

## RULES OF CLIMATE, SOIL AND VEGETATION ON DEVELOPMENT OF THE KARSTSYSTEM

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In the evaluation of environmentally sensitive karst regions for nature conservation value the most useful information is supplied by the changes in the ecological conditions of the climate-soil-vegetation system. The changes in the system determine matter and energy cycles. A change in any of the three factors involves changes in the other two and eventually in the future functioning of the whole karst system. Climate influences the physical, chemical and biological processes of the karst system.

Air temperature, humidity, precipitation and evaporation influence the water and matter cycles. Temperature regulates life processes of the biota. Matter transport is a function of soil, vegetation, relief and climatic parameters. The karst regions of various nature are characterised by different processes. In landscape planning and management this mechanism of interactions has to be taken into consideration in every case in the future.

## TIME AND KARST PROCESSES: SOME CONSIDERATIONS

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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 time scale for the development of karst features cannot be longer than that of the rocks on which they form. 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 (Tab. 1). In general, stratigraphic discontinuities, i.e. intervals of nondeposition (disconformities and unconformities), directly influence the intensity and extent of karstification. The higher the order of discontinuity under study, the greater will be the problems of dating processes and events. The order of unconformities influences the stratigraphy of the karst through the amount of time available for subaerial processes to operate. Results of paleokarst evolution are best preserved directly beneath a cover of marine or continental sediments, i.e. under sediments, which terminated karstification periods or phases. The longer the stratigraphic gap the more problematic is precise dating of the age of the paleokarst, if it cannot be chronostratigraphically proven. Therefore, ages of paleokarsts has been associated chiefly with periods just or shortly before the termination of the stratigraphic gap. The characteristic time scale for the development of a karst surface landform or a conduit is 10 to 100 ka.

Determining the beginning and the end of the life of a karst system is a substantial problem. In contrast to most of living systems development of a karst system can be „frozen“ and then rejuvenated several times (polycyclic and polygenetic nature). The principal problems may include precise definition of the beginning of karstification (e.g. inception in speleogenesis) and the manner of preservation of the products of karstification. Therefore, karst and cave fills are relatively special kinds of geologic materials.

The end of karstification can also be viewed from various perspectives. The final end occurs at the moment when the host rock together with its karst phenomena is completely eroded/denuded (tze end of the karst cycle) or sunken into the subduction zone. In such cases, nothing remains to be dated. Karst forms of individual evolution stages (cycles) can also be destroyed by erosion, denudation and abrasion, complete filling of epikarst and covering of karst surface by impermeable sediments, without the necessity of the destruction of the whole sequence of karst rocks. Temporary and/or final interruption of the karstification process can be caused by the fossilisation of karst due to loss of its hydrological function. Such fossilisation can be caused by metamorphism, mineralisation, marine transgressions, burial by continental deposits or volcanic products, tectonic movements, climatic change

Tab. 1: Evolution of selected karst features in time on the background of transgression-regression set within one hypothetical karst period related to unconformity order

Feature/Order*	1	2	3	4	5
Unconformity*	Megaunconformity	Superunconformity	Regional unconformity	Parasequence boundary	"Bedding plane"
Caribbean model*	Interregional karst		Local karst		Depositional karst
General model**	Karst period		Karst phase Type 1		Karst phase Type 2
Geological setting	Craton/Platform – centre	Craton/Platform + margins	Depositional basin		
Time (Ma)	X00-X0	X0-X	X-0.X	0.X-0.0X	0.0X-0.00X
Freshwater lens					
Protosol					
Caliche					
Soil					
Weathering profile					
Karren					
Sinkhole					
Cave					
Cave system					
Hypogenic karst					
Hydrothermal k.					
Early karst*					
Mature karst*					
Buried karst**					
Rejuvenated k.**					
Relict karst**					
Unroofed cave‡					

+ sensu Esteban (1991); \* sensu Choquette & James (1988); \*\* sensu Bosák *et al.*, (1989); § sensu Mihevc (1996); Weathering profile = more evolved weathering cover (like laterite, bauxite, kaoline, etc.); Hypogenic karst = deep-seated karst, interstratal karst, intrastatal karst, subjacent karst, subrosion. a

etc. Nevertheless, in contrast to living organisms, the development of the karst system can be „frozen“ and rejuvenated even for a multiplicity of times (polycyclic and polygenetic nature of karst). Further, the dynamic nature of karst can cause redeposition and reworking of classical stratigraphic order, making the karst record unreadable and problematic for interpretation.

