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On the stability of Earth's degree 2 mantle structure

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At the base of Earth's mantle, just above the boundary with the core, lie two large and nearly antipodal provinces characterized by anomalously slow seismic wave speeds, termed the Large Low Shear-wave Velocity Provinces (LLSVPs). One of these structures lies beneath Africa, and the other beneath the Pacific Ocean. Accumulating evidence has increasingly revealed that the LLSVPs play an important role in mantle dynamics, most notably in that they are spatially associated with most deep-seated mantle plumes, and they coincide with the broad, antipodal upwellings of Earth's degree 2 mantle flow. In affecting large-scale convection in the mantle, and the nucleation of plumes that can fragment the lithosphere, these lowermost mantle structures may furthermore influence long-term plate motions. A key question is therefore: how stable have these features been through time? Here we review multiple independent lines of evidence that indicate that the LLSVPs have been in approximately the same position for the last 300 Ma, and possibly considerably longer. Such long-term stability of the LLSVPs remains a contentious interpretation, and so we also discuss some of the important criticism that has been raised in response to it. Given the broad implications that this discussion carries for our understanding of the nature and history of mantle convection and plate tectonics, we regard the further interrogation of LLSVP stability beyond 300 Ma to be one of the foremost imperatives in modern geophysics. The way forward is not yet clear: innovative observational methods and novel experiments together with further numerical simulations are needed to resolve the question of Earth's degree-2 stability.