EUROPEAN GLACIAL LANDSCAPES

THE LAST DEGLACIATION

European Glacial Landscapes: The Last Deglaciation brings together relevant experts on the history of glaciers and their impact on landscape of the main European regions. Soon after the Last Glacial Maximum, a rapid process of glacial retreat began throughout Euro This was interrupted several times by abrupt climate cooling, which caused rapid, although moderate, re-advance of the glaciers, until beginning of the Holocene when the climate became relatively stable and warm. These successive glacial advances and retreats during Last Deglaciation have shaped much of the European landscape, reflecting abrupt climatic fluctuations.

As our knowledge of abrupt climate changes since the Last Glacial Maximum progresses, new uncertainties arise. These are cri for understanding how climate changes disseminate through Europe, such as the lag between climate changes and the expansio contraction of glaciers as well as the role of the large continental ice sheets on the European climate. All these contributions are include the book, which is an invaluable resource for geographers, geologists, environmental scientists, palaeoclimatologists, as well as researc in physics and earth sciences.

Key features

- Provides a synthesis that highlights the main similarities or differences, through both space and time, during the Last Deglaciatio Europe
- Features research from experts in Quaternary science, geomorphology, palaeoclimatology, palaeoceanography and palaeoglaciolog the Last Deglaciation in Europe during Termination I and the important Late Pleistocene-Holocene transition
- Includes detailed colour figures and maps, providing a comprehensive overview of the glacial landscapes of Europe during the Deglaciation.

Edited by:

David Palacios

Professor, Complutense University of Madrid, Madrid, Spain

Philip D. Hughes

Professor, University of Manchester, Manchester, United Kingdom

José M. García-Ruiz

Ad Honorem Research Professor, Pyrenean Institute of Ecology (IPE-CSIC), Zaragoza, Spain

Nuria Andrés

Professor, Complutense University of Madrid, Madrid, Spain

ELSEVIER

elsevier.com/books-and-journals

SCIENCE / Earth Sciences / General
SCIENCE / Earth Sciences / Geology
SCIENCE / Earth Sciences /
Meteorology & Climatology
SCIENCE / Earth Sciences / Hydrology

ISBN 978-0-323-9189

9 780323 91899

List of contributors xv
About the editors xix

Part I
Introduction 1

1. Introduction 3

David Palacios, Nuria Andrés, Philip D. Hughes and José M. García-Ruiz

1.1 The importance of the Last Deglaciation in the European landscape 3
1.2 The intensity of climatic changes during the Last Deglaciation and the delineation of the main subperiods 4
1.3 Objectives of the book 5
1.4 The glaciated European regions 6
1.5 The European landscapes shaped during the different periods of the Last Deglaciation 6
1.6 Standardised ages cited in the book 7
References 8

2. The terminations of the glacial cycles 11

David Palacios, Philip D. Hughes, María F. Sánchez-Goñi, José M. García-Ruiz and Nuria Andrés

2.1 The origin of glacial terminations 11
2.2 The trigger and pattern of the glacial terminations 12
2.3 The onset of the Last Deglaciation (Termination I) 15
2.4 The dynamics of glacial terminations 17
2.5 Conclusions 18
References 19

3. Previous synthesis of the Last Deglaciation in Europe 25

José M. García-Ruiz

References 27

Part II
Climate changes during the Last Deglaciation in the Eastern North Atlantic region 31

4. Introduction to the Last Deglaciation climate 33

Filipa Naughton, María F. Sánchez-Goñi, Amaelle Landais, Teresa Rodrigues, Natalia Vazquez Riveiros and Samuel Toucanne

References 35

5. Heinrich Stadial 1 37

Filipa Naughton, Samuel Toucanne, Amaelle Landais, Teresa Rodrigues, Natalia Vazquez Riveiros and María F. Sánchez-Goñi

5.1 Definition and timing of the HS 1 37
5.2 The pre-HS 1 and the two phases of HS 1 in the eastern North Atlantic and Europe 38
5.2.1 Pre-HS1 (~20–19 ka) 38
5.2.2 First phase of HS 1 38
5.2.3 The second phase of HS1 40
References 41

6. The Bølling–Allerød Interstadial 45

Filipa Naughton, María F. Sánchez-Goñi, Amaelle Landais, Teresa Rodrigues, Natalia Vazquez Riveiros and Samuel Toucanne

