Contents

1 Introduction ................................................................. 1
  1.1 Researching the Karst Surface and New Caves in the Course of Construction ......................................................... 3
  1.2 Research Led to New Insights About Karst Development .... 6
  1.3 Road Planning .......................................................... 11
  1.4 Cave Preservation ...................................................... 12
  1.5 Karst Protection in Light of Motorway Construction and Usage .......................................................... 15
  1.6 Conclusion ................................................................. 16

Part I Classical Karst: Construction Monitoring

2 Development and Karstification of the Karst Aquifer as Discovered Between Klanec and Črni Kal .................. 19
  2.1 Karst Surface and Karstification ....................................... 19
  2.1.1 Alveolinid-Nummulitid Limestones .............................. 19
  2.1.2 Flysch ................................................................. 20
  2.1.3 Karstification of the Alveolinid-Nummulitid Limestone .... 22
  2.2 Epikarst ................................................................. 22
  2.3 Discovered Caves ...................................................... 22
  2.4 Aquifer Development ................................................... 25
  2.5 Cave Preservation ...................................................... 27
  2.6 Conclusion ................................................................. 28

3 Unroofed Caves Near Kozina and Their Identification .......... 31
  3.1 Unroofed Caves and the Karst Surface ............................. 32
  3.2 Conclusion ................................................................. 37

4 The Section Between Divača and Kozina Revealed Many Characteristics of Karst Development .......... 39
  4.1 Karst Surface ........................................................... 39
  4.2 Newly Discovered Caves .............................................. 40
  4.3 Motorway Construction and Karst Features ....................... 44
  4.4 Conclusion ................................................................. 45
5 Great Cavernosity Between Dane and Fernetiči Points to Diverse Karst Formation .................................................. 47
5.1 Caves ...................................................................... 47
5.2 Road Construction ..................................................... 50
5.3 Conclusion ............................................................... 51

6 Unroofed Caves Discovered on the Route Between Čebulovica and Dane .......................................................... 53
6.1 Karst Near Divača ....................................................... 53
6.2 Dolines ................................................................... 54
6.3 Caves ....................................................................... 57
6.3.1 Cavernosity of Different Rock Types ....................... 57
6.3.2 Old Caves ............................................................ 58
6.3.3 Shafts .................................................................. 59
6.3.4 Road Construction and Caves ................................. 59
6.4 Conclusion ............................................................... 64

Part II Classical Karst: Newly Discovered Significant Karst Features

7 Unroofed Caves Provide Important Clues to the Karst Development .............................................................. 69
7.1 Identifying Unroofed Caves on the Karst Surface ........ 69
7.1.1 Types of Unroofed Caves ....................................... 73
7.1.2 Patches of Karst Terrain Which Are Covered by Unique Soil and Vegetation ................................................. 73
7.1.3 Flowstone and Cave Alluvium on the Karst Surface ... 74
7.1.4 Doline-like Shapes and Strings of Dolines .............. 74
7.1.5 Notches ............................................................... 75
7.1.6 Variegated Shapes of Cave Systems ....................... 75
7.2 Conclusion ............................................................... 75

8 The Large Unroofed Cave Near Povir .............................................................. 77
8.1 Speleological Characteristics of the Brezstropa Jama
Unroofed Cave ................................................................ 77
8.1.1 Discovery and Exploration of the Cave .................. 77
8.1.2 Shape of the Excavated Cave ............................... 77
8.1.3 Rock Relief on the Passage Walls ......................... 78
8.1.4 Forms Created Due to the Filling of the Passage with Sediments and Soil ............................................... 81
8.1.5 Cave Sediments .................................................. 81
8.2 Comparison of Sediments from Different Caves
Along the Motorway Route ............................................ 84
8.3 The Brezstropa Jama Unroofed Cave in Time and Space 85
9 Origin and Mineral Composition of Clastic Sediments on the Karst Surface Around Divača ........................................... 89
  9.1 Sites and Description of Clastic Sediments in Karst Depressions Around Divača ......................................................... 90
    9.1.1 The Brezstropa Jama Unroofed Cave Near Povir .......... 90
    9.1.2 Sediments from Two Filled-in Caves South of Povir ...... 95
    9.1.3 Filled-in Cave from the Divaški Hrib Hill ................. 96
    9.1.4 The Unroofed Cave at Grintavca ............................. 98
    9.1.5 Sediments from the Unroofed Cave in Bojni Dol ....... 99
  9.2 Conclusion .................................................................... 100

10 Composition of Sediments in Dolines ................................ 103
  10.1 Sediments from Dolines .............................................. 103
    10.1.1 Doline No. V1 ..................................................... 104
    10.1.2 Doline No. V2 ..................................................... 105
    10.1.3 Doline No. V3 ..................................................... 106
    10.1.4 Doline No. V4 ..................................................... 107
    10.1.5 Infilled Cave with Stalactites and Stalagmites ........ 109
    10.1.6 Doline No. V5 ..................................................... 109
    10.1.7 Doline No. V6 ..................................................... 111
  10.2 Conclusion .................................................................... 111

