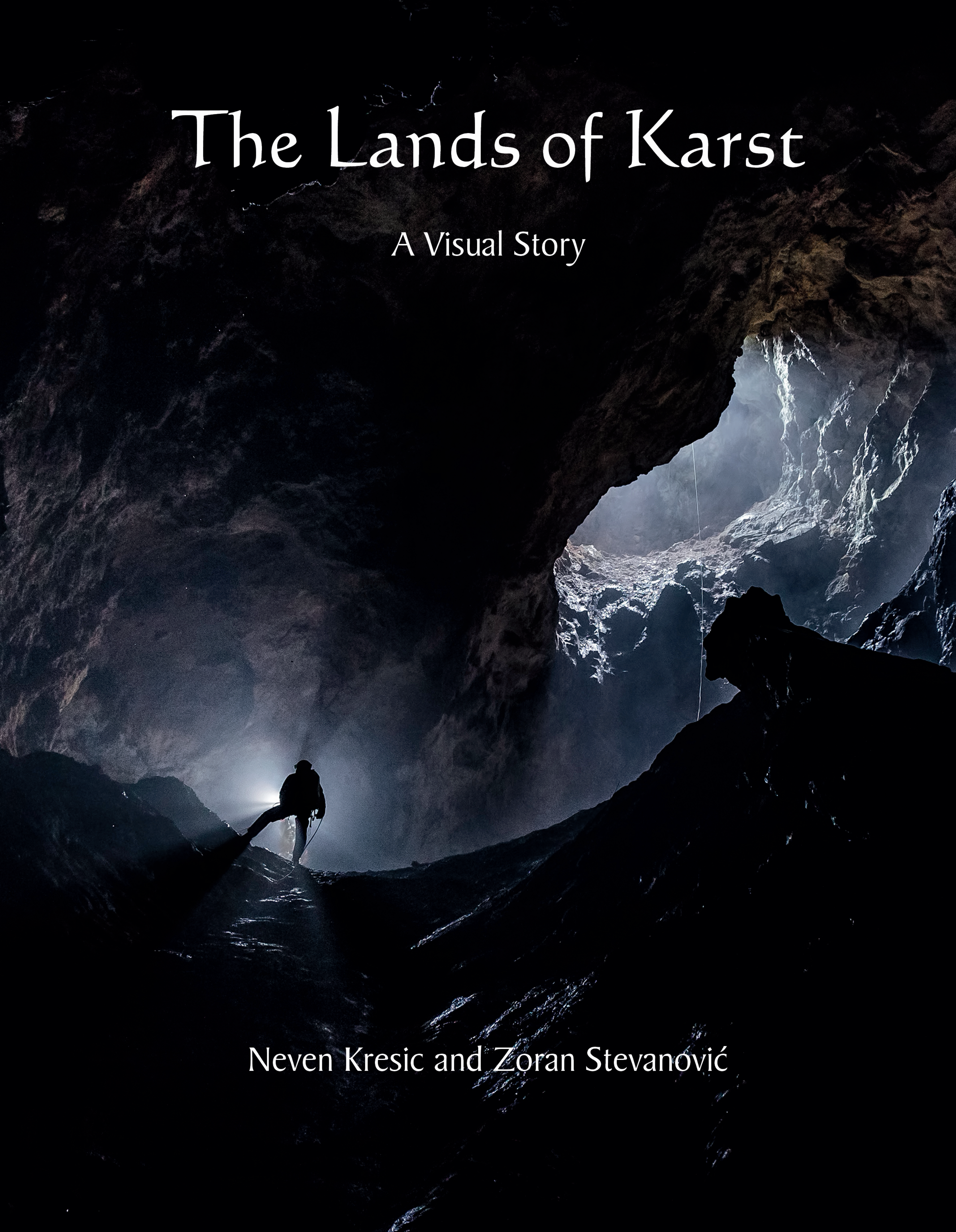
The Lands of Karst

A Visual Story



Neven Kresic and Zoran Stevanović

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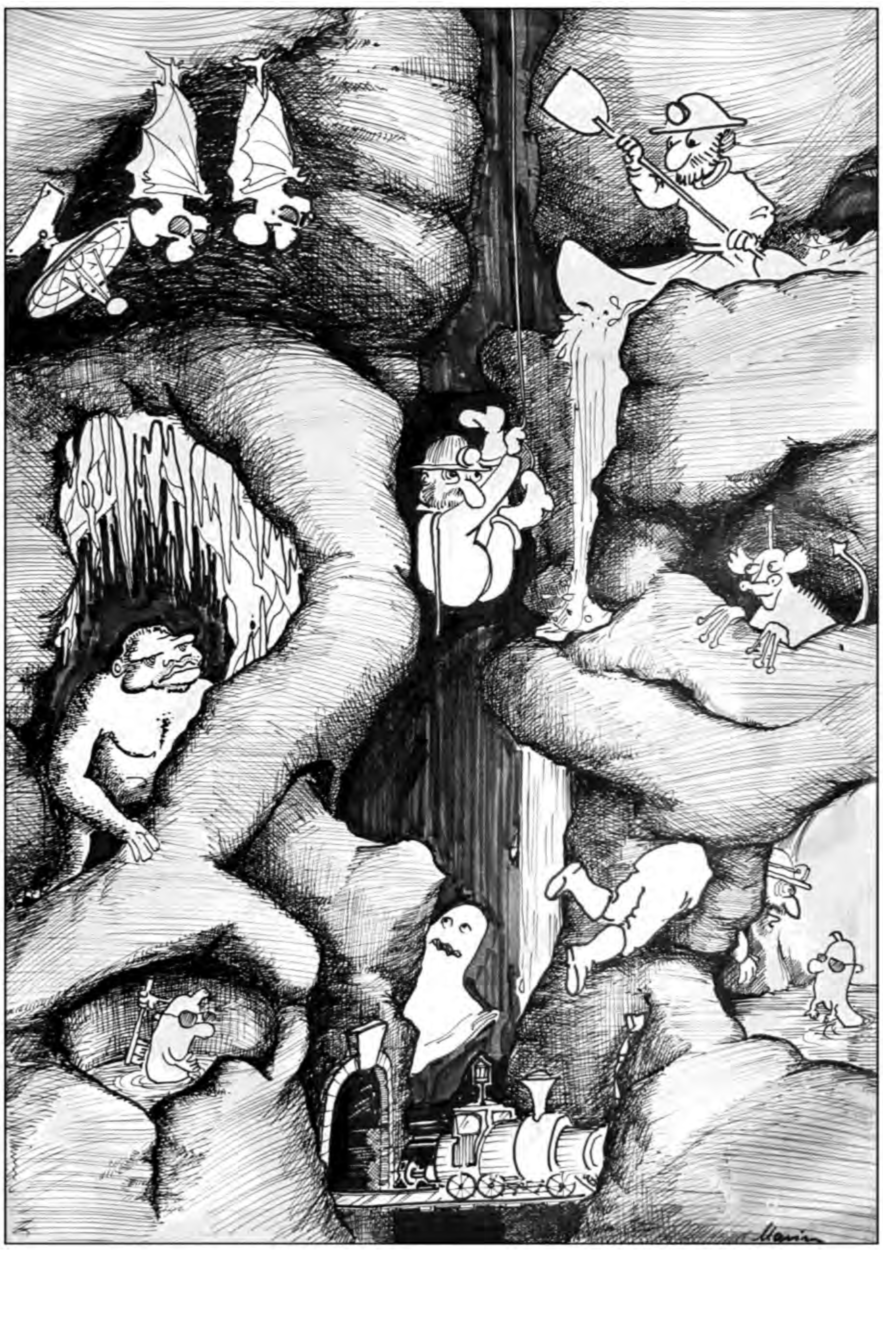
Stepping into Our Worlds



Stepping into Our Worlds

The idea for this book came spontaneously after we learned that 2021 is *The International Year of Caves and Karst.* What could be more natural than contributing to this celebration by sharing with the world a fascinating visual story from where we grew up, where we were formed professionally, and from where the very word *karst* originated? So, we reached out to our colleagues and asked them to contribute their favorite photographs for this story and spread the word beyond the karst community. The positive response we received was overwhelming, and from people who all grew up in, and learned to appreciate the many wonders that The Lands of Karst—Slovenia, Croatia, Bosnia and Herzegovina, Serbia, Montenegro, and North Macedonia have to offer. The hardest part of putting the book together was not being able to include many photographs because the space was inevitably limited for both the electronic and printed book versions. Also, we were most interested in what the photographs convey, not necessarily their technical perfection.

From the beginning, we decided to stick firmly to the widely accepted wisdom that "A picture is worth a thousand words". We have kept the narrative for individual chapters quite short, thinking of it as a "glue" loosely holding together the photographs that follow. However, we asked the contributors to provide their own captions with no word limits. Consequently, the descriptions vary in length; some felt like sharing more with us and the reader, and some let their photographs speak for themselves.

We also decided to make an electronic book, making it both more affordable and widely available. The Amazon Kindle format e-book is priced at less than three US dollars, and the pdf file of the book is available for free download via various sites hosted by karst and caves (speleological) organizations, and others. The printed versions, for those that would like to hold the book in their hands, are also priced nominally, solely to recover printing and administrative costs (which are not insignificant for a full-color book of photographs.)

As eloquently put by our Slovene friends "Karst is a unique world…It is where water and soluble rocks make contact. This has seen the emergence of a magic world filled with underground caves, disappearing rivers, dolines, and other karst landforms. In fact, our Karst plateau gives its name to all similar landscapes around the world with comparable soil composition and the whole set of karst natural phenomena."
(https://www.visitkras.info/en/)

Karst is a scientific term named after the geographic district located between the Gulf of Trieste, the Vipava Valley, and Brkini which has a very distinct landscape. It is a Germanic word for "carso" (in Italian) and "kras" (in Slovene), all three words being derived from the Indo-European word "kar" or "karra" which means rock. The following definition of karst and karst topography is based on the 1960 edition of the American Geological Institute Dictionary of Geology.

"In Karst, the limestone rocks are honeycombed by caverns and openings dissolved by groundwater. Most of the drainage is underground and the land is left dry and relatively barren. The landscape is dotted with sinkholes, interspersed with abrupt ridges and irregular protuberant rocks. Dry valleys are common, and valleys containing streams often end abruptly where the latter plunge into underground channels and caves, sometimes to reappear as large springs miles away. These features are so characteristic of the Karst district of the eastern Adriatic coast that the name karst has been applied to them elsewhere."

Some common words from the Slavic languages of the region have become international scientific terms describing karst features, mainly thanks to the Serbian geomorphologist Jovan Cvijić who was the first to defend a doctoral thesis and publish a scientific monograph exclusively devoted to karst (Das Karstphänomen, 1893). These include *doline* (sinkhole), *ponor* (swallow hole, sink), *jama* (pithole), and *polje* (very large closed depression with flat bottom characteristic of the Dinaric karst). Cvijić's insightful analysis of the karst relief and hydrography developed in the Dinaric orogenic belt led to wide international acceptance of the term "classic Dinaric karst" as a synonym for fully developed, mature karst. It stretches from Slovenia in the northwest, to North Macedonia in the southeast, encompassing portions of Croatia, Bosnia and Herzegovina, Montenegro, and western Serbia. Before he started working on his doctoral thesis in Vienna, Cvijić was already studying karst in eastern Serbia, which is not part of the Dinaric karst (it belongs to the Carpathians and the Balkan Mountains) but has equally impressive karst landforms. Additionally, the northern part of Slovenia belongs to the Alps and their spectacular limestone karst. Thus, we hope that the reader will learn something interesting from our visual story and step with us into Our Worlds, The Lands of Karst.

The Authors

Lithograph of Vilenica Cave in Slovenia by the Austrian painter Ferdinand Runk (1810) from the collection of National Library of Austria. Vilenica Cave is the oldest show cave in Europe, with first tourists recorded in 1633.

Contributors

Ivana Adžić
Ms. Adžić was born in 1987 in Zadar, Croatia. She studied biology at the University of Zagreb and finished her master's degree in Experimental Biology, module Botany at the Faculty of Science. She has been working as an expert associate biologist in Public Institution Paklenica National Park since 2013. She is currently working on different topics regarding nature conservation and protected area management such as wildlife monitoring and inventory (butterflies, Natura 2000 species, flora) national park management, visitors management, UNESCO World Heritage management, and interpretation of natural and cultural values of the protected area. Hiking is one of her many interests, such that the National Park and its surroundings provide a perfect living environment. Ms. Adžić has participated in professional conferences and has given professional and popular public lectures.

Natalija Andačić
Ms. Andačić (1979) was born in Makarska, Croatia. She finished primary school in Podgora, secondary school in Makarska, and completed her studies in geography and sociology at the University of Zadar. Since 2007 she has been working as a geographer in the professional service, and since 2017 as the Director of the Paklenica National Park. She specializes in speleology and high-altitude mountaineering and is a mountaineering instructor and mountain rescuer. Ms. Andačić has participated in several scientific and professional conferences and has given professional and popular lectures.

Nebojša Atanacković
Adventure and exploration of Nature does not exclusively mean distant and notorious destinations. One should first explore his or her own backyard which offers so many wonders that, sometimes, have to be searched for!
In short, this is the basic mission of the blog "Unreal Places" (https://nestvarna.blog/) by its author Nebojša Atanacković. Nebojša is not someone who "does not get off the mountain". A better part of his routine days he spends in the "valley of city dailiness" He is civil engineer by profession, married, and has three children. His blog is a "blitzkrieg" of self-arranged photojournalism excursions; most of them last less than 48 hours, sometimes even less than 24 hours. "One cannot make a living out of Nature, but she is here to rejuvenate and reinvigorate us, reminding us how insignificant we are in comparison to the Universe: *Homo parvus, natura inmensa."*

Dobrislav Bajović Bajone
Bajone is a retired army colonel since 2006, living in Nikšić, Montenegro. He was born in 1956 in Plužine, Montenegro. He graduated from the Military Academy of the Yugoslav People's Army and received other advanced military training. Photography is his hobby since 1976, and in 1977 he completed a course in photography with the famous photographer Ivo Eterović. His other passion is mountaineering which helps him easily find motifs for his photographs. His artistic photography is focused on landscape and ethnology. Bajone is vice president of the mountaineering club "Piva" from Plužine and a long-standing member of the mountaineering club "Javorak" in Nikšić. He presented his work at nine solo and numerous group exhibitions including internationally and was featured in Yugoslav and Montenegrin media. Bajone is proud of his extensive professional photo equipment. He won various prizes for his nature photographs which can be viewed at @FotoBajone.

Aleksandar Banović
Aleksandar is electrical technician, working at EEPCG (Electrical Enterprise of Montenegro) since 2007 on observation and recording of groundwater regime throughout the country. He is mountaineer amateur, always equipped with his camera on his trips.

Petar Begović
Mr. Begović is Master of Technical Sciences with specialization in geology. He was born in 1975 in Sarajevo, Bosnia and Herzegovina (in former Yugoslavia). He completed his undergraduate degree at the Faculty of Mining and Geology, University of Belgrade in 2000, and in 2004 he completed graduate studies in water resources management and systems at Politecnico di Torino, Italy. Mr. Begović started his professional career at the Urban Planning Institute of Republic of Srpska, Bosnia and Herzegovina, and currently works at the engineering geology company Ibis Engineering in Banja Luka, Bosnia and Herzegovina. His specialty is groundwater protection in karst and other porous media.

Matej Blatnik
Dr. Blatnik is a research assistant at Karst Research Institute (ZRC) of the Slovenian Academy of Sciences and Arts (SAZU). His research focus is karst hydrogeology (groundwater dynamics and quality), cave climate (study of periglacial processes and ice content in caves) and ecohydrology (connection of flooding dynamics with habitat types/land use). He is an active caver, participating in exploration of the deepest Slovenian caves, and amateur photographer.

Jelena Bogosavljević
Ms. Bogosavljević completed her undergraduate and graduate studies at the Faculty of Biology, University of Belgrade, where she is currently a PhD student. Her doctorate research is on the population of bats in urban Belgrade. She works as a curator at the Natural History Museum in Belgrade, Sector of Biology. Jelena was introduced to speleology and karst at the Student Speleological and Alpine Club where she completed a course in speleology and where she was an active member for many years. She likes field work and spending free time in nature, merging her love for research, travel, and photography.

Ognjen Bonacci
Dr. Bonacci is Professor Emeritus at the School of Civil Engineering, Architecture and Geodesy, University of Split, Croatia. He is one of the world’s most recognized experts in hydrology, ecohydrology and karst hydrology. Dr Bonacci published over 500 scientific and professional papers in leading international journals and is one of the most cited authors in these disciplines. He is author and co-author of nine books and over 30 chapters in other books and monograph. His most cited books are “Karst hydrology with special reference to the Dinaric karst”, “Environmental aspects of integrated flood management” and “Ekohidrologija” (Ecohydrology). Dr. Bonacci was founder and first President of the Croatian Hydrologic Society, and founder of the Yugoslav Hydrologic Society. Chinese Academy of Geological elected Dr. Bonacci to serve on its Committee of Karst Research. He is recipient of the Croatian State Award “Nikola Tesla” (1988) and Croatian State Award for Life Achievement for his overall contribution to scientific research in technical sciences.

Dragan Bosnić
Mr. Bosnić, born in 1950 in Belgrade, started learning electronics and ended up with the photography. Since 1980, when his photograph was featured on his first cover page of a magazine, until present, he had over five hundred cover pages and over one thousand photo journal articles published in leading national magazines. He also contributed his cartoons and illustrations to various monographs. Until his retirement he was photography editor for the National Review Serbia and is continuing with his long-lasting collaboration with the National Radio-Television, Tourist Association of Serbia, and other national organizations. He was author of several widely acclaimed photo monographs for which he received awards including for the 2016 book of the year. These large-format monographs were translated to half a dozen languages including English. Most interesting to the readers of this book are certainly two works by Mr. Bosnić that had multiple editions: “The Miraculous Serbia” (*Čudesna Srbija*) and “The Hidden Serbia” (*Skrivena Srbija*). “We are first attracted by old monasteries and fortresses, old deserted and picturesque villages… With time, you discover that tracks of human hands in these lands do not last long.” Mr. Bosnić wrote in the introduction to his book “*Putevi pored znakova*” (Roads by the Signs). “This is why I followed much longer lasting signs: calm and wild rivers, forests bent by the wind,

mountains washed by the flood waters, and human stories that change from one village to another, but remain the same nevertheless."
http://www.serbia.com/srpski/dragan-bosnic-priroda/

Vlado Božić

Vlado (Vladimir) Božić was born in Križevci, Croatia and attended schools in Križevci, Petrinja, and Zagreb. He graduated from the University of Zagreb, Faculty of Mechanical Engineering and Naval Architecture with a degree in naval architecture. From the University's Faculty of Physical Education, Mr. Božić received a title of speleology instructor. He started mountaineering and spelunking in 1951 and is a member of the Speleological Section of the Croatian Mountaineering Club "Željezničar: from Zagreb since 1955. Mr. Božić held various offices at the Croatian and Yugoslav mountaineering organizations and was Chair of the Speleological Education Committee of the Yugoslav Speleological Association. For many years, he has been teaching at speleological and mountaineering schools and workshops and attended numerous domestic and international gatherings of speleologists. Mr. Božić published five monographs on cave tourism, ten textbooks in speleology, and more than thousand articles and papers in domestic and international publications and journals. Among countless speleological expeditions, in Croatia and abroad, he considers a 750-meter descent into Lukina jama cave in Croatia his proudest achievement. Mr. Božić received highest honors and medals from the mountaineering and speleological organizations in Croatia and was awarded "Medal of the Order of Danica of Croatia with the Image of Franjo Bučar" in 2015 by the Croatian Ministry of Education and Sport.

Dujo Bušljeta

Mr. Bušljeta is ranger in the National Park Paklenica in Croatia and Croatian Speleological Society field research guide. In addition to his excellent nature photographs, he is best known for discovering A. busljetai sp. nov., new troglobiotic species of Alpioniscus (Illyrionethes), which is named after him. It is found in two caves in the coastal area of North Dalmatia. Both caves are threatened by human activities.

Boštjan Burger

Boštjan Burger (born 1966) is a Slovenian informatician, geographer, a panoramic and VR panoramic photographer and a speleologist. He was founder of the Burger.si website and had retired as computer programmer in the 1990s to become a geographic researcher on the hydrology of waterfalls. He used 360° Surround Photography as a tool in the research of landscapes. He was greatly influenced by geographer Don Bain for documenting the landscape with 360° Surround Photography and Hans Nyberg for his use of Quick Time VR full screen panoramas. His first 360° pictures—so called Cycloramas—were taken with BW negative film in 1982. The very first computer game (Okoli Sveta) with the virtual exploration of World made by Boštjan Burger was for the Commodore 64 in 1983 with the programming method of sprites combinations. The aim of the game was to travel around the World's landmarks, starting with Ljubljana Castle. With the right answers the player passed the level and continued to the next level - Moscow - China Wall - Statue of Liberty in NY - London - Paris and back to Ljubljana. The game was not commercial but was shared all over former Yugoslavia. For presentation of Bostjan's amazing work visit burger.si

Uroš Buzurović

Mr. Buzurović obtained his academic degree from the Faculty of Biology, University of Belgrade. He works at the Natural History Museum in Belgrade as Custos in Botanic. Since 2012 Mr. Buzurović works as an instructor at the Faculty of Biology where he collaborates in biogeography and plant ecology courses, as well as in field studies. He is author of a lab manual "Practicum in Biogeography – General and Phytogeography Sections" published by the Faculty of Biology. Mr. Buzurović regularly participates at national and international conferences and has published his research in scientific publications and peer-reviewed national and international journals. His research interests include flora od the Balkan Peninsula, and phylogeny and phylogeography of native plants.

Jelena Ćalić
Dr. Ćalić (1974) was born and grew up in Zagreb, and lives in Belgrade. She has warm emotions for both. Place she calls Home is Krbavica – a small karst polje in Lika, the Dinarides. Jelena has been Karst admirer since childhood, prior to knowing its scholarly definition. She is caver since 1996, and geographer (officially) since 1998. She is a member of ASAK (Student Speleological and Alpinistic Club) and works at Geographical Institute "Jovan Cvijić" in Belgrade. She obtained her PhD in Karstology from University of Nova Gorica, Slovenia with a research topic on karstic uvalas. Dr. Ćalić is National Delegate of Serbia in the UIS. She conducts her fieldwork throughout Dinarides and Carpatho-Balkanides. Her favorite caves (from west to east) are Doljašnica, Vjetrenica, Đatlo, Jama na Vjetrenim brdima, Mala Bizdanja, Buronov Ponor, Drenjarski Sistem, and Propas' in Činiglavci.

Golub Ćulafić
Mr Ćulafić (1981) was born in Ivangrad (Berane), Montenegro from father Ljubiša and mother Koviljka Maslovarić. He is married to Dragana–Gaga (Čvorović). His roots are in Ulotina and Božići, and he lives in a flat in Podgorica with his family. He finished primary and high schools in Andrijevica, and graduated from Department of History and Geography, Faculty of Philosophy, University of Nikšić, Montenegro. He received master's degree from the University of Belgrade, School of Geography where he is currently a Ph.D. student at the Geosciences Program. He works at the Institute of Hydrometeorology and Seismology of Montenegro, Department of Hydrology. He is an active mountaineer and speleologist, and is in love with Komovo Mountains, Nature, Water, and Karst. He is a Capricorn, free archer, and, just to be known, "he is still his very own."

Teo Delić
Teo Delić (1986): "I was fascinated by the natural world surrounding me (karstic rivers, mountains) from my early childhood in Split, Dalmatia. However, it was only during biology studies in Ljubljana (Slovenia), that I recognized the true values of Karst, that has been a vital part of my life. Knowing that there is a global hotspot of subterranean biodiversity in my garden, the Dinarides, made me consider the possible reasons underlying it. Slowly, I started exploring the subterranean world and its inhabitants, and got interested in all the scales of research, from basic taxonomy and faunistics to biogeography and evolutionary processes. In addition, and apart from being speleobiologist, I am actively participating in cave research as a part of Ljubljana cave exploration Society (DZRJL). Recently, I started gaining experience as a cave fauna photographer, mainly because I wanted to change the perception of my caving comrades, for whom all cave fauna is "a critter".

Neda Dević
Ms. Dević is Master of Sciences in karst hydrogeology and works at Geological Survey of Montenegro. Her research work is dedicated to methods of field investigations, hydrogeological mapping, and water resources in karst and intergranular aquifers. She is also interested in understanding groundwater and surface water interactions and their impacts on water quality in karst terrains. Ms. Dević's primary goal is better understanding and protection of karst water resources.

Ivo Eterović (1935-2011)
Mr. Eterović was a professional photographer. He learned his craft at "Leica" company in Wetzlar, Germany, and further specialized in color photography in "Ferrania" company, Milan, Italy. He emerged on the public scene in 1956 and ever since was recognized as one of the leading photographers in former Yugoslavia. He had short assignment as official photograph of the United Nations 1957 peace-keeping mission in the Middle East. He was photo editor at several leading magazines and journals in former Yugoslavia and moved to Belgrade in 1959 where he lived for the rest of his life. Mr. Eterović won numerous national and international prizes for his work and published several widely acclaimed books of photographs.

Contributors

Mike Ficco
Mike is a geologist and cave explorer from the United States. He has spent much of his life exploring and documenting caves and karst throughout the world, including in his home State of Virginia. His interest in the discovery and exploration of deep caves attracted him to the Dinaric karst of Montenegro, where he and his wife Katarina lead a project mapping some of the country's vast subterranean world. His strictly amateur photography is documentary in nature and intended to compliment the survey and study of caves during exploration. His leadership of the Cave Conservancy of the Virginias has helped the organization come to be recognized as one of the world's most important conservancies dedicated to the protection and study of caves and karst.

Mladen Garašić
Professor Dr. Garašić, born in Zagreb, Croatia, in 1951, earned his B.S. degree in geology and karst hydrogeology in 1977, and doctorate in geosciences and geological engineering in 1986. He has been teaching geology, karst hydrogeology, applied geology, engineering geology and speleology at the University of Zagreb, and Technical University of Graz (Austria). He authored more than 360 scientific and professional papers and about 800 speleological and geological reports. He serves as a Karst Committee secretary for the Croatian Academy of Sciences and Arts (HAZU) and is a member of UNESCO World Heritage Team for the Dinaric Karst, International Association of Hydrogeologists, and International Association for Engineering Geology and the Environment. Professor Garašić started caving in 1963 and was one of the founders and president of several caving clubs in Croatia. He served as the first president of the Croatian Speleological Federation from 1990 to 2010 and was Croatia's delegate to the International Union of Speleology (UIS) and the European Speleological Federation (FSE). He has conducted research in and explored and visited more than 5,000 caves in 80 countries on all continents.

Peter Gedei
Peter Gedei (1969), born and living in Ljubljana, embarked on the path of cave photographer soon after joining Ljubljana's caving club Železničar in 1987. After spending several years gaining experience primarily as an explorer of the subterranean world, in the early 1990s he began to devote increasing attention to cave photography. Over the years he perfected his lighting technique and creative approach and was awarded on several occasions with the highest accolades at Slovenian and international competitions. He has earned a reputation as one of the best world-renowned cave photographers who is set to tackle even the most challenging projects. He regularly publishes his photographs in Slovenian and foreign printed media, presents stories about his cave visits and appears on social media. Besides being actively engaged in stereo photography and video, he is a member of the Stereoscopic Society of Ljubljana, co-founder of the production group Place3D, and long-time former editor of Jamar (Caver) magazine. Gedei works as a designer at the monthly magazine Monitor.
Web: https://www.petergedei.com
Facebook: https://www.facebook.com/peterge
Instagram: https://instagram.com/petergedei/

Vojislav Ilić
Mr. Ilić is an attorney and amateur photographer from Belgrade. He travels throughout The Lands of Karst (former Yugoslavia), both professionally and for his own pleasure.

Zlatko Ilijovski
Dr. Ilijovski, born in 1966 in Kutretino, Demir Hisar, Macedonia, is an engineering geologist specialized in hydrogeology and focusing on groundwater protection and water supply. He is working at the Civil Engineering Institute Macedonia GIM in Skopje and teaches at the Faculty of Mining, Geology and Polytechnic in Štip. His hobby is mountaineering and nature photography.

Dunja Josipović
Ms. Josipović is an engineer of geology, born in Bijeljina, Bosnia and Herzegovina in 1995 where she also grew up. She obtained her BSc in hydrogeologic engineering in 2018 from the Department of Hydrogeology, Faculty of Mining and Geology, University of Belgrade where she is currently a graduate student of hydrogeology. Ms. Josipović works at Ibis-Engineering Company in Banja Luka, Bosnia and Herzegovina as a staff hydrogeologist.

Branimir Jukić
Mr. Jukić graduated from the Department of Geography, School of Natural Sciences and Mathematics, University of Zagreb, Croatia. He works at Department *More i krš* (Sea and Karst) of the Public Works for Management of Nature Preserve Areas in the Split-Dalmatia Canton. He is active member of the Croatian Mountain Rescue Corps (HGSS), and Officer of the HGSS Station Split. Speleology and photography are his hobbies, and he also serves as a mountaineering guide. Mr. Jukić works and lives in Split, Croatia, and has wife and three children.

Milorad Kličković
Mr. Kličković was born in 1968 in Topusko, Croatia (former Yugoslavia). He graduated in 2000 from the Faculty of Mining and Geology, University of Belgrade with the engineer of hydrogeology degree. Since 2002, he works at the Agency for Nature Protection of Serbia, Department of Geodiversity-Research and Development where he holds position of an Advisor. He is member of the Serbian Geological Society and its Karst Committee. Mr. Kličković is a speleologist since 1989 (Speleological Section Belgrade), and member of several mountaineering clubs from Serbia and Srpska Republic, Bosnia and Herzegovina where he is also a honorary member of the Mountaineering Association. Mr. Kličković is a mountaineering instructor and guide, and author and co-author of several publications and textbooks in speleology and mountaineering.

Herman Kosič
Herman Kosič graduated in psychology from the Faculty of Arts, Ljubljana. Throughout his career, he worked in the field of human resources, consulting, and IT education. After retirement, he and his wife Zorica Obid Kosič (also a gradute in psychology) have dedicated their time to their passion for the traditional architecture of Classical Karst. Herman's innovative spirit and Zorica's creative mind enabled them to quickly develop both traditional and innovative modern approaches to engineering and construction using the limestone of their home in Slovenia's Kras region. Herman's understanding of various types of limestone and their behavior enabled them to construct a traditional stone house with a limestone roof, a wine cellar, and a traditional "Sphnjenca," which refers to the cooking section of an old Karst house with the chimney.

Katarina Kosič Ficco
Dr. Kosič Ficco is a karst protection specialist for the Virginia Department of Conservation and Recreation, in the Natural Heritage's karst program. She is combining her B.S. in Political Science and Ph.D. in Karstology to successfully perform evaluation and protection of karst terrains and bring knowledge about karst, and the need for its protection, to a broader audience inside and outside of karst science. In addition to her professional caving activities, she is a keen cave explorer and has joined multiple caving expeditions in the USA and Europe. Many of these include both scientific and exploratory objectives. Originally from Slovenia, and passionate about Dinaric karst, she and her husband Mike organize annual caving expeditions to Montenegro, where they focus on the study and exploration of the country's caves.

Blaž Kogovšek
Mr. Kogovšek is a civil engineer, currently a PhD student in karstology and working at the Karst Research Institute ZRC SAZU, Slovenia. His main research areas are karst hydrology and hydrogeology, with special emphasis on the study of karst aquifers. Blaž enjoys spending a lot of time outdoors; photography, cycling, climbing mountains and exploring caves are his main hobbies.

Contributors

Dragan Kolčakovski
Professor Dr. Kolčakovski, born in 1958 in Skopje, North Macedonia, teaches at the Institute of Geography, Faculty of Natural Sciences and Mathematics, University of Skopje. His scientific interests and activities can be divided into two main periods: the first one almost exclusively devoted to research of karst and karst phenomena in Macedonia, resulting in publication of numerous papers and several monographs. The most significant results can be considered the explorations of several previously unknown caves, such as Dračevska, Christianova, Cave Slatinski izvor, caves on the mountain Galičica, caves in the eastern part of North Macedonia and others. In the second period, Professor Kolčakovski finds his interest in the geomorphology of high mountain areas.

Neno Kukurić
Dr Kukurić is a hydrogeologist with more than 30 years of experience gained worldwide, working as a field hydrogeologist, consultant, scientific researcher, and project manager. His professional interest is international water cooperation and application of informed management, encompassing technical, socio-economical, institutional, and political aspects of water-related issues. Dr. Kukurić is particularly focused on a global assessment and management of transboundary groundwaters. Since 2011, he serves as a director of IGRAC, the International Groundwater Resources Assessment Centre of UNESCO in Delft, The Netherlands. He is graduate of the Faculty of Mining and Geology, University of Belgrade, Serbia (former Yugoslavia).

Uroš Kunaver
Uroš Kunaver started with cave photography already in his youth, almost forty years ago. Then after a long pause he restarted to explore and photograph caves in 2012. Soon he discovered all the benefits of the new digital technology and started to improve his photographic abilities. In the last few years, he specializes in deep cave photography. From 2016 on he organized several photo-expeditions to deep caves. This activity culminated in the end of 2019 when he launched a dedicated five-day photo expedition to one of the deepest cave systems in Slovenia - Renejevo brezno-P4 cave system located on Kanin plateau. It was the first photo expedition that reached the final sump at the depth of 1240 m and one of the deepest if not the deepest photo expedition to Slovenian caves. He publishes his works in Slovenian and international media, contributes to different exhibitions, and appears in social media.
Web: https://www.uroskunaver.si/
Facebook: https://www.facebook.com/uros.kunaver
Instagram: https://www.instagram.com/uroskunaver/

Borut Lozej
Mr. Lozej was born in 1973. He became interested in photography as a college student. After joining the Gregor Žiberna caving club from Divača, Slovenia in 1996 he became interested also in cave photography. His first published photographs were pictures taken for the book of Divaška jama Cave published in 1999. Later he worked on a project of an abandoned coal mine in the city of Vreme, Slovenija. His photographs were a part of an exhibition at the Natural Museum of Trieste. As the ranger and guide employed at Škocjan Caves Park, he took countless photos and video materials used for public promotion of the Park. This work made Mr. Lozej widely recognized as one of the leading speleo-photographers in the world. His photographs received awards both domestically and internationally.

Vinko Ljubas
Mr. Ljubas was born in 1969 in Mostar, Bosnia and Herzegovina (former Yugoslavia). He lives in Tomislavgrad, Bosnia and Herzegovina where he works at Elektroprijenos a.d. BiH Company as electrical technician. Most of his free time he dedicates to his three hobbies—paleontology, archelogy, and petrography. “Simply put, I am dedicated to the amateur explorations of the natural environment that surrounds us. This includes karst poljes and all the wonders they abound with. I also spend lots of time in the mountains, both those near my hometown

and farther away. Photography is my great passion and I use it to record all my explorations, as well as the "events" in the world that surrounds me. On August 15, 2011, in the Cebara Quarry, Tomislav County, I discovered fossils of the animals that lived here in Miocene and Pliocene. Most abundant were proboscides from the genus Anancus *arvernensis* (Mastodons). They are now hosted at the Franciscan Museum in Tomislavgrad."

Vladimir Ljubojević
Vladimir (1966): "I have been caving during 1985 - 2010, in ASAK caving club in Belgrade. I was active mostly in Eastern Serbia, primarily exploring caves on Mt. Miroč. I always tried to learn about speleogenesis and earth sciences – not just to help me find those large caves, but to find answers to infinite questions that pop up after entering a cave: why are those sediments deposited only there and nowhere else, what shaped the walls this way, where this water comes from, and many more."

Ivo Lučić
Dr. Lučić (1960) is an independent researcher, journalist, and environmental activist, born and raised in Popovo Polje (Ravno, Bosnia & Herzegovina). He completed primary and secondary education in Dubrovnik, graduated in political sciences in Zagreb, and received his doctorate in karstology from the University of Nova Gorica in Slovenia. He earns his income from journalism, in which he covers science and the environment. His main scientific preoccupation is the perception of karst. He is author of the book "Karst Molting" (Presvlačenje krša) and an illustrated map of the Dinaric Karst, and editor and co-author of the book "Karst without Boundaries" (Krš bez granica). He led the research, popularization, and protection of the Vjetrenica cave (1999-2009), during which time Vjetrenica was established as the leading locality in the world in terms of subterranean biodiversity. He was a co-founder of the Center for Karstology of the Academy of Sciences and Arts of Bosnia and Herzegovina.

Mihajlo Mandić Zis
Zis is hydrogeologist by training, and speleologist by preference. He has been dedicating all his free time to the exploration of caves and pit holes for over forty years now. It was a logical combination as he believes that practicing karst hydrogeology without being a speleologist presents a serious handicap; namely, not being in a position to see all important things *in-situ*, and in a way that no photograph, map, or a mathematical model can convey. As a hydrogeologist, he spent his working career doing everything that hydrogeologists usually do, from water supply projects to hydrogeologic mapping. Still, his life work has been dedicated to speleology, as a member of the Student Speleological and Alpinist Club (ASAK) in Belgrade. Apart from field explorations, an important activity Zis very much enjoys is passing knowledge of karst hydrogeology and speleogenesis to young generations of speleologists. After breakup of Yugoslavia, and by default a cessation of speleological conferences and karst symposia gathering professionals from the six republics of the former country, Zis was one of the initial organizers of a new series of professional gatherings named *Symposia on Karst Protection* that continued to bring together professionals and karst enthusiast from Serbia and all other newly independent countries for 30 years now, providing an invaluable venue for the exchange of ideas and experience. Zis can be reached at zis@beotel.rs

Aleksandra Maran Stevanović
Dr. Maran is Curator-Paleontologist, museum adviser and scientific researcher at the Museum of Natural History in Belgrade, where she manages the Mesozoic Invertebrate Collection. Although she wanted to study literature, she followed in her father's footsteps and became a geologist. For the last thirty years, she has been devoted to the conservation of both immoveable and moveable geoheritage objects. As an expert in geoconservation, she was appointed the President of the Commission for the Geoheritage Conservation of the Serbian Geological Society. She is a national representative in the Panel of Experts on Geological Heritage of the European

Federation of Geologists and in the European Association for the Conservation of the Geological Heritage (ProGEO). Dr. Maran actively participated in the process of establishing the first geopark in Serbia— the Djerdap UNESCO Global Geopark.

Saša Maričić
Saša started his caving activities in 1984, as a member of Student Speleological and Alpinist Club (ASAK) from Belgrade. As a professional photographer and reporter for a number of magazines and newspapers, he also enjoys cave photography.

Srdjan Marinčić
Destined by birth in the Orient, in Ankara, Srđan posseses an innate curiosity and desire to reveal the secrets of nature that opened him to the beauty of the world. Open to people, open to challenges, his world is limitless and adventurous. Desires and dreams lure him to the loneliest, mystical islands of the Adriatic, to the most remote capes of the continents and celestial mountain peaks, immortalized in his widely awarded photographs. Srđan holds the post of Advisory Paleontologist, Curator at the Institute for Nature Conservation of Serbia in Belgrade, with a MSc degree in Geology (Paleontology). He was a leader in a number of environmental studies which contributed to the creation of government environmental protection policies. Srđan concieved and curated a range of nature exhibitions in Serbia and abroad. He coordinated international projects in the field of nature protection in partnership with world organizations (IUCN, UNESCO, etc.), including the European Green Belt and BioREGIO Carpathians. As a member of several teams for international nominations, he made significant contribution to the nomination of the Dinaric Karst to the UNESCO World Heritage List, and the designation of Djerdap as the first UNESCO Geopark in Serbia. Srđan is a member of the IUCN WCPA (World Commission on Protected Areas) and a participant in a number of prominent world conservation congresses

Veljko Marinović
Veljko is M.Sc. Hydrogeologist and Research Assistant at the Centre for Karst Hydrogeology, Faculty of Mining and Geology, University of Belgrade, Serbia. He is experienced hydrogeologist with demonstrated skills in research of karst environments including groundwater resource management, hydrogeologic characterization, and environmental impacts assessment.

Dragan Marjanović
Mr. Marjanović was born in 1995 in Sanski Most, Bosnia and Herzegovina. He spent his youth and grew up in Stara Pazova, Serbia. In 2019 he graduated from the Department of Geotechnics, Faculty of Mining and Geology, University of Belgrade where he is currently a graduate student. He works as a junior engineer and Head of the Laboratory for Geotechnics and Geomechanical Testing at Ibis Engineering Company in Banja Luka, Bosnia and Herzegovina.

Miroslav Marković
Professor Dr. Miroslav Marković taught many generations of future geologists at Belgrade University. Full time professor of Geomorphology and Remote Sensing at the Faculty of Mining and Geology, Professor Marković loved to teach about karst, including the authors of this book. Principal Investigator of numerous scientific research projects, Professor Marković was, among many other important roles and functions he had, a scientific representative of former Yugoslavia in an international project "Cosmotectonic map of Europe", and a representative of former Yugoslavia in the Space Sciences Committee of European Scientific Foundation. He worked as a consultant for numerous domestic and foreign companies and governmental institutions (in tectonics, neotectonics, engineering geology, hydrogeology, and geological mapping) in Venezuela, Peru, Libya,

Mozambique, Gabon, Guinea, Turkey, Jordan, Iraq, and Iran. Professor Marković now refers to himself as "a quiet old man, who saves the memories of good people with whom he worked."

Cyril Mayaud
Cyril Mayaud works as a hydrogeologist at the Karst Research Institute ZRC SAZU since June 2016. While he arrived in Slovenia with a background in groundwater modeling, the unique configuration of the Classical Karst made him more involved in field hydrogeology. Cyril focuses on understanding how complex flow processes affect the behavior of the karst aquifers around Postojna and is interested in studying the flooding dynamics of karst poljes. He has been a hobby-photographer for more than 10 years and likes to bring hydrogeology and natural sciences into his pictures of the Slovenian karst landscapes.

Iztok Medja
Mr. Medja is a freelance outdoor and commercial photographer based in Slovenia, known for low-light photography of diverse scenes from natural world. Part of his commissioned projects in tourism represented cave photography, where he was capturing images mainly in Postojna cave, Slovenia. For his night photography and other "low light worlds" captures he received several international awards and media recognitions. One of them was "IPA - curators selection" for a photo of Škocjan caves. More info at: www.iztokmedja.com

Dušan Mihailović
Dr. Mihailović (1962) is a Full Professor at the Department of Archaeology, Faculty of Philosophy, University of Belgrade where he serves as its Chair since 2018. As a director and co-director of numerous international and national projects, he was instrumental in the discovery and excavation of numerous Paleolithic sites in Serbia, Montenegro and Bosnia and Herzegovina, including Balanica, Pešturina, Crvenka-At and Petrovaradin Fortress. His field of expertise covers lithic technology and different aspects of investigation of the Palaeolithic and Mesolithic in the Balkans. Dr. Mihailović was President of the Serbian Archaeological Society, a member of the Upper Paleolithic Commission of Eurasia of International Union of the Prehistoric and Protohistoric Sciences (UISPP-CIPSH-UNESCO), and a member of the Board for Karst and Speleology of the Serbian Academy of Arts and Sciences. He is author of numerous papers published in national and international scientific journals, and author of four books.

Petar Milanović
Professor Dr. Petar Milanović received his B.Sc. in geologic engineering and PhD from the Faculty of Mining and Geology, University of Belgrade, Yugoslavia. As a geologist and member of expert panels, Dr. Milanović participated in various stages of investigation, design and construction of more than sixty dams, reservoirs and tunnels in karst regions around the world. His portfolio also includes numerous projects of underground excavation, grouting, water supply, irrigation and groundwater pollution control. Over many years, Dr. Milanovic gave lectures and presented at seminars on karst theory and engineering karstology at universities and water management institutions abroad including all countries of former Yugoslavia. He is President of the IAH National Chapter for Serbia, and member of the IAH Karst Commission since 1973. Dr. Milanovic wrote several important books on karst hydrogeology and engineering. Among them the most cited are *Karst Hydrogeology*, first published in 1979 in Yugoslavia, and the English edition published in the United States in 1981; *Water Resources Engineering in Karst* published by CRC Press, in 2004; *Engineering Karstology of Dams and Reservoirs*, CRC Press 2018; and *Dams and Reservoirs in Evaporites* (with N. Maksimovich and O. Meshcheriakova), Springer, 2019.

Contributors

Saša Milanović
Dr. Milanović (1972): "My connection with karst and love for karst began with my birth in Trebinje, the heart of the Dinaric Karst. Even today, after almost 25 years of work in the field of karst hydrogeology, and almost 30 years since the beginning of my speleological and cave diving research, that connection continues to grow stronger. As a geologist, consultant and member of boards of experts I participated in various stages of investigation, design and construction of dams, reservoirs, tunnels and taping structures, as well as speleological and cave diving explorations in many karst regions of the world (Bosnia and Herzegovina, Mexico, Iran, Turkey, Algeria, Somalia, Montenegro, Peru, and others)." Professor Dr. Milanović works at the Department of Hydrogeology, University of Belgrade, and is member of its Centre for Karst Hydrogeology.

Milovan Milivojević
Mr. Milivojević is a Scientific Associate at the Geographical Institute "Jovan Cvijić" in Belgrade. His focus is research and reconstruction of the dynamics of the Pleistocene glaciers on the high mountains of the Balkans. "Glacial morphology is perhaps best preserved on limestones, such that karst presents itself as an unavoidable subject in the research of Pleistocene landforms. Notably, in a period of about 6-7 years, I actively participated in speleological expeditions throughout Serbia, Montenegro, and Bosnia & Herzegovina. As a researcher of landforms, defined by their morphology, photography became my favorite tool, in addition to being a hobby. It helps me gather scientific evidence and research materials, but also serves as powerful means to communicate to the public and state agencies the importance of geological heritage, its preservation and promotion."

Ana Mladenović
Dr. Mladenović is structural geologist, mostly interested in active tectonics and earthquake generation processes. She came to the world of karst and speleology because of geology and faults, and quickly became passionate speleologist, fascinated by caves and (deformed) speleothems. Ana is member of the Student (Academic) Speleological and Alpine Club in Belgrade (ASAK), trying to make other speleologists interested in processes of tectonics and speleogenesis.

Lazar Mrčarica
Mr. Mrčarica is currently employed as a software test engineer. He is also a perpetual student of biology. He first learned about karst, caves, and pit holes during his high school days when he became member of the Student Speleological and Alpine Club (ASAK) from Belgrade. He is nature lover, spending all his free time on travel, photography, and drawing.

Marjan Niketić
Marjan (1961): "By vocation, I am a vascular plant taxonomist and Curator of the Natural History Museum in Belgrade, where I spent my entire career. I inherited my love for nature from my father, and knowledge of botany from Professor Vladimir Stevanović. At the beginning of my career, I met our famous photographer Milan Živković at the Museum and he revealed to me the secrets of wildlife photography. Although it has been over two hundred years since the beginning of botanical research in Serbia and the Balkans, a remarkable floristic diversity is yet not fully elucidated. So, we are still discovering new plants, and a dozen of new species we have described inhabit rocky ground, mostly on limestone. To make satisfactory plant images, special planning should include spending about an hour shooting one individual. In the end, however, everything depends on fortunate circumstances. Although I am fixed in one place at that time, static stress requires a lot of strength, so it is much easier to me to walk many kilometers when botanizing."

Gojko Nikolić

Mr. Nikolić obtained his PhD from the Institute of Geography, University of Montenegro, Nikšić, in the field of mapping and the disciplines of physical geography and geographical information. He has participated as an associate or a member of a professional team in the development of several scientific studies and research projects, including international projects, in which his professional and scientific engagement was focused on solving methodological problems, making corrections to numerous maps, atlases, and topographical, geographical and GIS databases in several scientific fields (geomorphology and geoecology, GIS and digital cartography). Dr. Nikolić is a representative of Montenegro in the International Cartographic Association, and member of the State Commission for Professional Assessment (Review) of the Spatial Plan of the Republic of Montenegro. He was engaged as a GIS expert on two state-level projects which were realized under the auspices of Montenegro's Ministry of Sustainable Development and Tourism – the first was "Plan of Integral (Cross-Border) Management of the Bojana/Buna Region", and the second was "Programme of Integral Management of the Coastal Region of Montenegro – CAMP CG."

Ana Paunović

Dr. Ana Paunović, born in 1969, is a Scientific Advisor at the Museum of Natural History in Belgrade, Serbia. As a zoologist, she specializes in amphibians and reptiles. She is the author and co-author of numerous scientific papers and three textbooks in biology. She is a regular contributor to numerous popular science journals and children's magazines, where she shares her love of the miraculous world of nature. Dr. Paunović has attended numerous national and international symposia and conferences, including the 5th International Congress of the Hellenic Speleological Society. "My field work has taken me to all parts of Serbia, including karst terrains. It is interesting that some of the amphibians and reptiles that can be found in Serbia occasionally find shelter from the strong sun in the summer and the severe cold in the winter in both deep and shallow caves. No part of nature is complete without living beings. My photographs are part of the Museum's collection, and I hope you will enjoy them."

Milan Paunović

Dr Milan Paunović is Director of the Museum of Natural History in Belgrade. Biologist by education (specialization in mammalogy) he is dedicated to research and protection of endangered species of mammals including the Balkan lynx, brown and black bears, bats, and other inhabitants of the karst terrains.

Dražen Perica

Dr. Perica was born in Drniš, Croatia in 1960. He finished primary and secondary school in Zagreb and completed his studies in geography, master's and doctorate degrees at the Department of Geography, Faculty of Science, University of Zagreb. In the period from 1990 to October 2002 he was employed at the Department of Geography, Faculty of Science, University of Zagreb as a research assistant, and from October 2002 to September 2005 at the Department of Pedology, Faculty of Agriculture, University of Zagreb as an assistant professor. Since October 2005, he has been employed as an assistant professor at the Department of Geography, University of Zadar, and in 2019 he was elected a full professor. His teaching activity is primarily related to physical geography courses, especially karst geography. As a researcher or leader, he participated in the implementation of numerous domestic and international scientific projects, scientific and professional conferences, and in the publication of more than 40 scientific papers, and 15 books. He has given numerous professional and popular lectures at seminars for teachers, mountaineering societies, schools, libraries and cultural centers. He is a member of the Croatian Geographical Society and the Croatian Soil Science Society. Dr. Perica loves mountaineering since his early childhood and is also a volunteer firefighter. He has been engaged in photography since primary school, and his photographs have been published in several books and featured at several exhibitions.

Borut Peric

Mr. Peric (1970) works at Škocjan Caves Park Public Service as Head of Professional Services. He manages the operation of the Caves which are part of the UNESCO World Heritage Sites network (first cave to be included on the list). He cooperates closely with the experts from the Karst Research Institute from Postojna in the areas of hydrogeology, speleology, and geomorphology as they relate to the Caves, but also to the Karst Region as a whole. Mr. Peric is a speleologist and karstologist interested in hydrodynamics of underground Reka River course between Škocjan Caves and the springs of Timavo River. As a nature lover and traveler, he occasionally enjoys taking pictures of beautiful karst landscapes and features.

Branislav Petrović

Dr. Petrović is research assistant at the Department of Hydrogeology, Faculty of Mining and Geology, University of Belgrade. He has an extensive experience in managing mid-scale hydrogeological projects for water resources management and evaluation, environmental impact and groundwater vulnerability assessments. His areas of research interests include limestone (dolostone) karst environments and epikarst, and engineering design of groundwater extraction. Branislav has been member of the Department's Centre of Karst Hydrogeology since its inception in November 2008.

Ester Premate

Ester is currently employed as a PhD candidate at the University of Ljubljana, Slovenia, where she is studying functional diversity of the subterranean amphipod genus *Niphargus*. She is broadly interested in the topics of speleobiology and speleology and is dedicated to transferring her knowledge to the younger generations of students and speleobiologists.

Saša Preradović

Mr. Preradović, born in Belgrade, received his degree from the Faculty of Applied Arts, University of Belgrade. Among various art disciplines he practiced, photography emerged as the most important and influential. His work is focused on the visual and esthetics aspects of photography, creative studio lighting, wildlife, nude, and portrait photography, and chronicling of contemporary cultural and sport events. In parallel, Mr. Preradović teaches at "Foton" School of Photography in his studio with the same name, as well as at the Academy of Arts in Belgrade where he offers six courses in photography. He worked on marketing campaigns for numerous companies including Puma, Gas, Vera Pele, Paul Mitchell and others. His work has been featured in magazines, daily newspapers, and electronic media. He collaborates with various nature organizations and institutions in Serbia and nature magazines including National Geographic Serbia. He had eight solo and 257 national and international group shows and exhibited his photographs in 54 countries, receiving 125 awards of which more than 30 were gold and winning medals.

Nenad Radaković

Mr. Radaković was born in 1971 in Negotin, Serbia where he finished *Predrag Kostić Gymnasium* high school. He got his B.S. and M.S. degrees from the Faculty of Forestry, University of Belgrade, where he is currently a Ph.D. student. Amateur photography and guitar are Mr. Radaković's favorite hobbies; he lives in Donji Milanovac, is married, has two children, and speaks fluent Russian. Mr. Radaković currently holds position of the Executive Director of the Djerdap National Park where he has been employed since 1996. In 2010, he attended a workshop on eco-tourism and regional development in Japan, and in 2012, he attended a course on management of national parks in the United States through an "Open World Leadership Center" program.

Martin Ristić

Mr. Martin Ristić (principal photography), and Mr. Ivan Savić (principal lighting) are cave photographers since 2014. As members of the speleological club SAIS from Knjaževac, they participate in exploration and photographing of caves in Eastern Serbia. To the light of day, they bring photographs of previously unseen channels of Vladikine ploče cave near Pirot, and Korenatac cave near Knjaževac. Speleologists of SAIS from Knjaževac formally formed their club in 2018, having practiced caving since 2006. They explore karst terrains of Eastern Serbia, from Mts. Suva and Stara planina to the mountains of Kučaj. They collaborated in explorations of some of the longest and deepest Serbian caves such as Lazareva and Cerjanska caves, caves of Vladikine ploče, and others. More recently, they are exploring channels of the Korenatec cave in the Knjaževac County.

Tin Rožman

Tin has been exploring and photographing karst subsurface for nine years now. He participates regularly in speleological explorations of the Dinarides including those focused on biospeleology where he enjoys putting his efforts and knowledge of macro photography in recording underground biota with the main goal of educating the public about the needs to preserve this natural treasure of the Dinarides. For his photography, Tin won two First Prizes at Croatian speleology photography competitions—in Ogulin in 2015, and in Karlovac in 2016. He has been publishing his photographs regularly in printed and electronic media, the most recognized being the photograph featured on the 2017 issue cover page of the international journal *Zoological Research*.

Natalija Samardžić

Ms. Samardžić, Master of Sciences in geology, holds position of Advisor for Hydrogeology at Federal Geological Survey in Sarajevo, Bosnia and Herzegovina. She has more than 15 years of experience in hydrogeological research of mineral, thermal and thermo-mineral waters. She also has extensive experience with the hydrogeology of karst and has participated in numerous projects related to groundwater tracing, groundwater protection, investigation for the purpose of dam construction, and others. Having grown up in the karstic area of Herzegovina region, Natalija is fascinated by the distinctive morphology of Dinaric area and large springs. In the future, she plans to dedicate more time to the promotion of natural and cultural heritage of Herzegovina.

Ivan Savić

Mr. Ivan Savić (principal lighting) and Mr. Martin Ristić (principal photography) are cave photographers since 2014. As members of the speleological club SAIS from Knjaževac, they participate in exploration and photographing of caves in Eastern Serbia. To the light of day, they bring photographs of previously unseen channels of Vladikine ploče cave near Pirot, and Korenatac cave near Knjaževac. Speleologists of SAIS from Knjaževac formally formed their club in 2018, having practiced caving since 2006. They explore karst terrains of Eastern Serbia, from Mts. Suva and Stara planina to the mountains of Kučaj. They collaborated in explorations of some of the longest and deepest Serbian caves such as Lazareva and Cerjanska caves, caves of Vladikine ploče, and others. More recently, they are exploring channels of the Korenatec cave in the Knjaževac County.

Ferid Skopljak

Professor Dr. Ferid Skopljak was born in 1964 in Brijesnica Velika near Doboj, Bosnia and Herzegovina. He is Deputy Director of the Hydrogeology Department at the Federal Geological Survey in Sarajevo and Associate Professor at the Faculty of Mining, Geology, and Civil Engineering, University of Tuzla. Dr. Skopljak authored and co-authored more than 70 scientific and research papers in national and international journals, two university textbooks, and five monographs. He was member of the scientific research teams and team leader for over 300 projects in hydrogeology and water resources including for water supply, transportation infrastructure, mining, irrigation, hydropower, and geothermal energy. Dr. Skopljak participated in and presented at numerous national and international conferences, symposia, and professional workshops. He is member of the editorial boards of several national and international scientific journals. For his professional work, Dr. Skopljak received wide recognition and numerous awards. His great satisfaction comes from the interactions with friends and family, and he loves to spend free time mountaineering, traveling, and reading literature and history books. “Water is the most precious treasure God gave to mankind. Not only because 70% of our body is water, but also because water is essential for our survival, and because we can find the rest in it, and enjoy everything it created on this Earth. Because of all that, the job of a hydrogeologist is one of the nicest and most rewarding as it keeps us alive and happy—what else can one wish for?”

