

Contents

1 Laboratory and Field Evidence for the Involvement of Fluids in Earthquake Faulting	1
1.1 Geological Evidence for Fluid Involvement in Earthquake Faulting	1
1.1.1 Fault-Valve Activity	2
1.1.2 Hydrothermal Extensional Veins	2
1.1.3 Implosion Breccia	5
1.1.4 Geochemical Evidence for Hydrothermal Fluid Circulation During Earthquake Faulting	7
1.2 Source of Fluids in Subduction Zones	8
1.2.1 Fluid Expelled from Subducting Sediment During Burial	8
1.2.2 Dehydration of Hydrous Minerals	9
1.3 Laboratory Studies of the Involvement of Fluids in Earthquake Ruptures	10
1.3.1 Fluid-Induced Seismicity in the Laboratory	10
1.3.2 Fluid-Mediated Restrengthening of Faults	11
1.3.3 Dehydration Reactions Due to Frictional Heating	12
References	13
2 Seismological Implications of Fluid Effect on Earthquake Occurrence	19
2.1 Effective Normal Stress and Coulomb's Law of Friction	19
2.2 Low P- and S-Wave Velocities and High V_p/V_s Values as an Indicator of the Presence of High-Pressure Fluid	21
2.3 Change of P- and S-Wave Velocities of Fault Zone Before and After the Occurrence of Earthquake	22
2.4 Reservoir-Induced Seismicity	23
2.5 Seismicity Induced by the Injection of High-Pressure Fluid	24
2.6 Seismicity Induced by the Groundwater Extraction	28

2.7	Relevance of Slow Earthquakes to the Presence of High-Pressure Fluid	28
2.8	Relevance of Earthquake Swarm to the Presence of High-Pressure Fluid	29
2.8.1	Correlation Between the Occurrence of Earthquake Swarm and the Existence of High-Pressure Fluid	29
2.8.2	Driving of Earthquake Swarm by Flow of High-Pressure Fluid and Elastic Stress Transfer	30
2.8.3	Aseismic Slip Coupled with Earthquake Swarm Activity	32
2.9	Contribution of High-Pressure Fluid to Postseismic Deformation of Large Shallow Earthquakes	34
2.10	Seismological Estimate of Fault-Zone Diffusivity and Permeability	35
	Appendix: Analytical Solutions for Spherically Symmetric Diffusion Equation	42
	References.	43
3	Fluid-Flow Properties of Fault Zones	51
3.1	Fault-Zone Structure	51
3.2	Evolution of Fault-Zone Structures	53
3.2.1	Formation Mechanism of Damage Zones	53
3.2.2	Principal Slip Zones in Fault Cores	56
3.3	Permeability of Fault Zones	57
3.3.1	Influence of Fault-Zone Structure on Fault Permeability	57
3.3.2	Permeability of Fault Cores	59
3.3.3	Effect of Clay Content on Permeability of Fault Gouge	60
3.3.4	Effect of Mean Stress on Permeability	60
3.3.5	Effect of Fault Slip on Permeability Anisotropy	62
3.3.6	Slip-Induced Dilatancy	63
3.3.7	Permeability Structures of Major Faults in Subduction Zones	64
	References.	66
4	Basic Equations for Linear Thermoporoelasticity	73
4.1	Development of Theory of Poroelasticity	73
4.2	Description of Fluid-Saturated Porous Medium	74
4.3	Increment of Fluid Content Under Isothermal Condition	75
4.4	Constitutive Equations Under Isothermal Condition	76
4.5	Concept of Effective Stress	80
4.6	Poroelastic Constants	81
4.7	Governing Equations Under Quasi-static and Isothermal Conditions	85

4.8	Constitutive Equations Under Nonisothermal Condition	88
4.9	Governing Equations Under Quasi-static and Nonisothermal Conditions	91
4.10	Slip-Induced Dilatancy	93
4.11	Derivation of Fluid Diffusion Equation from a Different Viewpoint Under Nonisothermal Condition	94
4.12	Dynamic Equation of Motion	95
4.13	Differences in Assumptions in Theoretical Studies of Earthquake Rupture	98
4.14	Dehydration Reaction	103
4.15	Example of Mathematical Analysis for Quasi-static Deformation Under Isothermal Condition	105
4.15.1	In-Plane Deformation	105
4.15.2	Displacement Function Method	106
4.15.3	1D Deformation Due to Fluid Pressure Loading on the Free Surface	107
	References.	110
5	Poroelastic Effects on Earthquake Rupture.	115
5.1	Fault Model	115
5.2	Hypotheses of Thermal Pressurization and Slip-Induced Dilatancy in the Theory of Fault Slip	118
5.3	Governing Equations for the 1D Model	120
5.4	1D Dynamic Analysis of the Effect of Thermal Pressurization	122
5.4.1	Nonzero Shear Zone Thickness	123
5.4.2	Zero Shear Zone Thickness	128
5.5	1D Dynamic Analysis of the Effect of Slip-Induced Dilatancy	131
5.6	Coupled Effects of Slip-Induced Dilatancy and Thermal Pressurization on 1D Dynamic Slip	134
5.6.1	Behavior Under Undrained and Adiabatic Conditions	134
5.6.2	Effects of Fluid and Heat Flows	138
5.7	A Few Remarks About the Modeling of Dynamic Rupture in a Fluid-Saturated Medium	143
	Appendix: Equations Governing the 1D and 2D Dynamic Poroelastic Deformations Due to Antiplane Slip	146
	References.	149
6	Effects of Fluid Migration on the Evolution of Seismicity	153
6.1	Interactions Between Slip Evolution and Change of Hydromechanical Properties of Fault Zone.	153
6.2	Modeling of Earthquake Swarm	155

6.2.1	Brief Overview of Historical Development of Modeling Study	155
6.2.2	Requisites for the Modeling Under the High Fluid Pressure Environment	156
6.2.3	Effects of Long-Sustained Local Supply of High- Pressure Fluid	158
6.2.4	Effects of Slip-Induced Dilatancy Coupled with Fluid Flow.	160
6.2.5	The Two Models for Earthquake Swarm.	164
6.2.6	A Few Remarks About How Slip Evolves in Fluid-Saturated Porous Media	167
6.3	Modeling of Aftershock Sequence	169
6.3.1	Possible Driving Mechanisms of Aftershocks	169
6.3.2	Driving of Aftershocks by Fluid Flow.	171
6.3.3	Driving of Aftershocks by Aseismic Afterslip and Its Relationship with Slip-Induced Dilatancy Coupled with Fluid Flow.	174
6.4	Comprehensive Understanding of the Generation Mechanisms of Earthquake Swarm, Aftershock Sequence, and Slow Slip Event Coupled with Tectonic Tremors	177
	Appendix: Equations Governing the 2D Quasi-Static Poroelastic Deformation Due to Antiplane Slip.	177
	References.	180
Index	185



<http://www.springer.com/978-4-431-56560-4>

Involvement of Fluids in Earthquake Ruptures

Field/Experimental Data and Modeling

Yamashita, T.; Tsutsumi, A.

2018, XIII, 187 p. 45 illus., 16 illus. in color., Hardcover

ISBN: 978-4-431-56560-4