Driving the Earth Machine?

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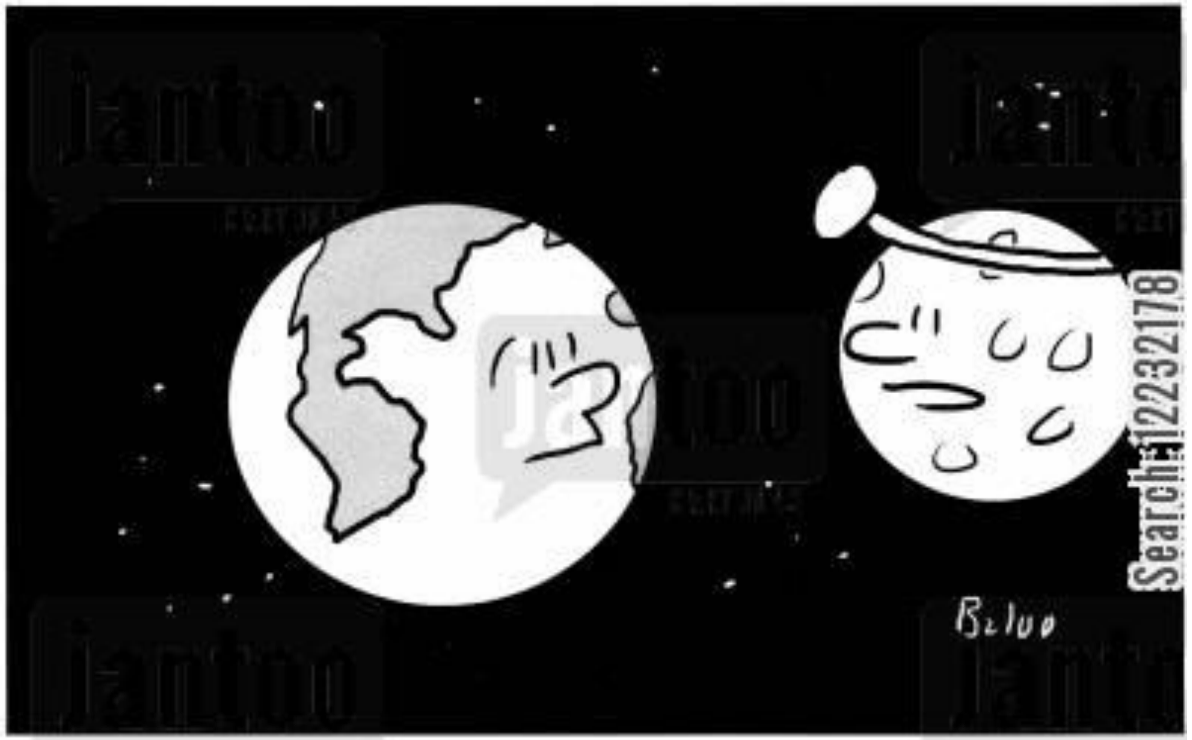
Presented by Molly Ellowitz

What was the question?

- Are mantle plumes or the asthenosphere the source for hot spot magmas?
  - What impact does the asthenosphere have on the mantle?
  - Where are heterogeneous lavas derived?
  - What is the depth range of the asthenosphere?
  - Why is the asthenosphere hotter than expected?

The Hypothesis

“Recent studies suggest that the asthenosphere may play a more active role as the source of the heat and magma responsible for intraplate volcanoes.”



“How long have you had these hot spots?”

Plate Tectonics

What impact does the asthenosphere have on the mantle?

- Simulation without an asthenosphere
  - Narrow plumes
- Simulation with a weak asthenosphere
  - Two broad upwellings
  - Consistent with LSV provinces globally
  - Superplumes?

