Structure and composition of Earth's interior

(GEO4-1401)

Tentamen – November 5, 2018; 9:00-11:30
Arwen Deuss

The numbers in () indicate the percentage for evaluation. No documents are allowed during the examination. Please write clearly and don't forget to indicate your name. When answering the questions, please give references to the papers we have read and explain why these papers are relevant. A full list of references is attached to the exam paper.

1. We have seen a number of papers which attempt to reconcile the geochemical and geophysical data in constraining the properties and style of convection in the Earth's mantle and a range of models has been proposed.
   (a) (10) Explain the whole mantle convection model. Which data and observations are in favour of whole mantle convection?
   (b) (10) Explain the layered mantle convection model. Which data and observations are in favour of layered mantle convection?
   (c) (10) Kellogg et al (1999), Helffrich & Wood (2001) and Davies (2009) all try to reconcile geochemical, geophysical and seismological data constraining flow in the Earth's mantle. What are their models and why do they reach either similar, or different conclusions?
   (d) (10) Which is your preferred model and why? Give references to the papers we have read.

2. We have also seen several papers which discuss the density structure of the Earth's mantle.
   (a) (10) Why is it important to know the density distribution in the Earth's mantle?
   (b) (10) What methods have been used to map the Earth's density structure? Explain each of the methods.
   (c) (10) How can we constrain the viscosity structure of the Earth's mantle and what are the main findings in these studies?
   (d) (10) What are the methods used to constrain the importance of thermal versus compositional heterogeneity in the Earth's mantle? Give references to the papers we have read.

3. (a) (10) Describe the discontinuities in the upper mantle and lower mantle, including how they can be observed using seismic data and what mineralogical causes might explain these discontinuities.
   (b) (10) Describe the seismic properties observed in the inner core and speculate on what might cause these structures.

1. Hager et al, Lower mantle heterogeneity and the geoid, *Nature*, **313**, p. 541–545, 1985.

2. Phipps-Morgan & Shearer, Seismic constraints on mantle flow and topography of the 660-km discontinuity: evidence for whole mantle convection, *Nature*, **365**, p. 506–511, 1993.

3. van der Hilst et al, Evidence for deep mantle circulation from global tomography, *Nature*, **386**, p. 578–584, 1997.

4. Kellogg et al, Compositional stratification in the deep mantle, *Science*, **283**, p.1881–1884, 1999.

5. Ishii & Tromp, Normal-mode and Free-Air gravity constraints on lateral variations in velocity and density of Earth's mantle, *Science*, **285**, p. 1231–1236, 1999.

6. Forte & Mitrovica, Deep-mantle high-viscosity flow and thermochemical structure inferred from seismic and geodynamic data, *Nature*, **410**, p. 1049–1056, 2001.

7. Karato & Karki, Origin of lateral variations of seismic wave velocities and density in the deep mantle, *J. Geophys. Res.*, **106**, p. 21,771–21,783, 2001.

8. Helffrich & Wood, The Earth's mantle, *Nature*, **412**, p. 501–507, 2001.

9. Hernlund et al, A doubling of the post-perovskite phase boundary and structure of the Earth's lowermost mantle, *Nature*, **434**, p. 882–886, 2005.

10. Davies, Reconciling the geophysical and geochemical mantles: Plume flows, heterogeneities, and disequilibrium, *G-cubed*, **10**, p.1-19, 2009.

11. Deuss et al, Seismic observations of mantle discontinuities and their mineralogical and dynamical interpretation, *Phys. Chem. of the deep Earth*, p. 297–323, 2013.

12. Lau et al, Tidal tomography constrains Earth's deep-mantle buoyancy, *Nature*, **551**, p. 321–326, 2017.

13. Song & Richards, Seismological evidence for differential rotation of the Earth's inner core, *Nature*, **382**, p. 221–224, 1996.

14. Deuss, Heterogeneity and anisotropy of Earth's inner core, *Annu. Rev.*, **42**, p. 103–126, 2014.