DATING OF PROCESSES IN KARST AND CAVES: IMPLICATION FOR SHOW CAVES PRESENTATION

Pavel Bosák[1,2]

[1] Institute of Geology AS CR, v. v. i., Academy of Sciences of the Czech Republic, Rozvojová 269, 165 00 Praha 6 – Lysolaje, Czech Republic; bosak@gli.cas.cz
[2] Karst Research Institute, Scientific Research Center, Slovenian Academy of Sciences and Arts, Titov trg 2, 6230 Postojna, Slovenia

Abstract: Karst evolution depends particularly on the time available for process evolution and on the geographical and geological conditions of the exposure of the rock. The longer the time, the higher the hydraulic gradient and the larger the amount of solvent water entering the karst system, the more evolved is the karst. Unconformities influence the stratigraphy of the karst through the time-span that is available for subaerial processes. The end of karstification can also be viewed from various perspectives. The definite end occurs at the moment when the host rock, together with its karst phenomena, has completely been eroded/denuded. Karst forms of individual evolution stages (cycles) can also be destroyed by erosion, denudation and abrasion without the necessity of the destruction of the whole succession of karst rocks. Temporary and/or final interruption of the karstification process can be caused by the "fossilisation" of the existing karst phenomena due to loss of hydrological activity. The shorter the time available for karstification, the greater is the likelihood that karst phenomena are preserved in the stratigraphic record. The longer the duration of subaerial exposure, the more complex geomorphological agents are. Karst and cave fills are relatively special kinds of geologic materials. The karst environment favours both the preservation of paleontological remains and their destruction. On one hand, karst is well known for its richness of paleontological sites, on the other hand most cave fills are complete sterile, which is true especially for the interior cave facies. Another problematic feature of karst records is the reactivation of processes, which can degrade a record by mixing karst fills of different ages. Owing to the fact that unmetamorphosed or only slightly metamorphosed karst rocks containing karst and caves have occurred since Archean, we can apply a wide range of geochronologic methods. Most established dating methods can be utilised for direct and/or indirect dating of karst and paleokarst. The karst/paleokarst fills are very varied in composition, including a wide range of clastic and chemogenic sediments, products of surface and subsurface volcanism (lava, volcaniclastic materials, tephra), and deep-seated processes (hydrothermal activity, etc). Stages of evolution can also be based on dating correlated sediments that do not fill karst voids directly. The application of individual dating methods depends on their time ranges: the older the subject of study, the more limited is the choice of method.

Keywords: karst, speleogenesis, karst sediments, dating methods, geochronology, show caves

Show cave managers have to try to improve education of visitors (public) not only by stressing conservation and protection issues on karst in general (e.g., karst landscape, caves, speleothems), but also to attract people in scientific themes. One of the most attractive, for cave visitors, seems to be archaeological and paleontological finds in caves. Nevertheless, those issues are only a small part of very broad discipline of dating of processes in karst and caves. Lot of caves have been evolving for very long time, even from the geological point of view, i.e. millions of years; on the other hand others represent relicts of old evolutionary phases (relict karst *sensu* Bosák, Ford and Głazek 1989). Such cave can be nearly completely cut from active hydrogeological system and therefore represent real paleokarst (*sensu* Bosák, Ford and Głazek 1989). The selected examples are presented in Tab. 1. This kind of information could be interesting for public, as well.

