GEOLÓGIA, GEOMORFOLÓGIA A PALEONTOLÓGIA

LITHIFIED PALAEOKARST DEPOSITS IN OKNO CAVE, DEMÄNOVSKÁ VALLEY, SLOVAKIA: RELICS OF AN ANCIENT KARST HISTORY

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Abstract: Lithified palaeokarst turbidite deposits in Okno Cave, Demänovská Valley occur in non-meteoric cavities and are intersected by the main relict fluvial passages of the cave. The deposits indicate the existence of an ancient period of cave development after the folding of the limestone but before the incision of the Demänovská Valley.

Key words: palaeokarst, Demänovská Valley, speleogenesis, turbidite, post-tectonic

INTRODUCTION

Exposures of lithified palaeokarst in caves, where the cave wall intersects a palaeokarst deposit, are quite uncommon in general (Ford, 1995; Osborne, 2000, 2002). They appear to be rare in Europe with a few cases reported from Hungary (Korpás, 1998; Korpás et al, 1999; Bolner-Takács, 1999) and Romania (Ghergari et al, 1997; Silvestru & Ghergari, 1994). The examples described here some of the very few, and probably the best, I have been able to discover during extended searches in central Europe 1997 and 2001.

Exposures of this type are characteristic features of the caves of the Palaeozoic limestones of eastern Australia. Just why these features are so common in eastern Australia and so uncommon in Europe is not entirely clear. In part it arises from the great age of the landscapes and the slow rate of geomorphic processes in Australia during the Cainozoic compared with those in Europe, but this is not a sufficient explanation.

Lithified palaeokarst deposits are important evidence for the existence of ancient periods of speleogenesis. They can provide important insights into palaeogeography and geological history.

SETTING

Geomorphological Setting. The Demänovská Valley was excavated through the E – W trending Nízke Tatry Mountains (Western Carpathians) by the Demänovka River flowing north towards the Liptovská Basin.

The entrance to Okno Cave is located at an elevation of 916 metres above sea level, high in the eastern side of Demänovská Valley, some 150 metres above the active bed of the Demänovka River (Figure 1).

Geological Setting. Okno Cave is developed in the Triassic Gutenstein limestone. Biely et al. (1992) indicated that in the vicinity of the cave the strata dip 30 degrees to the east. The limestone at the cave entrance is massive with beds 1 m, or more, thick (Figure 2). To the east of the cave entrance the limestone dips at 30º towards 060º magnetic.

Okno Cave. Okno (Window) Cave with a plan length of 930 m is principally composed of south to north flowing former stream passages, extending in an arc for some 600 metres south from its entrance (Figure 3). The cave is almost horizontal in long-section. In detail the northern and southern sections of the cave are structurally-guided rooms, while the centre section is meandering, although still probably structurally-guided, in plan.

A fluvial origin for the main passages is supported by the presence of scallops indicating a northerly flow, well developed in the walls of Sieň smútočnej vŕby (Location 4 in Figure 3, Figure 4A), and by large deposits of fluvial sediments, now strongly cemented, composed of coarse sand and rounded cobbles (Location 5 in Figure 3, Figure 4B).

In addition to the dominant fluvial elements, a number of elliptical cupolas are developed in the cave ceiling (Figure 5). These are oriented obliquely to the fluvial passages and appear to be guided by a different set of vertical joints (striking N – S and E – W) to those that guide the fluvial passages (striking generally NW – SE and NE – SW).

The palaeokarst deposits occur in a wall pocket (intersected cupola) and in a small SW – NE trending passage that appear morphologically to be more related to the cupolas than to the fluvial passages.

