Hotspot motion inferred from mantle flow models: implications for global plate reconstructions

(fitting the track of the Hawaiian–Emperor seamount chain, including the bend)

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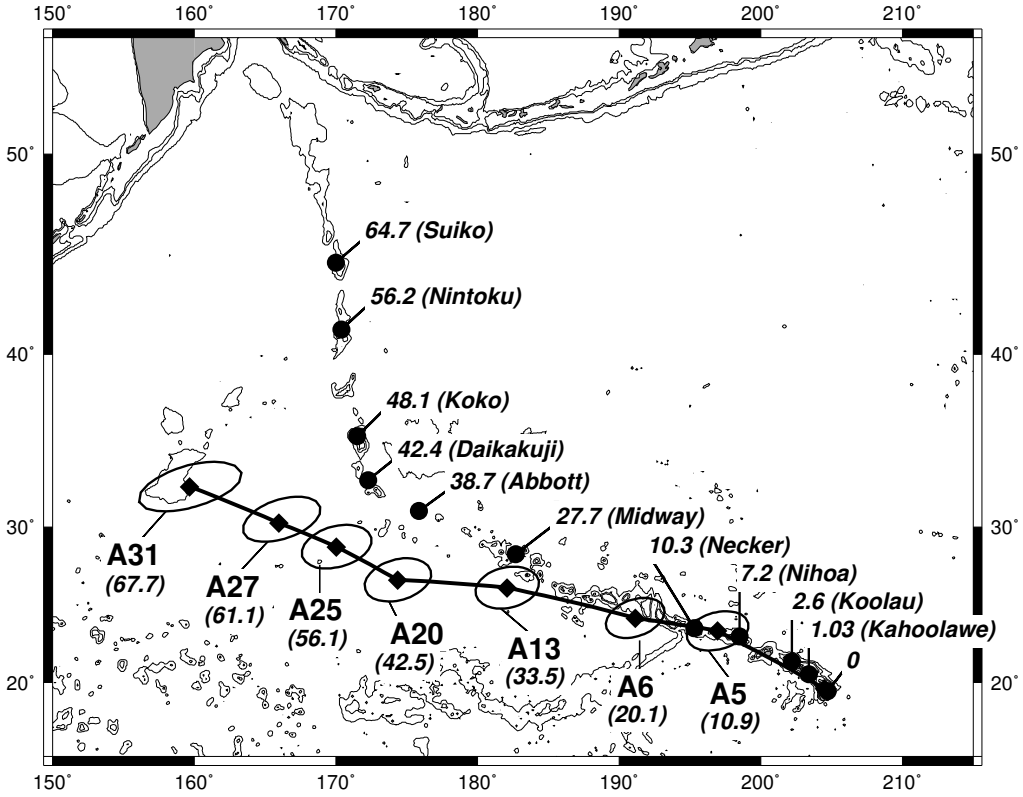
Introduction:

Long–known discrepancy between Hawaiian hotspot track and predicted track from plate circuits assuming hotspot fixity (e.g. Molnar and Stock, 1987)

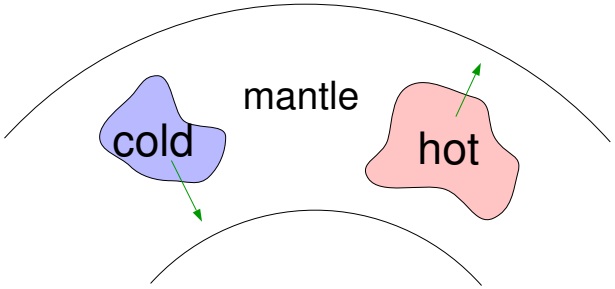


(figure from Cande et al., 1995)

Here we show how this discrepancy can be resolved by a combination of **hotspot motion**, obtained from geodynamic modeling, and **intraplate deformation** in accord with geologic observations.