6.1 Definition, timing and causes of the Bølling–Allerød episode 45

6.2 The impact of B-A in the eastern North Atlantic and Europe 47
References 48

7. The Younger Dryas Stadial 51

Filipa Naughton, María F. Sánchez-Goñi, Amaelle Landais, Teresa Rodrigues, Natalia Vazquez Riveiros and Samuel Toucanne

7.1 Definition, timing and causes of the Younger Dryas Stadial 51
7.2 The impact of YD in the eastern North Atlantic and Europe 52
7.2.1 YDa (~12.9–12.7 kyr cal BP) 52
7.2.2 YDb (~12.7–12.4 kyr cal BP) 52
7.2.3 YDc (~12.4–12.0 kyr cal BP) 55
7.2.4 YDd (~12.0–11.7 kyr cal BP) 55
References 55

Part III
The European glacial landforms during main deglaciation (18.9-14.6 ka) 59

8. Concept and global context of the glacial landforms from deglaciation 61

José M. García-Ruiz, David Palacios, Philip D. Hughes and Nuria Andrés

References 64

Section 1
The European regions that were covered by the European Ice Sheet Complex (EISC) 69

9. European Ice Sheet Complex evolution during main deglaciation (18.9–14.6 ka) 71

Monica C.M. Winsborrow, Anna L.C. Hughes and Sarah L. Greenwood

9.1 European Ice Sheet Complex evolution during the main deglaciation 71
9.2 Main deglaciation landscapes and landforms of the EISC 76
9.3 Ice streams of the EISC 77
9.4 Outlook 79
References 80

10. Fennoscandia: glacial landforms during initial deglaciation (18.9–14.6 ka) 85

Sarah L. Greenwood, Anna L.C. Hughes and Rachael S. Avery

10.1 Denmark and Skåne 85
10.2 Baltic Sea 88
10.3 Fennoscandian Shield 88
10.4 Scandinavian mountains 91
10.5 Conclusions 91
References 92

11. Northern Central Europe: glacial landforms during deglaciation (18.9–14.9 ka) 95

Leszek Marks, Albertas Bitinas, Mirosław Błaszkiewicz, Andreas Börner, Rimante Guobyte, Vincent Rinterknecht and Karol Tylmann

References 101

12. European Russia: glacial landforms during deglaciation 105

Olga Korsakova, Andrey Vashkov and Olga Nosova

12.1 Introduction 105
12.2 Vepsa Stade landforms (17–15 cal ka BP) 106
12.3 Krestsy Stade landforms (16.7–16.0 cal ka BP) 106
12.4 Luga Stade landforms (15.7–14.6 ka BP) 108
12.5 Conclusion 109
References 109

13. The Eurasian Arctic: glacial landforms during main deglaciation (18.9–14.6 ka) 111

Mariana Esteves, Henry Patton and Monica C.M. Winsborrow

13.1 Introduction 111

13.2 Barents Sea 112
13.2.1 High Arctic islands and archipelagos 113
13.2.2 Kara Sea and Arctic Russia 115
References 116

14. The North Sea and Mid-Norwegian continental margin: glacial landforms during deglaciation, the Bølling–Allerød Interstadial and the Younger Dryas Stadial 119

Berit Oline Hjelstuen and Hans Petter Sejrup

References 126

15. Britain and Ireland: glacial landforms during deglaciation 129

Philip D. Hughes, Chris D. Clark, Philip L. Gibbard, Neil F. Glasser and Matt D. Tomkins

15.1 Introduction 129
15.2 Climatic context 129
15.3 Rapid retreat, thinning and break-up of the British–Irish Ice Sheet 131
15.4 Readvance and stabilisation – the evidence from onshore 132
15.5 Conclusions 137
References 137

Section 2

European regions that were not covered by the EISC 141

16. The Polar Ural Mountains: deglaciation history 143

John Inge Svendsen, Jan Mangerud, Dmitry Nazarov and Carl Regnéll

16.1 Introduction and background 143
16.2 The lake basins of Bol. Shchuchye and Mal. Shchuchye 145
16.3 Deglaciation chronology 147
References 147