The ancient caves recently accessible represent unique feature in karst due to the steady process of chemical denudation – lowering of the karst surface by dissolution, which acts,

Table 1. Examples of ancient caves, their origin and opening of connection to surface

Location		Estimated age		Origin	References
Cave	Region	of cave	open to surface		
Koněpruské Caves show cave	Czech Karst (CZ)	Oligocene – Lower Miocene	Lower Miocene	ascending waters, meteoric, phreatic and vadose	Bosák *et al.* 1989 Bosák 1996, 1998, 2000
Kůlna Cave show cave	Moravian Karst (CZ)	Oligocene	(1) Oligocene (2) post-Middle Miocene	water-table	Bosák *et al.* 1989
Amatérská Cave System	Moravian Karst (CZ)	Lower Miocene	(1) Middle Miocene (2) Pliocene (3) Quaternary	water-table multi-story	Panoš 1964 Bosák *et al.* 1989 Bosák *et al.* 1999
Javoříčské Caves show cave	Central-northern Moravia, Javoříčko Karst (CZ)	Oligocene – Lower Miocene	(1) Middle Miocene (2) Pliocene	water-table multi-story, ascending waters	Bosák *et al.* 1989 Pučálka *et al.* 2001
Králova Cave	Central Moravia, Tišnov Karst (CZ)	Upper Carboniferous – Lower Permian	Post-Badenian (?)	hypogene (mineralized), phreatic and vadose	Bosák 1983 Bosák *et al.* 1989
Javorka Cave	Czech Karst (CZ)	Permian to ?Middle Jurassic	Oligocene or Lower Miocene	hypogene, meteoric	Žák 2006
Únorová Chasm	Czech Karst (CZ)	Early to Middle Triassic	(1) Early to Middle Triassic (2) Cenozoic	meteoric	Žák *et al.* 2007
Špička Cave	Northern Moravia (CZ)	Lower Cretaceous (Hauterivian to Aptian)	(1) Lower Cretaceous (2) Quaternary?	mixing water	Bosák *et al.* 1989
Bližná Cave	Southern Moravia (CZ)	Upper Eocene to Lower Miocene	(1) Lower Miocene (2) Recent	meteoric, deep phreatic	Bosák 1991, 1997
Belianska Cave show cave	Belianske Tatry (SK)	Miocene	topmost Miocene to basal Pliocene	ascending waters, deep phreatic, probably hypogene low thermal sulphuric acid-enriched waters	Bella *et al.* 2010
Domica-Barada Cave System show caves	Slovak-Aggtelek Karst (SK-H)	pre-Pliocene	(1) pre-Pliocene (2) Pleistocene	water-table single level	Bosák *et al.* unpubl.

according to climatic conditions and lithology of host rocks, in range of several meters up to 760 m per 1 million years (Ma), in average some 20 to 50 m per 1 Ma (for detail see e. g., Ford and Williams 1989, 2007). More diagenetically mature and metamorphosed carbonate rocks are more resistant to chemical denudation in average. Lowering of surface by the chemical denudation leads to the origin of so called unroofed caves (*sensu* Mihevc 1996, for details see Mihevc 2001). Caves are expected to persist for 10 Ma in a single erosive cycle as expected by Sasowsky (2007) in respect of the formation depth and chemical denudation rate. Nevertheless, the complex sequence of transgressions, connected with sediment deposition, and regressions, connected with sediment weathering, erosion and denudation, can halt the action of chemical denudation for a long time. Owing to such complicated geological history of both folded and platform regions, even Palaeozoic caves can be accessible recently (e.g., Bosák 1983; Osborne 2010). General frames of dating of karst processes and related problems were summarized by Bosák (2002, 2007, 2008); this compilation is based on those three papers principally.

Determining the beginning and the end of the life of a karst and cave system is a substantial problem. In contrast to most of living systems, the development of a karst system can be „frozen“ and then rejuvenated several times, i. e. it can has polycyclic and polygenetic nature (*cf.* Bosák *et al.*, Eds. 1989) so that karst deposits represent a special kind of geological record (Bosák 2002). The principal problems may include precise definition of the beginning of karstification (e. g., legacy karst – Wright 1991; Wright and Smart 1994 or inception in speleogenesis – Lowe 1999) and the manner of preservation of the products of karstification. Karst evolution is particularly dependent upon the time available for process evolution and on the geographical and geological conditions of the exposure of the rock. The longer the time, the higher the hydraulic gradient and the larger the amount of solvent water entering the karst system, the more evolved is the karst (Bosák 2008).

