

Isotopic evolution of the mantle in numerical models of mantle convection and plate tectonics

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Model

The thermal and chemical evolution of Earth's mantle and plates are inextricably coupled by the plate tectonic - mantle convective system. Convection causes chemical differentiation, recycling and mixing, while chemical variations affect the convection through physical properties such as density and viscosity, which depend on composition. In this presentation, numerical models of mantle convection that combine a treatment of major and trace-element geochemical evolution with a dynamically-consistent mantle convection-plate tectonics model will be presented. Melting is simulated using an experimentally-based solidus with melt assumed to erupt instantaneously, forming a crust. Trace elements partition between melt and residue. The internal heating rate depends on local U, Th and K concentrations, which are tracked along with other important trace elements. A suite of numerical experiments is run to systematically investigate the sensitivity of the resulting behavior to uncertain physical properties such as variation of density with chemical composition, elemental partition coefficients, viscosity stratification, and total amount of heat producing elements.

Results

If eclogite is denser than pyrolyte or residue in the deep mantle, the system tends to evolve towards a chemically stratified state, with a basal layer of subducted crustal material enriched in heat-producing elements displaying a HIMU-like signature and an upper mantle dominated by residuum. If a basal layer of primitive material initially exists, it gets diluted by subducted crustal material unless it is substantially denser. Regions with a high ³He/⁴He may self-consistently develop, consistent with the model of Coltice et al. (2000). Degassing of ⁴⁰Ar is consistent with constraints from ⁴⁰Ar concentrations in Earth's atmosphere. Isotope ratios of erupted basalts are in some cases consistent with MORB but can have high ³He/⁴He ratios if a large amount of depleted residuum exists in the upper mantle.

References

- Coltice, N., S. Ferrachat and Y. Ricard (2000), *Geophys. Res. Lett.*, **27**, 1579-1582.
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Competitive adsorption of oxyanions

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Introduction

Because of the ubiquitous distribution, high reactivity, and high specific surface areas of colloidal (hydr)oxide minerals, these surfaces often act as reservoirs for oxyanions. However, strongly sorbed oxyanions such as PO₄³⁻, AsO₄³⁻, and AsO₃³⁻ may be displaced from mineral surfaces by more weakly sorbed oxyanions, including HCO₃⁻, SO₄²⁻, and H₄SiO₄, that often occur at much higher concentrations.

Modeling Silica-Arsenite Competitive Sorption

In batch equilibration experiments, arsenite (as H₃AsO₃) was more strongly sorbed on goethite than silica (as H₄SiO₄), and was only minimally displaced at silica concentrations that otherwise saturated the goethite surface. However, even the relatively ineffective competition of silica for surface sorption sites dramatically increased equilibrium solution arsenite concentrations.

The competitive sorption of arsenite and silica on goethite was modeled using the Charge-Distribution Multisite-Complexation (CD-MUSIC) model (Hiemstra and Van Riemsdijk, 1996), with FITEQL version 4.0 as the numerical engine (Tadanier and Eick, 2002). Intrinsic equilibrium constants K_{int} for inner-sphere sorption of arsenite and silica were individually determined by fitting the CD-MUSIC model to equilibrium sorption data at several concentrations of each oxyanion. Surface potential data obtained by laser-Doppler-velocimetry photon-correlation spectroscopy was used to calibrate the single ion sorption models. Competitive interactions between arsenite and silica were described with single ion sorption K_{int} values. Both single ion and competitive sorption data were well described by the CD-MUSIC model at all surface loadings. Surface potential data was also well described; however, only if monodentate surface complexes were included in the sorption model.

Conclusions

Surface potential data can be used to discriminate between sorption models that describe sorption data equally well, which may result in different surface speciation of a sorbed ion.

References

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