Speleological Club “Peoni” – Skopje
Speleological Club "Peoni" from Skopje was established on November 13, 1961 with a mission to research, promote and protect caves and karst in North Macedonia.

Ljubica Stajić
Ms. Stajić (1994-2020) finished the Graphic Design High School in Belgrade, specialization in photography. In 2020, she graduated from the Faculty of Philosophy, University of Belgrade with B.Sc. in Archaeology and started her master’s degree studies at the Faculty of Mining and Geology with a specialization in geoarchaeological investigations. Tragically, her young and productive life ended that same year. During her studies at the Faculty of Philosophy, Ms. Stajić participated in almost all field investigations of the Paleolithic cave sites organized by the Faculty.

Dragovan Stojadinović-Sule
Sule, an urban citizen of Kragujevac, Serbia by official records, is a naturalist by choice and conviction. He is a passionate lover of water, especially “her” springs and waterfalls on her courses. This passion led Sule to literary all notable waterfalls in Serbia, culminating with a book of photographs “*Waterfalls of Serbia*” published in 2013. Despite of lack of any comprehensive literature, after travelling thousands of kilometers for eight full years, with not-so-small sacrifices, and with plenty of patience, Sule managed to track them all down, known and unknown, often with the help of local population, and record and photograph all of them. A part of this vast record can be found at www.vodopadisrbije.com.

Dinko Stopić
Mr. Stopić (1976) holds M.Sc. degree in civil engineering from the University of Zagreb and specializes in bridge design. He lives in Karlovac, Croatia. Speleology has been his great passion since 1996. Mr. Stopić is co-founder of the Karlovac Speleological Club where he served as President and Vice-president several times. He is Vice-president of the Croatian Speleological Society and Chair of its Committee for Speleophotography. Mr. Stopić participated in numerous speleological expeditions in Croatia, as an organizer, leader, or a member. He also joined an international expedition to Ozerna Cave in Ukraine in 2009. He is particularly interested in cave photography and surveying. For his work in speleophotography Mr. Stopić received national and international awards including the feature photograph for the cover page of the 2018 Speleoproject calendar, and First Prize at the largest European speleophotography competition organized by the Slovakian Speleological Society. He is current member of the Judges’ Panel for the speleophotography competition of the Croatian Speleological Society. Mr. Stopić enjoys teaching a beginner’s course in speleophotography to the members of the Karlovac Speleological Club.

Predrag Stošić Peca
Peca is an active caver since 1982 and member of Student Speleological and Alpinist Club (ASAK) from Belgrade. He participated in cave explorations throughout former Yugoslavia including as leader of several international expeditions on Mt. Durmitor, Mt. Giljeva and Mt. Maja Rusolija. Peca has been leading numerous

caving trips and speleology courses as well. He is especially fond of long-lasting close cooperation with the cavers from Polish clubs KKS, AKG and TKTJ.

Igor Škero

Igor is a mountaineer from Trebinje, Herzegovina, nature lover and outdoor enthusiast. He is president of the Mountaineering Club "Vučji zub" (Woolf's Fang) since 2007.
The Club's website is at https://www.vucjizub.org/

Ljiljana Vasić

Dr. Vasić (1981): "I am a hydrogeologist who from early student days has been in love with groundwater in karst as well as in karst terrains in general. During my scientific and professional education, I have had an opportunity to explore and resolve various issues related to groundwater genesis, origin, and recharge mechanisms, analyzing hydrochemical, geochemical and isotopic water data. In this way, in addition to enjoying the beauty of karst, I discovered some of the secrets waters hide as they enter the magnificent world of underground cavities and channels of karst systems."

Milan Vlahović

Milan: "I graduated from the Faculty of Mining & Geology in Belgrade in 1982, where I also obtained MSc degree in 2005. I work at EPCG (Electric Enterprise of Montenegro) where I have been involved in long-term maintenance of surface water reservoirs and grout curtains in Nikšićko polje where prevention of water losses is recognized as an essential issue. This is notably emphasized in Slano reservoir, for which I was in charge of designing the grout curtain rehabilitation and supervising the extensive works performed. My 38-year experience is translated into the Monograph: "Surface reservoirs in Niksicko polje – hydrogeological and engineering-geological aspects", reviewed by professors Zoran Stevanović, Petar Milanović and Mićko Radulović."

Andjela Vujović

Ms. Vujović is an engineer of hydrogeology, born in 1995 in Trebinje, Bosnia and Herzegovina. She grew up on the Herzegovina and Montenegro karst, thus love for geology and rocks. In 2018, Ms. Vujović completed her studies in hydrogeology at the Faculty of Mining and Geology, University of Belgrade where she is currently a graduate student at the Department of Hydrogeology.

Željko Zubac

Mr. Zubac graduated from the Faculty of Mining and Geology, University of Belgrade. He has more than 15 years of experience in the investigation of karst and, as an engineer of hydrogeology and project manager at the HET (Hydropower Plant System Trebišnjica), he participated in the design and executions of field investigations related to karst hydrogeology and engineering geology, and design and construction of many objects which are part of the multipurpose hydroelectric system on the Trebišnjica River. Željko is member of the International Association of Hydrogeologists (IAH) and has been continuously engaged as an organizer of various workshops, courses, and conferences on karst.

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The Father of Modern Karstology

1. The Father of Modern Karstology

Vienna, early autumn of 1889, the long hall of the Faculty of Philosophy. Jovan, a young student from Serbia, who has arrived a few weeks earlier for his doctoral studies in geography, is sitting on an antique wooden chair in front of the cabinet of the famous Professor Albrecht Penck. He has already attended Professor's lectures in geomorphology, hydrography, and general geography, but is now waiting for the first consultation about the further direction of his studies and the topic of his thesis. He feels some discomfort thinking about the approaching discussion, fearing what Professor will think about his views, expertise, knowledge of the German language…

Thoughts are flying swiftly through his head, taking him back to his homeland, the time of his childhood and the years he spent studying in Belgrade. "I really have no idea who should suggest the topic, me or the Professor? My new friends told me that it is usually he who provides advice. If so, it could be the glaciation processes, I heard that it was his favorite topic. Paleogeography and glaciers' extension to the Balkans, why not? If that happens, I could suggest focusing on glacial lakes, the 'mountain eyes', they are gorgeous, peaceful, so elegant…Or maybe karst – limestone dissolution?" His memories take him back to his childhood in Korenita, in Western Serbia, and to his grandfather explaining to him why during the summer villagers would fill cracks and holes at the bottom of small dolines with clay to transform them into small ponds and thus prevent rainwater from escaping so they could use it to water their cattle, do the laundry and soak the hemp. They had brought this technique from Herzegovina, and now, as refugees, they were practicing it in a new environment, less wild but still not quite perfect for easy farming. "My summer excursions to the Carpathian karst of Eastern Serbia, which I took with my namesake from Belgrade, professor Žujović, also turned me into a lover of that chaotic environment. Yes, the crazy landforms and long caves were caused by the dissolution of limestones, but there must also be some order in the way everything was created and functioning! There are so many charming places to explore around the Empire... But, let's see what Penck will say. I hope he has an open mind and will be willing to listen. Hold your head up, Jovan!"

This could be how things have transpired, but then again, they might have not. We really know only the epilogue. Jovan Cvijić defended his doctoral thesis *Das Karstphänomen* in December 1892, under the mentorship of Professor Albrecht Penck. For this purpose, he went on numerous excursions and performed extensive field work throughout the Austro-Hungarian Empire and the Balkans, from the Carso area near Trieste (today the border area between Italy and Slovenia), to Kranjska in Slovenia, Istria and Rijeka, Dubrovnik, Boka Kotorska and the terrains surrounding Cetinje, Nikšić and Gacko. He also visited karst areas in Dachstein, Austria and the surroundings of Macocha (the area of Moravska, today's Czech Republic).

In his recommendation to support Cvijić's travels, Penck praised his "gift of well-educated observation and dedication to the subject matter". Deeply aware of the importance of field work and direct observation when collecting scientific facts *in situ*, Cvijić underlined: "My studies would be worth very little without these excursions. Studying in Austria without seeing terrains that are similar or highly related to ours (the Alps and Carpathians) would mean failure to fulfil the core of my duty".[1]

[1] From autobiographic notes of Jovan Cvijić (prepared by V. Čubrilović, 1987)

Figure 1.1 Professors and graduates of the Vienna University, September 1893, and Cvijić's PhD diploma

Prior to returning to Belgrade, he remained in Vienna for two additional weeks to prepare his dissertation manuscript for publishing. It was published in early March 1893 in the journal *Geographische Abhandlungen* (Wien, Bd. V, Heft 3, 1893) which was edited by Penck. As it was customary at the time, the dissertation was circulated to various scientific institutions around the world. Referring to congratulations that arrived from all parts of the globe, and from leading European scientists in particular, Cvijić wrote that being acknowledged as a recognised scientist strongly boosted his enthusiasm. Obviously, he did not expect that his work was to become not only timeless ("not become obsolete"), but that it would actually provide foundations for an entirely new scientific discipline – karstology or karst geomorphology.[2] Furthermore, Slovenian and Serbo-Croatian terms he used in the dissertation have since become reference terms for certain karst-related phenomena. *Doline, polje, uvala, ponor, jama* and *hum* are still widely used by experts and scientists engaged in this area. Still, the Carso area – or, Germanized, Karst – became the *locus typicus*, together with the Dinarides, and is nowadays recognized as "classical karst".

The book *Das Karstphänomen* (translated into Serbian in 1895 as *Karst*) is composed of seven large chapters: Karren; Dolines; Karst Rivers; Karst Valleys; Poljes; Adriatic Karst Coast; and The Distribution of Karst Phenomena. The most detailed part covers the genesis of dolines, a topic that at the time was the focus of global science. Abandoning his initial, then widespread opinion of the origin of dolines (i.e. collapse of a cave roof, as presented in his first scientific paper), Cvijić used numerous examples from the Trieste karst and karst from Eastern Serbia to show that most of the dolines have in fact resulted from "chemical erosion caused by atmospheric water and its carbon acid".

[2] From "Jovan Cvijić–Founder of Karstology and Karst Hydrogeology" (Z. Stevanović, 2015)

In 1972 Marjorie Sweeting presented her position that “knowing Cvijić’s work is crucial for any student of karst morphology“ and that *Das Karstphänomen* “... marks the beginning of quality karst studies“, while in his paper entitled “Jovan Cvijić and the Founding of Karst Geomorphology” (2005), Derek Ford, Sweeting’s former doctoral candidate and one of the current leading experts in geomorphology of karst terrains, called Cvijić the “father of karst geomorphology”, stating that he had been impressed by Cvijić’s work for more than 50 years.

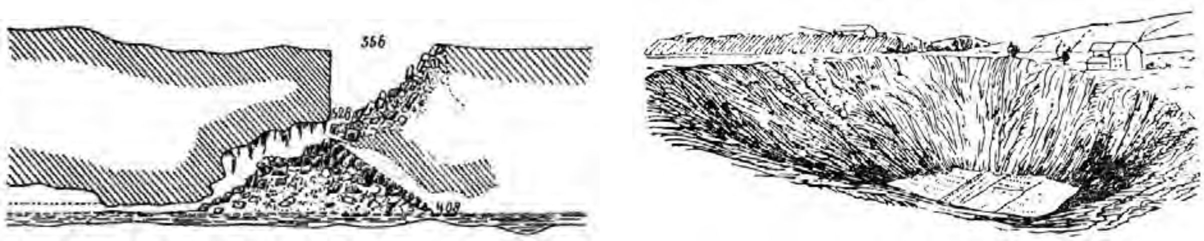


Figure 1.2 Left: Černa jama (pit hole) above Postojna, right: Kozina doline (sinkhole)
(from Das Karstphänomen, 1893*)*

The results of Cvijić’s studies of karst in Eastern Serbia became an integral part of his dissertation and important substantiation for his conclusions on the genesis and functioning of certain phenomena (Stevanović 1997; Stevanović and Mijatović 2005). However, most of the field studies’ results were published only after Cvijić returned from Vienna. Three such studies discussed the distribution and genesis of surface and underground landforms caused by karstification. An extensive evaluation of these features was followed by a systematic classification and categorization of dolines, caves, springs, and peat bogs.

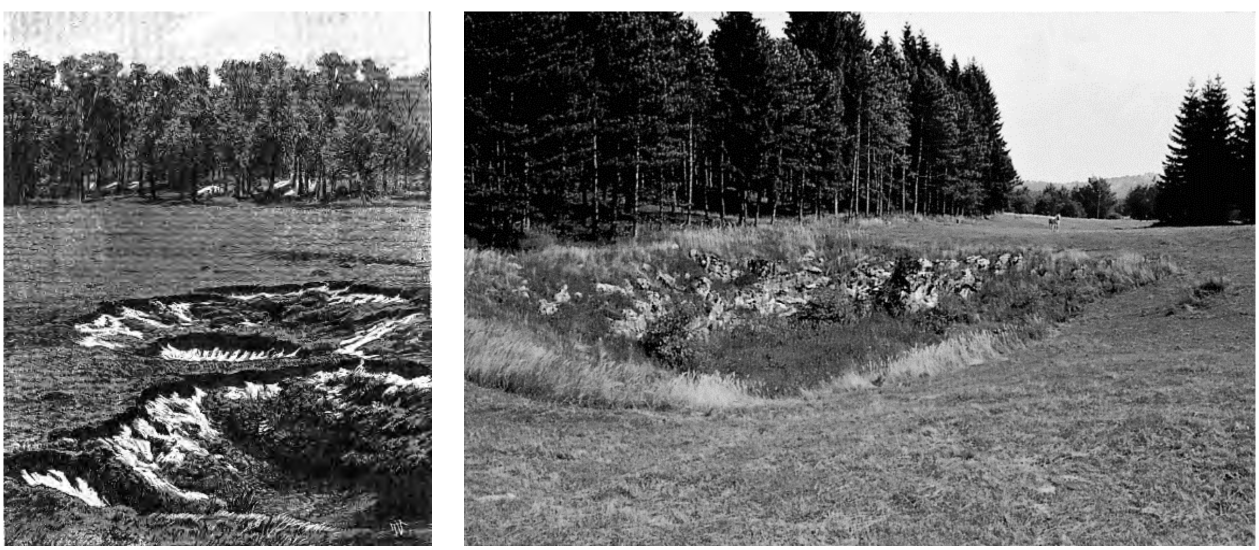


Figure 1.3 Dolines on Velika Brezovica plateau (Kučaj, Eastern Serbia); left: J. Cvijić’s drawing from Das Karstphänomen (1893)*; right: photo of Z. Stevanović of the same site (1985)*

Cvijić’s paper titled *Hydrographie souterraine et evolution morphologique du Karst* (1918) was written at the time when he had already produced a synthesis of some of the results of his extensive field excursions, particularly in the Dinarides. In this paper, Cvijić wrote that „karst erosion does not follow the same laws as normal erosion“. He believed that it was necessary to establish erosion of each individual landform, prove and “explain transition from one to another, and correlate everything with underground hydrography”. “The infiltrating water dissolves limestone on the surface, enters the cracks and spreads inside, continuing its dissolving action. ... Expanded cracks are thus the initial and fundamental process of karst development".

Cvijić's theory on vertical distribution of water in karst and three hydrographic zones was a response to two, at the time, conflicting theories: the theory of Grund on one hand, and Katzer and Martel's theory on the other.

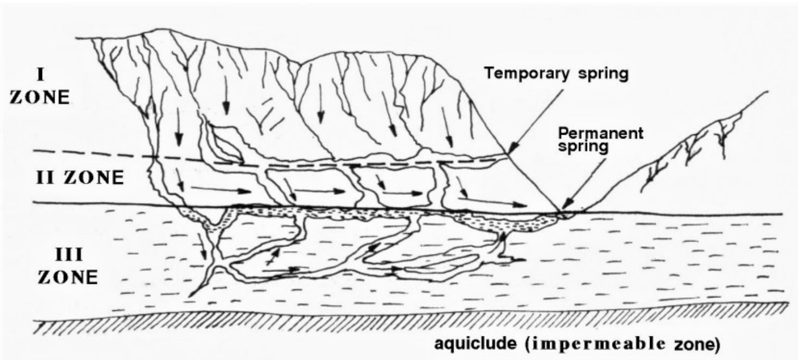


Figure 1.4 The three underground hydrographic zones proposed by Cvijić (Mijatović, 1989, after Cvijić's concept he described in 1918)

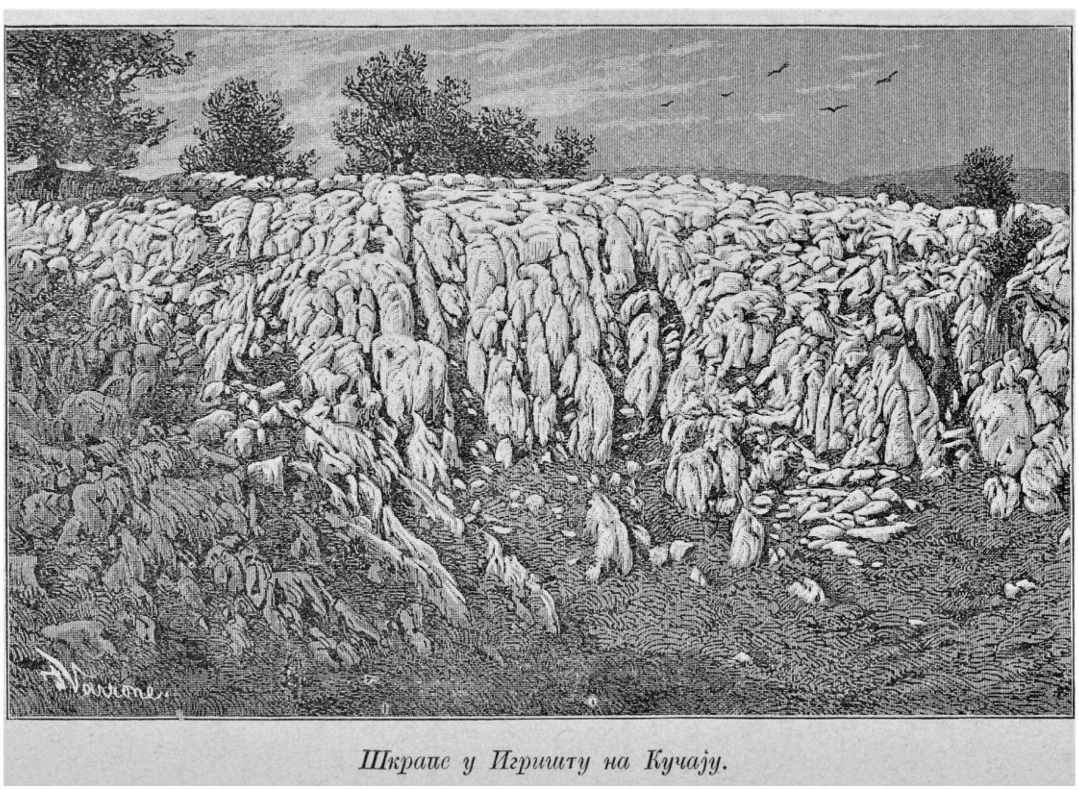
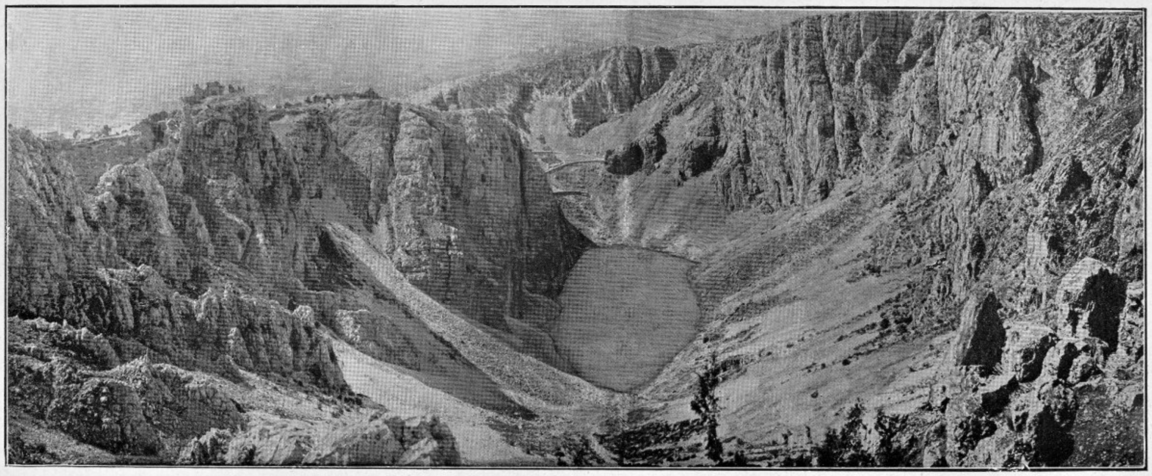


Figure 1.5 Karren field in uvala Igrište on Kučaj Mt. in Serbia (from Das Karstphänomen**,** 1893*)*

Upon his return to Belgrade, Cvijić was appointed full-time professor at the Great School, where he promptly founded the Institute of Geography. In addition to his enormous work energy and a broad spectrum of interests, during his travels he also collected as much information as he could on the terrains he studied, people inhabiting them and their customs. These led to another love – of ethnographic and anthropological studies of the entire Balkans.

Figure 1.6 Cvijić on horseback, on one of his numerous excursions in the Balkans (courtesy of Jovan Cvijić Museum)

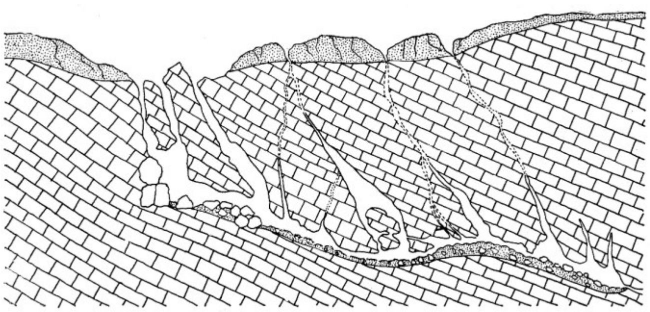
Figure 1.7 Jovan Cvijić and his research team, 1908 (courtesy of Jovan Cvijić Museum)



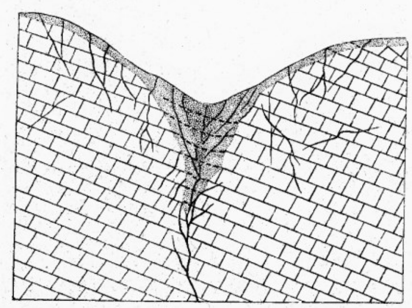
Cliché J. Cvijić.

122. **Модро Језеро,** изнад Иматског-Далмација; око 400—500 м. дужине, 250 м. ширине, дубоко 70—80 м.; стране скоро вертикалне, глатке, при дну сипари који засипају језеро. Вертикалне пукотине дуж којих се стропоштавали пакети од слојева. Бунараста вртача постала саломом пећинског тавана.

Figure 1.8 Modro jezero in Imotski, Croatia (from Geomorphology, 1926*)*



369. **Мале Јаме,** активне издухе и понори код села Чаваша у Попову. Размер 1 : 500.



Пресек 3 м. дубоке вртаче с подлогом. Д. Логотец у Крањској.

Figure 1.9 Left: "Little Pits" and active sinks near Čavaš village in Popovo polje (from Geomorphology, 1926*). Right: Deep sinkholes with fill; Donji Logotec in Kranjska, Slovenia (from* Das Karstphänomen, 1893*)*

Over time, Cvijić was elected corresponding (in 1896) and full member (in 1899) of the Serbian Royal Academy and became one of the eight initial full-time professors at the reformed University of Belgrade in 1905. He served two terms as the University Rector (President), first in 1907–1908 and then after the Great War, during the difficult period of restoration of the University (1919–1920).

In 1919, at the Peace Conference in Versailles, Jovan Cvijić led the Historic-Ethnographic Section of the newly created country – the Kingdom of Serbs, Croats and Slovenians. As a strong believer in the unity of Slavic nations and a scientist who knew better than anyone else the genesis, relations and habits of people who inhabited the Balkans (*La Péninsule balkanique*, Paris, 1918), he invested enormous effort and energy, both before and during the conference, to have the borders of the new Kingdom properly drawn, particularly in the areas of Soča River, the Adriatic coast and the Vardar basin.

Figure 1.10 Jovan Cvijić in Cazin, 1921

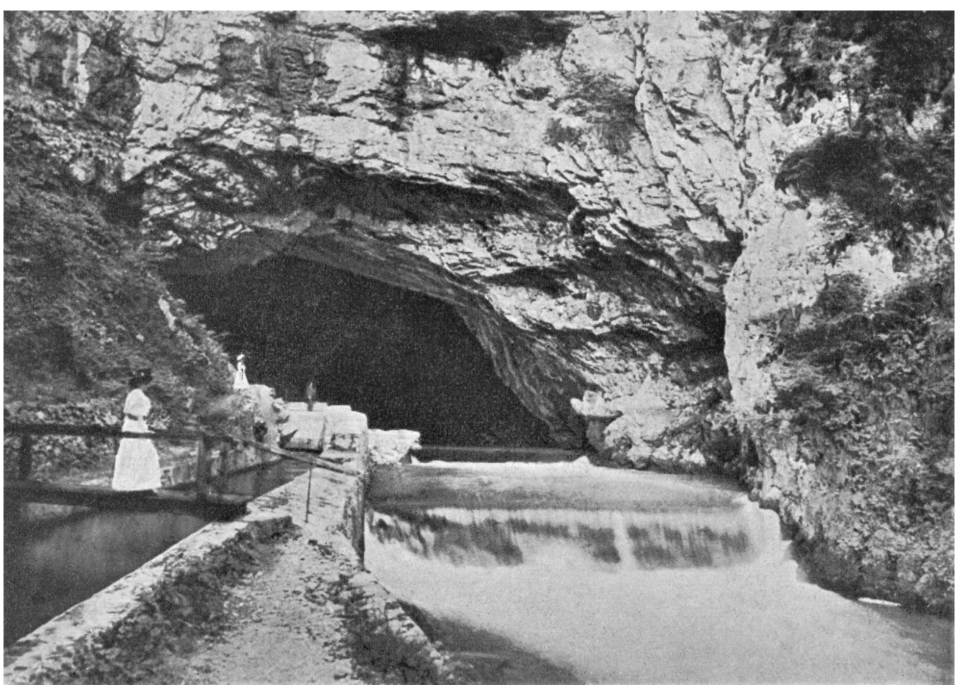


Figure 1.11 Unec spring, Planinsko polje, Slovenia (from Geomorphology, 1926*)*

From 1921 until his death in 1927, Cvijić led the Serbian Royal Academy. He accomplished all this in the difficult war and post-war era of the early 20th century. Unfortunately, it affected his health, and he passed on when he was just 62 and could have accomplished so much more.

Serbia, however, paid its respects properly. Cvijić's own house hosts a namesake Museum of Jovan Cvijić, there is geographical institute that was named after him, scientific meetings are held to commemorate his works, a monument was raised in his honor, there is a banknote bearing his portrait, schools and streets are named after him... People say that "natural scientists are rarely so widely recognized".

Figure 1.12 The Cullum Geographical Medal of the American Geographical Society presented to Jovan Cvijić in 1924 "For the scholarship he displayed in his published works on the geography of the Balkan countries and for the originality of his field studies on the complicated physiography of the Karst." (Courtesy of Jovan Cvijić Museum, Belgrade.)

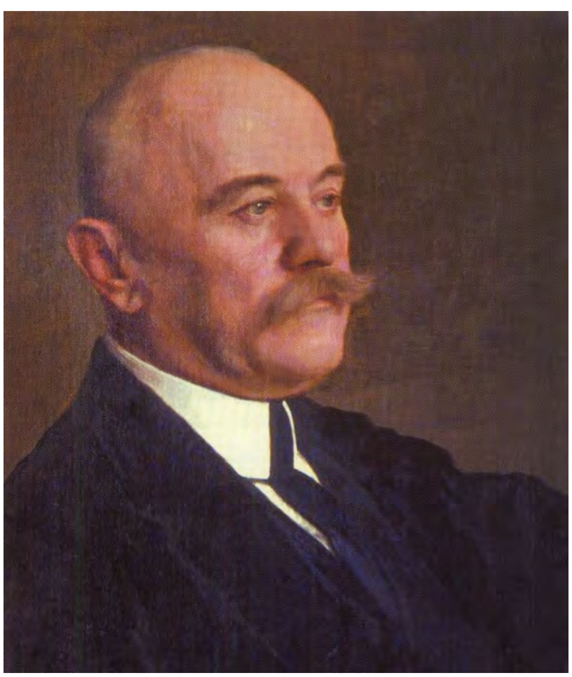


Figure 1.13 Portrait of Jovan Cvijić by Uroš Predić, 1923

Wild Mountains, Noisy Rivers, Silent Lakes, the Sea

2. Wild Mountains, Noisy Rivers, Silent Lakes, the Sea

Mutat enim mundi naturam totius aetas
In fact, time totally changes the world

Lucretius, De Rerum Natura

Place: The Eastern Mediterranean basin
Time: Geological timescale

Scene 1 – Cretaceous Time: some 90 million years ago

The ocean is all around and its name is Tethys. It has been here for so long that it seems as if it had engaged Poseidon and Neptune to rule this sea world together. The ocean is very deep, its water level higher than that of today by some 200 meters. Water is considerably warmer. Islands are very rare, and only a few are peeking out.

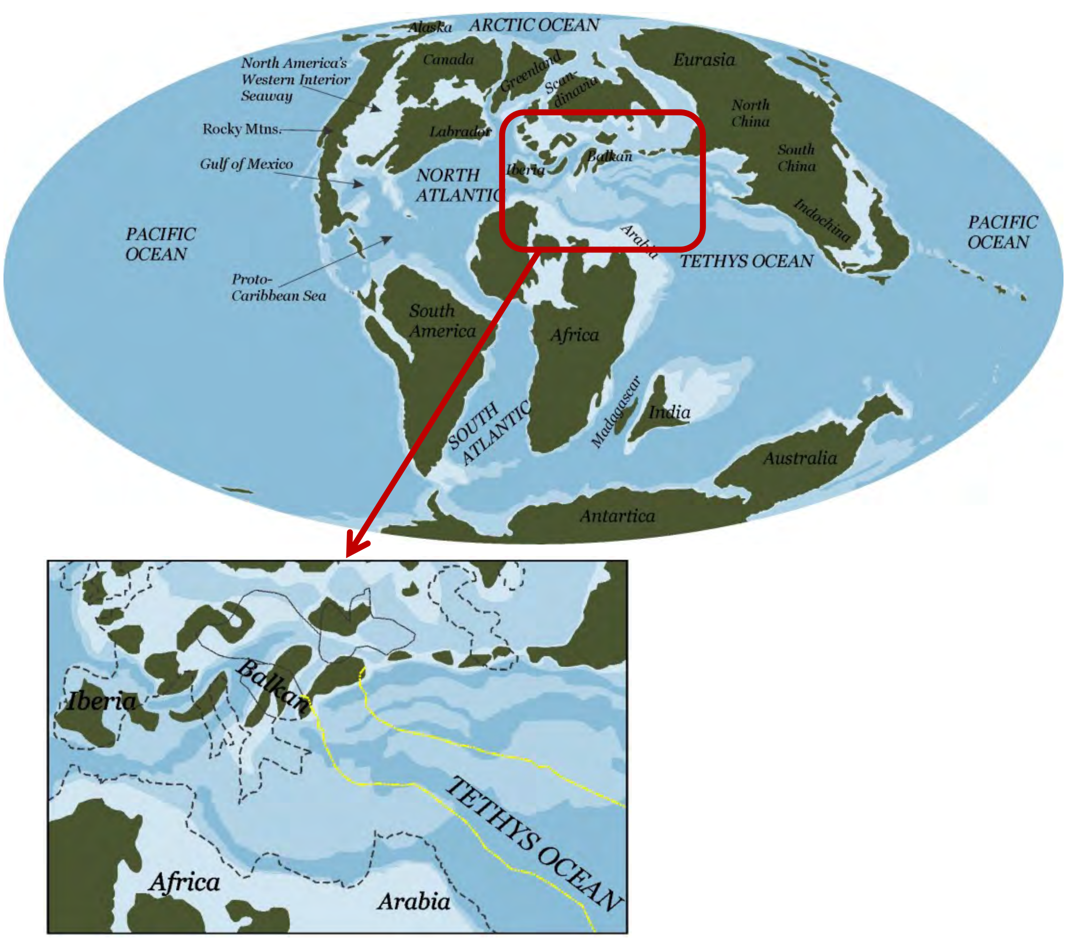


Figure 2.1 Paleogeographic sketch of Cretaceous time - some 90 million years ago. Dashed lines on the enlarged sketch of the Mediterranean basin show approximate contours of subsequent continental parts

Scene 2 – Eocene time, some 55-40 million years ago

The Tethys is still around, but its water is a bit shallower. The number of islands has increased. Very strong tectonic pressure has already caused significant uplifting of the ocean floor and the appearance of dominantly carbonate sediments on the surface. Lateral and bottom stresses continue. The process is slow, but more and more rocks are appearing on the surface, only to become deformed by gravity forces. The closing of the Mediterranean basin, and the collision which in the earlier era had caused the uplifting of the Alpine orogeny mountain chains, continues.

Scene 3 – Oligocene Time: some 25 million years ago

The Tethys is still around, but the Mediterranean Sea with the Adriatic Gulf starts to take shape that is similar to what we see today. The Alpine orogenic belt, and the Dinarides as its integral part, is continually exposed to compression forces and both are rising further up. Carbonate rocks are slightly folded, while some major faults are dissecting the NW-SE oriented main structure. Normal hydrographic network is being created, but the dissolution of carbonate rocks and mechanical erosion stimulate percolation of rainfall and water runoff along preferential flow paths deep into the rock mass.

Scene 4 – Miocene Time: some 6-5 million years ago

The Tethys Ocean is now considerably reduced, disintegrated, and isolated from other oceans. It functions like a large salty lake in the Mediterranean depression. The Messinian salinity crisis is caused by a powerful

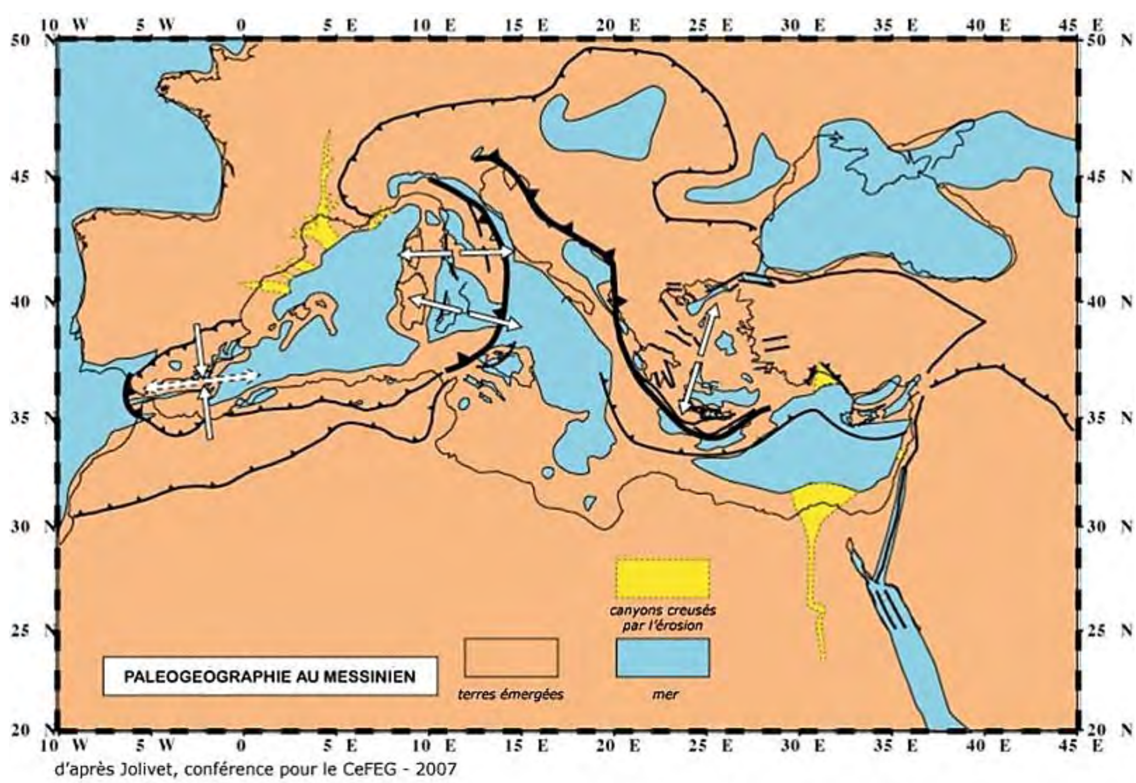


Figure 2.2 Sketch map of the Mediterranean basin at the time of the Messinian crisis, 6-5.3 million years ago (after Jolivet et al. 2006; copyright Elsevier, printed with permission)

combination of geodynamic and climatic drivers; the connection between the Mediterranean Sea and the Atlantic Ocean via the Gibraltar strait has broken. In just 100,000 years, the sea level was lowered by more than 1,500 meters. The mountains continue to rise and are increasingly folded and faulted. The process of karstification is intensifying, the landscape is changing, and the formation of main depressions (*poljes*) is starting because of intense faulting. Underground forms such as caves and pit holes (*jamas*) are enlarging.

Scene 5 – Pleistocene: Ice Ages 2.5 – 0.1 million years ago

The entire Europe is covered by a very thick layer of ice. Reduced inflow of fresh water into the Mediterranean basin causes another lowering of the sea level and reduction of the volume of the sea water pool. During the period of maximum glaciations, the seashore line in the Adriatic basin has moved up to tens of kilometers to the west, while the sea level is more than 100 meters lower than today. Most of today's islands are nothing but peaks and ridges of numerous hills, with deep depressions and paleo valleys extending between them. Intense karstification has already created very large caves and deep vertical jamas (pit holes), but they are mostly dry and exposed to alternate freezing and melting. During interglacial phases, moraine material moves toward large depressions, melted water fills large river valleys, while degraded riverbeds hold smaller sinking tributaries.

Scene 6 – Our Time

The Alpine orogenic belt in the territory of former Yugoslavia consists of three branches: the largest is the Dinarides, extending from Carso (the area between Italy and Slovenia) to the western part of North Macedonia and the Vardar Valley. The orientation of the system is NW-SE, parallel with the Adriatic Sea. The other two branches are the Karnian Alps and the Carpathians, extending over northern Slovenia and eastern Serbia, respectively.

Intensive tectonic activities have resulted in the creation of a complex system of faults and fractures that now act as preferential groundwater flow paths. Moreover, climatic conditions, particularly the successions of wet and warm periods, have significantly contributed to karstification. And finally, a very specific relief has formed, both on the surface and underground.

Although the name of the *locus typicus* area between Italy and Slovenia (around Trieste), named *Carso* (*Kras* in Slovene), came from the Indo-European word "kar" or "karra" which means rock, the name for this type of rocky environment has been altered locally to form several similar terms. Out of these, Slavic "kras" and "krš" are two that are most commonly used by the inhabitants of The Dinarides (Roglić 1960). The latter is especially interesting as is also used to denote a bunch of unsorted things, a mess, a chaotic distribution of objects. And, come to think of it, most of karst terrains are exactly that.

The Dinarides are a mountainous chain with numerous intermountain depressions, large karst poljes or valleys. The Slovenian section, i.e. the Julian Alps (named after Gaius Julius Caesar), recognized as a Man and Biosphere reserve, includes the highest mountain peak in the entire region – Triglav (meaning: "Three Heads") with the altitude of 2864 m. Triglav is now one of the oldest European national parks, established as such in 1924. It covers the surface of some 800 km^2, dividing two large catchments: the Soča River which flows to the Adriatic Sea, and the Sava River which is a part of the Black Sea basin.

From the Slovenian Notranjsko area, the Dinaric chain extends to Gorski Kotar, which makes up the border between Slovenia and Croatia while also representing the physical barrier towards the Adriatic coast, the Istria Peninsula and the Gulf of Rijeka. More to the south, the high Velebit Mountain stretches as a long barrier that divides the seashore from the continent. The massifs of Velika and Mala Kapela and Plješevica are located parallel but further inland, while long islands of Krk, Cres, Pag and Dugi Otok represent an outer common paleo mountain system, now separated by the sea. The group of islands called Kornati, a true jewel of the Adriatic, is part of this section.

The Dinara Mountain (Mt.), separating Croatian Dalmatia and Bosnia, gave the name to the entire region. Several large poljes – Ličko, Glamočko, Duvanjsko, Kupreško and Livanjsko – settled between the hills, hold a few smaller sinking streams. Livanjsko polje is the world's largest, with the surface of 380 km^2, or 433 km^2 if one counts the adjacent Buško Blato.

Mts. Ljubuša, Čvrsnica, Prenj and the more inland-positioned Treskavica, Bjelašnica, Jahorina and Romanija are all parts of the Inner Dinarides, while numerous beautiful Croatian islands such as Brač, Hvar, Vis, Korčula, Lastovo and Mljet are situated in the central Adriatic. The Neretva river delta is opposite of the long Pelješac Peninsula, which runs parallel with the Dinarides, in the NW-SE direction. Further south, near Dubrovnik, the so-called Elafiti islands (Koločep, Lopud, Šipan) are the last group of large Adriatic/Dinaric islands. And this is where our trip through the beautiful Dinaric wilderness reaches culmination. Cvijić wrote: "There is no karst that is developed better or more deeply than that of Herzegovina-Montenegro, between the lower Neretva River, Lake Skadar and the Adriatic Sea!"

Mt. Orjen shared by three countries – Bosnia & Herzegovina, Croatia and Montenegro – is a glacial relict. It is also highly karstified. Observed from the air, it looks like Mt. Orjen in the west and Mt. Lovćen in the east are guarding the most beautiful and narrowest bay, indeed a fjord, in the entire Mediterranean basin, known as the Gulf of Boka Kotorska. Petar Petrović Njegoš, the famous poet and sovereign of Montenegro named Boka "the bride of Adriatic". Mt. Durmitor in Montenegro, with its complex geology, karstic and glacial forms, is considered the most beautiful among the Dinaric mountains by many. Maglić is the highest mountain in Bosnia & Herzegovina and extends to Montenegro, while Vojnik, Mt. Pivska, Sinjajevina and Komovi are other high mountains of Montenegro whose peaks are also usually covered with snow until late summer. Prokletije Mts., which stand between Montenegro and Albania, got their name (meaning: "Damned Mountains") because of the rough relief and high peaks that seem to touch the sky.

The Dinaric karst of western Serbia consists of a nearly continuous chain of mountains, starting from Mts. Povlen and Maljen in the north ("Lelić karst", some 100km from Belgrade) extending over Mts.Tara, Zlatibor, Zlatar, Babine and Giljeva, and ending in the south at Mts. Mokra Gora and Hajla in Kosovo and Metohija. Pešter, the largest karst polje of the eastern Dinarides, is in this region.

Šar Mt. separates North Macedonia from Kosovo and Metohija, while Mts. Suva Gora and Galičnik extend toward a depression filled with the water of Ohrid and Prespa lakes. These two lakes are separated by the karstic massif of Galičica. Most geographers consider Mt. Pelister and Pelagonia depression to be the southeasternmost part of the Dinarides of former Yugoslavia. The Dinaric chain extends to Albania ("Albanian Alps"), and to the south it continues as Pindes Mts. into Greece, which are part of the same orogenic belt.

Large rivers such as Soča, Cetina, Krka, Neretva, Zeta and Morača in the Adriatic basin, and Una, Vrbas, Sana, Piva, Tara, Lim and Drina in the Black Sea (Danube) basin have a perennial character and are deeply incised in karstic terrains, in some cases all the way down to impervious bedrock. The hydrogeological and hydrological regimes of surface water streams in the Dinaric karst depend mostly on the interactions between groundwater and surface water. As an example, Bonacci (2012) describes the "Eight Names River", a unique stream which disappears into *ponors* (swallow holes, sinks) eight times, only to reappear at springs, while crossing the border between Croatia and Bosnia & Herzegovina multiple times, and creating several waterfalls (Kravica is the largest). On its journey to the Neretva River it also changes names multiple times. The final name of this sinking river, before it reaches the mouth, is Trebižat.

In most carbonate rock complexes of high mountains, the permanent surface stream network is almost completely degraded, and these areas often represent "mountain deserts". Local populations depend on collecting rainwater or melted snow for water supply. Shortage of water is also present on many Adriatic islands.

The tectonic pattern and fast karstification triggered the creation of waterfalls in numerous other riverbeds. Among them stand out the River Una cascades near Martin Brod and at downstream sections from Bihać to Novi; the Plitvice lakes on the Korana River; the Skradinski buk, Topoljski, and Manojlovački cascades on the Krka River; and the Velika Gubavica cascades on the Cetina River.

The hydrologic regime of rivers is characterized by large variations between maximum and minimum flows. Heavy rains (total annual precipitation in mountain regions ranges from 1500 to 5000 mm, the maximum recorded annual average being also the highest in Europe) can result in flash floods, but prolonged droughts

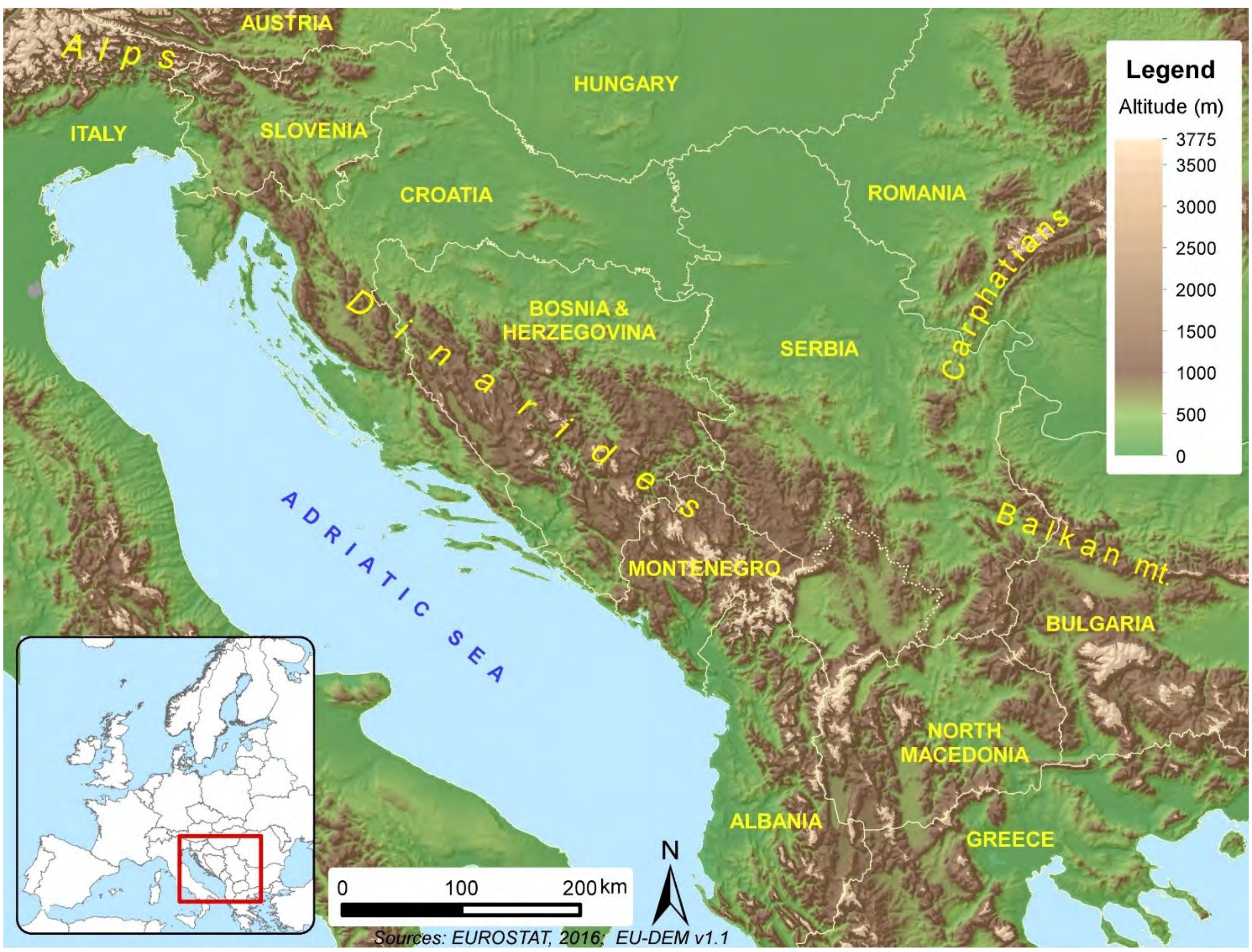


Figure 2.3 Relief map of the Dinarides and their surroundings

Figure 2.4 Areas (shaded) with fully developed karst in The Lands of Karst

during summer months significantly reduce the flows. A typical example of this great variation is the Iška River in Trnovski Gozd, Slovenia, where after three days of heavy rain in September 2010 the rapid flow through karst formation caused a massive flood wave with a peak of 59.3 m^3/s, while before and soon after the wave the riverbed was almost dry.

Prior to being regulated by two dams and channels (described in chapter 10), Trebišnjica River was the largest European sinking stream. In Herzegovina, there are many such short "blind" streams that flow through karst poljes and percolate in large ponors located at the margins. Many surprising connections of these ponors with springs in lower-elevation poljes have been proven by tracing tests.

High permeability of karstic rocks did not prevent the creation of numerous lakes. Some, in higher altitudes, originated from glaciers, while others were formed in closed depressions such as poljes or uvalas located along the Adriatic coast and on the islands. Bohinj and Bled lakes in Slovenia belong to the former group, while the latter includes Vrana near Biograd, Large and Small Lakes on the island of Mljet in Croatia, and Šasko Lake near Ulcinj in Montenegro. The picturesque Crno jezero (Black Lake) at the Durmitor foothill in Žabljak, Montenegro is a sinking glacial lake. Water from this lake flows underground for some 18km and appears at Dubrovska vrela spring, deep in the Piva River canyon. The Plav Lake between Komovi and Prokletije is of glacial origin, but its creation was largely due to tectonic forces. Some other smaller "mountain eyes" (locally known as "gorske oči") are settled in non-karstic rocks, commonly in impervious flysch sediments. A nice example is Biogradsko lake on Mt. Bjelasica. Such lakes can also be fed by springs draining surrounding karst terrains.

Lake Skadar, shared by Montenegro and Albania, is the largest natural reservoir of fresh water in the Balkans. It is situated in a large depression filled by thick glacial and fluvial deposits. The catchment area of the Skadar Lake covers an area of approximately 5600 km^2. The lake and its surroundings represent a very important aquatic ecosystem, and there are lacustrine (submerged) springs (vruljas, locally called "oka" meaning "eyes") that are of great importance for the aquatic biota of Lake Skadar. The mean annual underground inflow to the south-western section of the lake has been estimated at around 10 m^3/s (Radulović M.M. *et al.* 2015).

The southeastern-most part of the Dinarides contains a specific hydrogeological karst system. Prespa and Ohrid Lakes, aquatic environments recognized for their rich biodiversity, are connected by a network of natural karst underground channels that divert water, via Zaver ponor, from the upper positioned Prespa Lake to the lower Ohrid Lake. Prespa and Ohrid are two depressions filled with stagnant lake water which are thus functioning similarly to connected cascade poljes. Their connection was proven by a tracing test, which showed one of the highest ever recorded apparent groundwater velocities of 80 cm/s (Eftimi 2010). Notably, Ohrid Lake is the deepest lake in the Balkans and one of the deepest and oldest in Europe, with over 200 endemic life forms some of which are in existence since Tertiary. Probably the most famous of them is the Ohrid Trout.

The above-mentioned localities are just some of many wonders of the Dinaric karst. The list is much longer, almost endless. Rich eco-systems that inhabit the Dinarides are presented in Chapter 9, while Chapter 10 includes more about man-made reservoirs and structures used to manage sinking rivers.

The other two sections of the Alpine orogeny in the region are the Karnian Alps and the Carpathians in Serbia. They extend over borders of Slovenia and Austria, and Serbia and Romania, respectively. Karavanke of the Karnian Alps are an elongated mountain chain mostly built from Triassic limestones and dolomites. Their highest peak is Stol, with the altitude of 2236 m. Together, Kamnik-Savinja Alps, Pohorje and Karavanke are often jointly called the Southern Limestone Alps.

Like a long snakelike structure, the Carpathian mountain chain extends over five countries (Austria, Slovakia, Hungary, Ukraine, Romania) before entering eastern Serbia. From the Danube gorge in the north, the structure extends to the southeast and the Stara Planina Mts. at the border with Bulgaria. The Carpathians further extend to the Balkanides in Bulgaria. The Carpathian karst of Serbia is not a continuous structure; it consists of numerous karst mountains separated by large valleys of Nišava, Crni Timok, Mlava, Pek and several other perennial rivers. Kučaj-Beljanica is the largest among the karst massifs, hosting numerous large caves and springs in the foothills. Miroč is the largest massif in the northern part and on the right bank of the deep Danube gorge. It has some of the deepest jamas (pit holes) in the region, while its springs are submerged by the Danube reservoir formed by the large Djerdap dam, built jointly by Romania and Serbia in the early 1970s. Other large mountains, made up mostly of Jurassic and Cretaceous karstified rocks, are Tupižnica, Ozren, Devica, Suva Planina and Svrljiške Planine.

The Dinaric region abounds with beauty and wilderness. It is easy to understand why Venetians, as well as Romans, Greeks and Phoenicians before them, when sailing across the Adriatic Sea, were afraid to venture into the mainland behind the high mountains that must have looked like giants observing their movements. Merchants of the Republic of Ragusa (Dubrovnik), however, developed relatively safe routes on their way to Byzantium, the Ottoman Empire, and to Bosnia and Serbia to engage in free trade granted by the rulers of these states.

Several areas and sites of the Dinaric karst are recognized and protected by international and national legislative acts. The most important are the four UNESCO World Heritage sites: the Plitvice Lakes in Croatia, the Škocjan Caves in Slovenia, the Durmitor National Park in Montenegro, and Ohrid Lake in North Macedonia which is shared with Albania. The areas that are on the UNESCO tentative list are: the Velebit Mountain (Croatia), Classical Karst (Slovenia) and the Tara National Park (Serbia), while Cerkniško Polje (Slovenia), Neretva Delta (Croatia), Livanjsko polje (Bosnia & Herzegovina), Vrana Lake (Croatia), Pešter polje (Serbia), and Skadar Lake (Montenegro) are protected under the Ramsar List. In the UNESCO Global Geoparks of the region, karst is present in Djerdap (Serbia), Vis Archipelago (Croatia), and to a lesser extent in Papuk (Croatia) and Idrija (Slovenia). Therefore, in addition to numerous natural monuments or preservation areas that are protected by national laws, the Dinaric region also contains a large number of internationally protected sites. However, the region as a whole has never been placed under protection. This deficiency has been recognized in the report of Paul Williams (2008), who recommended to the International Union of Conservation of Nature (IUCN) to initiate the process of recognition of the Dinaric karst as a World Heritage area, and seek help of the host countries in doing so:

"Recommendation 1: *That States Parties whose territories embrace the Dinaric Karst of Europe consider a transnational serial nomination that would include a representative range of karst values and features of all scales above and below ground from the mountains to the sea. Such a property should represent the international type-site of karst by illustrating a full range of the region's karst features and by providing evidence for their evolution. Explicit inclusion of associated biodiversity values would also be important*".

Scene 7 – What is likely to happen in the future?

Looking ahead just a few hundred years, we can imagine an Adriatic coastline that has moved more inland, with some deltas and lowlands such as those of Neretva and Bojana now mostly under the sea, the water of Lake Skadar brackish, the Prespa Lake significantly smaller, and more riverbeds dry during summer months…

As a rule, geology, geomorphology, and climate cannot remain unchanged. It is, however, our duty not to relentlessly interfere with and accelerate their dynamics. It is also our duty to protect, and an enormous privilege to enjoy *Our Time* and *Our Lands* as much as possible.

Authors' suggestion:
To enjoy the wonders of karst presented in the following pages more, you may want to listen another kind of wonders played by Agnes Obel (Familiar, Riverside), Chambao (Como el agua), Caro Emerald (I Belong to You, acoustic*), Philip Wesley (Far and Away), Atomsko sklonište (Treba imat dušu), and finally Bajaga & Instruktori (442 do Beograda). Jazz fans may add to this list Miles Davis (Shhh/Peaceful from album In a Silent Way), Keith Jarret (In Front from album Facing You), and Jan Garbarek (Parce Mihi Domine from album Officium.) Alternatively, they may listen to their own favorites while joining us on this unforgettable visual journey.*

Photo captions

Note: all photo captions are provided by the authors of individual photographs hence the diversity—some felt like sharing more information with the reader, some left the photographs speak for themselves, giving only the essentials.

Photo 2.1 View of the central portion of Dinara mountain from Paško polje in Croatia. Dinara is the longest mountain (100 kilometers or 62 miles) in the chain named after it (Dinaric Orogenic Belt.) It has all forms of mature karst developed on and in it, thus the term "Classic Dinaric Karst". It separates Croatia from Bosnia and Herzegovina and hosts the highest peak in Croatia (1831m). In 2021, the mountain was declared a Nature Park. Photo by Srdjan Marinčić.