Karstification of the host rocks *may start* during their formation phases – diagenesis – converting the soft sediment into consolidated material shortly after deposition itself. Such karstification is a consequence of the emergence of part of a depocenter (sedimentary basin) and the introduction of meteoric water into the diagenetic system. The formation of a fresh-water lens and a halocline zone related to the surface relief and sea-level changes is the result. The early stages of the origin of dissolutional (karst) porosity by meteoric diagenesis in carbonate rocks have been described in numerous sedimentological and paleokarst studies (a.o., Longman 1980; James and Choquette 1984; Tucker and Wright 1990; James and Choquette, Eds. 1988; Wright, Esteban and Smart, Eds. 1991; Wright and Smart 1994; Moore 1989, 2001; Mylroie and Carew 2000). Some authors suppose karst to be merely the facies of meteoric diagenesis (Esteban and Klappa 1983).

The *end* of karstification can be viewed also from various perspectives. The final end of karstification occurs at the moment when the host rock, together with its karst phenomena, is completely eroded/denuded, i.e. at the end of the karst cycle *sensu* Grund (1914; see also Cvijić 1918). In such a case, nothing is left to be studied. Karst forms of individual stages of evolution (cycles) can be destroyed also by other non-karst erosion processes or by the complete filling of epikarst and burial of karst surfaces by impermeable sediments, without the necessity of destroying the entire succession of karst rocks (the cycle of erosion of Davis 1899; see also Sawicki 1908, 1909). Temporary and/or final interruptions of karstification can be caused by fossilisation due to the loss of the hydrological function of the karst (Bosák 1989, p. 583) and it becomes paleokarst (Bosák 1981, 1989; Bosák, Ford and Głazek 1989; Ford and Williams 1989), independent of whether the karstification is halted definitely or only temporarily. Such fossilisation can be caused by metamorphism, mineralisation, marine transgressions, burial by continental deposits or volcanic products, tectonic movements, climatic change etc. (for a review, see Bosák 1989). The introduction of new energy (hydraulic head) to the system may cause reactivation of karstification reflected in the polycyclic and polygenetic nature of karst formation. The most common reasons for reactivation are regression, deglaciation and uplift (for a review, see Osborne 2002). Multiple reactivations are result in polycyclicity of karst formation, which is a characteristic feature (e.g., Panoš 1964; Ford and Williams 1989, 2007; Osborne 2002). The polygenetic nature of many karsts features that evolved during several different steps should be stressed, too (Ford andliams 1989); these may take the form of, for instance, an overprint of cold karst processes on earlier deep-seated/hydrothermal products, which themselves followed meteoric early diagenesis (e.g., Bosák 1997) or the succession of other processes (a.o., Osborne 2000, 2002; Osborne *et al.* 2006).

Karst sediments are a special kind of geologic materials. The development of karst and/or part of the karst system can be „frozen“ and rejuvenated for a multiplicity of times (Bosák 1989, 2002, 2003), and the dynamic nature of karst can lead to re-deposition and reworking of classical stratigraphic order. Those processes can make the karst record unreadable and problematic for interpretation (see Osborne 1984). Temporary (e.g., filling by cave sediments) and/or final interruption of karstification (fossilization *s.s.*) is due to the loss of the hydrological function of the karst (Bosák 1989, p. 583). The introduction of new energy (hydraulic head) to the system may cause reactivation of karstification reflected in the polycyclic and polygenetic nature of karst formation.

The karst environment favours both the preservation of palaeontological remains and their destruction. On one hand, karst is well known for its wealth of palaeontological sites (e. g., Horáček and Kordos 1989), but most cave fills are completely sterile on the other hand. The role of preservation is very important because karstlands function as traps or preservers of the geologic and environmental past, especially of terrestrial (continental) history where correlative sediments are mostly missing, but they carry also marine records (Horáček and Bosák 1989).

