

Contents

Tributes	xi
Eduardo GARZANTI, Vincent GODARD, Rodolphe CATTIN, György HETÉNYI, Jean-Luc EPARD and Martin ROBYR	
Foreword	xvii
Rodolphe CATTIN and Jean-Luc EPARD	
Preface. From Research to Education: The Example of the Seismology at School in Nepal Program	xix
György HETÉNYI and Shiba SUBEDI	
Part 1. Surface Process	1
Chapter 1. Orogenesis and Climate	3
Frédéric FLUTEAU, Delphine TARDIF, Anta-Clarisse SARR, Guillaume LE HIR and Yannick DONNADIEU	
1.1. Introduction	3
1.2. Climate in Asia: present and past	4
1.2.1. Present-day climate	4
1.2.2. Cenozoic climate evolution	7
1.3. Reconstructing the paleo-elevation of landforms	10
1.4. The contribution of climate modeling	12

1.4.1. Impact of orogenesis on the atmospheric circulation	13
1.4.2. Impact of orogenesis on the ocean circulation	18
1.4.3. Impact of orogenesis on the chemical composition of the atmosphere	20
1.5. Conclusion	21
1.6. References	23
Chapter 2. Eroding the Himalaya: Processes, Evolution, Implications	29
Vincent GODARD, Mikaël ATTAL, Saptarshi DEY, Maarten LUPKER and Rasmus C. THIEDE	
2.1. Introduction	29
2.2. Main process domains in the Himalaya	30
2.2.1. Himalayan rivers	30
2.2.2. The glaciated High Range	35
2.2.3. Critical hillslopes	36
2.3. Extreme events and their contribution to denudation	37
2.4. 1–10 ka timescale and climatic oscillations	39
2.5. Impact of long-term tectonic and climatic evolution over several Ma . .	42
2.6. Out of the Himalaya: sediment transport and storage from the range to the sedimentary basin	45
2.7. Conclusion	48
2.8. References	49
Part 2. Natural Hazards	55
Chapter 3. Glaciers and Glacier Lake Outburst Floods in the Himalaya	57
Christoff ANDERMANN, Santosh NEPAL, Patrick WAGNON, Georg VEH, Sudan Bikash MAHARJAN, Mohd Farooq AZAM, Fanny BRUN and Wolfgang SCHWANGHART	
3.1. Introduction	57
3.2. Glaciers and their future	61
3.2.1. The present state of glaciers at a regional scale	61
3.2.2. On the interest of monitoring glaciers	64
3.2.3. What will happen to the Himalayan glaciers and Karakoram glaciers?	65
3.3. Glacier lakes	66

3.3.1. Formation and present distribution of glacier lakes in the Himalaya	66
3.3.2. Historic changes of glacier lake abundance and size	69
3.3.3. Projections of future glacier lakes	71
3.4. Glacial lake outburst floods and downstream propagation	72
3.4.1. GLOF triggers	72
3.4.2. Dam breach	74
3.4.3. Flood propagation	75
3.4.4. Early warning	77
3.5. Consequences and impact	79
3.6. Role in landscape formation	81
3.7. Conclusion	83
3.8. References	83
Chapter 4. Landsliding in the Himalaya: Causes and Consequences	95
Odin MARC, Kaushal GNYAWALI, Wolfgang SCHWANGHART and Monique FORT	
4.1. Introduction	95
4.2. Understanding landsliding and their links to the dynamics of the Himalayan range	96
4.2.1. Preliminary notions on the mechanics of landsliding	96
4.2.2. Seasonal landsliding caused by monsoons and extreme rainfall	99
4.2.3. Landslide induced by earthquakes and other exceptional perturbations	102
4.2.4. Giant and paleo-landslides	106
4.3. Landslides within Himalayan society	110
4.3.1. Hazard cascades and their societal impact	110
4.3.2. Human activities as an additional trigger of landslides	111
4.3.3. Potential for mitigation	114
4.3.4. Climate change and future landsliding	117
4.4. Conclusion	118
4.5. References	119
Chapter 5. Himalayan Surface Rupturing Earthquakes	131
Laurent BOLLINGER, Matthieu FERRY, Romain LE ROUX-MALLOUF, Jérôme VAN DER WOERD and Yann KLINGER	
5.1. Introduction	131
5.2. The large devastating earthquakes in the Himalaya	133