Fig. 1. View of Demänovská Valley looking south from high on western bank. The arrow indicates the location of the entrance to Okno Cave. Photo P. Bella

Fig. 2. Limestone cliff to the east of the cave entrance looking south, note thick bedding and development of phreatic tube with cross-section oriented to conjugate joints. Scale is 1m folding rule (464). Photo: A. Osborne

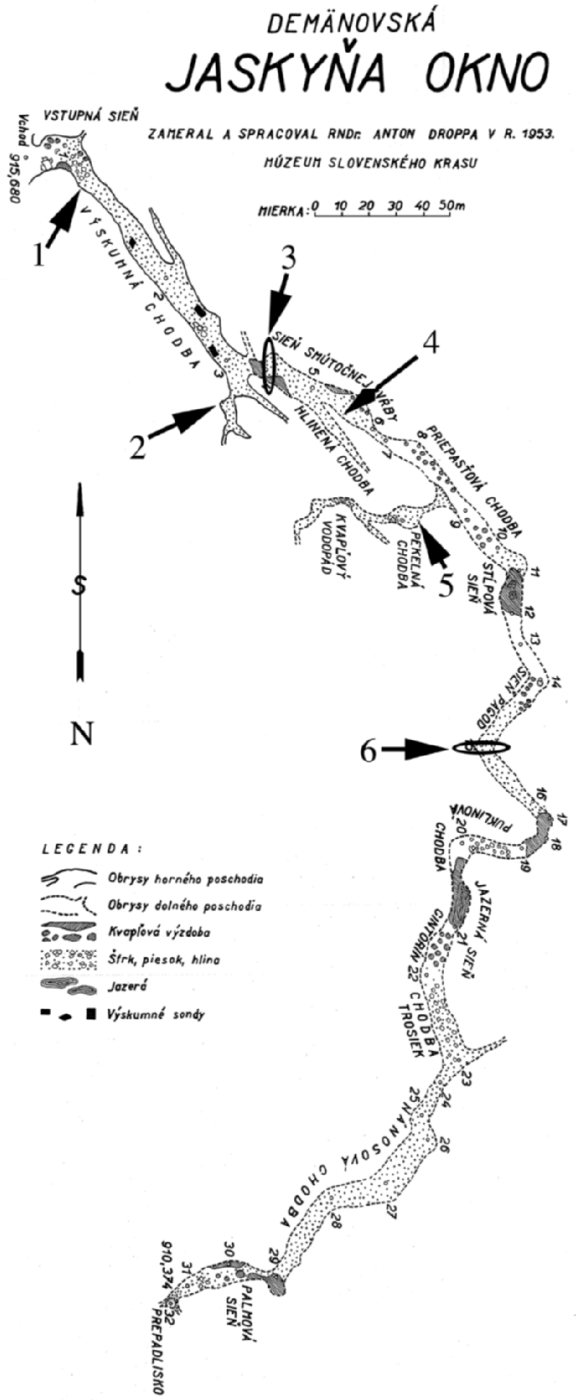
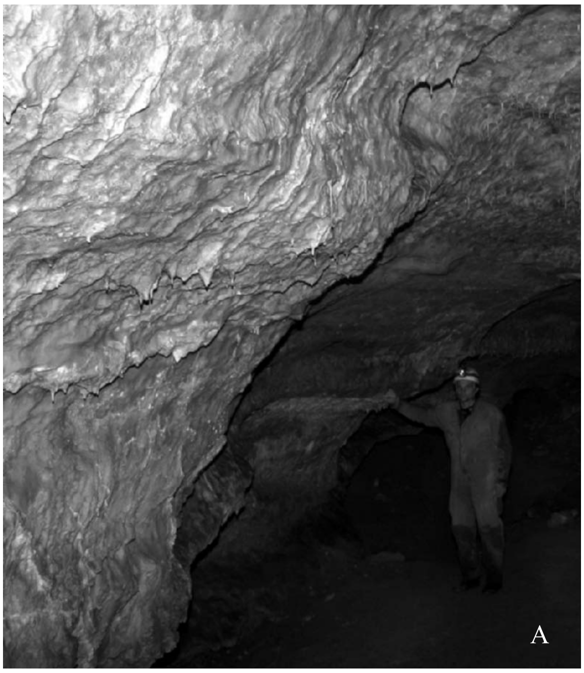