11 Cave Sediments from the Infilled Cave Near Divača ............. 117
  11.1 Methods .................................................................... 117
  11.2 Infilled Cave Located South of Divača ......................... 119
    11.2.1 Results of Mineralogical Analyses ......................... 119
    11.2.2 Results of Palaeomagnetic Analyses ....................... 120
  11.3 Conclusion .................................................................... 124

12 Palaeomagnetic Research of an Unroofed Cave Near Kozina .... 125
  12.1 Morphological and Geological Circumstances ................. 125
  12.2 Site Location and Characteristics .................................. 125
  12.3 Description of the Profile .......................................... 126
  12.4 Palaeomagnetic Analyses ........................................... 127
    12.4.1 Laboratory Procedures ....................................... 128
    12.4.2 Palaeomagnetic Research Results ......................... 128
    12.4.3 Magnetostratigraphic Research Results ................. 129
  12.5 Findings .................................................................... 130
  12.6 Conclusion .................................................................... 132

13 Sediments in the S-647 Cave in the Kastelec Tunnel ............. 135
  13.1 Speleomorphological Description of the Cave ................. 136
  13.2 Cave Sediments ...................................................... 138
  13.3 Conclusion .................................................................... 142
### The History of Karstification on the Upper Cretaceous and Lower Paleogene Limestones in the Wider Kozina Area

- **14.1 Geology of the Area**
- **14.2 Upper Cretaceous Paleokarst**
  - 14.2.1 Description
  - 14.2.2 Interpretation
- **14.3 Current Karst System**
  - 14.3.1 Description
  - 14.3.2 Interpretation
- **14.4 Conclusion**

### Part III Comparison with Low and Covered Karst and Karst in Breccia: Dolenjska region

- **15 The Dolenjska Karst Area Uncovered on the Bič–Korenitka Motorway Section**
  - 15.1 Geological Characteristics of the Area
  - 15.2 Uncovered Karst Formations
    - 15.2.1 Karst Uvalas with Estavelles
    - 15.2.2 Karren
    - 15.2.3 Caves
  - 15.3 Conclusion

- **16 Karst Formations Uncovered on the Pluska–Ponikve Motorway Section**
  - 16.1 Subsoil Karst Formations
  - 16.2 Caves
  - 16.3 Conclusion

- **17 Stone Forest Near Trebnje**
  - 17.1 Morphological and Geological Features of the Area
  - 17.2 The Shape of the Stone Forest and Its Columns, and Their Rock Relief
  - 17.3 Conclusion

- **18 Karst Formations Uncovered on the Ponikve–Hrastje Motorway Section**
  - 18.1 Karst Surface
  - 18.2 Caves
  - 18.3 Conclusion

- **19 Subsoil Stone Forests and Other Karst Formations Between Hrastje and Lešnica**
  - 19.1 Morphological and Geological Characteristics of the Region
  - 19.2 Karren Surface
  - 19.3 Subsoil Stone Forests
  - 19.4 Karst Cavities
  - 19.5 Conclusion
20  Palaeomagnetic Results from the Filled Karst Depression on the Motorway Section Hrastje–Lešnica ................. 207
   20.1  Profile ................................................. 207
       20.1.1  Lithology ......................................... 207
       20.1.2  Palaeomagnetic Results ........................... 207
   20.2  Conclusion .............................................. 212

21  The Karst Between Lešnica and Kronovo, Revealed During the Motorway Construction ............................ 213
   21.1  Newly Discovered Karst Phenomena ..................... 213
       21.1.1  Subsoil Stone Forests ............................... 213
       21.1.2  Underground Cavities ................................ 218
   21.2  Conclusion ................................................ 219

Part IV  Comparison with Low and Covered Karst and Karst in Breccia: The Vipava Valley

22  The Karst in the Breccia of Rebrnice in the Vipava Valley ....... 223
   22.1  Geological Conditions in the Area of the Road Route ....... 224
   22.2  Geomorphological Development of the Slopes of Mount Nanos ........................................... 226
       22.3  Characteristic Relief Forms in the Motorway Route .. 229
           22.3.1  Structural Forms ................................. 229
           22.3.2  The Structural Level of Mount Nanos .......... 229
           22.3.3  Relief Forms on Carbonate Rubble or Breccia  230
           22.3.4  Breakdown Forms .................................. 230
           22.3.5  Breakdown Blocks .................................. 230
           22.3.6  Erosion Forms ..................................... 230
           22.3.7  Hummocky Ground .................................. 231
       22.4  Anthropogenic Forms .................................... 231
           22.4.1  Paths Reshaped Due to Erosion .................... 231
           22.4.2  Escarpments, Piles and Dry Walls ................. 231
       22.5  Breccia Formation ....................................... 231
       22.6  Breccia Karstification and Cavities .................... 233
       22.7  Karstification of Flysch and of the Contact with Carbonates ........................................ 236
       22.8  Conclusion ................................................ 241

