PART I

THE THERMAL AND COMPOSITIONAL STRUCTURE OF THE EARTH

INTRODUCTION

Part I consists of chapters giving seismological and mineral physics observations on the structure of the Earth's interior (Fig. 1). During the last two decades, there has been a major revolution in the way in which we understand how the Earth and the other planets might have evolved. The two most influential driving forces leading this revolution are (i) high-resolution imaging of the Earth's deep interior mainly by seismology, and (ii) high-pressure mineral physics studies. High-resolution seismological studies have established that there are large heterogeneities in deep interior of Earth including huge low velocity anomalies in the lower mantle beneath Africa and the South Pacific, sometimes referred to as *superplumes* (Fig. 2).

Zhao shows the 3-D P-wave tomographic images for the two superplumes, in addition to the several other plumes with or without tails at core-mantle boundary (hereafter abbreviated as CMB). Moreover, the stagnant slabs are commonly present at 410–660 km depth range (mantle transition zone) in most of the deep subduction zones throughout the world, by this improved tomographic method, based primarily on P waves and other body-wave phases.

To infer the origin of a superplume, an understanding of the post-perovskite phase change in the lower mantle holds the key (Fig. 3). Hirose summarizes the phase relations in both pyrolite and MORB compositions from surface to CMB conditions, and emphasizes the importance of the recently discovered post-perovskite phase, that is stable in D″ layer. Furthermore, the solubility of light elements such as Si, O, Mg in iron liquid is reviewed.

Due to the uncertainties in the pressure-scale under extremely-high pressure conditions (Hirose et al., 2006), it is necessary to calculate the Clapeyron slope of perovskite/post-perovskite transformation by first-principles quantum mechanical calculations. Tsuchiya et al. present a critical review of this debate, and recommend a value of 7.5 MPa/K. However, there are still large variations due to the particular method used in these calculations.

If the catastrophic collapse of once stagnant low-temperature slabs at the mantle transition zone occurs and moves into the lower mantle, the core dynamics must also be strongly affected by a cold slab avalanche due to its refrigerating effect on the liquid core. The direction of flow in the outer core is from north to south in the bundle of

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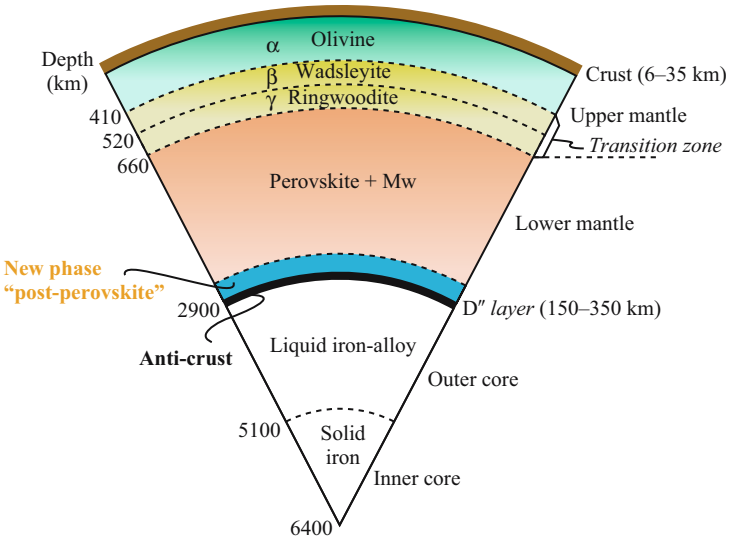


Figure 1. Change of mineral assemblage in the mantle with depth. The seismological boundaries are delineated in the solid Earth.

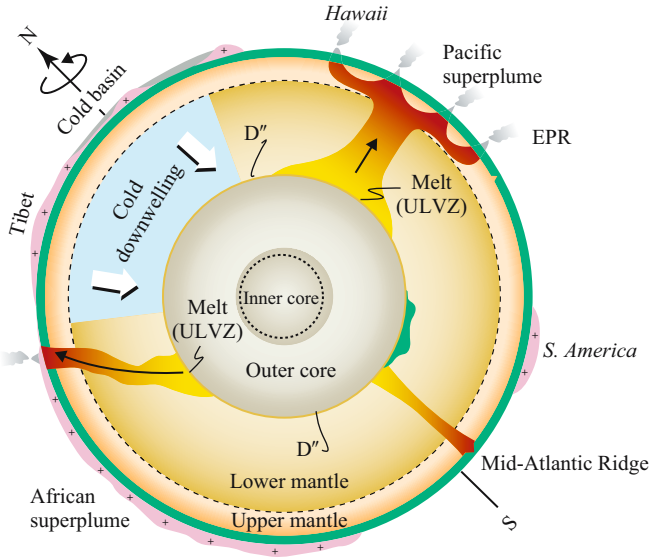


Figure 2. General pattern of mantle convection of the Earth. Two superplumes in the Pacific and Africa, and one super-downwelling underneath Asia form the major convection pattern. The mantle under the Tibet-China-Japan-W. Pacific is the coldest region but most of it is enriched in water by subduction. At 410 km depth small amounts of melt may accumulate. Majorite may also be present as a thin layer at 500–600 km depth, but only in a high-T region such as the central Pacific and Africa.