5.2.1. Historical chronicles and earthquakes	133
5.2.2. Strong instrumental earthquakes	135
5.3. Surface expression of the seismic deformation in the landscape and within paleoseismological excavations	138
5.3.1. In the mesoseismal trace of the 1934 earthquake	138
5.3.2. In the mesoseismal trace of the 1714 earthquake in Bhutan	142
5.3.3. In the mesoseismal trace of the 1950 earthquake	145
5.4. Overview of the paleoseismological excavations along the Himalayan arc	147
5.5. Abandoned alluvial terraces, an archive of the paleoearthquakes	149
5.6. Conclusion	151
5.7. References	151
Chapter 6. Seismic Coupling and Hazard Assessment of the Himalaya	155
Sylvain MICHEL, Victoria STEVENS, Luca DAL ZILIO and Romain JOLIVET	
6.1. Introduction	155
6.2. From current ground motion to the buildup of slip deficit at depth	158
6.2.1. Geodetic observations of the interseismic period	160
6.2.2. Inferring coupling along the MHT with a Bayesian analysis	160
6.2.3. Interseismic coupling distribution	162
6.2.4. Discussion	164
6.3. Seismic potential of the MHT	167
6.3.1. Conservation of the seismic moment	167
6.3.2. Magnitude–frequency distribution in the Himalaya	169
6.3.3. Including the physics of fault slip in seismic hazard	172
6.3.4. Seismic potential of the MHT	173
6.4. Seismic hazard in the Himalaya	175
6.4.1. Ground motion prediction equations and V_{s30}	176
6.4.2. Modeling scenario events	177
6.4.3. Probabilistic seismic hazard assessment	180
6.4.4. From hazard to risk	183
6.5. Conclusion	184
6.6. References	184
Part 3. Focus	191

Chapter 7. Recent and Present Deformation of the Western Himalaya	193
François JOUANNE, Jean-Louis MUGNIER, Riccardo VASSALLO, Naveed MUNAWAR, Awais AHMED, Adnan Alam AWAN, Manzoor A. MALIK and Ramperu JAYANGONDAPERUMAL	
7.1. Introduction	193
7.2. Structural styles and tectonic prism model	195
7.2.1. The main structural zones	195
7.2.2. The Himalaya in the west of the syntax	195
7.2.3. The Himalaya of the Jammu–Kashmir area	198
7.2.4. A structural evolution in agreement with the tectonic prism model	199
7.3. Out-of-sequence deformation in the western Himalayan syntax	201
7.3.1. Quaternary out-of-sequence activity of the NW Himalayan thrusts	201
7.3.2. Out-of-sequence seismological and paleoseismological activity in the NW Himalaya	205
7.4. Deformation associated with a ductile décollement, not always aseismic	208
7.4.1. Seismic coupling assessment along the MHT	208
7.4.2. Occurrence of ruptures on asperities	209
7.4.3. Transition between thin-skin and thick-skin tectonics	211
7.5. Conclusion	212
7.6. References	213
Chapter 8. The 2015 April 25 Gorkha Earthquake	217
Laurent BOLLINGER, Lok Bijaya ADHIKARI, Jérôme VERGNE, György HETÉNYI and Shiba SUBEDI	
8.1. Introduction	217
8.2. The mainshock and its effects on the ground	219
8.2.1. Overview description of the mainshock	219
8.2.2. Ground motion and deformation	221
8.3. Investigating the seismic source at depth	222
8.4. Aftershock activity and post-seismic relaxation	225
8.4.1. Early aftershocks and the occurrence of the Kodari earthquake	225
8.4.2. Seismicity monitored by denser, dedicated temporary networks	226
8.4.3. Post-seismic relaxation monitored by geodetic and seismological networks	229

8.5. A more earthquake-informed and earthquake-resilient local community in the aftermath of the earthquake	231
8.6. Conclusion	232
8.7. References	233
Chapter 9. Crustal Fluids in the Nepal Himalaya and Sensitivity to the Earthquake Cycle	239
Frédéric GIRAULT, Christian FRANCE-LANORD, Lok Bijaya ADHIKARI, Bishal Nath UPRETI, Kabi Raj PAUDYAL, Ananta Prasad GAJUREL, Pierre AGRINIER, Rémi LOSNO, Chiara GROppo, Franco ROLFO, Sandeep THAPA, Shashi TAMANG and Frédéric PERRIER	
9.1. Introduction	239
9.2. Overview of thermal springs geochemistry in Nepal	240
9.3. Overview of gaseous emission zones in Nepal	249
9.4. Spatial organization of crustal fluid release	253
9.5. Temporal variations of crustal fluid release: a tectonic control	256
9.6. Conclusion	260
9.7. References	261
Conclusion	267
Rodolphe CATTIN and Jean-Luc EPARD	
List of Authors	269
Index	275
Summaries of other volumes	279