16th INTERNATIONAL CONGRESS OF SPELEOLOGY

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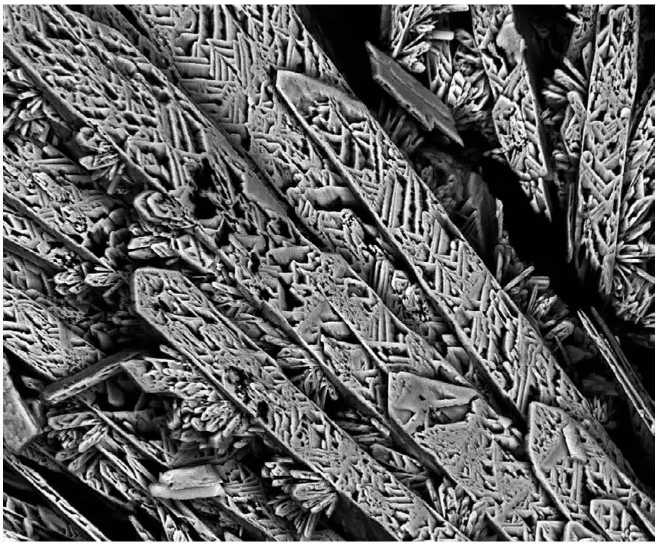
VOLUME 3



Edited by
Michal Filippi
Pavel Bosák

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BRNO 2013 CZECH REPUBLIC
WHERE HISTORY MEETS FUTURE

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Cover photos (some photos were adjusted/cropped)
Top left – Specific carbonate speleothem decorations in the Ghost Chamber, Sima de la Higuera Cave. Photo by V. Ferrer. For details see the paper by F. Gázquez and J.-M. Calaforra.
Top right – A challenging exploration in the Cueva de los Cristales. Mexico. Photo by La Venta Exploring Team and Speleoresearch & Films. For details see the paper by F. Gázquez et al.
Bottom left – An example of a microcrystalline grained halite speleothem, the Octopus formation in the 3N Cave, Qeshm Island, Iran. Photo by NAMAK team. For details see the paper by Filippi et al.
Bottom right – Internal skeleton structure of cryogenic gypsum crystals caused by the presence of partitions oriented parallel to the faces. For details see the paper by Kadebskaya and Tchaikovsky.

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A CONCEPTUAL MODEL OF SPELEOGENESIS IN GREECE

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Over 70 % of Greece's territory consists of carbonate rocks (limestone and marble). This almost homogenous geology in correlation with the special tectonic regime of the broader region of the east Mediterranean makes the region an ideal site for cave development. The exact number of Greek caves is still unknown since there is no formal cadastral. However, there is an estimation of more than 10,000 caves and rockshelters. Here, we attempt to make a correlation between the cave dimensions and their locality. First, a creation of a cadastral took place using data provided by cavers and caving clubs. Statistical analyses of depth, length and altitude of the caves were performed in order to define the key factor for the development of the caves and to create a general conceptual model about the speleogenesis in Greece. The combination of the above revealed a clear difference on the speleogenesis between the caves in the outer and the inner part of the Aegean orogeny.

1. Introduction

The lithological structure of Greece consists mainly of carbonate rocks in combination with the Mediterranean climate, favors the development of karst phenomena to a large extent. A rough estimation of the total number of karst caves in Greece includes more than 10,000 caves. During the last decades the development of cave exploration in Greece along with the increasing interest of many European cavers has led to numerous caving expeditions. However, little attention has been paid to the study of caves from a scientific point of view. In this work we attempt for the first time to create a general conceptual speleogenetic model for the Greek caves based on cave statistics of their characteristics, such as depth, width and length. A correlation between cave locality and the tectonic regime is tested.