The methodology applied to obtain dating results depends on the nature of the geologic material filling the karst. The fills of exokarst landforms (especially some epikarst forms) offer more possibilities for the preservation of fossil fauna and flora than do cave interiors. The cave environment can be divided from the sedimentological point of view into an entrance facies and an interior facies (Kukla and Ložek 1958). The *entrance facies* includes fine-grained sediments transported from the vicinity of the cave by wind and water and coarser clasts transported into the cave by slope processes. The entrance facies represents the most valuable section of the cave from a stratigraphic point of view. The cave entrance contains pollen as well as datable archaeological and palaeontological remains that are protected from surface erosion, weathering and biochemical alteration (Ford and Williams 1989, 2007). The *interior facies* develops in those parts of the cave that are more remote from the surface. Sedimentary sequences here can be extensive, consisting of fluvial gravels and sands overlain by flood or injecta deposits of laminar silts and clays often intercalated by speleothems. They can also contain dejecta, colluvial material and outer clastic sediments (including marine ones) often redeposited and/or injected for longer distances within the cave (*cf.* Ford and Williams 1989, 2007). They form in vadose conditions. Due to the dynamic environment of cave interiors and periodicity of events, sedimentary sequences often represent a series of depositional and erosional events (sedimentary cycles). They are separated by unconformities (breaks in deposition), in which substantial time-spans can be hidden (Bosák *et al.* 2000b; Pruner and Bosák 2001; Bosák 2002, 2003; Bosák, Pruner and Kadlec 2003). The erosional phases can be much longer that depositional events. Troglobitic fauna and flora are usually much too small in number and volume to be significant (Ford and Williams 1989, 2007). Therefore, fossil remains within a cave, that come from the surface (carried in by sinking rivers) or from trogloxenes (e. g., cave-using bats, some birds and mammals), are more important. Airborne grains (pollen, volcanic ash) can only be important when favourable air-circulation patterns are developed within a cave. Nevertheless, cave sediments, especially far from the ponor or other entrance, tend to be highly depleted in fossil fauna (Bosák, Pruner and Zupan Hajna

1998) and/or the preservation of the fossils is too poor for precise determinations (Bosák *et al.* 2000a). Relics of phreatic silts and clays are relatively rare and they typically contain no fossils.

The stratigraphic order in sedimentary sequences is usually governed by the law of superposition, according to which the overlying bed is younger than the underlying one under normal tectonic settings. The law is valid for the majority of sedimentary sequences. However, river terraces and karst environment may present exceptions. The succession of processes connected with entrenchment of river systems cause higher levels of sediments to be older than lower ones. Karst, owing to its dynamic nature, polycyclic and polygenetic character carries some other thresholds – the karst records can be damaged by the simple process of erosion and re-deposition. The reactivation of karst processes often mixes karst fill of different ages (collapses, vertical re-depositions in both directions, etc., e.g., Horáček and Bosák 1989). Contamination of younger deposits by re-deposited fossil-bearing sediments has been known elsewhere in caves (Bosák, Pruner and Kadlec 2003). Well-known are also sandwich structures, described by Osborne (1984): younger beds are inserted into voids in older ones. Those processes degrade the record in karst archives (Horáček and Bosák 1989).

The final accumulation phase has been dated in caves in most cases, i.e. when the cave is in a quasi-stationary state because the input of energy (water) has been interrupted, detaching the cave from the local hydrological regime for different reasons and for highly differing time-spans; the cave becomes fossilised, at least temporarily. The temporary fossilisation of the cave (i.e. fill by cave sediments) and rejuvenation (excavation of sediments) mostly reflect changes in the resurgence area, especially vertical change (in both directions) of base level at the karst springs. The rejuvenation of the karst process can excavate the previous cave fill/fills completely, which is the most common case resulting from the polycyclic nature and dynamics of cave environments (e.g., Panoš 1964; Kadlec *et al.* 2001). Under favourable settings, fills belonging to more infill phases (cycles) separated by distinct hiatuses (unconformities) can occur in one sedimentary profile. Such amalgamation is typical especially in ponor (sinkhole) parts of the cave (e.g., Kadlec *et al.* 2001).