Photo 2.2 View from Vrtača, 2180 m high peak in the Karavanke mountains, towards the highest mountain of this ridge – Stol (2236 m). In the background, the Julian Alps rise from the sea of fog. Photo by Uroš Kunaver.

Photo 2.3 Waterfall *Kravica* on Trebižat river in western Herzegovina. This river is also known as "Eight-names River" because it disappears at ponors and re-appears at springs several times. It also crosses borders between Croatia and Bosnia & Herzegovina several times before it finally reaches the Neretva River. Photo by Zoran Stevanović.

Photo 2.4 Pokljuka is a plateau between *Bohinj* lake and the Triglav mountain range. It rises into a ridge on its northern edge. It has long been thought that there are no deep caves in this area, but this has proven to be wrong, as there is a system of three over 500 m deep caves (pit holes) in this area. Photo by Uroš Kunaver.

Photo 2.5 The largest of Krka river cascades over thick tufa deposits, Krka National Park near Šibenik, Croatia. Photo by Neven Kresic.

Photo 2.6 *Galjipovac* lake (in the front, with deep blue color) formed in a sinkhole, and *Prološko blato* (shallow water body in the central portion of the photo; "blato" means "mud" in Croatian) formed in a karst polje near Imotski, Croatia. Photo by Branimir Jukić.

Photo 2.7 Cascades and waterfalls on the Korana river in the world-famous Plitvice National Park in Croatia. "Embedded in a mosaic of forests and meadows in the lower elevations of the Dinarides, Plitvice Lakes National Park conserves a strikingly beautiful and intact series of lakes formed by natural tufa barriers. The tufa barriers are the result of longstanding and ongoing interaction between water, air, sediments (geological foundation) and organisms. The extension of the dynamic, constantly evolving lake system, the proportion of the tufa barriers, jointly with the numerous dynamic waterfalls and clear water courses and the expression of colours, make Plitvice Lakes National Park an aesthetically outstanding natural spectacle of global importance." (https://whc.unesco.org/en/list/98/.) Photo by Neven Kresic.

Photo 2.8 The Piva reservoir behind the Mratinje dam built in late 1970s on Piva River, Montenegro. Photo by Zoran Stevanović.

Photo 2.9 A section of a narrow and attractive 900 m long canyon of *Tribuća* river, tributary of the Trešnjica river in western Serbia. The canyon is passable only during low water periods and with help of special equipment. Photo by Dragovan Stojadinović-Sule.

Photos 2.10 Top: *Mamić* and *Knezović* lakes in *Lokvičići* near Imotski, Croatia. Bottom: Red Lake (*Crveno jezero*) near Imotski, one of the deepest sinkholes in the world. Depth of water varies between 234 and 317 meters. The bottom of the sinkhole is 6 meters below sea level (the sinkhole is a crypto depression). Both photos by Branimir Jukić.

Photos 2.11 *Modro jezero* (Blue Lake) near Imotski, Croatia, formed in a massive sinkhole (the same sinkhole is featured in Cvijić's Geomorphology – see Figure 1.8 in Chapter 1.) When the lake dries out (top photo) it becomes a soccer field where two local teams, "Vilenjaci" (Sorcerers) and "Vukodlaci" (Werewolves) battle it all out. When there is water in it, it becomes a favorite swimming hole, especially during hot summer months. Both photos by Branimir Jukić.

Photo 2.12 *Grbaja* river valley near Gusinje, Montenegro is formed in a former glacial valley incised in thick, massive Jurassic-Cretaceous limestones. It is close to border with Alabania in this part of the Prokletije mountains. Photo by Milovan Milivojević.

Photo 2.13 The Precambrian karstified marbles on Jakupica mountain in North Macedonia. Depicted is a characteristic meteorological phenomenon on Jakupica – movement of clouds over a vertical escarpment at elevation 2200-2300 m. Photo by Zlatko Ilijovski.

Photo 2.14 Djerdap Gorge, the most striking part of the Danube river course, formed when the river incised into the uplifting Carpathians in Paleogene, cutting through thick Upper Jurassic limestones. The gorge is the longest cut-through river gorge in Europe. The southern half of the Daube channel belongs to Serbia (here right in the photo) and the northern to Romania. The narrowest portion of the gorge, "Mali Kazan", is only 150 m wide, and the depth of water there is 90 m. In 2020 Djerdap became first UNESCO Global Geopark in Serbia. Photo by Aleksandra Maran Stevanović.

Photo 2.15 *Lazarev kanjon* (Lazar Canyon) of the intermittent *Lazareva reka* river near the town of Zlot in Eastern Serbia. The canyon is carved in Lower Cretaceous limestones and along with a cave of the same name was the first nature area proposed to be protected by the state. The proposal was made in 1924 by Petar Pavlović, Director of the Natural History Museum in Belgrade. Photo by Dragan Bosnić.

Photo 2.16 Kanin Plateau in Slovenia during winter (and night). Kanin Plateau is a high karst plateau ranging between 2000 and 2500 m asl in Julian Alps (NW Slovenia). It is highly karstified with more than 2500 registered caves on about 30 km^2 (Slovenian and Italian sides). The area is also characterized by high precipitation (up to 5000 mm per year) resulting in thick snow cover during winters. This photo was made in the middle of winter (at the end of January 2018) showing snow-covered plateau with the top called Vrh Laške Planje and bivouac for cavers. The purpose of the trip was looking for entrances of two (at that time not yet connected) caves *Renejevo brezno* and *Brezno rumenega maka (P4)*. The latter was opened (the ventilation was sufficient to keep it open) whereas the entrance of Renejevo brezno (pit hole) was covered with snow. Taking into account precise coordinates of the entrance and constant error of GPS, we were digging at the right place and successfully found the entrance. The evening before the sky was clear providing for good conditions for taking photographs. Photo by Matej Blatnik.

Photo 2.17 A small, closed karst depression near Sobra on the Island of Mljet, Croatia. Photo by Zoran Stevanović.

Photo 2.18 Reka river in Slovenia flows as a surface stream for some 50 kilometers and disappears in Škocjan Caves through a magnificent swallow hole after it has reached permeable limestone ground. Photo by Borut Lozej.

Photo 2.19 Waterfalls of *Sikolska reka* river near Mokranje, eastern Serbia. Photo by Dragovan Stojadinović-Sule.

Photo 2.20 Alpine waterfall *Kozjak* in a narrow gorge, Slovenia. Kozjak is a tributary to Soča river near the town of Kobarid. It flows over numerous cascades, among which waterfall Kozjak is the largest and the most picturesque. Because water has deeply eroded the gorge, the layers of deep-water Cretaceous limestone (Volče limestone) are nicely exposed. Photo by Matej Blatnik.

Photo 2.21 Meanders of Unica river in Planinsko polje, Slovenia. The Unica river is characterized by very meandrous flow – over the 5km x 2km area of Planinsko polje its course is about 19 km long. The photograph is showing Unica's meanders before it sinks into a ponor group called *Škofov lom* at the northern border of Planinsko polje. Most of the year, the riverbed is dry, whereas during high waters the area is completely flooded. This photograph shows a moderate flooding. Photo by Matej Blatnik.

Photo 2.22 Meanders of the Unica river in Planinsko polje, Slovenia during seasonal flood. Photo by Cyril Mayaud.

Photo 2.23 Planinsko polje in Slovenia is flooded up to 3 months per year on average, usually during winter but sometimes the flood extends into late spring or begins in early autumn. Because of the very flat bottom, almost the whole depression can be covered by water. The images show the look of the polje during different seasons of the year and during different hydrological conditions. The shape of the village (distribution of buildings) nicely denotes the extent of the highest floods. For the purpose of the collage, numerous hikes on the hill *Planinska gora* have been made to capture all different situations. They are not all shown, only the most illustrative. Photo by Matej Blatnik.

Photo 2.24 *Grmožur* island in Skadar lake near Virpazar, Montenegro. Until the Great War, Grmožur was a prison also known as "Montenegrin Alcatraz". Photo by Zoran Stevanović.

Photo 2.25 *Niagara* waterfall on Cijevna river 7 km upstream of its mouth to Morača River. The river is incised in fluvial-glacial sediments and got its name because of the tube-like riverbed. The waterfall is 10 m high, located at the end of a small reservoir which provided water to an old mill. Photo by Branislav Petrović.

Photo 2.26 Colluvium below *Vučji zub* (Wolf's Fang) peak of the Orjen mountain, Hercegovina and Montenegro. Photo by Igor Škero.

Photo 2.27 Karst plateau *Bojovića bare* in *Nikšićka župa* county, Montenegro. Photo by Saša Milanović.

Photo 2.28 Dabarsko polje is some 20 km long, and up to 3 km wide tectonic-erosional depression in Eastern Herzegovina. Photo by Zoran Stevanović.

Photo 2.29 Message of love on behalf of the Earth! A heart-shaped emerald – *Trnovačko jezero* glacial lake is situated at an altitude of 1517m, in the northwest Montenegro and very close to the border with Bosnia & Herzegovina (B&H). Nested in the middle of a huge amphitheater of karst peaks, Trnovačko Lake is surrounded by mountains Maglić (the highest peak in B&H), Volujak, Vlasulja, Bioč and Trnovački Durmitor, all higher than 2000m in altitude. Its unique heart shape makes it a natural phenomenon and adds to its already striking features. I always return to this place with joy in my heart! Photo by Srdjan Marinčić.

Photo 2.30 Two panoramic views of the Kamnik-Savinja Alps in Slovenia, with peaks *Kočna* (2540m, top photo) and *Krofička* (2083m, bottom photo). Both photos by Boštjan Burger.

Photo 2.31 Meanders of the Uvac river canyon in western Serbia incised in the Mesozoic limestones. Photo by Saša Preradović.

Photo 2.32 *Divje jezero* (Wild Lake) near Idrija, Slovenia. Photo by Boštjan Burger.

Photo 2.33 For more than 120 years, researchers have been trying to discover the underground flow of the Reka river in Slovenia. It is accessed in a small number of potholes/caves, but as a rule they are all about 320 meters deep. At the bottom of *Kanjeduce* cave, researchers were rewarded with a giant water tunnel, which can be flooded to the ceiling during peak rainy seasons. Photo by Peter Gedei.

Photo 2.34 *Rokina bezdana* pithole in Jezerane, Lika, Croatia. The 100m deep vertical entrance leads to a large channel of the biggest subterranean river in Croatia. The channel soon ends with a syphon that can be negotiated only with scuba diving equipment. The river is home to Proteus anguinus ("man's fish" in Slavic languages of the region; see Photo 8.7 in Chapter 8). An interesting detail connected to Rokina bezdana is that the dye injected in a surface water sink 2km away quickly showed up in the subterranean river in the cave in the matter of hours, but it took several months for it to show up at two karst springs 30km away. Photo by Dinko Stopić.

Photo 2.35 Small Dragalj Polje in Montenegro is filled with glacio-fluvial sediments sometimes used as construction materials. Photo byAndjela Vujović.

Photo 2.36 Central part of small karst polje of Ljubinje in eastern Herzegovina. The polje is almost never flooded, and its rich soil supports local agriculture as well as significant export of produce. Photo by Neven Kresic.

Photo 2.37 View of the Old Bridge on Neretva river in Mostar, Hercegovina which was commissioned by the Ottoman Sultan Suleiman the Magnificent in 1557 and designed by Mimar Hayruddin. Built entirely of limestone and in one span, without any pillars, it is considered an architectural masterpiece. Photo by Natalija Samardžić.

Photo 2.38 Mehmed Paša Sokolović Bridge on Drina river in Višegrad, Bosnia and Herzegovina. Built entirely of limestone, it was completed in 1577 by the most famous Ottoman court architect Mimar Sinan on the order of Grand Vizier Mehmed Paša Sokolović. UNESCO included the bridge in its 2007 World Heritage List ("*The unique elegance of proportion and monumental nobility of the property as a whole bear witness to the greatness of this style of architecture*.") "The Bridge on Drina" is name of a novel written by the Yugoslav Nobel Prize winner Ivo Andrić who spent his high school years in Višegrad. Photo submitted to **"***Trace of Soul***"**, a public photography competition featuring natural and cultural heritage in the territory of Republic of Srpska – one of two equal entities in Bosnia and Herzegovina. Competition was organized by Wikimedia users from Republic of Srpska in 2015. Photo by Velika beba - Own work, CC BY-SA 3.0; available at: https://commons.wikimedia.org/w/index.php?curid=41481462.

Photo 2.39 *Gvozdeni most* (Iron Bridge) over Zalomka river near Nevesinje, Eastern Herzegovina, in dry and wet (flood) seasons. Both photos by Željko Zubac.

Photo 2.40 River Krka is 72.5 km long. It cut most of its canyon into the North Dalmatian Corrosion Plain. Seven travertine barriers were created on it, of which *Manojlovački buk* stands out with 59.6 m height. Because of the extreme importance, and in order to better protect and preserve tufa as a fundamental phenomenon, most of the canyon was protected as Krka National Park in 1985. Photo by Dražen Perica.

Photo 2.41 Canyon of Unac river in Bosnia and Herzegovina. Photo by Petar Begović.

Photo 2.42 Island of Biševo in the Croatian Adriatic, famous for its Blue Cave (*Plava špilja*; see Photo 7.27 in Chapter 7). Photo by Branimir Jukić.

Photo 2.43 Island of Murvica in the Croatian Adriatic, with a working lighthouse of the same name built in 1896. Photo by Branimir Jukić.

Photo 2.44 View of the karst massif Karanfil from *Ropojani* valley which was reshaped by a glacier during the last Ice Age. "The Prokletije mountains are one of the highest and without doubt most hyperkarstic mountain ranges of the Balkan Peninsula whose white bare karstic and jagged ridges and peaks, build form limestone and dolomite, show many cirques that create an imposing wild image which sends shivers and fear to visitors… Nowhere in the Balkan the glaciers have left such a deep trail of their erosion as in the Prokletije mountain range…" (Jovan Cvijić, Serbian geographer, a visionary in his time). The Prokletije Mountains abound with inaccessible, uninhabited, and mystical places of exceptional beauty. They are often referred to as "Southern Alps of Europe." Photo by Srdjan Marinčić.

Photo 2.45 The karst massif of Durmitor in Montenegro is arguably the most spectacular display of geology and karst in the Dinarides, reshaped by glacial erosion during Ice Ages. Of 48 peaks higher than 2000 meters, the special place belongs to *Sedlena greda* (2227 m), often referred to locally as The Saddle of Gods, which dominates over *Dobri do* (Good Valley) in the southeastern part of Durmitor National Park which was designated as World Heritage Site in 1980. Photo by Srdjan Marinčić.

Photo 2.46 Tree reflections in front of *Postojnska jama* (Postojna Cave) in Slovenia. December 2020. Photo by Cyril Mayaud.

Photo 2.47 Canyon of the Drina river is in places over 1000 m deep, with the most impressive portion being an incised meander cut into the Mesozoic limestones of the Zvijezda mountain in Tara National Park. The canyon is also the border between Serbia and Bosnia and Herzegovina. Thanks to unique microclimate of the area, the canyon and the Tara National Park are one of the last few places in Europe with preserved Tertiary biota, the most famous being Pančićeva omorika (*Picea omorika* Panč.), commonly called Serbian Spruce in the West. It is an endemic relict 20 million years old (see Photo 9.23 in Chapter 9.) Before Ice Age, Serbian Spruce was spread throughout Europe, and can now be found only along the middle course of the Drina River. Photo by Srdjan Marinčić.

Photo 2.48 View of the highest peaks of Velebit mountain in Croatia, with the canyon of *Mala Paklenica* descending to the Adriatic Sea. Photo by Dražen Perica.

Photo 2.49 Waterfall *Skakavica* on the Grabovica river in Montenegro. Photo by Dobrislav Bajović Bajone.

Photo 2.50 *Galjipovac* lake in Lokvičići near the town of Imotski, Croatia. The deepest and water-richest sinkhole lake in the area. Photo by Branimir Jukić.

Photo 2.51 Bare gray limestone of the Triglav ("Three-heads") massif in Slovenia, the highest mountain in the Lands of Karst (2864m altitude), exposed here above the clouds. Photo by Srdjan Marinčić.

Photo 2.52 The Precambrian karstified marbles at *Solunska glava* peak in North Macedonia (2540m altitude). The 400m high vertical section below the peak is of tectonic origin. Photo by Zlatko Ilijovski.

Photo 2.53 View of the Prokletije mountains, with bare karstic and jagged ridges and peaks, built form limestone and dolomite. Photo by Srdjan Marinčić.

Photo 2.54 Left: A daring path that leads along the Hanke Channel of Škocjan Caves is safely embedded into the cave walls at the height of twenty to thirty meters above the raging underground river. Before the underground canyon opens into the Martel Hall, it reaches height of 150 meters. Right: Reka river that sinks into Škocjan caves is torrential by nature. The ratio between the minimal and the maximal flow is more than 1:3000. Both photos by Borut Lozej.

Photo 2.55 Mouth of Cetina river in Omiš, Croatian Adriatic, 105 kilometers from its source (see Photo 5.1 in Chapter 5.) Photo by Branimir Jukić.

Photo 2.56 The Neretva river delta, southern Croatia. This wetland on the Adriatic coast, which through the history have been turned into agricultural land, is famous as an ornithological and ichthyological reserve with more than 300 registered bird species. The Neretva river delta has been listed under the Ramsar Convention since 1993 and is included in Annex I of the EU Habitats Directive (NATURA 2000 list). Photo by Veljko Marinović.

Photo 2.57 Karst springs issuing in the Neretva river canyon upstream from the town of Konjic. The canyon carved in dolomitic rocks of the Triassic age is some 30 km long and in some sections 700 m deep. Photo by Ferid Skopljak.

Photo 2.58 Dinaric peaks – "Sunrise on Zelengora". Zelengora mountain is often referred to as the "Queen of Herzegovina", the place of exceptional beauty. No great effort and climbing skills are needed to access its wonders (from "Nestvarna mesta" blog.) Photo by Nebojša Atanacković.

Photo 2.59 Incredible Zelenegora mountain. Photo by Nebojša Atanacković.

Photo **2.60** The magic of *Kučka krajina* in Montenegro. Reflections of the *Kučke planine* mountains in the *Bukumirsko jezero* lake. Photo by Nebojša Atanacković.

Photo 2.61 Waterfall near the ruins of the old *Bećirovića mlin* water mill in Donja Bijela village, Piva basin, Montenegro. The water is from a large karstic spring *Oko Bijele* located a few hundred meters upstream. Photo by Zoran Stevanović.

Photo 2.62 A green oasis –canyon of Krupa river. "Just one-half hour drive from the Adriatic coast in the south Velebit mountain foothills is a gorgeous canyon of Krupa River. This green oasis, because of its unusual contrast against the sorrounding rocky environment, is one of the most beautiful walking experiences in the region" (Nebojša Atanacković "Nestvarna mesta" blog). Photo by Nebojša Atanacković.

Photo 2.63 Winter on Durmitor mountain peaks (from blog of Nebojša Atanacković "Nestvarna mesta"). Photo by Nebojša Atanacković.

Photo 2.64 *Šareni pasovi* (Colorful Bends), intensely folded limestone layers on Durmitor mountain, Durmitor National Park, Montenegro. Photo by Dobrislav Bajović Bajone.

Photo 2.65 *Škrčko jezero* lake in Durmitor National Park, Montenegro. The highest peak of Durmitor, *Bobotov Kuk*, is on the right. Photo by Dobrislav Bajović Bajone.

Photo 2.66 *Lukavica* river waterfall, Montenegro. Photo by Dobrislav Bajović Bajone.

Photo 2.67 View of Popovo polje in eastern Herzegovina from the north rim. Photo by Ivo Lučić.

Photo 2.68 Canyon of *Rosomačka reka* river, on *Stara planina* mountain in southeastern Serbia. At the upstream end is the village of Rosomač whose population calls the canyon *Rosomački lonci* (Rosomač Pots). At the downstream end, in the village of Slavinja, the name of the canyon is *Slavinjsko grlo* (Slavinja Throat). The canyon is entrenched in the Jurassic clayey to marly fossiliferous limestones which are thin-bedded and contain chert nodules which cause uneven erosion and spectacular views. Photo by Jelena Ćalić.

Photo 2.69 On its way from the sea to 69km long estuary, Zrmanja river represents the southeastern border of Velebit mountain in Croatia. It is mostly fed by drainage from the Velebit's hinterland and a subterranean river (sinking stream) from Lika. Photo by Dražen Perica.

Photos 2.70 Left: Tara River Canyon, Montenegro, as seen from the famous highway bridge in Djurdjevića Tara. Right: Vintgar Gorge, carved by Radovna River, is located near Bled, Slovenia. More than 500 meters of bridges and galleries were built in 1893 and the gorge was regulated and open for public. Photos by Neven Kresic.

Photo 2.71 Meanders of Šuica river in Šuičko polje near Tomislavgrad, western Herzegovina. Photo by Vinko Ljubas.

Photo 2.72 View of the city of Trebinje ("Capital of Herzegovina Karst"), and Trebišnjica river with the Ottoman *Arslanagića most* bridge (see also Photo 10.31 in Chapter 10). Photo by Dunja Josipović.

Photo 2.73 *Manito jezero* (Mad Lake) on Lukavica mountain, Morača River basin, Montenegro. The name is given by local villagers after an incident when young boy drowned in the lake. It is 220 m long and 140 meters wide. The greatest depth is 13 m. Photo by Neda Dević.

Photo 2.74 *Kapetanovo jezero* (Captain's Lake) in Montenegro. According to a legend, Captain Mušović, who controlled this area, received as a gift a young and beautiful girl named Krstinja to serve him as a bondmaid. Krstinja, however, had not agreed with such a destiny and one night escaped. Although not a swimmer, she successfully crossed to the other bank of wild Zeta river thanks to one big arm of a willow tree extended over the troubled water. Photo by Neda Dević.

Photo 2.75 *Rijeka Crnojevića* river originates from a single large karst spring and after just a few kilometers makes a large bend and from that section is submerged by the Skadar Lake. Photo by Borut Peric.

Photo 2.76 *Karuč* gulf with a large fishpond is another beautiful and peaceful site on the *Rijeka Crnojevića* river (previous photo). Two large *vruljas* (sublacrustine springs, locally called "eyes") at the depth of about 20 m (15 m below sea level) are issuing from the surrounding highly karstified limestones. Photo by Zoran Stevanović.

Photo 2.77 Stone bridge *Ovčiji brod* with three arches is located on the river Zalomka near the village of Bratač (Municipality of Nevesinje, eastern Herzegovina). It was built of limestone and tufa and is about 35 meters long. In this area, the riverbed is dry during summer months. It is believed that the bridge was built in the 17th century. The name of the bridge (Ovčiji brod = Sheep Crossing) probably comes from the shepherds who used it to move their flocks of sheep in the springtime, from the lower parts of Herzegovina in the mountainous areas of Morine, Zelengora and Treskavica. The bridge was proclaimed a national monument of Bosnia and Herzegovina in 2018 by the Commission to Preserve National Monuments of Bosnia and Herzegovina. It has also been nominated for inclusion on the UNESCO World Heritage List. Near the bridge there are numerous Illyrian stone mounds, well-preserved remains of a Roman road, necropolises with "stećak" tombstones, and other traces of people's lives from the ancient past. Photo by Natalija Samardžić.

Photo 2.78 Views from the top of Volujak mountain (1091 m above sea level) towards Boka Kotorska Bay. The location, underlain by Upper Jurassic massive limestones with corals, was used as a military observatory of the Montenegrin army on the Lovćen front (1916) during World War I. The town of Kotor is in the front, while in the center of the photo are the ridges of Vrmac (785 m), and the panoramic Tivat Bay with Luštica and Prevlaka in far distance. The massif of Orjen (1679 m) is on the right. Photo by Gojko Nikolić.

Photo 2.79 Collapsed doline (sinkhole) in the Škocjan Caves Park system. Photo by Borut Lozej.

Photo 2.80 Picturesque Krka waterfalls in Krka National Park, Croatia. Before it reaches the Adriatic Sea, the Krka river falls across stepped travertine barriers some of which are almost 50 meters high, like the one shown here. Photo by Borut Peric.

Photo 2.81 The narrowest section of *Nevidio* ("Invisible") canyon, 1.5m wide. Large parts of this attractive narrow canyon, created by one of the tributaries of Piva river in Montenegro, is accessible only through water. Photo by Aleksandar Banović.

Photo 2.82 Panoramic view of Djerdap Lake and *Treskavac*, a volcanic cliff on the Romanian side of the Danube Gorge, from Kovilovo in Serbia. Photo by Nenad Radaković.

Photos 2.83 Top photo: Panoramic image of the high karst of Montenegro taken from the *Mravljanik* peak (1336 m altitude) showing the central amphitheater of Vrba and Njeguško karst polje (2.3 km^2). The Lower Jurassic limestones were covered with fluvioglacial sediments during the Ice Age. Bottom photo: Linearly oriented decameter sinkholes on the northern slopes of Kolovir (1315m altitude) with preserved *Fagion Illyricum* beech trees including the association *Fagetum montenegrinum* Blecic on their southeastern side. The most common in this area are sinkholes—bowl-shaped, funnel-shaped, and well-shaped—which also appear linearly oriented and in series. In many sinkholes, the bedrock sides were exposed and undercut by erosion. Both photos by Gojko Nikolić.

Photo 2.84 Grabovica River and *Skakavica* waterfall on Durmitor mountain in Montenegro. Photo by Branislav Petrović.

Photo 2.85 "Baćinska jezera" (Baćina Lakes) in Dalmatia, Croatia are permanent freshwater lakes formed at the lowest level of the Dinaric karst poljes, closest to the Adriatic coast. Photo by Neven Kresic.

Photo 2.86 "Buganja greda" on the Orjen mountain near the city of Trebinje, eastern Herzegovina. Photo by Igor Škero

Photo 2.1 *Dinara Mountain, Croatia*. Srdjan Marinčić

Photo 2.2 *Karavanke Mountains, Slovenia.* Uroš Kunaver

Photo 2.3 *Kravice Waterfall, Herzegovina*. Zoran Stevanović

Photo 2.4 *Pokljuka Plateau, The Alps, Slovenia.* Uroš Kunaver

Photo 2.5 *Krka River Waterfalls, Croatia.* Neven Kresic

Photo 2.6 *Galjipovac Lake, Imotski, Croatia*. Branimir Jukić

Photo 2.7 *Plitvice Lakes National Park, Croatia*. Neven Kresic

Photo 2.8 *Piva Reservoir, Montenegro*. Zoran Stevanović

Photo 2.9 *Tribuća River Canyon, Serbia.* Dragovan Stojadinović-Sule

Photos 2.10 *Mamić and Knezović Lakes (top), Red Lake (bottom), Croatia*. Branimir Jukić

Photos 2.11 *Blue Lake, Imotski, Croatia*. Branimir Jukić

Photo 2.12 *Prokletije Mountains, Montenegro*. Milovan Milivojević

Photo 2.13 *Jakupica Mountain, North Macedonia*. Zlatko Ilijovski

Photo 2.14 *Djerdap Gorge, Danube, Serbia and Romania*. Aleksandra Maran Stevanović

Photo 2.15 *Lazar River Canyon, Serbia*. Dragan Bosnić

Photo 2.16 *Kanin Plateau, Slovenia*. Matej Blatnik

Photo 2.17 *Sobra, Mljet Island, Croatia*. Zoran Stevanović

Photo 2.18 *Reka River Swallow Hole, Slovenia*. Borut Lozej

Photo 2.19 *Sikolska River Waterfall, Serbia*. Dragovan Stojadinović-Sule

Photo 2.20 *Kozjak River Waterfall, Slovenia*. Matej Blatnik

Photo 2.21 *Planinsko Polje, Slovenia*. Matej Blatnik

Photo 2.22 *Planinsko Polje, Slovenia.* Cyril Mayaud

Photos 2.23 *Planinsko Polje, Slovenia*. Matej Blatnik

Photo 2.24 *Skadar Lake, Montenegro*. Zoran Stevanović

Photo 2.25 *Cijevna River, Montenegro*. Branislav Petrović

Photo 2.26 *Orjen Mountain, Herzegovina and Montenegro*. Igor Škero

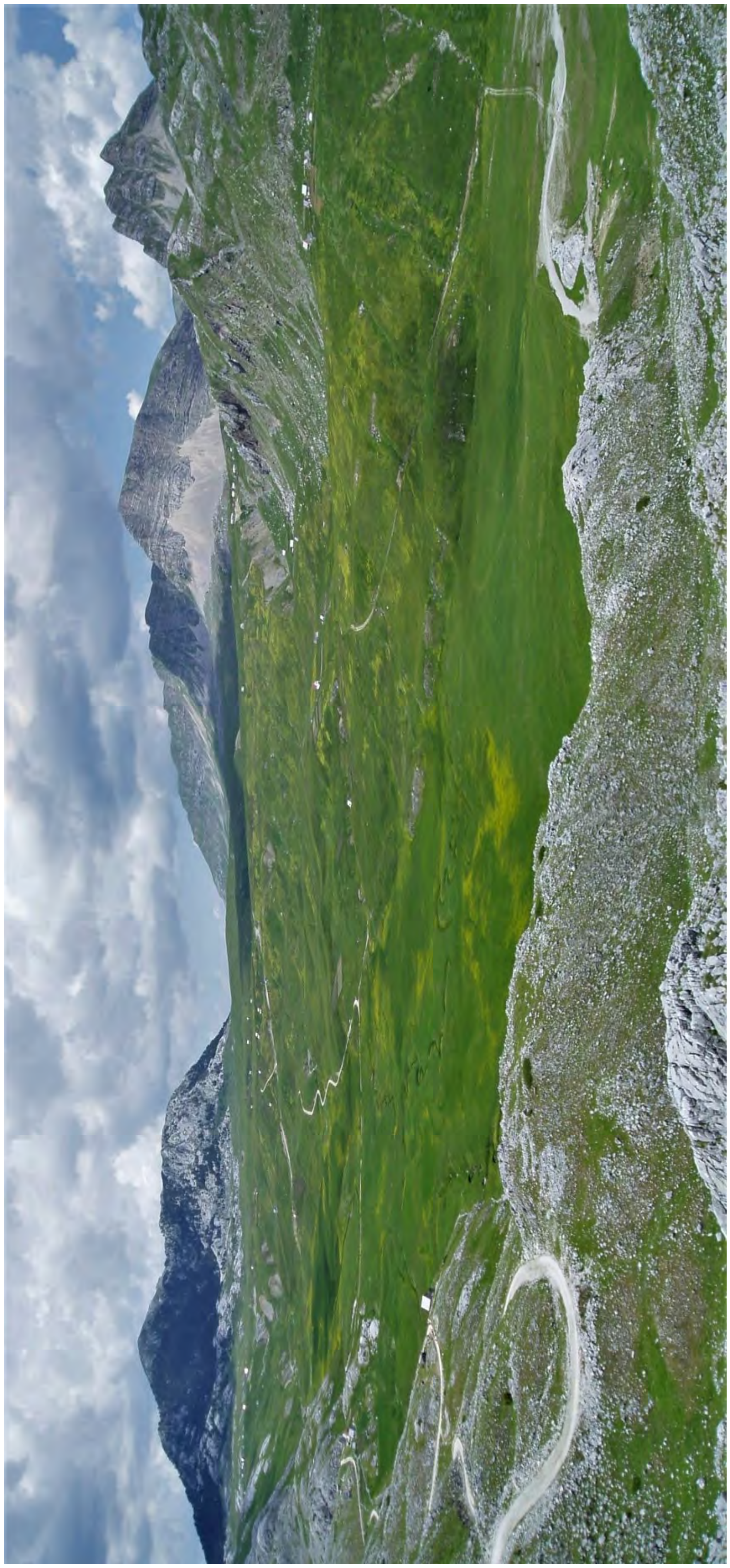
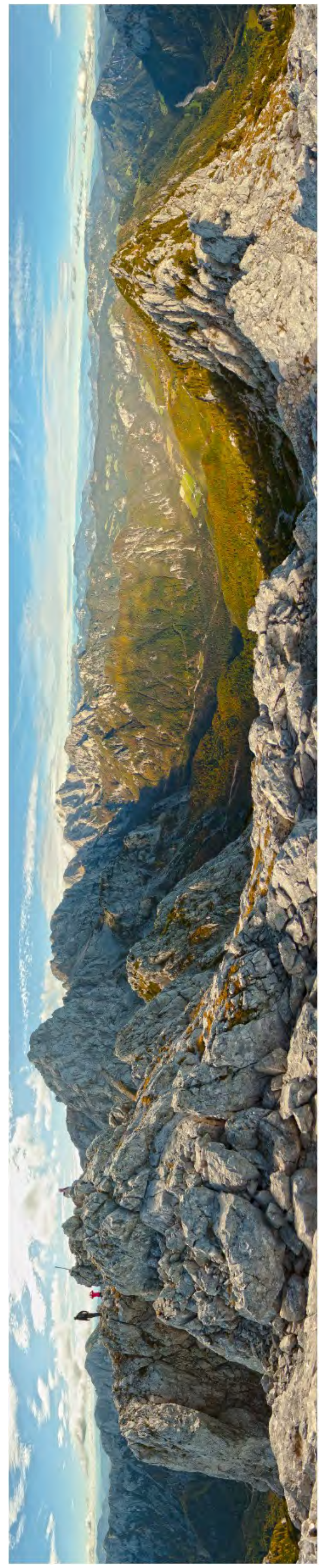


Photo 2.27 *Bojovića Bare Plateau, Montenegro*. Saša Milanović

Photo 2.28 *Dabarsko Polje, Herzegovina*. Zoran Stevanović

Photo 2.29 *Trnovačko Lake, Montenegro*. Srdjan Marinčić



Photos 2.30 *Kamnik-Savinja Alps, Slovenia*. Boštjan Burger

Photo 2.31 *Uvac River Canyon, Serbia*. Saša Preradović

Photo 2.32 *Divje Lake, Slovenia*. Boštjan Burger

Photo 2.33 *Underground Course of Reka River, Kanjeduce Cave, Slovenia*. Peter Gedei

Photo 2.34 *Rokina Bezdana Cave, Croatia*. Dinko Stopić

Photo 2.35 *Dragalj Polje, Montenegro*. Andjela Vujović

Photo 2.36 *Ljubinsko Polje, Herzegovina*. Neven Kresic

Photo 2.37 *Old Bridge, Mostar, Herzegovina*. Natalija Samardžić

Photo 2.38 *Višegrad Bridge, Bosnia*. Photo by Velika beba - Own work, CC BY-SA 3.0

Photos 2.39 *Gvozdeni Most Bridge, Zalomka River, Herzegovina*. Željko Zubac

Photo 2.40 *Krka River, Croatia*. Dražen Perica

Photo 2.41 *Unac River Canyon, Bosnia*. Petar Begović

Photo 2.42 *Biševo Island, Croatia*. Branimir Jukić

Photo 2.43 *Murvica Island, Croatia*. Branimir Jukić

Photo 2.44 *Karanfil Karst Massif, Prokletije Mountains, Montenegro*. Srdjan Marinčić

Photo 2.45 *The Saddle, Durmitor Mountain, Montenegro*. Srdjan Marinčić

Photo 2.46 *Postojna, Slovenia*. Cyril Mayaud

Photo 2.47 *Drina River Canyon, Serbia and Bosnia*. Srdjan Marinčić

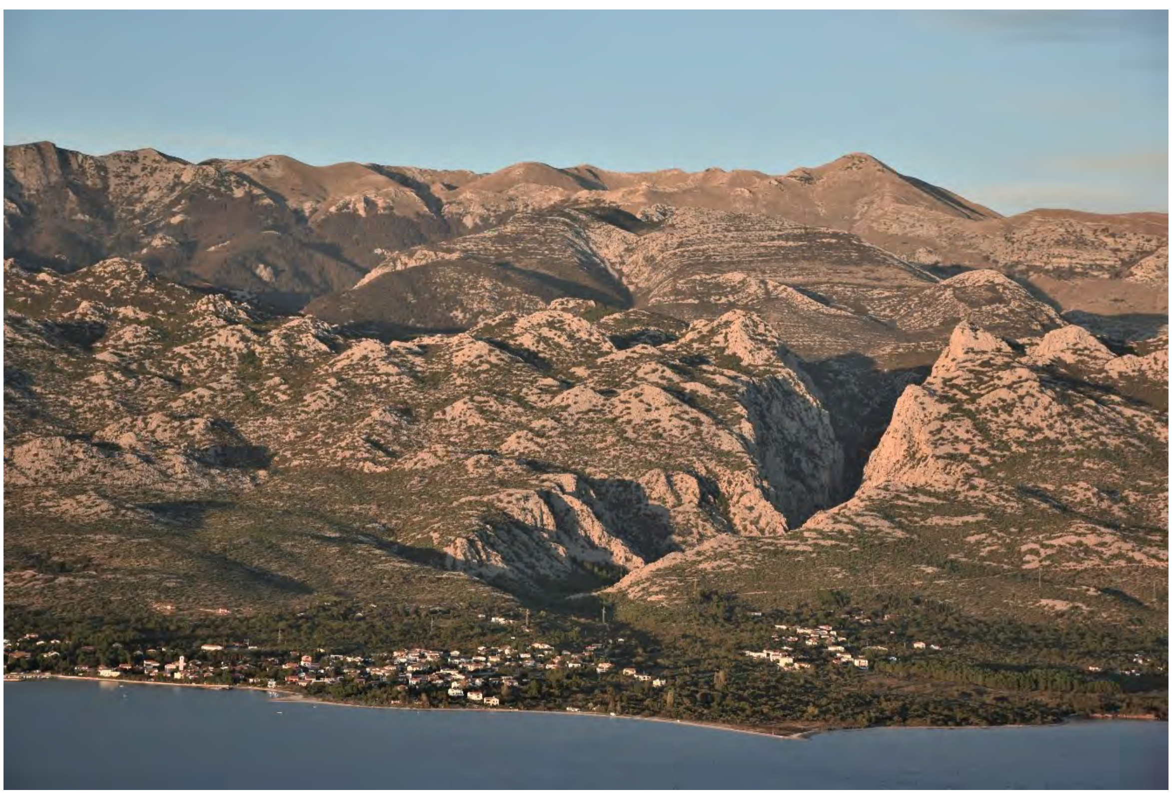


Photo 2.48 *Paklenica River Canyon, Velebit Mountain, Croatia*. Dražen Perica

Photo 2.49 *Skakavac Waterfall, Durmitor Mountain, Montenegro*. Dobrislav Bajović Bajone

Photo 2.50 *Galjipovac Lake, Imotski, Croatia*. Branimir Jukić

Photo 2.51 *Triglav Mountain, Slovenia*. Srdjan Marinčić

Photo 2.52 *Solunska Glava, North Macedonia*. Zlatko Ilijovski

Photo 2.53 *Prokletije Mountains, Montenegro*. Srdjan Marinčić

Photos 2.54 *Škocjan Caves (left) and Reka River (right), Slovenia*. Borut Lozej

Photo 2.55 *Cetina River Mouth, Omiš, Croatia*. Branimir Jukić

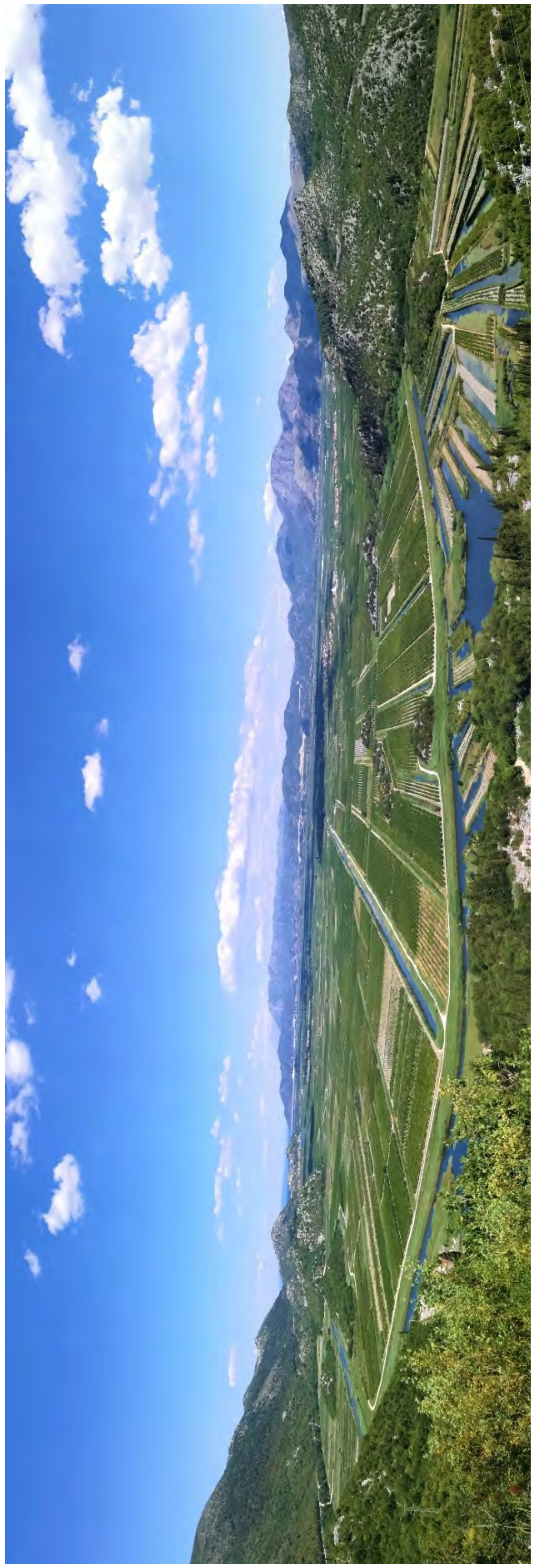


Photo 2.56 *Neretva River Delta, Croatia*. Veljko Marinović

Photo 2.57 *Neretva River Canyon, Bosnia*. Ferid Skopljak

Photo 2.58 *Zelengora Mountain, Bosnia and Herzegovina*. Nebojša Atanacković

Photo 2.59 *Zelengora Mountain, Bosnia and Herzegovina*. Nebojša Atanacković

Photo 2.60 *Bukumirsko Lake, Kučke Mountains, Montenegro*. Nebojša Atanacković

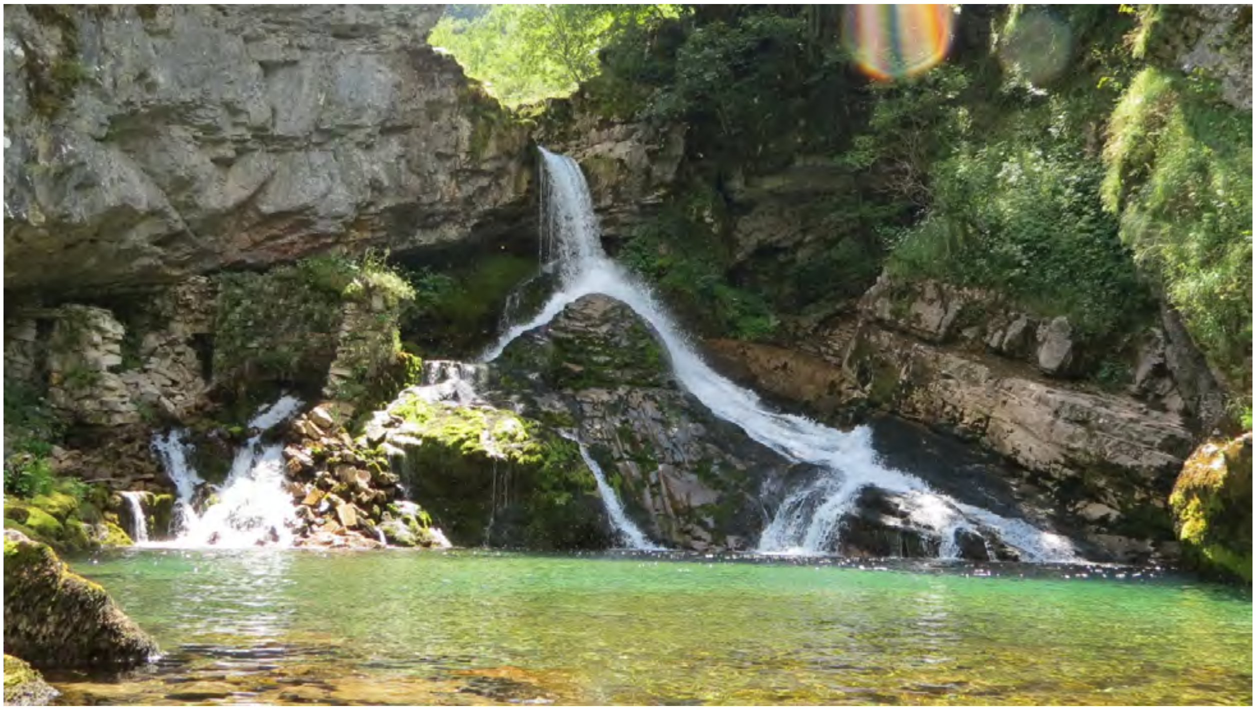


Photo 2.61 *Waterfall below Oko Bijele Spring*, Montenegro. Zoran Stevanović

Photo 2.62 *Krupa River Canyon, Croatia*. Nebojša Atanacković

Photo 2.63 *Durmitor Mountain, Montenegro*. Nebojša Atanacković

Photo 2.64 *Durmitor Mountain, Montenegro*. Dobrislav Bajović Bajone

Photo 2.65 *Škrčko Jezero Lake, Durmitor, Montenegro*. Dobrislav Bajović Bajone

Photo 2.66 *Lukavica River Waterfall, Montenegro*. Dobrislav Bajović Bajone

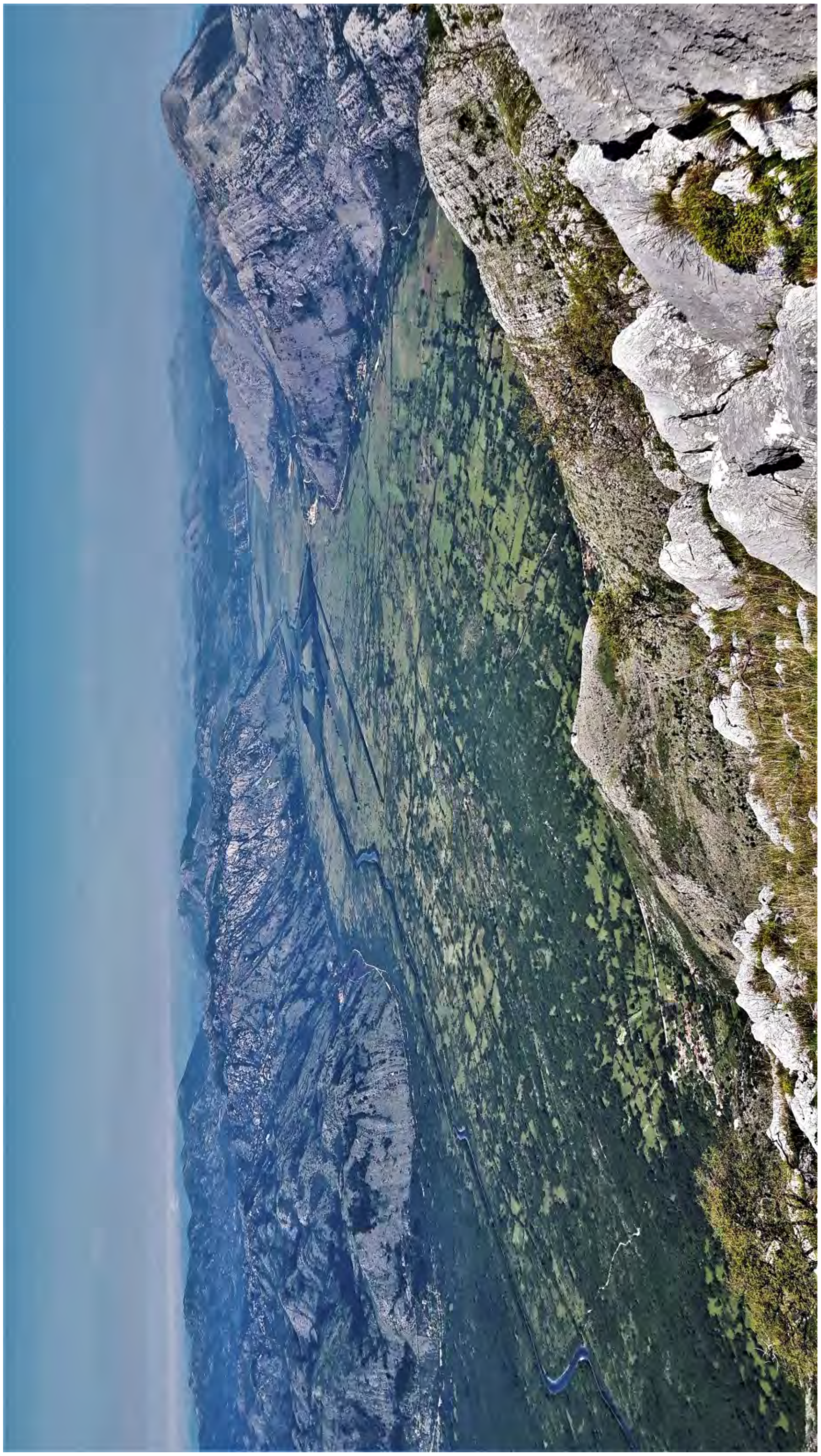


Photo 2.67 *Popovo Polje, Herzegovina*. Ivo Lučić

Photo 2.68 *Rosomačka River Canyon, Serbia.* Jelena Ćalić

Photo 2.69 *Zrmanja River Canyon, Croatia*. Dražen Perica

Photos 2.70 *Left: Tara River Canyon, Montenegro. Right: Vintgar Gorge, Slovenia*. Neven Kresic

Photo 2.71 *Šuica River, Tomislavgrad, Herzegovina*. Vinko Ljubas

Photo 2.72 *Trebinje, Herzegovina*. Dunja Josipović

Photo 2.73 *Manito Jezero (Mad Lake), Lukavica Mountain, Montenegro*. Neda Dević

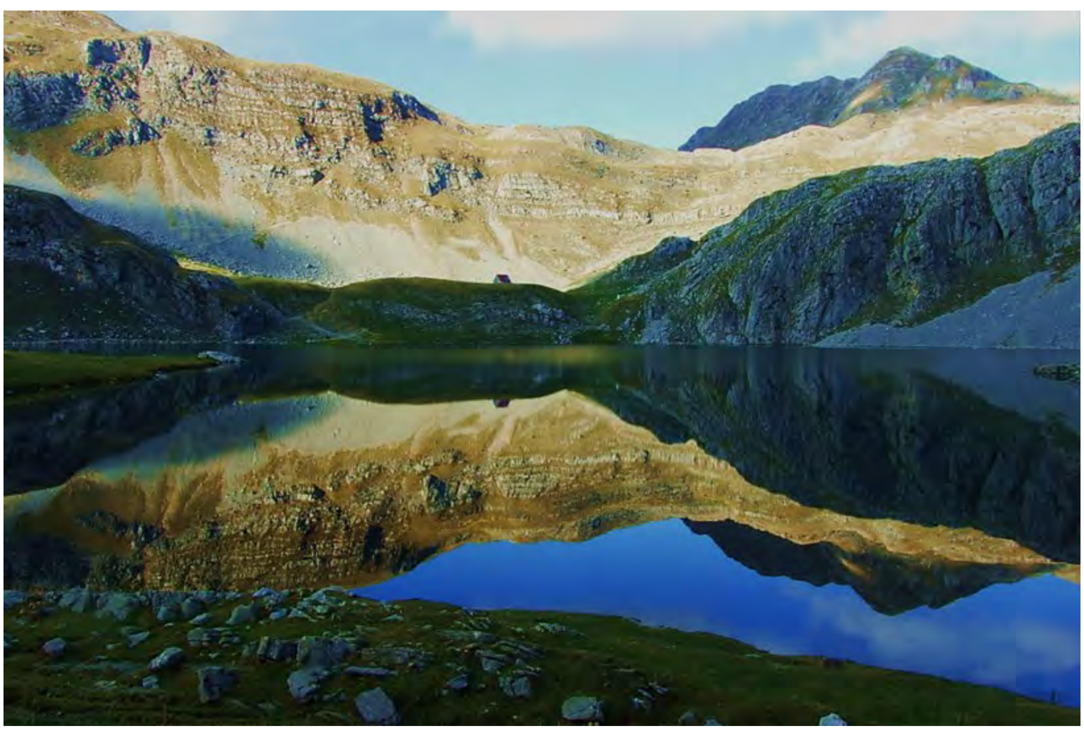


Photo 2.74 *Kapetanovo Jezero (Captain's Lake), Montenegro*. Neda Dević

Photos 2.75 *Rijeka Crnojevića River, Montenegro*. Borut Peric

Photo 2.76 *Karuč Gulf, Rijeka Crnojevića River, Montenegro*. Zoran Stevanović

Photo 2.77 *Ovčiji Brod Bridge, Zalomka River, Herzegovina*. Natalija Samardžić

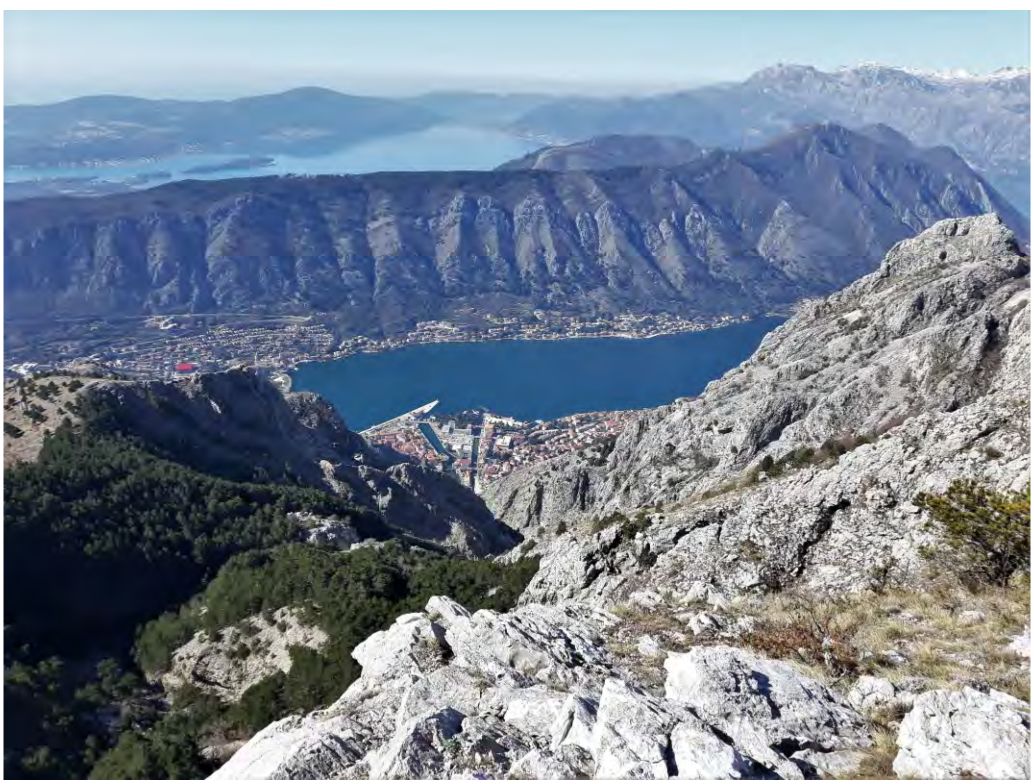


Photo 2.78 *Boka Kotorska Bay, Montenegro*. Gojko Nikolić

Photo 2.79 *Škocjan Caves Park, Slovenia*. Borut Lozej

Photo 2.80 *Krka River Waterfalls, Croatia*. Borut Peric

Photo 2.81 *Nevidio Canyon, Montenegro.* Aleksandar Banović

Photo 2.82 *Djerdap Lake, Danube, Serbia and Romania*. Nenad Radaković

Photos 2.83 *Njeguško and Vrba Poljes (top) and Sinkholes of High Karst of Montenegro*. Gojko Nikolić

Photo 2.84 *Grabovica River, Skakavac Waterfall, Durmitor, Montenegro*. Branislav Petrović

Photo 2.85 *Baćinska Jezera, Croatia*. Neven Kresic

Photo 2.86 *Orjen Mountain, Herzegovina*. Igor Škero

Limestone Walls

3. Limestone Walls

Mesozoic limestones of the Lands of Karst are very strong, moderately hard rocks with low matrix porosity and high density which all means they are excellent building materials that can resist abrasion and weathering due to temperature extremes (freezing and thawing). They can be shaped in large blocks (“megalithic stones”) and smaller brick sizes thus allowing for great versatility of building design. Limestone is easily hand-carved and can be highly polished which is why it has been a preferred material for creating sculptures and works of art since antiquity.

Limestone’s older cousin, marble (a metamorphic form of limestone created under high pressure during natural tectonic movements of the earth’s crust), has all the same qualities, except to a higher degree. It is much less abundant though, and much more expensive and valued. Limestone’s younger cousin, tufa, is deposited from surface water and groundwater supersaturated with calcium carbonate when the geochemical (“hydrochemical”) equilibrium is disturbed, such as due to aeration which causes the calcium carbonate to precipitate out of the aquatic solution. This deposition creates natural tufa cascades (waterfalls) in surface streams for example, tufa deposits at karst springs, and many different and fascinating forms of *speleothems* in caves, stalactites and stalagmites being the most widely known. Tufa deposits abound in the Lands of Karst and have also been mined as building material for millennia. Tufa is highly porous, light and even easier to cut and shape than limestone. However, the pores, formed to a large degree by the initial presence of organic material such as plant leaves and branches at the land surface over which the water is flowing, are chaotic and not continually interconnected. This makes tufa an excellent thermal insulation material.