Fig. 3. Okno Cave, after Droppa (1953) showing location of features described in text

THE DEPOSITS

Deposit 1. This deposit is located in an alcove in the southwestern wall of Okno Cave, about 25 m from the cave entrance (Location 1 in Figure 3). It partly fills the remnant of a cupola-shaped cavity 2.5 m high (Figure 6 A). The upper third of the cavity is dome shaped. Below the dome there is a distinct notch in the southern wall where the cavity reaches its greatest width of 1.5 m. The notch is less-developed in the northern wall, where a less distinct notch forms the top of a well-developed facet. The top of the deposit just fills the notch (Figure 6B).



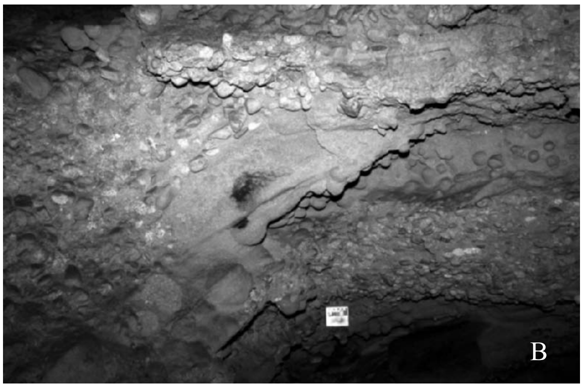


Fig. 4. Evidence for a fluvial origin for the main passages: A – Scallops in western wall of Sieň smútočnej vŕby at Location 4 (508).
B – Fluvial sediments in Pekelná chodba at Location 5. Note rounded cobbles in upper and lower conglomerate layers and concretionary sand balls in centre coarse sandstone layer Black squares on scale = 10 mm (488). Photo: A. Osborne

Fig. 5. Composite image of elliptical cupola located just south of gate at Location 3 in Figure 4. Axis of cupola is oriented approximately N – S, oblique to the passage. Long axis of cupola is approximately 10 m. Photo: A. Osborne

The deposit is 1.3 m thick at its broken (eroded) outer edge and consists of three units, an upper dark laminated unit (SK6), a middle brown pyritic unit (SK7) and a lower brown sandy unit (SK8). The upper surface of the deposit, which is partly covered by a thin veneer of flowstone, dips to the north-northeast (24°→ 024° Magnetic). The strata in the top unit also dip to the centre of the cavity, forming distinct dish-shaped bedding (Figure 6C). On the southern side of the deposit the layers of middle unit are folded, dipping to the south probably as a result of slumping (Figure 6C).

Deposit 2. This deposit in located in a side tube off a north-south trending branch from the southern end of Vyskunna Chodba (Location 2 in Figure 3). The tube containing the deposit has an unusual triangular profile, modified by two distinct notches, and is 1.6 m wide at its base (Figure 7A). The deposit is situated 100 mm below a flowstone false floor. The upper surface of the flowstone is 100 mm below the top (apex) of the tube (Figure 7 B).

The deposit dips to south and has a maximum thickness of 130 mm at its southern side. It is fine-grained and strongly indurated. The upper third of the deposit consists of a single bed with visible laminations, while the lower third consists of four thinner beds. A sample Sk10 has been collected for further analysis from the lowest bed on the northern side of the deposit, indicated by the arrow in Figure 7B.

PETROLOGY

Samples of the three lithotypes from Deposit 1 were examined in polished blocks and in thin-section under a polarising stereomicroscope and a petrographic microscope. Samples of fluvial sandstone from Location 5, a broken piece of flowstone from near Deposit 2 and bedrock from near the cave entrance have been collected for comparative study.

