

Guest Editorial

Archives of climate and environmental change in Karst



1. Introduction

Until recently, most Quaternary paleoclimate and paleoenvironmental reconstructions came from deep-sea sediments, ice cores, peat deposits, and a variety of geomorphologic archives. Over the last 2 decades, scientists increasingly have recognized that caves preserve some of the best continental Quaternary archives. Among cave deposits, speleothems seem to be the ideal candidates to complement marine and other terrestrial deposits in helping us to understand past climate changes. Speleothems have by far surpassed all other cave elements traditionally used in paleoclimate studies, such as fossil remains or cave sediments, due to several outstanding features: (i) they are sensitive to climate changes as their growth mechanism is linked to Earth's atmosphere and hydrosphere in a number of ways, (ii) they are available from the tropics to the Arctic, from caves below the present sea level to those at high elevations, (iii) in deep-cave settings speleothems form undisturbed in an environment free of weathering processes or bioturbation, (iv) unlike biological archives, speleothems are not prone to adaptation over long periods of time, and above all (v) in most cases they may be U-series dated offering a reliable, high-precision chronology that can be tied to their stratigraphy. Although many intimate processes that control the multiproxy variations are yet to be fully understood, we do believe speleothems will continue to produce meaningful and exciting information about past climate, fluctuations of sea level, vegetation changes, hydrology, water–rock interaction, landscape history, and human activities.

Ten years after the first *Climate Change: the Karst Record* meeting (Bergen, Norway; Lauritzen, 1996), the “Emil Racoviță” Institute of Speleology and the Romanian Society for Speleology and Karstology convened the 4th Conference in May 2006 with the goal to address or answer complex problems that regard the relationship between speleothem geochemistry, macroclimate, karst aquifer, vegetation/soil cover, and intimate crystal growth mechanisms. Emphasis was placed on presenting high-resolution paleoclimate and paleoenvironmental data generated with the most advanced technical facilities available at hand. The meeting also aimed to involve graduate students, so that they could become familiar with the possibilities and challenges of paleoclimate and geochronology in various cave environments.

The venue was a pleasant hotel in Băile Herculane (Romania), an old Roman thermal spa located in one of the most spectacular karst landscapes in Romania (e.g., Danube Gorge, Mehedinti Plateau, etc.) that offers a number of caves with well-documented archives of climatic changes (Constantin et al., 2001a, b, 2007a). A one-day field trip during the meeting visited the Danube Gorge and Ponicoava Cave. Two post-conference field trips (5 days each) were organized in order to provide the participants with particular examples of sites from where Late Pleistocene to Holocene climate and environmental reconstructions were obtained.

The Western Carpathians trip highlighted past and ongoing climate research in two major caves: Scărișoara and Urșilor (Bears). The first one is famous for its 100,000 m³ layered ice block accumulated over the last 2000 years or more, which provides a detailed record of the Late Holocene climate events (Racoviță and Onac, 2000, Zak et al., this volume). The Bears Cave is not only the major show cave in Romania, but also hosts a variety of speleothems and cave bear bones. Based on these archives, the mid-European Holocene climate conditions were characterized (Constantin et al., 2001b, Onac et al., 2002).

The Southern Carpathians trip was designed as an enroute experience starting from the Danube towards the east, to the Prahova Valley. One of the key sites visited was the cave of Topolnița, an extensive karst system >20 km in length where sedimentological (Horoi, 1993) and speleothem studies may be combined for a better



Fig. 1. Participants at the 4th International “Climate Change: the Karst Record” conference.

understanding of cave evolution as related to climatic constraints. A large part of the trip focused on the karst around the laboratory cave of Cloșani, where speleothem studies provided the first high-resolution climatic reconstruction of the Second Termination in Romania (Constantin et al., 2007b) and combined paleomagnetic data and U-series dating of a flowstone deposit indicate ages older than 1.4 Ma.

The Fourth “Climate Change: the Karst Record” conference gathered 148 scientists from 28 countries which presented a total of 107 papers (Onac et al., 2006) (Fig. 1). Perhaps the most fascinating aspect of the meeting was the diversity of approaches—not surprising considering that karst science itself is highly inter-disciplinary. Clearly, one may notice a trend for a more systematic monitoring of present-day climatic conditions coupled with calcite precipitation and drip-waters monitoring which are all essential for understanding the extent to which the $\delta^{18}\text{O}$ and $\delta^{13}\text{C}$ may be used as paleoclimatic proxies and their controlling factors. The number of reported speleothems analyzed also increased—this is an important step in extending density, consistency and time range of speleothem records but, on the other hand, it raises concerns related to cave conservation issues.