Because of the strength of limestone blocks and bricks which are resistant to external stresses, the structures made of limestone are strong and durable and have stood the test of time. Limestone is one of the most common sedimentary rocks worldwide as well. Consequently, many of the global landmarks and architectural masterpieces have been built of limestone: the Pyramids of Giza and the Great Sphynx of Egypt, the Mayan temples in Mexico and Central America, and Greek and Roman temples including the most famous of them all, The Parthenon in Athens, Greece. In addition, numerous Gothic cathedrals, city walls, castles and important public buildings in Europe and, more recently, The Empire State Building, The Lincoln Memorial, and The National Cathedral in the United States, to name just a few, are all made of limestone.

Limestones of the Lands of Karst are chemically very pure, often containing more than 95 percent calcium carbonate. They are therefore usually white to light gray in color. Traces of iron or manganese can give limestone an off-white to yellow to red color, whereas the presence of organic material in high amounts can make it dark gray or almost black.

Pure limestone has a unique clean look, as if washed of any unwanted “dirt” or mud. And indeed, rainwater has much to do with this visual perception, except that one can only indirectly comprehend its action. As it dissolves calcium carbonate in the rock, it is transported away, primarily through the karstified subsurface as groundwater. What remains at the surface is a clean landscape, changing its shape ever so slowly, standing strong and defying gravity because of the exceptional strength of limestone. The most fascinating result of this interplay between rainwater, rock, and gravity, are natural limestone walls of every imaginable shape, texture, and size. They vary from magnificent vertical canyon walls of wild rivers, hundreds, or thousands of feet high, to grand vertical underground pits of similar depths, all the way to miniature masterpieces of natural wall design.

All the humans living in the Lands of Karst had to do was to observe their surroundings and then mimic the master builder – The Nature herself. They realized, millennia ago, that limestone is their friend. Inhabitants also intuitively knew all along what has been proven scientifically only relatively recently: that limestone has pronounced natural antiseptic and antiallergenic properties. One might therefore conclude that limestone and its inhabitants are ideally suited to each other.

Photo Captions

Note: all photo captions are provided by the authors of individual photographs hence the diversity–some felt like sharing more information with the reader, some left the photographs speak for themselves, giving only the essentials.

Photo 3.1 Dry limestone walls were constructed from stones that were obtained when people cleared land; they piled them along the rims of dolines, parcel borders, or along paths. Photo by Borut Lozej.

Photo 3.2 Vertical canyon wall of the Korana River built of massive limestone, Plitvice Lakes National Park, Croatia. Photo by Neven Kresic.

Photo 3.3 Limestone beds of Dinara Mountain in Croatia. Note a human figure in the central right for scale. Photo by Branimir Jukić.

Photo 3.4 The Reka River in Slovenia occasionally rises from its bed and floods underground spaces, the main reasons for that being heavy precipitation in its drainage area and the limited capacity of sinks at the end of the cave that are not able to swallow swollen waters. The highest floods that occur about every ten years can reach the height of 130 metres. Seen here are the flood waters covering vertical limestone walls in the Big Collapse Doline by the village of Škocjan (see also Photo 2.91 in Chapter 2). Photo by Borut Lozej.

Photo 3.5 Vertical wall of “Crveno jezero” (Red Lake) near Imotski, Croatia, one of the deepest sinkholes in the world. See also Photo 2.11 in Chapter 2. Photo by Neven Kresic.

Photo 3.6 Sinkhole “Veliki Samograd” on the Grabovica plateau near the village of Kovači, western Herzegovina. This sinkhole and a larger sinkhole in the next photo (which is in the same general area of the Grabovica plateau) have been a subject of scientific argument among karst geomorphologists in Croatia and Bosnia & Herzegovina. Some believe they were formed primarily by faulting whereas others call them “collapse sinkholes”. Whatever the case may be, it is very clear to most that (initial) faulting/fracturing had to play a role in their formation, as with almost all other sinkholes. Photo by Vinko Ljubas.

Photo 3.7 Sinkhole “Arnautovac” with a smaller sinkhole “Mali Samograd” at its edge (in the lower left), in the vicinity of the Kovači village (and the city of Tomislavgrad), western Herzegovina. Photo by Vinko Ljubas.

Photo 3.8 Natural slit passage in highly karstified limestones. Margin of the Karuč Gulf of Skadar Lake, Montenegro. Photo by Zoran Stevanović.

Photo 3.9 Limestone folds on Durmitor Mountain., Durmitor National Park, Montenegro. Photo by Predrag Stošić Peca.

Photo 3.10 Highly folded limestones of Uvito ždrijelo (elevation 2100m above sea level), Durmitor National Park, Montenegro. Photo by Zoran Stevanović.

Photo 3.11 Tabula Traiana (Trajan's plaque) is an inscription carved in a limestone block. It is dedicated to Roman Emperor Trajan and is a part of antique monuments on the Roman road which include the remains of the bridge which Trajan built over the Danube River. Translated from Latin, the inscription on Trajan's plaque says: "Emperor Caesar son of the divine Nerva, Nerva Trajan Augustus, victor over the Germans, Pontifex Maximus, invested for the fourth time as Tribune, Father of the Fatherland, Consul for the third time, excavating mountain rocks and using wood beams has made this road." The construction of a road and a large number of fortifications point to the importance of Djerdap as a border of Roman Empire, until the final conquest of Dacia in the early 2nd century. The construction of the road, which extended right next to the Danube, was conditioned by the needs for a faster and safer river traffic. It is now located 2.5 km upstream of Tekija Village and had been removed from its original place during the filling of the large Djerdap Reservoir on the Danube. Photo by Zoran Stevanović.

Photo 3.12 Smoke tree (*Cotinus Coggygria*) often inhabits spaces between dry walls. The bush is especially interesting in autumn when it becomes vividly yellow, orange or red. Photo by Borut Lozej.

Photo 3.13 Beds of limestone which has been used as the most natural choice of building material in the Dinaric karst for millennia. Photo by Neven Kresic.

Photo 3.14 Roman emperor Diocletian's palace in Split, Croatia built entirely of limestone (see also Photo 10.1 in Chapter 10). The Avars badly damaged the palace, but, when their incursion was over (*c.* 614), the inhabitants of the nearby ruined city of Solin (Salona; Diocletian's birthplace) took refuge within what remained of the palace and built their homes, incorporating the old walls, columns, and ornamentation into their new structures. That area now comprises the nucleus of the "old town" of Split protected by UNESCO as a World Heritage site (Encyclopedia Britannica). Photo by Neven Kresic.

Photo 3.15 Old houses in Split outside the Diocletian Palace, as well as in many other towns built on limestone, were often founded directly on outcrops which were seamlessly incorporated as virtual house walls. Photo by Neven Kresic.

Photo 3.16 View of the old part of Mostar, Herzegovina with limestone walls of the houses rising from the banks of Neretva River, the largest tributary of the Adriatic Sea. Photo by Neven Kresic.

Photo 3.17 The "Stiniva" cove formed in a large collapsed sinkhole, Adriatic island of Vis, Croatia. Photo by Branimir Jukić.

Photo 3.18 Monumental limestone walls of the Old City of Dubrovnik on the Adriatic coast of Croatia. Photo by Neven Kresic.

Photo 3.19 Jama (pit) Šlapice, the deepest one in the Japaga area, central Velebit Mountain., Croatia was explored by the Karlovac Speleological Club. This photograph won multiple awards and was featured on the cover page of the 2019 SpeleoProjects calendar. Photo by Dinko Stopić.

Photo 3.20 The area of Snežnik Mountain. near the Slovenian-Croatian border is known for its wilderness and remoteness. Nevertheless, cavers discovered some deep caves there. One of these is the 606 m deep "Brezno treh src", which unfortunately ends with a meander too narrow for passage. The picture shows the "Supernova" pit at a depth of 200 m. Photo by Uroš Kunaver.

Photo 3.21 Subvertical beds of the carbonate facies of the Cretaceous-Paleogene Durmitor flysch, folded during the Alpine Orogeny in Tertiary. The beds are comprised of lithologically diverse members – breccias, limestones, marly limestones, and marls. Selective erosion of the beds of differing resistance and mineral composition resulted in truly spectacular relief forms. Durmitor Mountain, Montenegro. Photo by Srdjan Marinčić.

Photo 3.22 Ammonite – trace of ancient marine life from the Tethys Sea, fossilized on the steep rocky slopes of Trnovački Durmitor massif above the heart-shaped Trnovačko glacial Lake (Nature Park Piva – Montenegro). Ammonites are extinct marine cephalopods typically distinguished by a coiled, plan spiral shell with folded and often complex suture lines. Ammonite shell is divided into chambers by septa. Picture shows the shell preserved within Jurassic red limestones "rosso ammonitico" infilling later chambers, and crystalline calcite the earlier chambers. The latter contain cavities into which well-formed calcite crystals have grown. Photo by Srdjan Marinčić.

Photo 3.23 Profile of the beds of Lower Cretaceous limestones and dolomites on the Croatian island of Svetac ("Saint") which were deformed by intrusion of a salt diapir several million years ago. This locality, named "Stone Book" (Kamena knjiga) is part of the Vis Archipelago UNESCO Geopark. The island is deserted and infrequently visited by the Zanki family, its owners for the last 250 years. It hosts a rare falcon species *Falco eleonorae* which inhabits only a few more small islands in the Adriatic and is virtually absent on the mainland. Photo by Srdjan Marinčić.

Photo 3.24 Stone lighthouse "At the End of the World" built in 1878 on the Adriatic island of Sušac, Croatia. At the elevation of 94 m, high on a vertical cliff formed by a major fault, it safeguards boats and seamen on the open sea. The cliff, built of Upper Jurassic limestones and rich with microfossil fauna, extends vertically down to depth of 25m below sea level. Photo by Srdjan Marinčić.

Photo 3.25 The Dalmatian coast of Croatia belongs to a type of ingress folded coast where synclines are turned into canals and bays, and anticlines into islands and peninsulas. In the area of Kornati National Park and Telaščica Nature Park, a partially submerged karst relief is characteristic. The outer series of islands is characterized by structural cliffs. Photo by Dražen Perica.

Photo 3.26 "Klinje", the first major dam in The Lands of Karst at the time, built between 1888 and 1896 by the Austro-Hungarian Empire during its occupation of Bosnia and Herzegovina. It is an arch dam built of limestone on Mušnica River, with a purpose of providing water for the irrigation of Gatačko polje during dry season. The reservoir is now used for water supply of thermo electrical plant in Gacko in the Republic of Srpska, Bosnia and Herzegovina. Photo by Blaž Kogovšek.

Photo 3.27 "Stone Eyes" (Kamene oči) on Kučino brdo hill near Trebinje, eastern Herzegovina. The locale was used for religious ceremonies during Pagan times. It can be reached by a trail that starts at Geljevo bridge in Trebinje. Photo by Igor Škero.

Photo 3.28 Upper Jurassic–Lower Cretaceous marly limestones with ammonites in the Boljetinska River Gorge. Djerdap UNESCO Global Geopark. Photo by Aleksandra Maran Stevanović.

Photo 3.29 Pećina Ponor ("Sink Cave") near Pirot in eastern Serbia was first explored by Jovan Cvijić who published the results of his investigations and the cave map in 1894. A detail surveying and further exploration of the cave was performed in 2016 by ASAK (Student Alpine and Speleological Club from Belgrade). The cave is formed at the edge of a large depression "Ponor", at a contact between sandstones of the Lower Triassic and the overlying Middle Triassic limestones. It is almost entirely controlled by the tectonic fabric thus very regular rectangular, flat cave walls and ceilings. It represents a textbook example of this type of caves where the erosional action of flowing water is predominant (the water is from a creek that sinks into the cave and reappears at the nearby Žuberna spring.) Particularly interesting is a "3D spiral" of the cave channel directly below the entrance to the cave with no apparent connection between the two. Photo is taken at the end of the underground creek (which flows through the entire cave – a "flowthrough cave") before it sinks at the end of the channel (text by Mihajlo Mandić Zis). Photo by Predrag Stošić Peca.

Photo 3.30 The Mrtvica River canyon in Montenegro. Photo by Dobrislav Bajović Bajone.

Photo 3.31 Subvertical beds of an intensely folded and faulted limestone sequence on Durmitor Mountain, Montenegro. Photo by Neven Kresic.

Photo 3.32 Building of stone drywalls and terraces was the way of uneasy cohabitation between humans and harsh karst landscape for millennia. There are many types of stone terraces, all with one main purpose to enhance and keep farmed soil from being eroded away. They can be round, parallel, interwoven (zigzag), built as large staircases on steep hills or in narrow passages, and anything in between. They enhance infiltration of rainwater into soil and keep moisture during hot dry summers. The terraces also prevent spread of wildfires which are common in hot dry Mediterranean climate. The ecological function of limestone drywalls and terraces is therefore invaluable and yet not well understood. Photo by Ognjen Bonacci.

Photo 3.33 Dry limestone wall for containing cattle in the village of Bratač, Nevesinje Municipality, Eastern Herzegovina. Photo by Natalija Samardžić.

Photo 3.34 "Velji ubao" waterworks in the village Mali Zalazi (Lovćen Mountain) at elevation 900m. Where there was water, there was a little bit of soil - squeezed as in a handful; from it the Montenegrins squeezed the heritage of their ancestors, created conditions for life and hope for their descendants. The aqueduct is at the contact zone of the Upper Jurassic and Upper Cretaceous limestones and is located on the south side of the village, just above the former road that went from Dobrota and Sv. Stasija (0 m above sea level) climbing along the Kotor Bay sides and the slopes of Kostilica, to the pass near the village of Mali Zalazi, and further towards the villages of Velji Zalazi, Njeguši and Cetinje. The aqueduct is walled with drywall in two uneven cylindrical rows of roughly hewn stone. The upper boundary wall protected the aqueduct which served primarily as the main rural watering hole for cattle. Photo by Gojko Nikolić.

Photo 3.35 Railroad Belgrade-Bar in the Lim River canyon between Gostun, Serbia and Bijelo Polje, Montenegro. Photo by Zoran Stevanović.

Photo 3.36 The Neretva River canyon, Bosnia and Herzegovina. Photo by Natalija Samardžić.

Photo 3.37 “Lokva” (groundwater eye) at the “Trolokva” locality, island of Brač, Croatia. Photo by Branimir Jukić.

Photo 3.38 Dry karst walls shape the karst landscape. In 2019, they were included in the serial UNESCO intangible heritage list as part of a serial nomination. The Karst is criss-crossed by several thousands of kilometres of such walls. Photo by Borut Lozej.

Photo 3.39 Highly karstified massive limestone on Prekornica Mountain in Montenegro, about 1 km southwest of the “Kula” peak (elevation 1927m). Photo by Milan Milivojević.

Photo 3.40 “Rocks on the Reovačke Rims” (Stijene na Reovačkim gredama), Orjen Mountain, Montenegro. This part of the rim is one of the most attractive features on the entire mountain. The rim separates two distinct areas of Orjen—Krivošije and Bijela gora (“White Mountain”). Photo by Igor Škero.

Photo 3.41 Rock landslide on “Škrila od Metlina” (Croatian island of Kornat) is a result of corrosion along the diastrome. Based on dating using cosmogenic nuclides, it was determined that it was activated 2400 ± 150 years ago. Photo by Dražen Perica.

Photo 3.42 "The window" carved in Jurassic limestone on the road to Veliki Štrbac, Miroč Mountain, Djerdap UNESCO Global Geopark. Photo by Nenad Radaković.

Photo 3.43 Marble quarry in Lipica, Slovenia. Photo by Blaž Kogovšek.

Photo 3.44 Tufa walls of “Leotar”, first grand hotel in Trebinje, Herzegovina built after WWII. Photo by Neven Kresic.

Photo 3.45 Quarry at one of the massive tufa terraces deposited by the *Taorska vrela* spring in western Serbia. Photo by Milorad Kličković.

Photo 3.46 Jama (Pit) Munižaba on southern Velebit Mountain is a legend of the Croatian subsurface. It is the first large pit explored in the Crnopac area and it fascinates with its dimensions. Several more deep and large pits were discovered nearby and are together forming the Crnopac system with the current length of interconnected channels exceeding 52 kilometers. Photo by Dinko Stopić.

Photo 3.1 *Limestone Drywall, Kras, Slovenia*. Borut Lozej

Photo 3.2 *Plitvice Lakes National Park, Croatia.* Neven Kresic

Photo 3.3 *Dinara Mountain, Croatia*. Branimir Jukić

Photo 3.4 *Big Collapse Doline, Škocjan, Slovenia*. Borut Lozej

Photo 3.5 *Red Lake, Imotski, Croatia*. Neven Kresic

Photo 3.6 *Veliki Samograd, Grabovica Plateau, Herzegovina*. Vinko Ljubas

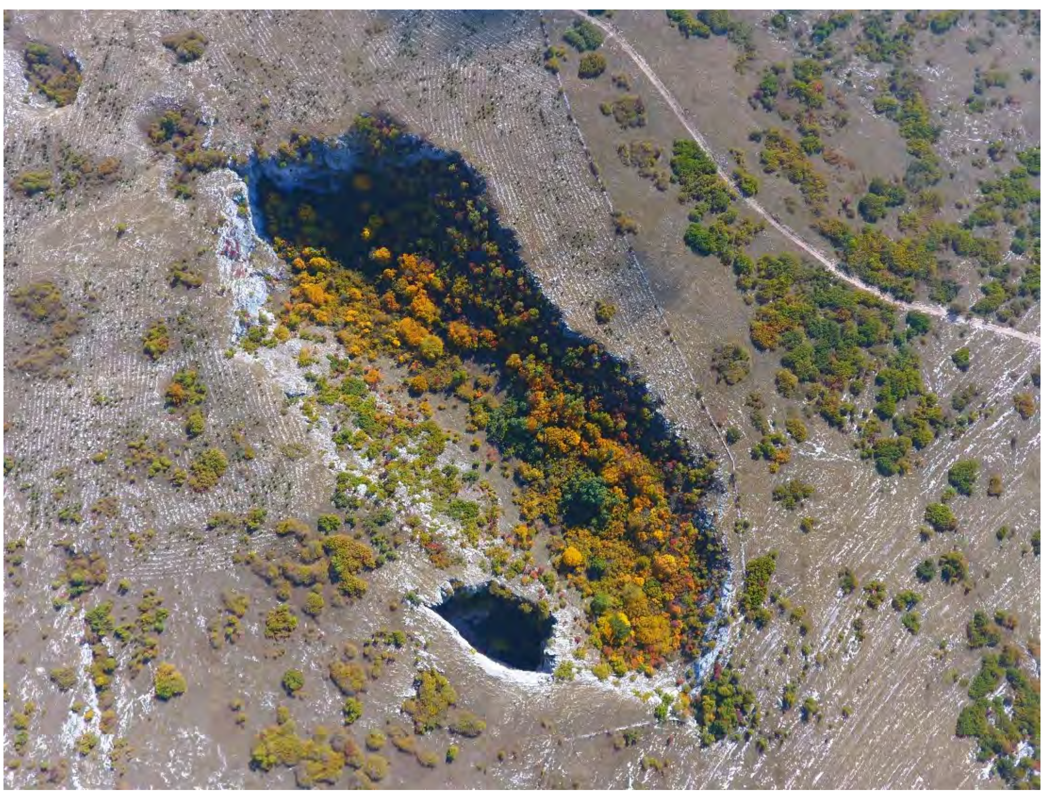


Photo 3.7 *Arnautovac, Grabovica Plateau, Herzegovina*. Vinko Ljubas

Photo 3.8 *Karuč Gulf, Skadar Lake, Montenegro*. Zoran Stevanović

Photo 3.9 *Durmitor National Park, Montenegro*. Predrag Stošić Peca

Photo 3.10 *Durmitor National Park, Montenegro*. Zoran Stevanović

Photo 3.11 *Tabula Traiana, Danube Gorge, Serbia*. Zoran Stevanović

Photo 3.12 *Smoke Tree (Cotinus Coggygria) and Limestone Drywall, Kras, Slovenia*. Borut Lozej

Photo 3.13 *Old Limestone Quarry, Herzegovina*. Neven Kresic

Photo 3.14 *Diocletian Palace, Split, Croatia*. Neven Kresic

Photo 3.15 *Split, Croatia*. Neven Kresic

Photo 3.16 *Mostar Old Town, Herzegovina*. Neven Kresic

Photo 3.17 *Stiniva Cove, Vis Island, Croatia*. Branimir Jukić

Photo 3.18 *Dubrovnik Old Town, Croatia*. Neven Kresic

Photo 3.19 *Jama (Pit) Šlapice, Velebit Mountain, Croatia*. Dinko Stopić

Photo 3.20 *Brezno (Pit) Trh Src, Snežnik Mountain, Slovenia*. Uroš Kunaver

Photo 3.21 *Carbonate Flysch, Durmitor Mountain, Montenegro*. Srdjan Marinčić

Photo 3.22 *Ammonite, Trnovački Durmitor, Montenegro*. Srdjan Marinčić

Photo 3.23 *Svetac Island, Croatia*. Srdjan Marinčić

Photo 3.24 *Sušac Island Lighthouse, Croatia*. Srdjan Marinčić

Photo 3.25 *Kornati Islands, Croatia*. Dražen Perica

Photo 3.26 *"Klinje" Dam, Mušnica River, Bosnia and Herzegovina*. Blaž Kogovšek

Photo 3.27 *Kamene Oči (Stone Eyes), Trebinje, Herzegovina*. Igor Škero

Photo 3.28 *Boljetinska River Gorge, Djerdap UNESCO Global Park, Serbia*. Aleksandra Maran Stevanović

Photo 3.29 *Pećina Ponor (Sink Cave), Pirot, Serbia*. Predrag Stošić Peca

Photo 3.30 *Mrtvica River Canyon, Montenegro*. Dobrislav Bajović Bajone

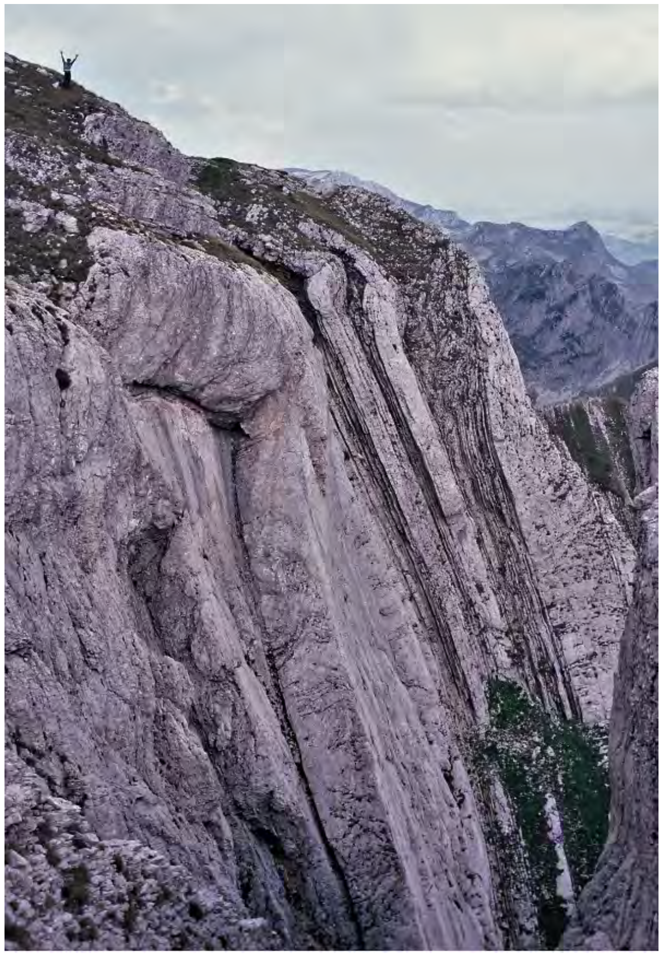


Photo 3.31 *Durmitor Mountain, Montenegro*. Neven Kresic

Photo 3.32 *Hvar Island, Croatia*. Ognjen Bonacci

Photo 3.33 *Limestone Drywall, Bratač, Nevesinje, Herzegovina*. Natalija Samardžić

Photo 3.34 *"Velji Ubao" Waterworks, Mali Zalazi Village, Lovćen Mountain, Montenegro*. Gojko Nikolić

Photo 3.35 *Lim River Canyon, Serbia*. Zoran Stevanović

Photo 3.36 *Neretva River Canyon, Herzegovina*. Natalija Samardžić

Photo 3.37 *"Lokva", Brač Island, Croatia*. Branimir Jukić

Photo 3.38 *Limestone Drywalls, Kras, Slovenia*. Borut Lozej

Photo 3.39 Prekornica Mountain, Montenegro. Milan Milivojević

Photo 3.40 *Orjen Mountain, Montenegro*. Igor Škero

Photo 3.41 *Škrila od Meltina, Kornati Islands, Croatia*. Dražen Perica

Photo 3.42 *Miroč Mountain, Djerdap UNESCO Global Park, Serbia*. Nenad Radaković

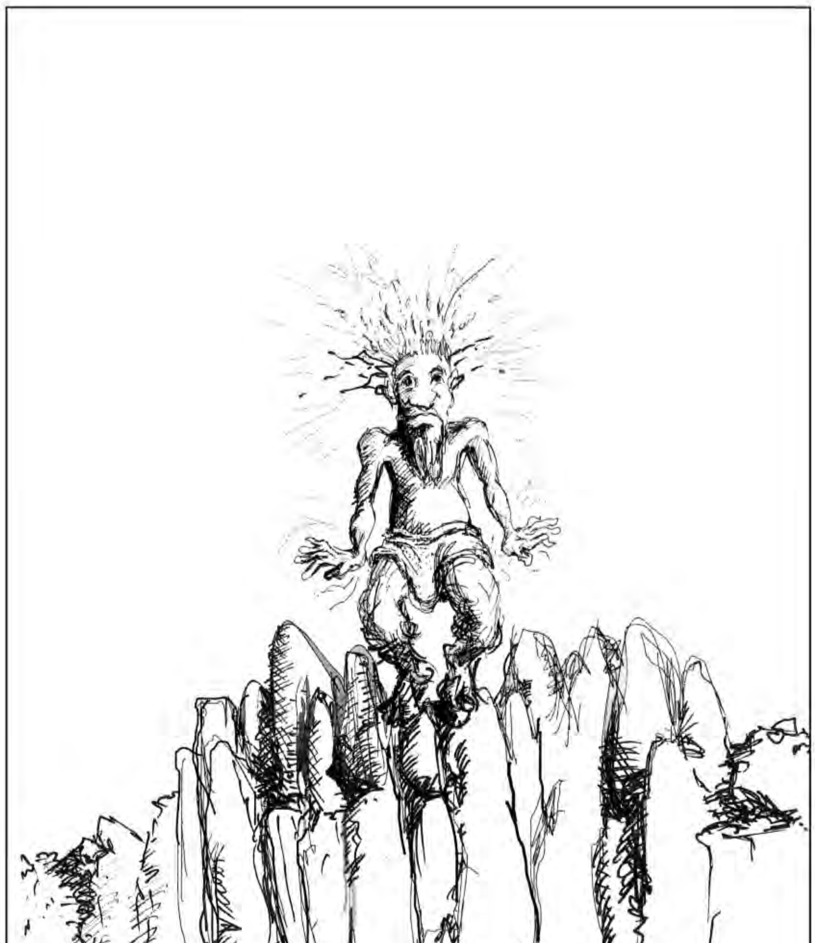
Photo 3.43 *Lipice Quarry, Slovenia*. Blaž Kogovšek

Photo 3.44 *Hotel Leotar, Trebinje, Herzegovina*. Neven Kresic

Photo 3.45 *Taorska Vrela Quarry, Serbia*. Milorad Kličković

Photo 3.46 *Jama (Pit) Munižaba, Crnopac, Velebit Mountain, Croatia.* Dinko Stopić

Rough Surfaces



4. Rough Surfaces

Karren is a German word generally used to describe channels or furrows, of various shapes, on limestone surfaces. The Serbo-Croatian synonym is *škrape* and the French word is *lapiés*. Regardless of the shape, which can vary quite a bit depending on specific mechanisms of their formation, the karren channels are separated by ridges, and are formed by corrosion (dissolution of limestone by flowing rainwater) often along joints or systems of joints over the initial, relatively smooth rock surface. This dissolution can also happen at random, over a jointless rock surface. If one were interested in describing specific forms of karren, one may opt to use additional terms such as *rillenkarren* (shallow channels separated by sharp ridges 2-3 centimeters apart); *rinnekarren* (flat-bottomed groves several centimeters apart); *kluftkarren* (joints enlarged by solution), *spitzkarren* (large deep groves extending down from steep spires or pinnacles), and quite a few more “karren” words thanks to a classification proposed by Alfred Bögli in 1960 (Kalklösung und Karrenbildung. In: Zeitschrift für Geomorphologie, Supplement Band 2, p. 4–21.) In any case, it is sufficient to refer to all these forms as *karren*, understanding that the word means a rough surface of the limestone rock in question.

Water does not dissolve limestone surfaces only in a linear way, creating channels and ridges (karren). This dissolution can be quite chaotic at first glance, resulting in a variety of shapes including holes, sometimes similar to Swiss cheese or a honeycomb for example. Parts of the rock may have slightly different mineral compositions, or local fissuring, or some other “heterogeneity”, enough to start a differential corrosion resulting in the uneven, rough surface, including pots and holes.

Thanks to the dissolution of limestone by water, not only the rock surfaces but often the entire karst landscape (“land surface”) can be described as “rough” because there is hardly anything smooth about them. Notable exceptions are landforms created by constantly flowing water, especially in the karst subsurface, as illustrated in Chapter 7. This highlights another aspect of the rough surfaces in karst – the question of scale or the viewpoint. Seen from the space, or simply a higher altitude (for example flying in a plane or using a drone camera), a karst landscape dotted with sinkholes can often resemble a rock surface seen from up close. For example, compare photos 4.8 and 4.13 with any number of closeup photos such as 4.3 (and use a little bit of imagination…)

Equally important as water in creating the rough-looking karst landscape are two other major forces – the tectonics, or folding, faulting and fracturing of the initial limestone sediment deposits, and the ongoing earthquakes which more than abound in the Lands of Karst. Together, they have had in the past and are continuing to break, shutter, “dissect”, bend, or otherwise shape the karst landscape to the point of creating what one may refer to as complete chaos at every imaginable scale. It is for this reason that the folk tales and legends in the Lands of Karst are full of giants, dragons, and other mythical creatures which playfully, or mischievously, or angrily, leave their mark on the surrounding landscape by scratching the rocks and the mountains, shattering them, or throwing them in every so direction. Humans, on their part, are constantly at awe what the Nature has created and like to embrace the miracle, sometimes by bringing and giving special places to fantastic rocks in front of their homes or as public monuments.

Photo Captions

Note: all photo captions are provided by the authors of individual photographs hence the diversity–some felt like sharing more information with the reader, some left the photographs speak for themselves, giving only the essentials.

Photo 4.1 A typical example of what the inhabitants across the Lands od Karst call "angry karst" (ljuti krš). Biokovo mountain near Makarska, Croatia. Photo by Neven Kresic.

Photo 4.2 Karren ("škrape" in Serbo-Croatian) on the Jurassic-Cretaceous limestone of Prekornica mountain in Montenegro, 1km southwest of the Kula Peak (1927m altitude). Photo by Milovan Milivojević.

Photo 4.3 Rillenkarren (solution flutes), southern Velebit mountain, Croatia. Photo by Dražen Perica.

Photo 4.4 Grikes below Krn mountain in Julian Alps, Slovenia. Rillenkarren and grikes are nicely exposed in many places with sparce vegetation. The photo was made during a 600 km long hike through Slovenia. Photo by Matej Blatnik.

Photo 4.5 Karst massif of Bolj features some of the most impressive karrenfeld on Durmitor mountain in Montenegro. Photo by Mihajlo Mandić Zis.

Photo 4.6 Small sharp karren on dissected blocks of highly karstified limestones above "Kaludjerovo oko" spring at the northern margin of Skadar Lake (Malo Blato Gulf). Photo by Zoran Stevanović.

Photo 4.7 High-resolution orthogonal aerial photograph, Eastern Herzegovina. Green areas surrounded by sparse vegetation are dolines (sinkholes) used mainly for pasture and local vegetable gardening. Courtesy of Professor Dr. Radmila Pavlović, Laboratory for Methods of Geologic Mapping (LMGK), University of Belgrade.

Photo 4.8 Astronaut optical color photograph of Biokovo mountain range on the Adriatic coast of Croatia, approximately 40 km across. Mega and large sinkholes dot this part of the classic Dinaric karst (see Photo 4.9 for a ground view). The town of Makarska is in the middle portion of the coastline. Bright white color at the mountain tops is from snow. The photograph was acquired on December 29, 2008, with a Nikon D2Xs digital camera fitted with a 180 mm lens. It is provided courtesy of the ISS Crew Earth Observations experiment and the Image Science & Analysis Laboratory, NASA Johnson Space Center.

Photo 4.9 Biokovo mountain in Croatia is dotted with large sinkholes like this one. Photo by Neven Kresic.

Photo 4.10 Sinkholes on Treskavica plateau in Herzegovina at elevation of about 2000m. The sinkhole density is up to 40 per square kilometer. The Treskavica karst aquifer, formed in the Triassic limestones, is drained by numerous springs along its perimeter which are issuing at the contact with the underlying low-permeable flysch sediments. Photo by Ferid Skopljak.

Photo 4.11 The karren field (karenfeld in German) and faulted limestone blocks in Karuč Bay of Skadar Lake, the largest lake in the Balkans, shared between Albania and Montenegro. The lake is formed in tectonic depression filled with fluvial and glacial sediments. Photo by Zoran Stevanović.

Photo 4.12 Life always finds its way… The agave plant (*Agave americana L.*; "century plant") growing from a crevice on a steep limestone surface with karren, the Croatian island of Šolta. Agave was introduced to the Adriatic from Mexico in the 16th century. Photo by Srdjan Marinčić.

Photo 4.13 View from a commercial flight Tivat, Montenegro–Belgrade, Serbia, 10 minutes after takeoff. Photo by Neven Kresic.

Photo 4.14 Semi-wild horses grazing on Biokovo mountain in Croatia. Photo by Neven Kresic.

Photo 4.15 Islet of Kamik in the Adriatic Vis Archipelago, Croatia. Photo by Branimir Jukić.

Photo 4.16 View of the Kornati archipelago in the Croatian Adriatic, now devoid of forests due to relentless logging over the centuries. The archipelago consists of 89 islands, many of them deserted or never inhabited. Photo by Srdjan Marinčić.

Photo 4.17 Rillenkarren on Mount Kanin, Slovenia, August 2020. Photo by Cyril Mayaud.

Photo 4.18 Karren in the Slovenian Alps. Photo by Blaž Kogovšek.

Photo 4.19 Rešeto Sink in Cerkniško Polje, Slovenia. Photo by Blaž Kogovšek.

Photo 4.20 Typical landscape with sinkholes, several tens of meters in diameter and about 10-15m deep, near town of Sjenica on Pešter karst plateau in southwestern Serbia. Pešter plateau, which continues to Montenegro, is one of the most promising areas for new speleological discoveries in Serbia. Photo by Mihajlo Mandić Zis.

Photo 4.21 Extensive karren on Kaženik mountain in Montenegro. Photo by Katarina Kosič Ficco.

Photo 4.22 In addition to karren, dissolution of limestone on Kaženik mountain in Montenegro has created many other spectacular karst landforms such as this one. Note (with a little effort and for scale) a human figure in blue shirt standing on the right-hand side at the base of the central column. Photo by Mike Ficco.

Photo 4.23 "A Ghost" from Giljeva mountain, near town of Sjenica, SW Serbia. Photo by Jelena Ćalić.

Photo 4.24 A typical Karst sight – a hollowed stone and a smoke tree. Photo by Borut Lozej.

Photo 4.25 Limestones of Majevica mountain, Bosnia. Photo by Dunja Josipović.

Photo 4.26 Mliječni Do, Durmitor mountain in Montenegro. Photo by Predrag Stošić Peca.

Photo 4.27 Runnels (deep solution grooves) formed in the Paleogene–Neogene breccias, Paklenica National Park, Croatia. Photo by Dražen Perica.

Photo 4.28 Dolines (sinkholes) in the Bojinac area, Velebit mountain, Croatia, at elevation 1110 m. Photo by Dražen Perica.

Photo 4.29 Landscape of the Kornati National Park in Croatia is mostly bare limestone karst with karrenfeld. It is dominated by limestone drywalls which delineate sheep pastures. Photo by Dražen Perica.

Photo 4.30 “Kamenica” (solution pan) is a small-scale geomorphological shape in karst formed by action of rainwater that falls on a monolithic soluble rock (limestone or dolomite) of suitable morphology for water retention. Over time, in the process of dissolution, a small initial “dent” is shaped into a bowl or a pan. The dimensions of “kamenica” are from a few centimeters to one meter in diameter, with depth up to 10 cm. In waterless terrains, such as Herzegovina, “kamenica” had a certain importance in the not so distant past. The people lived in poverty so even an empty bottle would be a pity to lose or break. In such circumstances “kamenica” had its value, because after a shower of rain and a day or two later, it would provide shepherds, foresters, and occasional travelers with some water (sometimes of not so good quality) so they can last through their day. However, someone who intended to quench thirst in a summer day often found an unpleasant surprise - there was no water, because both wild and domestic animals knew better than humans where they are located and even from a large distance by sense of smell could estimate whether the water awaits them. Only 40-50 years earlier, the inhabitants of a karst village knew of every “kamenica” in the vicinity. Stories about their locations were passed from generation to generation. Some smaller “kamenica” (up to 5-7 cm in diameter) can be seen on medieval "stećak" tombstones; this is an indicator of how much time is needed for the formation of such a geomorphological shape. “Kamenica” at the Pupoš location shown here is surrounded by numerous "stećak" tombstones waiting for a modern human creature to drink some water, sit on one of the "stećak", admire their perfect carving and decoration, and ask himself or herself: "Did anyone before me learn how to love and respect the ancestors?" Photo by Natalija Samardžić.

Photo 4.31 Almost naked karst with rare trees in northern part of the Slovenian Dinaric Karst. Photo by Borut Peric.

Photos 4.32 Karren in the North Velebit National Park, Croatia. Both photos by Dražen Perica.

Photo 4.33 Karren on Orjen mountain, Montenegro. Photo by Miroslav Marković.

Photo 4.34 Micro folds in limestone near village of Bratač in the Tucala area, Eastern Hercegovina. Photo by Natalija Samardžić.

Photo 4.35 Open and strangely shaped karst landscape in the northern part of Durmitor mountain in Montenegro is mostly used for pasturing today. Photo by Borut Peric.

Photo 4.36 Karren jungle on Maganik mountain, Montenegro. Photo by Dobrislav Bajović Bajone.

Photo 4.37 A rudimentary sinkhole (1.2m across) in rough limestone surface near Makarska, Croatia. Photo by Neven Kresic.

Photo 4.38 Smooth karren on Vranica mountain, Bosnia and Herzegovina. Photo by Ferid Skopljak.

Photo 4.1 *Biokovo Mountain, Makarska, Croatia*. Neven Kresic

Photo 4.2 *Prekornica Mountain, Montenegro*. Milovan Milivojević

Photo 4.3 *Velebit Mountain, Croatia*. Dražen Perica

Photo 4.4 *Krn Mountain, Julian Alps, Slovenia*. Matej Blatnik

Photo 4.5 *Bolj Massif, Durmitor, Montenegro*. Mihajlo Mandić Zis

Photo 4.6 *Northern Margin of Skadarsko Lake, Montenegro*. Zoran Stevanović

Photo 4.7 *Eastern Herzegovina*. Courtesy of Radmila Pavlović, LMGK

Photo 4.8 *Biokovo Mountain and Makarska Riviera, Croatia*. Courtesy of NASA

Photo 4.9 *Biokovo Mountain, Croatia*. Neven Kresic

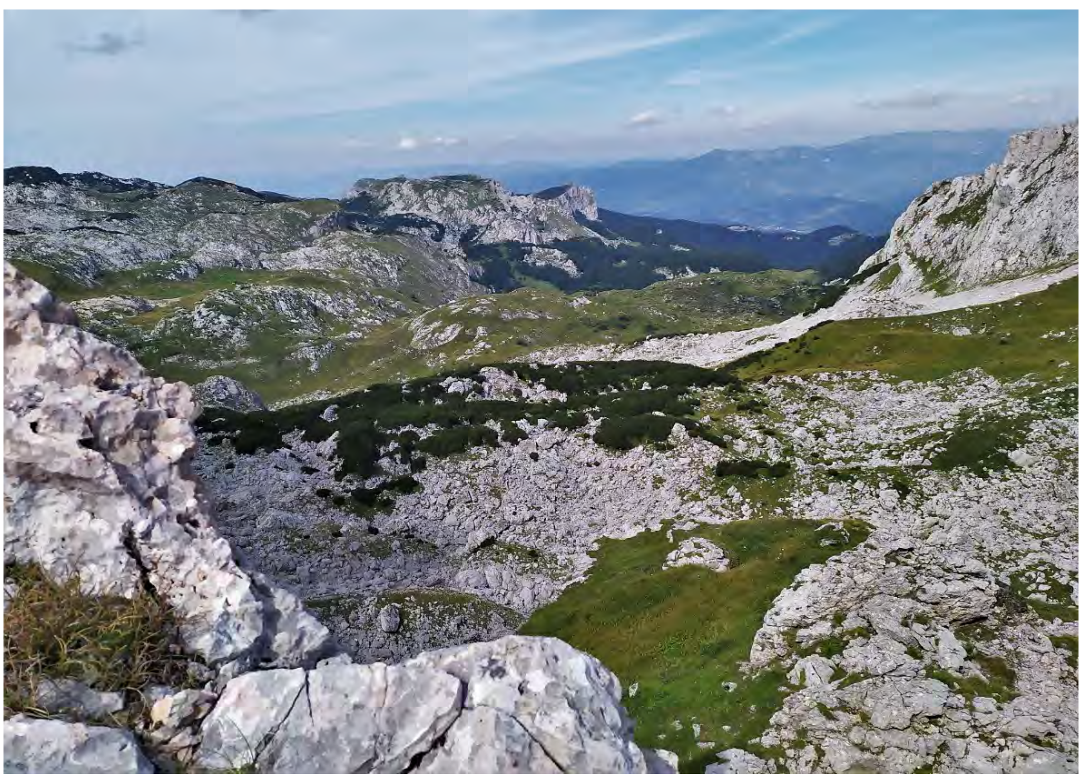


Photo 4.10 *Treskavica Mountain, Bosnia and Herzegovina*. Ferid Skopljak

Photo 4.11 *Karuč Bay, Skadarsko Lake, Montenegro*. Zoran Stevanović

Photo 4.12 *Šolta Island, Croatia*. Srdjan Marinčić

Photo 4.13 *High Karst of Montenegro*. Neven Kresic

Photo 4.14 *Biokovo Mountain, Croatia*. Neven Kresic

Photo 4.15 *Kamik Islet, Croatia*. Branimir Jukić

Photo 4.16 *Kornati Archipelago, Croatia*. Srdjan Marinčić

Photo 4.17 *Kanin Mountain, Slovenia*. Cyril Mayaud

Photo 4.18 *Slovenian Alps*. Blaž Kogovšek

Photo 4.19 *Cerkniško Polje, Slovenia*. Blaž Kogovšek

Photo 4.20 *Pešter Karst Plateau, Sjenica, Serbia*. Mihajlo Mandić Zis

Photo 4.21 *Kaženik Mountain, Montenegro*. Mike Ficco

Photo 4.22 *Kaženik Mountain, Montenegro*. Mike Ficco

Photo 4.23 *Giljeva Mountain, Serbia*. Jelena Ćalić

Photo 4.24 *Classic Karst, Slovenia*. Borut Lozej

Photo 4.25 *Majevica Mountain, Bosnia*. Photo by Dunja Josipović

Photo 4.26 *Durmitor National Park, Montenegro*. Predrag Stošić Peca

Photo 4.27 *Paklenica National Park, Croatia*. Dražen Perica

Photo 4.28 *Velebit Mountain, Croatia*. Dražen Perica

Photo 4.29 *Kornati National Park, Croatia*. Dražen Perica

Photo 4.30 *Pupoš Village, Herzegovina*. Natalija Samardžić

Photo 4.31 *Dinaric Karst, Northern Slovenia*. Borut Peric

Photos 4.32 *North Velebit National Park, Croatia*. Dražen Perica

Photo 4.33 *Orjen Mountain, Montenegro.* Miroslav Miroslav Marković

Photo 4.34 *Bratač Village, Herzegovina*. Natalija Samardžić

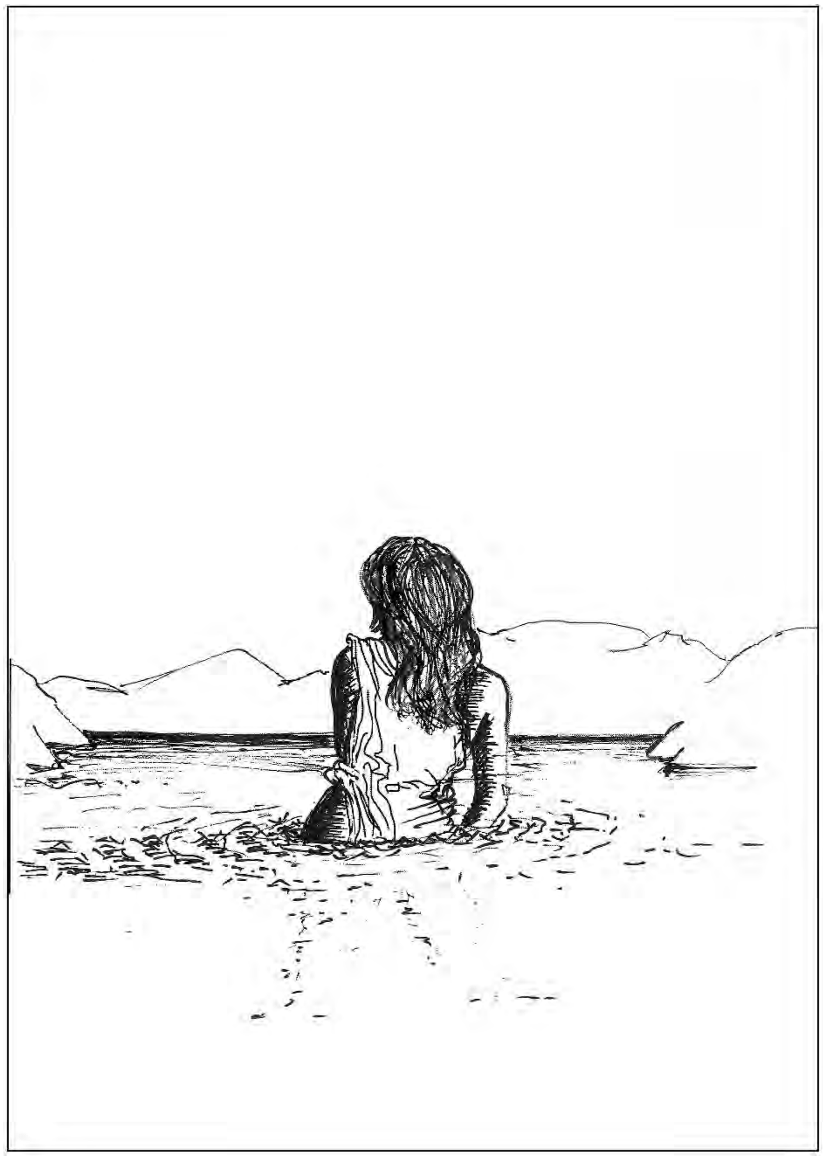
Photo 4.35 *Piva Plateau, North Durmitor Mountain, Montenegro*. Borut Peric

Photo 4.36 *Maganik Mountain, Montenegro.* Dobrislav Bajović Bajone

Photo 4.37 *Makarska, Croatia*. Neven Kresic

Photo 4.38 *Vranica Mountain, Bosnia and Herzegovina*. Ferid Skopljak

Fountains of Life



5. Fountains of Life

"Life is water" and "Water is life": there is no difference between these two common phrases. This is remarkably important in arid regions and regions with a shortage of water. Do Alpine, Dinaric and Carpathian karst areas belong to this group? Well, yes and no. This is one of the richest regions in Europe in total annual precipitation and water availability per capita. In several countries of Dinaric karst each citizen has more than 5000 m^3 of water available annually, the amount which is ten times higher than the level which in certain UN documents is indicated as limit for "water stressed countries". In Montenegro, in an average hydrological year, each inhabitant has more than 20000 m^3 of water available but utilizes just 1.2 % of this volume (FAO/AQUASTAT 2016, Stevanović 2021). In Bosnia and Herzegovina, the utilization rate is even lower, below 1%. In Croatia, this rate is higher but still at less than 5% of water available in one hydrological cycle. In contrast, there is a pronounced shortage of water on karst mountains and in many places along the Adriatic Coast and on the islands during the summer-early autumn season. In virtually all the mountains of the Lands of Karst, high above sea level and the erosional base, the groundwater table is often very deep, with no available surface waters due to the rapid infiltration of rainfall into the karst subsurface. As a result, the local population and ecosystems often suffer from long periods of drought.

The large karstic springs as "Fountains of Life", but also natural wonders, are numerous across the Lands of Karst and ensure a potable water supply from time immemorial. During Roman times, many cities were established in the vicinity of springs as Romans preferred spring water to any other source of water. For example, the three largest cities on the Dalmatian coast in Croatia are in this group: Rijeka, Split, and Dubrovnik, as well as Kotor in Montenegro.

The *Rižana* spring in Slovenia supplies water for more than 120000 people. *Jadro* spring is the main source of water for Split. It drains the thick Cretaceous limestones of the Mosor mountain. The main spring outlet is at the contact point with impervious Eocene flysch sediments. This is also the case with many other springs along the Adriatic coastline. *Vrelo Omble* is the largest spring in southern Croatia and supplies the city of Dubrovnik. *Vrelo Bune* spring in Blagaj, Bosnia and Herzegovina is a very attractive site for many tourists and visitors mainly because of its high discharge, from minimal 3 m^3/s to several hundred m^3/s. Numerous sublacustrine springs locally called "eyes" are registered along the rim of Skadar Lake in Montenegro. It is estimated that the total average discharge of all Montenegrin submerged springs of the Lake exceeds 40 m^3/s. In the littoral karst of Montenegro, the most important springs are those along the coastline of Boka Kotorska Bay. Some of those springs even dry out completely during summer or function as submarine springs – *vruljas* while after intensive rainfall or at the end of winter some of them can discharge well over 100 m^3/s. *Sopot* and *Spila* springs are amongst most spectacular such springs in the world, with their photographs featured in several classic textbooks on karst and hydrogeology.

Vrelo Mlave spring at the northern edge of the Beljanica massif in Serbia is the largest spring of the Carpathian karst. *Vrelo Perućac* near the town of Bajina Bašta is the largest karst spring in the Dinarides of western Serbia, supplying water for one of the largest trout fisheries in the country. *St. Naum Spring* at the Ohrid Lake shore near the border with Albania has an average discharge of 5.5 m^3/s mostly fed by sinking waters of the Prespa Lake.

In the Dinaric region of former Yugoslavia there are 230 springs with a minimal discharge of over 100 L/s, while about 100 springs have a minimal discharge of over 500 L/s (Komatina 1984). The World Karst Aquifer

Maps (WOKAM) project confirms that the region has the densest concentration of large springs, with minimal discharge exceeding 2 m^3/s, in the world.

Four capital cities of the Western Balkans receive drinking water from the karstic aquifers: Sarajevo (Bosnia & Herzegovina) Podgorica (Montenegro), Skopje (North Macedonia), and Tirana in the neighboring Albania. The springs are of crucial importance not only for ensuring the water supply for the local population and dependent ecosystems, but also for industry and tourism. However, a large variation of discharge of karst springs throughout the year, with lowest discharge almost always occurring during periods of peak demand, in summer, causes water shortage in many areas and restrictions in water supply imposed by local waterworks.

In contrast to water shortage, the large discharge of the springs and rivers during winter or springtime causes frequent seasonal flooding of cultivated land in valleys and karst poljes. This was the main reason why large projects to regulate spring and river flows were initiated in all the countries in the region after WWII and many of these were implemented during the 1960s and 1970s. Today, major karstic rivers are dammed, and their waters are utilized by hydropower plants. Large dams have been built on the Cetina, Krka, Lika, Gacka, Zrmanja, Neretva, Trebišnjica, and Zeta rivers which belong to the Adriatic watershed, and Kupa, Drina and Piva rivers which belong to the Danube (Black Sea) watershed.

When it comes to water extraction, an important requirement for sustainable water resources management is to define water demands of dependent eco-systems. The springs and their waters are inhabited by rich biocenoses, which include aquatic vegetation with rare and protected plants, endemic fish species, large colonies of birds, various amphibians, and reptiles. A large part of the watercourses in the karst areas start their flow at karst springs but diverting most of these waters for public water supply or irrigation may cause a deficit of water at the springs and downstream, particularly during the dry summer periods when the demand for water is the highest.

Former Yugoslavia is at the center of the Balkans where in the 1990s new states and boundaries have been created. This gave rise to many questions regarding common and optimal water strategy in the region. However, during the last decade, many joint (“transboundary”) initiatives and actions have been completed and now provide an optimistic ambience for future work and cooperation.

Photo captions

All photo captions are provided by the authors of individual photographs hence the diversity–some felt like sharing more information with the reader, some left the photographs speak for themselves, giving only the essentials.

Note*:* *Vrelo* is Slavic word for a large spring issuing from karst. Typically, *vrelo* is source of a river and the spring’s name often refers to the name of the river. For example, V*relo Bune* means “Spring of River Buna.” Sometimes, the name is used alone, without reference to the river, and may or may not include word *vrelo*. However, local population understands that the spring is indeed source of a river. For example, *Krupajsko Vrelo* is a stand-alone term designating a remarkable, famous spring. Rarely, locals would also use term *Vrelo Krupaje* which means “Spring of River Krupaja.” General Slavic term for any spring is *izvor*. It is often used instead of *vrelo*, with the same rules.

Photo 5.1 Vauclusian karst spring of the Cetina river in Vrlika village, Croatia with estimated depth of 115m. It is called the “Most beautiful eye of Dalmatia” and *Glavaš* (which means “Head“). Orthodox church of The Ascension was built above the spring in 1939. Photo by Branimir Jukić.

Photo 5.2 Main spring of Bosna river (*Vrelo Bosne*) in Ilidža near Sarajevo, the capital of Bosnia and Herzegovina. This is group of diffuse springs issuing from the Triassic limestones of the Igman karst massif. Their water is partially used for water supply of Sarajevo. Photo by Natalija Samardžić.

Photo 5.3 Spring of Buna river (*Vrelo Bune*) near Mostar, Bosnia and Herzegovina is one of the largest in the world, with maximum flow rate of several hundred cubic meter per second. Photo by Neven Kresic.

Photo 5.4 *Vrelo Grze* at the foothill of Kučaj Mountain in eastern Serbia. This is gravity spring with highly variable discharge (the ratio of minimum and maximum discharge is 1:50.) Photo by Saša Milanović.

Photo 5.5 *Dubci* submarine spring near the town of Brela on the Dalmatian coast, Croatia. Photo by Neven Kresic.

Photo 5.6 Karst spring and waterfall *Boka* in Slovenia. With 90 m of height, waterfall Boka is one of the highest and most picturesque waterfalls in Slovenia. About 30 m before the waterfall is an overflow spring, draining Kanin Plateau. During dry season the spring ceases to flow whereas during wet season it discharges several tens of cubic meters per second. The photograph is taken from a drone and shows the spring and the and the waterfall during low waters. To reach the spring and top of the waterfall there is a nice scenic 45 min long hike and it is worth the effort. Photo by Matej Blatnik.

Photo 5.7 Temporary spring *Kužica* at intermittent lake *Palško jezero* in Slovenia. Kužica discharges from a cave at the rim of the lake Palško jezero. During dry season it acts as a sink (*ponor*). Photo by Matej Blatnik.

Photo 5.8 Spring of Mlava river (*Vrelo Mlave*), the largest karst spring in the Serbian Carpathians with the maximum discharge of 20 cubic meter per second. This ascending, vauclusian spring is the main drain of a large karst aquifer formed in the Lower Cretaceous limestones. The spring is in the foothill of Beljanica mountain, at the periphery of the city of Žagubica. Jovan Cvijić described the spring in detail in 1895. Of particular interest is his description of bathymetry of the spring’s deep syphon. Cvijić constructed a small raft and used a cannon ball for systematic measuring of the spring’s lake depth. Cvijić also provided important data on the spring’s regime in the aftermath of a strong earthquake that happened on 27 March 1893. By establishing a telegraph connection with the chief of the railway station in Žagubica, he provided instructions how to measure water turbidity and temperature and estimate discharge during on-going after shock tremors. He then continually compared these measurements with the seismograph recordings at the seismic station located in Belgrade. The speleo diving conducted in 1980s found that depth of the siphon is greater than 75m, which is three times deeper than what Cvijić had been able to measure; the cannonball used by Cvijić apparently could not pass a ledge (“knee”) observed by the divers. Photo by Branislav Petrović.