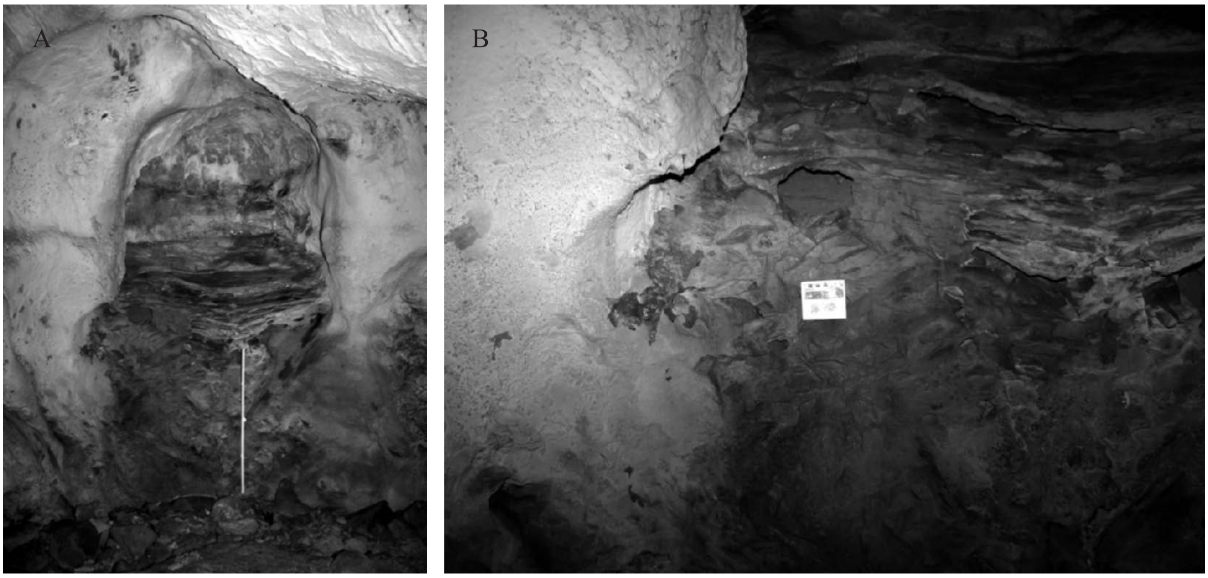


Fig. 6. Deposit 1: A – Wide-angle view of alcove, looking NW. Note dome-shaped upper profile, distinct notch and well-developed facet on RHS. Scale is 1 m folding rule (467). B – detail showing SW side of deposit. Pocket-knife for scale is 85 mm long (2001 Image). C – Detail of southern side of deposit. Note folding of bedding, possibly due to slumping above and to the right of scale bar and dish-shaped bedding in top centre of deposit. Black squares on scale = 10 mm (469)

