Chapter 1
Introduction

The Earth's lower mantle (extending from a depth of 660–2900 km) comprises more than half (~56%) of the total volume of the Earth. Most of the Earth's geodynamic processes stem from the mantle, which is reflected in the Earth's structure. However, its composition and structure are not yet well known.

Until recently, three major data sources have been used to draw conclusions regarding the composition and structure of the lower mantle: theoretical calculations; experiments conducted under high pressure, high-temperature conditions; and seismological observations. The first general models of the lower mantle were created based on these data sources. However, each of these data sources has both its advantages and disadvantages. Theoretical calculations are limited to simple compositions and may be used only as an approximation of the natural system. Experimental results depend upon the conditions of the experiments (e.g., type of compression medium and its hydrostaticity, type of heating, speed of heating and compression, duration time of high-pressure treatment and starting material) and are frequently contradictory. Depths of lower mantle scatterers established from different earthquakes, vary by hundreds of kilometres; estimation of seismic boundaries, made at different receiving stations from the same events may vary even more. The nature of the scatterers may be merely an estimation.

In recent decades, a series of lower mantle minerals and microxenoliths were discovered to be included in from diamonds in four continents. These findings support studies investigating the real composition of lower mantle material. They add significant information to our knowledge on the lower mantle but are rarely used for the lower mantle model compilations; most experimental and geophysical works ignore this data. To date, more than 2000 publications are in existence ranging from those containing results of experiments imitating lower mantle conditions, to those with ab initio calculations of mineral composition within the lower mantle, to the interpretations of seismic anomalies within the lower mantle, to other aspects of the lower mantle composition and structure. However, none of these papers used the observed geological data; hence, geological observations from experimental and theoretical data are disconnected. As a result, numerous

F.V. Kaminsky, *The Earth's Lower Mantle*, Springer Geology,
DOI 10.1007/978-3-319-55684-0_1

contradictions and discrepancies exist, which cannot be resolved if these results remain independent of each other. This represents the main reason why the author of this book set out to summarize the observed facts on the composition and structure of the material of the natural lower mantle and to compare this data with the data from areas of indirect constructions.

Some of the observed data on the natural lower mantle are in disagreement with experimental models. For example, one of the most enigmatic problems in the mineralogy of the lower mantle is the content and composition of ferropericlase. According to the theoretical and experimental constructions, ferropericlase, along with bridgmanite and CaSi-perovskite, is one of the major minerals in the lower mantle, where it should comprise up to 16–20%. However, among mineral inclusions in the lower mantle, diamond ferropericlase grains comprise 48.0–63.3% (average: 55.4%) of the total mineral content in the lower mantle, i.e., approximately three times more than the level previously suggested. Furthermore, the composition of ferropericlase, according to experiments in pyrolitic systems in the pressure range 25–60 GPa, should be highly magnesian, with the magnesium index $mg = Mg/(Mg + Fe)_{at}$ at *c.* 0.90. However, in the lower mantle per se, ferropericlase may vary locally to include more iron-rich compositions with $mg = 0.36$.

Another unexpected observation (from the theoretical and experimental perspectives) is the presence of free silica in all lower mantle associations. Silica inclusions, which were never predicted by theoretical constructions, were identified in all sets of lower mantle minerals observed in diamond from all regions and areas: 2.6–4.8% from Brazil; 8.2% from Guinea; and 10–20% from Canada.

One further feature of the real lower mantle composition that was not predicted is the existence of the carbonatitic mineral association, which was never observed in the upper mantle and comprises almost 50 mineral species, including carbonates, halides, fluorides, phosphates, sulphates, oxides, silicates, sulphides and native elements, as well as volatiles.

Kapitza (1966), in his recollections of Lord Rutherford, specifically underlined how the contradictions between theory and observation enable us to widen our knowledge of nature. Indeed, natural facts that contradict theoretical data allow regularities to be unveiled that could not be modelled by theoretical and experimental constructions alone, whilst also opening up the possibility for creating the most realistic models of the composition and structure of the deep Earth. Some discrepancies that exist between the model and the observed compositions of the lower mantle cannot be fully explained by the current hypotheses. However, I hope that even the act of just establishing such discrepancies will produce more realistic composition models of the Earth and its history.

In this work, I collected the most current geological data on the lower mantle, compared them with the available experimental, mineral physics and geophysical data, and tried to find general regularities in the composition of the lower mantle. The creation of a harmonious lower mantle model is an answer for several unknown quantities in one equation, and that would be too presumptuous to settle this problem. The main goal of the author was not to settle all the problems of the lower mantle composition and structure, but rather to summarize the current available data and to outline the major problems in this field, including its controversies. Geodynamic problems were not included in the scope of this work. I hope that the following pages will be of use for all geologists, petrologists and mineralogists studying deep Earth processes, as well as for experimental and theoretical researchers.

I would like to thank my colleagues with whom I worked in the field, collecting diamonds with lower mantle inclusions, analyzing these inclusions, studying and discussing different aspects of the lower mantle composition, and publishing results of these studies: A. Abakumov, P. Andreazza, E. Belousova, L. Bindi, F.E. Brenker, D.M. De R. Channer, P. Cartigny, E.M. Galimov, R. Davies, W.L. Griffin, B. Harte, P.C. Hayman, B. Jacobsen, G.K. Khachatryan, J.F. (Afu) Lin, S. Matsyuk, J. Matzel, C. McCammon, F. Nestola, S.Y. O'Reilly, M.P. Palot, I.D. Ryabchikov, S.M. Sablukov, A. Schreiber, A.A. Shiryaev, T. Stachel, G. Silversmit, R. Wirth, O.D. Zakharchenko and others, whose collaboration was invaluable. Images for crystal structures were created by Hong Yang (HPSTAR, Shanghai) with the use of CrystalMaker 9.2.7 software on the basis of certain observed mineral parameters obtained from geological samples or in high pressure–temperature experiments. I am particularly thankful to Yu.A. Litvin, discussions with whom inspired the writing of this monograph.

I understand that the present work may not be free of faults and will be thankful to the readers for any notes and remarks.

Reference

Kapitza, P. (1966). Recollections of Lord Rutherford. *Proceedings of the Royal Society of London. A294*, 123–137.