

Preface

Natural and anthropogenic hazards in karst areas

Karst is among the most vulnerable environments of the world to man-induced and/or natural hazards, due to a number of peculiar geological and hydrogeological features, including but not limited to the presence of fractured rock mass, karst cavities and conduits, and the rapid concentrated flow that is typical of karst aquifers. Among the many possible hazards, subsidence, sinkhole development, floods, and slope movements are very frequent, and often cause serious damage in different karst areas of the world. Agriculture and land use changes, on the other hand, may lead to degradation of the karst landscape through practices such as stone clearing and crushing, so favouring the development of erosion and eventually resulting in rocky desertification. In addition, other anthropogenic activities such as intensive quarrying cause partial or total destruction of both the karst landscape and near-surface caves, with loss of the important geological and archaeological evidence they contained.

The fragility of karst environments is further evidenced by karst groundwater systems, which are extremely important water supplies (about 25% of the global population is supplied largely or entirely by karst waters), but whose quality is very susceptible to degradation. Over-exploitation of karst water resources, sea-water intrusion, and events of pollution, with consequent deterioration in the water quality, occur worldwide. It has to be stressed that many of the hazards affecting karst environments can be fully appreciated only through a multi-disciplinary approach, combining expertise from different fields, including geomorphology, engineering geology, hydrology, hydrogeology, biology, geophysics, and geochemistry.

This special issue of Natural Hazards and Earth System Sciences contains selected contributions from the session entitled “*Natural and anthropogenic hazards in karst areas*” held in the framework of the 1st General Assembly of the European Geosciences Union in Nice, France, from 25 to 30 April 2004.

Even though the symposium was introduced for the first time in 2004 in the Natural Hazards programme of the Assembly, it resulted in a good success, counting 32 contributions that were subdivided in thirteen oral and nineteen poster presentations. All the abstracts are available on the EGU web site at: <http://www.copernicus.org/EGS/egsga/nice03/programme/overview.htm>, in the Natural Hazards section of

the programme. The goal of the symposium was to share experiences from different karst areas in the world, and to discuss methodologies and techniques for a better comprehension of the different hazards which may occur in this very fragile environment, and the more appropriate methods for its management, with a particular emphasis on the interaction between human activity and karst.

This issue contains ten of the thirty-two contributions presented at the symposium. Since the topic of the session was fairly broad, covering all the hazards that may occur in karst areas, the articles presented here have dealt with a large spectrum of topics, from sinkholes, to slope instability, groundwater vulnerability, and engineering problems.

The difficulty in quantitative studies of catchment basins in karst was pointed out by *Bonacci*, who stressed the importance of determining the catchment area as the essential basis for any hydrological analysis and management of water resources. At the same time, changes in the karst catchment areas may occur as a consequence of human activities, natural phenomena, or a combination of the two. This was shown by the author through a number of examples from the Dinaric karst, covering areas from Croatia to Bosnia-Herzegovina.

The assessment of water resource vulnerability is a particularly complex problem in karst, due to difficulty in the definition of the main factors influencing it, including stage and type of karst, and the underground discharge characteristics. *Marsico, Giuliano, Pennetta* and *Vurro* have presented attempts to evaluate the intrinsic vulnerability in karst areas. The approach consisted of the implementation of a well-known method in groundwater vulnerability assessment (SINTACS R5), which was specially integrated with data about karst features.

The topic of groundwater pollution, both from input of polluting substances from the ground and from sea-water intrusion related to over-exploitation of water resources, was the subject of two other contributions in different areas of the Apulia region in southern Italy. In the first case, *Spizzico, Lopez* and *Sciannamblo* examined the hydrogeological setting in the Brindisi province where, similarly to wide sectors of Apulia, two aquifers are present, the deep one being the main groundwater resource in the region. The authors focused their attention on the physical and chemical characterization of the aquifers, and the determination of pollution

related to agriculture practices in the shallow aquifer. They pointed to the role played by the shallow aquifer in protecting the deep aquifer from contamination of anthropogenic origin.

In the second case dealing with groundwater pollution in Apulia, *Margiotta* and *Negri* combined geological and geophysical analysis in an attempt to verify the deterioration of groundwater due to saline intrusion. As in many coastal areas of the Mediterranean basin, the growth of built-up areas, and seasonal anthropogenic pressure determine the increasing activity of a high number of wells during the summer, which results in sea-water intrusion inland.