23  Karst Phenomena Between Vipava and Selo ......................... 243
   23.1  Geological Characteristics of the Region .................... 243
   23.2  Karst Cavernosity of the Rock ............................. 243
   23.3  Along the Protective Archaeological Excavations on the Motorway Route Between Log and Ajdovščina .......... 244
       23.4  Conclusion ................................................ 247
Part V \hspace{2mm} Planning

24 \hspace{2mm} Karstologic Research for the Engineering of a Preliminary Design for the Motorway Section Bič–Hrastje, Subsection Ponikve–Hrastje, Sv. Ana Variant .................. 251
24.1 Geomorphological Conditions .......................... 251
24.2 Caves ............................................. 254
24.3 Hydrogeological and Hydrological Conditions .......... 256
\hspace{2mm} 24.3.1 Hydrological Measurements ......................... 258
\hspace{2mm} 24.3.2 Directions and Velocities of the Underground Flow of Water ........................................ 260
\hspace{2mm} 24.3.3 Physicochemical Properties and Water Quality .... 262
\hspace{2mm} 24.3.4 The Importance of the Karst Water in the Area of the Temenica River .................................. 263
24.4 Conclusion .......................................... 263

25 \hspace{2mm} Planning of the Motorway in the Pivka and Reka Rivers Catchment Areas, the Evaluation and Reduction of Impacts on Known Caves. ................................ 265
25.1 Geomorphological and Hydrogeological Situation Along the Proposed Motorway ......................... 265
\hspace{2mm} 25.1.1 Possible Impacts Due to Motorway Construction and Methodology ......................... 266
25.2 Results ............................................ 268
\hspace{2mm} 25.2.1 Direct Impact .................................. 268
\hspace{2mm} 25.2.2 Indirect Impact by Vibration ......................... 269
\hspace{2mm} 25.2.3 Downstream Indirect Impact by Waters .......... 270
\hspace{2mm} 25.2.4 Upstream Indirect Impact by Water ............... 270
\hspace{2mm} 25.2.5 Hydrodynamical Impact ................................ 270
25.3 The Karstological/Speleological Mitigation and Optimization of the Planned Motorway ............................ 271
25.4 Conclusion .......................................... 272

Part VI \hspace{2mm} Construction and Use of Motorways with Regard to Karst Waters

26 \hspace{2mm} Biological Assessment of Habitats and Fauna in the Škocjanske Jame Caves and Reka River in the Motorway Construction Area of Influence ........................................ 275
26.1 Description of Methods and Techniques for Biological Sampling of Invertebrates in Aquatic Ecosystems ................. 275
26.2 Biodiversity in the Underground Reka River .............. 278
26.3 Fauna of Percolating Water in Škocjanske Jame Caves .......... 279
26.4 Terrestrial Fauna of Škocjanske Jame Caves ................ 280
26.5 Water Quality of the Reka River .......................... 281
27 Impact of Motorways on Karst Waters ........................................ 285
  27.1 Motorways as a Source of Pollution .................................... 285
    27.1.1 Pollutants from Road Runoff .................................... 285
    27.1.2 Motorway Runoff Impact on Biota .............................. 286
    27.1.3 Protection and Remediation Measures ......................... 286
  27.2 Particularity of Motorway Runoff in Karst Areas ................. 288
    27.2.1 Pollution of a Karst Water Source Due to the Spillage
        of Gas Oil During a Traffic Accident ............................ 289
    27.2.2 Pollution of a Karst Water Source Due to the Spillage
        of Gas Oil from a Warehouse for Oil Derivatives .............. 292
  27.3 Conclusion ............................................................. 296

28 Transfer of Contamination from Motorways Towards Karst
Water Sources: The Example of the Malenščica Karst Spring .. 299
  28.1 Measures for Limiting the Negative Impact of Motorways
      on Water Sources ..................................................... 299
  28.2 The Motorway in the Recharge Area of the Karst
      Water Source of Malenščica ....................................... 301
  28.3 The Composition of Water Flowing off the Motorway .......... 301
    28.3.1 Initial Periodic Measurements ............................... 301
    28.3.2 Sampling During Precipitation Events ...................... 304
  28.4 The Composition of Water Flowing from the Oil Separator ... 307
  28.5 Transfer of Contaminants Through the Karst Aquifer ......... 308
    28.5.1 Tracer Test in the Area of the Oil Separator B
        at Postojna ......................................................... 309
  28.6 Conclusion ............................................................. 311

Regarding the Planning and the Construction of Slovenian Motorways
in the Karst Region .......................................................... 313

References ................................................................. 315
Cave Exploration in Slovenia
Discovering Over 350 New Caves During Motorway Construction on Classical Karst
Knez, M.; Slabe, T. (Eds.)
2016, XIII, 324 p., Hardcover
ISBN: 978-3-319-21202-9