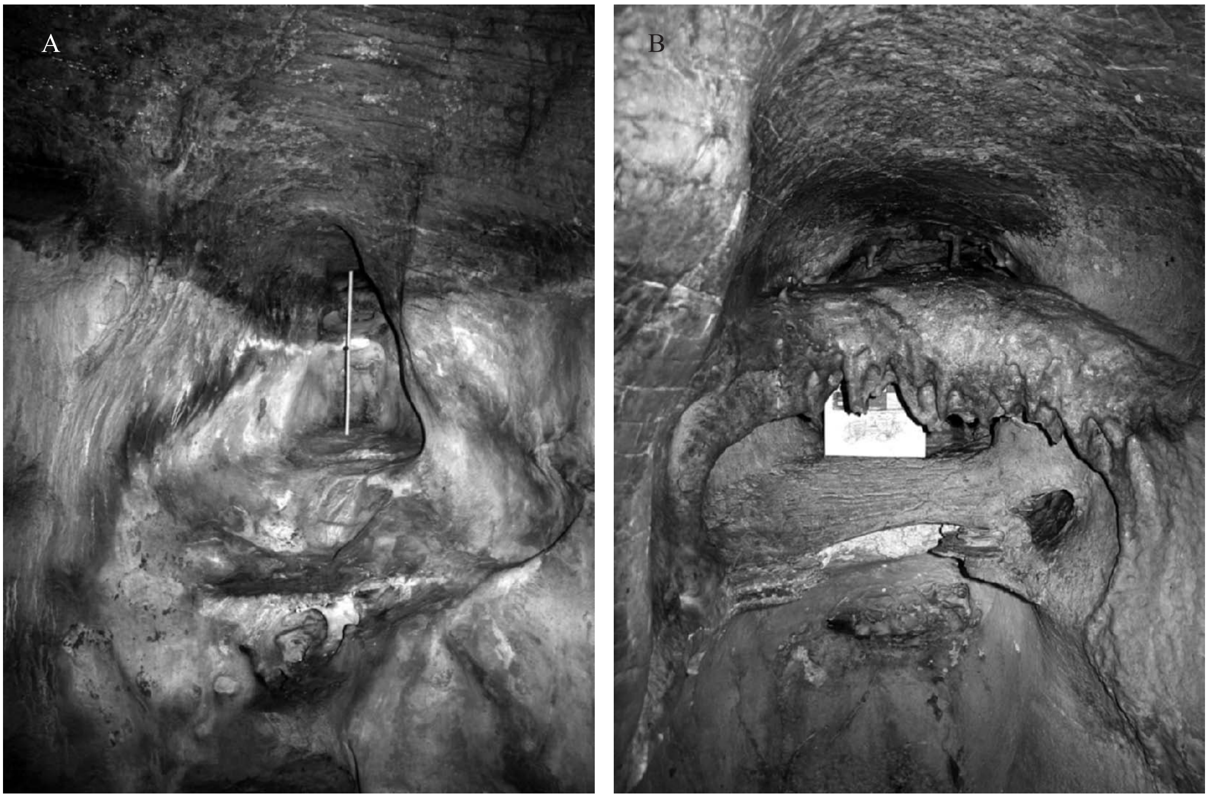


Fig. 7. Deposit 2: A – Wide-angle view looking W, note triangular profile. Arrow points to deposit, shown in detail in B. Scale is 1 m folding rule (473). B – Detail, deposit 2 is layer showing laminations below scale, arrow indicates source of sample Sk10. Colour blocks on scale bar are 20 mm (479)

Dark laminated unit. The dark laminated unit (SK6) is a very finely laminated grey-brown lime mudstone with some development of pyrolusite dendrites. Under low power, it is seen to consist almost entirely of calcite with poorly developed laminations. Some of the laminae are displaced by micro faults.

Apart from calcite, there are a few elongate brown, possibly organic grains present and under high power rare, very fine quartz grains are resolved. The quartz grains undergo undulate extinction and some have well-developed crystal faces.

Brown pyritic unit. The brown pyritic unit (SK7) is a finely graded carbonate siltstone/sandstone with cyclic laminae. Major laminae are approximately 5 mm thick and graded. Minor laminae are approximately 0.5 mm thick, finer grained and darker (tan coloured). Bedding is cross cut by solution voids, some open and some filled with spar.

The siltstone is almost completely composed of calcite. There are some elongate brown, possibly organic grains aligned parallel to bedding and rare, angular quartz grains that show little sign of transport.

Brown sandy unit. The brown sandy unit (SK8) is coarser grained than the other two units and consists of interbedded very coarse and finer sands. Some leisegang banding is developed.

It is composed of large angular to subangular clasts up to 1 mm in a fine brown carbonate matrix. The large clasts include:

- calcite crystal fragments,
- polycrystalline calcite aggregates,
- limestone lithoclasts,
- slate lithic fragments,
- silicic volcaniclastic fragments,
- quartz,
- rare apatite, probably bone.

The striking characteristics of this unit are its poor sorting and the variety and immaturity of the larger clasts.

ENVIRONMENT OF DEPOSITION

The lithified sediments in both Deposit 1 and Deposit 2 are fining upwards sequences. The three units from Deposit 1 have sedimentary features characteristic of cave turbidites (Osborne, 1983, 1984): distal laminates, graded-bedding units and proximal poorly-sorted sandy units. The coarser organised and disorganised conglomerate facies are not present.

