The lithospheric structure at Japanese Islands: Integrated petrological and geophysical modeling

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論　文　内　容　の　要　旨

To understand the earthquakes and volcanic activities that occur around the Japanese Islands, it is necessary to understand the subsurface lithospheric structure around the Japanese Islands, which have complex plate boundaries. Although there have been studies on the deep subsurface structure of a limited area of the land and sea areas of the Japanese Islands, few studies have covered a vast area, including the Japanese Islands and the surrounding sea areas. The scope of this work was to model the crustal thickness and the geometry of the Mohorovičić (Moho) discontinuity, the lithosphere, and the upper mantle boundary at the Japanese archipelago from the sight of geophysics and petrology. For this purpose, I used the available receiver function results in seismic studies, seismic tomography models, global crustal thickness, and geological and tectonic information as constraints. The offshore areas are not well studied despite the seismometers spread around the Japanese Islands and several localized, small-scale seismic studies. The satellite data has a wide coverage, allowing us to explore rough terrain and vast regions. It also enables the study of long-wavelength geological structures. This thesis includes four chapters. The two main chapters include the depth distribution to the Moho discontinuity around the Japanese Islands and the LAB (Lithosphere-Asthenosphere Boundary) distribution, which are the two key objectives of this study.

Chapter 1 introduces the research framework, objectives, background, and motivation. It also includes the thesis structures.

Chapter 2 discusses the 3-D density model, crustal thickness, and Moho depth map in the Northwestern Pacific Ocean area and the contribution of stagnant slabs in satellite gravity gradients data. I used the latest satellite gravity model of Gravity Field and Steady-State Ocean Circulation Explorer (GOCE) GOCO06s with a spatial resolution of 80 km, covering the study area. The study had three steps: the data corrections followed by the inversion and the modeling and comparing the estimated results with previous models and analyses. I used the previous seismic results in various positions to constrain my inversion algorithm results. I used the 3-D non-linear gravity inversion constrained by previous seismic data and geological information to model the 3-D crustal density variation, the crustal thickness, surface geometry of the Moho, and geometry of the stagnant slab in the Kuril Trench, Japan Trench, Nankai Trough, and Izu-Bonin Trough.

This study used the constraints of available receiver function results, seismic tomography models, global crustal thickness, and geological and tectonic information. Integration interpretation of various geophysical and geological data would constrain and minimize the interpretation uncertainty. The inversion algorithm used 34 km as a Moho reference depth and 600 kg/m^3 as a density contrast. The resulting crustal thickness model and the depth to the Moho layer beneath the Japanese Islands and the area around were compared with the global thickness models and the Moho depths from global and localized seismic studies. The resulted model shows that crustal thickness ranges from 14 to 43 km, and the depth of Moho has a -0.78 mean misfit with previous Moho depths from seismic. The misfitting between the observed and calculated gravity data is 0.16 mGal. The normalized analytical signal helped delineate the different plates and their edges sharply. Three cross-sections were conducted to model the stagnant slab along the Eastern Eurasian plate subduction zone, western Pacific plate, Okhotsk plate, and Philippine Sea plate. The eastern area of the entire region (Pacific plate) had a lower crust thickness and high density than the western area (Eurasian plate), which had a high crust thickness and low density. The Moho depths model from gravity inversion can be used in the integrated geophysical and petrological inversion.

Chapter 3 discusses the results of integrated inversion of a geophysical and petrological analysis of mantle xenolith samples. Mantle xenoliths of volcanic rocks appear for the compositional and thermal structure of the Lithospheric Mantle. Chemical and Petrological analysis shows the differences between the Northeast and Southwest of Japan. The published xenolith analysis results represent only localized areas, which may not constrain the composition and evolution of the Japanese Islands. Mantle petrology affects the density distribution and the geometry of LAB. I used the published petrology analysis of xenolith samples and tectono-thermal age of different domains to constrain my inversion. In this study, I applied the integrated inversion of geophysical observations and fields (elevation, crustal thickness, geoid height, gravity, gravity gradients) with the Petrological analysis of Mantle xenoliths. The methodology depends on the chemical composition through self-consistent thermodynamic calculations to compute the seismic velocities and density at 400 km depth. To minimize the misfit between the calculated and observed data, the geometry of the crust and the lithosphere and mantle composition was modified within the uncertainty range. The output model is the variations in temperature, density, composition and the crustal and lithospheric thickness of the Lithosphere beneath the Japanese Islands.

Chapter 4 summarizes the results and findings of this dissertation in addition to the future research directions.