phase D in silica-excess and Mg-excess compositions as well as aluminous compositions. Phase D has a high bulk modulus but a relatively low density so that hydrous slabs penetrating 660 km may be buoyant [2]. Further experimental work is required for a meaningful constraint on possible H contents of the lower mantle.

[1] Bolfan *et al. (2002) Geophys. Res. Lett* **30**, GL0178182.
[2] Hushur *et al.* (2011) *JGR* in press.

Hot summers in the Western United States during the Late Cretaceous and Early Cenozoic

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Understanding how seasonal temperatures on land respond to global greenhouse climate conditions is important for predicting effects of climate change on ecosystem structure, agriculture and distributions of natural resources. Fossil floral and faunal assemblages suggest winter temperatures in middle and high latitude continental interiors during the Cretaceous and early Cenozoic were at or above freezing, whereas terrestrial summer temperature estimates are uncertain. Carbonate clumped isotope (Δ_{47}) temperature estimates from lacustrine and paleosol carbonates appear to be generally biased toward summer temperatures in middle and high latitudes. Though problematic for reconstructing mean annual temperature (MAT), this bias presents an opportunity to reconstruct terrestrial summer temperatures and, through comparison with paleobotanical data, estimate past terrestrial seasonality.

Here, we compile MAT estimates from paleoclimate and paleoelevation studies in the western United States. We then compare these data with existing [1, 2] and new Δ_{47} temperature estimates from Late Cretaceous – Present lacustrine and paleosol carbonates from the western United States. In this compilation, land temperatures are warm during the Late Cretaceous, reach an apex during the early-middle Eocene and then cool to the present (sharply from the late Miocene to Pleistocene). Both MAT and summer temperature estimates are warmer than modern MAT and summer temperature estimates at the study sites throughout the Cenozoic and Late Mesozoic. Summer temperatures from low paleoelevation sites during the Late Cretaceous to the Early Eocene are relatively warm (~30 – 40°C), though these values may include a few degrees of radiant solar heating of the surface. Regardless, these data suggest that at middle latitudes, both winters and summers in continental interiors may warm substantially under greenhouse climate conditions.

[1] Passey *et al.* (2010) *PNAS* **107**, 11245–11249.
[2] Huntington *et al.* (2010) *Tectonics* **29**, TC3005.