

## GUEST EDITORIAL

# Cova des Pas de Vallgornera: an exceptional coastal karst cave in the Western Mediterranean basin

Joan. J. Fornós

Dept. Ciències de la Terra, Universitat de les Illes Balears  
Crta. Valldemossa, km 7.5, 07122 Palma de Mallorca, Illes Balears, Spain  
E-mail address: joan.fornos@uib.es

Joaquín Ginés

Federació Balear d'Espeleologia  
C/ Uruguai s/n, Palma Arena  
07010 Palma de Mallorca, Illes Balears, Spain  
E-mail address: jginesgracia@yahoo.es

Mallorca Island represents an European benchmark with respect to coastal karst and Quaternary investigations (Ginés et al., 2012). As an exponent of the early explorations, E.A. Martel discovered in 1896 important extensions in Coves del Drac when crossing the brackish pools of an outstanding littoral karst phenomenon that nowadays is the most visited show cave in Europe. The relevance and amount of coastal karst studies in Mallorca were growing during the 20<sup>th</sup> century, but explorations recently conducted in Cova des Pas de Vallgornera (CPV), particularly from 2004 till today, led to a tremendous increase in the knowledge of Mallorcan karst. With over 74 km of surveyed passages and chambers, including more than 17 km of underwater conduits, CPV is the longest cave of the Balearic Archipelago. The cave was accidentally discovered on 1968 when building a touristic hotel in the southern coast of the island. Since then, and thanks to the involvement of many cavers and, more recently of speleo-divers, the present surveyed length continues to grow and there is no foreseeable end in sight, particularly in the underwater extensions.

The cave develops in Upper Miocene reef limestones whose progradation built an extensive tabular platform (90 km long and up to 20 km wide) that has been intensely karstified, especially near the littoral where an interesting eogenetic coastal karst (Vacher & Mylroie, 2002) is widely developed (Ginés et al., 2007). Facies changes linked to the architecture of the Upper Miocene reefal rocks produced a great sedimentological and textural variability observable along the whole cave system. These lithological settings have been invoked as the main factors controlling the pattern and morphology of CPV. Mineralogy and speleothem distribution are also explained, in part, by these lithological factors.

Cova des Pas de Vallgornera can be considered a very peculiar and complex phenomenon of coastal karst, a topic that has been an object of increased scientific interest over the last decades. However, the complexity of the morphogenetic features observed in CPV does not fit strictly the standard models of coastal cave development, known as the *Flank Margin Cave Model* and the *Carbonate Island Karst Model*, and formulated from 1990 onwards (Mylroie & Mylroie,

2007; Lace & Mylroie, 2013). In fact, the cave pattern of CPV and their morphological features suggest the necessity of shifting from a carbonate island karst model towards a *Carbonate Coast Karst Model*. In our case, the speleogenesis of CPV includes besides coastal mixing processes other hydrogeological inputs, as for example, the existence of a deep-seated geothermal recharge. The diverse speleogenetic pathways invoked in this particular case, bring up again an unsolved terminological problem: what must be considered a *hypogenic process*? (Palmer, 2007; Klimchouk, 2007). Throughout all the papers included in this issue, the authors have used this term exclusively when referring to uprising waters from depth, independently of the source of aggressiveness; therefore, simple coastal mixing processes are not termed hypogenic in order to better identify the speleogenetic factors involved.

## CONTRIBUTIONS IN THIS VOLUME

The collection of papers gathered in the present issue covers a broad range of topics, aiming to document the current scientific knowledge on the Cova des Pas de Vallgornera.

The first article of this issue includes an historical introduction to the exploration of the cave. Signed by the most involved explorers, both in the air-filled passages and underwater extensions, the paper by *Merino et al.* makes an accurate and concise description of the cave system, illustrated with a couple of topographical surveys corresponding to the different stages in its exploration; some comments on the future prospects regarding research and exploration are also addressed. The paper ends with information about the legal situation of the cave in relation with its protection and management status.

The geological aspects and the speleogenesis of the cave are tackled by *Ginés et al.* in an extensive paper that highlights the role played by the sedimentological characteristics of the bedrock over the cave patterns and passages morphology. On the basis of different morphological informations as well as data from cave deposits with vertebrate fauna, the authors revise the complex implication of different agents that have been involved in the speleogenesis, such as: coastal

mixing dissolution, drainage of meteoric diffuse recharge, and hypogene basal recharge related to local geothermal phenomena. The paper ends with a geochronological timeline of the cave evolution that takes into consideration the role played by the sea level fluctuations since the mid-Pliocene.

A third paper by *Merino et al.*, deals with the typologies and distribution of the speleothems within this eogenetic cave system. The authors discuss the role played by the factors that control their distribution, e.g., the lithological characteristics (mainly textural variations), the hydrogeology, and other speleogenetic aspects. Special attention is devoted to the description of several speleothem types not found in any other cave in Mallorca; these are documented by spectacular images that contribute to their description. Particular attention is addressed to the phreatic overgrowths on speleothems (POS) that precisely record the Holocene and Pleistocene sea levels (Tuccimei et al., 2006; Dorale et al., 2010; Ginés et al., 2012).