17. Iceland: glacial landforms during deglaciation 149

Ívar Örn Benediktsson, Skafti Brynjólfsson and Lovísa Ásbjörnsdóttir

17.1 The onset of deglaciation of the Iceland ice sheet 149
17.2 Deglaciation of the Iceland shelf 150
17.3 Ice sheet collapse and the formation of marine limit shorelines 152
References 154

18. The evolution of glacial landforms in the Tatra Mountains during the deglaciation 157

Jerzy Zasadni, Piotr Kłapyta and Michał Makos

18.1 The Tatra Mountains and their palaeoenvironmental condition before and during the deglaciation 157
18.2 History of research on the deglaciation 159
18.3 Landscape evolution of the High Tatras during the deglaciation 159
18.4 Landscape evolution of the Western Tatras during the deglaciation 161
18.5 Moraine and rock glacier interaction during the deglaciation 161
18.6 Final remarks 163
References 163

19. The Romanian Carpathians: glacial landforms during deglaciation (18.9–14.6 ka) 165

Petru Urdea, Florina Ardelean, Mircea Ardelean and Alexandru Onaca

19.1 Eastern Carpathians 167
19.2 Southern Carpathians 167
19.3 Apuseni Mountains 170
References 172

20. The Alps: glacial landforms during the deglaciation (18.9–14.6 ka) 175

Susan Ivy-Ochs, Giovanni Monegato and Jürgen M. Reitner

References 181

21. The Pyrenees: environments and landforms in the aftermath of the LGM (18.9–14.6 ka) 185

Magali Delmas, Yanni Gunnell, Marc Calvet, Théo Reixach and Marc Oliva

21.1 Introduction 185
21.2 The early LGIT in the eastern Pyrenees 186
21.2.1 Two stillstand positions in the upper Ariège valley during the early LGIT 186
21.2.2 Spatial variation of glaciation, with palaeoclimatic implications 190
21.2.3 Post-LGM glacier recession and readvance in the Carlit massif 190
21.3 The early LGIT in the central and western Pyrenees 193
21.3.1 Noguera de Tor and Noguera Ribagorçana 193
21.3.2 Garonne valley 195
21.3.3 Ésera valley 195
21.3.4 Upper Gállego valley 195
21.4 Conclusions 199
References 199

22. The evolution of glacial landforms in Iberian Mountains during deglaciation 201

Marc Oliva, Nuria Andrés, José M. Fernández-Fernández and David Palacios

22.1 The Iberian Mountains and their palaeoenvironment during the deglaciation 201
22.2 The deglaciation in the Cantabrian Mountains 202
22.3 The deglaciation in NW Ranges 202
22.4 The deglaciation in the Iberian Range 204
22.5 The deglaciation in the Central Range 205
22.6 The deglaciation in the Sierra Nevada 205
22.7 Synthesis of the deglaciation in the Iberian ranges 205
References 207

23. The Italian Mountains: glacial landforms during deglaciation (18.9–14.6 ka) 209

Adriano Ribolini, Matteo Spagnolo and Carlo Giraudi

23.1 Introduction 209
23.2 The role of stratigraphic markers in the glacial chronology 209
23.3 Northern Apennines 211
23.4 Central Apennines 212
23.5 Southern Apennines 216
23.6 Final remarks 217
Acknowledgments 218
References 218
Further reading 220

24. The Balkans: glacial landforms during deglaciation 221

Philip D. Hughes, James L. Allard, Jamie C. Woodward and Richard J.J. Pope

24.1 The evidence of glaciation and deglaciation over the period 18.9–14.6 ka 221
24.2 Greece 222
24.3 North Macedonia 225
24.4 Kosovo 226
24.5 Montenegro 226
24.6 Bosnia 226
24.7 Croatia 227
24.8 Bulgaria 227
24.9 Summary: glacier advance, stabilisation, and retreat in the deglaciation interval 18.9–14.6 ka 227
References 229

25. The Anatolian Mountains: glacial landforms during deglaciation (18.9–14.6 ka) 233

Naki Akçar

25.1 Introduction 233
25.2 Eastern Black Sea Mountains 234
25.3 Western Taurus Mountains 235
25.4 Central Taurus Mountains 236
25.5 Northwestern Anatolia 236
25.6 Central Anatolia 236
25.7 The Anatolian Mountains during deglaciation: a synthesis 237
References 239

