
Summary of Session 2.1: Physical Modelling and Simulation of the Earthquake Cycles

Mitsuhiro Matsu'ura

Department of Earth and Planetary Physics, University of Tokyo, Tokyo 113-0033, Japan
(e-mail: matsuura@geoph.s.u-tokyo.ac.jp; phone: +81-3-3812-2111 ext. 4318; fax: +81-3-3818-3247).

The final purpose of Macroscopic Simulation Working Group (WG2) is to develop a realistic computer simulation model for the entire process of earthquake generation cycles, which consists of tectonic loading due to relative plate motion, quasi-static rupture nucleation, dynamic rupture propagation and stop, and fault lithification and healing. For this purpose, in Session 2.1, we set up the following three key issues and five essential questions.

1. Macroscopic modelling of earthquake cycles and predictability of earthquakes
 - Is the concept of earthquake cycle reasonable?
 - Can large earthquakes be separated from smaller earthquakes?
 - How should we describe the basic equations governing the earthquake generation cycle?
2. Crustal structure and tectonic environments for earthquake generation
 - What are the key parameters controlling the earthquake generation processes?
3. Physical process of tectonic stress accumulation and release during earthquake cycles
 - How can we model the tectonic loading process reasonably?

A very active discussion was held about these problems, especially about the concept of earthquake cycles, the interaction between large earthquakes and smaller earthquakes, and the predictability of earthquakes. Although definite answers to the questions could not be obtained, we came to the following conclusions through the discussion in Session 2.1 and also Sessions 2.3 and 4.2.

1. The classical concept of earthquake cycles, such as elastic rebound theory, characteristic earthquakes, and the time- or slip-predictable model, is too simple to understand complexity in earthquake history on a fault system. It should

be re-examined and understood to be a concept describing the process of tectonic stress accumulation and release repeated on a complex interacting fault system. This problem is closely related with the fault-fault interaction issues discussed in Session 2.3. The concept of earthquake cycles is probably useful in describing large, plate boundary earthquake sequences.

2. The essential difference between large and smaller earthquakes are in their stress accumulation and release processes. The large earthquakes that break down the entire seismogenic zone can be regarded as the process of tectonic stress release, while the smaller earthquakes that break down only a part of the seismogenic zone should be regarded as the process of local stress redistribution. A hierarchic fractal structure of fault systems is a key to understand the interaction between large and smaller earthquakes. This is closely related with the scaling problem discussed in Session 4.2.
3. The fundamental elements needed for the quantitative description of the entire earthquake generation cycle are viscoelastic slip response functions relating fault slip with stress changes, fault constitutive laws prescribing the relation between shear stress and fault slip during the earthquake cycle, and tectonic loading functions.
4. The processes of earthquake generation strongly depend on fault geometry, constitutive parameters (especially the critical weakening displacement), and tectonic environments (especially thermal states). In constructing realistic models of earthquake generation cycles regional differences in tectonic setting become essential.
5. The process of tectonic loading due to relative plate motion can be rationally modelled by considering viscoelastic stress relaxation in the asthenosphere and realistic frictional properties of the fault. The fundamental cause of tectonic loading is the increase of slip deficit in high-strength seismogenic regions on a plate boundary. In the stress accumulation and release process of a complex fault system, interaction between adjacent seismic faults is essential.