The proper and exact dating of karst processes, including filling of cave/karst voids, is most often the only means of reconstructing the evolution of individual karst features, extensive karst regions, speleogenetical or fossilization processes. The application of a number of dating methods in past decades enabled also the more exact dating of processes in the karst (Ford and Williams 1989, 2007; Bosák 2002). Owing to the fact that unmetamorphosed or only slightly metamorphosed karst rocks have existed since the Archean, we are facing the wide range of application of geochronologic methods. Most of the methods outlined below can be utilised for direct and/or indirect dating of karst and paleokarst processes. Karst/paleokarst fills are highly variable in origin and composition, including a wide range of clastic and chemogenic sediments, products of surface and subsurface volcanism (lava, volcaniclastic materials, tephra), and deep-seated processes (hydrothermal activity, etc). During burial, paleokarst forms can be cut or penetrated by products of younger deep-seated processes (volcanic or hydrothermal – ore – veins). Evolutionary karst stages can be based also on dating of correlative sediments, which do not fill karst voids directly, i.e. glacial deposits, river terraces, eolian and lacustrine sediments, marine deposits and fossils. Certain dating methods cannot be used for karst events at all, especially those requiring magmatic and/or metamorphic lithologies as suitable materials.

Colman and Pierce (2000) reviewed the range of geochronologic methods for the Quaternary period. Their conclusions can be adapted also for older chronologic units. The methods are grouped into six categories: (1) *sidereal* (calendar or annual) methods, which determine calendar dates or count annual events; (2) *isotopic* methods, which measure changes in isotopic composition due to radioactive decay and/or growth; (3) *radiogenic* methods, which measure cumulative effects of radioactive decay, such as crystal damage and electron energy traps; (4) *chemical and biological* methods, which measure the results of time-dependent chemical or biological processes; (5) *geomorphic* methods, which measure the cumulative results of complex, interrelated, physical, chemical, and biologic processes on the landscape; and (6) *correlation* methods, which establish age equivalence using time-independent properties. Results of dating can be classified into four groups as follows: *numerical-age*, *calibrated-age*, *relative-age*, and *correlated-age* (Colman and Pierce 2000, p. 3). They also proposed to abandon the term *absolute date* in favour of *numerical date*.

The application of individual dating methods depends on their time-spans. In general, we can state that the older is the subject of our study, the more limited are the methods of dating available. The nature of geologic materials to be dated represents another threshold. Not all geologic materials are suitable for numerical dating. On the other hand, most of materials are suitable to attempt correlated-age (see detailed review in Bosák 2002, 2007, 2008). (AV0Z30130516)

References

Bella P., Bosák P., Pruner P., Głazek J. (2010): Vývoj doliny Bielej vo východnej časti Belianskych Tatier: implikácie z morfológie a veku sedimentov v Belianskej jaskyni. – Zborník abstraktov z 15. kongresu Slovenskej geografickej spoločnosti a 6. vedeckej konferencie Asociácie slovenských gomorfológov pri SAV, Košice 8.–11. 9. 2010: 79–82. Košice.

Bosák P. (1981): Terminology and study of ancient karst phenomena. – Český kras, VI: 58-66. Beroun (in Czech).

Bosák P. (1983): Polycyclic development of karst phenomena in the Tišnov area (Western Moravia, Czechoslovakia). – Proceedings. European Regional Conference on Speleology, 2: 253–256. Sofia. Published in 1985.

Bosák P. (1989): Problems of the origin and fossilization of karst forms. – In: P. Bosák, D.C. Ford, J. Głazek & I. Horáček (Eds.): Paleokarst. A Systematic and Regional Review, Elsevier-Academia, Amsterdam-Praha: 577-598.