Photo 5.9 Krupaja spring (*Krupajsko vrelo*) at north-western margin of the Beljanica mountain. This is a strong ascending spring issuing from a submerged cave carved in the Lower Cretaceous limestones. In the foothills of Beljanica, the karst aquifer is over thrusted by the Permian red sandstones which caused creation of a very deep, almost vertical siphon explored to a depth of 133m. Near this freshwater spring there is a small thermal spring with water temperature of 26ºC. Photo by Ljiljana Vasić.

Photo 5.10 *Potpećko vrelo* karst spring near the city of Užice in western Serbia. The spring is issuing from the Triassic limestones and cave of the same name which has the largest entrance of all caves in the Dinaric karst of Serbia. The height of the entrance is 50m. The cave is protected as a Natural Monument. Photo by Zoran Stevanović.

Photo 5.11 Taorska springs (*Taorska vrela*) issues from the Cretaceous limestones near Kosjerić, western Serbia. There are numerous cascades on thick tufa deposits, and 12 water mills, now inactive, that used the spring water in the past. Photo by Dragovan Stojadinović-Sule.

Photo 5.12 Paleozoic marbles form a plateau on the Šar mountain in North Macedonia. An intermittent surface watercourse on the plateau sinks and after an underground flow of about 500m appears as an intermittent spring at the vertical face of layered marbles. Photo by Zlatko Ilijovski.

Photo 5.13 60-meter high Savica waterfall (*Slap Savice* in Slovene), the source of *Savica* river in north-western Slovenia. The spring drains an extensive karst aquifer which is partially recharged by sinking waters of the Triglav mountain lakes valley. Savica ("little Sava") flows into *Bohinjsko jezero* lake and flows out of it as *Sava bohinjka*, eventually merging with *Sava dolinka* to form *Sava*, the river with the largest drainage area entirely within the Lands of Karst. The confluence of rivers Sava and Danube is in Belgrade, Serbia. Photo by Zoran Stevanović.

Photo 5.14 Aerial photograph of *Vrelo Omble* spring and *Rijeka Dubrovačka* bay (submerged valley of a former river fed by the spring), near Dubrovnik, Croatia. See also photos 5.15 and 5.16. Photo by Neno Kukurić.

Photo 5.15 View of *Rijeka Dubrovačka* (submerged valley of a river, now bay) from above *Ombla* spring to the confluence with the Adriatic Sea. The entire bay has been declared a protected landscape. *Vilina špilja* cave at the spring is an underground biodiversity hotspot with 67 species of underground animals (stigobionts and troglobionts including an endemic troglobitic arthropod *Niphargus hercegoviensis*), rich bat community, giant water bug *Lethocerus cordofanus*, and endemic fish *Phoxinellus ghethaldii*. Freshwater turtle *Mauremys rivulata* inhabits the short course of the *Ombla* river before it empties into the bay. The photograph is taken from the top of a karst massif above the spring, close to the international border between Croatia and Bosnia & Herzegovina. The spring is in the lower right corner. Photo by Ivo Lučić.

Photo 5.16 *Vrelo Omble* is the largest spring on the coastal part of the Dinaric Karst. It is about 135 meters deep, issuing at the base of a limestone hill shaped like an amphitheater, at the end of a narrow bay (submerged stream valley) called *Rijeka Dubrovačka* (Dubrovnik River) shown on the previous two photographs. In its natural state, the spring had an average flow of 33 m^3/s, which is reduced to 24 m^3/s by hydropower interventions in the Trebišnjica River basin. Ombla is also a hotspot of subterranean biodiversity, one of the richest in the world. The long bay became one of the first objects and non-sacral themes of the Dubrovnik Renaissance poetry. The poets associated it with an ideal landscape. Numerous mansions of the Dubrovnik lords were built along the bay at the time. The landscape and the magic of the bay were significantly altered by the passage of the main

Adriatic highway in the 1960s. Its future is uncertain due to constant pressure from development. Photo by Ivo Lučić.

Photo 5.17 Spring issuing from the *Petnica* cave near the city of Valjevo drains part of the Lelić Karst in western Serbia. The cave and the spring are near the renowned Science Center Petnica where talented high school students from all Lands of Karst attended multi-day sessions in sciences including geology and hydrogeology. A life-long Head of the Geology Department, hydrogeologist Radisav Golubović, is featured on the photo for scale. Photo by Neven Kresic.

Photo 5.18 Entrance to the *Planinska jama* cave– spring of the Unica river in Slovenia. With the range of the discharge between 0.1 to almost 100 m^3/s and mean value of 25 m^3/s, the spring of the Unica River is one of the largest in the Lands of Karst. The water comes out of more than 6 km long cave *Planiska jama*, with a large underground confluence of rivers Rak and Pivka. Photo by Neven Kresic.

Photo 5.19 *Ostrovo* spring near St. Naum, the largest spring in North Macedonia. Photo by Dragan Kolčakovski.

Photo 5.20 Aerial photograph of *Vrelo Ričine* spring in the Buško blato depression (extension of Livanjsko polje), Bosnia and Herzegovina. This spring is partially fed by waters of the sinking stream Šujica, which flows through Duvanjsko polje. Photo by Vinko Ljubas.

Photo 5.21 Spring pool (locally called “oko” which means eye) used for watering cattle. Tomislavgrad municipality, western Herzegovina. Photo by Vinko Ljubas.

Photo 5.22 *Bijeli Nerini* group of springs at northwestern foothills of the Maganik mountain in Montenegro. The springs are issuing from large blocks of limestones and dolomites at the right bank of the Mrtvica River. The maximum discharge of the springs is over 2 m^3/s. Photo by Golub Ćulafić.

Photo 5.23 *Vrelo Sopotnice* spring, located high above the Lim river in western Serbia, forms massive tufa deposits and some of the most breathtaking waterfalls in the Dinarides. It is a protected Natural Monument. Photo by Vojislav Ilić.

Photo 5.24 PhD hydrogeology student Oleksandra Pedchenko in front of the town of Ston public fountain built in the 16th century by Dubrovnik Republic. Photo taken by unknown author during field trip of the 2017 Conference of the International Association of Hydrogeologists held in Dubrovnik, Croatia.

Photo 5.25 Old intake of a small spring in *Kučka korita*, Montenegro. It is located several kilometers away from the village of Kučka korita and can be accessed only via a very rugged road. Photo by Mike Ficco.

Photo 5.26 *Vrulja Plantaža* – a submarine karst spring within Paklenica National Park near the city of Starigrad, coast of Dalmatia, Croatia. Photo by Dražen Perica.

Photo 5.27 *Majerov izvor* (Mayer's Spring) is the most important source of the Gacka river. It is a typical Vauclusian karst spring. Photo by Dražen Perica.

Photo 5.28 Vauclusian karst spring at the entrance to Ropojan valley in the Prokletije mountains, 6 km south of the town of Gusinje in Montenegro, about 4.5 km from the Albanian border. Photo by Milovan Milivojević.

Photo 5.29 View from the *Cathedral Cave* in Bukovica, Bosnia and Herzegovina. During Ottoman occupation, the cave was used for religious purposes. Photo by Vinko Ljubas.

Photo 5.30 Krušnica spring (*Vrelo Krušnice*) some 5 km away from the town of Bosanska Krupa, Bosnia and Herzegovina. Krušnica river is just 6,5 km long before its confluence with the Una River. Photo Petar Begović.

Photo 5.31 Krušćica spring (*Vrelo Krušćice*) at the foothill of Vranica mountain is used for water supply of the city of Bugojno in Bosnia and Herzegovina. It has been extensively explored by speleo divers. Photo by Petar Begović.

Photo 5.32 *Vrelo Sopot* spring in Boka Kotorska Bay near the town of Risan, Montenegro. The upper spring outlet, hydrologically active only during periods of major rainfall on the heavily karstified Orjen mountain, is a cave 20 m above sea level, whereas two main outlets, always active, are submerged at depths of 28 m and 36 m below sea level (Milanović, S., 2007). Depending on the saturation level, but commonly after 2-3 days, the upper cave outlet is activated, producing enormous discharge of well over 150 m^3/s, one of the world's largest. Photo by Saša Milanović.

Photo 5.33 *Bolje sestre* karst spring, one of the most powerful sublacustrine (submerged) karst springs located in the Malo Blato Gulf of the Skadar Lake. The spring was explored in 2007-2009 and has been utilized for water supply of the Montenegrin coast since 2010. The design capacity of the waterworks is 1.6 m^3/s and the design length of water mains is 140 km. This centralized system and the spring finally solved the 30-year long problem of securing enough drinking water for the coastal population and rapidly growing tourism. A challenging task of preventing mixing of fresh karst groundwater and the lake water at the intake was solved by building a coffer dam and mobile rubber gate operated by two compressors. The system maintains a higher water level inside the intake than in the lake (Stevanović, 2015). The cost of the project, which is often called "Project which has changed Montenegro", is around 140 million euro. It is considered the largest water supply project from karst in the entire Mediterranean basin in the last 50 years. *Bolje sestre* spring is on the list of 150 most important springs of the world (WOKAM-UNESCO; Goldscheider et al. 2020). Photo courtesy of Regional Waterworks of Montenegro Coast.

Photo 5.34 *Beli izvor* ("White Spring"). This jewel of pristine and fast-flowing water is in the vicinity of the large copper mining center Majdanpek in eastern Serbia. The spring is inside boundaries of the Djerdap UNESCO Global Geopark and is characterized by thick tufa deposits which create numerous high cascades in the riverbed. Photo by Dragan Bosnić.

Photo 5.35 *Opačac*, the largest spring of the Vrljika river in Croatia. It is captured for water supply of the *Imotska krajina* province. Photo by Branimir Jukić.

Photo 5.36 *Dva oka* spring (Spring of Two Eyes) of the Vrljika river near Imotski, Croatia. Photo by Branimir Jukić.

Photos 5.37 *Veliko vrelo* spring (Big Spring) at the foothill of Beljanica mountain, eastern Serbia. Couple hundred yards after the source, the surface water stream formed by the spring falls over massive tufa deposits. The area of the spring and the waterfall are designated nature preserve. Photo by Neven Kresic.

Photo 5.38 *Crno vrelo* (Black Spring). Deep siphonal spring some 25 km away from the city of Mostar in Bosnia and Herzegovina. It was explored by French and Bosnian speleo diving teams to a depth of 85 m. Photo by Saša Milanović.

Photo 5.39 *Sušec* waterfall is an occasional kart spring in south Slovenia below *Snežnik* Mountain. This intermittent spring starts flowing soon after moderate rainfall. It is a tributary to the Reka river that flows to Škocjan Caves. Photo by Borut Peric.

Photo 5.40 *Zaslapnica* – intermittent spring in the 50-meter-deep limestone canyon under the cliff, accessible only by a path carved in the rock. At certain places it is very dangerous to walk through. The spring is captured and supplies the village of Zaslap in Montenegro by gravity conveyance. Photo by Milan Vlahović.

Photo 5.41 *Bukovica* spring on Durmitor mountain, Montenegro. Photo by Vojislav Ilić.

Photo 5.42 *Jadro* spring captured for water supply of Split, the largest Dalmatian city on the Adriatic coast, Croatia. The spring was first captured by the Romans for water supply of the Diocletian Palace, built by Emperor Diocletian as his retirement home (see Photo 10.1). Photo by Zoran Stevanović.

Photo 5.1 *Vrelo Cetine, Croatia*. Branimir Jukić

Photo 5.2 *Vrelo Bosne, Sarajevo, Bosnia and Herzegovina*. Natalija Samardžić

Photo 5.3 *Vrelo Bune, Bosnia and Herzegovina*. Neven Kresic

Photo 5.4 *Vrelo Grze, Serbia*. Saša Milanović

Photo 5.5 *Vrulja Dubci Submarine Spring, Brela, Croatia*. Neven Kresic

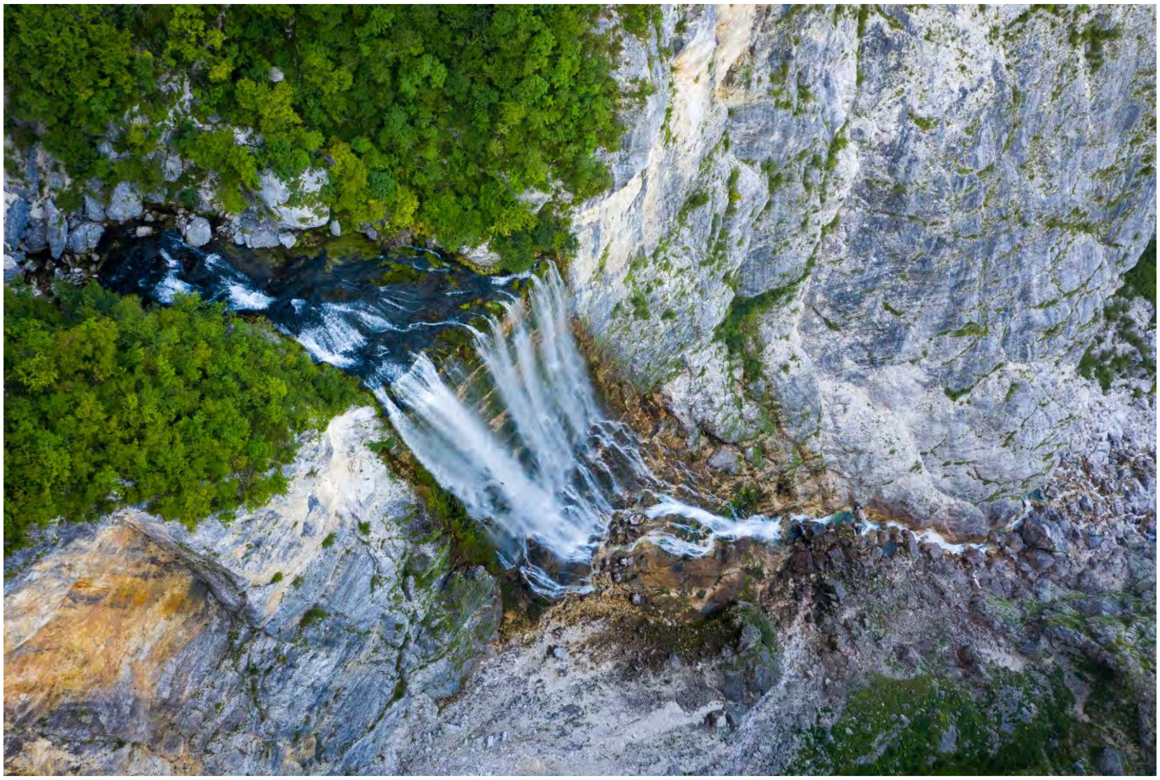


Photo 5.6 *Boka Spring and Waterfall, Slovenia*. Matej Blatnik

Photo 5.7 *Kužica Spring, Palško Lake, Slovenia*. Matej Blatnik

Photo 5.8 *Vrelo Mlave, Serbia*. Branislav Petrović

Photo 5.9 *Krupajsko Vrelo, Serbia*. Ljiljana Vasić

Photo 5.10 *Vrelo Potpeć, Serbia*. Zoran Stevanović

Photo 5.11 *Taorska Vrela, Serbia*. Dragovan Stojadinović-Sule

Photo 5.12 *Spring on Šar Mountain, North Macedonia*. Zlatko Ilijovski

Photo 5.13 *Savica River Spring, Slovenia*. Zoran Stevanović

Photo 5.14 *Vrelo Omble and Popovo Polje, Croatia amd Herzegovina*. Neno Kukurić

Photo 5.15 *Dubrovačka Rijeka and Vrelo Omble, Dubrovnik, Croatia.* Ivo Lučić

Photo 5.16 *Vrelo Omble, Dubrovnik, Croatia*. Ivo Lučić

Photo 5.17 *Petničko Vrelo, Serbia.* Neven Kresic

Photo 5.18 *Unica River Spring, Slovenia*. Neven Kresic

Photo 5.19 *Ostrovo Spring, North Macedonia*. Dragan Kolčakovski

Photo 5.20 *Vrelo Ričine, Buško Blato, Bosnia and Herzegovina*. Vinko Ljubas

Photo 5.21 *Oko Spring, Tomislavgrad, Bosnia and Herzegovina*. Vinko Ljubas

Photos 5.22 *Bijeli Nerini Group of Springs, Maganik, Montenegro*. Golub Ćulafić

Photo 5.23 *Vrelo Sopotnice, Serbia*. Vojislav Ilić

Photo 5.24 *Town of Ston Public Fountain, Croatia*. Unknown

Photo 5.25 *Spring at Kučka Korita, Montenegro*. Mike Ficco

Photo 5.26 *Vrulja Plantaža Submarine Spring, Croatia*. Dražen Perica

Photo 5.27 *Majerovo Vrelo, Gacka River, Croatia*. Dražen Perica

Photo 5.28 *Vauclusian Spring, Ropojan Valley, Montenegro*. Milovan Milivojević

Photo 5.29 *Cathedral Cave Spring, Bukovica, Bosnia and Herzegovina*. Vinko Ljubas

Photo 5.30 *Vrelo Krušnice, Bosanska Krupa, Bosnia and Herzegovina*. Petar Begović

Photo 5.31 *Vrelo Kruščice, Bugojno, Bosnia and Herzegovina*. Petar Begović

Photo 5.32 *Vrelo Sopot, Boka Kotorska Bay, Montenegro*. Saša Milanović

Photo 5.33 *Bolje Sestre Spring*. Courtesy of Regional Waterworks of Montenegro Coast

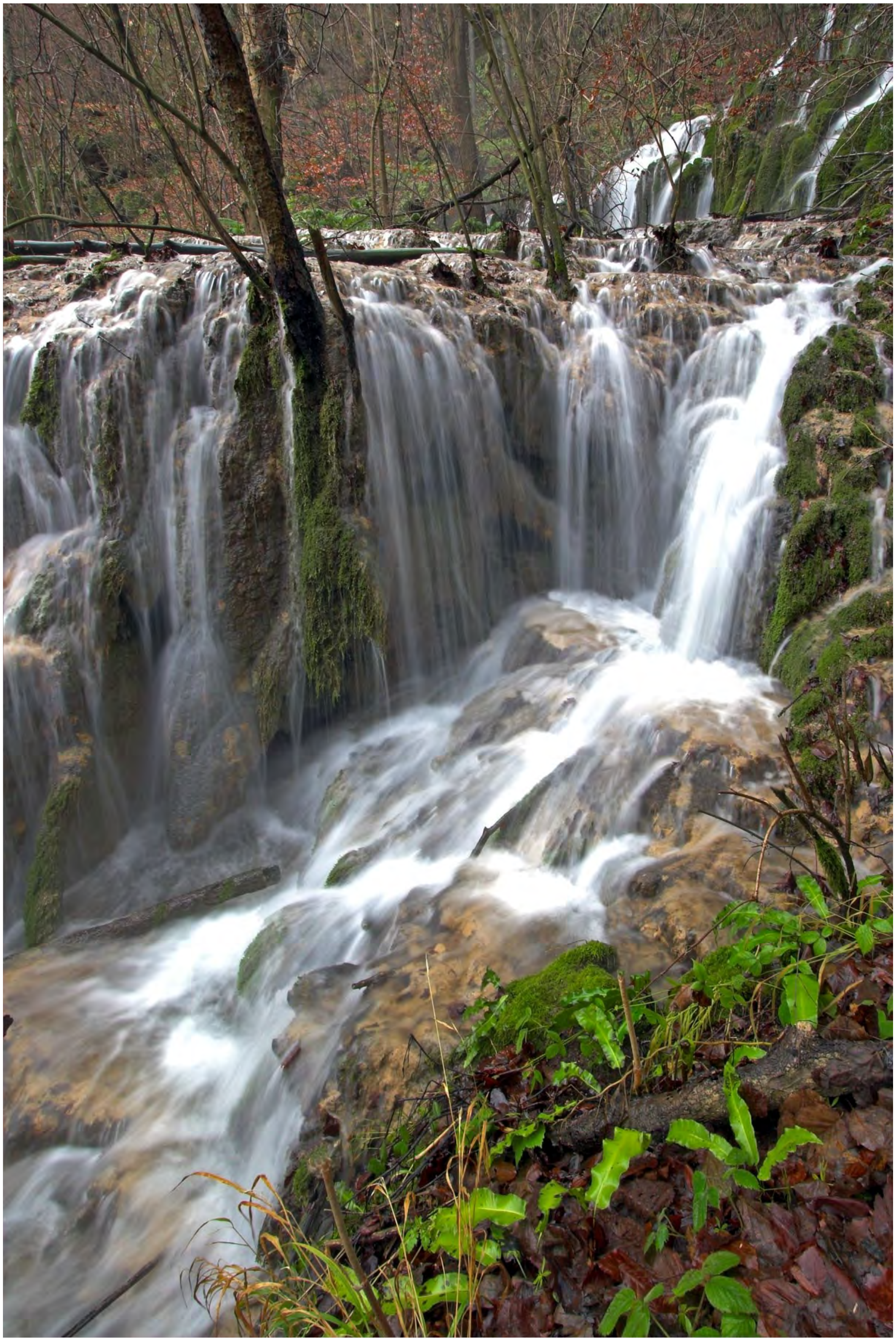
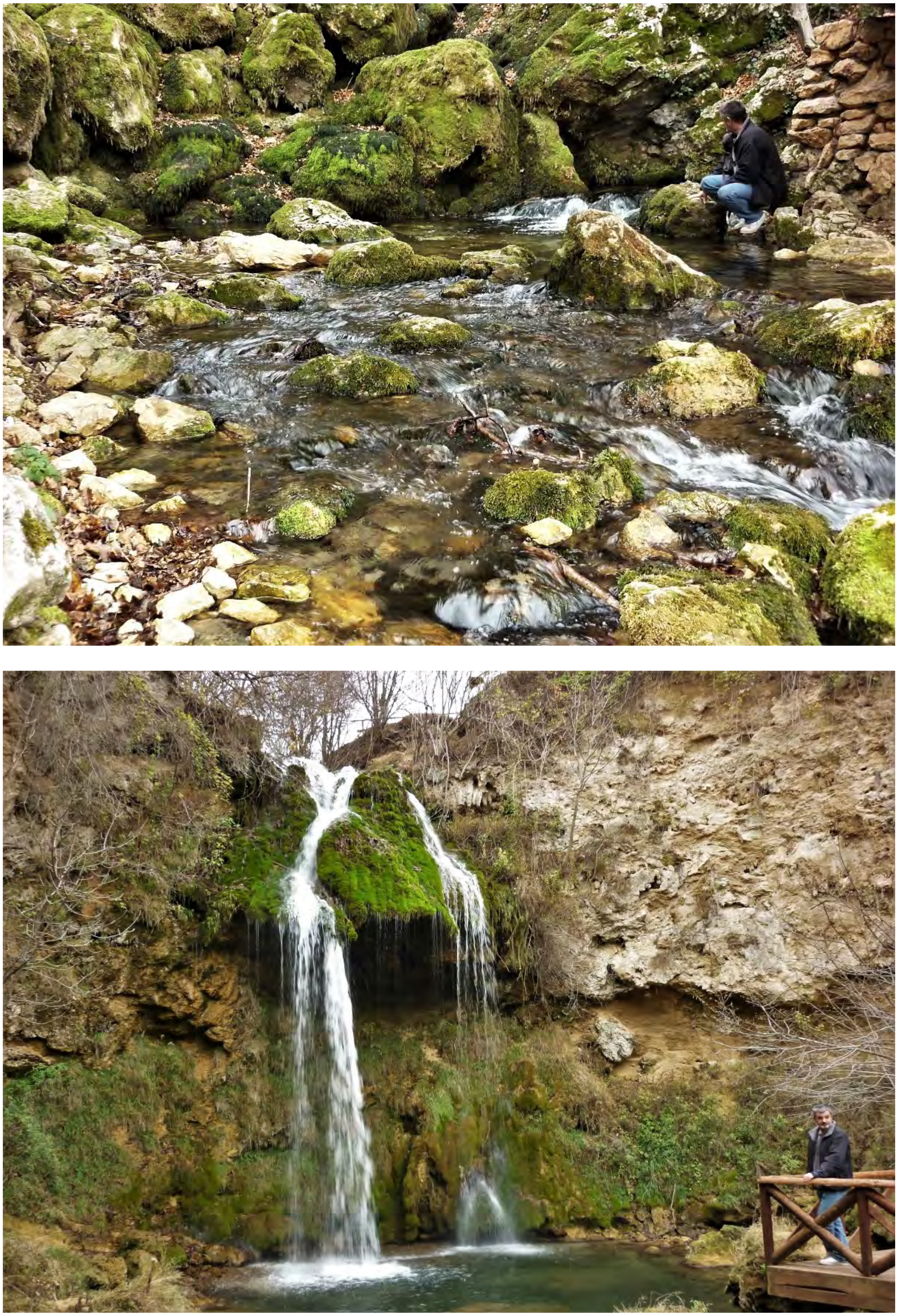


Photo 5.34 *Beli Izvor, Serbia.* Dragan Bosnić

Photo 5.35 *Opačac Spring, Vrljika River, Croatia*. Branimir Jukić

Photo 5.36 *Dva Oka Spring, Vrljika River, Croatia*. Branimir Jukić



Photos 5.37 *Veliko Vrelo, Beljanica Mountain, Serbia*. Neven Kresic

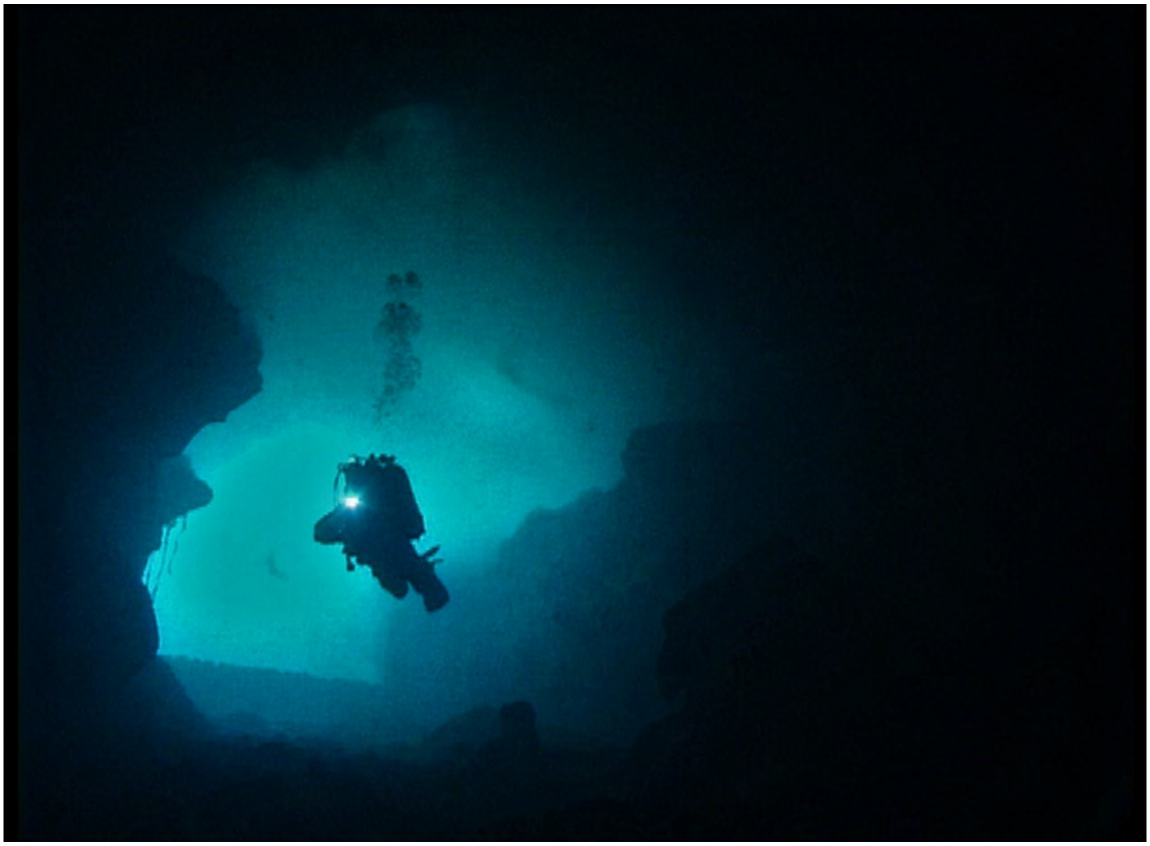


Photo 5.38 *Crno Vrelo, Bosnia and Herzegovina*. Saša Milanović

Photo 5.39 *Sušec Spring, Snežnik Mountain*, Slovenia. Borut Peric

Photo 5.40 *Zaslapnica Spring, Village of Zaslap, Montenegro*. Milan Vlahović

Photo 5.41 *Vrelo Bukovice, Durmitor Mountain, Montenegro*. Vojislav Ilić

Photo 5.42 *Izvor Jadra, Split, Croatia*. Zoran Stevanović

Windows to Unknown

6. Windows to Unknown

Apart from show caves, the most conspicuous entrance to a karst subsurface and the most obscure one have one thing in common – they act as powerful magnets for those that seek thrills and crave an adrenaline rush. From an urban dweller to a seasoned speleologist, the reasons for this may vary, but one thing is certain – they both will face the unknown once they go through that window that separates two worlds, the world of light, and the world of darkness. Even when entering the same cave multiple times, there will be something they have not noticed before, either because it remained hidden in the dark or is now seen in a different light, from a different angle, for example. And if our curious adventurer is going through the window for the first time, almost any previously unknown experience is possible including seeing some mythical creature for the first time (much less likely), or a just awakened and therefore very angry bear (somewhat more likely), or a beautiful unique speleothem (much more likely because they are never exactly the same in two different caves no matter what).

What several photos will also illustrate is that there are windows of a different kind in The Lands of Karst including many fascinating natural limestone bridges. Passing below them, or over them for the first time also brings an unknown, thrilling experience. Often, they are remnants of former caves, entrances to former caves, a result of collapsed cave ceilings, or some combination of all those things. As such, they are windows to an unknown past and a thrilling challenge to those that love reconstructing the history of the karst landscape around them.

Camp of speleologists looking for windows to unknown, Durmitor mountain, Montenegro.
Photo by Predrag Stošić Peca

Photo Captions

Note: all photo captions are provided by the authors of individual photographs hence the diversity–some felt like sharing more information with the reader, some left the photographs speak for themselves, giving only the essentials.

Photo 6.1 Underground flow of Reka river, which sinks into the world-famous *Škocjan Caves* and empties into the Gulf of Trieste, can be accessed in a few deep pits-caves. The longest of them is *Kačna jama* cave near Divača, Slovenia, which impresses with its picturesque abyss entrance 186 meters deep, which in the lower part extends into a huge hall 60 meters high. Photo by Peter Gedei.

Photo 6.2 Panoramic photo of *Zeljnske jame* caves near the town of Kočevje, Slovenia. Photo Boštjan Burger.

Photo 6.3 Little Natural Bridge (*Mali naravni most* in Slovene) in Rakov Škocjan, Slovenia is a set of collapses at SE part of karst valley *Rakov Škocjan*, which present remnants of a former cave. The water is coming from more than 5 km long cave *Zelške jame* and flows at the bottom of the collapses, before it continues its flow over a karst valley. Little Natural Bridge is about 35 m long arch that connects the walls of a collapse. The picture is the result of a longer exposure, where the bridge walls and the water of the stream have been illuminated by the lights on two cave helmets. Photo by Matej Blatnik.

Photo 6.4 Entrance to *Renejevo brezno* pit located at 2257m altitude, on the Kanin plateau in Slovenia. With a depth of over 1300 m, it is one of the Slovenia's deepest pits. Photo by Ester Premate.

Photo 6.5 **W**indow (*vigled*) of *Bogovinska pećina* cave, which is one of the longest caves in the Carpathian karst of eastern Serbia. The cave is carved in the Lower Cretaceous limestones by a strong sinking stream. The window is a fossil spring orifice of the underground stream, which nowadays flows through deeper, inaccessible channels. Photo by Zoran Stevanović.

Photo 6.6 *Jama Mandelaja* (Mandelaja Pit) above the train station in Ostarije, 45 min train ride from Karlovac, Croatia. "As novice speleologists during 1990s, we frequently visited the cave by train, not having our own automobiles. As opposed to my other photographs, which were improvised in the field, this one is perhaps the only one I have composed in my head over the many years I have been visiting the cave." Photo by Dinko Stopić.

Photo 6.7 The majority of active and former channels in Škocjan Caves (*Škocjanske jame*) were formed along the limestone bedding plains that, in combination with tectonic movements, enabled the formation of initial channels. The last swallow hole of river *Reka* in the Big Collapse Doline behind the Big Natural Bridge (*Veliki naravni most*) is seen in the background. Photo by Borut Lozej.

Photo 6.8 Big Natural Bridge (*Veliki naravni most*) in Rakov Škocjan, Slovenia. Photo by Blaž Kogovšek.

Photo 6.9 A scenic collapse doline near Sežana in the classic Karst of Slovenia can be reached easily and is a typical example of formation of collapse dolines and karst phenomena in general. Photo by Borut Lozej.

Photo 6.10 *Samar*, natural stone bridge ("prerast" in local dialect) in the Carpathian karst of eastern Serbia. The arch, about 15m high and 15m wide, is created by the Prerast river (locally also called *Perast*). It is located about 20km from the town of Žagubica and protected as Natural Monument of 3rd Category. Photo by Zoran Stevanović.

Photo 6.11 Entrance to pit *Brezno rumenega maka*, also known as P4, lies at an altitude of 2121 m on the Kanin plateau. The pit was discovered in 1999 and has progressed in depth very slowly due to many obstacles. In the summer of 2019, a connection was found with the neighboring *Renejevo brezno* and the *Renejevo brezno – P4* system was created, which is now one of the deepest cave systems in the *Kanin* mountains. Photo by Uroš Kunaver.

Photo 6.12 *Bukovica* cave near Bukovica, Tomislavgrad Municipality, Herzegovina, also known as "Cathedral". During Ottoman Muslim occupation it was used for religious ceremonies and sermons by the local Christian population. Photo by Vinko Ljubas.

Photo 6.13 *Dobra jama* (Good Pit), also known as *Ledena pećina* (Ice Cave) on *Orjen* mountain in Herzegovina, at about 1500 altitude. Because of a thick snow cover built up at the entrance during winter, the temperature in the cave never exceeds 0 degrees Celsius such that even during the summer months ice stalactites abound in the cave and the cave floors are covered with a layer of ice. In the past, when the mountain pastures where full of cattle, the shepherds would harvest the cave's ice for watering the cattle. Photo by Igor Škero.

Photo 6.14 Little Natural Bridge (*Mali naravni most* in Slovene), Rakov Škocjan, Slovenia. Photo by Katarina Kosič Ficco.

Photo 6.15 *Medvidina špilja* (Monk Seal Cave) on the island of Biševo is the longest partially submerged cave on the Croatian Adriatic. Biševo also hosts the most famous such cave, *Plava špilja* (Blue Cave – see Photo 7.27 in Chapter 7) The cave got its name after one of the most endangered world mammals – Mediterranean monk seal, *Monachus monachus,* which ones lived and raised its babies deep in the cave, in complete darkness, at the end of a 160m long channel, on a small sand beach. The entrance to the cave is over 20m high and located on a fault face in the Lower Cretaceous dolomite. The cave was declared a geomorphological (natural) monument in 1967. The Vis archipelago, which includes the island of Biševo, has the highest concentration of natural monuments in Europe. Photo by Srdjan Marinčić.

Photos 6.16 Entrances to two of the largest caves in the Uvac river canyon in western Serbia which were partially submerged by the reservoir behind the Uvac hydropower dam (*HE Uvac*) built in 1979. Both photos by Neven Kresic.

Photos 6.17 Big Natural Bridge (*Velika prerast*) on Vratna river in eastern Serbia. This part of Serbia has the largest concentration of natural bridges in the Lands of Karst and all of Europe. Right: Entrance to *Kaćunova pećina* cave, Pešter plateau, Serbia. Photos by Neven Kresic.

Photo 6.18 Collapse doline (sinkhole) in Pirni dol on *Durmitor* mountain, Montenegro. It is 50m in diameter and about 50m deep. It ends with a partially visible opening which "begs" for someone to enter it and explore the subsurface. This part of the karst plateau of Piva (*Pivska površ*) is still largely unexplored by speleologists but very promising – several vertical pits more than 100m deep have been discovered recently. Given the depth of the surrounding canyons of Tara and Piva rivers, a potential exists for pits more than 700m deep. Photo by Mihajlo Mandić Zis.

Photo 6.19 Natural bridge *Samar* on Perast river, tributary to Tisnica river in eastern Serbia (see also Photo 6.10 for a different view.) Photo by Ana Mladenović.

Photo 6.20 Mountain *Kaženik*, Montenegro. A large double shaft is so massive that it is visible on the aerial photography, which enabled the explorers to find it and map it. It is also the house of the Alpine choughs, blackbirds that live on the karst mountains and are often found in karst shafts. Photo by Katarina Kosič Ficco.

Photo 6.21 Entrance hall of *Dubočka pećina* cave near the village of Duboka in eastern Serbia after which it was named. The cave has more than 2200 of explored channels and an intermittent underground river with about 1000m long visible course in the cave. This underground river is continuation of a sinking stream *Ponorska reka* river, whereas the cave is often referred to as "tunnel cave" even though there are channels at multiple levels. The spacious 30m high and 40m wide entrance hall pictured often hosts speleologists on multi-day expeditions. Photo by Mihajlo Mandić Zis.

Photo 6.22 Natural tunnel in *Rožanski kukovi* – Velebit mountain, Croatia. Photo by Dražen Perica.

Photo 6.23 Big Stone Bridge (*Velika prerast*) in the Vratna river gorge between Donji Milanovac and Negotin, eastern Serbia is a protected natural monument. Together with two more natural bridges in the gorge – Little and Dry (*Mala prerast* and *Suva prerast*) it is part of the geoheritage site inside boundaries of the Djerdap UNESCO Global Geopark. Jovan Cvijić, who was the first to describe these natural bridges in 1896, suggested that their origin can be explained by the dissolution of limestone and a partial collapse of the former cave ceiling. The Great Stone Bridge is 40m long, 35-40m wide, and 26m high. Photo by Aleksandra Maran Stevanović.

Photo 6.24 View of the partially submerged channel of the *Odysseus* cave from the Calypso's chamber on land. Odysseus Cave is one of many karst and other natural wonders on the Croatian island of Mljet. Photo by Tin Rožman.

The legend, passed on for many generations by the local population, tells how this is the very cave by which Odysseus, King of Ithaca, swam to the rocky shore after surviving the wrath of Zeus who destroyed his only remaining ship and drowned all his men. Zeus had destroyed them to appease Helios, the god of the Sun. Odysseus men, against their King's advice, stole and ate the Helios' oxen and the furious god demanded Zeus punish them, so Zeus did. The King of Ithaca, however, managed to survive by building a raft from the remnants of the ship. He drifted and paddled for nine days before crashing on a rock by the shore of Ogygia, what is today Mljet, on the tenth day. After swimming to the rocky shore by a mysterious deep blue cave, and before passing out from exhaustion, the Greek caught a glimpse of the most beautiful woman he ever saw.

The woman, the immortal goddess Calypso, fell in love with the man the very moment she saw him. As he was recovering in the azure cave home of his hostess, Odysseus learned that she was one of nine sea nymphs, daughters of the Titan god Atlas and goddess Tethys. She was forced to come to Ogygia in exile, because she supported her father in the battles between the Titans and the Olympian gods headed by the mighty Zeus.

The nymph fell in love with Odysseus so much so that she offered to make him her immortal husband and give him eternal youth. But he refused it and kept dreaming about going back to his Ithaca and his beloved wife

Penelope and son Telemachus. Having no other choice because she could not defeat herself, Calypso put the spell on Odysseus and made him her lover. They lived together for seven years on the spellbinding island and she gave birth to twin sons, Nausithous and Nausinous. Still, after sharing the bed with the goddess at night, the Greek would every day go to the shoreline, looking at the horizon and beyond, towards Ithaca where his true family was.

All along, Zeus' daughter Athena could not stand the suffering that Odysseus, her protege, was going through on the magic island. Finally, Athena gathered courage and asked her father to free Odysseus from Calypso and Ogygia. Zeus agreed and sent the messenger of the gods, Hermes, to persuade the nymph to let Odysseus go. The daughter of Atlas was devastated when she heard the message from Zeus but could not possibly disobey the mighty King of the Gods. All she could do was to say this to Hermes: "Cruel folk you are, unmatched for jealousy, you gods who cannot bear to let a goddess sleep with a man, even if it is done without concealment and she has chosen him as her lawful husband."

As the last gesture of her boundless love for Odysseus, the beautiful nymph helped him build his boat, provided him with enough food and drink, and watched him sail away towards his Ithaca, to his faithful wife Penelope and son Telemachus whom he had not seen for twenty long years.

Photo 6.25 Entrance to a cave in the Korana river canyon, Plitvice National Park, Croatia. The cave is partially submerged by the process of impoundment behind one of the spectacular natural tufa dams on the river. Photo by Neven Kresic.

Photos 6.26 Left: Pit by the mountaineering lodge near Košara on *Dinara* mountain, Croatia. It is just one of many pits in this part of *Dinara* south of the Sinjal peak. Right: Speleologist at the entrance to famous *Munižaba* pit. The 200m deep vertical entrance continues into a maze of horizontal channels, lakes, and enormous chambers and halls; Munižaba has the largest volume of underground space in Croatia. Both photos by Vlado Božić.

Photo 6.27 Caves in the Peshti gorge on Babuna river in North Macedonia, explored by Manaković (1964). Photo by Dragan Kolčakovski.

Photos 6.28 Cave *Pešna* is cave with the largest opening in North Macedonia (40m high and 56m wide.) The New York Times compared it to Helms Deep, an imaginary cave from the movie Lord of the Rings. Both photos by Speleological Club "Peoni"—Skopje.

Photo 6.29 The deepest pit in North Macedonia, *Slovačka jama* (Slovak Pit). The vertical distance from the opening to the current end is -700 m. It is one of a more complex pits in the Balkans and will be further explored in near future. Photo by Speleological Club "Peoni"–Skopje.

Photo 6.30 *Solunska jama* (Solun Pit). In addition to the impressive opening with dimensions of 25 by 30 m, this pit features the longest pure (absolute) vertical drop in North Macedonia (-265 m). Photo by Speleological Club "Peoni"–Skopje.

Figure 6.31 Higher fossil entrance and current entrance to an intermittent sinking stream cave, high on the Pešter karst plateau in southwestern Serbia. Photo by Neven Kresic.

Figure 6.32 First reconnaissance of a potential entrance to the underground world of Durmitor mountain, Montenegro. Photo by Vojislav Ilić.

Figure 6.33 The cave in the photo must have made a marvelous shelter as it is strategically located. It is hidden from view, except from one vantage point, and protected by massive karst shafts and rugged karst terrain. Mountain Kaženik, Montenegro. Photo by Mike Ficco.

Figure 6.34 *Otliško okno* (Otlica window) is a natural opening at the edge of a high Dinaric plateau Trnovski gozd. It is about 12 m high, 7 m wide and provides a nice view of Vipava Valley. The photo was made during 600 km long trail over Slovenia. Photo by Matej Blatnik.

Photo 6.1 *Kačna Jama, Slovenia*. Peter Gedei

Photo 6.2 *Zeljnske Jame, Slovenia*. Boštjan Burger

Photo 6.3 *Mali Naravni Most, Rakov Škocjan, Slovenia*. Matej Blatnik

Photo 6.4 *Renejevo Brezno, Kanin Plateau, Slovenia*. Ester Premate

Photo 6.5 *Bogovinska Pećina, Serbia*. Zoran Stevanović

Photo 6.6 *Jama Madelaja, Ostarije, Croatia*. Dinko Stopić

Photo 6.7 *Škocjan Caves, Slovenia*. Borut Lozej

Photo 6.8 *Veliki Naravni Most, Rakov Škocjan, Slovenia*. Blaž Kogovšek

Photo 6.9 *Collapse Doline, Sežana, Slovenia*. Borut Lozej

Photo 6.10 *Samar Natural Bridge, Perast River, Serbia*. Zoran Stevanović

Photo 6.11 *Brezno Rumenega Maka, Kanin Plateau, Slovenia*. Uroš Kunaver

Photo 6.12 *Bukovica Cave, Tomislavgrad Municipality, Herzegovina*. Vinko Ljubas

Photo 6.13 *Dobra Jama, Orjen Mountain, Herzegovina*. Igor Škero

Photo 6.14 *Mali Naravni Most, Rakov Škocjan, Slovenia*. Katarina Kosič Ficco

Photo 6.15 *Medvidina Špilja, Biševo Island, Croatia*. Srdjan Marinčić

Photos 6.16 *Uvac River Gorge, Serbia.* Neven Kresic

Photos 6.17 *Left: Velika Prerast, Vratna River, Serbia. Right: Kaćunova Pećina, Serbia*. Neven Kresic

Photo 6.18 *Pirni Dol, Durmitor Mountain, Montenegro*. Mihajlo Mandić Zis

Photo 6.19 *Samar Natural Bridge, Perast River, Serbia*. Ana Mladenović

Photo 6.20 *Kaženik Mountain, Montenegro*. Katarina Kosič Ficco

Photo 6.21 *Dubočka Pećina, Serbia*. Mihajlo Mandić Zis

Photo 6.22 *Rožanski Kukovi, Velebit Mountain, Croatia*. Dražen Perica

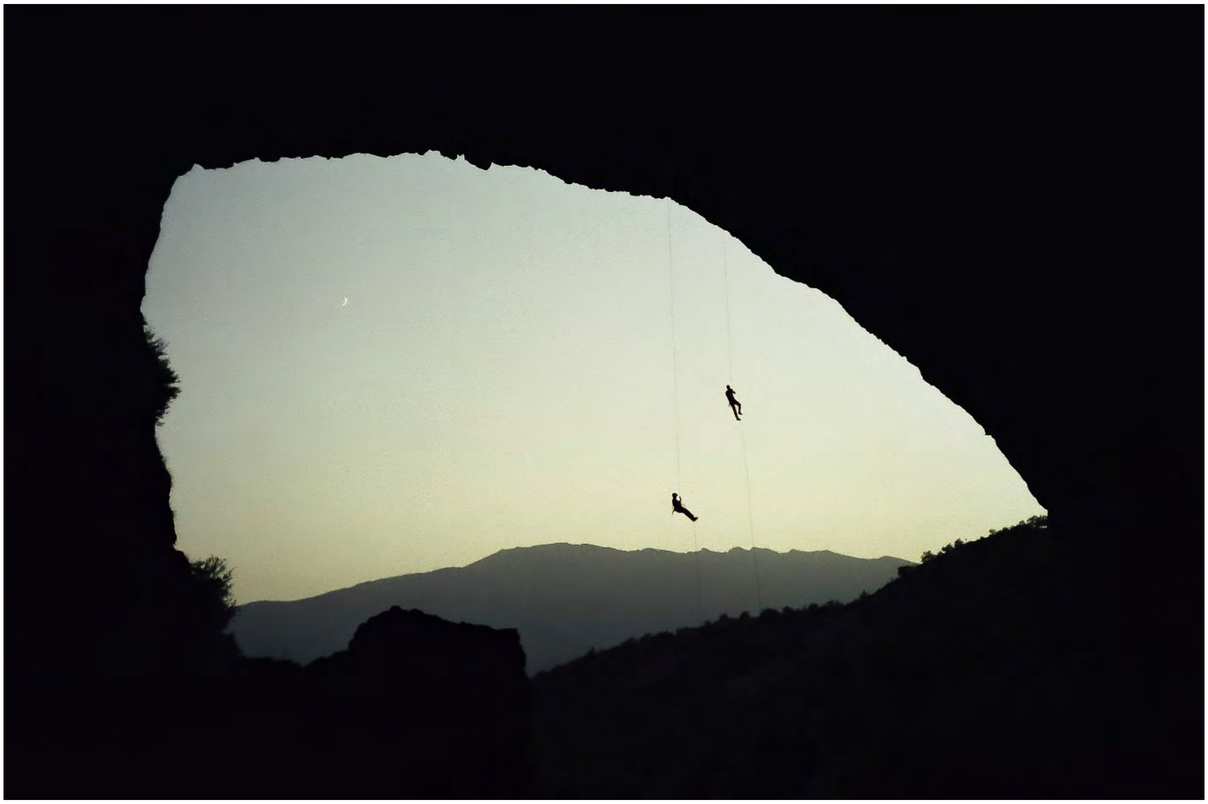
Photo 6.23 *Velika Prerast, Vratna River Gorge, Serbia.* Aleksandra Maran Stevanović

Photo 6.24 *Odysseus Cave, Mljet Island, Croatia*. Tin Rožman

Photo 6.25 *Plitvice Lakes National Park, Croatia*. Neven Kresic

Photos 6.26 *Left: Jama near Košara, Croatia. Right: Jama Munižaba, Croatia*. Vlado Božić

Photo 6.27 *Pešti Gorge Caves, Babuna River, North Macedonia*. Dragan Kolčakovski



Photos 6.28 *Pešna Cave, North Macedonia*. Speleological Club "Peoni"–Skopje

Photo 6.29 *Slovačka Jama, North Macedonia*. Speleological Club "Peoni"–Skopje

Photo 6.30 *Solunska Jama*, *North Macedonia*. Speleological Club "Peoni"–Skopje

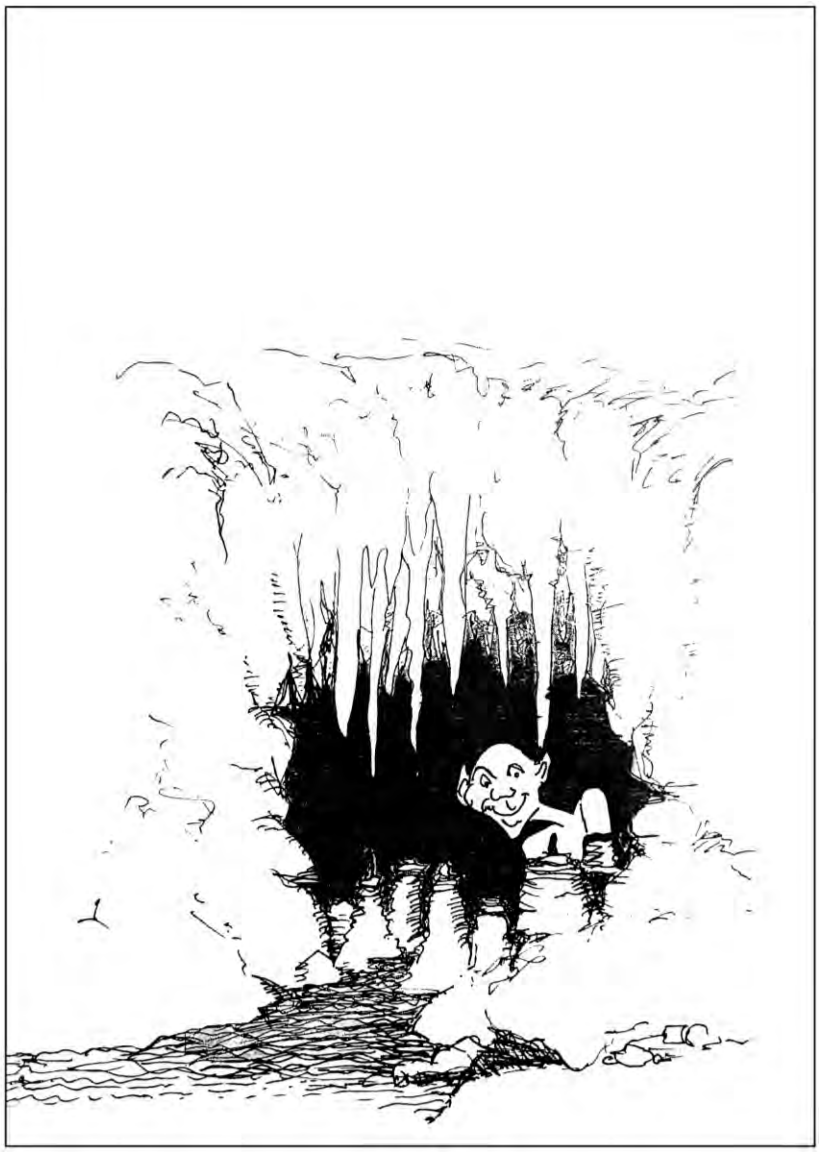
Photo 6.31 Pešter, Serbia. Neven Kresic

Photo 6.32 Durmitor, Montenegro. Vojislav Ilić

Photo 6.33 *Kaženik Mountain, Montenegro*. Mike Ficco

Photo 6.34 *Otlica Window, Slovenia*. Matej Blatnik

Magic Chambers



7. Magic Chambers

On the occasion of his 30th anniversary as a cave photographer, Peter Gedei, native of Slovenia and one of the contributors to this book, said “Caves, besides the bottom of the sea, represent the last unexplored areas of our planet. It is basically the world below us. Discovering a place where there has never been a human being before is a wonderful feeling. Any further discovery of new parts of the cave is all the more exciting. Of course, it is our responsibility to act responsibly and make sure that such discoveries are made with as little cave damage as possible. Every human presence in the cave has consequences….As a photographer, I try to bring the cave world closer to all who do not know it and to inform people that in addition to our everyday world, there is also an underworld. If you show them a beautiful photo, people will remember the cave as a place that is worth keeping intact.” (*Sierra,* The Magazine of the Sierra Club, 2021)

There are tens of thousands of surveyed and registered caves in the Lands of Karst, and many more are yet to be inventoried in some official capacity. Before the breakup of Yugoslavia, information on caves was classified by the Department of Defense, except of course for several dozen show caves, some of which were, and continue to be visited by hundreds of thousands of visitors each year, including foreigners. Recently, this secrecy has abated to a large extent. Still, the vast majority of registered and unregistered caves will never be visited by more than a handful of enthusiasts, spelunkers, speleologists, and occasional scientists such as hydrogeologists, archaeologists or biologists. The reasons for this vary, but the most obvious is that all caves are hidden in darkness. Although bringing a flashlight or a more sophisticated and powerful lighting source may suffice in experiencing the magic caves have to offer, any visit to a cave brings with it a number of potential risks, for unprepared “adventurers” and experienced speleologists alike. It is therefore the advice and the plea of the authors to any cave visitors that they take their safety and the safety of their company as seriously as possible. And to never go alone to a cave, and always ask or seek someone with experience to accompany them.

For the future visitors of show caves in the Lands of Karst, we have the following advice – every single one is more than worth of seeing as they were carefully selected for that purpose. Their names, locations and useful information can be found at various web pages addresses of which are provided at the end of the book. Not to completely “shortchange” some of the most famous ones, we have included a few photographs from their lesser known parts or sections closed to tourists. Most of the photographs that follow are from the caves and pits that were and will be visited only by a select few, including the bravest and the most experienced. It is thanks to their skills, dedication, and love of the karst underworld that we can share them here. Many of the photographs were taken by some of the best cave photographers in the world, including professionals, all natives of the Lands of Karst. And many were taken by “pure” speleologists for whom cave photography is a hobby or a means to record some important detail, often known only to themselves.

The most difficult, and inevitable, task for the authors was to choose which photographs to include in the book. Limited space made it a necessary task. We tried to showcase everything the magic underground chambers and spaces have to offer, from sheer grandiosity (some are among the deepest, highest, largest and such in the world), to minute details like a helictite or a calcite crystal. Some may perhaps be of interest only to a geologist – speleothems or limestone blocks that have moved very recently or were broken by natural forces (“neotectonics”). And some are arguably of interest to almost anyone because of the incredible interplay of colors, shapes, light, and water.

Dinko Stopić, speleologist, amateur photographer, and another contributor to the book, sums up the crucial role light plays in bringing our magic chambers out into the open: “Darkness is my greatest inspiration. It is as if I have a blank, black canvass in front of me, waiting for me to paint on it with light. You alone pick the motif to be painted, the amount of light, the angles where it will come from, you are in complete control." And he quickly emphasizes that the final product, the painted canvas, could not have been made possible without the help from his fellow spelunkers who were all part of the magic.

Mainly for nostalgic reasons, we have also included photographs that were made many years ago, in the pre-digital era, when the outcome of taking photographs was unknown for days on end until the film was developed and photographs made in a darkroom. In any case, we hope that the collection of cave photography presented here for the first time for all of the Lands of Karst will inspire new speleologists and cave visitors to not only take their own photographs and enjoy the cave magic along the way, but also to advocate for the protection of karst and all beings living on and in it, for future generations.

Photo Captions

Note: all photo captions are provided by the authors of individual photographs hence the diversity–some felt like sharing more information with the reader, some left the photographs speak for themselves, giving only the essentials.

Photo 7.1 The pioneers in *Škocjanske jame* (Škocjan Caves) explorations penetrated down the Reka River in wooden boats and used carbide lamps and torches to light the walls of vast underground spaces. The inner parts of Škocjan Caves in Slovenia were first explored back in 1839. Photo by Borut Lozej.

Photo 7.2 Underground canyon of *Škocjanske jame* (Škocjan Caves) in Slovenia. It is criss-crossed by precipitous paths and was fully explored already in the 19th century. After sinking, the Reka River penetrates deep into the cave and descends over rapids and falls along its entire length, until it reaches an unpassable syphon. The vertical drop from the swallow hole to the syphon exceeds one hundred metres. The cave was designated World Natural Heritage site by UNESCO in 1986, one of only four caves in the world to receive this status. Photo by Borut Lozej.

