

Contents

I. First Steps Towards Modeling a Multi-Scale Earth System 1
*Klaus Regenauer-Lieb, Thomas Poulet, Delphine Siret,
Florian Fousseis, Jie Liu, Klaus Gessner, Oliver Gaede,
Gabriele Morra, Bruce Hobbs, Alison Ord, Hans Muhlhaus,
David A. Yuen, Roberto Weinberg and Gideon Rosenbaum*

1 Introduction 2

2 Multiscale Non-Equilibrium Thermodynamics 3

2.1 The Equilibrium Yardstick 3

2.2 Non Equilibrium Thermodynamics and Multiscaling 5

2.3 Coupling Mechanics and Chemistry 6

2.4 Classical Brittle-Ductile Modeling 8

3 Mathematical Formulation 10

3.1 Classical Constitutive Approaches for the Lithosphere 10

3.2 Energy Approach 12

3.3 Scale Dependence of Ductile Shear Zones 15

3.4 Intrinsic Length Scales for Brittle Faults 17

3.5 Scale Dependence for Brittle Faults 19

4 Discussion 20

References 22

II. 3D Mesh Generation in Geocomputing 27
Huilin Xing, Wenhui Yu and Ji Zhang

1 Introduction 28

2 Geometrical Modeling 32

3 Hexahedral Mesh Generation 33

3.1 Introduction 33

3.2 Fracture Dominated Reservoir System 35

3.3 Meshing Interacting Fault System of South Australia
with Mapped Block Method 39

3.4 All Hexahedron Mesh Generation for a Whole-Earth
Model 43

3.4.1	The PREM whole-Earth model	43
3.4.2	The Whole-Earth Crust with Plate Boundaries	44
4	Tetrahedral Mesh Generation	49
4.1	Introduction	49
4.2	Automatic Tetrahedral Mesh Generation for the Stratigraphy Point Set	50
4.3	Visualizing and Meshing with the Microseismicity Data.....	52
5	Conclusions	59
	References	59
III.	Strategies for Preconditioning Methods of Parallel Iterative Solvers for Finite-Element Applications in Geophysics.....	65
	<i>Kengo Nakajima</i>	
1	Background.....	65
1.1	Why Preconditioned Iterative Solvers?	65
1.2	Selective Blocking Preconditioning for Contact Problems ...	67
1.2.1	GeoFEM Project.....	67
1.2.2	Selective Blocking.....	69
1.3	Overview of this Work	70
2	Various Approaches for Parallel Preconditioning Methods in III-Conditioned Problems.....	72
2.1	Selective Fill-Ins.....	72
2.2	Selective Overlapping	76
2.3	Local Reordering in Distributed Data	79
2.4	HID (Hierarchical Interface Decomposition)	82
3	Examples: Contact Problems	86
3.1	Effect of Selective Fill-Ins and Selective Overlapping	86
3.2	Effect of Local Reordering	88
3.3	Effect of HID	90
4	Examples: Linear-Elastic Problems with Heterogeneous Material Properties	92
4.1	BILU($p+$, ω)-($d+$, α)	92
4.2	Problem Description	93
4.3	Effect of Selective Fill-Ins and Selective Overlapping	96
4.4	Effect of Local Reordering	98
4.5	Effect of HID	101
5	Concluding Remarks	103
	References	105

6	Appendix 1: Parallel Iterative Solvers in GeoFEM	107
6.1	Distributed Data Structure	107
6.2	Localized Preconditioning	109
7	Appendix 2: Selective Blocking	111
7.1	Robust Preconditioning Methods for Ill-Conditioned Problems.....	111
7.2	Strategy for Parallel Computations.....	114
7.3	Large-Scale Computations	116
IV.	Algorithms for Optimizing Rheology and Loading Forces in Finite Element Models of Lithospheric Deformation.....	119
	<i>Youqing Yang and Mian Liu</i>	
1	Introduction	119
2	Methodology.....	120
3	A Plate Flexural Model.....	123
4	A Three-Dimensional Viscous Model of Lithospheric Deformation.....	127
5	Discussions and Conclusions.....	136
	References	137
V.	Mantle Dynamics – A Case Study	139
	<i>Klaus-D. Gottschaldt, Uwe Walzer, Dave R. Stegman, John R. Baumgardner and Hans B. Mühlhaus</i>	
1	Introduction	140
1.1	Energy Budget of the Mantle.....	140
1.2	Physics of Mantle Convection in a Nutshell	140
1.3	Surface Tectonics	141
1.4	Volcanism.....	141
1.5	Core and Magnetism.....	141
1.6	Composition	142
2	Physics of Mantle Convection: Basic Equations	142
2.1	Conservation of Mass	142
2.2	Conservation of Momentum.....	143
2.3	Conservation of Energy	143
2.4	Equation of State	144
2.5	Constitutive Relations	144
3	Case Study: Stirring in Global Models of the Earth’s Mantle	145
3.1	Background.....	146