Bosák P. (1991): Phreatic cave system of the Bližná graphite deposit, South Bohemia, Czechoslovakia. – Studia carsologica, 5: 7–35. Brno.

Bosák P. (1993): Předběžné výsledky hodnocení zkrasovění v koněpruské oblasti. – Český kras (Beroun), XVIII: 14–20.

Bosák P. (1996): The evolution of karst and caves in the Koněprusy region (Bohemian Karst, Czech Republic) and paleohydrologic model. – Acta Carsologica, 25: 57-67. Ljubljana.

Bosák P. (1998): The evolution of karst and caves in the Koněprusy region (Bohemian Karst, Czech Republic), part II: hydrothermal paleokarst. – Acta carsologica, XXVII/2, 3: 41–61. Ljubljana.

Bosák P. (2000): The evolution of karst and caves in the Koněprusy region (Bohemian Karst, Czech Republic), part III: Collapse structures. – Acta carsologica, 29, 2, 2: 35–50. Ljubljana.

Bosák P. (1997): Paleokarst of the Bohemian Massif in the Czech Republic: an overview and synthesis. – International Journal of Speleology, 24, 1995, 1-2: 3-40, L´Aquila.

Bosák P. (2002): Karst processes from the beginning to the end: how can they be dated? – In: F. Gabrovšek (Ed.): Evolution of Karst: From Prekarst to Cessation, Carsologica, Založba ZRC, Postojna-Ljubljana: 191-223.

Bosák P. (2003): Karst processes from the beginning to the end: how can they be dated? – Speleogenesis and Evolution of Karst Aquifers, 1, 3: 24 pp.

Bosák P. (2007): Time and karst: some considerations. – Acta carsologica, 36, 1: 207–208. Postojna.

Bosák P. (2008): Karst processes and time. – Geologos, 14: 15–24. Poznań.

Bosák P., Ford D.C., Głazek J. (1989): Terminology. – In: P. Bosák, D.C. Ford, J. Głazek, I. Horáček (Eds.): Paleokarst. A Systematic and Regional Review, Elsevier-Academia, Amsterdam-Praha:

