Contents

1 Fundamentals of Earthquake Prediction: Four Paradigms
V.I. Keilis-Borok 1

1.1 Introduction 1
1.2 Lithosphere as a Complex Hierarchical System 5
1.2.1 Hierarchy 5
1.2.2 "Physical" Instability 7
1.2.3 "Geometric" Instability 10
1.2.4 Generalization: Complexity and Critical Phenomena 13
1.3 General Scheme of Prediction 14
1.3.1 Formulation of the Problem 15
1.3.2 An Early Example 15
1.3.3 Data Analysis 17
1.4 Error Diagrams 19
1.5 Four Paradigms 21
1.5.1 First Paradigm: Basic Types of Premonitory Phenomena 21
1.5.2 Second Paradigm: Long-Range Correlations 23
1.5.3 Third Paradigm: Similarity 25
1.5.4 Fourth Paradigm: Dual Nature of Premonitory Phenomena . . 27
1.6 Earthquake Prediction and Earthquake Preparedness 32
1.7 A Turning Point: Emerging Possibilities yet Unexplored 34
1.7.1 The Near-at-Hand Research Lines 34
1.7.2 The Goals 36

2 Hierarchical Models of Seismicity
M. Shnirman, E. Blanter 37

2.1 Introduction 37
2.1.1 Modeling and Hierarchy 37
2.1.2 Self-similarity of Seismicity 37
2.1.3 Inverse Cascade Models 38
2.1.4 Earthquake Prediction and Synthetic Seismicity 39
2.2 Static Hierarchical Models 40
2.2.1 General Description 41
2.2.2 Phase Transition in a Homogeneous Model 44
2.2.3 Heterogeneity and Stable Criticality 46

2.3 Dynamic Hierarchical Models 49
2.3.1 General Description of the Dynamic Model 50
2.3.2 Stationary Solution and Phase Transition 51
2.3.3 Heterogeneity in the Dynamic Model 52
2.3.4 The Feedback Relation and the Evolution of Scaling Properties 57
2.3.5 Prediction and Predictability of Strong Events 60
2.4 Complex Hierarchical Model 63
2.4.1 Description of the Model 63
2.4.2 Seismic Patterns in the Model 66
2.5 Conclusions and Discussion 68

3 Models of Dynamics of Block-and-Fault Systems
A. Soloviev, A. Ismail-Zadeh 71

3.1 Introduction 71
3.2 Description of the Model 75
3.2.1 Block Structure Geometry 75
3.2.2 Block Movement 76
3.2.3 Interaction Between Blocks and the Underlying Medium 76
3.2.4 Interaction Between Blocks Along Fault Planes 77
3.2.5 Equations of Equilibrium 79
3.2.6 Discretization 80
3.2.7 Earthquake and Creep 81
3.3 Dependence of a Synthetic Earthquake Flow on Structure Fragmentation and Boundary Movements 82
3.3.1 Block Structures and Cases of Boundary Movements Under Consideration 82
3.3.2 Results of Modeling 84
3.3.3 Discussion of Results 85
3.4 Space–Time Correlation Between Synthetic Earthquakes 88
3.4.1 Clustering of Synthetic Earthquakes 89
3.4.2 Long-Range Interaction Between Synthetic Earthquakes 91
3.5 Block Models of Seismicity in Arc Subduction Zones 96
3.5.1 A Model of an Abstract Arc Subduction Zone 96
3.5.2 Model of the Sunda Arc 106
3.6 Models of Block-and-Fault Dynamics of the Vrancea Region (the Southeastern Carpathians) 110
3.6.1 Introduction to the Seismicity and Geodynamics of the Region 110
3.6.2 Block Structure of the Vrancea Region: Model A 113
3.6.3 Comparing Vrancea Seismicity with the Results from Model A 115

3.6.4 Numerical Tests on Model A Parameters 123
3.6.5 Source Mechanisms of Synthetic Seismicity 125
3.6.6 Block Structure of the Vrancea Region: Model B 128
3.6.7 Synthetic Features of Model B and Vrancea Seismicity 130
3.7 Modeling Block Structure Dynamics of the Western Alps 132
3.7.1 Block Structure Approximating a Morphostructural Scheme of the Western Alps 132
3.7.2 Synthetic Features and the Seismicity of the Region 134
3.8 Conclusion 138

4 Earthquake Prediction
V. Kossobokov, P. Shebalin 141

4.1 Introduction 141
4.2 What Is an Earthquake Prediction? 146
4.3 Reproducible Prediction Algorithms 147
4.3.1 Data for Precursor Detection 148
4.3.2 General Scheme of Data Analysis 149
4.3.3 Major Common Characteristics of Premonitory Seismic Patterns 151
4.3.4 Statistical Significance and Efficiency of Predictions 152
4.4 Validated Precursory Seismic Patterns 153
4.4.1 Pattern Σ 154
4.4.2 Burst of Aftershocks or Pattern B 154
4.4.3 Algorithm M8 155
4.4.4 Algorithm MSc or "The Mendocino Scenario" 158
4.4.5 Global Testing of Algorithms M8 and MSc 159
4.4.6 Algorithm CN 175
4.4.7 Will a Subsequent Strong Earthquake Occur Soon? Algorithm SSE 179
4.5 Seismic Patterns Submitted for Testing 187
4.5.1 Seismic Reversal (SR) 188
4.5.2 Premonitory Increase of the Correlation Range (Pattern ROC) 197
4.5.3 Premonitory Spreading of Seismicity Across the Network of Faults: Pattern Accord 201
4.6 Discussion 205

5 Earthquake Prediction Strategies: A Theoretical Analysis
G.M. Molchan 209

5.1 Introduction 209
5.2 Prediction Involving Two Types of Alert 211
5.2.1 The Error Diagram 211
5.2.2 The Optimal Prediction Strategy 216
5.2.3 Prediction of the Characteristic Earthquake 218

5.2.4 Stability of the Minimax Strategy 220
5.2.5 Prediction on the San Andreas Fault 223
5.3 Prediction with Multiphase Alerts 224
5.4 Statistical Problems 229
5.4.1 The Performance of Prediction Algorithms 229
5.4.2 Estimation of (n, τ) 230
5.5 Estimation of $r(t)$ 230
5.5.1 Comments 232
5.6 Appendix 233

6 Recognition of Earthquake-Prone Areas
A. Gorshkov, V. Kossobokov, A. Soloviev 239

6.1 Introduction 239
6.2 Unraveling Earthquake-Prone Areas as a Pattern Recognition Problem 240
6.2.1 Parameterization of Recognition Patterns 247
6.2.2 Evaluating the Reliability of Recognition 252
6.3 Choosing Objects for Recognition 257
6.3.1 The Basics of Morphostructural Zoning 257
6.3.2 Objects of Recognition Derived from Morphostructural Zoning 265
6.4 Recognition of Where Strong Earthquakes Can Occur 267
6.4.1 The Greater Caucasus 268
6.4.2 The Western Alps 282
6.4.3 Pattern Recognition Applied to Earthquakes in California ... 288
6.4.4 Pattern Recognition of the Great ($M \geq 8.2$) Earthquake-Prone Segments of Major Seismic Belts 297
6.5 Conclusion: Confirmation of Pattern Recognition Results by Subsequent Large Earthquakes 305

References 311

Index 333