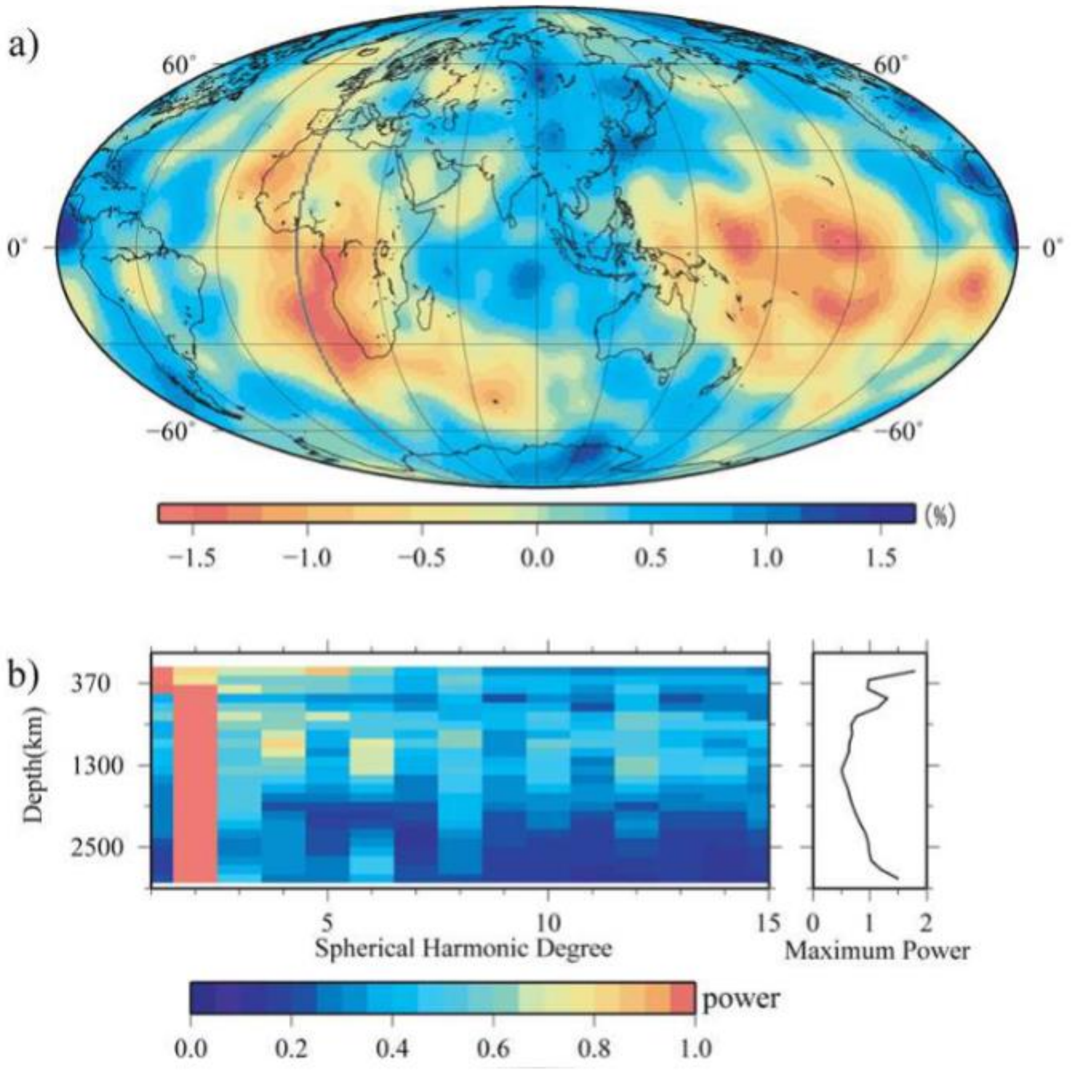


Figure 1. Shear wave velocity heterogeneity for the tomographic model S20RTS shown (a) in map view at 2750 km depth and (b) as the normalized power spectra at different depths. Figure 1b (right) shows the maximum power at different depths that is used to normalize the power.

Heterogeneous lavas

Where are heterogeneous lavas derived in hot spot volcanism?