These sediments were most likely deposited by turbidity currents resulting from slumping of material into a low-energy phreatic environment. The presence of coarse allochthnous grains indicates a surface source, with the sediment most likely entering the cave via an entrance facies cone that then slumped into the ponded water.

PROVENANCE OF THE SEDIMENT

The larger clasts in the brown sandy unit include both cave (crystal and composite calcite fragments) and surface derived (quartz and lithic grains) material. The quartz and lithic grains are likely to be derived from the crystalline complex located to the south of the limestone.

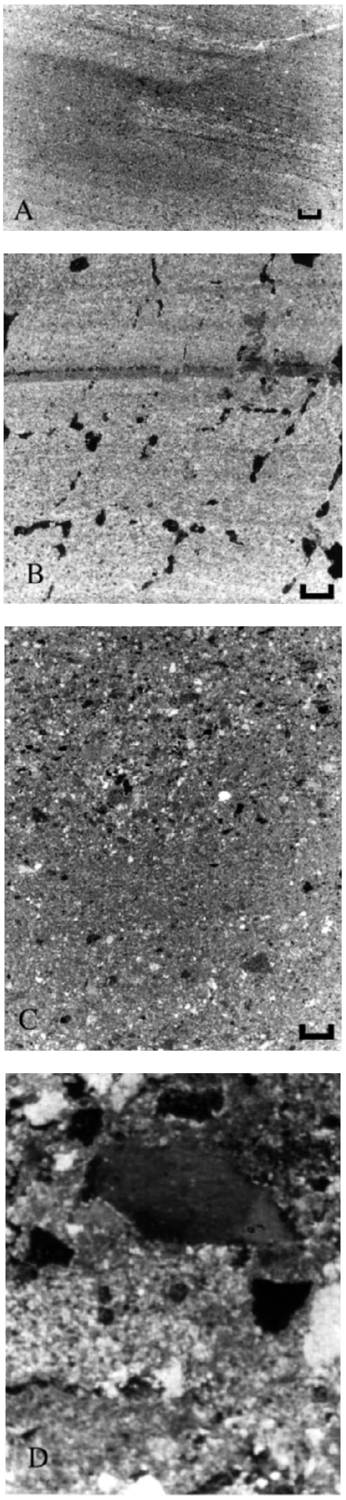


Fig. 8. Thin Sections: A – Sample SK6, Crossed Nicols, 6.4 x, scale 1 mm. Note grading and fault. B – Sample Sk7, Crossed Nicols, 6.4 x scale 1 mm. Note: Graded Laminae; voids, ?birds' eyes and dendrites on fine mud layer. C – Sample Sk8, Crossed Nicols, 6.4 x scale 1 mm. Note: Large angular clasts; Variety of clasts: calcite crystal fragments, calcite composite grains, quartz, lithic fragments apatite, ?bone fragments; poor sorting and grading. D – Sample Sk8, Crossed Nicols, 40 x Note: Large angular quartz, lithic clasts and matrix support

CONSTRAINTS ON THE AGE OF THE DEPOSITS

The deposit is constrained in time between a minimum age set by the excavation of Demänovská Valley and a maximum age set by the tectonic processes that resulted in the dip of the enclosing limestone beds.

UNUSUAL FEATURES OF THESE DEPOSITS

Apart from being examples of a phenomena that is apparently rare in Europe, these deposits have a number of characteristics that set them apart from other examples of palaeokarst deposits exposed in cave that have been described in the literature.

Firstly the palaeokarst deposits have not been intersected by per ascensum speleogenesis, which Ford (1995) indicated to be the usual situation when caves intersect palaeokarst. Rather a meteoric (per descensum) fluvial case has in this case intersected palaeokarst deposits that were apparently deposited in an older non-meteoric, per ascensum cave.

Secondly the manner by which the palaeokarst deposits were intersected here does not occur in any of the four situations or involve four of the five other processes described by Osborne (2002) where palaeokarst may be exhumes or reactivated.

