Student questions: Dr. Mingming Li colloquium on "Unstable Structure and Dynamics in Earth's Deepest Mantle"

2/16/22

Question 1: Professor I heard you mentioning the temperature, how is it related to plate tectonics in this type of study?
Plate tectonics is driven by mantle convection. Mantle convection is due to lateral difference of density which is greatly controlled by the difference of temperature.

Question 2: What is the main features of the thermochemical plumes?
They are hot and have different composition than the surrounding mantle.

Question 1: Is it possible to determine the ratios of different elements in the mantel through the analysis of seismic data?
Analysis of seismic data only provides density and seismic velocities. To relate these properties to compostion (or elements) of rocks, we need to know the density and seismic velocities of different rocks, e.g., through mineral physics experiments.

Question 2: If the LLVPs are actually pieces of the Theia impactor, is it possible that material from the LLVPs might have a similar composition to lunar rocks?
Yes, it is possible, since both may from Theia.

Question 1: Have numerical models applied to Earth dynamics given you more insight into how other planets evolve?
The same physical laws, such as conservations of mass, force, and energe, apply to the interior of different planets. Therefore, it is possible to apply our understanding of the Earth's deep processes to predict or estimate that in other planets' interior. For example, lots of our understanding about the interior processes of Mars, Venus and Moon have been based on numerical simulations of the long-term evolution of the Earth.

Question 2: How is solar development related to Earth dynamics ?
The present-day Earth may represent the past or future of other solar planets.

Question 1: How can thermochemistry piles periodically generate plumes at their edges?
Plumes are generated when rocks are heated (by the core) to have enough buoyancy. Once formed, plumes are advected to edges of piles and rise. The piles do not generate plumes by themselves.

Question 2: Do you think we would be able to harness energy from these plumes?
We could harness heat from mantle plumes once they reach shallow depths. The melting due to plumes and the associated volcanism provide heat energy to us.

Question 1: What can be done to test if there is evidence for rise in the Africa LLVP in geologically recent time?
The rise of the Africa LLVP could lead to rise of surface topography that may affect sea-level. Therefore, we could look at the topography of Africa in the past. We could also use seismic observations of anisotropy to provide information about mantle flows.

Question 2: Can a geodynamic model that is similar to the one that calculates the h of llvps, be done to analyze the past of a basaltic planetary body such as a satellite?
Yes, absolutely. The mantle convection in different planets follows the same physical laws.

Question 1: Which numerical model, either finite element models or finite difference models do a better job of explaining the relationship between solar and extrasolar development?
Both numerical methods have been widely used, and provided the same results.

Question 2: How much of a part do mantle plumes play in mantle convection?
Mantle convection in the Earth is mainly driven by the sinking of cold slabs and less by plumes. However, in other planets without plate tectonics, plumes play a dominant role in mantle convection.

Question 1: Does the existence of LLVPs indicate there are areas of large high velocity provinces?
Regions outside the LLVPs have high velocities, but we do not call them as LHVPs.

Question 2: In the video clips (e.g., the one showing the effective buoyancy rate), what happens to the material that appears to be ejected from the LLVP?
They are later cooled down and mixed with the surrounding mantle materials.

Question 1: Do LLVPs play any part in Super Volcano eruptions?
Yes, super volcanoes can be caused by mantle plumes. Many mantle plumes form at the margins of the LLVPs.

Question 2: Do we study LLVPs on any other planets?
Not yet. Perhaps because LLVPs have been confirmed by seismic observations on other planets.

Question 1: How were mantle convections involved (if any) in the formation of large igneous provinces like what we see in the Deccan Traps in India, Siberian Traps, etc.?
The large igneous provinces are thought to be caused by the melting of big hot head of mantle plumes. The rise of mantle plumes is an essential part of mantle convection.

Question 2: What is the danger of the Africa anomaly to human populations, due to its unstable density?
In a geological time scale, it will cause large volcanoes, continental rifting, Earthquakes, and change surface topography that affect sea-level and weather.

Question 1: How likely is it that there are undiscovered large bodies of resistant material in the mantle?
The large structures in the deep mantle such as the LLVPs have been consistently revealed in different seismic imaging models. However, these models differ in the distribution of relatively small structures due to lack of spatial resolution. Small structures remains to the detected or confirmed.

Question 2: How common is it for other planets to have active tectonics, and is a liquid core absolutely needed for that to happen?
Earth is the only planet in the solar system that has Earth-like plate tectonics, but other planets show evidence of tectonic processes. A liquid core is needed for the generation of magnetic field but is not essential for active tectonics. Tectonic processes are mainly controlled by convection in the interior. As long as convection exerts some stresses to the outermost shell (crust, lithosphere), the shell will deform.

Question 1: What type of waves gives the best resolution for the lower mantle?
The waves that travel to the lower mantle.

Question 2: Is there a geochemical interpretation of the low-velocity zone that fits the seismic modeling?
It has been proposed that the low-velocity zones may be enriched in iron, which make them dense and have low melting temperatures (and easy to be molten).

Question 1: If there are large low-velocity provinces, are there small low-velocity provinces as well, and if so, what are their importance?
Yes, they are wide-spread relatively small low-velocity structures on the core-mantle boundary. These structures provide information about Earth's present-day thermal and chemical status and their long-term eovolution, the processes of interaction between the core and mantle.

Question 2: What ideas have been proposed for the effect of LLVPs on tectonics and hotspot volcanic activities? I remember this was briefly addressed, but I was wondering if there is a more in-depth answer.
The LLVPs are still relatively small in volume compared to the large mantle. They occupy less than 10% of mantle volume. So, they are often thoughted to be mainly passively advected by mantle convection. Their presence on the core-mantle boundary reduced the heat released from the core into the mantle, which speeds up the cooling of mantle. However, it remains unclear how LLVPs contribute to plate tectonics. Many hotspots are thought to be caused by mantle plumes. It has been found that mantle plumes preferentially occur above the margins of the LLVPs. Therefore, the LLVPs play an important role in determining the locations of mantle plumes and the resulted hotspots on the surface.

Question 1: Why are the LIP eruption sites better for thermochemical models than for isochemical models?
Both thermal and thermochemical plumes could lead to LIP eruption. However, thermochemical plumes typically lead to less rise of surface topography because they are denser than thermal plumes. The lava compostion caused by thermal and thermochemical plumes is also different.

Question 2: When studying these thermochemical piles of mantle plumes, are you finding similarities between the Pacific and Africa sites?
Plume-induced hotspot volcanic rocks on the Pacific and Africa sites both have much complex geochemistry than the mid-ocean ridge lavas, suggesting that hotspots on both sides may be caused by thermochemical plumes that contain some different compositions than the regular background mantle.

Question 1: You said the Africa anomaly may be unstable; do you have any ideas about what this could mean for the future in terms of plate tectonics?
It may lead to continental rifting and volcanism, such as the east African rift.

Question 2: Have you found any evidence that there may be more LLVP's than just the two known about?
The large-scale structures with a size of LLVPs of Earth's mantle have been well establised by seismic observations. There is no evidence of a 3rd LLVP in the mantle.

Question 1: How can we use this model to understand the mechanisms of mountain forming and faulting?
In order to understand mountain building and faulting, we need to include more physical laws that describe these processes in the models. The models could become more complex.

Question 2: How could we use hand samples/fieldwork to further understand the formation of LLVPs?
We could collect and analyze igneous rocks that may have been origin from the LLVPs. We could also heat a tank of fluid from the bottom to simulate the process of mantle convection and study the dynamic interaction among different materials.