Known karst records for the 1<sup>st</sup> and 2<sup>nd</sup> orders of stratigraphic discontinuity cover only from 5 to 60 % of geological time (time not recorded in any correlated sediments in old platforms usually represents 40 to 90 % of time). The shorter the time available for karstification,

the greater is the likelihood that karst phenomena will be preserved in the stratigraphic record. While products of short-lived karstification on shallow carbonate platforms can be preserved by deposition during the immediately succeeding sea-level rise, products of more pronounced karstification can be destroyed by a number of different geomorphic processes. The longer the duration of sub-aerial exposure, the more complex are those geomorphic agents.

The dating of cave initiation and evolution, i.e. the origin of the void within the bedrock is more problematic. The age of the erosional cave falls between the age

of the host rock and that of the oldest dated fill. With the inception theory, the true start of speleogenesis can hardly be estimated. Many caves contain only very young fills, older ones having been excavated during repeating cave exhumations/rejuvenations caused by changes in

hydraulic conditions, spring position, climate, etc. The minimum age for the cave initiation phase is estimated to be a minimum of 10 ka and cave enlargement up to accessible diameters usually takes about 10-100 ka under favourable conditions.

## URANIUM-THORIUM AGES OF STALAGMITES FROM KATERLOCH CAVE (STYRIA, AUSTRIA)

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Speleothems recently experienced growing importance in the light of paleoenvironmental research. Absolute age determination using Uranium-series methods allow for precise age constraints of environmental information preserved in speleothems, particularly in stalagmites and flowstones.

Katerloch Cave, situated within the Styrian Karst Province near Graz was chosen as an object of extensive paleoenvironmental studies. Abundantly decorated cave chambers show a clear dominance of stalagmites over stalactites, many of them being several meters in length. The majority of stalagmites are of the candle-stick type, a morphology suggesting fast growth.

Five inactive stalagmites were recovered and dated using the U-Th method. In addition, drill cores were obtained from the base of in-situ growing stalagmites. The dating of calcite sub-samples of these cores give an age of growth inception of the respective stalagmites. Age measurements were carried out using Multi Collector-ICP-Mass Spectrometry at the Institute of Geology at

Bern, Switzerland. Our dating campaign allowed detecting several speleothem generations: stalagmites from the current Interglacial, the Marine Isotope Stage 3 and the Last Interglacial (MIS 5.5), indicating major speleothem growth during relatively warm (and wet?) climate conditions. The ages of two stalagmites are beyond the range of the U-Th method, i.e. they are older than ~ 450 kyr.

Two Holocene stalagmites, 73 and 139 cm in length, yielded ages between  $10.32 \pm 0.13$  and  $7.02 \pm 0.14$  kyr and between  $9.80 \pm 0.24$  and  $7.88 \pm 0.09$  kyr, respectively. Age models derived from dating of multiple sub-samples along the stalagmite growth-axis suggest growth rates of 0.2 to 0.7 mm/yr. These rates are very high compared to caves in the alpine region. Two stalagmites from the preceding Interglacial (MIS 5.5) suggest similar growth rates than those of the Holocene stalagmites. Furthermore, fast growth of speleothems in Katerloch Cave is corroborated by stalagmite petrography, displaying a lamination of alternating white-porous and compact-translucent layers.

## COPEPOD CRUSTACEAN DIVERSITY IN SOUTH FLORIDA KARST, U.S.A.

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Southern Florida is mostly occupied by the Everglades, an extensive subtropical wetland ecosystem that formed during the past 5,000 years when peat and marl were deposited within a pre-existing limestone depression in the southern peninsula. The high porosity of the limestone of the aquifer allows for considerable flux between surface water and ground water. Hydrologically, karst systems in

South Florida are very open, and numerous epigeal invertebrates often penetrate the aquifer by means of sinkholes, some of them establishing permanent populations in the aquifer.

The inventory of free-living freshwater copepods recorded from peninsular Florida includes a total of 65 taxa: 9 calanoids, 41 cyclopoids, and 15 harpacticoids.