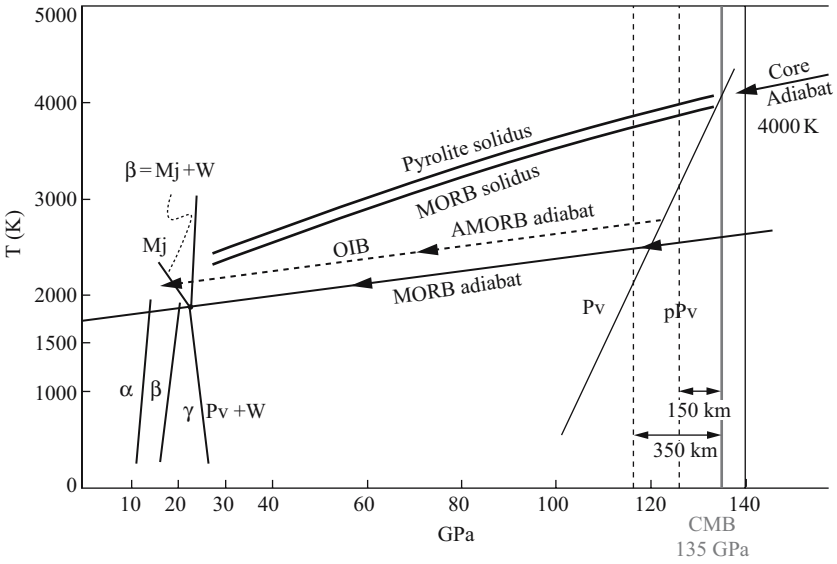


Figure 3. Stability of the post-perovskite phase. The Clapeyron slope of the perovskite/post-perovskite is still being debated.

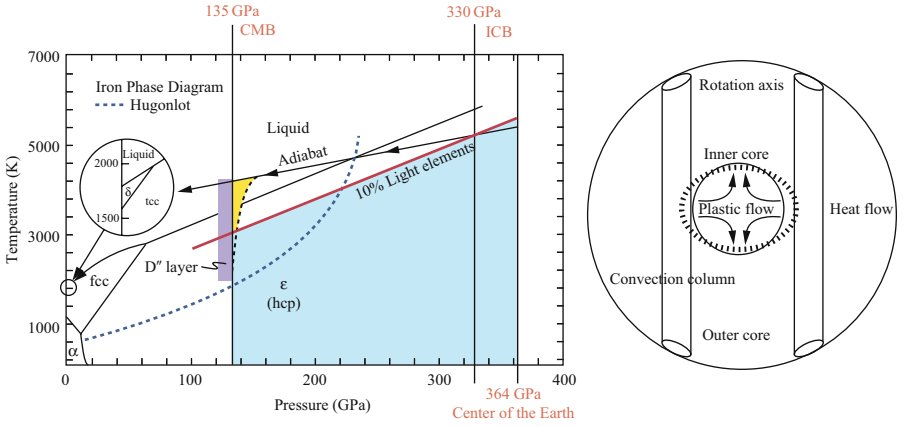


Figure 4. Dynamics of the core. Left: A phase diagram of Fe down to the center of the Earth (Anderson, 2003). ICB may be 5000 K. The core adiabat shows 4000 K at CMB, whereas the coldest zone on the top of the D″ layer (350 km thick) underneath Asia indicates 2000 K. A large temperature gradient is inferred to be present at the CMB. Right: North–south directed columnar dynamo convections in the outer core cool the equatorial solid inner core to cause the plastic flow in the central core (Yoshida et al., 1996).

convective columns, which may cause the preferential growth at the equatorial zone of the solid inner core to the polar regions (Yoshida et al., 1996). This controls the convective plastic flows in the solid inner core (Fig. 4). The concepts of an isotropic upper outer core and an anisotropic lower inner core, and the argument of a possible phase transition of Fe are introduced.

M. Ishii reviews the recent progress on core dynamics, in addition to her own recent works. The structure of the solid inner core can be determined by seismology in great detail. Unlike the liquid outer core, the solid inner core has a rich structure that contains potentially important clues to understanding the evolution and dynamics of the Earth. Ishii's paper provides a good guideline to the use of seismological literature on the core in order to understand the dynamics and evolution of this planet.

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