- Zone of concentrated shearing

    Influences the composition of lavas

    - Homogeneous and heterogeneous lavas
        - Plumes vs. asthenosphere mixing

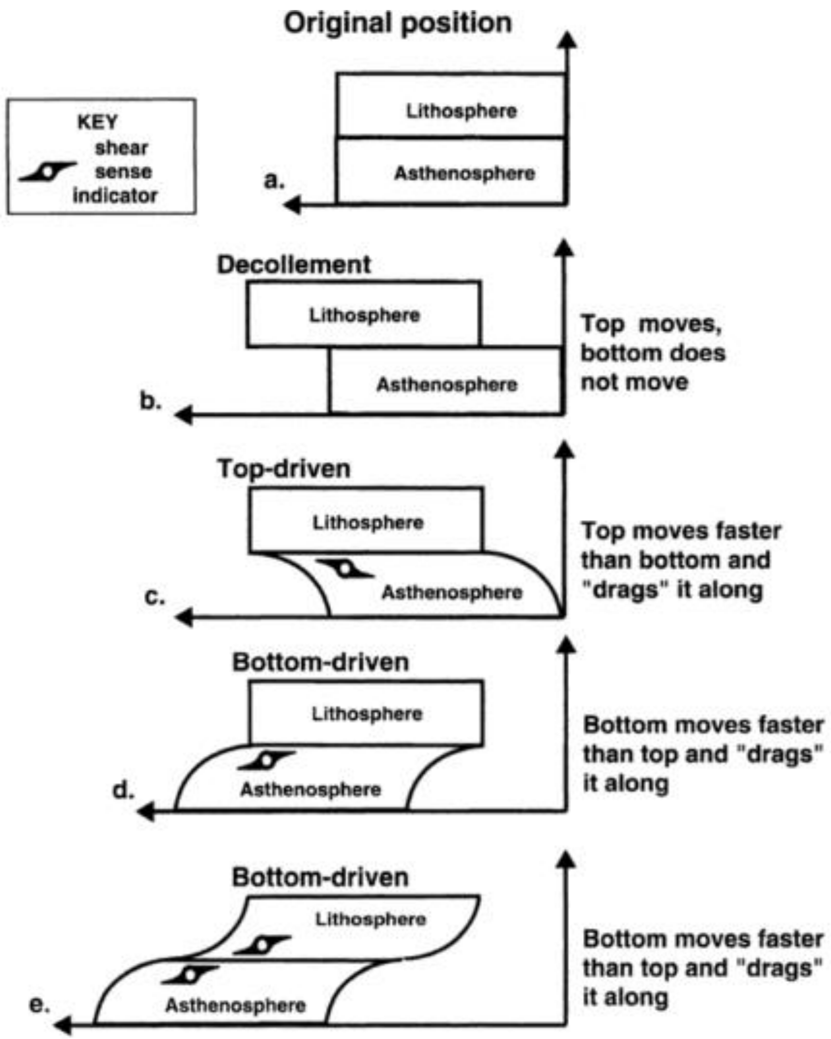


Fig. 5. Vertical, cross-sectional views of the relation between crustal and mantle deformation. The indicator represents an imaginary, initially vertical line that changes orientation with deformation (a loose line). The crust moves the same amount in all cases, but the relation between the upper crust and the mantle changes. Detachments (**b**) cause no fabric and are not consistent with the coincidence of crust and mantle deformation. Top-driven systems (**c**) produce the opposite sense of shear from bottom-driven systems (**d,e**). The lower crust can be involved (**e**), or not (**d**), in a bottom-driven system. Bottom-driven systems are expected to be the norm in orogenic belts. Modified from Tikoff *et al.* (2002).

Depth Range

What is the depth range of the asthenosphere?

- Consistent with the presence of partial melt
- The bottom boundary of the asthenosphere isn't defined

