Asymmetry of plume-ridge interaction around The Gálapagos

and Iceland controlled by spreading-ridge geometry

Summary

1 We quantify the degree of symmetry of observables as a function of plume centre location.
   - Centres of symmetry for bathymetric and crustal thickness profiles coincide with independently constrained plume centre locations.
   - Centres of symmetry for incompatible elements and their isotopes lie away from plausible plume centre locations.

2 We develop a simple kinematic model to predict the effect of mid-ocean ridge geometry on composition of outflowing material.
   - Enriched components in the plume progressively melt out during flow through the deep parts of spreading centre melt regions.
   - Ridges receive plume material that has experienced variable extents of depletion, as a function of the material’s distance transited through melting regions.

Asymmetry around Iceland and the Gálapagos is explained by radially symmetric plumes interacting with asymmetrically distributed ridge systems.

Asymmetry in observables

1. Iceland

   Reykjanes Ridge
   Galápagos Ridge

2. Galápagos

   Western GSC
   Eastern GSC

Select plume centres

1. Iceland

   Galápagos

2. Galápagos

   Eastern GSC
   Western GSC

Symmetry mapping

1. Iceland

   Reykjanes Ridge
   Galápagos Ridge

2. Galápagos

   Eastern GSC
   Western GSC

Sub-ridge plume flow length

- Plume material is modelled to consist of a depleted matrix containing enriched streaks. Material upwells and the fusible enriched component undergoes partial melting.
- The plume head partially melts when it passes under spreading centres. The bulk plume composition thus becomes more depleted the greater the distance it has travelled beneath ridges.

Sub-ridge flow path length

- Iceland

   Using the calculation of the distance plume material has flowed in sub-ridge melt regions before reaching a ridge segment, and assuming a reasonable melt region upwelling velocity, we can calculate the depletion of a fusible incompatible element (eg) in the enriched material of the outflowing plume head.

Plume-ridge case studies

1. Iceland plume and the Reykjanes and Kolbeinsey spreading centres

   Galápagos plume and the Galápagos Spreading Centre

Conclusions

1. Along-ridge profiles of Sr and Nd isotopes are distributed asymmetrically around the Iceland and Galápagos plumes.

2. Geophysical proxies for plume head dispersal for the Iceland and Galápagos plumes are consistent with its outflow being radially symmetric in the shallow asthenosphere.

3. Decoupling between geophysical and geochemical tracers of the plume head can be understood in terms of the partial melting and depletion of enriched blobs in the outflowing plume material, as it transit sub-ridge melt regions.

4. Asymmetry in along-ridge geochemical profiles can be explained by the plume-ridge geometry.