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Geophysical Monograph 170

Earthquakes: Radiated Energy and the Physics of Faulting

Rachel Abercrombie

Art McGarr

Giulio Di Toro

Hiroo Kanamori

Editors

 American Geophysical Union
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Front cover image: Pseudotachylytes are considered the primary evidence of ancient earthquakes on exhumed faults. They are interpreted as solidified, friction-induced melt produced during seismic slip. These pseudotachylyte-bearing fault and injection veins are associated with Late Paleozoic dextral strike-slip faulting in the ultramylonite of the Fort Foster Brittle Zone, Maine. Cross-cutting veins illustrate the effectiveness of frictional welding after earthquake slip (optical microscope, crossed polars, 1cm-wide view). *Courtesy of Rachel E. Abercrombie.*

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PREFACE

Understanding the energy changes that take place during an earthquake is one of the most challenging problems confronting the earth science community. An earthquake releases accumulated elastic strain energy, partitioning it into radiated energy, the energy consumed in overcoming fault friction, and the energy of expanding the rupture surface area. Although this energy budget can be stated quite simply, our understanding of it is only qualitative at best; arguments concerning the magnitudes of the four components in this budget range over an order of magnitude, or more.

The challenge posed by these fundamental uncertainties regarding the energy changes of earthquakes has attracted earth scientists from many disciplines, spawning a considerable amount of debate at meetings and in the literature in recent years. In this monograph, we capture the current spirit of debate by presenting an overview of what we know and have yet to know about earthquake energy budget phenomena. Some papers describe recent progress in how well we understand energy changes associated with earthquakes whereas other papers emphasize the outstanding questions and indicate new research directions that provide novel insights into the physics of faulting. For example, techniques for measuring radiated energy have improved in recent years, thus reducing the uncertainty of this important earthquake source parameter. Despite this progress, however, there remains substantial disagreement about the scaling of radiated energy with earthquake size. Pseudotachylytes, which represent both a breakthrough as well as a major gap in our understanding of how earthquakes work, can now be produced in laboratory experiments under controlled loading conditions. Nonetheless, we still do not know how relevant pseudotachylytes are to the physics of earthquake faulting. Other papers report progress in our understanding of fracture energy, an enigmatic component of the energy budget of earthquakes. Studies based on both geologic field work and dynamic rupture modeling of earthquakes suggest that seismological estimates of fracture energy may include frictional energy as well, a finding that could change the way we view the role of this parameter in the dynamics of earthquake rupture. How much energy is consumed in overcoming the frictional strength of mature active faults (e.g., the San Andreas) is a question that has vexed the earth science community for nearly forty years. It needs to be answered if we are to understand the energy budgets of earthquakes.

Given the state of the science, we organized an American Geophysical Union Chapman Conference from which this monograph derives. “Radiated Energy and the Physics of Earthquake Faulting” was held in Portland, Maine in June 2005. Nearly 130 earth scientists from 14 countries attended the conference to debate the many controversial issues concerning the energy budgets of earthquakes. Their expertise represented many disciplines including observational and theoretical seismology, fault-zone geology, laboratory rock mechanics, fracture mechanics, and geochemistry.

We chose Portland as the venue site because of its proximity to the Two Lights fault zones and the Fort Foster brittle zone, two coastal areas showing excellent exposures of faults, exhumed due to uplift and erosion from depths of about 10 km, that had produced earthquakes approximately 300 million years ago. A highlight of the conference was a field trip to these two coastal outcrops that was led by Mark Swanson, who, with his students, has been studying these ancient faults for nearly 20 years. During this outing, we were able to observe fault zone evidence of seismic slip, including pseudotachylyte (evidence of melting due to fault friction), at typical seismogenic depths. The fieldguides prepared by Mark Swanson to both the Fort Foster and Two Lights fault zones are included on the CD-ROM which accompanies this volume.

This volume would have been impossible without the hard work of all the reviewers and the publishing team at AGU, including our Acquisitions Editor, Allan Graubard, and Production Manager, Maxine Aldred. We also thank those who helped make the Chapman Conference a success. We are pleased to acknowledge the contributions of the Chapman Conference Program Committee: Greg Beroza, Judith Chester, Jim Evans, Satoshi Ide, Kevin Mayeda, Jim Mori, Kim Olsen, Xyoli Perez-Campos, Eliza Richardson, Bruce Shaw, Rick Sibson, Shri Singh, Mark Swanson and Terry Tullis. Brenda Weaver, Marlie Brill, and Mellisa Ficek, of the American Geophysical Union provided key logistical support for the Conference. Finally, we acknowledge the generous support and endorsement from the National Science Foundation, the US Geological Survey, the Southern California Earthquake Center, UF3 Llc, and the Seismological Society of America.

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