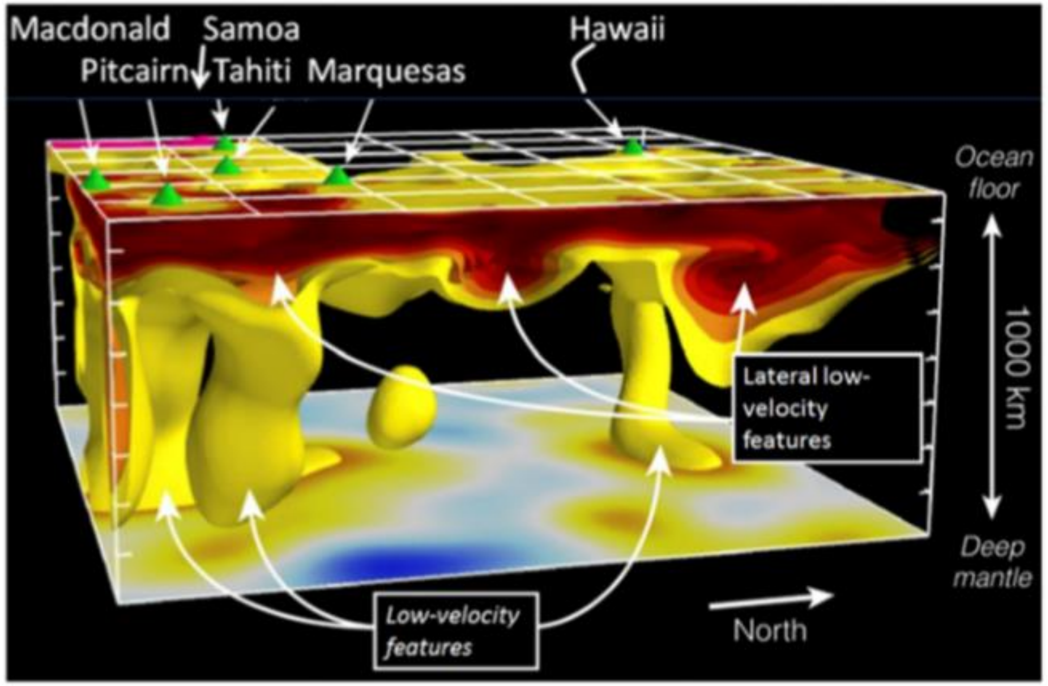
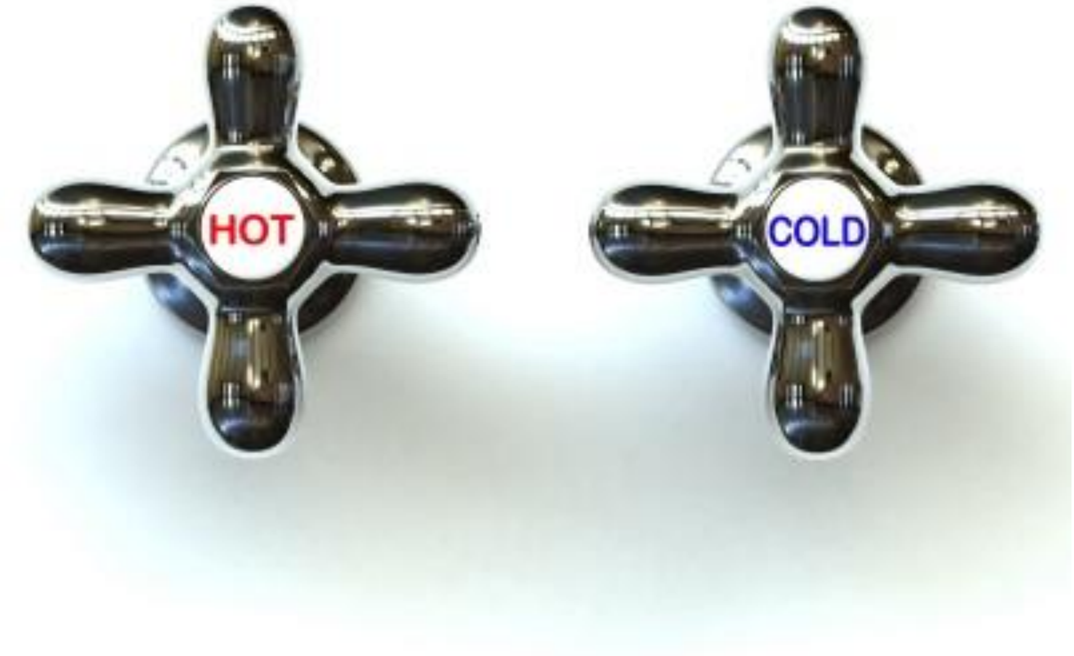