Section 3
Synthesis of Part III 241

26. The European glacial landscapes from the main deglaciation 243

José M. García-Ruiz, Philip D. Hughes, David Palacios and Nuria Andrés

26.1 Introduction 243

26.2 Glacial evolution and landforms of the European Ice Sheet Complex 244
26.3 Glacial evolution and landforms in mountain areas 251
26.4 Similarities and differences between regions and their causes 252
26.5 Pending research 254
26.6 The 18.9–14.6 ka period: The beginning of the end 255
References 255

Part IV
The European glacial landforms from the Bølling–Allerød Interstadial (14.6–12.9 ka) 261

27. Concept and global context of the glacial landforms from the Bølling–Allerød Interstadial 263

David Palacios, Philip D. Hughes, José M. García-Ruiz and Nuria Andrés

27.1 The concept of the Bølling–Allerød Interstadial 263
27.2 Bølling–Allerød Interstadial versus Antarctic Cold Reversal 264
27.3 The meaning of the Bølling–Allerød Interstadial in the evolution of glacial landscapes 265
27.4 Conclusions 266
References 266

Section 1
European regions that were covered by the European Ice Sheet Complex (EISC) 271

28. European Ice Sheet Complex evolution during the Bølling–Allerød Interstadial (14.6–12.9 ka) 273

Sarah L. Greenwood, Monica C.M. Winsborrow and Anna L.C. Hughes

28.1 EISC evolution during the Bølling–Allerød 273
28.2 Bølling–Allerød landscapes and landforms of the EISC 277
28.3 The role of meltwater in ice sheet and glacial landscape development 278
28.4 Outlook 281
References 282

29. Fennoscandia: glacial landforms during the Bølling–Allerød Interstadial (14.6–12.9 ka) 287

Sarah L. Greenwood, Anna L.C. Hughes and Rachael S. Avery

29.1 Fennoscandian Shield 287
29.2 Baltic Sea 292
29.3 Scandinavian Mountains 292
29.4 Conclusions 294
References 294

30. Northern Central Europe: glacial landforms from the Bølling–Allerød Interstadial 297

Leszek Marks, Albertas Bitinas, Mirosław Błaszkiewicz, Andreas Börner, Rimante Guobyte, Vincent Rinterknecht and Karol Tylmann

References 301

31. European Russia: glacial landforms from the Bølling–Allerød Interstadial 305

Olga Korsakova, Andrey Vashkov and Olga Nosova

31.1 Introduction 305
31.2 The Fennoscandian ice sheet and main proglacial lakes in the Bølling–Allerød Interstadial 305
31.3 Bølling–Allerød glacial landforms: the Neva end moraine belt 307
31.4 Conclusions 309
References 309

32. The Eurasian Arctic: glacial landforms from the Bølling–Allerød Interstadial (14.6–12.9 ka) 311

Henry Patton, Monica C.M. Winsborrow and Mariana Esteves

32.1 Introduction 311
32.2 Ice stream collapse 312
32.3 Unzipping of the Barents Sea ice sheet 313
32.4 Isostatic recovery 313
References 315

33. Britain and Ireland: glacial landforms during the Bølling–Allerød Interstadial 319

Philip D. Hughes, Chris D. Clark, Philip L. Gibbard, Neil F. Glasser and Matt D. Tomkins

33.1 The Bølling–Allerød Interstadial in Britain and Ireland 319
33.2 Evidence of glaciers in the Bølling–Allerød (Windermere) Interstadial in Scotland 320
33.3 Evidence of glaciers in the Bølling–Allerød (Windermere) Interstadial in England and Wales 322
33.4 Evidence of glaciers in the Bølling–Allerød (Woodgrange) Interstadial in Ireland 324
33.5 Problems and prospects for understanding glacier dynamics through the Bølling–Allerød Interstadial in Britain and Ireland 324
References 326

Section 2
European regions that were not covered by the EISC 329

34. Iceland: glacial landforms and raised shorelines from the Bølling–Allerød Interstadial 331

Ívar Örn Benediktsson, Skafti Brynjólfsson and Lovísa Ásbjörnsdóttir

34.1 Introduction (paleo-environment) 331
34.2 West and south-west Iceland 332
34.3 North-east Iceland 334
34.4 North-west Iceland 337
34.5 Synthesis and ice sheet reconstruction 337
References 337

