

Carbonatite extraction and seismic anomalies in the Galápagos plume

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Conventional models of plume-ridge action call on plume material (either melt or solid mantle) flowing along the base of the lithosphere toward the ridge. This model is inconsistent with a number of seismic and geochemical paradoxes in the Galápagos Archipelago. Although the Galápagos Spreading Center is contaminated with plume Sr, Nd, and Pb, there is no plume He in GSC lavas. Many of the northern Galapagos volcanoes have less of a plume isotopic signal than any GSC lava from within 400 km of the Galapagos hotspot. GSC magmas contain water from the Galapagos plume; there are no data bearing on whether the plume is richer in CO₂ than the GSC or whether plume CO₂ contaminates the GSC.

Combined surface and S-wave tomography reveals 4 velocity zones in the Galapagos plume: a 1 to 2% slow zone extending from 400 to 100 km, a normal velocity zone from 100 to 80 km, a zone 2% slow zone from 80 to 15 km, and the crust. The deep slow zone is unlikely to be due to hydrogen in olivine or temperature, owing to the magnitude of the velocity anomaly. Instead, we propose that it is due to a carbonatite melt that is produced at depths >400 km. A reasonable estimate of the carbon concentration of the Galapagos mantle is 500 ppm (as CO₂), which could yield a ~0.1% carbonatite melt. This melt is likely to extract the noble gases from the rock and ascend vertically to Fernandina's magmatic system. The zone with normal seismic velocity at 100 to 80 km may represent the intersection of the plume with the water-bearing solidus, as the removal of water from olivine is likely to result in an increased seismic velocity. For example, 150 ppm H₂O would depress the anhydrous solidus by about 55 km (Hirschmann, 2006). The shallower slow zone is likely caused by more extensive partial melting of the silicate phases in the garnet facies, producing a basaltic melt. Fernandina's high ³He/⁴He magmas result from mixing of the carbonatite and silicate melts above the plume axis, and trace element models are consistent with this hypothesis.

We propose that plume material is carried to the GSC by deep return flow of the asthenosphere toward the GSC (>100 km depth), not along the base of the lithosphere. Flow at this depth will incorporate plume material that is depleted in He and carbon, accounting for the lack of these signals in GSC lavas. Also, the shallow asthenosphere might be flowing with the plate, away from the GSC. Magmas from the northern Galapagos then are created by melting of mantle that has already had melt extracted at the GSC, accounting for their more depleted compositions. Carbonatite may be the cause of deep (>100 km) seismic anomalies in plume provinces on a worldwide basis.

Engineered nanoparticle sorption onto mineral surfaces

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The strong increase in the use of engineered nanoparticles (NPs) during the last decade may ultimately result in their release in environmental settings as predicted for different types of NPs by Gottshalk et al.¹. As part of previous modeling works, it has been showed that soils and sediments were able to accumulate high amounts of NPs while waters were acting as a dispersion agent. Thus, in order to be able to predict the fate of NPs in natural systems, an accurate understanding of the interactions involving the mineral surfaces is highly required. This study aims to estimate the NPs sorption properties onto model mineral substrates, to depict the molecular scale processes at work, and to assess the impact of the NPs physico-chemical properties, such as the NPs aggregation state.

For this study, the bulk structure of commercial ZnO NPs have been investigated using XRD analysis in combination with high-resolution TEM observations. The physico-chemical properties of the NPs surface were estimated from zeta potential measurements and XPS spectroscopy. And the NPs aggregation state was measured using DLS and cryo-TEM techniques. The sorption kinetics of ZnO NPs on mica surfaces and Al₂O₃ (1-102) oriented single crystals have been measured using atomic force microscopy (AFM) in 0.01M NaNO₃ solution. This revealed a fast sorption, in the order of minutes, followed by a slower evolution of the system during few hours. Furthermore, sorption studies on synthetic micro-sized goethite and alumina have been conducted at pH 7.0 in 0.01M NaNO₃ solutions. The time of exposure has been fixed at three hours and various mineral/NPs ratio have been tested. The obtained sorption isotherms could only be described using the Temkin equation, thus revealing a decrease in NPs affinity for the mineral surface with an increase in the total NPs sorption rate. This trend can be partly explained by TEM and cryo-TEM observations that showed a preferential sorption of aggregated NPs on the mineral surfaces compared to individual NPs. Finally, the NPs aggregation state appears to be one of the major controls of the NPs sorbing properties.

This study constitutes an essential step to understand the fate of NPs in soils, and demonstrates the importance of the NPs physico-chemical properties during their interaction with mineral surfaces.

[1] Gottshalk F., Sonderer T., Scholz R.W., and Nowack B., *Environmental Science and Technology*, 2009, 43, 9216-9222