*Onac et al.*, while describing the mineral assemblages present in the cave, reinforce the role of the three speleogenetic pathways that have configured the present pattern and morphological features of the cave, i.e. the sea coast mixing, the meteoric recharge, and the ascending warm groundwater. Their interaction produces certain unusual minerals (barite, celestine, nordstrandite, etc.) completely different when compared to other cave minerals in the island, which are clearly dominated by carbonates. Several of the not common minerals were found within or nearby clear hypogenic morphologies although none of them are sulfuric acid by-products.

The detrital sedimentary infilling is covered by the paper of *Fornós et al.* Although sediments have not a conspicuous presence along the cave, they represent a good example of the complex sedimentation processes that can take place in those coastal karst environments. Autochthonous carbonate materials (detached rock particles, calcite rafts, etc.) intermix with allochthonous infillings carried into the cave through small surface openings (soil infiltration) or larger entrances that allow direct deposition of eolian sands and a rich paleontological content. Presence of Mn- and Fe-rich in the sediments of the underwater passages give new insights into the sedimentary processes involved during the cave evolution.

Two different papers account for the paleontological content of the sediments present in CPV. The paper of *Bover et al.*, brings good paleontological and chronological data on the vertebrate remains discovered in the Galeria del Tragus, once an entrance facies sedimentary deposit related to an ancient opening. The exceptional preservation state shown by these Early Pleistocene fossils had allowed the characterization of its faunal assemblage, which otherwise is poorly documented till now in the Balearics. Paleontological data are supplemented by a fossil vertebrate database paper (*Díaz et al.*) including three endemic mammals, two taxa of Chiroptera, sixteen taxa of birds, one Reptilian taxon and one Amphibian from the Early Pleistocene.

Geochemical and isotopic studies on phreatic waters are covered in the paper of *Boop et al.* This study deals with the geochemical factors that controls the precipitation of calcite or aragonite in the uppermost part of the brackish pools giving way to POS that have important implications for sea level history. The authors compare the degassing of CO<sub>2</sub> in two Mallorcan caves (CPV and Coves del Drac), where different POS mineralogies are present, and discuss the relation with the air cave ventilation and the salinity values resulting from mixing waters.

Microbiology topic is present with two different papers. *Busquets et al.* report the species diversity of the microbial communities found along three cave pools of this anchialine environment (mainly *Gammaproteobacteria* and *Actinobacteria*). Their biogeochemical role in precipitating calcite and controlling the variability of crystal habit and growth according to different species is highlighted. *Menning et al.*, describe the species richness and the relative abundance of Achaea, Bacteria, and microbial eukaryotes by means of quantitative PCR. The vertical profiles investigated in CPV as well as in three different pools of Coves del Drac (a touristic cave), report results that highlight the importance of the anthropic influence in the touristic cave as well as reinforce the similarities in the microbiological presence for both caves.

## **FUTURE PROSPECTS AND ACKNOWLEDGEMENTS**

Most of the current research lines, namely, morphological, mineralogical, sedimentological, geochronological, geochemical, or microbiological are represented in the 10 papers included in this issue. Nevertheless, the potential for new investigations remains wide open because just the general trends of every field have been outlined. To begin with, most of the physical parameters of the cave atmosphere and waters remain largely unpublished; such studies are in progress along with their spatial distribution and seasonal variation. Furthermore, corrosion studies due to condensation processes are now being explored, as well as several aspects concerning the deposition of Fe-Mn sediments, radon concentration, terrestrial and anchialine fauna, etc. These are only a few of many other research topics that are currently under way.

Some other important topics remain only partially solved, as is establishing the overall chronological framework of the processes that have acted in the development of the cave. Future investigations on this topic will contribute to a better knowledge of the evolution of littoral karst systems in the Balearics, supplying additional insights to the broadening interpretation of coastal karst phenomena in complex geologic settings.

Most of the research projects developed in CPV have been performed as collaborative tasks involving cavers from the *Federació Balear d'Espeleologia* together with Mallorcan scientific institutions as the *Universitat de les Illes Balears* (UIB) or IMEDEA

(CSIC-UIB), sometimes in collaboration with other foreign universities (*Università di Roma Tre, University of South Florida, or Babes-Bolyai University* in Cluj).

It must be specifically highlighted the tasks carried out by many individuals from a number of speleoclubs grouped in the *Federació Balear d'Espeleologia* who through their continuous and anonymous work have improved the knowledge of this exceptional cave system; their support during the scientific field-trips has been decisive.

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Nowadays the cave is protected by the regional environmental authority and was declared a Site of Community Importance (Natura 2000 Network, ECC). The exploration for new extensions, especially in the flooded passages has not yet finished. It is our hope that the results expressed in the present issue will encourage new generations to pursue, not only with

the exploration but with the scientific research, which surely will increase the knowledge on coastal karst thanks to the enormous investigation potential shown by the Cova des Pas de Vallgornera.

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