Management of karst water resources was again stressed by *Kovacic* and *Ravbar* who illustrated the case of Slovenia, a country where karst groundwater contributes about 50% to the total drinking water supply. The three examples described by the authors showed that episodes of pollution, due to the extreme vulnerability of karst aquifers and improper protection of the important water resources, are very frequent in Slovenia. Therefore, there is a need for in-depth knowledge of sustainable water management in karst regions.

Considering a more general approach to the natural and anthropogenic hazards affecting karst, the contribution by *Parise*, *Qirazi* and *Sala* describes the present situation in Albania. There, as in many other karst areas in the world, especially in developing countries and areas emerging from recent military problems, there has been serious, sometime irrecoverable, damage to the karst environment. Agricultural practices, intensive quarrying, the use of caves and dolines as sites of illegal disposal of wastes, and pollution of groundwater resources are only some of the many hazards described by the authors.

Sinkholes are among the most common hazards of karst areas, due to their connection with underground caves, and the complex subterranean drainage which may favour their formation. The rapid occurrence of these phenomena often results in serious consequences for the anthropogenic environment, as *Delle Rose*, *Federico* and *Parise* have shown in their study of sinkholes in southern Italy. The authors also highlighted the negative role often played by man in causing the development of sinkholes through actions such as overcharge of the ground above karst caves, settlement and erosion of filling deposits by leakage waters, etc. Analysis of the existing literature, and in situ surveys, integrated by speleological activities, allowed the authors to delineate three possible types of mechanism for sinkhole formation in the Apulian karst.

Due to many of the hazards discussed above, and especially the difficulty in predicting the presence and distribution of underground caves, engineering projects in karst may be more difficult than in other natural environments. The problems related to railway tunnel construction in a karstic area have been described by *Casagrande*, *Cucchi* and *Zini*. A geomorphological and hydrogeological approach, which had also to take into account the presence of karst caves, was considered necessary since the study area contains many dolines and caves. The integration of classical geological surveys with the speleological data allowed the authors to per-

form a valid analysis of the karst features in the area, and this resulted in the identification of the sectors with greater possibility of intersecting underground caves.

Two other contributions to this volume dealt with the study of karst in areas of high landscape, historical and archaeological values. The case study of the Tremiti Archipelago by *Andriani*, *Walsh* and *Pagliarulo* represented an interesting example of analysis of coastal changes due to erosion and slope movements, the occurrence of which is strictly related to karst caves and conduits. The presence of these features, and the high solubility of the carbonate rock mass when attacked by the combined actions (physical through wave action, and chemical through solution) of the sea-water, are among the main factors influencing the present evolution of the coastal morphology.

Again as regards slope instability, the use of integrated geophysical methodologies was implemented by *Leucci* and *De Giorgi* for the assessment of the stability in a karst cave. The work was aimed at safeguarding a site of archaeological importance, and consisted in the combined use of electrical resistivity tomography and ground-penetrating radar.

In conclusion, the ten papers presented in this volume illustrate the importance of studying natural and anthropogenic hazards in karst areas for a better understanding of their causes, and their often negative effects on both the natural and the built-up environment. The need to safeguard very fragile karst environments, and their precious water, which was the main object of discussion during the symposium in Nice, was again pointed out by many of the contributions in this volume. As a final remark, we would therefore like to highlight that appropriate land management, which aims to promote a sustainable use of resources, must be properly considered in any project regarding land use planning in karst areas.

Acknowledgements. We acknowledge many people for their help in managing and publishing this volume. First of all, the very efficient support of the EGU Editorial and Production Offices, and especially of K. Gänger, who provided a valuable help throughout the work of the volume production. Our warmest thanks to all the referees, for their precious work that undoubtedly increased both the quality and the clarity of the papers. Everyone benefitted from their suggestions.

We acknowledge also the scientists who attended the symposium, and are especially grateful to the authors who contributed to this volume. Finally, we are grateful to the European Geosciences Union, for providing the opportunity to convene the symposium, and for giving us the possibility to publish selected papers on this journal.

Mario Parise, Bari, Italy

John Gunn, Huddersfield, UK

Special Issue Editors