Preface

Over the past four decades, great progress has been made in scientifically understanding earthquake source processes; in particular, advances in the field of earthquake physics have contributed substantially to a profound understanding of earthquake generation processes in terms of the underlying physics. Yet, a fundamental problem has remained unresolved in this field. The constitutive law governing the behavior of earthquake ruptures provides the basis of earthquake physics, and the governing law plays a fundamental role in accounting quantitatively for the entire process of a scale-dependent earthquake rupture, from its nucleation to its dynamic propagation to its arrest, in a unified and consistent manner.

(see Chapters 5 and 6). To quantitatively account, in a unified and consistent manner, for scale-dependent physical quantities inherent in the rupture over a broad scale range, it is critically important to formulate the governing law so as to incorporate the scaling property inherent in the rupture breakdown. This is another requirement that must be met for the constitutive formulation for scale-dependent earthquake ruptures (Chapters 3 and 4).

Accordingly, the properties of fault heterogeneity and of physical scaling are the keys to rational formulation of the constitutive law for earthquake ruptures. In light of these properties, it is possible to rationally formulate the governing law (or constitutive law) for earthquake ruptures, based on the basic research on the physics of rock fracture and friction.

The primary reason I had for writing this book was that there are no published books on earthquake physics written deductively in a consistent manner based on the basic research on the physics of rock fracture and friction, achieved by high-resolution laboratory experiments. The time is ripe to write such a book, because underlying physical laws, such as a unifying constitutive law and a constitutive scaling law, and a physical model of shear rupture nucleation have been derived from high-resolution laboratory experiments properly devised for the purpose intended.

Chapter 1 of this book is an introductory chapter mostly devoted to the description of seismogenic fault inhomogeneities. Fundamental items of rock fracture/friction mechanics are described in Chapter 2. The central theme of this book is described in the remaining chapters. A key characteristic of this book is that the constitutive law for shear rupture, including earthquake ruptures, is formulated as a unifying law which governs not only frictional slip failure on a precut rock interface but also the shear fracture of intact rock, and into which the scaling property inherent in shear-rupture breakdown is incorporated. This is the common thread that runs through the entire book. In terms of a single constitutive law, the process of a shear rupture generation – from its stable, quasi-static nucleation to its unstable, dynamic propagation – is accounted for quantitatively in a unified and consistent manner, and scale-dependent physical quantities inherent in the rupture over a broad range from laboratory-scale to field-scale are treated consistently and quantitatively in a unified manner.

High-resolution laboratory experiments on shear rupture on an inhomogeneous fault are best suited for fully elucidating the physical nature of a scale-dependent shear rupture generation process from its nucleation to the subsequent dynamic rupture. Based on these experiments, therefore, the shear rupture nucleation process is physically modeled (Section 5.1), and observed data on seismic nucleation are consistently accounted for in quantitative terms based on the physical model (Section 5.2). In addition, strong motion source parameters such as peak slip velocity and peak slip acceleration are theoretically derived from the laboratory-derived constitutive equation, and discussed in quantitative terms (Section 5.3). Chapter 6 focuses on the root cause of scale-dependent physical quantities, and it is shown that the scale-dependence of scale-dependent physical quantities, such as slip acceleration, nucleation zone size and the duration time of nucleation, is attributed to the scale-dependent breakdown displacement or the characteristic length representing the geometric irregularity of rupturing surfaces. In Chapter 7, the final chapter, it is shown that large-earthquake generation cycles and accompanying seismic activity can be accounted for consistently under the premise that the governing law for earthquake ruptures is a slip-dependent constitutive law, and that the seismogenic layer and individual faults therein are heterogeneous. In addition, the final section of this chapter focuses on the predictability of large earthquakes.

Since 1985, I have had many opportunities to present my research findings at international meetings, and to discuss outstanding issues regarding earthquake phenomena with leading researchers from around the world. In these international meetings, I also had opportunities to personally get to know leading senior colleagues in the field of earthquake seismology. From the early 2000s, some of those who expressed a positive interest in my leading-edge research findings and deductive approach to addressing outstanding issues regarding earthquake phenomena encouraged me to write a book about the physics of earthquakes on the basis of laboratory-derived physical laws or formulae and physical model of shear rupture nucleation. Since I myself had intended to write such a book, their encouragement gave me the inspiration and keen desire to do so. Hence, I am grateful to international meetings' organizers/conveners for inviting me to take part in their meetings, and to scientific participants for fruitful or critical discussions. In particular, I wish to thank the following: the late Leon Knopoff, the late Keiiti Aki, Massimo Cocco, Shamita Das, James H. Dieterich, Raul Madariaga, Mitsuhiro Matsu'ura, Takeshi Mikumo, Peter Mora, James R. Rice, Christopher H. Scholz, and Xiang-chu Yin.

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