

ACADEMIC PRESS LIMITED
24-28 Oval Road
London NW1 7DX

FRACTURE MECHANICS OF ROCK

edited by

BARRY KEAN ATKINSON

*Department of Geological Sciences,
University College London*



ACADEMIC PRESS

Harcourt Brace Jovanovich, Publishers

London San Diego New York Berkeley
Boston Sydney Tokyo Toronto



CONTENTS

List of Contributors

Preface

1 INTRODUCTION TO FRACTURE MECHANICS AND ITS GEOPHYSICAL APPLICATIONS

Barry Kean Atkinson

1.1	Background	1
1.2	Concepts, Definitions and Theory	4
1.3	Overview of Geophysical Applications	18
1.4	Future Perspectives	20
1.5	Plan of this Volume	22
	References	23

2 JOINTS AND SHEAR FRACTURES IN ROCK

Terry Engelder

2.1	Introduction	27
2.2	Historical Background	27
2.3	The Isolated Crack	29
2.4	Microcracks	31
2.5	Joints: Record of a Rupture	33
2.6	Recracking	41
2.7	Shear Fracturing	44
2.8	Patterns of Multiple Fractures and Joints	51
2.9	Loading Conditions Leading to Propagation of Joints	59
2.10	Conclusions	65
	References	65

3 THEORY OF CRACK INITIATION AND PROPAGATION IN ROCK

Anthony R. Ingraffea

3.1	Introduction	71
3.2	Crack Initiation	74
3.3	Crack Propagation	90
3.4	Notes on Implementation of Crack Initiation and Propagation Theories	107
	References	108

4 THE THEORY OF SUBCRITICAL CRACK GROWTH WITH APPLICATIONS TO MINERALS AND ROCKS	111
Barry Kean Atkinson and Philip George Meredith	
4.1 Introduction	111
4.2 Micromechanisms of Fracture	114
4.3 Mechanisms of Subcritical Crack Growth	117
4.4 Constitutive Modelling of Subcritical Crack Growth	125
4.5 Overview of Experimental Data	136
4.6 Extrapolation of Subcritical Crack Growth Data to the Crustal Environment	149
4.7 Requirements for Further Studies	161
References	162
5 TIME-DEPENDENT DEFORMATION AND FAILURE	167
Laurence S. Costin	
5.1 Introduction	167
5.2 Microcrack Growth	169
5.3 Prediction of Rate-dependent Properties	181
5.4 Closure	210
References	211
6 FRACTURE MECHANICS APPROACH TO HYDRAULIC FRACTURING STRESS MEASUREMENTS	217
F. Rummel	
6.1 Introduction	217
6.2 Experimental Observations	218
6.3 Fracture Mechanics Approach to Hydraulic Fracturing	228
6.4 Application of Fracture Mechanics to Experimental Results	237
6.5 Concluding Comments	238
References	239
7 FRACTURE MECHANICS APPLIED TO HOT, DRY ROCK GEOTHERMAL ENERGY	241
Hideaki Takahashi and Hiroyuki Abé	
7.1 Introduction	241
7.2 Theoretical Consideration of the Behaviour of Artificial Cracks	242
7.3 Fracture Behaviour of Crustal Rock Mass	249
7.4 Concluding Remarks	272
References	275

8 THEORETICAL DISPLACEMENTS AND STRESSES NEAR FRACTURES IN ROCK: WITH APPLICATIONS TO FAULTS, JOINTS, VEINS, DIKES, AND SOLUTION SURFACES	277
David D. Pollard and Paul Segall	
8.1 Introduction	277
8.2 Elementary Elastic Crack Theory	281
8.3 The Displacement Field	294
8.4 The Stress Field	305
8.5 Approximate Fields in Special Regions	321
8.6 Applications to Selected Problems in Structural Geology and Tectonics	329
References	347
9 MECHANICS OF SHEAR RUPTURE APPLIED TO EARTHQUAKE ZONES	351
Victor C. Li	
9.1 Introduction	351
9.2 Shear Fracture Mechanics	354
9.3 Slip-weakening Model of Shear Rupture	366
9.4 Slip Distributions and Interactions	398
9.5 Summary and Conclusion	424
References	425
10 DYNAMIC ROCK FRAGMENTATION	429
D. E. Grady and M. E. Kipp	
10.1 Introduction	429
10.2 Dynamic Fracture Strength	431
10.3 Fragment Size Predictions in Dynamic Fragmentation	440
10.4 Particle Size Distributions in Dynamic Fragmentation	453
10.5 Continuum Modelling of Dynamic Fracture and Fragmentation	468
References	472
11 EXPERIMENTAL FRACTURE MECHANICS DATA FOR ROCKS AND MINERALS	477
Barry Kean Atkinson and Philip George Meredith	
11.1 Introduction	477
11.2 Experimental Constraints and Limitations	478
11.3 Experimental Methods	483
11.4 Experimental Data	517
References	519