Photo 7.3 International Channel of the Lazar Cave (*Lazareva pećina*), the longest in Serbia (over 17500 meters of explored channels so far). This part of the cave is overcrowded with massive flowstones, stalactites, and stalagmites. In the context of their size, the humans appear small, temporary, and not all that significant. Photo by Martin Ristić, lighting Ivan Savić.

Photo 7.4 Part of world-famous Postojna Cave (*Postojnske jame*) in Slovenia called *Otoška jama*. Photo by Iztok Medja.

Photo 7.5 Detail from the International Channel of the Lazar Cave (*Lazareva pećina*) in Serbia. Shapes that only karst and water can create. Photo by Martin Ristić, lighting Ivan Savić.

Photo 7.6 Numerous speleothems beautify this part of *Vladikine ploče* cave in Serbia named Imperial Chamber. Photo by Martin Ristić, lighting Ivan Savić.

Photos 7.7 *Križna jama* (Cross Cave) in Slovenia, eight kilometers long, is one of the most beautiful and best-preserved tourist caves in Europe, renowned for its emerald-green underground river and lakes, and mesmerizing speleothems. It is a hot spot of underground life and biodiversity. Top photo: *Kalvaria* chamber, the favorite stop on the boat tours of the cave. Bottom photo: *Kitlova brezna*, a more than 120 meters deep submerged pit ending with an unpassable sump where the underground river sinks. Photos by Peter Gedei.

Photo 7.8 Hanke Channel in *Škocjan Caves*, Slovenia is only up to five meters wide at the beginning while it reaches a height of almost one hundred meters (330 feet). Photo by Borut Lozej.

Photo 7.9 Stalactites in the Andesite Chamber of cave *Ceremošnja* near the town of Majdanpek, eastern Serbia. Photo by Neven Kresic.

Photo 7.10 Drapery in cave *Puralo* near Poreče, North Macedonia. Photo by Dragan Kolčakovski.

Photo 7.11 Waterfall in cave *Ubavica*, on Bukovik mountain in North Macedonia. The cave was first explored by Manaković in 1970. Photo by Dragan Kolčakovski.

Photo 7.12 Rimstone pools in cave *Vjetrenica* in eastern Herzegovina. The cave hosts the largest number of underground life forms anywhere in the world, as well as the highest number of endemic species, 37, that do not live anywhere else. Photo by Neven Kresic.

Photos 7.13 *Kaćunova pećina* cave on the Pešter karst plateau in southwestern Serbia was discovered by the Academic Alpinist and Speleological Club (Akademski speleološko alpinistički klub, ASAK) from Belgrade, Serbia in 1980s, around the time these photos were taken. The location of the cave remains secret (undisclosed) to this date to protect it from unwanted visitors. In the (subjective) opinion of the author, this is one of the most beautiful and unique caves he ever visited not only in the Lands of Karst but globally (and he did visit quite a few caves around the world.) When pressed to name at least one cave that can compete with it, he could only think of Caverns of Sonora in Texas, the United States. Even though the two caves are dissimilar in many ways, the first impression of seeing them for the first time was very similar – a complete awe. Photos by Neven Kresic (top left and bottom) and Predrag Stošić Peca (top right).

Photo 7.14 Erosional morphology of cave *Ponor* near the village of Dojkinci on Stara planina mountain, eastern Serbia. Photo by Predrag Stošić Peca.

Photo 7.15 Crawling passage in *Ledena pećina* (Ice Cave), part of the *Ušački pećinski sistem* (Ušac Cave System) near Sjenica in southwestern Serbia. Photo by Saša Maričić.

Photo 7.16 *Dežmanov rov* is one of the dry passages in the entrance part of cave *Križna jama* in Slovenia. Permanent underground stream flows below the passage but during the high-water level it can be at this point completely flooded. The passage ends with a submerged sump. The walls of the passage are covered with impressive scallops which glitter playfully under the speleologists' lights. Photo by Peter Gedei.

Photo 7.17 *Ledena jama na Stojni* (Ice Cave on Stojna Plateau) above the town of Kočevje in Slovenia. The north-facing, high-altitude entrance to the cave/pit, preserves the ice deposits in the cave for almost the entire summer. However, the melting of the ice has been accelerating over the last couple of decades. “When I visited the cave for the first time in 1991, it was not accessible. Because of climate change, a huge amount of ice melted and opened new entrances to the lower parts of the cave.” Photo by Peter Gedei.

Photo 7.18 At the beginning of 2019, a new promising cave area south of Bohinj, Slovenija was "discovered". The deepest and longest cave in this area is the more than 4.5 km long *Grvn*. The picture shows a scenic pit at a depth of about 140 m with stone “rings” probably formed due to differently resistant layers of rock. Photo by Uroš Kunaver.

Photo 7.19 *Jama Munižaba* pit on Velebit mountain, Croatia. One of monumental horizontal passages that can be reached after a 200 m deep vertical entrance. See also photos 7.23 and 7.30. Photo by Dinko Stopić

Photo 7.20 *Planinska jama* cave is part of the Ljubljanica river network. The cave is the source of the Unica river, which then flows through Planinsko polje. A special feature of the cave is the confluence of two underground rivers—Rak, which flows from Rakov Škocjan, and Pivka, which flows from Postojna. Between WWI and WWII, the Italians started to develop it as a tourist cave, but today only a small part of the cave remains accessible to tourists. Photo by Uroš Kunaver.

Photo 7.21 *Jama Munižaba* pit on Velebit mountain, Croatia. It is famous for its dimensions. After a 200 m deep vertical entrance pit, it continues into a series of monumental chambers (the on pictured here is 100x 200m – notice a spelunker at the center bottom for scale). Photo by Dinko Stopić.

Photo 7.22 Chamber of *Vlaška pećina* cave on Beljanica mountain in eastern Serbia. The cave is an example of erosion along bedding planes and fractures; this chamber was formed at an intersection of two systems of fractures. Photo by Ana Mladenović.

Photo 7.23 P*lava špilja* (Blue Cave) on the island of Biševo, Croatian Adriatic. Photo by Branimir Jukić.

Photo 7.24 *Dimnice* is a show cave near the villages of Slivje and Markovščina, not far from the Kozina–Rijeka regional road in Slovenia. There are passages on two levels. The upper passages are dry, full of beautiful speleothems, and are arranged with tourist pathways. An underground stream runs through the lower passages, before flowing into the Rižana River spring. Visitors are most enthusiastic about the gigantic dripstone formations that could easily be featured in the Guinness World Records. See also photo 7.36. Photo by Peter Gedei.

Photo 7.25 One of the newly discovered channels in *Cerovačke špilje* (Cerovac Caves), the largest show cave in Croatia, located near the town of Gračac at the foothill of Crnopac, southern Velebit mountain. The caves were discovered at the beginning of 20th century during road construction. Speleological Club Karlovac has been exploring the cave for the last 20 years, adding kilometers of new passages. Photo by Dinko Stopić

Photo 7.26 Rimstone pools in the main channel of *Jama Munižaba* pit, southern Velebit mountain, Croatia. See also photos 7.21 and 7.23. Photo by Dinko Stopić.

Photo 7.27 *Špilja Tounjčica* cave in the town of Tounj, near Karlovac, Croatia. Cave divers recently conquered this 30-m deep syphon and connected the cave with a 10-km long *Tounjčica* cave system. Photo by Dinko Stopić

Photo 7.28 *Markov spodmol* is a sinkhole cave at the end of Sajevško polje in Slovenia. It is full of potholes, washed walls and lakes. It is also known for its speleothems (cave decorations), especially at the end of the cave, where they create magic color contrasts. Photo by Peter Gedei.

Photos 7.29 *Pološka jama* cave above Tolmin in Slovenia is interesting mainly because the main part of the cave (approximately 500 meters above the entrance) has been explored upwards. The cave at the upper end came so close to the surface that one could easily break through the narrow passage to open the upper entrance. The whole cave is a labyrinth with a few streams. This part shows strong water activity as the walls are smoothed and full of facets. The presence of a thin layer of mud along the walls suggests that this part of the cave may still be occasionally flooded. Photo by Uroš Kunaver.

Photo 7.30 *Postojnska jama* (Postojna Cave) the largest show cave in Slovenia, and the second longest, is the most famous in the Lands of Karst and one of the most famous in the world. Each year it is visited by more than one million visitors which, among other wonders, can tour the cave by underground trains. Only a fraction of the cave is open for tourists. Featured here is one of the most beautiful parts of the cave named *Pisani rov* (Painted Passage) which is closed to visitors. Photo by Peter Gedei.

Photo 7.31 Show cave *Dimnice* in Slovenia is renowned for its gigantic cave decorations (speleothems) which can be seen only under the helmets' lights as the cave is not electrified. The most famous formation in Dimnice is the Great Curtain pictured here. Photo by Peter Gedei.

Photo 7.32 Flowstone in a cave in Slovenia. Photo by Blaž Kogovšek.

Photo 7.33 Calcite crystals in a monumental cavern discovered during construction of the St. Rock tunnel through Velebit mountain in Croatia. Photo by Natalija Andačić.

Photo 7.34 The riverbed of this underground river is completely covered with flowstone, because the water is very rich in calcium carbonate. In the upper part of this cave there are a few pits with waterfalls after which the slope becomes less steep and the cave continues as a water channel until it ends with a sump. The cave is quite fragile – it is easy to brake flowstone formations if not careful. Therefore, we decided not to disclose cave's name. Photo by Uroš Kunaver.

Photo 7.35 *Renejevo brezno* pit on Kanin plateau is one of the deepest caves in Slovenia. A more than 1000 m deep series of pits leads to an almost horizontal underground stream, which disappears into a sump at the depth of 1240 m. The sump lies at the bottom of a huge hall called Copacabana, named after the fine sand on the shores of sump lake. Two diving operations were carried out in the sump, which deepened the entire cave to a depth of 1322 m. Photo by Uroš Kunaver.

Photo 7.36 *Križna jama* cave is one of the most beautiful water caves in Slovenia, perhaps even in the world. Most of the cave runs through a partially flooded channel with numerous lakes, separated by flowstone barriers. The only way to visit the cave is by boat. The cave is accessible to tourists, but due to the extraordinary care of local cavers it is extremely well preserved. The picture shows the so-called Matjaž's pillars in one of the side passages. Photo by Uroš Kunaver.

Photos 7.37 Top: Details from *Kojina jama* pit near the town of Slunj in Croatia. Bottom: In *Gospodska špilja* cave by the Cetina river spring in Croatia, at the bottom of a 17-m deep vertical channel, there is a stone with two generations of stalagmites growing on each other. A strong water current or perhaps a tremor moved the stone which had a "grove" of small stalagmites, and then new stalagmites started growing on the old ones. All photos by Vlado Božić.

Photo 7.38 *Pišalo* ("Pisser" in English). An amazing thin stream of water coming out of a tall flowstone cave formation located about 200 m below the entrance to *Bezdanjača* pit near the town of Vrhovno in Lika, Croatia. Photo by Vlado Božić.

Photo 7.39 Baldacchino canopy with helictites, in the upper horizon of *Bogovinska pećina* cave; Kučaj mountain, eastern Serbia. Photo by Jelena Ćalić.

Photo 7.40 Eccentric speleothem in cave *Bezdan* on Giljeva mountain near the town of Sjenica, southwestern Serbia Photo by Predrag Stošić Peca.

Photo 7.41 Stalactites photographed from below in a cavern opened during construction of a highway in Lika, Croatia. Photo by Mladen Garašić.

Photo 7. 42 Facets (scallops) on the walls of an affluent syphon in *Momačka pećina* cave, located in Džervinska greda stripe karst, near Miroč mountain, eastern Serbia. Photo by Vladimir Ljubojević.

Photo 7.43 *Martina jama* cave near Krka river canyon, Croatia. Photo by Mladen Garašić.

Photo 7.44 Detail from the upper horizon of *Lazareva pećina* cave at the eastern foothill of Kučaj mountains in eastern Serbia. This is the longest cave in Serbia, explored by many national and international teams; the documentation is kept and administered by the caving and outdoor club "Rock and Ice" from the town of Bor. This is an outflow cave, permanently hydrologically active. The lowest passages are in the phreatic zone, below the level of the intermittent Lazareva reka river. Photo by Jelena Ćalić.

Photo 7.45 Caving trip with almost 30 participants (including 7 children) organized by ASAK from Belgrade as an educational trail led by caver and hydrogeologist Mihajlo Mandić. *Bogovinska pećina* cave, Kučaj mountain, eastern Serbia. Photo by Predrag Stošić Peca.

Photo 7.46 Cave *Propas'* in the Činiglavci village on Vidlič mountain, southern part of Stara Planina mountain in southeastern Serbia. The vertical entrance drop of –56 m leads to the largest known cave chamber in Serbia, with the volume of approx. 110,000 m^3. The photo shows only a part of the chamber (note a caver in the center!) The cave was mapped in detail by V. Gajović from ASAK, in the period 2010-2012. Photo by Predrag Stošić Peca.

Photo 7.47 Cavern discovered during tunneling for the A-1 highway through Velebit mountain in Croatia. Photo by Mladen Garašić.

Photo 7.48 Lake in a 10-km long *Tounjčica* cave system, near the town of Tounj, in Croatia. Photo by Mladen Garašić.

Photo 7.49 Syphon at the bottom of *Rakin ponor* cave, (cave depth is -256 meters) on Miroč mountain, eastern Serbia. Some of the deepest caves in Serbia are in this area. Their entrances are only 5 km away and 300 meters above Danube River. Photo by Vladimir Ljubojević.

Photo 7.50 *Lipska pećina* cave near the town of Cetinje in Montenegro. This is first and only cave in Montenegro accessible for group visits. Photo by Milovan Milivojević.

Photo 7.51 Since 2020, visitors to *Škocjan Caves* in Slovenia can opt for an alternative route that follows Hanke Channel; the steep and more than one-hundred-year-old path, often carved into steep cave walls, undoubtedly offers an unforgettable experience. Photo by Borut Lozej.

Photo 7.52 The process of speleothem formation by dripping water, as captured in Postojna Cave (*Postojnska jama*), Slovenia. Photo by Iztok Medja.

Photos 7.53 Top: Cave pearls from *Dimnice Cave* in southwest Slovenia. Bottom: A typical example that illustrates how cave pearls are formed – flowstone that concentrically covers sand grains, bits of bones or other small objects. Photos by Borut Lozej.

Photo 7.54 Soda straw stalactite in cave *Korenatac* near the village of Gornja Kamenica, Knjaževac municipality, Serbia. It is formed by a slow supply of water from a crack in the cave ceiling and precipitation of calcium carbonate along the perimeter of the water column, in form of transparent rings. Soda straws are extremely fragile and any movement in their vicinity should be done with utmost care. Photo by Lazar Mrčarica.

Photo 7.55 "Pipe Organ" formation in *Rajkova pećina* cave near Majdanpek, eastern Serbia. Part of the cave is open for tourists. The cave, one of the most beautiful in The Lands of Karst, abounds with speleothems many of which are made of pure white crystal calcite. It was one of the main locations featured in support of the establishment of the UNESCO Djerdap Geopark during a visit of the evaluators from Spain and Germany in August 2017 (at the same time when these two photos were made, with different cameras and lighting, and by two different photographers.) Left photo by Zoran Stevanović, right photo by Srdjan Marinčić.

Photo 7.56 Cave *Momiček*. One of the most beautiful caves in North Macedonia, in the area of Porečje. It is renown for its speleothems and the variety of colors. Photo by Speleological Club "Peoni", Skopje.

Photos 7.57 *Nevestinska* (*Puralo*) *Cave*, one of the North Macedonia's caves richest in different and rare types of speleothems. Photo by Speleological Club "Peoni", Skopje.

Photos 7.58 Cave *Alilica* in North Macedonia. This cave system consists of *Upper* and *Lower Alilica* which are connected by a vertical shaft. Photo by Speleological Club "Peoni", Skopje.

Photos 7.59 *Babuna* – cave at the source of the Babuna river in North Macedonia. This spring drains the karst massif of Jakupica and is one of the most significant karst springs in the country. Photo by Speleological Club "Peoni", Skopje.

Photo 7.60 *Pivska jama* cave, part of the Postojna Cave (*Postojnska jama*) underground water system. Photo by Iztok Medja.

Photo 7.61 Rimstone pools in *Stopića pećina* cave near the village of Rožanstvo in western Serbia, at the foothill of *Zlatibor* mountain. There are tens of pools in the Pool Chamber, some of which are up to 12m long, 3m wide, and 5m high; this is the most attractive group of monumental rimstone pools in the Lands of Karst discovered so far. Stopića Cave is protected as a Nature Monument. Part of it is open for tourists since 2009. Photo by Milorad Kličković.

Photo 7.62 Huge stone blocks that fell from the cave walls or roof cover the bed of the underground river Reka which flows through *Škocjan Caves* in Slovenia. Thick flowstone formations can be seen on the right. Photo by Borut Lozej.

Photo 7.63 During the construction of tunnel St. Rok on the highway Zagreb—Split near Maslenica, Croatia, about 50 caverns were encountered. Among all of them, with its length of 1137 meters and monumental dimensions, a cavern at the station km 200 + 525 stands out. The cavern is also interesting for the variety of speleothems. Photo by Natalija Andačić.

Photos 7.64 Left: “Colossus”, a giant stalagmite adopted for the emblem of *Vernjikica* show cave in eastern Serbia. Right: Humans and their nemesis, “Giant Monster”, turned to stone in *Taborska jama* cave in Slovenia. Photos by Neven Kresic.

Photo 7.65 “Kid stuff” in one of the spectacular caves of the Slovenian classic Karst. Photo by Matej Blatnik.

Photos 7.66 Details from *Bogovinska pećina* cave, Serbia, captured during early explorations of extensive new passages discovered in the 1980s. The cave is one of the longest in Serbia. All photos by late Slaviša Maksić, member of the ASAK speleological club from Belgrade.

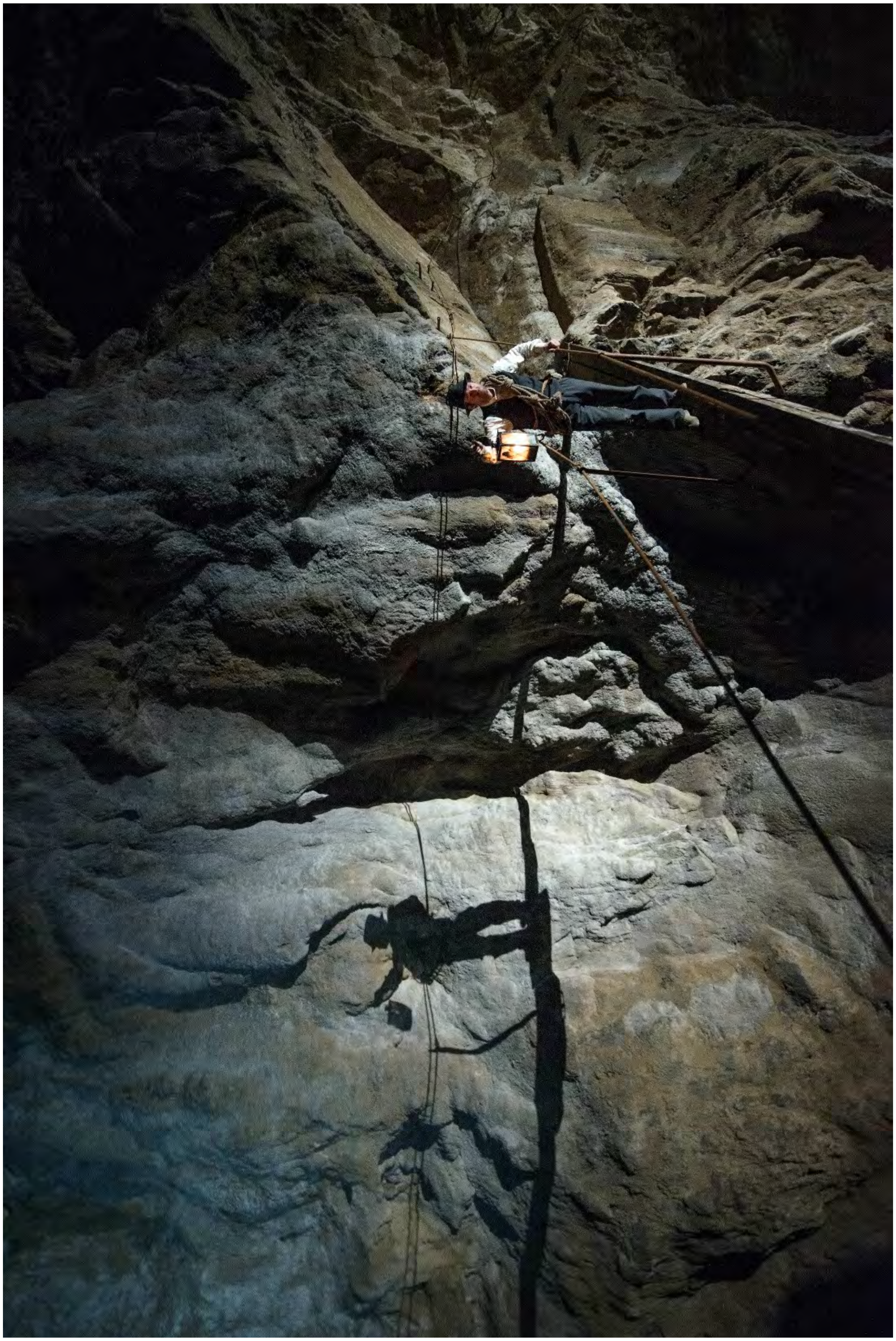


Photo 7.1 *Škocjan Caves, Slovenia*. Borut Lozej

Photo 7.2 *Škocjan Caves, Slovenia*. Borut Lozej

Photo 7.3 *Lazar Cave, Serbia*. Martin Ristić, lighting Ivan Savić

Photo 7.4 *Postojna Cave*. Iztok Medja

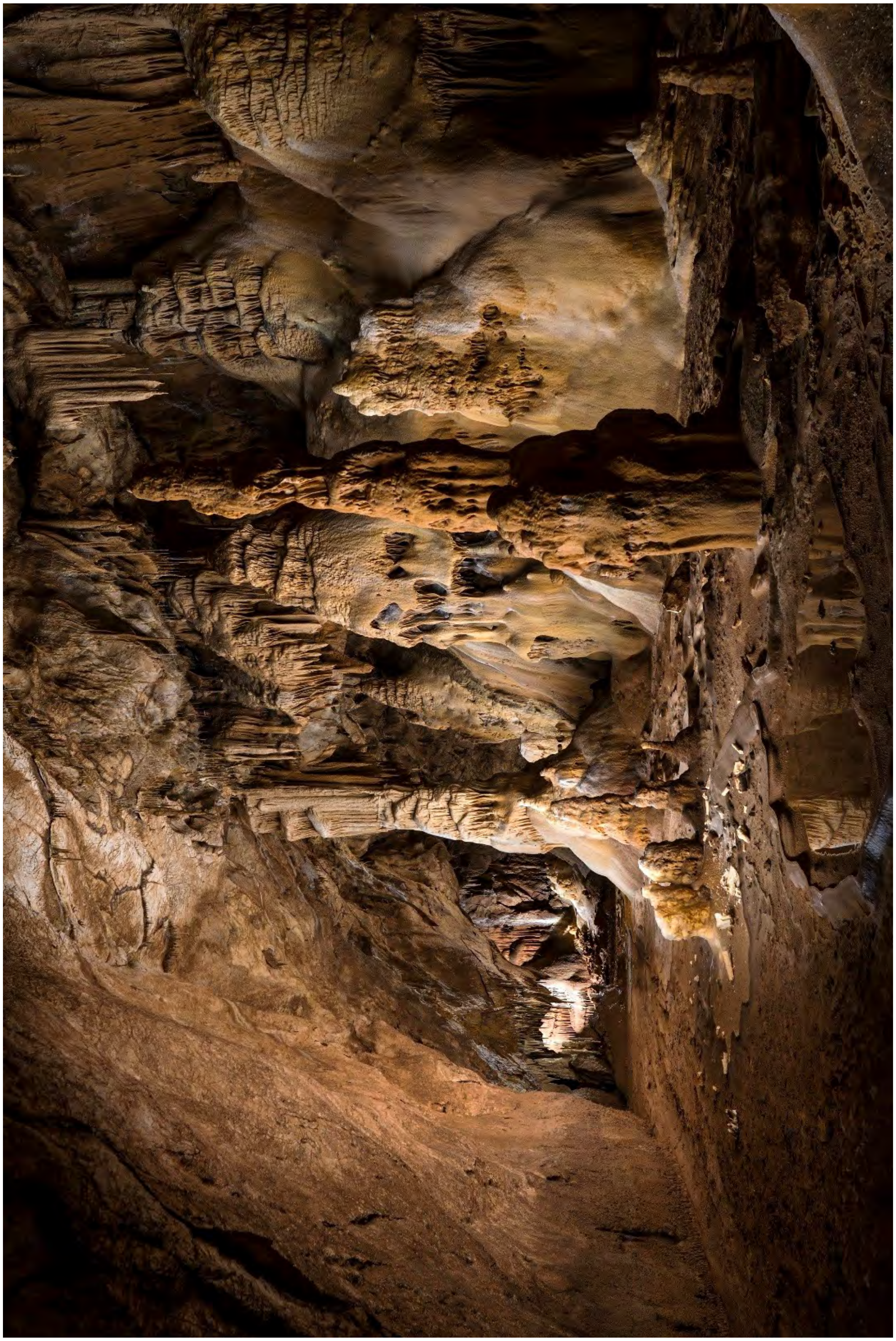


Photo 7.5 *Lazar Cave, Serbia*. Martin Ristić, lighting Ivan Savić

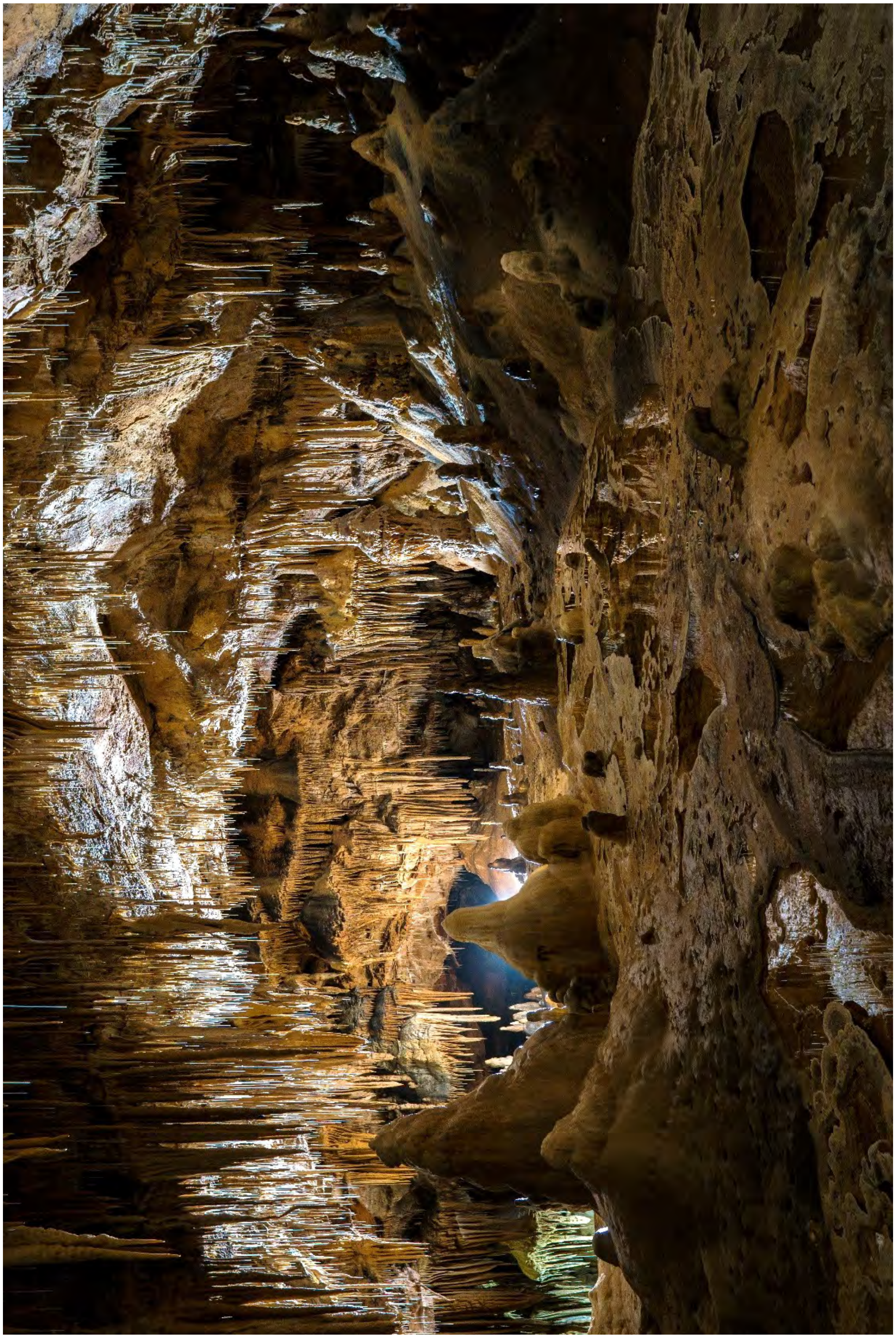


Photo 7.6 *Vladikine Ploče Cave, Serbia*. Martin Ristić, lighting Ivan Savić

Photos 7.7 *Križna Cave, Slovenia*. Peter Gedei

Photo 7.8 *Hanke Channel, Škocjan Caves, Slovenia* Borut Lozej

Photo 7.9 *Ceremošnja Cave, Kučevo, Serbia*. Neven Kresic

Photo 7.10 *Puralo Cave, Poreče, North Macedonia*. Dragan Kolčakovski

Photo 7.11 *Ubavica Cave, Bukovik Mountain, North Macedonia*. Dragan Kolčakovski

Photo 7.12 *Vjetrenica Cave, Popovo Polje, Herzegovina*. Neven Kresic

Photos 7.13 *Kaćunova Cave, Serbia*. Top Left & Bottom: Neven Kresic. Top Right: Predrag Stošić Peca

Photo 7.14 *Cave Ponor, Stara Planina Mountain, Serbia*. Predrag Stošić Peca

Photo 7.15 *Ledena (Ice) Cave, Ušac Cave System, Serbia*. Saša Maričić

Photo 7.16 *Križna Cave, Slovenia*. Peter Gedei

Photo 7.17 *Ledena (Ice) Cave, Stojna, Slovenia*. Peter Gedei

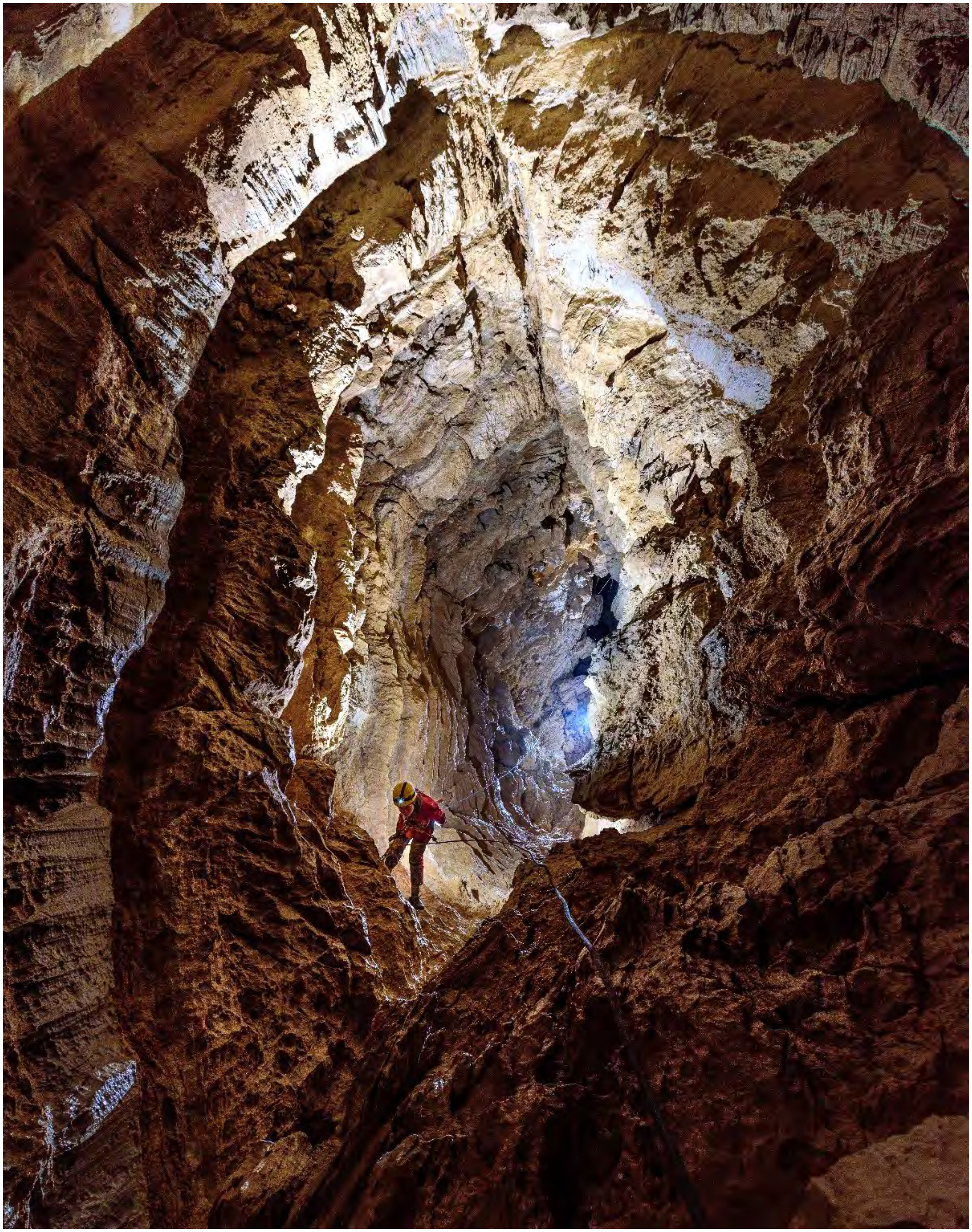


Photo 7.18 *Cave-Pit Grvn, Slovenia.* Uroš Kunaver

Photo 7.19 *Jama (Pit) Munižaba, Croatia*. Dinko Stopić

Photo 7.20 *Planinska Cave, Slovenia*. Uroš Kunaver

Photo 7.21 *Jama (Pit) Munižaba, Croatia*. Dinko Stopić

Photo 7.22 *Vlaška Cave, Serbia*. Ana Mladenović

Photo 7.23 *Blue Cave, Biševo Island, Croatia*. Branimir Jukić

Photo 7.24 *Dimnice Cave, Slovenia*. Peter Gedei

Photo 7.25 *Cerovac Caves, Croatia.* Dinko Stopić

Photo 7.26 *Jama(Pit) Munižaba, Croatia*. Dinko Stopić

Photo 7.27 *Tounjčica Cave, Croatia*. Dinko Stopić

Photo 7.28 *Markov Spodmol Cave, Slovenia*. Peter Gedei

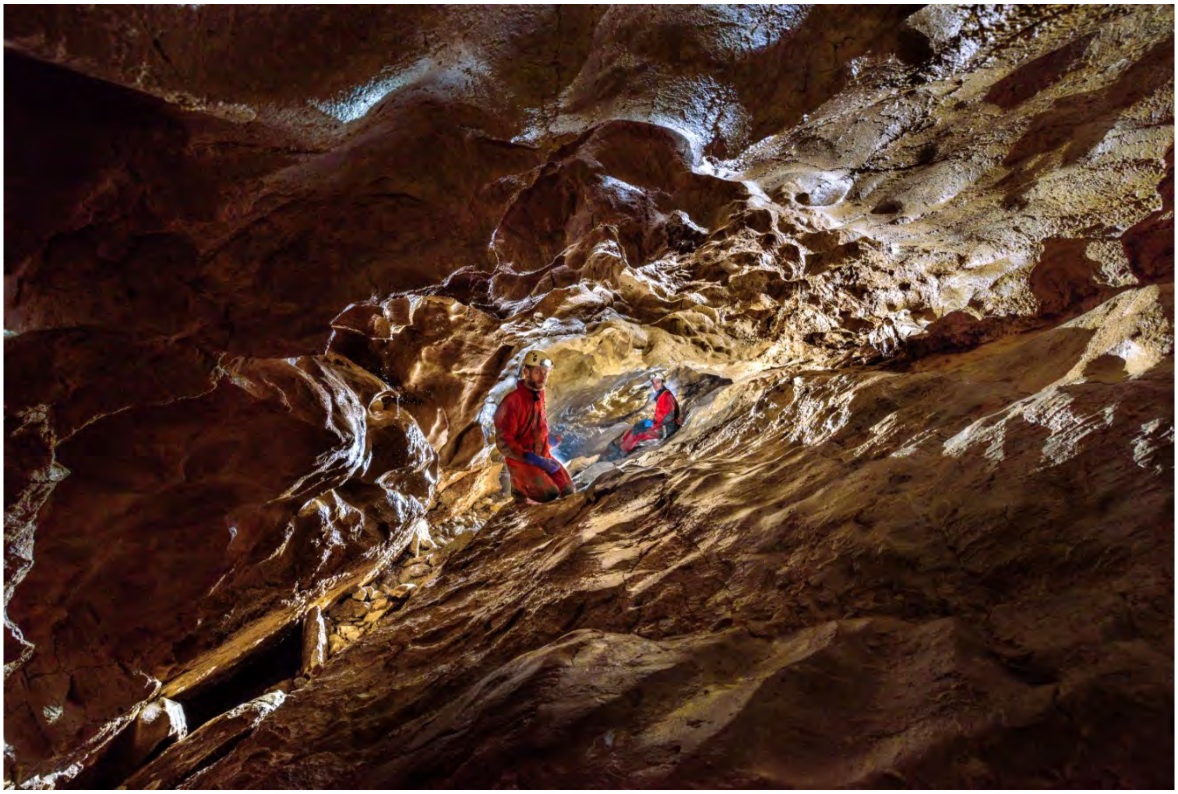


Photo 7.29 *Pološka Cave, Slovenia*. Uroš Kunaver

Photo 7.30 *Postojna Cave, Slovenia*. Peter Gedei

Photo 7.31 *Dimnice Cave, Slovenia*. Peter Gedei

Photo 7.32 *Undisclosed Cave, Slovenia*. Blaž Kogovšek

Photo 7.33 *Cave on Velebit Mountain, Tunnel Construction, Croatia*. Natalija Andačić

Photo 7.34 *Undisclosed Cave, Slovenia*. Uroš Kunaver

Photo 7.35 *Renejevo Brezno (Pit), Kanin Plateau, Slovenia*. Uroš Kunaver

Photo 7.36 *Križna Cave, Slovenia*. Uroš Kunaver



Photos 7.37 *Top: Kojina Jama (Pit); Bottom: Gospodska Cave, Croatia*. Vlado Božić

Photo 7.38 *Jama (Pit) Bezdanjača, Croatia*. Vlado Božić

Photo 7.39 *Bogovinska Cave, Serbia*. Jelena Ćalić

Photo 7.40 *Bezdan Cave, Giljeva Mountain, Serbia*. Predrag Stošić Peca

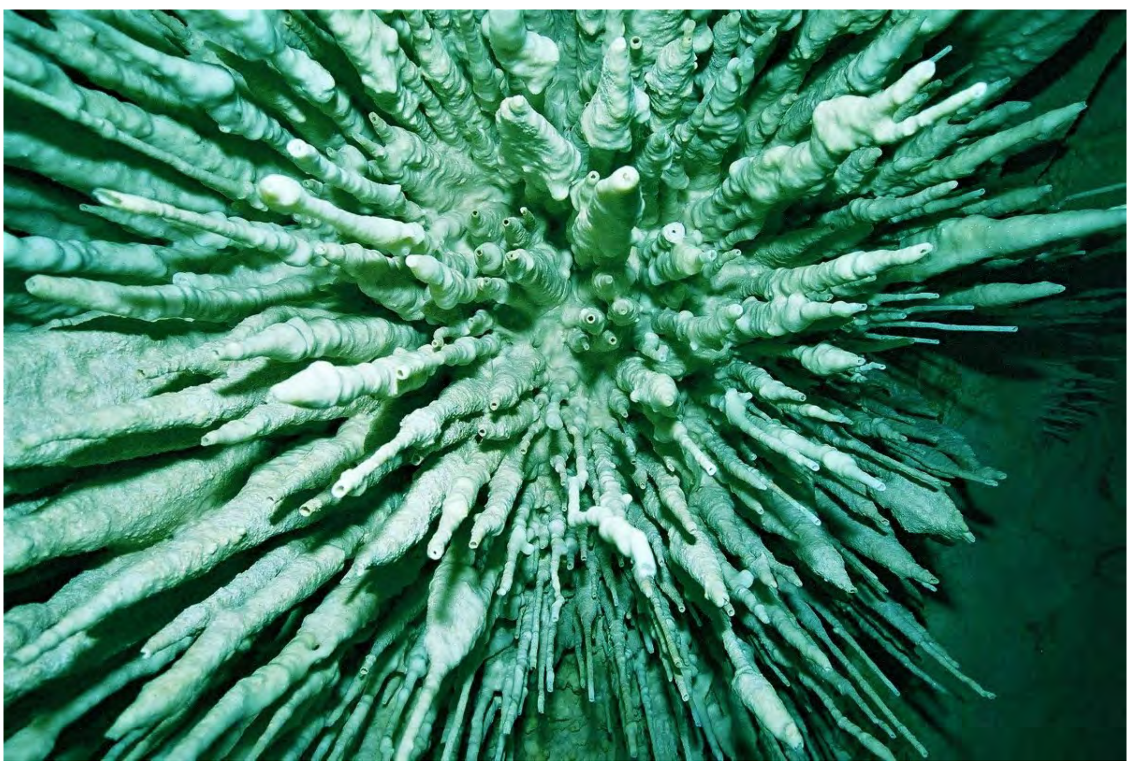


Photo 7.41 *Unnamed Cavern, Highway Construction, Croatia*. Mladen Garašić

Photo 7.42 *Momačka Cave, Serbia*. Vladimir Ljubojević

Photo 7.43 *Martina Jama (Pit), Croatia*. Mladen Garašić

Photo 7.44 *Lazar Cave, Serbia*. Jelena Ćalić

Photo 7.45 *Bogovinska Cave, Serbia*. Predrag Stošić Peca

Photo 7.46 *Propas' Cave, Vidlič Mountain, Serbia*. Predrag Stošić Peca

Photo 7.47 *Cavern, Tunnel Construction, Highway A-1, Velebit Mt., Croatia*. Mladen Garašić

Photo 7.48 *Tounjčica Cave, Croatia*. Mladen Garašić

Photo 7.49 *Rakin Ponor Cave, Miroč Mountain, Serbia*. Vladimir Ljubojević

Photo 7.50 *Lipska Cave, Montenegro*. Milovan Milivojević

Photo 7.51 *Hanke Channel, Škocjan Caves, Slovenia*. Borut Lozej

Photo 7.52 *Postojna Cave, Slovenia*. Iztok Medja

Photos 7.53 *Dimnice Cave, Slovenia*. Borut Lozej

Photo 7.54 *Korenatac Cave, Serbia*. Lazar Mrčarica


Photos 7.55 *Rajkova Cave, Serbia*. Zoran Stevanović (left), Srdjan Marinčić (right)

Photo 7.56 *Momiček Cave, North Macedonia*. Speleological Club “Peoni”, Skopje

Photo 7.57 *Nevestinska Cave, North Macedonia*. Speleological Club “Peoni”, Skopje

Photo 7.58 *Allica Cave, North Macedonia*. Speleological Club “Peoni”, Skopje

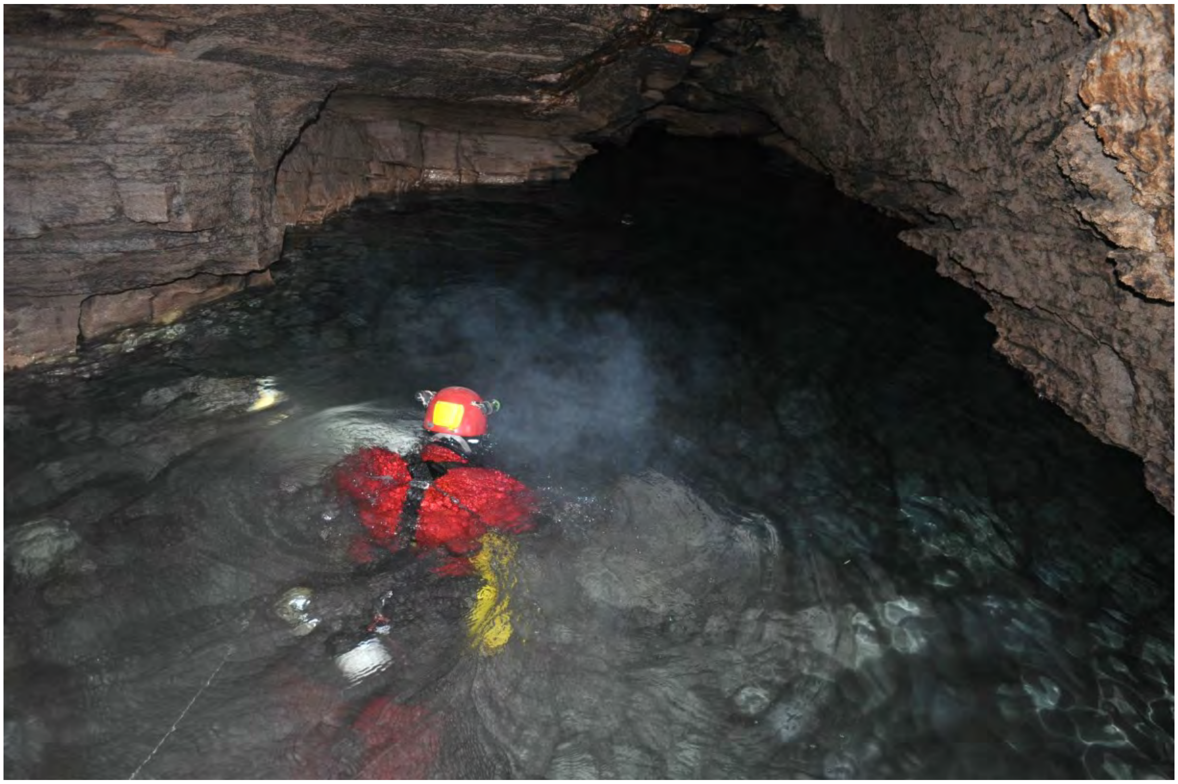
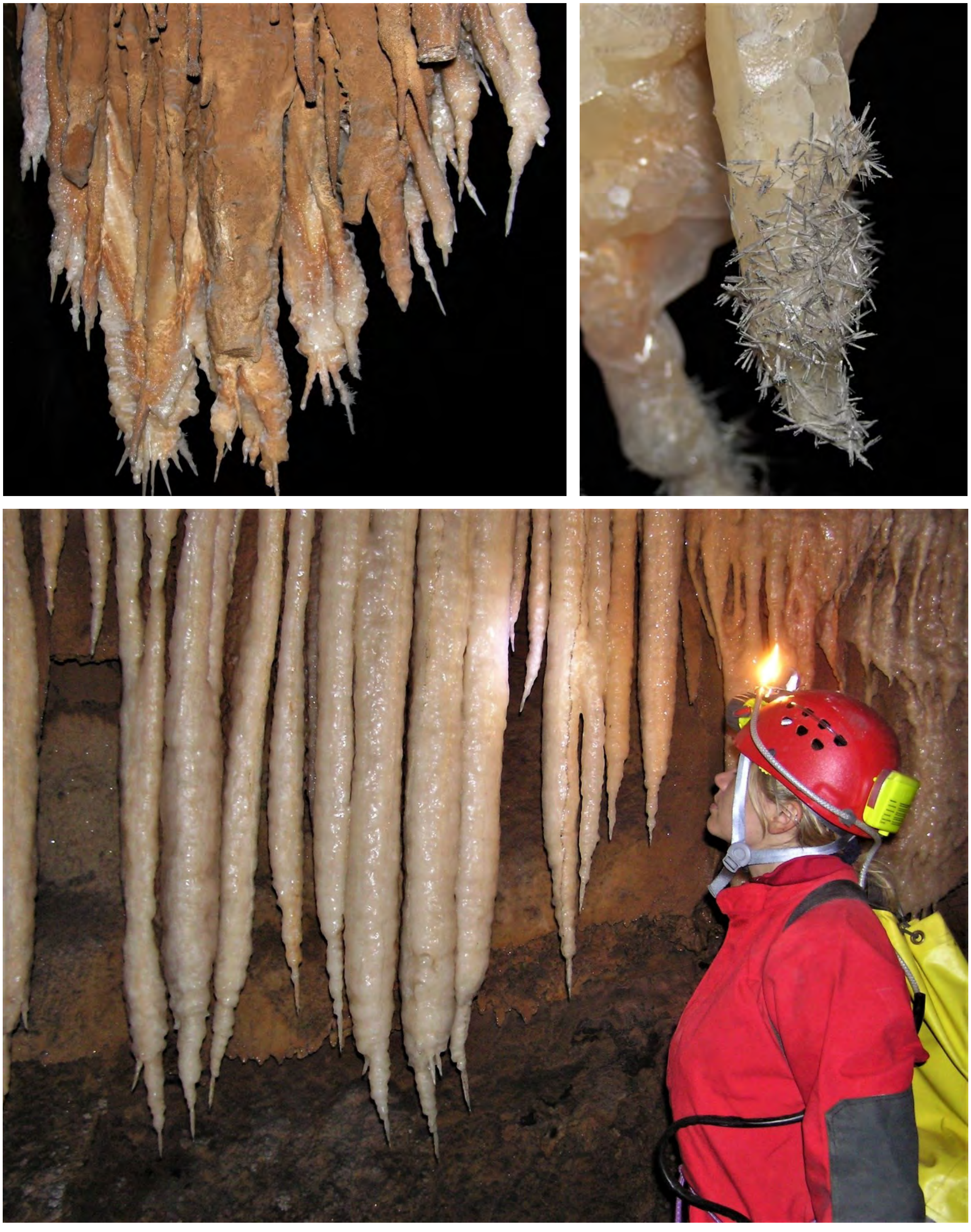


Photo 7.59 *Babuna Cave, North Macedonia*. Speleological Club “Peoni”, Skopje

Photo 7.60 *Pivska Cave, Slovenia*. Iztok Medja

Photo 7.61 *Stopića Cave, Zlatibor Mountain, Serbia*. Milorad Kličković

Photo 7.62 *Škocjan Caves, Slovenia*. Borut Lozej



Photos 7.63 *Cavern, St. Rok Tunnel Construction, Highway Zagreb—Split, Croatia*. Natalija Andačić

Photos 7.64 *Vernjikica Cave, Serbia (left); Taborska Cave, Slovenia (right)*. Neven Kresic

Photo 7.65 *Undisclosed Cave, Slovenia*. Matej Blatnik

Underground Life

8. Underground Life

Cave animals fit into three categories based on the amount of time they spend in a cave (https://www.nps.gov/ozar/learn/education/cave-biology.htm):

Trogloxenes*:* from the Greek words *"troglos"* (cave) and *"xenos"* (guest). These are temporary residents that freely move in and out of caves. These cave visitors seek out such a habitat from choice, and never complete their entire life cycle in the cave. Bats are usually the first trogloxenes that come to mind. Some species prefer the constant temperature of caves for hibernation and to bear their young. Bats, bears, skunks, moths, and people are examples of trogloxenes. Many of these animals are not dependent on the cave for their survival and they show no special adaptations to the cave environment.

Troglophiles: from the Greek words *"troglos"* (cave) and *"phileo"* (love). These cave loving animals live in the dark zones of a cave and they can also survive outside the cave. They will venture out in search of food. This group includes earthworms, some beetles, cave crickets, frogs, salamanders, and some crustaceans (such as crayfish).

Troglobites: from the Greek words *"troglos"* (cave) and *"bios"* (life). They are the true cave dwellers which spend their entire lives in the cave. Living permanently in the dark zone, these species cannot survive outside the caves. Most troglobites range from white to pinkish in color. They lack pigment because they have no need for protection from the sun's rays or for camouflage to hide them from predators.

Troglobites have developed special adaptations to help them survive in caves. The sense organs and physical adaptations of troglobites are devoted to finding food. Those senses that are essential to survival are enhanced, and those that are not necessary have weakened over time. Many have no eyes, or they are poorly developed due to the darkness of their environment. What the troglobites have lost, they make up for with longer legs and antennae, or feelers, and with adaptations that enable them to go for long periods of time with little food. Animals that have completely adapted to cave life include cave fish, cave crayfish, cave shrimp, isopods, amphipods, millipedes, some cave salamanders, and insects.

Caves may look devoid of life at first glance (excluding of course the most notable and famous cave dwellers of them all – bats), but they are full of microorganisms which serve as the base of the cave food chain. Together with fungi, they decompose into simple foods and nutrients various food sources that are brought into caves by sinking streams or occasional floods. These include leaves, twigs, and other organic matter. Microorganisms also feed on droppings from animals that go outside to feed then return to the cave to sleep or raise their young such as bats and crickets. Insects, such as beetles and mites, feed on the fungi and bacteria and then become the food supply for the larger predators like salamanders or crayfish. In turn, the droppings from larger cave animals replenish the food supply for fungus and bacteria and the food chain continues.

Unfortunately, densely visited or animal-populated caves are reservoirs of various bacteria, fungi and viruses reported to be pathogens for humans and animals. As discussed by Jurado et al. (2010), a review on the biodiversity and distribution of bacteria in subterranean environments reveals scant knowledge of these topics. Proteobacteria represent the major portion of bacteria in caves when using molecular tools, but Actinobacteria constitute most isolates. This suggests that caves are a habitat particularly favorable for this group of bacteria. Importantly, Actinobacteria produce about two-thirds of all naturally derived antibiotics.

In any case, visitors are strongly advised not to disturb anything in the cave, and especially not any bat droppings ("guano"). In addition, they should not touch cave walls, floors, or speleothems, not only because of their own safety but because of the safety and well-being of all cave animals, however small or big. Speleologists and scientists should of course be familiar with all the safety and environmental requirements before embarking on their cave research and explorations.

From the Adriatic Sea to the high Alpine environments (the Alps, Dinarides, and Carpathians), the Lands of Karst have an extraordinary rich underground life like no other karst area in the world. This is understandable given the diversity of subsurface karst forms, climate, and hydrologic conditions. And yet, only a tiny fraction of these caves and underground habitats have been explored in a systematic, "biospeleological" fashion. Even the caves that have been a focus of biospeleologists for decades constantly bring new surprises. For example, when the book "Karst and Caves of Yugoslavia" came out 33 years ago, the *Vjetrenica* cave in Herzegovina was cited as one of the richest in the world for biodiversity with "more than 50 cave animal species" reported (Kresic, 1988). Today, it is officially the richest, with over 200 troglobites many of which are endemic (they do not live anywhere else). The cave is included on the UNESCO World Heritage list. Not far behind are *Križna jama* in Slovenia, *Vilina špilja* cave in Croatia, and the list goes on.

The interest in subterranean life in Karst started with the writings of Baron Janez Vajkard Valvasor (also spelled Johann Weichert; 1641-1693), who was a Slovene nobleman, scholar, and member of the Royal Society (Slovenia was part of the Austrian Empire at the time). In his monumental work "The Glory of the Duchy of Carniola" (Die Ehre des Herzogthums Crain), published in 1689 in 15 volumes, in which he described his beloved lands, there is recount of a local story about baby dragons being washed out of the cave at the spring of river *Ljubljanica* after heavy rains. The locals believed that the strange pale creature was indeed a baby dragon because of three pinkish-reddish external gills on each side of the head. After being presented with the creature, he described it as "Barely a span long, akin to a lizard, in short, a worm and vermin of which there are many hereabouts." Thus, thanks to Valvasor, for the first time in history a true troglobite, an animal living in and restricted to caves, was described.

Proteus anguinus, as the creature was scientifically named by Josephus Nicolaus Laurenti in 1768, is an aquatic (amphibic) salamander, or olm, living only in the Dinaric Karst, from Slovenia to Herzegovina (and probably Montenegro, which is yet to be fully confirmed), and nowhere else on earth. For an unknown (and perhaps peculiar) reason, it was introduced into several caves elsewhere in the 20th century, notably in France. It is considered a national treasure by the government of Slovenia, strictly protected, and honored by one of the country's coins. It is now a crime to remove *Proteus* from its natural habitat or from anywhere in Slovenia. It is also protected in Croatia and on the path to be fully protected in Bosnia and Herzegovina as well (it is currently on the list of endangered species there.)

