Can Seismic Tomography See Mantle Plumes?

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Seismic tomography is often used to study the three-dimensional structure of the upper and lower mantle, and is the most powerful tool for imaging structure beneath “hot spots”. Tomography experiments have often found regions of low wave speed beneath hot spots (and elsewhere) that might be an effect of high temperatures such as thermal plumes, but such results are seldom reproducible from one study to another. The basic reason for this difficulty is the sparseness and unevenness of the sampling of the Earth by seismic waves, a consequence of the sparse geographical distribution of earthquakes and seismometers. An infinite number of three-dimensional models are consistent with any real data set. The common practice of inverting seismic data to derive one such model is thus not informative, since the results are so highly non-unique.

The North Atlantic Ocean provides a good illustration of these difficulties. This region is sampled relatively well by seismic waves, due to the abundance of seismometers in Europe and North America and on Iceland and other islands, and to a favorable distribution of seismicity (compared to the central Pacific Ocean, for example). Nevertheless, derived mantle models differ in seeing or not seeing features that can be interpreted as mantle plumes. The locations, orientations, etc. of these features also differ from study to study.

Despite the shortcomings of real data sets, however, they do usually contain useful information. Even though an infinite number of conceivable models are consistent with available data, even more models are inconsistent with the data. A useful way forward is to use data to test hypothetical models, seeking to rule out some of the competing hypotheses about the Earth, as suggested by Tarantola (2006).

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