The 4.4 km-long Hermannshöhle is one of the largest caves in the Lower Austroalpine Unit. The cave is unusual in two respects: its dense network of corridors is arranged in a three-dimensional maze and the most outstanding macro- and micromorphologic features were caused by paragenesis. The aim of this study was to enlighten the origin of this cave using morphological and sedimentological observations as well as U/Th dating of speleothems. First results show that the palaeo-environment of the Hermannshöhle was drastically different from today. Highly corrosive water sourced from nearby non-karstic gneisses and schists gave rise to well-developed contact karst features. A distinct system of paragenetic canyons developed following pulses of clastic sediment input creating the unique maze character of the cave. Preliminary U/Th results suggest that speleothems from the middle level of the cave are already older than ca. 600 ka.

1. Introduction

Hermannshöhle located near Kirchberg am Wechsel (Lower Austria) is one of the biggest caves in the Lower Austroalpine tectonic unit (Pfarr et al. 2012). It developed in an isolated block of weakly metamorphic banded marble. Within only 140 × 160 m ground area and 73 m of elevation difference a total of 4.4 km of corridors formed in a three-dimensional maze. There are three more caves nearby (Mäanderhöhle, Antonshöhle and Rauchspalten) and it is presumed that all four are genetically related (Hartmann et al. 1997) giving a length of almost 5 km.

Due to the labyrinthic array and the geological features (e.g., the extensive sediment fill and the fact that one part of the cave developed below the local base level but still is dry) the cave is special and its genesis – especially the extremely labyrinthic character (cf. Palmer 1975, 2011) – has remained unexplained.

Comprehensive studies including cave biology, mineralogy, geology, meteorology and other fields culminated in a monograph by Hartmann et al. (1997). Despite attempts to describe the evolution of the Hermannshöhle (Mrkos 1997), the mechanisms driving its formation are not fully understood, as modern concepts of speleogenesis (e.g., Klimchouk et al. 2000) have not been considered. Speleothem dating was also performed using $^{14}$C in comparison with alpha-spectrometric U/Th but the results were inconclusive (Seemann et al. 1997).

The focus of this study is to understand the origin of the extreme maze structure and the almost omnipresent paragenetic features in Hermannshöhle. Using state-of-the-art MC-ICP-MS U/Th dating of well-selected speleothems we are striving to constrain the chronology of speleogenesis in this cave and its connection to the evolution of the adjacent Kirchberg Basin.

2. Geographic and geologic implications

Hermannshöhle is located in the Eulenbergh hill near the village Kirchberg am Wechsel in the South of the province of Lower Austria. The host rock are Middle Triassic carbonates which are part of the Lower Austroalpine unit, bordered by a Palaeozoic gneiss-and-schist-complex in the North. In the South the area is covered by Neogene and Quaternary sediments of the Kirchberg Basin (580 m a.s.l.), which was formed during the last phase of the alpide orogeny due to lateral extrusion (Ebnner 1991; Faupl 2003; Figure 1). The basin is linked to branches of one of the largest strike-slip fault in Austria, the SEMP (Salzachtal-Ennstal-Mariazell-Puchberg-Fault) and the Mur-Mürz-Fault, respectively (Decker et al. 1994).

The rather isolated carbonate block hosting the cave system consists of a foliated, weakly metamorphic calcite marble...
that is part of the Lower Austroalpine Semmering-Wechsel-System. This system consists of the tectonically overlying Semmering-Unit built up of Permo-Mesozoic sedimentary rocks above a series of coarse-crystalline gneisses. The Wechsel-Unit marks the lowest level of the Austroalpine and is exposed in tectonic windows. At the northern margin of the largest of these tectonic windows the Kirchberg Basin developed during the Neogene. On its eastern margin Permo-Triassic metamorphic carbonates of the Eulenberg are exposed, forming a karst system that was and probably is still fed by the Rams brook. This brook originates in the nearby gneisses and schists and therefore contains corrosive water (Hartmann et al. 1997; Figure 2).

Due to its strong faulting and probably also its foliation the marble provides good conditions for the formation of caves. The internal morphology of the cave is quite baffling. On a very small area of only 140 × 160 × 73 m a 3D-maze developed that is unique not only in the Lower Austroalpine caves but also in the entire Eastern Alps. The cave ranges from about 600 m to 680 m a.s.l. Although the overall volume of passages is roughly only 17,000 m³ (1 % of the neighbouring host rock) the cumulative length and density of corridors are remarkable. The corridors developed along prominent fault directions and NW-SE striking corridors are the most abundant. Most are sub-horizontal with almost no inclination and some are inclined between 40 and 60° but only very few are subvertical. The second main strike direction is NE-SW, which is nearly perpendicular to the first one with more or less horizontal corridors.

Speleothems are abundant throughout the cave comprising flowstones, dripstones, helicitites, popcorn, calcite rafts, a shield, and moonmilk. Besides some vadose dripwater the cave is dry today. A conspicuous feature is the lack of a single water path and instead a maze with multiple flow paths formed. This maze extends in all three spatial directions with corridor sizes of all scales from non-passable up to 10 m in diameter (Fürstenhalle) and 16 m of height (Great Dome).