25-32.
Bosák P., Ford D.C., Głazek J., Horáček I. (Eds., 1989): Paleokarst. A Systematic and Regional Review. – Elsevier-Academia, Amsterdam-Praha, 728 pp.
Bosák P., Horáček I., Panoš V. (1989): Paleokarst of Czechoslovakia. – in P. Bosák, D.C. Ford, J. Głazek, I. Horáček (Eds.): Paleokarst. A Systematic and Regional Review: 107–135. Elsevier–Academia. Amsterdam–Praha.
Bosák P., Kadlec J., Otava J., Polák P., Vít J. (1999): Exkurzní průvodce, Moravský kras, Česká republika. Excursion Guide, Moravian Karst, Czech Republic. – Čes. speleol. spol: 1–55+1–55. Praha.
Bosák P., Knez M., Otrubová D., Pruner P., Slabe T., Venhodová D. (2000a): Palaeomagnetic Research of Fossil Cave in the Highway Construction at Kozina, SW Slovenia. – Acta Carsologica, 29, 2, 1: 15-33, Ljubljana.
Bosák P., Pruner P., Mihevc A., Zupan Hajna N. (2000b): Magnetostratigraphy and unconformities in cave sediments: case study from the Classical Karst, SW Slovenia. – Geologos, 5: 13–30. Poznań.
Bosák P., Pruner P., Kadlec J. (2003): Magnetostratigraphy of cave sediments: application and limits. – Studia Geophysica et Geodaetica, 47, 2: 301–330. Praha.
Bosák P., Pruner P., Zupan Hajna N. (1998): Paleomagnetic research of cave sediments in SW Slovenia. – Acta Carsologica, XXVII/2, 3: 151-179, Ljubljana.
Colman, S.M., Pierce, K.L. (2000): Classification of Quaternary geochronologic methods. – In: J.S. Noller, J.M. Sowers, W.R. Lettis (Eds.): Quaternary Geochronology. Methods and Applications, American Geophysical Union: 2-5, Washington.
Cvijić J. (1918): Hydrographie souterraine et évolution morphologique du Karst. – Rec. Trav. Inst. Géogr. Alpine, 6, 4: 376-420.
Davis W.M. (1899): The geographical cycle. – Geogr. J., 14: 481-504.
Esteban M., Klappa C.I. (1983): Subaerial exposure environments. – In: P.A. Scholle, D.G. Bebout, C.H. Moore (Eds.): Carbonate depositional environments, Amer. Assoc. Petroleum Geol., Tulsa: 1-54.
Ford D.C., Williams P.W. (1989): Karst Geomorphology and Hydrology. – Unwin Hyman, London, 601 pp.
Ford D.C., Williams P.W. (2007): Karst Hydrology and Geomorphology. – Wiley, 562 pp., Chichester.
Grund A. (1914): Der geographische Zyklus im Karst. – Ges. Erdkunde, 52: 621-640.
Horáček I., Bosák P., 1989: Special characteristics of paleokarst studies. – In: P. Bosák, D.C. Ford, J. Głazek, I. Horáček (Eds.): Paleokarst. A Systematic and Regional Review, Elsevier-Academia, Amsterdam-Praha: 565-568.
Horáček I., Kordos L. (1989): Biostratigraphic investigations in paleokarst. – In: P. Bosák, D.C. Ford, J. Głazek, I. Horáček (Eds.): Paleokarst. A Systematic and Regional Review, Elsevier-Academia, Amsterdam-Praha: 599-612.
James N.V., Choquette P.W. (1984): Diagenesis 9. Limestones – the meteoric diagenetic environment. – Geoscience Canada, 11: 161-194.
James N.V., Choquette P.W. (Eds., 1988): Paleokarst. – Springer, New York: 416 pp.
Kadlec J., Hercman H., Beneš V., Šroubek P., Diehl J.F., Granger D. (2001): Cenozoic history of the Moravian Karst (northern segment): cave sediments and karst morphology. – Acta Musei Moraviae, Sci. geol., LXXXV: 111-161. Brno.
Kukla J., Ložek V. (1958): K problematice výzkumu jeskynních výplní. – Československý kras, 11: 19–83. Praha.
Longman M.W. (1980): Carbonate diagenetic textures from near-surface diagenetic environments. – Amererican Association of Petroleum Geologists Bulletin, 63, 4: 461-487, Tulsa.
Lowe, D.J., 1999: Why and how are caves „organized": does the past offer a key to present. – Acta Carsologica, 28/2, 7: 121-144, Ljubljana.
Mihevc A., 1996: Unroofed cave at Povir. – Naše jame, 38: 92-101. Ljubljana. (in Slovenian)

