Solid Earth Science

2021-05-18

Outline of Solid Earth Science Group

The solid Earth is a very large-scale complex system, consisting of the crust, mantle, outer core and inner core which are different, both physically a nd chemically, from each other. This group aims to reveal the complex structure, composition and state of the Earth’s interior and to achieve a better and more unified understanding of the various geophysical, geochemical and geological processes operating on different temporal and spatial scales. In order to fulfill the above purposes, the six subgroups, named Structure of the Earth’s Interior, Dynamics of the Earth’s Interior, Magma Dynamics, Global Tectonics, Dynamic Geomorphology and Earthquake Physics, will be set up in this group. The first three subgroups mainly focus on structure and processes in the deep interior. The central subject is how the internal structure prescribes the dynamic processes and how the dynamic processes evolve the internal structure. This subject will be addressed from three different viewpoints of seismology, geodynamics and material science. The latter three subgroups mainly focus on structure and processes in the Earth’s surface. The central subject is how we can construct a unifying theory that can rationally explain complexity and diversity in tectonic structure and crustal activities including earthquake occurrence, volcanic eruption and mountain building. This subject will be addressed from geophysical, geological and geomorphological points of view. Another essential subject is thermo-mechanical coupling between mantle dynamic processes and crustal dynamic processes. The three subgroups, Dynamics of the Earth’s Interior, Magma Dynamics and Global Tectonics, will collaborate with each other to address this subject. Solid

Earth Science covers diverse research fields. Therefore, the education of Solid Earth Science in Graduate Course will be conducted in collaboration with many faculty members in Ocean Research Institute and Earthquake Research Institute.

Structure of the Earth’s Interior

The goal of this subgroup is to determine the the structure (density, compressibility, rigidity, viscosity, pressure, and temperature), composition, and state of the Earth’s interior. The main approaches used by this group will be seismological observations and high-pressure laboratory experiments on minerals. In order to obtain the most accurate possible models of the structure of the Earth’s interior, we should directly analyze seismic waveforms, as opposed to using only secondary data such as travel times or surface wave phase velocities. In order to analyze seismic waveforms we need efficient and accurate methods for calculating synthetic seismograms. Our subgroup has developed such computational techniques, and now is in the process of applying them to actual data to invert for 3-D Earth structure. Determining the Earth’s 3-D structure has important implications for geodynamics. In order to be able to interpret these data properly, we need better knowledge of the behavior of minerals at the pressures and temperatures in the Earth’s interior. This subgroup will study mineral physics experimentally using facilities such as SPRING-8.

Dynamics of the Earth’s Interior

From a dynamical point of view the solid Earth operates as three coupled convective systems in the fluid outer core, the subsolidus mantle and the outermost solid shell. In the outer core magnetohydrodynamic motions generate the geomagnetic field. In the mantle, in addition to the global-scale thermal convections that would be responsible to plate tectonics, there exist local-scale thermal plumes that cause hot-spot volcanism. In the Earth’s surface global plate motions with accretion of new plate areas at ocean ridges and consumption of old plate areas at ocean trenchs are driven by gravitational forces arising from thermal contraction associated with cooling. This subgroup aims to quantitatively understand the dynamic processes of these convective systems and to reveal the mechanisms of interaction between them, namely the viscous, magnetic and topographic coupling at the core-mantle boundary and the viscous and thermo-mechanical coupling between plates and mantle convection, through the analysis of geophysical and geological data and the large-scale computer simulation based on geophysical and geochemical models. In order to achieve this goal, collaboration with the other subgroups, Structure of the Earth’s Interior and Magma Dynamics, is necessary.

Global Tectonics

Tectonics is concerned with the nature and causes of the large-scale deformation of the lithosphere, ranging from the large deformations seen in mountain belts in plate boundary zones to the long wave deformation of plate interiors. Microscopic scale deformation is also very important to understand a basic process of tectonics. Oceanic tectonics is a science of the Mesozoic and Cenozoic, whereas continental tectonics takes us back to the Archean. Definite objective of this subgroup is to make clear the problem of how the lithosphere shortens, extends and flexes and how bulk deformations are accomplished in the brittle upper crust, the ductile lower crust and in the mantle lithosphere. Areas of current particular interest are tectonics of plate convergent zones and its evolution through earth history.

Magma Dynamics

Magma is a product of melting of the Earth’s and planetary interiors, which plays an important role in material and energy transportation, hence in the evolution of the Earth and the planets. The research targets of this group range from a microscopic scale such as behavior of elements and molecules in the magma, to a global scale phenomena as a field of magma generation, such as mantle convection-melting systems. Consequently, a wide spectrum of methods and approaches will be used: for example, spectroscopic observations of solid and melt, field survey and sampling of rocks, high-pressure and temperature experiments, numerical modeling of the processes. Combining all the available methods and data, the role of magma in the Earth's and planetary systems will be analyzed.

Dynamic Geomorphology

The formation and evolution of the Earth's landforms have been one of the most important subjects in Earth sciences, but are not yet fully understood. A real understanding of the Earth's morphology, in turn, is a key to revealing geologic processes acting on other planets, because most of observational data are of surface morphology that were obtained by remote-sensing methods. Topography of the Earth is formed both by endogenic processes (plate interaction, magmatic activity, etc.) and by exogenic processes (weathering, erosion, etc.). The formation of larger scale topography is controlled by progressively deeper Earth's properties such as density, temperature, and rheology. Therefore, a real understanding of the Earth's morphology requires highly multi-disciplinary collaboration by scientists from different fields of Earth sciences. This research group will consist of researchers from geomorphology, marine geology, and solid Earth physics. By combining geologic/geophysical observations and modeling, we will attempt to understand the Earth's morphology from an essentially new point of view.

Earthquake Physics

The scientific goal of earthquake physics is the understanding of the entire physical process of earthquake generation, consisting of tectonic loading due to relative plate motion, quasi-static rupture nucleation, dynamic rupture propagation and stopping, and fault lithification and healing. In order to achieve this goal, this subgroup will conduct research and education in mechanics of earthquakes, physics of earthquake rupture, crustal deformation due to faulting, theory and application of geophysical data inversion, and computer simulation of earthquake generation cycles. The education of earthquake physics in Graduate Course will be conducted in collaboration with faculty members in Earthquake Research Institute. In the research of computer simulation, collaboration with Crustal Activity Modeling Group of Earth Simulator Project promoted by STA (Science and Technology Agency of Japan) and Microscopic Simulation Group of ACES (APEC Cooperation for Earthquake Simulation) will be strengthened.

Web page of Solid Earth Science Group