3.1.1	Mantle Composition and Crustal Segregation	146
3.1.2	Phase Transitions in the Mantle	146
3.1.3	Geochemistry – a Primer.....	148
3.1.4	Geochemical Heterogeneities.....	149
3.1.5	Mantle Degassing.....	150
3.1.6	Interpretation of Reservoirs.....	150
3.1.7	Age of Reservoirs.....	151
3.1.8	Size of Reservoirs	151
3.1.9	Reconciliation of Geophysical and Geochemical Constraints	152
3.2	Model Setup.....	155
3.2.1	Rheology	156
3.2.2	Boundary Conditions	157
3.2.3	Initial Conditions.....	158
3.3	Numerics.....	159
3.3.1	Mantle Convection Code: TERRA	159
3.3.2	Treatment of Compositional Fields.....	160
3.3.3	Definition of Two Components	160
3.4	Model Results.....	161
3.5	Discussion.....	166
3.5.1	Influence of Geometry	167
3.5.2	Influence of Rheology	167
3.5.3	Influence of Initial Conditions	169
3.5.4	Minor Influences	170
3.6	Conclusions	170
3.6.1	Relevance for the Earth.....	171
3.6.2	Other Hints for a Change of Convective Mode.....	173
3.6.3	Outlook	174
	References	175
VI. The ESyS_Particle: A New 3-D Discrete Element Model with Single Particle Rotation		183
<i>Yucang Wang and Peter Mora</i>		
1	Introduction: A Review of the Discrete Element Method	183
1.1	Dimensionality: 2-D or 3-D.....	184
1.2	Contact Laws: Linear or Non-Linear	185
1.3	Particle Shapes: Disks/Spheres or Polygons/Polyhedrons.....	185
1.4	Single Particle Rotation: With or Without	185
1.5	Algorithm for Integrating the Equations of Motion	186
1.6	Bonded or Not Bonded.....	186

1.7	Interactions Between Particles: Complete or Simplified.....	187
1.8	Criterion for Bond Breakage	187
1.9	Frictional Forces	187
1.10	Parameter Calibration	188
2	The Model, Equations and Numerical Algorithms to Integrate These Equations	189
2.1	A Brief Introduction to the ESyS_Particle	189
2.2	Equations	190
2.3	Algorithms to Integrate the Equations of Rotation	191
3	Contact Laws, Particle Interactions and Calculation of Forces and Torques	193
3.1	Bonded Interaction	193
3.1.1	The Bonded Model.....	193
3.1.2	Calculation of Interactions due to Relative Motion ...	194
3.1.3	Criterion for Bond Breakage	200
3.2	Solely Normal Repulsive Interaction	201
3.3	Cohesionless Frictional Interaction	201
4	Parameter Calibration	204
4.1	Elastic Parameters: Spring Stiffness	204
4.1.1	2-D Triangular Lattice	204
4.1.2	3-D Lattices: HCP and FCC.....	205
4.2	Fracture Parameters	209
4.3	Other Parameters	210
4.3.1	Time Step	210
4.3.2	Artificial Damping	210
4.3.3	Loading Rate	211
5	Some Recent Simulation Results.....	211
5.1	2-D Tests	211
5.1.1	Uni-Axial Tests	211
5.1.2	Wing Crack Extension	213
5.1.3	Shearing and Crushing of Aggregates.....	214
5.1.4	Simulation of Brittle Fracture by Dynamic Impact....	215
5.2	3-D Tests	216
5.2.1	Uniaxial Test	216
5.2.2	Wing Crack	217
6	Discussion: Major Differences of the ESyS_Particle Compared with the Other Existing DEMs.....	219
7	Conclusions	220
	References	222

VII. The TeraShake Computational Platform for Large-Scale Earthquake Simulations	229
<i>Yifeng Cui, Kim Olsen, Amit Chourasia, Reagan Moore, Philip Maechling and Thomas Jordan</i>	
1 Introduction	230
2 The TeraShake Computational Platform	232
3 TeraShake Application: Anelastic Wave Model	234
4 Enhancement and Optimization of the TeraShake Application.....	237
4.1 Porting and Optimizations	237
4.2 Optimization of Initialization	239
4.3 Optimization of I/O	240
4.4 Mapping TS-AWP to Different TeraGrid Architectures	242
4.5 Scaling the Code up to 40k Processors.....	243
4.6 Preparing for TeraShake Executions	245
4.7 Maintenance and Additional Techniques for the TeraShake Platform	247
5 Data Archival and Management	248
5.1 SCEC Data Grid	249
5.2 Wave Propagation Simulation Data Archival	252
5.2.1 SCEC Data Management Challenges.....	253
5.2.2 Comparison to Grid Technology.....	255
5.3 SCEC Digital Library	256
6 TeraShake Visualization.....	257
6.1 Visualization Techniques	258
6.1.1 Surface Visualization	258
6.1.2 Topographic Visualization	259
6.1.3 Volumetric Visualization	261
6.1.4 Static Maps.....	262
6.1.5 Self Contoured Maps	262
6.1.6 Map Service Portal for Surface Data	262
6.2 Visualization Tools and Results	264
6.3 Visualization Discussion	264
7 Scientific Results of TeraShake-1 and TeraShake-2	265
8 Lessons Learned from Enabling Very-Large Scale Earthquake Simulations.....	268
9 Summary.....	273
References	275

VIII. Probabilistic Forecast of Tsunami Hazards along Chinese Coast ...	279
<i>Yingchun Liu, Yaolin Shi, Erik O.D. Sevre, Huilin Xing and David A. Yuen</i>	
1 Introduction	280
2 Geological and Geophysical Analysis	283
3 Probabilistic Forecast of Tsunami Hazards	288
3.1 Probabilistic Forecast of Tsunami and Seismic Hazards	288
3.2 Linear and Non-linear Modeling Potential Tsunami Sources	291
4 Probabilistic Forecast of Tsunami and Seismic Hazard in China Sea Region	296
4.1 Probabilistic Forecast of Seismic Hazard in South China Sea Region	296
4.2 Probabilistic Forecast of Seismic Hazard in Eastern China Sea Region	297
4.3 Tsunami Numerical Simulation in China Sea Region	298
4.4 Probabilistic Forecast of Tsunami Hazard in China Sea Region	303
5 Discussions and Summary	310
6 Conclusion	312
References	314
Index	319



<http://www.springer.com/978-3-540-85877-5>

Advances in Geocomputing

Xing, H.

2009, XVIII, 325 p. With DVD., Hardcover

ISBN: 978-3-540-85877-5