Mihevc A., 2001b Speleogeneza Divaškega krasa. – Zbirka ZRC, 27: 180 pp. Ljubljana.
Moore C.H. (1989): Carbonate Diagenesis and Porosity. – Developments in Sedimentology, 46, Elsevier, New York: 338 pp.
Moore C.H. (2001): Carbonate Reservoirs. Porosity Evolution and Diagenesis in a Sequence Stratigraphic Framework. – Developments in Sedimentology, 55, Elsevier, Amsterdam: 444 pp.
Mylroie J.E., Carew J.L. (2000): Speleogenesis in Coastal and Oceanic Settings. – In: A.A. Klimchouk, D.C. Ford, A.N. Palmer, W. Dreybrodt (Eds.): Speleogenesis. Evolution of karst aquifers, Nat. Speleol. Soc., Huntsville: 226-233.
Osborne R.A.L. (1984): Lateral facies changes, unconformities and stratigraphic reversals: their significance for cave sediments stratigraphy. – Cave Science, 11, 3: 175-184.
Osborne R.A.L. (2000): Paleokarst and its Signinficance for Speleogenesis. – In: A.A. Klimchouk, D.C. Ford, A.N. Palmer & W. Dreybrodt (Eds.): Speleogenesis. Evolution of karst aquifers, Nat. Speleol. Soc., Huntsville: 113-123.
Osborne R.A.L. (2002): Paleokarst: Cessation and Rebirth? – In: F. Gabrovšek (Ed.): Evolution of Karst: From Prekarst to Cessation, Carsologica, Založba ZRC, Postojna-Ljubljana: 97-114.
Osborne R.A.L. (2010): Rethinking eastern Australian caves. – Geological Society, London, Special Publication, 346: 289-308.
Osborne R.A.L., Zwingmann H., Pogson R.E., Colchester D.M. (2006): Carboniferous clay deposits from Jenolan Caves, New South Wales: implication for timing of speleogenesis and regional geology. – Australian Journal of Earth Sciences, 53: 377-405.
Panoš V. (1964): Der Urkarst in Ostflügel der Böhmishen Masse. – Zeitschrift für Geomorphologie, N.F., 8, 2: 105-162.
Pruner P., Bosák P. (2001): Palaeomagnetic and magnetostratigraphic research of cave sediments: theoretical approach, and examples from Slovenia and Slovakia. – Proceedings, 13th International Speleological Congress, 4th Speleological Congress of Latin America and the Carribean, 26th Brazilian Congress of Speleology, Brasilia, July 15–22, 2001, Vol. 1: 94–97 + CD ROM.
Pučálka R., Panoš V., Buček A., Čížek O., Holzer M., Vašátko J. (2001): Krajinné charakteristtiky javoříčského a mladečského krasu. – In: Jirka Z. (Red.): Speleoterapie. Principy a zkušenosti: 156-254. Univ. Palackého. Olomouc.
Sasowsky I.D. (2007): Clastic Sediments in Caves – Imperfekt Recorders of Processes in Karst. – Acta Carsologica, 37, 1: 143-149. Ljubljana.
Sawicki L. (1908): Skizze des slowakischen Karstes und der geographischen Zyklus im Karst überhaupt. Kosmos, 6-7, 395-444, Lwów. (in Polish)
Sawicki L. (1909): Ein Beitrag zum geographischen Zyklus im Karst. – Geogr. Zeitschrift, 15: 185–204. Wien.
Tucker M.E., Wright V.P. (1990): Carbonate Sedimentology. – Blackwell, Oxford: 482 pp.
Wright V.P. (1991): Palaeokarst types, recognition, controls and assocations. – In: V.P. Wright, M. Esteban, P.L. Smart (Eds.): Palaeokarsts and Palaeokarstic Reservoirs, P.R.I.S. Occas. Publ. Ser., 2, Reading: 56-88.
Wright V.P., Esteban M., Smart P.L. (Eds., 1991): Palaeokarsts and Palaeokarstic Reservoirs. P.R.I.S. Occas. Publ. Ser., 2, Reading: 158 pp.
Wright V.P., Smart P.L. (1994): Paleokarst (Dissolution Diageneis): Its Occurrence and Hydrocarbon Exploration Significance. – In: K.H. Wolf, G.V. Chilingarian (Eds.): Diagenesis, IV, Developments in Sedimentology, 51, Elsevier, Amsterdam: 489-502.
Žák K. (2006): Geologický a karsologický popis jeskyně Na Javorce. – Speleofórum, 25 (2006): 19-20. Česká speleologická společnost. Praha.
Žák K., Pruner P., Bosák P., Svobodová M., Šlechta S. (2007): New type of paleokarst sediments in the Bohemian Karst (Czech Republic), and their regional tectonic and geomorphological relationships. – Bulletin of Geosciences, 82, 3: 275–290. Praha.