35. The evolution of glacial landforms in the Tatra Mountains during the Bølling–Allerød Interstadial 341

Jerzy Zasadni, Piotr Kłapyta and Michał Makos

35.1 The Tatra Mountains palaeoenvironment during the Bølling–Allerød Interstadial 341
35.2 Landscape evolution in the High Tatra Mountains during the Bølling–Allerød Interstadial 342
35.3 Landscape evolution in the Western Tatra Mountains during the Bølling–Allerød Interstadial 343
35.4 Final remarks 344
References 345

36. The Romanian Carpathians: glacial landforms during Bølling–Allerød Interstadial (14.6–12.9 ka) 347

Petru Urdea, Florina Ardelean, Mircea Ardelean and Alexandru Onaca

36.1 Introduction 347
36.1.1 Eastern Carpathians 349
36.1.2 Southern Carpathians 349
36.1.3 Apuseni Mountains 352
36.2 Conclusions 352
References 352

37. The Alps: glacial landforms from the Bølling–Allerød Interstadial 355

Susan Ivy-Ochs, Giovanni Monegato and Jürgen M. Reitner

References 358

38. The Pyrenees: glacial landforms from the Bølling–Allerød Interstadial (14.6–12.9 ka) 361

Magali Delmas, Marc Oliva, Yanni Gunnell, Marcelo Fernandes, Théo Reixach, José M. Fernández-Fernández and Marc Calvet

38.1 Evidence of intense and rapid warming 361
38.2 Almost full glacier extinction in the eastern Pyrenees 362
38.3 Extensive glacier recession in the western and central Pyrenees 365
38.4 Local evidence of glacial oscillations in the higher central part of the mountain range 365
38.5 Conclusion 367
References 367

39. The evolution of glacial landforms in the Iberian Mountains during the Bølling–Allerød Interstadial 369

Marc Oliva, Nuria Andrés, José M. Fernández-Fernández and David Palacios

39.1 The Iberian palaeoenvironment during the Bølling–Allerød (B-A) Interstadial 369

39.2 The glaciers in the Cantabrian Mountains during the Bølling–Allerød Interstadial 369
39.3 The glaciers in the NW Ranges during the Bølling–Allerød Interstadial 370
39.4 The glaciers in the Iberian Range during the Bølling–Allerød Interstadial 370
39.5 The glaciers in the Central Range during the Bølling–Allerød Interstadial 374
39.6 The glaciers in the Sierra Nevada during the Bølling–Allerød Interstadial 374
39.7 Synthesis of the glacial evolution in the Iberian Mountains during the Bølling–Allerød Interstadial 374
References 376

40. The Italian Mountains: glacial landforms from the Bølling–Allerød Interstadial (14.6–12.9 ka) 379

Adriano Ribolini, Matteo Spagnolo and Carlo Giraudi

40.1 The environment of the Italian Peninsula during the Bølling–Allerød Interstadial 379
40.2 Low-altitude and marine proxies 379
40.3 High-altitude proxies 382
40.4 The Venacquaro Interstadial and the glaciers of the Italian mountains 382
40.5 Final remarks 383
Acknowledgements 384
References 384

41. The Balkans: glacial landforms from the Bølling–Allerød Interstadial 387

Philip D. Hughes, James L. Allard, Jamie C. Woodward and Richard J.J. Pope

41.1 Introduction 387
41.2 Glacier behaviour during the Bølling–Allerød 387
41.3 Conclusions 391
References 391

42. The Anatolian Mountains: glacial landforms during the Bølling–Allerød Interstadial 395

Naki Akçar

References 395

Section 3
Synthesis of the Part IV 397

43. European glacial landscapes from the Bølling–Allerød Interstadial 399

David Palacios, Nuria Andrés, José M. García-Ruiz and Philip D. Hughes

43.1 Introduction 399
43.2 Glacial evolution and landforms of the European ice sheet complex and Iceland ice sheet 399
43.3 Glacial evolution and landforms on mountain areas 404
43.4 Similarities and differences between regions and their causes 407
43.5 Pending research 408
43.6 The 14.6–12.9 ka period: A "false-start" to the current interglacial 410
References 410

Part V
The European glacial landforms from the Younger Dryas Stadial (12.9-11.7 ka) 413

44. Concept and global context of the glacial landforms from the Younger Dryas 415

José M. García-Ruiz, David Palacios, Philip D. Hughes and Nuria Andrés

References 418

Section 1
European regions that were covered by the European Ice Sheet Complex (EISC) 423

