A Journey Toward the Center of the Earth – Iron/Light-Element Alloys at Extreme Conditions and Their Implications for the Earth's Core

A Dissertation Presented

by

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Abstract of the Dissertation

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Understanding the composition of the Earth's core is integral to answering many questions in the Earth Sciences, including the mechanisms and timing of core formation and the conditions under which the core formed, and also has important implications for the composition of the Earth's mantle. Because of the remote nature of the core, seismic profiles of the Earth's interior must be relied upon to determine the velocity and density structure of the deep Earth, and these profiles must then be compared with experimental data on candidate core phases at extreme conditions. The work presented in this dissertation was designed to study the physical properties of several iron/light-element alloy (ILEA) compounds at high pressures and temperatures in order to quantify their behavior under extreme conditions. Four such materials (Fe_3P, FeS_2, FeS and ε-FeSi) were studied in this investigation using a combination of synchrotron-based static compression experiments in Diamond Anvil Cells (DAC) and combined ultrasonic interferometry and synchrotron X-radiation in a Multi-Anvil Cell (MAC). The results of these two different types of experiments were remarkably similar, showing much better agreement than has ever before been seen between MAC and DAC experiments on these types of materials. The results of these experiments have provided an important benchmark for future studies on these materials and have resolved some of the controversy regarding the physical properties of these phases under extreme conditions.

The results of the ultrasonic experiments were extrapolated to pressures and temperatures relevant to the Earth's inner core, and a compositional-density-velocity model was constructed for the solid portion of the core. This model was then compared with existing cosmochemical and experimental data, as well as element partitioning studies, to form a more comprehensive model of the Earth's inner and outer cores. Previous models of core composition have been conducted under the assumption that Birch's Law, which states that acoustic velocity is solely a function of density, is valid for Fe and ILEA phases have thus far been unable to account for all aspects of the PREM model. By treating the existing data on pure Fe differently than previous studies and accounting for the fact that iron does not seem to follow Birch's Law, a model accounting for all aspects of PREM in the inner core, including the shear velocities, has been generated. This model, designed to account for experimentally observed deviations from Birch's Law, yields an inner core model containing 4.0-5.2 wt. % Si and ~0.1 wt. % O, corresponding to 4.8-6.12 wt. % Si and 5.3 wt. % O in the liquid outer core. This model satisfies geochemical constraints on the composition of the core as well as the density deficits observed in seismic profiles.