Two-thirds (44) of these are known from Everglades National Park and adjacent areas, partly as a result of more intensive sampling in this area; 10 have so far been found only in the Everglades. Of the species collected in central and northern Florida, 2 calanoids and 1 cyclopoid have been found only in the state, whereas all the others are widespread in North America and beyond. South of the Everglades, in the Florida Keys, recent collections from small permanent or ephemeral surface waterbodies, some of them brackish, yielded 2 species of calanoids, 27 cyclopoids, and 11 harpacticoids, adding 1 calanoid, 2 cyclopoids and 9 harpacticoids to the list for Florida. Ten species of cyclopoids and 1 harpacticoid collected in the Florida Keys were already known from the Everglades.

In peninsular Florida, the Nearctic fauna is predominant, but a small Neotropical component is present (1 calanoid, 6 cyclopoids, and 5 harpacticoids); 1 cyclopoid species is considered to be introduced. In the Florida Keys, the assemblage consisted mainly of cosmopolitan or Neotropical continental cyclopoids (1 introduced), and Neotropical, coastal harpacticoids, with only 2, Neotropical continental calanoids.

Because the Florida peninsula is relatively young geologically, we did not expect that a diverse endemic groundwater fauna would be present. However, several taxa that are usually known elsewhere from surface water, were collected in subterranean water in the Florida Everglades during the dry season, likely an adaptation to survive the drought. This happened for the 2 species of calanoids, 16 of the 27 cyclopoids, and 4 of the 13 harpacticoids; among them, stygophile taxa were represented by 6 cyclopoids and 3 harpacticoids. The species occurring in groundwater in the Everglades are either widely distributed elsewhere in North America or in the neotropics, members of speciose genera with both epigeal and hy-

pogean species, or members of predominantly marine groups with some brackish- or freshwater representatives. The low diversity of harpacticoids in groundwater habitats in the Everglades is surprising, because harpacticoids include the largest number of stygobitic forms within the copepods. The closest area in which true stygobitic copepods have been found is northern Florida, which has an older geological history. The relatively young age of the Everglades may not have allowed some taxa enough time to disperse here, or may not have allowed sufficient time for groundwater colonizers to evolve adaptations to life in subterranean habitats.

Besides the young geological age, historical and environmental conditions may also account for the Everglades' relatively depauperate groundwater copepod fauna. Both the higher-elevation marshes and the deeper central sloughs undergo periodic droughts of varying severity, which affect the composition of the copepod fauna. The hydrological regime is irregular because of variations in rainfall and water-management activities, and groundwater communities are dominated by surface copepods that colonize groundwater mainly during the dry season. The abundance and species richness decrease with depth, and sharply below the 3-m depth, due to high permeability of the limestone above 3 m and to the presence of a semipermeable layer at lower depths. Groundwater copepod communities are more similar on a local scale: when local surface-water populations enter the shallow aquifer by following the receding water table, they do not generally disperse widely through the groundwater system. The dissimilarity in communities over larger distances may reflect differences in surface habitats, as well as limitations on dispersal by different local porosities of the limestone.

## BLACK SEA LEVEL FLUCTUATIONS BASED ON THE STUDY OF SUBMERGED SPELEOTHEMES FROM DOBROGEA (ROMANIA)

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Several speleothem samples from Piatra Cave (Dobrogea, South-East Romania) were dated by means of alpha and mass spectrometry, in order to obtain absolute datings of the episodes during which speleotheme formation occurred here. Piatra Cave is a submerged cave located a few kilometers far from the Black Sea shore at an absolute altitude of 1-2 m, thus being suitable for recording the sea

level oscillations that took place in the past. Nine dates were performed by alpha spectrometry and one by mass spectrometry. In spite of a low Uranium content (0.04 – 0.1 ppm), all subsamples showed good chemical extraction yields, thus providing analytical reliable dates. One of the stalagmites appears to have been grown very fast during the Eemian (OI 5e), between  $112 \pm 10$  ka and 122

$\pm 13.5$  ka ( $1\sigma$ ). Another sample, dated by TIMS method yielded a date of  $597 \pm 108/-53$  ka. Although these dates are not sufficient for a detailed analysis of the Black Sea oscillations, they reveal two periods of time during which environmental conditions here were favourable for speleothem deposition as the cave was emerged. Most interesting are the samples dated from the warm OI substage 5e during which, the Black Sea level is supposed to have been 10 m higher than the present one. The area, during

the Quaternary, being virtually stable from the tectonic point of view (except for a narrow coastal area), leads us to three possible situations that allowed speleothem formation: either there was a slight subsidence in the area (around 15 m), or the sea-level was more than 15 meters lower than previously believed. The third possibility could be that during the main transgression that rose the level 10 meters above the present one, there has been a short period of low-stand.