45. The glacial legacy of the EISC during the Younger Dryas Stadial 425

Anna L.C. Hughes, Sarah L. Greenwood and Monica C.M. Winsborrow

45.1 EISC evolution during the Younger Dryas Stadial (12.9–11.7 ka) 425
45.2 Younger Dryas Stadial landforms of the EISC domain 427

45.3 The significance of proglacial lakes for (reconstructing) deglaciation 430
45.4 Outlook 431
References 432

46. The Fennoscandian Ice Sheet during the Younger Dryas Stadial 437

Jan Mangerud, Anna L.C. Hughes, Mark D. Johnson and Juha Pekka Lunkka

46.1 The overall pattern of the YD ice sheet 437
46.2 The Bergen district, western Norway 439
46.3 Western Norway north of Sognefjorden and northern Norway 440
46.4 The Oslofjorden area 442
46.5 Sweden 442
46.6 Southern Finland and NW Russia 446
46.7 Discussion and conclusions 446
Acknowledgements 449
References 449

47. Younger Dryas Stadial (YD) local moraines in western and northern Norway 453

Jan Mangerud

47.1 The Nordfjord-Møre area in south-western Norway 453
47.2 The Troms area in Northern Norway 457
Acknowledgements 457
References 457

48. Northern Central Europe: glacial landforms from the Younger Dryas Stadial 459

Leszek Marks, Albertas Bitinas, Mirosław Błaszkiewicz, Andreas Börner, Rimante Guobyte, Vincent Rinterknecht and Karol Tylmann

References 463

49. European Russia: glacial landforms from the Younger Dryas 467

Olga Korsakova, Andrey Vashkov and Olga Nosova

References 470

Chapter 50
The Eurasian Arctic: glacial landforms from the Younger Dryas Stadial (12.9–11.7 ka) 473

Lis Allaart, Henry Patton and Mariana Esteves

50.1 Introduction 473
50.2 Postglacial emergence of the High Arctic archipelagos 474
50.3 Evidence for YD glacial extents on Svalbard and in surrounding waters 474
50.3.1 Terrestrial 475
50.3.2 Marine 477
References 478

51. Britain and Ireland: glacial landforms during the Younger Dryas Stadial 481

Philip D. Hughes, Chris D. Clark, Philip L. Gibbard, Neil F. Glasser and Matt D. Tomkins

51.1 Introduction 481
51.2 Younger Dryas climate in Britain and Ireland 483
51.3 The geomorphological record of Younger Dryas glaciation 483
51.4 Scotland 485
51.5 England 487
51.6 Wales 488
51.7 Ireland 489
References 489

Section 2
European regions that were not covered by the EISC 495

52. Iceland: glacial landforms from the Younger Dryas Stadial 497

Ívar Örn Benediktsson, Skafti Brynjólfsson and Lovísa Ásbjörnsdóttir

52.1 Introduction 497
52.2 South-west and central West Iceland 497
52.3 West Fjords 500
52.4 North Iceland 502
52.5 North-east and central East Iceland and the East Fjords 502
52.6 Southern lowlands 504
52.7 Synthesis 505
References 505

53. The evolution of glacial landforms in the Tatra Mountains during the Younger Dryas Stadial 509

Jerzy Zasadni, Piotr Kłapyta, Anna Tołoczko-Pasek and Michał Makos

53.1 The Tatra Mountains palaeoenvironment during the Younger Dryas Stadial 509
53.2 Landscape evolution in the High Tatra Mountains during the Younger Dryas Stadial 510
53.3 Landscape evolution in the Western Tatra Mountains during the Younger Dryas Stadial 512
53.3.1 Final remarks 513
References 514

54. The Romanian Carpathians: glacial landforms from the Younger Dryas Stadial 517

Petru Urdea, Florina Ardelean, Mircea Ardelean, Alexandru Onaca and Oana Berzescu

54.1 Introduction 517
54.2 Eastern Carpathians 518
54.3 Southern Carpathians 520
54.4 Conclusions 523
References 523

55. The Alps: glacial landforms from the Younger Dryas Stadial 525

Susan Ivy-Ochs, Giovanni Monegato and Jürgen M. Reitner

References 536

56. The Pyrenees: glacial landforms from the Younger Dryas Stadial (12.9–11.7 ka) 541

Magali Delmas, Marc Oliva, Yanni Gunnell, Théo Reixach, Marcelo Fernandes, José M. Fernández-Fernández and Marc Calvet