Another interesting feature is that one part of the cave developed below the level of the Rams brook but is still dry. There are small ponors reported from the Rams brook (which were observed during river regulation) indicating an actively draining karst system, which is not yet explored (Mrkos 1997).

Figure 2 shows the Hermannshöhle and three nearby caves. The eastern one (Rauchspalten) was proven to be related to the Hermannshöhle via an aerated connection by a smoke test. The other two (Mänderhöhle and Antonshöhle) have no known connection to Hermannshöhle but it is assumed that they are genetically related (Hartmann et al. 1997).

3. Methods

3.1. 3D-vizualisation of the cave using Spelix

For the 3D visualisation of the cave Spelix was used, a software which is part of the Austrian online cave data. A 3D-vrml-model was generated using the data of the survey traverse (length, inclination and azimuth) as well as the extensions about the height and the width at each survey station.

3.2. Morphological and sedimentological observations

A detailed geological and morphological field mapping of the cave and its surrounding was performed focussing on the contact between the karstic and non-karstic rocks. This knowledge is essential to understand the tectonic implications of the formation of the Kirchberg basin and the cave itself.

In addition to sediment analyses undertaken by Seemann (1997), who investigated the mineralogical composition including heavy minerals, a couple of representative samples were taken in order to study grain size and shape.

3.3. Dating of flowstone

To constrain the minimum age of the cave (levels) and of certain sedimentation events speleothems were sampled using drilling as well as using a hammer and a chisel and processed for U/Th-dating (e.g., Scholz 2008).

4. Results

4.1. Morphology

Even though most passages are canyon-shaped, the cave shows exclusively phreatic features, and no indication of vadose speleogenesis was found as well as of epiphreatic conditions like karren or solution pockets.

Paragenesis on all scales is clearly the dominant morphological factor in this cave: almost all profiles are paragenetic canyons and most of the overhanging parts show well-developed paragenetic ceiling channels. Paragenetic dissolution ramps are abundant as well as paragenetic bypass tubes. In most passages the floor is covered by thick layers of sediment and many passages are clogged by sediment.
Scallops are abundant especially in the lower parts of the cave and were used to detect the palaeo-flow directions. Surprisingly, the overall flow direction is not parallel to the Rams brook but rather directed to the West, which is towards the centre of the marble outcrop. Clear cross-cutting relationships between the scallops and the paragenesis could be observed that show that the paragenesis is younger (Fig. 3).

Figure 3. Cave wall with scallops (arrow indicates flow direction from SE to NW). The paragenetic ceiling half tubes do not show scallops and are clearly a younger feature. Note the 1 € coin at lower left for scale.

4.2. Clastic sediments

Sediment fills are abundant, mostly covering the floor of passages to an unknown depth. Partly cemented relics of former sediment fills including sandstones and conglomerates can be observed up to the ceiling of some passages. The sediment contains mainly allochthonous material, i.e. schists and gneisses from the area north of the Eulenberg as studied by Seemann (1997). The grain size ranges from rocks with up to 30 cm diameter to clay. Little autochthonous sediment is observed, consisting mainly of local rock debris. Only a few poorly rounded marble cobbles were observed.

4.3. Speleothem dating

So far nine speleothem samples were dated by the U/Th method. Except for one recent flowstone (ca. 1 ka), all samples are rather old, ranging from 100 to ca. 500 ka. Two of the samples are out of range and are probably older than 600 ka. Surprisingly, these old ages were found in the middle niveau of the cave which is 45 and 60 m, respectively, above the Kirchberg Basin, which forms the base level of the karst system and only 25 and 40 m above Rams brook, which potentially fed the system in former times.

5. Discussion and Conclusions

Hermannshöhle represents a nice example of contact karst where undersaturated surface water sourced from schists and gneisses infiltrate into marble karst. A high sediment load in former times resulted in various forms of paragenesis (cf. Farrant and Smith 2011). For a modern karst system the most likely emergence would be on the south-eastern side of the carbonates at the confluence of the Rams brook into the Kirchberg Basin. However, the palaeo-flow indicators in the cave point to the West and the overall palaeo-flow direction beyond the cave remains enigmatic. Therefore it is likely that the palaeo-surface drainage was quite different from the modern setting which has implication for the age of the cave formation.

Two main processes are considered regarding the formation of the 3D-maze pattern: (a) a rather short flow distance through the soluble rock, and (b) a high discharge along many alternative routes during flooding events as discussed by Palmer (2007: 197). Furthermore, paragenesis created bypass tubes which enhanced the maze characteristics. A hypogenic origin of the cave was also considered, but apart from very few cupolas (e.g., at the upper entrance) there is no supporting evidence.

Preliminary speleothem dating results suggest that the cave is at least ca. 600 ka old. As these old speleothems were found in the middle level of the cave system it can be assumed that the upper parts, that are located 60 m higher are even older. Further datings are needed to validate these first results and to shed more light on the history of the cave system in comparison to the surface drainage system.

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