2. Geological setting.

The Greek territory consists mainly by carbonate rocks (marbles and limestones). In general, northern Greece consists of Paleozoic marbles and metamorphic rocks since it is part of the old continental crust around which the closing of the Tethys Sea took place during the Alpine orogenesis. In contrast, the rest of the Greek mainland as well as most of the Greek islands are mainly built up of Mesozoic limestones that represent the shallow and deep marine deposits of the Tethys Sea. The general structure is characterized by a series of stacked nappes, ~ 5–10 km thick (composite), consisting of the upper crust that decoupled from the present subducted continental and oceanic lithosphere of the Adriatic–African Plate (van Hinsbergen et al.; 2005, 2010; Jolivet and Brun 2010). These nappes (or "mega-units") were thrusted and stacked in a north-to-south direction since the Cretaceous (Faccenna et al. 2003; van Hinsbergen et al. 2005; Jolivet and Brun 2010) and form a strongly shortened representation of the paleogeographical distribution of continental ribbons and deep basins that existed in the western Neo-Tethys (e.g., Dercourt et al. 1986; Barrier and Vrielynck 2008; Stampfli and Hochard 2009).

The Aegean Sea and the surrounding areas belong to the active continental boundary of the Alpine–Himalayan belt (Fig. 1) and as a result suffer a large-scale active deformation, stemming from the subduction of the eastern Mediterranean lithosphere under the Aegean Sea, along the Hellenic Arc (Papazachos and Comninakis 1969). Consequently, the continental and coastal parts of Greece share the common characteristics of the back–arc extensional tectonics, expressed by the presence of a strong deformational pattern, volcanic activity and the development of fault bounded grabens, lying in accordance with the dominant N–S extensional stress field. However, as illustrated in Figure 1, the northern part of Greece is additionally influenced by a subsidiary right–lateral shear because of the coexistence with the North Aegean Trough, a dextral strike-slip structure associated with a series of strong earthquakes (McKenzie 1972).

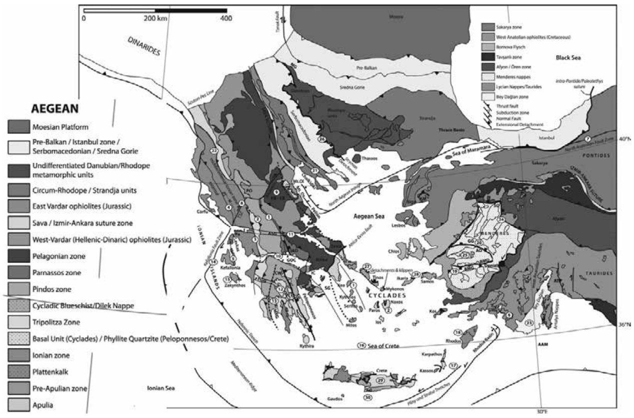

Figure 1. Geotectonic Regime of the Aegean (from van Hinsbergen and Schmid 2012).

3. Methodology

In order to investigate the key factors that influenced the development of Greek caves and to set up a general model concerning the speleogenesis in Greece, a proper cadastral was created. Parameters concerning cave dimensions such as depth, length and altitude, as well as the locality of almost 4,000 Greek caves are included. The cadastral is based on an enriched version of the SPELEO club cadastral (Theodosiadis 2011), while further data provided from the

Greek cavers K. Adamopoulos (SELAS caving club) and G. Sotiriadis (Proteas caving club). A statistical analysis of the relation between various speleometric parameters was conducted and explored through correlation plots. Moreover, ArcGIS software was used to create a thematic map with the position of the forty deepest caves in order to clarify the relation of the present tectonic regime and cave development.

4. Results and discussion

Statistical analysis revealed that there is no clear correlation between the altitude and the length of the studied caves (Fig. 2). This is probably due to the different geological and hydrological criteria that prevailing in the study area (Greece) and they are controlled by the regional geology, tectonic activity and the landscape.

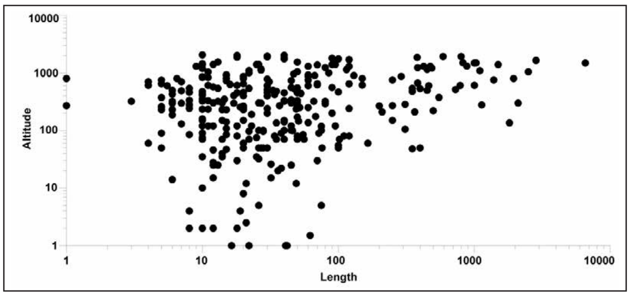

Figure 2. Altitude – length plot.

