Geophysical Research Abstracts, Vol. 8, 03464, 2006
SRef-ID: 1607-7962/gra/EGU06-A-03464

Seismic velocities in models of chemical differentiation of the Moon

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The Moon is the only extraterrestrial body for which we have information about seismic velocities as a function of depth. The composition of the Moon, though the subject of intense geochemical interest, remains largely a mystery. Area of controversy includes suggestions that the lunar mantle is enriched in FeO and refractory elements (Al, Ca). Some investigators believe that both suggestions are likely correct, others suggest that the lunar mantle is enriched in FeO by a factor 1.2-1.5, but not enriched in refractories. On the basis of geophysical constraints on the moment of inertia and mass of the Moon and method of mathematical modeling of phase relation and physical properties in the system CaO-FeO-MgO-Al_2O_3-SiO_2, we examine the hypothesis of chemical differentiation of the Moon as a result of partial melting of initially homogeneous material (hypothetical magma ocean). Thermodynamic modeling of phase relations and physical properties of multicomponent mineral system was used to develop a method for solving the inverse problem. The technique of Gibbs free energy minimization was used, and equations of state of minerals and solid solutions were included in the database. In solving inverse problem, we require a non-negative density gradient in the mantle and include additional geochemical and cosmochemical constraints. For the computation of phase diagram for a given chemical composition we have used the THERMOSEISM software. The package contains thermodynamic databases and subroutines for calculating mineral equilibria by the method of the minimization of total Gibbs free energy. The solution of the inverse problem is based on the Monte Carlo method. We determine the ranges of chemical composition, mineralogy, velocities and density in the upper, middle and lower mantle as well as constraining core sizes.

A probable law of the velocity distribution in the lunar mantle is obtained for varia-

tions in the bulk Al_2O_3 content in the range 3-9%. The results of our inversion procedure generate velocity distributions that are similar to those of Nakamura (1983) and Lognonnė et al (2003). We find that lunar mantle compositions are strikingly different to that of geochemical models of Ringwood (1979), Taylor (1982), Wanke and Dreibus (1986), Jones and Delano (1989) and O'Neill (1991). Bulk compositions and velocity structure in the lunar mantle are discussed.

This research was supported by Russian Academy of Sciences under Programs 25 and 27, and by RFBR grants (06-05-64308).