# Preface

Fluids such as water and $CO_2$ are known to exist ubiquitously, in the upper layer of the Earth and affect its deformation and earthquake occurrence. Such fluids may have origins in the dehydration reactions and sea water trapped at plate interface immediately before the subduction of oceanic slab; meteoric water and mantle-derived fluids are also mentioned as origins of fluids affecting earthquakes. As documented in Chaps. 1 and 2, abundant geophysical and geological evidence has now been accumulated that suggest the involvement of fluids in the occurrence of earthquakes. Fluid flow through connected pores can change the spatial distribution of fluid pressure and stress state of the solid. This may trigger earthquakes through change in the Coulomb failure stress coupled with the effective normal stress. Seismic sequences such as aftershocks and earthquake swarm may also be driven by such fluid flow. Coulomb's friction law coupled with the effective normal stress plays a key role in understanding the earthquake rupture phenomena in terms of fluids.

Dynamic slip can alter the hydro-mechanical properties of fault zone, which is known to be a principal pathway of fluids. Hence, intense nonlinear coupling is expected to occur between the slip evolution and fluid pressure change if the fault zone is permeated with fluid. Such intense coupling may give rise to complex fault slip behavior as observed in recent high-precision observations. There is a tendency in modeling studies that spatial heterogeneity of model parameters is regarded as an essential element to model the complexity of slip evolution. In fact, detailed spatial heterogeneity of model parameters is sometimes assumed to obtain a good fitness with observations. For example, strong and weak patches are assumed on a fault for the modeling of earthquake rupture complexity. This means that complex assumption is made to model complex behavior. However, whether the assumed model is good or not should be judged from the balance between the fitness with observations and simplicity of model. In fact, the scarcity of adjustable model parameters implies logical clearness of the model (Chap. 5). In addition, overly sophisticated modeling will be of little significance unless we have a deep knowledge about the underlying elementary process. Now we need an effort to find elements that play most important roles in modeling the phenomenon. What is required in such effort is the process of abstraction from our knowledge obtained through observations. Such way of thinking is based on a belief that apparently complex phenomena are governed by simple laws. In Chap. 3, we attempt to introduce some essential elements of deformation and internal fault-structures with a view to provide a useful guide to generalized fault-zone models. Experimentally deduced factors that can affect permeability structures are also introduced. These offers a basic scheme for evaluating fluid-flow properties in fault zones. In Chaps. 5 and 6, we try to understand complex earthquake rupture phenomena simply in terms of the involvement of high-pressure fluids on the basis of mathematical formulation of poroelasticity theory presented in Chap. 4. In other words, the existence of high-pressure fluids is shown to be a fundamental element forming the basis of abstract models for dynamic fault slip and sequence of seismicity.

Earthquake ruptures are not only complex but also show some regularity; the Gutenberg-Richter relation and the Omori law of aftershocks are well known examples. Since the coexistence of complexity and regularity is a conspicuous feature of non-linear system, there is a possibility that non-linearity plays a fundamental role in earthquake rupture. We can mention high-pressure fluids, constitutive friction law, interactions between slips on neighboring fault segments as examples of origin of such non-linearity. We take up high-pressure fluids in this book on the basis of recent studies and will show that the existence of high-pressure fluids and their flow plays a key role in comprehensive understanding of earthquake rupture phenomena. We believe that appropriate consideration of fluids play a key role to broaden our horizons about the mechanism of earthquake rupture.

This book originated from suggestion of Haruo Sato of Tohoku University to write a book that is helpful for beginners to understand earthquake source physics. Although we focused on the effect of fluid pressure change and its interaction with fault slip evolution, it will be one of the leading-edge fields of earthquake source physics. We tried to give a rather comprehensive description from a basic level, so that this book will easily be understandable for a broad range of readers. We hope that this book is useful to many people who are interested in earthquake rupture phenomena.

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Tokyo, Japan Teruo Yamashita
Kyoto, Japan Akito Tsutsumi

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