The average length of "human fish" (*čovečja ribica*), as *Proteus* is called by the Slavic population because of the color of its skin and small arms and legs (see Photo 8.7), is 23-25cm and it may grow up to 30 cm. It is thought to be the longest-lived amphibian species, up to 100 years by some estimates. *Proteus* is a relic of a Tertiary family of amphibians and it was known to Charles Darwin, who calls all cave animals in general *"wrecks of ancient life"* (in chapter 5 of his book *The Origin of Species*.) The eyes of *Proteus* are regressed, covered by skin but retain sensitivity to light (larvae, which are smaller versions of adults, have normal eyes.) The diet consists of insect larvae, mostly *Trichoptera*, *Ephemeroptera*, *Plecoptera* and *Diptera* larvae, molluscs (*Belgrandiella*), and amphipods (*Niphargus, Asellus, Synurella*).
(https://amphibiaweb.org/species/4229; after Bizjak-Mali 1995)

The most iconic cave dwellers, the bats, are unfortunately also the most misunderstood. It certainly does not help that they have been considered one of the main culprits in the COVID-19 pandemic that started in early

2020 in Wuhan, China and rapidly spread throughout the World, bringing unimaginable havoc on humanity around the world. Whatever the case may be, it is almost certain that bats did not directly infect humans because they only serve as natural reservoirs for diverse coronaviruses and are gentle, intelligent mammals that do not interact with humans and try to stay away from them as long as they possibly can. It is the humans that have been interfering with the bats and their habitats with increasing frequency for centuries, including consuming them and other exotic wild animals for food in China and certain other parts of the World.

After rodents, bats are the second largest order of mammals with over 1400 species and the only one that is capable of active sustained flying. Bats are of the order Chiroptera, Latin for "hand wing." The wings are composed of flexible skin spread over long fingers and joints which bats can move in every direction, instantaneously changing their flight path and velocity. This makes them the best and most efficient flyers in the animal kingdom. Bats can also navigate in complete darkness using echolocation. They produce sound waves at frequencies above human hearing, called ultrasound. The sound waves emitted by bats bounce off objects in their environment. Then, the sounds return to the bats' ears, which are finely tuned to recognize their own unique calls. Bats can change their calls for different purposes. They have different searching, feeding, and social calls. And each species of bat has its own unique call pattern (https://www.nps.gov/subjects/bats/echolocation.htm.). Interestingly, bats are called "blind mice" (*slepi miš*) in the Lands of Karst even though they can see perfectly.

All European bats, including in the Lands of Karst, are "insectivorous" – they feed each night only on insects, mainly mosquitoes, moths, and flying beetles thus maintaining a healthy environment. They rest and sleep during the day, hanging upside down, and many species of bats hibernate over winter. Their main habitat is caves, although they also live in other "cavernous" places such as abandoned buildings, mines, barns, rock crevices, and hollow trees. Bats benefit caves by providing important nutrients in their guano that support the growth of communities of cave organisms.

All bats in Europe are protected, including in the Lands of Karst. They are considered an endangered species because of a dramatic decrease in population due to various negative anthropogenic impacts such as loss of habitat and food sources, poisoning by pesticides and chemicals and, sadly, because of direct extermination by the humans. One reason for this cruelty is a false belief, by the uneducated, that bats attack humans and feed on human blood. This superstition (scientifically rebutted many times over) is based in part on the legend of Count Dracula and vampires in general who are believed to transform into bats before and/or after sucking human blood. However, out of more than 1400 species of bats, only one single species living in Central America feeds on the blood of mammals. All European bats feed exclusively on insects and are very timid when forced to interact with humans. Notably, in the Lands of Karst, it is forbidden to handle bats in any manner, and it is illegal to keep them as pets.

Cave bats range in size from three to five inches long (10-15cm), with wingspans between eight and thirteen inches (20-33cm) and weigh very little, less than an ounce (30 grams). They can live up to 25 years, and usually have only one offspring each year. As with other mammals, the baby bat is born alive and is fed milk by the mother. Females often nest in large colonies. They roost in caves during the day, preferring dome shaped ceilings for protection from predators (https://www.nps.gov/ozar/learn/education/cave-biology.htm).

Photo Captions

Note: all photo captions are provided by the authors of individual photographs hence the diversity–some felt like sharing more information with the reader, some left the photographs speak for themselves, giving only the essentials.

Photo 8.1 Part of a colony of *Miniopterus schreibersii* (Schreiber's Bent-winged Bat) in *Vernjikica* cave in eastern Serbia. The entire colony is some 25000 strong. This bat prefers tightly packed, big company during hibernation, and it bends its third and fourth fingers in as opposed to all other bat species that do not bend their fingers. Photo by Lazar Mrčarica.

Photo 8.2 Colony of *Rhinolophus ferrumequinum* (Greater Horseshoe Bat) in *Lazareva pećina* cave, eastern Serbia. Photo by Milan Paunović.

Photo 8.3 *Rhinolophus ferrumequinum* (Greater Horseshoe Bat) in *Dudićeva pećina* cave, Serbia. This is the largest horseshoe bat in Europe. During hibernation it stays either alone or in smaller groups where the individuals are in contact as seen on this photo. An interesting detail here is that they all picked a calcite vein to make themselves comfortable, avoiding smooth surfaces of the scallops (facets). Photo by Lazar Mrčarica.

Photo 8.4 Colony of European long-winged bats (*Miniopterus schreibersii*) in a cave in eastern Serbia. Shown here is a "kindergarden" surrounded by supervising adults while others are out hunting. Photo by Milan Paunović.

Photo 8.5 *Rhinolophus hipposideros* (Lesser Horseshoe Bat) in *Disina pećina* cave, eastern Serbia. This is the smallest horseshoe bat in Europe. While in hibernation, it is never in close contact with other bats as it prefers solitude. It completely envelops itself with wings such that the front of the body is not visible. Photo by Lazar Mrčarica.

Photo 8.6 "Here he flies". Photo of a flying Horseshoe Bat (*Rhinolophus* sp) taken in one of the most beautiful caves in eastern Serbia, *Bogovinska pećina*, during surveying and mapping of distant channels, some 3000 meters from the entrance. The author of the photograph, occupied with the task at hand, namely photographing this part of the passage, did not even notice that the frame included one of its "hosts" who apparently came to check what was going on in his home. Photo by Mihajlo Mandić Zis.

Photo 8.7 Proteus anguinus (*čovečja ribica* in Slavic languages, meaning "human fish") is the largest known cave animal that is widespread in Dinaric Karst from northeastern Italy and Slovenia to Montenegro. One of the most populated areas in Slovenia is *Planinska jama* cave, where more than 800 individuals have been counted. The individual shown on the photo was spotted during flow measurements and diving explorations in the *Rak* branch of the cave. Photo by Matej Blatnik.

Photo 8.8 Acarina – Mites are frequently found in the entrance parts of the caves, implying they manage to survive in the organic debris originating from the surface. However, many specialized and cave-adapted species of mites, similar to the one on the photo, are found deep within the subterranean domain. *Gorjanska jama* cave. Photo by Teo Delić.

Photo 8.9 *Aphenopidius treulandi* – With body length exceeding 1 cm, this subterranean beetle genus, found only in Slovenian and Austrian Southern Calcareous Alps, is one of the largest in Europe. Although lacking eyes, strong mandibles indicate its predatory lifestyle. *Veternica pri Vranskem* cave. Photo by Teo Delić.

Photo 8.10 *Plusiocampa* sp. – These fast-moving insects are easily recognized by narrow body and a pair of elongated filaments at the end of abdomen, so called cerci, which, in some cases, exceed the body length. *Vampirjeva jama* cave. Photo by Teo Delić.

Photo 8.11 *Ischyropsalis* sp. – Representatives of this surface harvestmen genus, eating an isopod crustacean *Androniscus*, are often encountered in the entrance parts of Alpine and Subalpine caves. Photo by Teo Delić.

Photo 8.12 *Leptodirus hochenwartii* Schmidt – This iconic beetle, found in the caves of the Dinaric Karst, was the first officially described cave-adapted animal in the world (by Ferdinand Shmidt in 1832; the beetle was discovered a year earlier in Postojna Cave, Slovenia by the famous cave guide Luka Čeč.) It was only after the beetle's description that people started to be aware that the life in the subterranean habitats is possible. *Vrtlina jama* cave. Photo by Teo Delić.

Photo 8.13 *Nemaspela borkoe* – The second species of the subterranean harvestmen genus *Nemaspela*, predominantly distributed in the Caucausus, described from the Montenegrin caves of the Dinaric Karst in 2020. *Vodna jama na Dragaljskom polju* cave. Photo by Teo Delić.

Photo 8.14 *Oryotus raduhensis* – Described from the famous "Snežna jama" (Ice cave) on Raduha mountain, Slovenia, this species is the easternmost representative of the Southern Alpine – Northern Dinaric genus, *Oryotus*. *Jelenja Zijalka* cave. Photo by Teo Delić.

Photo 8.15 Caves of the Dinaric Karst are home for numerous species of cave adapted pseudoscorpions, which, at the first sight, differ from the true scorpions by lacking the hind part of the body a poisonous sting. *Vampirjeva jama* cave. Photo by Teo Delić.

Photo 8.16 *Neobisium* sp. – Differently from the representatives of the family Chthoniidae, which are small and stout, the representatives of the family Neobisidae are characterized by elongated appendages and gracile, scissor-like pedipalps. *Žalcevo brezno* cave. Photo by Teo Delić.

Photo 8.17 *Verhoeffiella* sp. – This undescribed species is the first representative of a large subterranean collembolan genus, *Verhoffiella*, frequently found in the caves of the southern Dinarides, in Slovenian Alps. *Jelenja Zijalka* cave. Photo by Teo Delić

Photo 8.18 *Zospeum spelaeum* – Species of this tiny snail genus are found across some of the major limestone ranges in Europe, namely Alps, Pyrenees and Dinarides, and are hard to distinguish due to huge morphological variability of shells. *Pozabljena jama pri Kmetovovom breznu* cave. Photo by Teo Delić.

Photo 8.1 *Schreiber's Bent-winged Bat, Vernjikica Cave, Serbia*. Lazar Mrčarica

Photo 8.2 *Greater Horseshoe Bat, Lazareva Cave, Serbia*. Milan Paunović

Photo 8.3 *Greater Horseshoe Bat, Dudićeva Cave, Serbia*. Lazar Mrčarica

Photo 8.4 *European long-winged bats. Cave in Serbia*. Milan Paunović

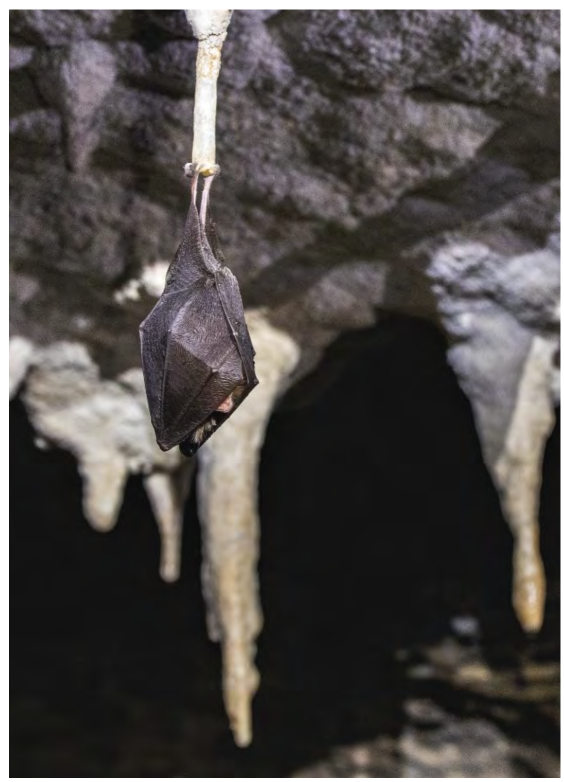


Photo 8.5 *Lesser Horseshoe Bat Disina Pećina, Serbia.* Lazar Mrčarica

Photo 8.6 *Horseshoe Bat, Bogovinska Pećina, Serbia*. Mihajlo Mandić Zis

Photo 8.7 *Proteus anguinus; Postojna Cave, Slovenia*. Matej Blatnik

Photo 8.8 *Acarina, Gorjanska Jama, Slovenia*. Teo Delić

Photo 8.9 *Aphenopidius treulandi; Veternica pri Vranskem, Slovenia*. Teo Delić

Photo 8.10 *Plusiocampa* sp.*; Vampirjeva Jama, Slovenia.* Teo Delić

Photo 8.11 *Ischyropsalis* sp.; *Slovenia*. Teo Delić

Photo 8.12 *Leptodirus hochenwartii* Schmidt; *Vrtlina Jama, Slovenia*. Teo Delić

Photo 8.13 *Nemaspela borkoe; Vodna jama na Dragaljskom polju, Slovenia.* Teo Delić

Photo 8.14 *Oryotus raduhensis; Jelenja Zijalka Cave, Slovenia.* Teo Delić

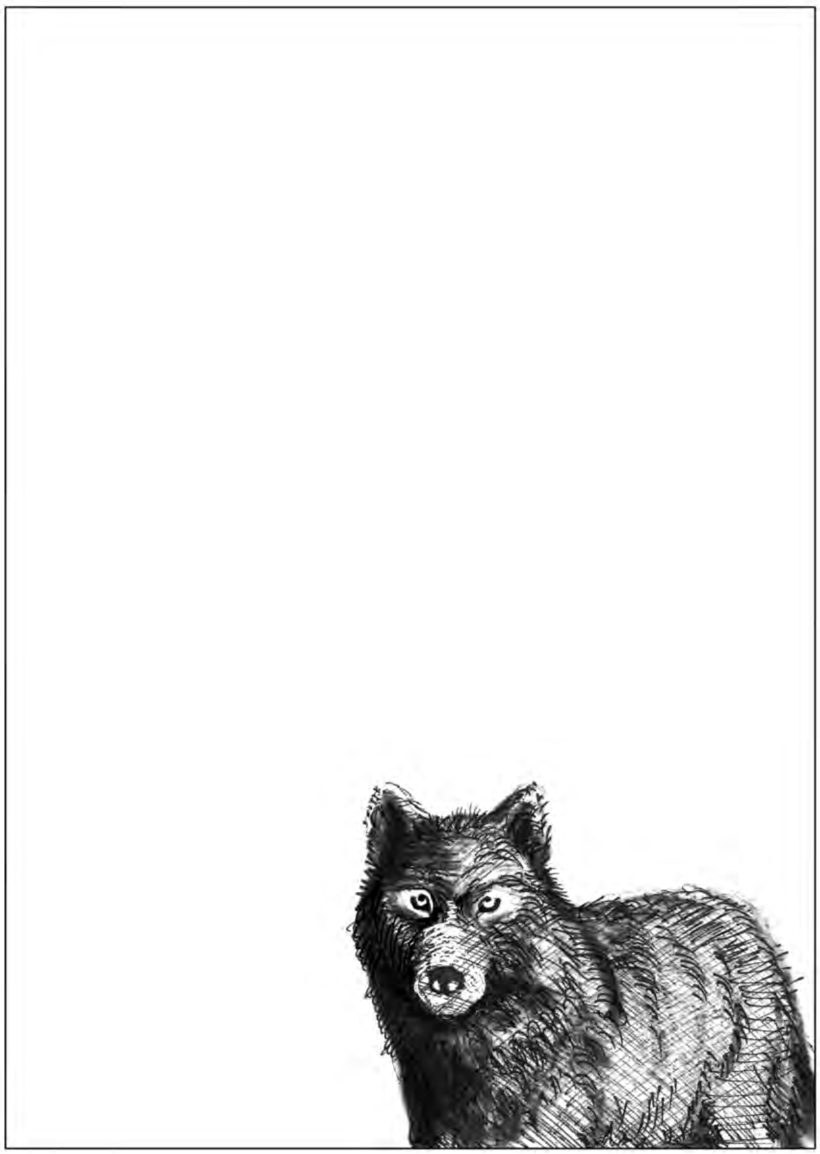
Photo 8.15 *Pseudoscorpion; Vampirjeva Jama, Slovenia.* Teo Delić

Photo 8.16 *Neobisium* sp.*; Žalcevo Brezno, Slovenia.* Teo Delić

Photo 8.17 *Verhoeffiella* sp.*; Jelenja Zijalka Cave, Slovenia.* Teo Delić

Photo 8.18 *Zospeum spelaeum; Pozabljena jama pri Kmetovovom breznu, Slovenia.* Teo Delić

Wildlife Habitats and Endangered Species



9. Wildlife Habitats and Endangered Species

The Lands of Karst are characterized by great geodiversity and biodiversity. There are high mountains, with peaks covered in snow until late summer; however, they are often without perennial streams and rainfall can be intensive but scarce. The rainfall can also have unequal distribution over barren rocky ground and numerous springs often dry out during summer.

The karst relief and landforms that have been shaped by erosion over millennia have resulted in some of the most breathtaking landscapes on our planet. In addition to its geology, the karst landscape has outstanding biotic values as it supports specific habitats with a high number of unique, rare, or endemic plant and animal species. Local variations in temperature, elevation, and moisture create not only incredible plant diversity but also amazing animal communities.

Current estimates for the number of species on Earth range between five million and one trillion. Unfortunately, we cannot obtain a more exact count because many live in inaccessible habitats or are hard to discover as they are too small to be seen. It is precisely such communities of plants and animals that find their home in the karst areas of the Dinarides and Carpathians.

The rich biodiversity of the entire Western Balkans has been studied for many years. Regional studies of rare and endangered plants and animals can be found in the works of Stevanović and Vasić (1995), Albrecht and Wilke, (2008), and Redžić et al. (2008), while various types of threats to biodiversity were discussed by Petrović et al. (2008), Kostoski et al. (2010), Bonacci (2013), and Vurnek et al. (2018).

The dominant species of the Dinaric karst mountain forests are conifers, including spruce, silver fir, and black pine, while a Tertiary relict, the famous Serbian or Pančić spruce (*Picea omorika*) is mostly limited to the area of Tara National Park (Tara mountain, western Serbia). Mixed fir, spruce, and beech forests and shrubs are typical for all the Dinaric mountains. Broadleaf beech and mixed forests (oak, linden, elm, hornbeam, ash, maple) with an outstanding diversity of deciduous oak species, predominate at medium and low altitudes, in canyons and valleys. Mosses, ferns, orchids, common lilacs, and other smaller plants cling to steep cliffsides.

In the Slovenian part of the Julian Alps 66% of the land cover is natural forests, and only about 2% is agricultural land, the fact reflected in great diversity of local flora and fauna. 2200 animal species, around 1000 lichen species and 1600 vascular plants have been recorded.

The varied forest communities of the Lands of Karst host a remarkable faunal diversity of birds, large and small mammals, insects, and reptiles. The griffon vulture, western capercaillie, peregrine falcon and kestrel are all present and listed as threatened Species of European Concern (SPECs). In the mountain ranges, there are significant populations of brown bears, lynxes, foxes, wolves, roe and red deer, chamois, wild boars, wildcats, and European badgers, to name just a few.

Like many other Dinaric mountains, the Velebit Mountain in Croatia has "two different faces" – one on the Adriatic coastal slopes and one on the continental slopes. The differences between them can be observed in a variety of ways – vegetation, habitats, and species. In the Velebit area about 90 different habitat types can be distinguished based on the CORINE classification, or 70% of all habitat types found in Croatia. Velebit has very high biological diversity, thanks to very diverse habitats but also to the fact that some parts of the mountain acted as refuge for numerous species during Quaternary glaciations. Some 2500 plant species have been described, about one hundred of them endemic.

Adriatic islands have rich and unique flora and fauna. The islands, islets, and cliffs of the Vis archipelago are habitats to as many as 126 bird species of which 11 are part of the ecological network Natura 2000. Among them the *Eleonora falcon* is of great significance since it is found almost nowhere else in Croatia, outside the open-sea islands. More than 800 plant species were inventoried in the Vis island flora, out of which 30 species are in the Natura 2000 network. (Natura 2000 is a network of core breeding and resting sites for rare and threatened species, and some rare natural habitat types which are protected in their own right. It stretches across all 27 European Union countries, both on land and at sea. The aim of the network is to ensure the long-term survival of Europe's most valuable and threatened species and habitats, listed under both the Birds Directive and the Habitats Directive.)

Plitvice Lakes, one of the most famous karst areas in the Lands of Karst, is designated as a World Heritage Site, Natura 2000 Site, and is the first National Park established in Croatia. The park hosts 1400 plant species, 50 species of mammals, and 22 species of bats. It has around 64 Special Protection Areas (SPA) for birds.

Fauna of vertebrates in Bosnia and Herzegovina includes around 120 fish species, 40 reptiles, 20 amphibians, and 85 mammals, of which 39 species are endemic ones, with the highest level of endemism among fishes and amphibians. Karst poljes in Bosnia and Herzegovina and Croatia are rich in flora and fauna despite frequent water shortages due to the presence of sinking streams and their highly variable flows. Livanjsko polje, the largest polje in the world, is home for an impressive 264 bird species, out of 349 recorded in the whole of Bosnia and Herzegovina. Due to this fact, Livanjsko polje was in 2008 declared a Wetland of International Importance by the Ramsar Convention, and in 2011 an Area of International Importance for Birds (IBA).

Durmitor Mountain National Park and the Tara River Basin in Montenegro together constitute a UNESCO Word Heritage Site and Man and Biosphere Reserve. They host diverse ecosystems including 1700 vascular plants out of which 900 species belong to high mountain flora (virgin stands of black pine forest, numerous endemic and relict species), mosses, fungi and lichens, over 120 species of birds, a wide range of newts, frogs, and lizards, great variety of insects, and 30 species of large and small mammals.

Skadar Lake area in Montenegro has the following international designations: Ramsar Sites of Wetlands of International Importance (based on the richness and diversity of ornithofauna), Important Plant Area (IPA), and Important Bird Area (IBA). Based on the criteria of Bern Convention, 17 Emerald habitats with good representation have also been identified in the Lake region. The Skadar Lake ecosystem is extremely complex, of sub-Mediterranean type, with dominantly freshwater and different other biotopes: water biotope, wetland biotope, vegetation biotope, flood forests and meadows, forest, bushes, and rocks biotopes. The lake area is a migration corridor for the avifauna (170 bird migratory and nesting species) and for aquatic animals between the Adriatic Sea and the hydrographic network of the south-western Balkans. Rich ichthyofauna includes 30 species of freshwater fish and 13 species and subspecies of migratory fish.

Ohrid–Prespa Transboundary Reserve in West Macedonia, designated by UNESCO in 2014, is a biodiversity hotspot of global importance and hosts numerous rare and endemic representatives of flora and fauna. There are 19 plant taxa from the IUCN (International Union for Conservation of Nature) World’s Red List of Threatened Plants, 17 fish species (out of which 10 are endemic), 23 species of birds, and 27 mammal species including the Balkan lynx (considered one of the most endangered mammals in the world), the Balkan chamois, gray wolf, and brown bear.

The Carpathian Mountains form the second largest mountain chain in Europe. They extend through eastern Serbia where the Djerdap UNESCO Global Geopark is located. This Geopark is one of the largest and the most northerly European sanctuary for Tertiary flora, with more than 50 different types of forest and bush communities, out which 35 are relict. Approximately 150 bird species are reported in the Geopark. Thanks to their diversity and the presence of rare, endangered birds, this area has been declared an Important Bird Area (IBA) of Europe. The abundance of mammals is to a large extent the result of well-preserved habitats; characteristic species include otter, wildcat, Eurasian lynx, brown bear, chamois, deer, roe deer and different bats which are all on the Preliminary Red List of Vertebrates of Serbia (i.e., a list of endangered species).

So far, a healthy population of wolves is present throughout the Lands of Karst but with an uneven status. In Croatia and Slovenia, the wolf is protected, in Montenegro it is on a path of being protected, whereas in Bosnia and Herzegovina, North Macedonia, and Serbia (outside of its northern province Vojvodina), there are no protections for the wolf.

Keeping in mind all the characteristics of karst terrains, aesthetic, scientific, ecological, and cultural, it is not surprising that large areas in the Lands of Karst are attractive to tourists. Caves, gorges, limestone cliffs, and waterfalls, along with their plant and animal dwellers, provide a diverse array for tourist and offer many possibilities for adventure. There, both the public and karst enthusiasts alike have a unique opportunity to feel and understand the unbreakable link between the non-living and living parts of nature.

Photo Captions

Note: all photo captions are provided by the authors of individual photographs hence the diversity–some felt like sharing more information with the reader, some left the photographs speak for themselves, giving only the essentials.

Photo 9.1 *Vipera ammodytes*, nose-horned viper ("poskok" in Slavic languages which means "jumper"), one of the most venomous snakes in Europe and widely spread throughout the Lands of Karst. This snake prefers limestone terrains where the abundance of crevices and cavities in the rocks provides for perfect habitat and shelter. Unique characteristic of the viper is its "horn" at the tip of the snout made of scales, the purpose of which is still unknown. Tara National Park, Serbia. Photo by Srdjan Marinčić.

Photo 9.2 Poskok (*Vipera ammodytes*), whose name freezes the blood in the veins, is the longest, most dangerous and most venomous snake in the Balkans, reaching a maximum length of 100 cm. Contrary to popular belief, "poskok" cannot jump. But, it can roll the back of the body, then raise the front part and quickly throw it forward to bite the victim, which gives the impression of "jumping". The range of such a "jump" is 40 cm. Males are ashy gray, while females are usually brown, gray-brown, or reddish-brown. There is a characteristic "zigzag" line on the back, which is broken in some specimens, forming rhombuses. The "poskok" is not aggressive and when it is upset it starts to hiss and tries to get away. During the bite, this species excretes about one-seventh of a gram of venom. The venom has an effect on the blood, which clots and causes a chemotoxic shock. Even newly hatched snakelet 15-18 cm long are equipped with venom and venomous teeth and can inflict a very serious and dangerous bite. Photo by Ana Paunović.

Photo 9.3 *Vipera ammodytes*, nose-horned viper. Photo by Dragan Bosnić.

Photo 9.4 *Natrix tessellate*, dice snake ("ribarica" in Slavic languages, which means "fishing snake"); Stara Planina mountain, eastern Serbia. It is a non-venomous snake of medium size, up to about 1.4 m long. Females are larger than males. The color of the back of the body varies from olive green-gray to completely black, without patterns or with darker square spots arranged similarly to dice. This snake inhabits fast or large rivers and lakes and is not found at high altitudes. In natural habitats it lives for up to 10 years and feeds almost exclusively on fish. In Serbia "ribarica" has been declared a strictly protected species. Photo by Ana Paunović.

Photo 9.5 *Lacerta viridis*, the European green lizard ("zelembać" in Slavic languages); Ozren mountain, eastern Serbia. This is one of the largest lizards in Europe. The total length reaches over 35 cm, of which at least two thirds are the tail. The color of the dorsal side of the body is green, in males it is bright green at the time of mating. The cubs are lighter in color and have a few light spots or 2-4 light thin stripes that extend along the hips. Typical habitat is dense bushy vegetation in open woodland, hedgerows, and field margins. The lifespan in nature of this species is up to 10 years. Photo by Ana Paunović.

Photo 9.6 *Ichthyosaura alpestris*, the alpine newt; Jarevac creek, Tara mountain., western Serbia. The mountain (or alpine) newt ("mrmoljak" in Slavic languages) is an amphibian from the order of tailed amphibians (Caudata). Females reach a size of up to 12 cm, and males up to 9 cm. The dorsal surface of the body is brown, gray, brown or olive, and sometimes completely black. In Serbia, the mountain newt has been declared a strictly protected species, primarily due to its small number, but also due to the destruction of its natural habitat. Their average lifespan is about 7 years, although some specimens can live much longer, probably more than 20 years. Photo by Ana Paunović assisted by Bora Milićević.

Photo 9.7 *Lacerta viridis*, the European green lizard. Photo by Dragan Bosnić.

Photo 9.8 Lizard (probably a *Podarcis muralis*) shot by a strong telephoto lens at the cliff of the Miroč mountain, Danube Gorge, the Serbian – Romanian border. Photo by Dragan Bosnić.

Photo 9.9 Frog from family Bombinatoridae, the yellow-bellied toad (lat. *Bombina variegata,* "žutotrbi mukač" in Slavic languages), below it in the water is a fishing snake. Photo by Ana Paunović

Photo 9.10 *Salamandra salamandra* ("šareni daždevnjak" in Slavic languages) – Fire salamander (yellow spotted). Kučaj mountain, eastern Serbia. Photo by Zoran Stevanović.

Photo 9.11 *Podarcis muralis*, common wall lizard; Rtanj mountain, Serbia. The wall lizard is the most widespread lizard in Central and Southern Europe. It is up to 24 cm in size, with the tail making up about two thirds of the total length. The body is relatively elongated, the legs are well developed. Males are larger than females and have larger heads, but slightly shorter bodies. This species is widespread and inhabits all natural and anthropogenically modified habitats that have at least a little rocky ground and enough sunlight and heat during the day. It is a frequent inhabitant of human settlements, including large cities. The recorded life expectancy of this species is up to 7 years in nature. Photo by Ana Paunović.

Photo 9.12 *Bombina variegata*. Photo by Ana Paunović

Photos 9.13 Top: The Brown bear (lat. *Ursus arctos*). Bottom: View from the bear's den. Photos by Milan Paunović.

Photo 9.14 The Beech marten (lat. *Martes foina*), also known as the stone marten. Photo by Milan Paunović.

Photos 9.15 The Balkan lynx (lat. *Lynx lynx balcanicus*) is a subspecies of the Eurasian lynx. It is the national symbol of North Macedonia and one of the rarest animals in the world. It is believed that less than 100 individuals now roam the Balkans – mostly in the wilderness of Macedonia, Montenegro, Albania, and Serbia (Tara National Park, Shara mountain between Macedonia and Kosovo province, Djerdap National Park, Kučaj mountain, Stara Planina mountain). Illegal waste dumping, deforestation for firewood and construction, and poaching (especially in Albania) have led to the Balkan lynx being classified as Critically Endangered on the Red List of threatened species, which is maintained by the International Union for Conservation of Nature (IUCN). In addition to humans, the main enemy of the Balkan lynx in Serbia is the Carpathian lynx which is displacing it to the west and south. Photos by Dragan Bosnić.

Photo 9.16 Young brown bear at the rim of the entrance to Barka cave in Slovenia. Brown bear is widespread in most of Slovenia, especially in Dinaric Mountains. "The bear shown on the picture is not the first one that I have seen, but since visiting the Barka cave, the frequency of bear meetings rapidly increased. It happened several times that we had a research work in this cave, while curious bears have been walking around the cave entrance and observing our work. After several such events I brought to the work the camera with a better zoom and captured this young bear." Photo by Matej Blatnik.

Photo 9.17 Chamois (lat. *Rupicapra rupicapra*) on the rim of Planinsko polje in Slovenia. "Chamois, a goat-like antelope, is a species common for the scarcely populated areas at higher altitudes but sometimes they can also come to lower altitudes. This one has been captured at the northern border of the Planinsko polje at 500 m asl. Unsurprisingly, it was timid and escaped immediately when I came closer." Photo by Matej Blatnik.

Photos 9.18 Griffon vulture (lat. *Gyps fulvus*) – "Beloglavi sup" in Slavic languages, inhabits the Special Nature Reserve "Uvac River Gorge" in southwestern Serbia. This bird belongs to a group of the "Vultures of Old World" (Aegypiinae and Gypaetinae). The griffon vulture is a species of vulture eagle, of impressive size, wingspan up to 3 meters, which makes it a powerful fighter whose flight has been researched by scientists and aeronautical engineers and used in the construction of aircraft. Its role in the food chain in the ecosystem is unique and irreplaceable - its exclusive food is dead animals, which prevents the spread of infections and thus makes "natural recycling". This rare species was on the verge of extinction after the Second World War. Thanks to the enthusiasm of the local population, the ornithologists of the Biological Institute from Belgrade, and the proclamation of the Special Nature Reserve "Uvac River Gorge" in 1971, griffon vultures have been preserved from complete extinction. However, in 1990, only about 10 griffon vultures survived on the territory of Uvac Lakes. This bird was protected by law in 1994, and the Manastirina feeding ground was organized, to which the bodies of dead animals are taken out to the "restaurant of griffon vultures in nature". By consistent implementation of the nutrition program (annually about 250 tons of food and slaughterhouse waste are provided), and above all by the efforts of the guards of the protected area, the number of griffon vultures has increased to about 110 nesting pairs, i.e. 450-500 individuals. It should be noted that, in previous years, another two species of eagle vulture, that once inhabited this area, have returned. Photos by Saša Preradović.

Photo 9.19 The griffon vulture – “beloglavi sup” in Special Nature Reserve Uvac River Gorge. The colony of this unique species of bird is the largest in the Balkans and one of the largest in Europe. Photo by Saša Preradović.

Photo 9.20 The marmot (lat. *Marmota marmota*) taking advantage of the last warm days before a long, snowy winter in the Alps (Kanin, Slovenia). Photo by Ester Premate.

Photo 9.21 The edible dormouse (lat. *Glis glis*) in Bastaši cave entrance, Bosnia and Herzegovina. The edible dormouse is a nocturnal animal and mostly inhabits old deciduous forests, but it is also found in orchards and gardens. It hibernates from late autumn to early spring. Edible dormice are omnivores and feed mainly on nuts, fruits, mushrooms and insects. They are easily recognizable by their long, bushy tail. Photo by Jelena Bogosavljević.

Photo 9.22 The chamois (lat. *Rupicapra rupicapra*) in Lazarev Canyon near Vernjikica cave, eastern Serbia. They inhabit rocky, steep mountains up to 3500 m. Chamois stay at mountain meadows and pastures in summer and autumn, above treeline, where they graze on grasses and herbs. In winter they descend to lower altitudes and reside in forests, where they feed mainly on moss and tree bark. Both males and females have horns that grow all their lives. They are very well adapted to moving on uneven surfaces and can perform jumps six meters long and two meters high. Chamois are primarily diurnal and they often rest during the middle of the day. Photo by Jelena Bogosavljević.

Photo 9.23 *Picea omorika* (Pančić) Purk. commonly known as Serbian spruce. Locality: Zmajevac Creek, Tara National Park, Serbia. Spruce is an endemic coniferous, slender tree. In nature, it occurs in few mountains in the western part of Serbia and Bosnia, as well as in several canyons in the Drina river basin. It also grows on the mountain Tara, where Josif Pančić, famous botanist, founder of the Institutes of Mineralogy and Geology, Zoological and Botanical Departments at the University of Belgrade (former Great School) and the first president of Serbian Royal Academy, discovered it. He heard from the inhabitants of western Serbia that a specific conifer grows in that area, and it looks similar to fir and spruce. Back in 1875, on an expedition with his students in western Serbia, he found spruce trees on Tara mountain, as well as their cones. After this remarkable discovery, he was able to describe a new species. Photo by Uroš Buzurović.

Photo 9.24 The black pine (lat. *Pinus nigra)*. One of the most picturesque views in the Tara National Park from the lookout point “Banjska stena” above the Perućac reservoir on Serbian side, looking towards canyon of the river Drina and the area of Osat on Bosnia and Herzegovina side. In the area of the Drina canyon, in the length of several tens of kilometers, valleys and canyons alternate. In many places the karst surface has rich soil cover on which dense forests are developed. Photo by Srdjan Marinčić.

Photo 9.25 The black pine (lat. *Pinus nigra)* with deformed canopy due to strong “bora”, north wind that often blows from the high Dinaric karst plateaus towards the Adriatic Sea. Photo by Borut Peric.

Photo 9.26 A view of Snow mountain (“Snežnik”, 1796 m), Slovenia from the deep karst depression at its southern part where due to temperature inversion spruce trees (*Picea abies*; European or Norway spruce) grow. Since this high karst plateau behaves as a barrier against humid air currents from the Adriatic Kvarner Bay, the annual precipitation can exceed 4000 mm. Photo by Borut Peric.

Photo 9.27 Wild Lake ("Divje jezero" in Slovene) in Slovenia is a karst spring, more than 150 m deep, surrounded with grand old beech trees (*Fagus sylvatica*). Photo by Borut Peric.

Photo 9.28 Beech forest (*Fagus sylvatica*) on Velebit mountain in Croatia. The beech forests of the Paklenica National Park and the Northern Velebit National Park were listed on UNESCO World Heritage List on 7th July 2017, and together with the beech forests of Albania, Austria, Belgium, Bulgaria, Italy, Germany, Romania, Slovakia, Slovenia, Spain and Ukraine they comprise the whole of **"**Ancient and Primeval Beech Forests of the Carpathians and Other Regions of Europe**"**. Photo by Ivana Adžić.

Photo 9.29 *Aquilegia kitaibelli* (lat. for "Kitajbelov pakujac") is an endemic plant species growing exclusively on the mountains of Croatia, Slovenia and Bosnia and Hercegovina above 1200 m altitude. Photo by Ivana Adžić.

Photo 9.30 Adriatic bellflower ("Jadranski zvončić"; lat. *Campanula fenestrellata)* is an endemic species which grows exclusively on rocks and cliffs of Velebit mountain in Croatia. Photo by Natalija Andačić.

Photos 9.31 All photos by Uroš Buzurović:

Senecio abrotanifolius L. – Plant 10-40 cm high, ascending, woody at the bottom, glabrous or loosely hairy, only branched at the top. Leaves 1-2 pinnate, with 1-2 mm wide. Flower heads 2-8, diameter 2.5-4 cm, yellow to red-orange. Fruits 3-4 mm long, with 6-8 mm long, yellowish pappus.

Gentiana verna L. – Montenegro, Durmitor mountain, limestone. A perennial plant of the Gentianaceae family. The leaves form a rosette, and flower stalks with leaves that are shorter than the leaves of the leaf rosette start from it. At the top of the flower stalk, individual flowers are formed that are intensely blue. It grows on rocks, wet and dry meadows, most often on pastures within the community *Nardetum strictae.* This species can often be found in shrubby vegetation within the *Vaccinio-Juniperetum nanae* community.

Dryas octopetala L. – Serbia, Suva planina mountain, Sokolov kamen, limestone. "Osmolist" in Serbian (*Octopetala*) is a glacial relic that has inhabited the highest mountainous regions around snowfields and rockfalls. It is a perennial, shrubby species. Its leaves are simple, oblong ovate and bluntly serrated around the rim. One large white flower is formed on the flower stalks. In the area of the Balkan Peninsula it is common on carbonate and silicate soils.

Galanthus nivalis L. – "Visibaba" in Serbian language. Photo from Tupižnica mountain, Serbia, limestone. It belongs to a group of plants called spring plants, i.e., plants that appear in early spring and which end their reproductive period before the forest leaves appear. It is a perennial plant, which forms a bulb in the ground. At the base of the stem, there are two leaves, between which there is a flower stem that ends with one white flower. In some Balkan countries this species is protected by law.

Potentilla clusiana Jacq. – Also known as Eastern Cinquefoil. It belongs to Rosaceae family.

Androsace villosa L. – Montenegro, Durmitor mountain, limestone. Perennial, densely bushy plant of the family Primulaceae. It inhabits high mountains of carbonate and silicate rocks and cliffs. It is part of the order *Seslerietalia juncifoliae* Horv. and *Crepidetalia dinaricae* Lakušić on the Dinarides, as well as *Edraiantho-Seslerietalia* Horv. in the Carpathians of Serbia and Bulgaria.

Photos 9.32 Both photos by Uroš Buzurović:

Lilium martagon L. – Croatia, Paklenica, Sveto brdo, limestone. Perennial plant belonging to the family Liliaceae. In the underground part, it forms a bulb from which the stem starts. The flowers are pink, reddish, violet to purple, with spots on the inside, and rarely without them. It can be found all over Europe. It grows in deciduous forests and thickets, as well as in mountain meadows. In Paklenica, it is designated as an endemic of the Dinarides characterized only by the purple color of the flowers without the presence of spots.

Lilium bosniacum (Beck) Fritsch – Croatia, Paklenica, Sveto brdo, limestone. Perennial plant belonging to the family Liliaceae. The flowers are golden yellow. The leaves of the perigon are bent upwards, and dark spots are formed on the inside. The species is widespread only on the Balkan Peninsula.

Photos 9.33 Both photos by Uroš Buzurović:

Saxifraga sempervivum K. Koch. – Serbia, Kopaonik, Bele stene, limestone. A perennial plant, whose leaves are arranged in a ground rosette. From the rosette come flower stalks that are covered with glandular hairs, and almost sessile flowers are formed on them. The calyx leaves are purple and covered with glandular hairs. It grows in the vegetation of carbonate rocks in the alpine zone.

Adonis vernalis L. – Serbia, Dimitrovgrad, limestone. “Gorocvet” in Serbian, which means “fire flower”. *Gorocvet* is a perennial, herbaceous plant. It belongs to the species that are steppe relics, i.e. the species that are the remnants of the steppe flora that settled in the area of the Pannonian Basin and the eastern parts of Serbia during the warm and dry post-glacial period, known as Xerotherm. It can be found on meadows and steppes, along the edge of forests and bushes. Gorocvet is a poisonous plant and is used in folk medicine for diseases of the cardiovascular system. It is a strong diuretic, but it is also used as a sedative. It is often grown as a horticultural plant because of its attractive and large yellow flowers.

Photo 9.34 *Euphorbia dendroides* L. commonly known as tree spurge (“mlječika” in Croatian) throughout the Mediterranean. Due to the influence of strong winds at the Palagruža Island that scatter even small amounts of precipitation (the lowest in the Adriatic), it does not grow a forest, but a bushy tree of tall deciduous woody milkweed (*Euphorbia dendroides* L.) / Tree Spurge / wide forest-like canopy. This exotic plant species shows an interesting phenomenon. The leaves in autumn are in gorgeous colors, they bloom in winter and at the end of spring they shed their leaves, while during the hot and dry summer they are in a leafless state in order to limit transpiration and thus fight dehydration better. The picture shows woody trees in the dormant phase in the summer. Photo by Srdjan Marinčić.

Photos 9.35 All photos by Marjan Niketić:

Ramonda serbica Pančić (Serbian ramonda). Eastern Serbia, Niš, Jelašnica, Jelašnička Gorge. In the flora of Serbia, two relict species from the genus *Ramonda*, which originate from ancient times with a subtropical climate, take an honorable place. One of them is called Serbian, but it can also be found in neighboring Balkan countries in the south and southwest.

Ramonda nathaliae Pančić & Petrović (Natalie's ramonda). Eastern Serbia, Niš, Jelašnica, Jelašnička Gorge. The secret of survival of ramondas lies in the ability to go into a state of latent life, or anabiosis, during the dry season. This plant, named in honor of Queen Natalija, is specially adapted for that.

Ramonda serbica Pančić & *Ramonda nathaliae* Pančić & Petrović (Serbian and Natalie's ramonda). For a long time, it was considered that the Balkan ramondas were geographically isolated from each other, but in 1986, it was discovered that both species grow together, and even their hybrids were found in two places in the vicinity of Niš.

Photos 9.36 All photos by Marjan Niketić:

Tragopogon pterodes Pančić ex Petrović (goatsbeard). Eastern Serbia, Niš, Gornji Matejevac, Banjica Gorge. This rare biennial plant is known from rocky areas of the Balkans and Anatolia. It could be recognized by very lanate leaves, lilac flowers and fruiting achenes winged at base.

Photos 9.37 All photos by Marjan Niketić:

Reichardia macrophylla Vis. & Pančić (large-leaved brighteyes). Western Serbia, Mokra Gora, Beli Rzav Gorge. East Dinaric perennial plant (southeastern Bosnia and Hercegovina, Montenegro, northern Albania, southwestern Serbia) which thrives on eroded and sunny limestone rocks and screes. In 1874 Josif Pančić described it from this very locality.

Campanula secundiflora Pančić (bellflower). Western Serbia, Brodarevo, Lim Canyon. East Dinaric perennial plant (southwest Serbia, northern Montenegro) which is adapted to growth from vertical limestone cliffs in gorges and canyons. It is characterized to 'fall' off a cliff, while the flowers turn to one side towards the light.

Pulsatilla halleri (All.) Willd. (Haller's anemone). Eastern Serbia, Suva Planina mountain, *Trem* locality. The species is known from the Alps, the Carpathians, and the Balkan Mountains. It starts to bloom early, after the snow melts and during fructification it has elongated feathery styles that resemble a cat's mustache.

Erysimum comatum Pančić (wallflower). Eastern Serbia, Suva Planina mountain, *Sokolov kamen* locality. This biennial plant is primarily rare on limestone cliffs in gorges and mountains, but after a fire it can spread significantly along the entire mountain ridge. It was reported from the Balkans and southwest Romania.

Photo 9.38 *Drypis spinosa* subsp. *linneana* Murb. & Wettst. is a xerothermic, lithophytic species that grows on screens, open, stony, or gravelly habitats between mountain and subalpine vegetation belt in Italy, Slovenia, Croatia, Montenegro, Albania, North Macedonia, and Greece. This endemic species is one of the most important plants of the pioneer vegetation. Name of the genus *Drypis* comes from Greek verb "dryptein" (disease) while name of the species – "spinosa" comes from the Latin word "spina" (thorn). The photo was taken by on southern slopes of Štirovnik, Lovćen mountain in Montenegro, at about 1700 m asl. Photo by Gojko Nikolić.

Photo 9.39 *Rosa pendulina* L. on Lovćen mountain in Montenegro. Rose hip is a widely spread plant, present in various mountain habitats in the Dinarides, including all types of open spaces and all types of forests. Its fruit is edible and has a lot of vitamin C. Name of the genus *Rosa* comes from Greek word "rhodon" (rose) while name of the species – "pendulina" means hanging fruit. Photo by Gojko Nikolić.

Photo 9.40 *Fragaria vesca* L., wild strawberry on Kom Vasojevićki, Komovi mountain, Montenegro. Although it is primarily a forest plant, it can often be found in the subalpine zone on open rocky areas, which are overgrown with their long stolons. In warmer places it can grow together with *Fragaria viridis*. Photo by Marjan Niketić.

Photo 9.41 *Lycoperdon pratense* Pers., commonly known as the meadow puffball, on Miroč mountain, Serbia. Photo by Nenad Radaković.

Photo 9.42 *Iris illyrica*, Illyrian Iris ("ilirska perunika" in Croatian.) The name "iris" comes from the name of the Greek goddess of rainbow, Irida, the messenger of the gods ("irida" is name for rainbow in Greek), and the Slavic name "perunika" which comes from the name of the supreme Old Slavic god of thunder "Perun" and his wife, the goddess "Perunika". Photo by Ivana Adžić.

Photo 9.43 *Zammenis situla*, European rat snake ("crvenkrpica" in Croatian.) One of the most beautiful snakes in Europe can be found on the lower altitudes in the Dinaric mountains. Photo by Natalija Andačić.

Photo 9.44 *Vipera ursinii macrops* ("planinski žutokrug" in Croatian) is the smallest venomous snake in Europe and an endemic subspecies of the Dinaric mountains. It is completely adapted to life in mountainous areas above 900 meters altitude. Photo courtesy of Paklenica National Park, Croatia.

Photo 9.45 *Felis sylvestris*, wildcat. Rarely seen in nature during the daylight, mostly nocturnal and very secretive. Wildcat is becoming more and more endangered in Europe. Photo by Dujo Bušljeta**.**

Photo 9.46 *Octopus vulgaris*. In the morning "bonaca", a ray of light shone at an "intelligent alien" on the karst below the sea level next to a boat anchored in a bay of the Island of Vis, Croatian Adriatic. Other Minds: The Octopus, the Sea, and the Deep Origins of Consciousness by Peter Godfrey-Smith: "Octopus flood their bodies with color according to their moods….The first octopus probably appeared 290 m years ago. They have lost their shell entirely during long path of evolution, which gave them mobility, dexterity, and nervous complexity, and also a live-fast-die-young lifestyle.… Octopuses have proportionally big brains, to compensate for their new vulnerability, and the large nervous system, which runs all through their body.…Octopuses are the most neurologically complex invertebrates on Earth. What is the point of building a large nervous system if the life is over in a year or two? What is all the brain power doing if you die less than two years after the birth? Why do such smart creatures live such a short time? Octopuses not only feel pain physically, but emotionally too! There's still a somewhat mysterious element there..." Photo by Srdjan Marinčić.

Photo 9.47 Typical Mediterranean shrub vegetation called *makija* in Serbo-Croatian (*macchia* in Italian) above the Boka Kotorska bay in Montenegro. It thrives on limestone soil and consists of dense scrub growths of xerophytic (drought-resistant) and sclerophyllous (leathery) shrubs and small trees, which are often fire-resistant. Photo by Zoran Stevanović.

Photo 9.48 "Wildflowers" on Treskavica mountain in Bosnia and Herzegovina. Bjelašnica mountain, site of downhill competition during the 1984 Sarajevo Winter Olympic Games, is in the distance. Photo by Ferid Skopljak.

Photo 9.1 *Vipera ammodytes*; Srdjan Marinčić

Photo 9.2 *Vipera ammodytes*; Ana Paunović

Photo 9.3 *Vipera ammodytes*; Dragan Bosnić

Photo 9.4 *Natrix tessellata*; Ana Paunović

Photo 9.5 *Lacerta viridis*; Ana Paunović

Photo 9.6 *Ichthyosaura alpestris*; Ana Paunović

Photo 9.7 *Lacerta viridis*; Dragan Bosnić

Photo 9.8 *Podarcis muralis?* Dragan Bosnić

Photo 9.9 *Bombina variegata* and *Natrix tessellata*; Ana Paunović

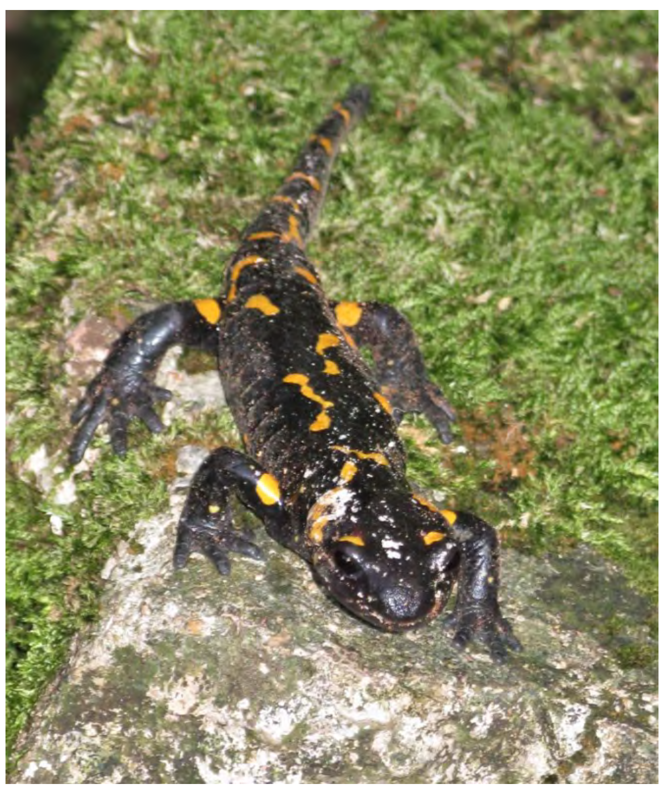


Photo 9.10 *Salamandra salamandra*; Zoran Stevanović

Photo 9.11 *Podarcis muralis*; Ana Paunović

Photo 9.12 *Bombina variegata*; Ana Paunović

Photos 9.13 *Ursus arctos*; Milan Paunović

Photo 9.14 *Matres foina*; Milan Paunović

Photos 9.15 *Lynx lynx balcanicus*; Dragan Bosnić

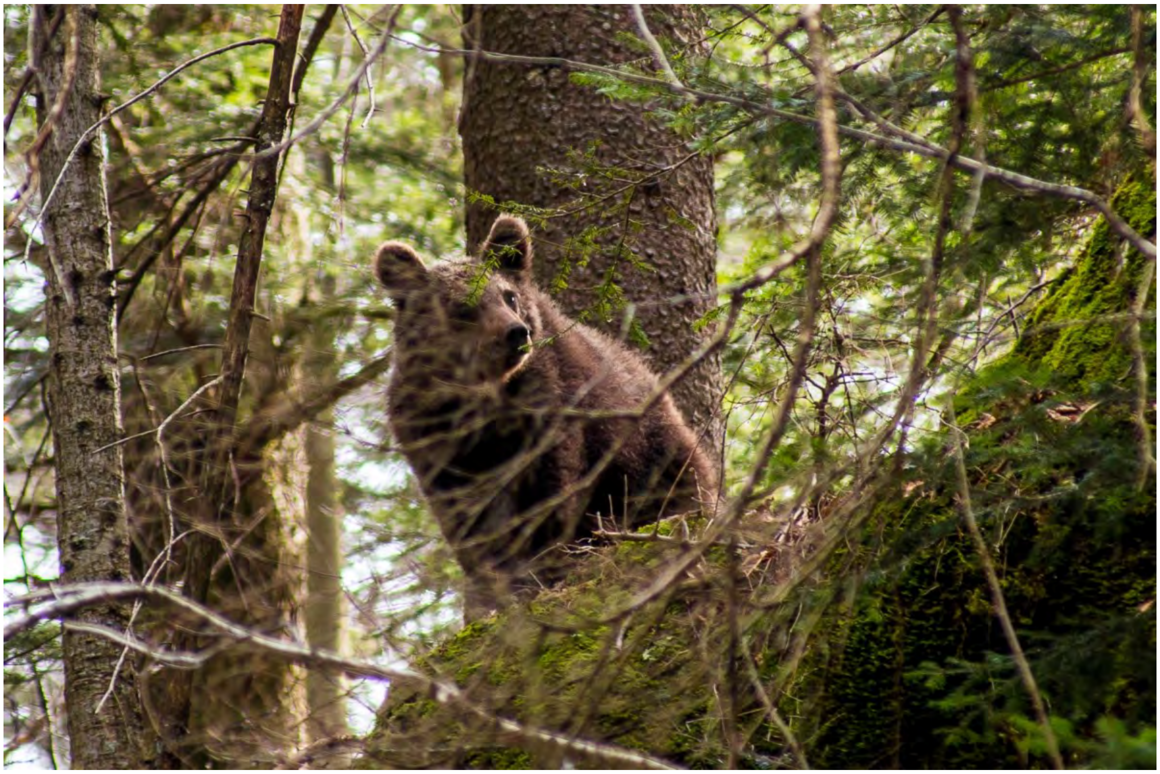


Photo 9.16 *Ursus arctos*; Matej Blatnik

Photo 9.17 *Rupicapra rupicapra*; Matej Blatnik

Photos 9.18 *Gyps fulvus*; Saša Preradović

Photo 9.19 *Gyps fulvus*; Saša Preradović

Photo 9.20 *Marmota marmota*; Ester Premate

Photo 9.21 *Glis glis*; Jelena Bogosavljević

Photo 9.22 *Rupicapra rupicapra*; Jelena Bogosavljević

Photo 9.23 *Picea omorika* (Pančić) Purk.; Uroš Buzurović

Photo 9.24 *Pinus nigra*; Srdjan Marinčić

Photo 9.25 *Pinus nigra*; Borut Peric

Photo 9.26 *Picea abies*; Borut Peric

Photo 9.27 *Fagus sylvatica*; Borut Peric

Photo 9.28 *Fagus sylvatica*; Ivana Adžić

Photo 9.29 *Aquilegia kitaibelii*; Ivana Adžić

Photos 9.30 *Campanula fenestrellata*; Natalija Andačić

Senecio abrotanifolius

Gentiana verna

Dryas octopetala

Galanthus nivalis

Potentilla clusiana Jacq.

Androsace villosa

Photos 9.31 All photos by Uroš Buzurović

Lillium martagon

Lillium bosniacum (Beck) Fritsch

Photos 9.32 Uroš Buzurović

Saxifraga sempervivum K. Koch

Adonis vernalis

Photos 9.33 Uroš Buzurović

Photo 9.34 *Euphorbia dendroides*; Srdjan Marinčić

Ramonda serbica Pančić

Ramonda nathaliae Pančić & Petrović

Ramonda serbica Pančić together with *Ramonda nathaliae* Pančić & Petrović

Photos 9.35 All photos by Marjan Niketić

Photos 9.36 *Tragopogon pterodes* Pančić ex Petrović. All photos by Marjan Niketić

Reichardia macrophylla Vis. & Pančić

Campanula secundiflora Pančić

Pulsatilla halleri (All.) Willd.