Corollary: Success of this model – based on assuming a deep plume origin – supports this assumption, for at least some major plumes.

Essentials of numerical model

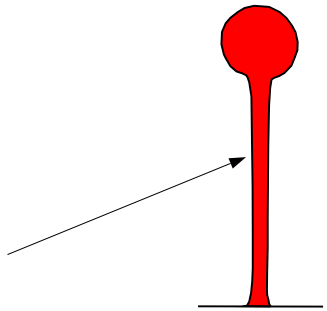


Mantle flow model

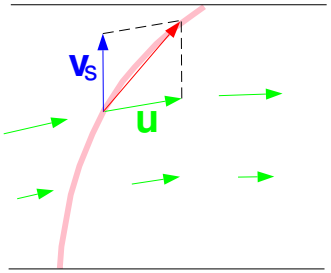
Large–scale flow inferred from surface plate velocities and internal density anomalies (from seismic tomography).

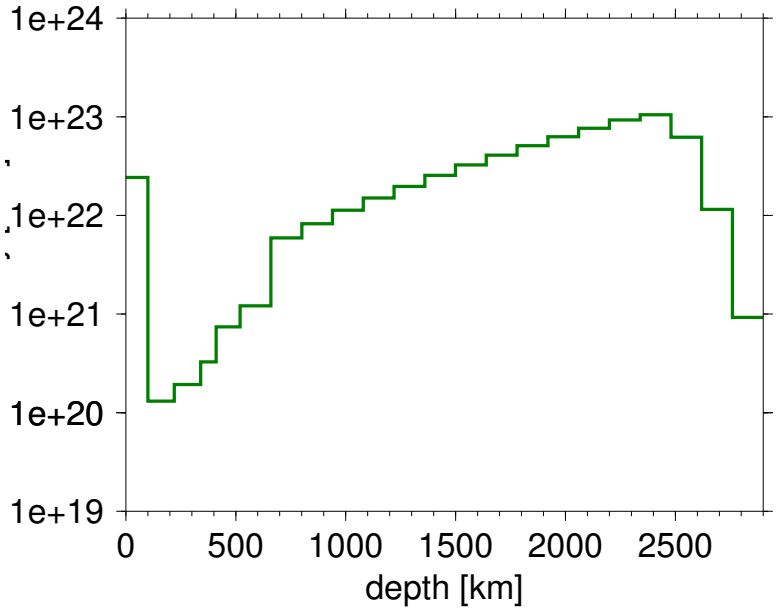
Plume Model

Initial condition: Vertical conduit



Advection of conduit in large– scale flow + buoyant vertical rising





Viscosity structure

Obtained from optimizing fit to geoid, with additional heat flow constraint (Steinberger and Calderwood, 2001)

Summary

- Mantle flow model in accordance with geoid, global heat flux, postglacial rebound – strong increase of viscosity with depth required.
- Southward motion of Hawaiian hotspot predicted. For some models, fast motion during formation of Emperor chain ($\sim$ agrees with paleolatitudes)
- Commonly slow motion ($\lesssim$ 1 cm/yr) predicted: Southward for Kerguelen ($\sim$ agrees with paleolatitudes), south-eastward for Louisville, southward (if any) for Tristan, eastward for Reunion
- Hotspot motion sufficient to fit hotspot tracks on both hemispheres after 43 Ma
- With $\sim$ 13 degrees of rotation between E and W Antarctica between $\sim$ 83 and 43 Ma(+ possibly deformation in New Zealand between $\sim$ 83 and 63 Ma) achieve approximate fit of hotspot tracks on both hemispheres for times before 43 Ma. Proposed deformation consistent with geologic evidence (R. Sutherland, unpublished manuscript).
- Antarctic deformation in accord with stresses from mantle flow — may have stopped after sufficient oceanic lithosphere had formed around Antarctica.
- Combination of hotspot motion and Antarctic deformation sufficient to account for Hawaiian hotspot track with bend at 43 Ma.