The cave is not located close to a major unconformity at the margin of a sedimentary basin and is not located close to the axis of an anticline. It does not occur in a narrow impounded karst in steeply-dipping limestone were modern and ancient caves intersect because they are guided by the same structures, rather it occurs in an aerially extensive karst and the intersecting caves (relict and palaeokarst) are guided by quite different sets of structures. The palaeokarst deposits do not contain sufficient unstable minerals to self-exhume by vadose weathering.

Eusatic sea level changes are clearly not involved, there is no evidence for paragenesis, there is no high-density speleogenesis, i.e. Okno Cave is not a complex maze impacting on a large volume of the rock mass, and while there has been glaciation in the area, there no evidence that the cave was ever below one.

One of the processes proposed by Osborne (2002) is involved and Demänovská Valley was used as an example of this, that is there is more chance in an karst area with extensive cave development at multiple levels that a cave might intersect some palaeokarst, than in an area where there is less extensive development. While this makes Demänovská Valley as a whole a likely site for chance intersection, it does not help explain a particular case.

Thirdly. Osborne's sixth process described above now turns out not to apply in the case of Okno Cave because Okno fluvial cave and Okno palaeokarst cave can not really be considered to have intersected by chance. Rather, because each cave is guided by different sets of structural planes that intersect obliquely, intersection was inevitable.

Fourthly, this is not the case of a modern cave intersecting an ancient one, but of a relict cave of significant age relative to the active caves in the area, that in the past intersected an even older system of palaeokarst caves and some of their sedimentary fill.

Fifthly both the relict fluvial sediments in Okno Cave and the palaeokarst deposits that it intersects are very highly cemented and both should be considered to be lithified sedimentary rocks (mudstones, sandstones and conglomerates), rather than cave sediments in the usual sense of the term.

Taken together these five points make the Okno Cave palaeokarst deposits both interesting and highly significant.

OTHER EVIDENCE FOR ANCIENT SPELEOGENESIS IN SLOVAKIA

Novotný and Tulis (2002) described palaeokarst sandstone from Skalné okno Cave and the presence of gravel, sandstone and bauxite on the adjoining karst surface.

Orvošová et al (2004) described hydrothermal palaeokarst calcite from Silvošova diera Cave located at an elevation of 1446 m some 10.8 km southeast of Okno Cave. They proposed that this calcite was a product of hydrothermal karstificatiion in pre-Pliocene, most likely Palaeogene times.

Large cupolas in the ceilings of apparently unrelated fluvial passages, such as those in Demänovská Ice Cave and the cupolas described here from Okno Cave are also suggestive of a previous phase of speleogenesis.

IMPLICATIONS FOR KARST HISTORY

There are now several pieces of evidence indicating that a period, or periods, of karstification occurred in the Nízke Tatry Mountains before the excavation of the large meteoric caves and probably before the development of the present landscape.

Until move evidence is available and some correlation can be made between the crystals, palaeokarst deposits and morphologies, the present evidence could point to one or more speleogenetic events. The crystals, the association of the palaeokarst described here with cupolas and the large cupolas intersected by the present meteoric caves suggest that the ancient speleogenesis was non-meteoric and probably hydrothermal.

All the evidence indicates a period or periods of karstification after the limestone beds attained their present orientation and before there was significant excavation of the Demänovská Valley.

ACKNOWLEDGEMENTS

The first deposit was discovered, initial observations made and samples recovered in August 2001 while the author was on a field trip with Dr Pavel Bosák and Dr Jaroslav Kadlec of the Czech Geological Institute. The second deposit was discovered and speleological observations made during additional fieldwork in August 2005 with the assistance of Pavel Staník of the SSJ.

Dr Pavel Bella and Dr Ľudovít Gaál of the SSJ provided logistical support and assisted with local geological and geomorphological knowledge. Ing Peter Gažík assisted with the reproduction of cave maps.

The initial discovery, later fieldwork, writing and presenting the paper took place while the author was on Special Studies Programs from the University of Sydney.

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