The importance of speleothems as multi-proxy archives was first recognized some 30 years ago by a handful of cave scientists who were well aware of both the advantages of using speleothems for scientific purposes and the necessity of cave environment conservation. Currently, the “speleothem people” form an eclectic population including scientists whose understanding of the cave environment is sometimes incomplete. Many speleologists and conservationists have started to worry about the extent to which this new scientific trend may affect pristine cave environments. Right now, this is hard to assess but, clearly, the growing need of new samples should be balanced by a smart conservationism based on a comprehensive understanding of speleothem formation in deep-cave settings.

2. Contributions in this volume

This volume comprises eight papers, which cover recently developed experimental methods in speleothem studies (3), paleoclimatic interpretations based on U/Th dating, isotopic and trace element measurements (3), the relationship between paleoclimate and cave fauna assemblage (1), and a review on cryogenic cave carbonates.

Jex *et al.*'s paper uses hyperspectral imaging to examine important visual characteristics of speleothems (e.g., color, lamination, changes in fabric, etc.). This technique has many advantages over standard optical techniques. Furthermore, analyzing the characteristic reflectance spectra of speleothems, the method has the potential to accurately document variations in calcite fabric along the growth axis, changes in porosity, amount of trace elements, and organic matter within various laminae. All these are important proxy records that are used in paleoclimate reconstructions. In addition, the authors investigate which waveband would best help identifying annual/sub-annual lamina in stalagmites and what the near infrared spectra look like.

Wiedner *et al.* report their experiments carried out to improve our understanding on the kinetic processes that take place during calcite precipitation under disequilibrium conditions. Precipitation of carbonate was contrasted under either slow or fast CO₂ degassing from both standing and flowing solutions. Measurements of the $\delta^{18}\text{O}$ and $\delta^{13}\text{C}$ in newly formed calcite (under fast outgassing setting) confirmed the so-called Hendy effect (Hendy, 1971), which pointed out that if kinetic fractionation occurs, both isotopes become enriched in concert.

One of the basic requirements in recovering good paleoclimate records is to select the right speleothem. Frappier's paper tackle this problem and describe a stepwise sample screening process (both in field and laboratory) to select storm-sensitive stalagmites from cyclone-active tropical karst regions.

The next series of papers present late Holocene paleoclimate reconstructions based on speleothems from Spain, New Zealand, and Florida, respectively. Introducing a cautionary note, Dominguez-Vilar *et al.* interpret their decadal-to-millennium-scale periodicities to relate with the rainfall amount, which may cause $\delta^{18}\text{O}$ fluctuations of up to 2‰.

Using two paired stalagmite $\delta^{18}\text{O}$ and $\delta^{13}\text{C}$ records from both North and South Island (New Zealand), Lorrey *et al.* identified key regional weather regime operation periods over the past ~4000 years. The cooler intervals were associated with stronger westerlies, whereas warmer periods appear to be related with subtropical air masses transported by easterly circulation.

A 170–180-year solar cycle is reported by van Beynen *et al.* based on strontium and carbon isotope variability in a speleothem from Central Florida. Both proxies were used to explain changes in soil productivity and precipitation above the investigated cave. Changes in soil productivity above the cave triggered by variable precipitation amount were inferred from the negatively correlated Sr concentrations and $\delta^{13}\text{C}$ values in the investigated calcite speleothem.

Zak *et al.*'s paper provides a thorough review on the cryogenic carbonates in cave (CCC) environments. Using the oxygen and carbon isotopic signature, the study highlights the existence of two modes of CCC occurrence:

cryogenic powder formed by rapid freezing and cryogenic coarse-grained crystals produced during slow freezing of water.

The last paper in the volume, by Döppes *et al.*, reveals how numerical dates of paleontological sites allow a critical discussion on the relationship between cave fauna assemblages and their ecological–climatic distribution. The authors emphasize that, although many problems must be faced (e.g., contradicting fauna, age differences, etc.), paleontological cave sites represent rich archives that provide important additional data for Middle to Upper Pleistocene paleoclimate reconstructions.

3. Conclusion

The eight papers assembled in this special issue reflect part of the proxy records from speleothems that are used to reconstruct the magnitude and frequency of climate and environmental changes in karst regions and bordering areas. In addition, the experiments reported in the first two papers provide insights into new techniques that have the potential to improve our understanding on the presence of annual and sub-annual laminations in speleothems and fractionation processes during precipitation of calcite. This collection of papers has emerged from an increasing interest in studying cave sediments and their archived stories.

A strong and ongoing emphasis of *Karst Paleoclimate* group is to encourage the new generation of young Quaternary scientists to carry out research in karst areas around the world. The growing of this community and the increased interest for studying new, exotic karst locations bodes well for the way forward. The next *Climate Change: the Karst Record* meeting (June 2–5, 2008) will be organized by the Southwest University of China in Chongqing (<http://www.climatechangekr5.org/>).

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