Erysimum comatum Pančić

Photos 9.37 All photos by Marjan Niketić

Photo 9.38 *Drypis spinosa linneana*; Gojko Nikolić

Photo 9.39 *Rosa pendulina* L.; Gojko Nikolić

Photo 9.40 *Fragaria vesca* L.; Marjan Niketić

Photo 9.41 *Lycoperdon pratense* Pers.; Nenad Radaković

Figure 9.42 *Iris illyrica*; Ivana Adžić

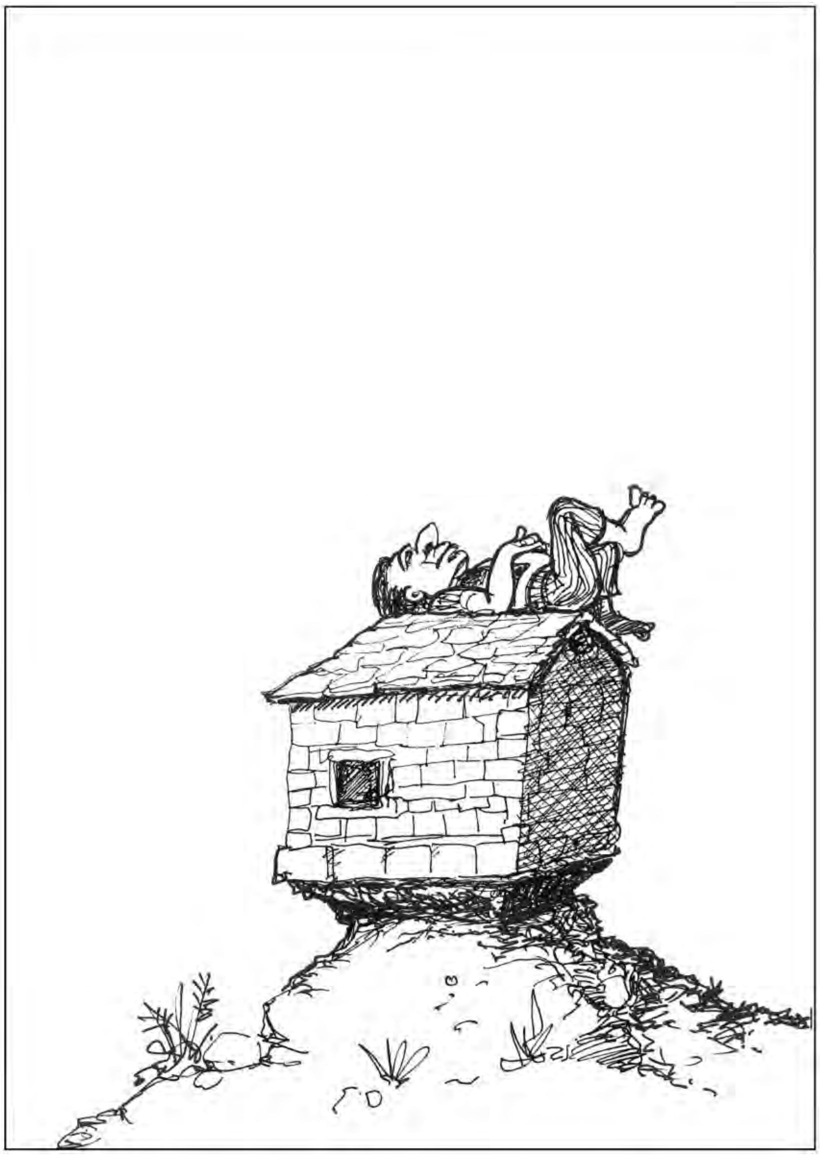
Photo 9.43 *Zammenis situla*; Natalija Andačić

Photo 9.44 *Vipera ursinii macrops*; Courtesy of Paklenica National Park, Croatia

Photo 9.45 *Felis sylvestris*; Dujo Bušljeta

Photo 9.46 *Octopus vulgaris*; Srdjan Marinčić

Humans in Karst
Past and Present



10. Humans in Karst, Past and Present

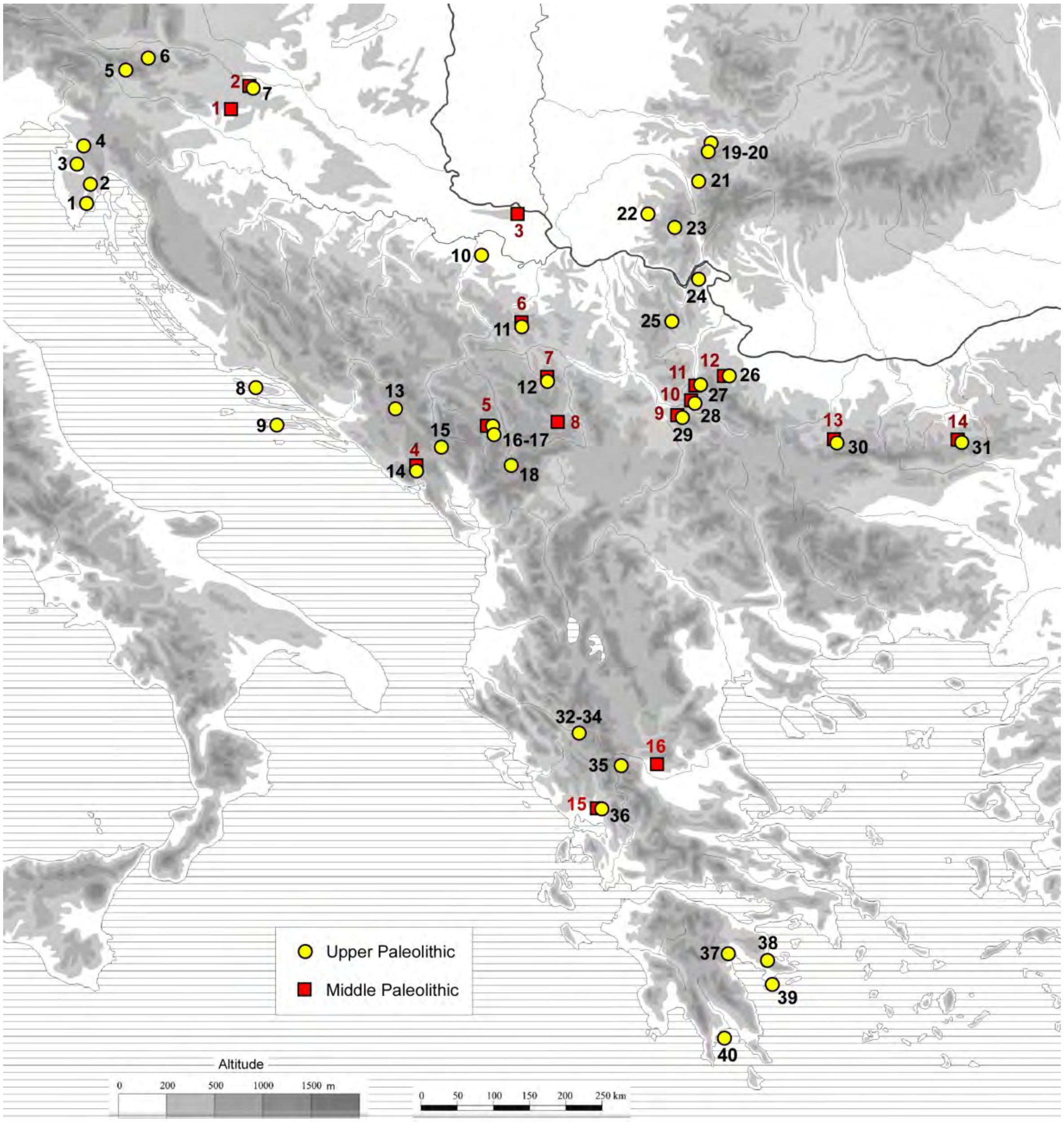
In the colonization of Europe during the Early (Lower) Pleistocene epoch (2.6 to 0.78 million years ago), the Balkans were one of the main corridors of migration. Discoveries in the caves of the Lands of Karst in the last two to three decades have established cultural connections with early hominids who arrived from Africa at least 1.8 million years ago. They settled in southwest Asia and southeast Europe (Dennell and Roebroeks 2003, Mihailović 2014).

In southeastern Europe during Early Pleistocene there was a gradual and uneven cooling and aridification. The Middle Pleistocene lasted between 780 and 130 thousand years ago, and the whole period was marked by phases of alternating long cold and somewhat shorter warm phases. For instance, during one of the longest interglacial cycles which lasted between 400 and 300 thousand years, the climate in Central Europe was warm and humid, and forest vegetation was firmly established (Mihailović 2014). Paleontological evidence in the caves as safe haven for animals and hominids was found in many caves across the Balkans.

Neanderthals populated Europe between 200 and 44 thousand years ago and they were the most numerous hominids in the period of the last interglacial period with milder climate, 130-70 thousand years ago (Mihailović 2017). At that time, the Neanderthals lived throughout the Balkans (the most famous finds are from Krapina in Croatia). Forty-four thousand years ago the Neanderthals became extinct and Homo Sapiens completed their push into Europe. It is believed that modern humans from the Near East populated Europe migrating along the lower Danube valley and that the Neanderthals possibly survived somewhat longer in the central parts of the Balkans. There are numerous caves and caverns with archaeological artifacts dating back to the Middle and Upper Paleolithic to support this theory (Mihailović 2014). The investigations conducted so far suggest that the border between the territories inhabited by Neanderthals and modern people was in the area of the Svrljig Mountains in eastern Serbia. In Baranica cave near Knjaževac the discovered artifacts are attributed to modern man, while at approximately the same time a nearby cave, Pešturina, was frequented by Neanderthals (Mihailović 2017).

"Šalitrena pećina", Middle Paleolithic site near Mionica, Serbia. Photo by Dušan Mihailović

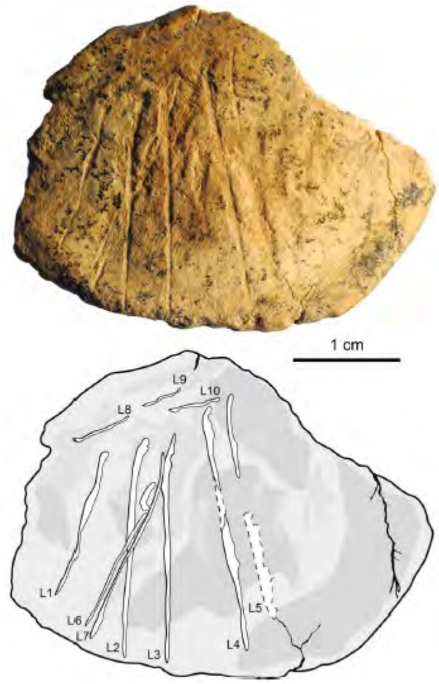
The appearance of Homo Sapiens in Europe was accompanied by frequent climatic changes and natural disasters, such as volcanic eruptions and cold spells. Whereas the former coincided with the almost complete distinction of the Neanderthals, the latter resulted in the retreat of vegetation and animal species from the northern regions toward the "glacial refugiums" in southern Europe. Not until recently was it known whether people found refuge in the sheltered parts of the Balkan Peninsula during this period. Investigations confirmed this assumption as many sites from the period have been discovered in the central Balkans (Mihailović, 2017.)



Upper Paleolithic sites in the Balkans (from Mihailović, 2014) : Šandalja II (1), Vešanska and *Pupićina pećina (2), Nugljanska pećina (3), Ovčja jama, Jama v lozi (4), Mokriška jama (5), Potočka zjalka (6), Vindija (7), Kopačina pećina (8), Vela spila (9), Kadar (10), Šalitrena pećina (11), Hadži Prodanova pećina (12), Badanj (13), Crvena stijena (14), Vrbička pećina (15), Mališina stijena (16), Medena stijena (17), Trebački krš (18), Koșava (19), Românești-Dumbrăvița (20), Tincova (21), Crvenka–At (22), Peștera cu Oase (23), Tabula Traiana Cave (24), Velika pećina (25), Kozarnika (26), Baranica (27), Donja pećina (28), Pešturina (29), Temnata Doupka (30), Bacho Kiro (31), Klithi, Megalakkos, Boila (32–34), Asprochaliko (35), Kastritsa (36), Kephalari (37), Klissoura (38), Franchthi (39), Lakonis (40)*

Middle Paleolithic sites in the Balkans (from Mihailović, 2014): Krapina (1), Vindija (2), Petrovaradin Fortress (3), Crvena stijena (4), Mališina stijena (5), Šalitrena pećina (6), Hadži Prodanova pećina (7), Smolućka pećina (8), Pešturina (9), Mala and Velika Balanica (10), Baranica (11), Kozarnika (12), Temnata Doupka (13), Bacho Kiro (14), Asprochaliko (15), Theopetra (16)

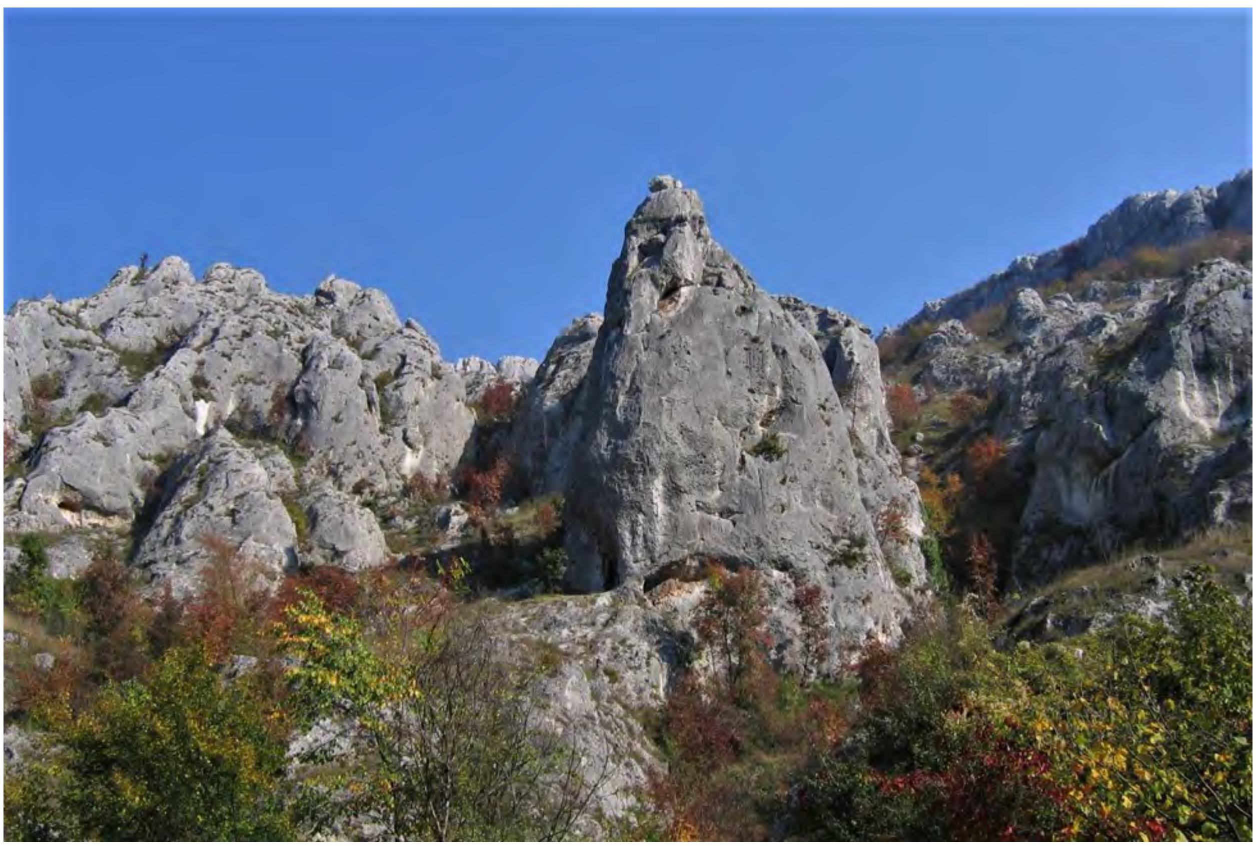
Archaeological excavation in the Mala Balanica cave in Serbia by the team from the Department of Archeology, Faculty of Philosophy, University of Belgrade, led by Prof Dr. Dušan Mihailović. Photos by Ljubica Stajić.



Left: chipped stone artefacts from Mala Balanica Cave, Serbia (photo by Velimir Pilipović). Right: animal bone with engraved lines from Pešturina Cave, Serbia found in the Neanderthal habitation layer (photo by Ana Majkić).

Mandible of Homo heidelbergensis from Mala Balanica cave. Photo by Mirjana Roksandić.

Evidence of the artistic endeavors of Paleolithic hominids can be found in Romualdova cave in Istria, Croatia. It is of profound significance (Ruiz-Redondo et al. 2019). The cave's walls in the main corridor, between 32 and 46 m from the entrance, are decorated. Forty-four graphic units were identified, divided in four panels. The bison is one of the most prevalent animals featured in this cave and in the Upper Paleolithic rock art in general. Although the precise chronology of the Romualdova cave art remains unknown (radiometric dates, the chronology of the human occupation at the entrance, and the painting style left time boundaries somewhere between 39 and 12.7 thousand years), its discovery represents a milestone among recent developments in the study of Paleolithic art (Ruiz-Redondo et al. 2019, 2020). This is the first evidence of figurative Upper Paleolithic rock art on the Balkan Peninsula, and these paintings enlarge the geographic distribution of European rock art significantly. It once again calls into question the traditional paradigm that assumes Upper Paleolithic cave art to be a Western European phenomenon.



Sićevo Canyon in Serbia features cave sites of exceptional significance for comprehension of cultural and biological evolution of man in the Middle and Upper Pleistocene. As such they are protected by the Serbian Act on Cultural Property and international conventions for protection of cultural heritage. Photo by Dušan Mihailović.

Photograph and tracing of the bison motif (graphic unit ROM.L2.02) from "Romualdova pećina" (Romualdo Cave) in Istria, Croatia. Figure by A. Ruiz-Redondo, printed with author's permission.

Engraved panel from "Pećina pod lipom" (Cave under the Linden Tree) near Sokolac, Bosnia and Herzegovina. Photo by A. Ruiz-Redondo. Printed with author's permission.

In the Balkans, there are many layers of prehistoric cultures whose creation and disappearance are linked to migrations of unidentified ethnic groups. During the Neolithic era, there were mixtures of Mediterranean and Pannonian cultures. One such culture, *Lepenski Vir*, was discovered between 1965-1968 on the right bank of river Danube. The archaeological investigation was conducted prior to the construction of a mega dam on the Danube. The creation of Djerdap Reservoir was going to submerge potentially interesting archaeological sites along the river. Before this discovery, the Danube was only known as a migratory path and as a setting for the myth of Jason and the argonauts and their search for Golden Fleece.

The Lepenski Vir settlement is dated between 9500 and 6000 BC. The site consists of one large settlement and approximately ten satellite villages with unique trapezoidal buildings and monumental sculptures. Numerous fish-like (piscine) sculptures and peculiar architectural remains were found at the site. The sculptures are made of massive cobbles, decorated with paints, and feature ornamental engravings. Characteristic sculptures represent styled human faces, or torso with head, and those of animal's fish images and stag heads. Archaeologist Dragoslav Srejović (1972), who first explored the site, said that such large sculptures so early in human history, and the original architectural solutions, define Lepenski Vir as a specific and very early phase in the development of European prehistoric culture. Some archaeologists even labelled it as "the first city in Europe".


Left: "Water Undine" sculpture dated 6200-5900 BC. Right: Excavated foundations of Lepenski Vir houses. Lepenski Vir Museum; Photos by Zoran Stevanović.

The Illyrians are one of the oldest ethnic groups with a distinct culture and art that were spread out over parts of Slovenia, Croatia, Bosnia and Herzegovina, Serbia, Montenegro, Albania and northern Greece. In the late 6th century BC, the Persians invaded the Balkans, and then proceeded to the fertile areas of Europe. In the 4th century BC, the first invasion of Celts is recorded. Celtic migrations displaced many Illyrian tribes from their former lands, but some Celtic and Illyrian tribes mixed. Concrete historical evidence for this period is scarce, but overall, it appears that the region was populated by a number of different peoples speaking distinct languages. Some simply disappeared, such as the Phrygians, who inhabited the southern Balkans, or Sarmatians who lived in the North. By the end of the 4th century BC, Greek language and culture were dominant not only in the Balkans but also in the entire Eastern Mediterranean. The Greeks were the first to establish a system of routes to facilitate trade with the natives, and between 700 BC and 300 BC, they founded a number of colonies including Dalmatia.

In the Roman period, Latin-speaking settlers from all over Roman Empire were encouraged to move to the region and settle amongst the Illyrians, together with retired Roman soldiers. Several towns in today's Croatia and Bosnia were founded under Roman rule. For example, the Roman town of Bona (today Blagaj, near Mostar) is built on the Buna River, just a stone's throw from one of the largest karst springs in the world, the source of the river (see Photo 5.3 in Chapter 5.) Similarly, many cities were established by Romans along the Adriatic Coast in the vicinity of large springs. Among them the largest are Rijeka, Split (Photo 10.1), Dubrovnik (Photos 10.2 and 10.3), and Kotor, which were all in the Western Roman Empire. The demand for a fresh water supply led to the founding of many small towns close to springs or inland rivers (Photo 10.4).

After the Roman period in the Balkans, a large number of Vlachs, descendants from a pre-Slavic population, lived in the Balkans. Christianity had already arrived in the region by the end of the 1st century, and numerous found artifacts and objects make this clear. After the Roman Empire collapsed, the first barbarian tribe to enter the Balkans was the Goths. The region was also conquered by Huns, and later by the Ostrogoths in mid-5th century. The Ostrogoth Kingdom was then defeated by the Byzantine Empire in the Gothic War (535-554).

The Slavs migrated from Central Europe and Eastern Europe in successive waves, but the bulk of migration to the Lands of Karst did not occur until the 6th century. They eventually became known as Southern Slavs, those that today inhabit the Lands of Karst.

After the arrival of Slavs, the turbulent history of the region continued, and it was as dynamic and unpredictable as the surrounding karst environment. We therefore will stop our history lesson here and recommend to those who want to learn more to look for historical books and sources discussing the impact of the invasions of the Avar, Bulgar, and Magyar tribes, and then the influence of the Byzantine Empire, Republic of Venice, Ottoman Empire, Napoleon's France, and Austro-Hungarian Empire on the medieval states, provinces, and towns established and ruled by the Slavs.

Life in a karst landscape can be very difficult, especially away from the Adriatic coast or fertile soil deposited along large river valleys and in karst poljes. In high karst mountains there are often water and soil shortages. Collecting rainwater in cisterns was the only way to ensure enough water for people and animals (Photo 10.5.) Some major springs can dry out during prolonged droughts (Photos 10.6.) In contrast, during periods of floods many karst poljes are transformed into temporary lakes. In addition, farmers have very short crop season.

In insecure and tumultuous environments, caves were often used to provide shelters to the local population. In some caves located on high cliffs, large monasteries or even cities were established while some cave entrances were simply walled off to protect villagers from attackers or were used as hermitage sites. Although preparing and forming hard limestone building blocks is never an easy task, in the absence of other kinds of rocks, they were used as the principle material for building houses, fortresses, fencing the property land, or making tombstones (medieval "stećci") and memorial plaques (Photos 10.7 – 10.16.)

People in the mountainous areas with limited natural resources are forced to adapt to circumstances, and generally respond with a modest and humble style of life. The ways of land cultivation and cropping, cattle breeding, and food preparation have not changed much from one generation to another. This became known as "traditional dinaric" style of living. This tradition also resulted in some "special products", such as Lipizzan horses, “the white pearls of the Karst”, or tasty grapes, olives, pomegranates, figs, and other plants that thrive on karst soil (Photos 10.17 – 10.38.)

When it comes to wine production, the region’s notoriety begins with the Ancient Greek settlers, and their wine production on the southern Dalmatian islands of Vis, Hvar and Korčula which dates back some 2500 years. White wines such as Istrian *Malvasia*, *Pošip* from Korčula and Pelješac Peninsula, *Žilavka* from Herzegovina, and red wines such as *Teran* from Slovenian Kras, *Plavac* from Dalmatia, *Dingač* from Pelješac Peninsula, *Blatina* from Herzegovina, *Vranac* from the Zeta Valley in Montenegro, or *Kratošija* from Tikveš, North Macedonia are just some of the famous wines made from autochthonous vines and grapes (Photos 10.32-33.) *Primitivo*, the wine made from grapes rich in sugar, is the third-most planted grape in Puglia, in southern Italy. *Primitivo* is a red wine grape variety that is also known as zinfandel. The grapes were brought from Dalmatia in the 18th century and planted across Puglia. This has been confirmed by DNA testing which established that *Primitivo* is the same as the Croatian variety *Crljenak Kaštelanski*. Although the Italian name was given by merchants and their point of view of the area of origin in it is clear, the *Primitivo* is nothing more than an excellent primitive wine.

The Croat Miljenko "Mike" Grgić traveled to the Napa Valley in California to contribute to its famous status by making his own wines based on knowledge and experience obtained from the Dalmatian Coast.

Cvijić (1914) wrote an anthropogenic study describing the impact of life conditions in the Lands of Karst on human personality and psychology. He highlighted the following as general characteristics of Dinaric people: intellectual sensitivity, instinct to feel danger and to survive, great energy, and high imagination, often leading to mysticism. In addition, cheerfulness and a love of humor can be evident, but so too can vanity, pride, and, not rarely, stubbornness.

To change the harsh environment and to adapt it to human needs was a dream of many generations. But only after WWII did engineers from former Yugoslavia start to modify karst characteristics to meet needs of the populace. As such, the *Trebišnjica Multipurpose Hydro System* project was initiated in the early 1950s to control the flow of the Trebišnjica sinking river (the largest in Europe) and prevent flooding of arable land in karst poljes. The System consists of seven dams, six reservoirs, six water conveyance tunnels, and four canals. Although still not complete, it is an excellent example of successful construction of large structures in Dinaric karst. Experiences from this mega project and some other water regulation projects in karst, such as one in Nikšićko polje in Montenegro, were used for many similar projects throughout the Lands of Karst (Photos 10.39 – 10.46.)

In an attempt to preserve the cultural heritage of the region threatened by the creation of reservoirs, the engineers organized to resettle, stone-by-stone or brick-by brick, bridges (such as famous medieval Ottoman *Arslanagića bridge* near Trebinje; Photo 10.42), or complete monasteries and churches. For example, a medieval Piva Monastery in Montenegro has been moved to a new location to enable building of the *Mratinje* dam on the Piva River (Photo 10.48.) Important lessons learned during the investigation, design, construction, and operation of these large engineering projects have greatly contributed to the development and global promise of applied karstology as a unique engineering and scientific discipline.

However, not all the results and effects of the engineered changes of nature are positive. This “wild and beautiful” karst nature deserves a great deal of attention of the local population and decision makers to ensure sustainable development. Some recently conducted international projects and initiatives such as DIKTAS (The Protection and Sustainable Use of the Dinaric Karst Transboundary Aquifer System) are steps in the right direction, but awareness of the importance of sustainable and equitable use of natural resources, and protection from pollution or devastation must grow through educational and promotional activities.

We may close this story by the sentence which is very common in all the Lands of Karst: “the World belongs to young ones.” (Photos 10.51-52).

For farewell moments we recommend to all of you over age of 18, to take a glass of wine (preferably from the region) and use earphones for listening some nice songs. We kindly suggest representatives of the rock(s) music from the six Lands of Karst (ordered from North to South): “Čekaj me” by Zoran Predin; “’Bi mogo da mogu” by Haustor (Darko Rundek); “Gracija” by Azra (Džoni Štulić); “Sve će to o mila moja” by Bijelo dugme; “Samo jednu ljubav imam” by Vlada Divljan; and “Jovano Jovanke” by Vlatko Stefanovski. Cheers! Živeli!

Photo Captions

Photo 10.1 Jadro spring (see Photo 5.42), currently utilized for water supply of the largest Dalmatian port Split, was used by the natives for millennia and was tapped by the Romans for water supply of the Palace of Emperor Diocletian. Water was conveyed to the palace by an aqueduct, preserved to this day (photo by Ivo Eterović). Bottom: Reconstruction of the Palace in its original appearance upon completion in 305 AD by the French town planner Ernest Hébrard, published in 1912. Diocletian retired to this palace near his birthplace Salona (Solun in Croatian). It is the largest and best-preserved example of Roman palatial architecture in the world. It constitutes the main part of the UNESCO World Heritage site that was designated in 1979. The Avars badly damaged the palace, but, when their incursion was over (c. 614), the inhabitants of the nearby ruined city of Solin took refuge within what remained of the palace and built their homes, incorporating the old walls, columns, and ornamentation into their new structures (see also Photo 3.14 in Chapter 3.)

Photo 10.2 Great Fountain of Onofria in Dubrovnik, Croatia designed and built by the Italian architect Onofria della Cave in 1440. Water for the fountain, which includes the water storage reservoir, was conveyed from a group of springs by a 12 km-long system of canals and aqueducts. After the fountain shown was completed, a new law was enacted stating that “The right hand of everyone caught diverting water from or plugging the conveyance canal will be cut off.” and “Public servants will be sent every week to check the entire water conveyance system and determine if anything is damaged or spoiled.” (Tušar, 2008). Although hardly imaginable today in the civilized world, this practice shows that those stealing, or “spoiling” water designated for the use of others should bear some well-defined consequences. Photo by Vojislav Ilić.

Photos 10.3 The Old Town of Dubrovnik is dotted with beautiful public fountains fed by spring water. Photos by Neven Kresic.

Photo 10.4 Village Osp next to a collapse doline and spring of the river *Osapska reka* (Slovenia). Photo by Matej Blatnik.

Photo 10.5 A typical cistern – reservoir for collecting rainwater in the mountain areas of Krnovo, between Nikšić and Šavnik (Montenegro). Photo by Zoran Stevanović.

Photos 10.6 *Spila Risanska* spring. One of several intermittent springs in the coastal area of Boka Kotorska Bay, Montenegro. During rainy periods the spring discharges several cubic meters per second, while during summer and early autumn months it completely dries out. Claude Touloumdjian's diving exploration discovered a 340 m long submerged channel which ends with an unpassable sump, 73 m below elevation of the cave entrance. Before construction of the regional waterworks for the Montenegrin Coast this spring was a single potable water source for the town of Risan. Photos by Neven Kresic (top) and Petar Milanović (bottom).

Photo 10.7 Predjama Castle, Slovenia. "The picturesque and mighty castle proudly sits embedded high into the cliff above the mysterious underground tunnels of the Cave under the Castle. Here, the Predjama treasure cache lay hidden for many centuries and tells the story of the social life spent at candle-lit dinners and tables full of food and drink. During the siege, the castle was the refuge of its most famous owner – Erazem of Predjama. The legend of the brave outlaw knight Erazem, who remained undefeated until he was betrayed by one of his servants, still lives on in local folklore" (https://www.zelenikras.si.) Photo by Zoran Stevanović.

Photo 10.8 Ostrog Monastery, the most important pilgrimage site of Montenegro, visited annually by more than 100000 people. This monastery of the Serbian Orthodox Church is situated on high karstic cliffs above the Bjelopavlići Plain, 50 km from Podgorica and 15 km from Nikšić. It is dedicated to *Sveti Vasilije Ostroški* (St. Basil of Ostrog), who died and was buried here in 1671. Some years after his death, St. Basil was canonized. His body is enshrined in a reliquary kept in the cave-church dedicated to the Presentation of the Mother of God to the Temple. According to the stories of pilgrims, praying by his body has cured many believers and helped in lessening the difficulties in their lives. Photo by Zoran Stevanović.

Photos 10.9 Left: Fortified entrance to *Jankovićeva špilja* cave named after "hajduk" (outlaw) Stojan Janković who used it as a hideout during Ottoman times. Behind the entrance is a monumental chamber that can accommodate 100+ people. The cave is in the Korana river canyon near the town of Rakovica, Croatia. Right: Entrance to *Špilja Kuća* cave, near Cetingrad, Plitvice, Croatia fortified with a thick wall. Behind the wall is a spacious chamber with a small brook that emerges and then sinks inside the chamber. During Ottoman incursions and final occupation of the Balkan lands, in the 15th, 16th and 17th centuries, Turks were crossing the territory of what is today Croatia many times including during any push further west to Austrian Empire. Ahead of the regular Ottoman armies, armed bands of "kindjije" were sent to terrorize, loot, and kill local population. The noblemen would retreat to castles and fortresses, while peasants and others would seek shelter in numerous caves waiting for the disaster to pass and hoping they would not be discovered. Over time, the local population learned how to find "the right" caves and fortify them. Photos by Vlado Božić.

Photo 10.10 *Zidana špilja na Krbavskom polju* cave in Croatia is one of several caves around the polje perimeter with well-preserved walls. These caves were used as temporary shelters by one or two families during tumulus medieval times. When Ottoman Turks finally conquered the area, they used this cave as a prison according to a legend. Photo by Vlado Božić.

Photo 10.11 Osp Cave in Slovenia is overshadowed by a huge wall and hides a mysterious wall enclosure. It is an example of the so-called spring caves, which means that after heavy rainfall a magnificent Osp River emerges through its entrance. Photo by Borut Lozej.

Photo 10.12 Archaeological site “stećci” (medieval tombstones) on the southwest side of Bjelašnica mountain (close to Lukomir village) in Bosnia and Herzegovina. Stećci are monolithic tombstones dated back to period between 12 and 15 centuries, when local population called “Bogumili” or “Patareni” inhabited Bosnia and Herzegovina and its high mountains. Stećci are inscribed on the World Heritage List by UNESCO since 2016, with a selection of some 4000 individual monoliths, grouped in necropolises at 28 locations, of which 22 are in Bosnia and Herzegovina, two in Croatia, three in Montenegro, and three in Serbia. Photo by Ferid Skopljak.

Photo 10.13 A medieval hunt motif from a “stećak” in *Radimlja* necropolis near Stolac in Herzegovina, the largest and most impressive such necropolis in the Lands of Karst. Photo by Neven Kresic.

Photo 10.14 "Stećak" tombstone in the village of Bratač at Pupoš, Nevesinje, Bosnia and Herzegovina. A medieval tombstone in the form of a chest (“sandučar”), decorated with motifs of a rosette and a tendril, is one of the 130 “stećak” tombstones preserved at the Pupoš site. All the stećak tombstones at this site are monoliths carved from limestone; they are mostly in the form of chests, flat or ridge/saddle-roofed (“sljemenjak”), and there are also several pieces of antic architecture and “stela” with figural decoration, which were used as “stećak” tombstones. They are decorated with various motifs (peripheral decoration, tendril, cross, weapon, hand, human figure). Local inhabitants call them "Greek tombs". Nevesinje is the municipality with the largest number of “stećak” tombstones in Bosnia and Herzegovina. Photo by Natalija Samardžić.

Photo 10.15 *Golubački grad* (Golubac Fortress) on the Danube riverbank near Golubac, Serbia. It is a medieval fortified town built during the 14th century by the medieval Serbian state. It is split into three compounds with ten towers, most of which are with square base, and several of which received multi-sided reinforcements with the arrival of cannons. Towers were not connected for easier defense. Golubac Fortress has had a tumultuous history with more than 100 conquering attacks. Prior to its construction it was the site of a Roman settlement. During the Middle Ages, it became the object of many battles, especially between the Ottoman Empire and the Kingdom of Hungary. It changed hands repeatedly, passing between Turks, Bulgarians, Hungarians, Serbs, and Austrians, until 1867, when it was turned back to Serbia. It was reconstructed during 2014-2019 and is now one of the main tourist attractions and a sightseeing point on the Danube boat tours within the Djerdap National Park and UNESCO Global Geoparks. Photo by Zoran Stevanović.

Photo 10.16 *Hadži Prodanova pećina* cave and church at its entrance. It is an archaeological site of the Paleolithic period and a National Natural Monument near Ivanjica, Serbia. Photo by Zoran Stevanović.

Photo 10.17 Village Lukomir is the highest permanent settlement in the Dinarides (1496 m above sea level). It is located on southwestern slopes of Bjelašnica mountain, 50km from Sarajevo, and above the canyon of Rakitnica River. The village is settled since the 14th century and has numerous monolithic tombstones (“stećci”). Photo by Ferid Skopljak.

Photo 10.18 Rudinske kolibe, a group of shepherd huts used for 2-3 summer months. It is located between Volujak mountain (2336 m) and Trnovačko jezero lake in Montenegro, in a karst environment built from the Triassic limestones and the Pleistocene glacial moraine materials. Photo by Milovan Milivojević.

Photo 10.19 Small speleological expedition on its way to a cave on the Pešter karst plateau in southwestern Serbia, passing by a sheep farm stacked with hay for an upcoming long winter. Photo by Neven Kresic.

Photo 10.20 Family photo: Grandpa and his sheep in a small karst polje of Krbavica, Croatia. Photo by Jelena Ćalić.

Photo 10.21 Making sheep cheese is a tradition in the Central Dinaric mountains of Bosnia and Herzegovina. The sheep is standing on the Devonian marble limestone outcrops in the Vrtače village on Vranica mountain. Photo by Ferid Skopljak.

Photo 10.22 Family photo: Granny is spinning wool into yarn. Lika Krbavica, Croatia. Photo by Jelena Ćalić.

Photos 10.23 Top: People from the Rudinski katun in Montenegro saddle horses to go on firewood collection. Bottom: Semi-wild horses of the Rudinski katun. Photo by Milovan Milivojević.

Photos 10.24 – 10.27 The Karst Plateau, located in today's Republic of Slovenia, is not only famous for its caves, but also for the Lipizzan horses, the white pearls of the Karst. The original stud farm of this magnificent horse breed is the Lipica Stud Farm. Its long and varied history started on 19 May 1580, when the Habsburg Archduke Charles II, son of the Habsburg Emperor Ferdinand I, purchased the Lipica estate. Soon afterwards, the Karst horses were crossbred with Spanish, Italian and Arab horses, so the Lipizzan horse breed was created and "sculptured" by the Karst landscape and climate. With their talent for classical dressage and elegant carriage driving, these noble horses became the famous white horses of the Spanish riding School in Vienna. The breeding of the Lipizzans spread to other countries of the Habsburg monarchy and all over the world. Today, the Lipizzan Horse Breeding Traditions of eight countries are nominated for inscription on UNESCO's Representative List of the Intangible Cultural Heritage of Humanity, while the cradle of the bred, the Lipica Stud Farm, welcomes visitors from all over the world. Photographs by Jošt Gantar, Boris Pretnar, and Mitja Božić for the Lipica Stud Farm. More information at: info@lipica.org and www.lipica.org.

Photo 10.28 Traditional way of making bread. It is practiced even today in the Rudine "*katun*" (shepherds' summer village). Vraćenovići, Volujak mountain, Montenegro. Photo by Milovan Milivojević.

Photo 10.29 Preparation of *belmuž* – traditional pastoral specialty from the mountainous regions of eastern Serbia, is included in the list of intangible cultural heritage of Serbia. It is made from young sheep and cow cheese and corn flour. Courtesy of the National Park Djerdap.

Photo 10.30 "The last ploughboy" (Velebit mountain in 1995). Traditional way of cultivation of small pieces of land fenced by stone drywalls. Photo by Dražen Perica.

Photo 10.31 "Bunje" – traditional shelter houses built from limestone without use of mortar. Photo by Dražen Perica.

Photo 10.32 Autochthonous vines native to Herzegovina produce some of the best wine grapes in the Lands of Karst. The vines love karst soil reach with iron (its presence is easily noted by red color of the soil, "terra rosa") and lime. Top: *Žilavka* wine grape vineyard of the Tvrdoš Orthodox Christian Monastery near Trebinje, Eastern Herzegovina. Bottom: The monastery's wine cellar. Photos by Neven Kresic.

Photos 10.33 Top: Closeup of *Žilavka* wine grape in the vineyard of Mr. Raspudić at the foothill of Orlac karst hill north of Mostar, Herzegovina. Bottom left: Mr. Raspudić training his young cousin in the skills of growing a successful vineyard, passing the knowledge he inherited from his father and grandfather who grew up in Čitluk, Herzegovina, center town of one of the best known wine regions in the Lands of Karst. The cousin is holding a cluster of *Blatina* grape. Bottom right: Famous *Blatina* red wine, legendary brand "Orlac", for which Mr. Raspudić was awarded multiple gold medals at unofficial competitions of select independent wine makers in Herzegovina. "Orlac" is not sold commercially and can be tasted only by close friends and family, and special guests. We went through unimaginable hurdles and troubles before we managed to taste it, thanks to the influence of some of our most important connections in the region. The most intriguing to us was a part of the wine's label stating, "sufficient alcohol." Photo by Neven Kresic.

Photos 10.34 Pomegranate is one of the most cherished fruits in parts of the Lands of Karst with Mediterranean climate. It grows wild or semi-wild literary everywhere where there is even a trace of soil on limestone. The fruit is packed with vitamin C, vitamin E, antioxidants, and many other beneficial ingredients. Health benefits of consuming pomegranate are too many to list; here are only a few: it is antiviral and antibacterial, anti-inflammatory, helps lower blood pressure, improves memory, and decreases insulin resistance (fights diabetes.) Village of Brusje on the Hvar island, Croatia. Photos by Ognjen Bonacci.

Photos 10.35 Olive tree is emblematic of the Mediterranean. In the Lands of Karst, it grows from Istria Peninsula in the north to the coast of Montenegro in the south. The olive grove in the photo, on the Adriatic island of Lopud, Dubrovnik archipelago, is one of the oldest in Dalmatia. It was planted centuries before the catastrophic earthquake of April 6, 1667 which devastated Dubrovnik and the islands. Photos by Neven Kresic.

Photos 10.36 Young fig tree on the island of Lopud near Dubrovnik, Croatia. Photo by Neven Kresic

Photo 10.37 Abandoned farmstead. Mountain Kaženik, Montenegro. Photo by Mike Ficco.

Photo 10.38 "Spahnjenca," built in modern days to celebrate the heritage of karst culture. "Spahnjenca" was the kitchen of a traditional Karst house (*Kraška hiša* in Slovene). The name means bulged out and refers to the fact that the chimney area was bulged out to minimize the smoke in the house. Photo by Herman Kosič.

Photo 10. 39 Popovo polje, eastern Herzegovina. One of the largest karstic poljes in southern Dinarides. Before construction of the *Trebišnjica Multipurpose Hydro System* and regulation of the namesake sinking river, the polje was regularly flooded for more than 200 days annually. Photos: Sulejman Balić (top, 1978) and Petar Milanović (bottom, 2020.)

Photo 10.40 Grančarevo Dam on the Trebišnjica river in eastern Herzegovina, the key component of the *Trebišnjica Multipurpose Hydro System* project. Photo by Neven Kresic.

Photo 10.41 Channeled Zeta River in Nikšićko polje, Montenegro. The channel is crossing Vrtac Reservoir on the way to compensation reservoir of the HE Power Plant Perućica at the polje's margin. This reservoir is almost never filled with water due to highly porous limestone bedrock and permanent water leakage. Photo by Zoran Stevanović.

Photo 10.42 *Arslanagića bridge* in Trebinje, Herzegovina. It was moved to its current location stone-by-stone from the original upstream location that was subsequently flooded by a reservoir on the Trebišnjica River, the largest sinking stream in Europe. Photo by Neven Kresic.

Photo 10.43 New Moračica bridge, almost 1km long, on the highway Podgorica – Mateševo in Montenegro. This is one of the most impressive structures on the highway. It is supported by five pillars, the highest being 161 m high. Vertical distance from the bottom of the riverbed of Morača to carriageway amounts to more than 200 meters (660 feet.) Photo by Zoran Stevanović.

Photo 10.44 Tunnel *Omiš* (Adriatic Sea region, the town of Omiš, Croatia) during construction. Photo by Mladen Garašić.

Photo 10.45 Railway and tunnel in karst of Vela Draga, Park of Nature Učka, Croatia. Photo by Blaž Kogovšek.

Photo 10.46 Elliptical dam around *Slivlje ponor* (swallow hole) at southeastern margin of Nikšićko polje in Montenegro. The dam is constructed to prevent water percolation into large active ponor when the polje is flooded and to divert water towards HE Power Plant Perućica. The first exploration of Slivlje ponor and its vertical channel dates to 1939, but most intensive were speleological investigations carried out by French, Slovene, Serbian and Montenegrin teams in 1955. The exploration conducted in 2005 and 2007 completed the picture of cave's shape and dimensions. In total, 252 m of cave channels are explored. Photo Golub Ćulafić.

Photo 10.47 Hydroelectric power plant "Jaruga" (*HE Jaruga*) is the second oldest major alternating current (AC) power plant in the World, built on *Skradinski buk* (waterfall on the Krka River) near Šibenik, Dalmatia. The plant went into operation on August 28, 1895 (under the name "Hydropower Plant Krka-Šibenik") or only 3 days after the first one on the Niagara Falls in the United States. Booth dams were constructed using design of Nikola Tesla, one of the most famous Serbian scientists who grew up not far from here in the village of Smiljan, Lika province (part of the Austro-Hungarian Empire at the time) what is now Croatia. Photo by Neven Kresic.

Photo 10.48 Mratinje dam on the Piva River in northern Montenegro. The dam, one of the highest in the world built in karst, was completed in late 1970s. Hydroelectric power plant *HE Piva* at the dam produces electrical energy for Montenegro and Serbia. Photo by Zoran Stevanović.

Photo 10.49 Forest fire on Velebit, August 2007. Due to high temperatures, limestone blocks cracked and rock surface partly disintegrated and powdered. Photo by Dražen Perica.

Photo 10.50 Top left: Croatian woman playing *gusle* – single-string solid wood instrument, traditionally used in the Dinaric region of Southeastern Europe, always accompanied by singing the epic poetry. Photo by Aleksandra Maran Stevanović. Top right: Little Vlah, representative of the Vlach communities in eastern Serbia that follow various pre-Christian religious beliefs, including their well-known magic rituals and witchcraft. They relate to the iconographs and symbols of nature and entail many mysterious practices (Courtesy of the National

Park Djerdap). Bottom: “Tambura” folk orchestra from Gospić, Croatia at the Opening ceremony of the International Conference on Dinaric Karst, Plitvice, 2009. Photo by Aleksandra Maran Stevanović.

Photo 10.51 One of just a few small springs issuing from a perched karst aquifer of the Volujak mountain (border area between Montenegro and Bosnia & Herzegovina). The kids fetch this water for a nearby “katun”, a summer shepherd village. Photo by Milovan Milivojević.

Photo 10.52 “Speleo kindergarten” in the Bogovina cave, Eastern Serbia. Photo by Predrag Stošić Peca.

Photos 10.1 *Top: Roman Viaduct, Split, Croatia*; Photo by Ivo Eterović
Bottom: Diocletian Palace, Split, Croatia; Drawing by Ernest Hébrard (1912)

Photo 10.2 *Great Fountain of Onofria, Dubrovnik, Croatia*. Vojislav Ilić

Photos 10.3 *Public Fountains, Dubrovnik, Croatia*. Neven Kresic

Photo 10.4 *Osp Village, Slovenia*. Matej Blatnik

Photo 10.5 *Krnovo Plateau, Montenegro*. Zoran Stevanović

Photos 10.6 *Spila Risanska Spring, Montenegro.* Neven Kresic (top), Petar Milanović (bottom)

Photo 10.7 *Predjama Castle, Slovenia*. Zoran Stevanović

Photo 10.8 *Ostrog Monastery, Montenegro*. Zoran Stevanović

Photos 10.9 *Left: Jankovićeva Špilja, Rakovica, Right: Špilja Kuća, Cetingrad, Croatia*. Vlado Božić

Photo 10.10 *Zidana Špilja, Krbavsko Polje, Croatia*. Vlado Božić

Photo 10.11 *Osp Cave, Slovenia*. Borut Lozej

Photo 10.12 *Lukomir Village, Bjelašnica Mountain, Bosnia and Herzegovina*. Ferid Skopljak

Photo 10.13 *Stećak Detail, Radimlja Necropolis, Stolac, Bosnia and Herzegovina*. Neven Kresic

Photo 10.14 *Bratač Village, Pupoš, Nevesinje, Bosnia and Herzegovina*. Natalija Samardžić

Photo 10.15 *Golubac Fortress, Danube, Serbia*. Zoran Stevanović

Photo 10.16 *Hadži Prodanova Pećina, Ivanjica, Serbia*. Zoran Stevanović

Photo 10.17 *Lukomir Village, Bjelašnica Mountain, Bosnia and Herzegovina*. Ferid Skopljak

Photo 10.18 *Rudinske Kolibe, Volujak Mountain, Montenegro*. Milovan Milivojević

Photo 10.19 *Pešter Plateau, Serbia*. Neven Kresic

Photo 10.20 *Grandpa with his sheep, Krbavica Polje, Croatia*. Jelena Ćalić

Photo 10.21 *Vrtače Village, Vranica Mountain, Bosnia and Herzegovina*. Ferid Skopljak

Photo 10.22 *Grandma, Lika Krbavica Village, Croatia*. Jelena Ćalić

Photos 10.23 *Rudinski Katun, Volujak Mountain, Montenegro*. Milovan Milivojević

Photo 10.24 *Lipice Stud Farm, Slovenia*. Jošt Gantar (source www.visitkras.info)

Photo 10.25 *Lipice Stud Farm, Slovenia*. Boris Pretnar (source www.slovenia.info)

Photo 10.26 *Lipice Stud Farm, Slovenia.* Mitja Božić (source Kobilarna Lipica)

Photo 10.27 *Lipice Stud Farm, Slovenia.* Mitja Božić (source Kobilarna Lipica)

Photo 10.28 *Rudine Katun, Volujak Mountain, Montenegro*. Milovan Milivojević

Photo 10.29 *"Belmuž", Serbia*. Courtesy of the National Park Djerdap

Photo 10.30 *Velebit Mountain, Croatia*. Dražen Perica

Photo 10.31 *"Bunje" Shelter, Croatia*. Dražen Perica

Photos 10.32 *Tvrdoš Monastery, Popovo Polje, Bosnia and Herzegovina.* Neven Kresic

Photos 10.33 *Orlac, Mostar, Bosnia and Herzegovina*. Neven Kresic

Photos 10.34 *Brusje Village, Hvar Island, Croatia*. Ognjen Bonacci

Photos 10.35 *Lopud Island, Croatia*. Neven Kresic

Photos 10.36 *Lopud Island, Croatia*. Neven Kresic

Photo 10.37 *Kaženik Mountain, Montenegro*. Mike Ficco

Photo 10.38 *"Spahnjenica" Kitchen, Kras, Slovenia*. Herman Kosič

Photos 10.39 *Popovo Polje, Herzegovina*. Top: Sulejman Balić (1978); Bottom: Petar Milanović (2020)

Photo 10.40 *Grančarevo Dam, Bosnia and Herzegovina*. Neven Kresic

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Photo 10.45 *Vela Draga, Park of Nature Učka, Croatia*. Blaž Kogovšek

Photos 10.46 *Slivlje Ponor, Nikšićko Polje, Montenegro*. Golub Ćulafić

Photo 10.47 *Jaruga Hydroelectric Plant, Krka River, Croatia*. Neven Kresic

Photos 10.48 *Mratinje Dam, Piva Reservoir, Montenegro*. Zoran Stevanović

Photos 10.49 *Forest Fire, Velebit Mountain, Croatia*. Dražen Perica

Photos 10.50 Aleksandra Maran Stevanović; Top right: Courtesy of the National Park Djerdap

Photo 10.51 *Volujak Mountain, Montenegro*. Milovan Milivojević

Photo 10.52 *Speleo-Kindergarten, Bogovinska Pećina, Serbia*. Predrag Stošić Peca

THE END

(AND THE BEGINNING)

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Web Resources

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Caves of Croatia
https://croatia4travel.com/caves-of-croatia/

Caves of Serbia
https://www.srbija.travel/en/experience-serbia/nature/caves

Caves of Slovenia
https://www.slovenia.info/en/things-to-do/discover-nature/caves

Djerdap UNESCO Global Geopark, Serbia
https://geoparkdjerdap.rs/en/

FAO, AQUASTAT website. Food and Agriculture Organization of the United Nations (FAO). http://www.fao.org/aquastat/en/databases/

GBIF web site. The Global Biodiversity Information Facility, an international network and data infrastructure funded by the world's governments and aimed at providing anyone, anywhere, open access to data about all types of life on Earth
https://www.gbif.org/occurrence/search

International Union of Speleology (Union Internationale de Spéléologie, UIS)
https://uis-speleo.org/
International Union for Conservation of Nature, IUCN web site: Protected area categories.
https://www.iucn.org/theme/protected-areas/about/protected-area-categories

Karst Commission, International Association of Hydrogeologists (IAH)
https://karst.iah.org/

Karst Region of Slovenia (Classic Karst or “Kras” in Slovene)
https://www.visitkras.info/en/
https://www.zelenikras.si/en/green-karst

Karst Waters Institute (KWI)
https://karstwaters.org/

Mljet National Park, Croatia
https://np-mljet.hr

National Parks of Bosnia and Herzegovina
https://meetbosnia.com/national-parks-of-bosnia-and-herzegovina/

National and Nature Parks of Croatia
https://www.parkovihrvatske.hr/en/parks

National Parks of Montenegro
https://www.visit-montenegro.com/tourism/national-parks/

National Parks of North Macedonia
https://visitmacedonia.eu/explore-macedonias-national-parks/

National Park Tara, Serbia
https://www.nptara.rs/

Plitvice Lakes National Park, Croatia
https://np-plitvicka-jezera.hr/en/natural-and-cultural-heritage/natural-heritage/karst-landscape/

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http://www.plantsoftheworldonline.org/

Special Nature Reserve Uvac, Serbia
http://www.uvaclake.com/

Speleological Committee of the Croatian Mountaineering Association
https://speleologija.eu/KS/speleocommittee.html
http://speleologija.hr/

Speleological Association of Slovenia (Jamarska zveza Slovenije)
https://www.jamarska-zveza.si/index.php/foreigners

Vjetrenica Cave, Bosnia and Herzegovina
https://www.vjetrenica.ba/en/

Photographs of Nebojša Atanacković
https://nestvarna.blog/

Photographs of Dobrislav Bajović–Bajone
@FotoBajone

Photographs of Dragan Bosnić
http://www.serbia.com/srpski/dragan-bosnic-priroda/

Photographs of Boštjan Burger
https://www.burger.si/SLOCaves.html

Photographs of Peter Gedei
https://petergedei.com/

Photographs of Uroš Kunaver
https://www.uroskunaver.si/

Photographs of Vinko Ljubas
http://fotografija.ba/members/jablan/

Photographs of Saša Preradović
https://sasapreradovic.com/

Photographs of Dragovan Stojadinović - Sule
www.vodopadisrbije.com

Photographs of Dinko Stopić
https://500px.com/p/dine_hr?view=photos

About the Authors

Professor Dr. Zoran Stevanović is Head of the Centre for Karst Hydrogeology at the Department of Hydrogeology of the University of Belgrade, Serbia, and member of the Faculty of Mining & Geology (FMG) where he teaches advanced hydrogeology courses. He is Consultant of the United Nations organizations FAO and UNESCO and has worked with and led groups of hydrogeologists implementing several large projects for groundwater utilization and protection. He has extensive international experience in projects involving hydrogeological exploration, groundwater management, and aquifer utilization and protection in Algeria, Iraq, Georgia, Bhutan, Seychelles, Somalia, Ethiopia, Bosnia & Herzegovina, Montenegro, and North Macedonia. Professor Stevanović was participant in numerous international cooperative research programs and expert exchanges with France, Slovakia, Romania, Bulgaria, China, Slovenia, and other countries. He was invited lecturer and member of scientific committees of numerous professional gatherings in Serbia and abroad. He has published more than 350 papers, four textbooks, and authored, co-authored, and edited fifteen monographs including *Karst Aquifers - Characterization and Engineering* (Springer, 2015) and *Karst without boundaries* (CRC, 2016).

Dr. Stevanović is Co-chair of the Karst Commission of the International Association of Hydrogeologists and Co-chair of the Board on Karst and Speleology of the Serbian Academy of Science and Arts. He is Past President of the Serbian Geological Society (SGS), and founder and Chairman of the Karst Commission of the SGS. Professor Stevanović is Member of the Scientific Society of Serbia and Corresponding member of the Academy of Engineering Sciences of Serbia. He is Honorary member of the Hungarian Geological Society and Member of the Bulgarian Geological Society. He served as Member of the Assembly of the University of Belgrade and the Scientific council on technical sciences. Professor Stevanović is recipient of the Serbian Geological Society Awards in 1991 and 2020, and the Branislav Milovanović Award in 2004, as well as appreciation certificates from international universities, research centers and scientific societies.

Dr. Neven Kresic, P.G. holds position of a Senior Consultant with Geosyntec Consultants based in Washington, D.C., the United States. He has more than 35 years of experience focused on groundwater and surface water related consulting, research, and teaching, specializing in characterization and analysis of complex groundwater systems. He is an expert in the practical application of numerical models for simulating groundwater flow, and contaminant fate and transport in groundwater for a variety of water supply and groundwater remediation projects.

Dr. Kresic has worked on major projects in the United States, Eastern Europe, Middle East, North Africa, and South America for U.S. and international clients including industry and government agencies. He was Senior Fulbright Scholar at the United States Geological Survey in Reston, Virginia, and the George Washington University, Washington, D.C. where he conducted novel research on characterization and modeling of groundwater flow and contaminant fate and transport in fractured rock and karst aquifers. Prior to moving to the United States in 1991, Dr. Kresic was professor of Groundwater Dynamics at the University of Belgrade in former Yugoslavia where he also worked on groundwater supply and engineering projects for utilities, industrial clients, and government agencies.

Dr. Kresic taught academic courses and professional workshops in hydrogeology, groundwater modeling, and groundwater remediation at universities, government agencies, and conferences in the United States and around the World. He authored and co-authored numerous papers and seven books on the topic of groundwater, including *Water in Karst, Management, Vulnerability, and Restoration* (McGraw Hill, 2013). Dr. Kresic is former Co-chair of the Karst Commission of the International Association of Hydrogeologists. He currently serves on the Board of Directors of Karst Waters Institute, the United States.

Zoran Stevanović (second from the left) and Neven Kresic (first from the right) with Professors Dr. Nadežda Dimitrijević (first from the left) and Dr. Budimir Filipović who established Department of Hydrogeology at the University of Belgrade and served as its Chairs and Co-chairs for many years. Professor Filipović was mentor for Ph.D. theses of Zoran and Neven, both having karst hydrogeology for subject.

Zoran and Neven patiently waiting for the karst spring to start flowing again… (see also Photos 10.6 in Chapter 10.)

This story of the "Lands of Karst", where the term karst originated, includes hundreds of color photographs contributed by over 70 karst enthusiasts from Slovenia, Croatia, Bosnia and Herzegovina, Montenegro, Serbia, and North Macedonia.

Featured are all types of fascinating landscapes and life: Wild Mountains, Noisy Rivers, Silent Lakes, Limestone Walls, Rough Surfaces, Fountains of Life, Windows to Unknown, Magic Chambers, Underground Creatures, Wildlife, and Human Inhabitants in the Past and Present.

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