Zoned mantle convection

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We review the present state of understanding of mantle convection with respect to geochemical and geophysical evidence, and we suggest a model for mantle convection and its evolution over Earth's history that can reconcile this evidence. Whole mantle convection, even with material segregated within the D" region just above the core mantle boundary, is incompatible with the budget of argon and helium and with the inventory of heat sources required by the thermal evolution of the Earth. We show that the deep mantle composition in lithophile incompatible elements is inconsistent with the storage of old plates of ordinary oceanic lithosphere, i.e., with the concept of plate graveyard. Isotopic inventories indicate that the deep mantle composition is not correctly accounted for by continental debris, primitive material, or subducted slabs containing normal oceanic crust. Seismological observations have begun to hint at compositional heterogeneity in the bottom 1000 km or so of the mantle, but there is no compelling evidence in support of an interface between deep and shallow mantle at mid-depth.

We suggest that in a system of thermo-chemical convection lithospheric plates subduct to a depth that depends on their composition and thermal structure. The thermal structure of the sinking plates is primarily determined by the direction and rate of convergence, the age of the lithosphere at the trench, the sinking rate, and the variation of these parameters over time (i.e., plate tectonic history) and is not the same for all subduction systems. The sinking rate in the mantle is determined by a combination of thermal (negative) and compositional buoyancy, and as regards the latter we consider in particular the effect of the loading of plates with basaltic plateaus produced by plume heads. Barren oceanic plates are relatively buoyant and may preferentially be recycled in the shallow mantle. Oceanic plateau-laden plates have more pronounced negative buoyancy and can more easily founder to the very base of the mantle. Plateau segregation remains statistical and no sharp compositional interface is expected from the multiple fate of the plates.

We show that the variable depth subduction of heavily laden plates can prevent full vertical mixing and preserve a vertical concentration gradient in the mantle. In addition, it can account for the preservation of scattered remnants of primitive material in the deep mantle and therefore for the Ar and ^{3}He observations in ocean island basalts.

Oxygen isotopic composition of single aerosol particles: a study of Saharan dust sources

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To understand the climatic impact of mineral dust in the atmosphere, emission mechanisms and source strength must be known in addition to the dust physico-chemical properties. A new method to estimate the sources of mineral dust independently from atmospheric observation is reported here. The O isotopic composition of individual quartz grains from 2 to 10 µm were measured in an aerosol sample collected over the Cape Verde islands and in 4 soils from Saharan regions having strong dust emission rates (Morocco, Algeria, Niger and Chad). O isotopes were also measured in coarse-grained quartz from the soils to study their relationship with geological sources.

O isotope ratios were measured by ion microprobe microbeam (1 µm) analysis, after chemical isolation of quartz (Syers et al., 1968). Grains of interest were located by imaging of ^{16}O and then measured individually using an electron multiplier. The internal precision and external reproducibility were close to 3‰. Coarse grains were measured using multicollection and Faraday cup detectors with a precision close to 0.5‰.

$\delta^{18}O$ values of quartz in the coarse soil fractions can be compared with the major geological formation of each region indicating that each soil can be considered representative of regions ~100×100 km. More distal contributions in the 2-10 µm fractions suggest a regional aeolian mixing by low intensity winds. Differences between the fine fractions from soil to soil indicates that this mixing does not exist at the 1000 km scale. $\delta^{18}O$ values of aerosol quartz are comparable with the soil fine fractions. The highest $\delta^{18}O$ values (+30 to +40‰) observed in the aerosol and in some soil fine fractions are attributed to lacustrine cherts formed in evaporitic environments in the Chad basin. Their proportions and the direct comparison of the $\delta^{18}O$ distributions indicate that the most probable source of the sampled dust event is the Niger region. These observations suggest that dust in the Sahara is regionally mixed by low intensity winds but not globally and that dust carried over long distances is emitted in the high troposphere by temporally and spatially discrete dust storms.

References

Syers J. K., Chapman S. L., Jackson M. L., Rex R. W and Clayton R. N. (1968) *Geochim. Cosmochim. Acta* **32**, 1022-1025.