56.1 Climatic and environmental conditions during the Younger Dryas 541
56.2 Record of glacier responses to colder and drier conditions 542
56.2.1 Central Pyrenees 545
56.2.2 Western Pyrenees 546
56.2.3 Eastern Pyrenees 549
56.3 Synthesis and conclusions 550
References 550

57. The evolution of glacial landforms in the Iberian Mountains during the Younger Dryas Stadial 553

Marc Oliva, Nuria Andrés, José M. Fernández-Fernández and David Palacios

57.1 The Iberian palaeoenvironment during the Younger Dryas Stadial 553
57.2 The glaciers in the Cantabrian Mountains during the Younger Dryas Stadial 556
57.3 The glaciers in the NW Ranges during the Younger Dryas Stadial 556
57.4 The glaciers in the Iberian Range during the Younger Dryas Stadial 557
57.5 The glaciers in the Central Range during the Younger Dryas Stadial 557
57.6 The glaciers in the Sierra Nevada during the Younger Dryas Stadial 559
57.7 Synthesis of the glacial evolution in the Iberian Mountains during the Younger Dryas Stadial 560
References 560

58. The Italian Mountains: Glacial landforms from the Younger Dryas Stadial (12.9–11.7 ka) 563

Adriano Ribolini, Matteo Spagnolo and Carlo Giraudi

58.1 The environment of the Italian Peninsula during the Younger Dryas Stadial 563
58.1.1 Low-altitude and marine proxies 563
58.1.2 High-altitude proxies 564
58.2 The Aquila stadial and the glaciers/rock glaciers of the Italian Mountains 565
58.3 Final remarks 567
Acknowledgements 568
References 568
Further reading 570

59. The Balkans: glacial landforms during the Younger Dryas Stadial 571

Philip D. Hughes, James L. Allard, Jamie C. Woodward and Richard J.J. Pope

59.1 Introduction 571
59.2 Greece 571
59.3 Albania/North Macedonia 573
59.4 Kosovo 574
59.5 Montenegro 574
59.6 Bosnia 574
59.7 Bulgaria 575
59.8 Discussion and conclusions 577
References 577

60. The Anatolian Mountains: glacial landforms from the Younger Dryas Stadial 581

Naki Akçar

60.1 Introduction 581
60.2 Eastern Black Sea Mountains 581
60.3 Western Taurus Mountains 582
60.4 Central Taurus Mountains 582
60.5 Northwestern Anatolia 584
60.6 The Anatolian Mountains during the Younger Dryas: A Synthesis 585
References 585

Section 3
Synthesis of Part V 587

61. European glacial landscapes from the Younger Dryas Stadial 589

José M. García-Ruiz, David Palacios, Philip D. Hughes and Nuria Andrés

61.1 Introduction 587
61.2 Glacial evolution and landforms of the European ice sheet complex and the Iceland ice sheet 588
61.3 Glacial evolution and landforms in mountain areas 592
61.4 Similarities and differences between regions and their causes 593
61.5 Pending research 596
61.6 The Younger Dryas Stadial: processes and landforms at the end of Termination 1 597
References 598

Part VI
The Synthesis of the European Landscapes from Last Deglaciation 605

62. The importance of European glacial landscapes in a context of great climatic variability 607

David Palacios, Philip D. Hughes, José M. García-Ruiz and Nuria Andrés

62.1 The Main Deglaciation (18.9–14.6 ka) impact in the European glacial landscapes 607
62.2 The impact in European glacial landscapes facing a drastic increase in temperatures and a sharp rise in sea level during the Bølling–Allerød (14.6–12.9 ka) 609
62.3 The impact in European glacial landscapes facing a drastic decrease in temperatures during the Younger Dryas (12.9–11.7 ka) 611
62.4 European glacial landscapes from Last Deglaciation – pending scientific challenges 612
62.5 European glacial landscapes from Last Deglaciation as geoheritage and geodiversity values 614
62.6 The Holocene European glacial landscapes and the challenge of understanding the sensitivity of present glaciers to climate change 615
References 616

Index 619