The core-mantle boundary region, hotspot motion and geochemistry

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In this presentation, I discusss possible relationship between seismic heterogeneities near the core-mantle boundary, hotspot motion and isotope geochemistry observed on the ocean floor, focusing on the region in the Indian and south-Atlantic oceans as an example. Recent seismic results revealed a rapidly-varying very low-velocity province (VLVP) at the base of the mantle extending from the south Atlantic ocean to the Indian ocean. It has been suggested that the VLVP represents an "ancient" compositional anomaly produced early in the Earth's history [Wen et al., 2001, Wen, 2001]. At the Earth’s surface, the south Atlantic and the Indian oceans have a large number of hotspots and many impressive island chains and aseismic ridges, that are thought to be the tracks left by the passage of surface plates over major hotspots. The orientations and age progressions of these hotspot tracks can be used to study the relative motion between the hotspots. I show that three major long-lived surface hotspots (Tristan, Marion and Kerguelen) geographically within the VLVP exhibit small relative motions (<9 mm/yr) in the past 80 Ma, while other hotspots appear to drift away from the Tristan-Marion-Kerguelen hotspot group. The ocean floor in the south Atlantic and Indian oceans also exhibits the largest isotopic domain delineated on the Earth's ocean floor, the “Dupal anomaly”, which has been suggested to have formed early in the Earth's history. I show that the “Dupal anomaly” maximum observed on the Indian-Atlantic ocean floor geographically coincides with the VLVP when the past plate motions are taken into account. These observations can be explained and related by invoking a mechanism that the Tristan-Marion-Kerguelen hotspots manifest long-lived thermo-chemical plumes and the VLVP serves as an anchor for their relative slow motion and source for the unique Dupal geochemical signature. It is also interesting to note that most of other hotspots, such as Reunion, Comoros, Bouvet and Shona, are geographically adjacent to the VLVP. One possible explanation is that they manifest thermal plumes that are preferentially generated by a large lateral themal gradient and/or a rapid change of rheological properties from outside the VLVP to inside.

Reference

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Structure and properties of silicate perovskites in the deep mantle

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Reconciling the geochemical and geophysical constraints on the both the evolution and the current structure and dynamics of the lower mantle requires a complete understanding of the structure, chemistry and elasticity of silicate perovskites at mantle pressures, temperatures and compositions. But the exact structural state of even pure magnesium silicate perovskite at mantle conditions is as yet undetermined. And recent partitioning experiments [e.g. 1], while impressive, only extend to conditions appropriate for the upper-most part of the lower mantle.

We are pursuing an alternative and complimentary approach based upon the crystallographic systematics of perovskites. We have determined by single-crystal diffraction the cation distribution in $(Mg,Fe,Al,Si)O_3$ perovskite. We have also determined by single-crystal diffraction the structural evolution with pressure of a wide range of perovskites containing both compatible and incompatible elements [e.g. 2]. These new data clearly demonstrate that, contrary to previous belief, the compression of the octahedral sites is significant and that the evolution of the perovskite structure with pressure is controlled by a new principle; that of equipartition of bond-valence strain across the structure [3]. This new paradigm, together with the minimal information available from high-pressure powder diffraction studies, may provide the possibility of predicting the structural state and elastic properties of silicate perovskites of any composition at mantle pressures and temperatures. Cation partioning between silicate perovskites and other phases should then be predictable through the application of a Brice-style model [e.g. 1,4]. The geochemical implications of our initial exploration of this analysis will be presented.

References

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