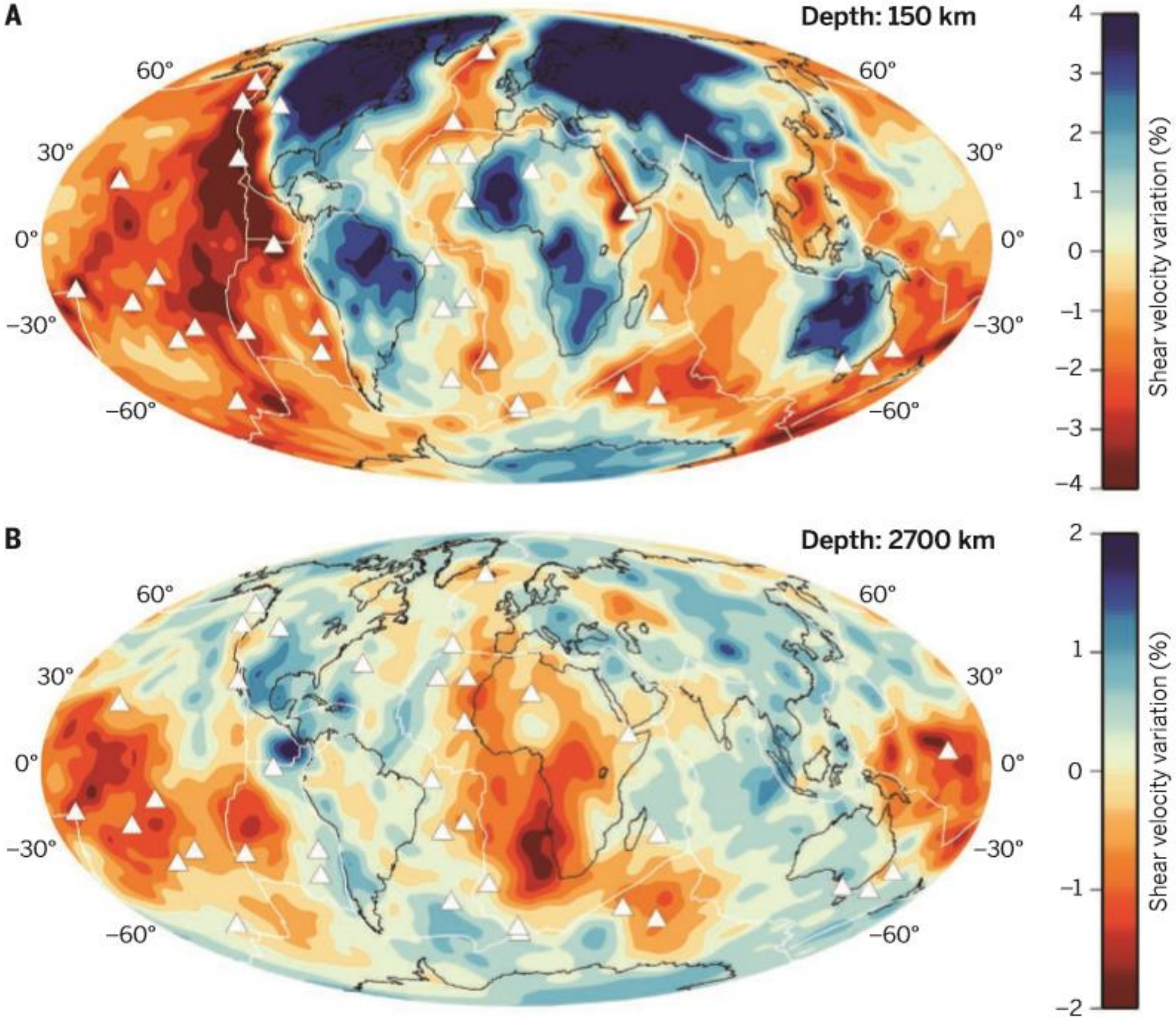
Fig. 2. A 3D perspective of seismic model SEMum2, shear-velocity structure of the upper mantle beneath a portion the Pacific, viewed from the southeast. Low-velocity regions are yellow-orange. Active ends of linear volcanic chains at the surface are green triangles. Active ends of linear volcanic chains at the surface are green triangles. Active ends of linear volcanic chains at the surface are green triangles. Minimum and maximum isosurface levels are –3% and 1%, respectively. See caption to figure 4 in ref. 2 for details. The view shows several low-velocity features extending from 1,000 km in the mantle toward the surface, converging on widespread regions of least velocity (dark red) distributed beneath the lithospheric lid, and comprising the widespread low-velocity region beneath the Pacific plate. The low-velocity features broaden into wide pedestals at 1,000 km (the lower mantle). Adapted from ref. 2; reprinted with permission from AAAS.

Hot vs. Cold

Why is the asthenosphere hotter than expected?

- Tectonic plates are insulating
- Lateral temperature variations
  - Decay of radiogenic elements





Top or bottom? Seismic anomalies in the asthenosphere (**A**) and at the base of the mantle, just above the core (**B**); the anomalies are relative to a one-dimensional reference model. The correlation between hot spots (triangles) and the edges of the slow (red) anomalies in the lower mantle has been used to argue that hot spots originate from plumes at these depths. However, hot spots correlate as well if not better with slow–wave speed anomalies in the asthenosphere, the region where the lavas originate.

Conclusion

- Since the hottest part of the mantle lies beneath the lithosphere, the concept that heat is needed to be brought up from the core in narrow plumes is unnecessary.

- "… the asthenosphere is by far the largest, most accessible, and most plausible source for hot spot magmas."

References

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