In contrast as it seen in the diagram between the depth and the length of caves (Fig. 3) there is appositive correlation between these two parameters. This is because the measured length of the cave is a function of the surveyed depth, deep caves tend to be long and *vice versa*.

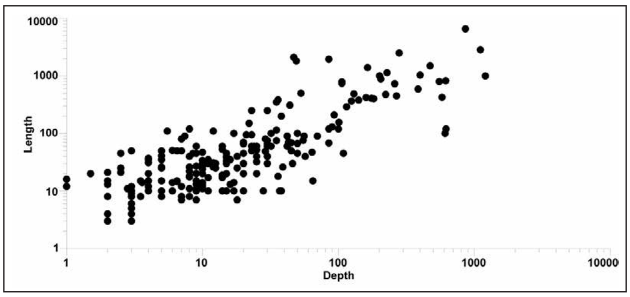

Figure 3. Length – depth plot.

Furthermore, the diagram created to investigate the relationship between the depth and the altitude at which the caves appear (Fig. 4) shows that the majority of the deeper caves occur at an altitude over 400 m. There is also an upper boundary of cave altitude, controlled by the topography. The lower boundary (slope 0.91) is connected to the internal relief; deep caves are found in terrain of great relief.

In order to further investigate the factors that influenced Greek cave development a map showing the positions of the studied caves and the tectonic setting of Greece with the main tectonic lines was created (Fig. 5). In this map, it becomes evident that the deepest caves tend to be located in areas adjacent to the subduction arc. This is explained by the fact that at these areas compressive stress results in constant uplift and in intense (tensional) fracturing of the bedrock at high altitudes. The continuous raising of these

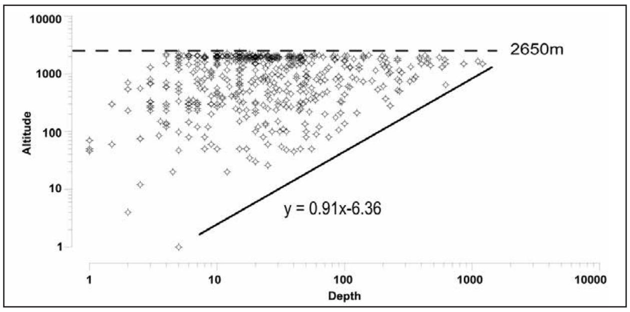

Figure 4. Altitude – depth plot.

regions (and erosion) lead to continuous lowering of the phreatic zone and, as a consequence, to the creation of a deep vadose zone. This fact, in combination with the strong fracturing favors the creation of deep caves.

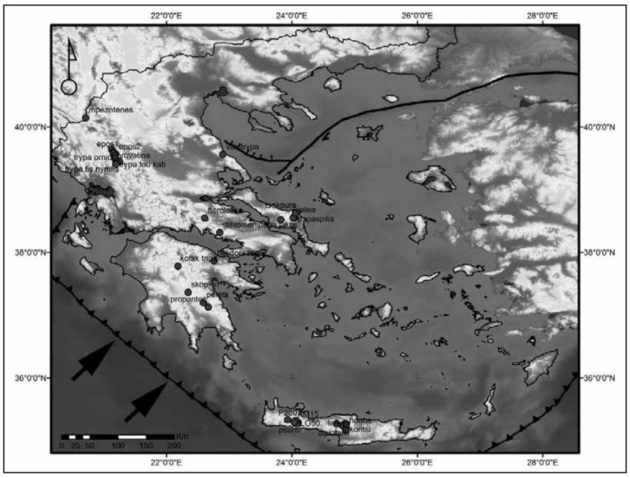

Figure 5. Map of the region with the main tectonic lines. The positions of the forty deepest Greek caves are depicted with dots.

5. Conclusions

The exploratory statistical analysis of the cave parameters in relation to the spatial distribution of the deep caves suggests that the major factor controlling the speleogenesis in the area is the tectonic activity of the region. The tectonic setting of the broader Greek territory results in the fracturing of the carbonate bedrock in accentuated topographic relief, creating ideal conditions for vadose speleogenesis (most deep caves of the World are essentially vadose). The high tectonic activity is responsible for the continuous lowering of the phreatic zone creating a high vadose zone in which the deep caves occurred.

Acknowledgments

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