## HIGH-RESOLUTION SPELEOTHEM RECORDS FROM SOQOTRA ISLAND (YEMEN), AS RECORDERS OF INDIAN OCEAN MONSOON VARIABILITY

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The arid tropical island Soqotra is situated in the Indian Ocean between the Horn of Africa and the Arabian Peninsula. Here a bi-annual rainy season is active, due to the passing of the inter-tropical convergence zone (ITCZ) twice each year, known as the Indian Ocean Monsoon system. Only recently more than 35 km of underground cave passages in around 50 caves were discovered and explored, revealing an important karst potential for paleoclimate and paleoenvironmental research.

By evaluating the first available meteorological data (rainfall and temperature) from the last 5 years, we calculated that approximately 85% of the rainfall is related to the NE Monsoon period, while only 15% is related to the SW Monsoon period with an important irregular geographical distribution over the island. Differences in the oxygen isotope composition of meteoric water versus groundwater are used to estimate amount and timing of karst aquifer recharge, because seasonal fluctuations of rainwater oxygen isotopic composition are related to the amount of rainfall. Karst aquifer recharge at the NE lime-

stone plateau takes only place during the NE Monsoon rainy period when a rainfall threshold of 80-90mm is exceeded, explaining the more negative cave drip waters and groundwater in general. Because the controls on the isotopic composition of nowadays forming speleothem calcite could be monitored in this region, two caves in this area were chosen as research location.

A sampled speleothem from Hoq Cave (S STM1) and one from Casecas Cave (S-STM5) have formed over the last 6 ka BP and the last 1 ka BP (U/Th dating) respectively. Carbon and oxygen isotopic measurements were performed at a resolution up to 50 m, corresponding to a time resolution of up to one month. The two sampling locations, distant of 6km, display similar isotopic changes in both speleothems over the last 1 ka. The speleothems also clearly registered seasonal variations, coinciding with the alternation of dark compact and white porous layers, representing annual banding in both stalagmites. These observations suggest that the speleothems reliably registered Monsoon climate variability.

## EVOLUTIONARY CHANGE IN CAVE ADAPTED ORGANISMS

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Change of selective constraint on a gene may be expected following changes in the environment or life history. This is especially true for switches to the cave environment. The purpose of this work is to explore selective pressures and functional change on a variety of protein

coding genes across cave- and non cave related taxa to assess general patterns of evolutionary changes in different lineages, and whether (and to what extend) they depend on environmental conditions. Protein coding sequences that appear to be undergoing adaptive evolution

or changes of function along specific branches of the tree will be analyzed in detail as to determine the specificity and functionality of those changes. Results of this work will be incorporated into the publicly accessible TAED

database (<http://www.sbc.su.se/~liberles/TAED2002/>) and will help pinpoint target genes for future studies on cave organisms and their environment (e.g., karst).

## TEMPO OF CHANGES IN KARST BIOLOGICAL VERSUS PHYSICAL PROCESSES

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Time is an essential parameter for understanding any ecosystem. Landscape, habitats, community composition, genetic pools and species distribution change with time, in a more or less connected way. Yet, integrative approaches linking physical and biological karst processes in a time perspective are scarce in the literature. One of the intriguing property of subterranean karst systems is

that time required for biological or physical processes may differ considerably from that required for similar processes in surface karst or non-karst systems. Essential aspects of this peculiar tempo of changes in karst are presented here. Their interest for understanding paleogeography and organism evolution are discussed.

## KARST AS A MODEL SYSTEM TO EXAMINE TERRESTRIAL MICROBIAL BIOGEOGRAPHY PATTERNS THROUGH TIME: AN EXAMPLE FROM THE EPSILONPROTEOBACTERIA

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The evolutionary mechanisms that govern the distribution of microbes on Earth are poorly understood. The concept that geographic isolation among microorganisms can lead to endemism is controversial. Because microbes are small in size, are metabolically tenacious, and are overwhelmingly abundant on Earth, microbes may be distributed everywhere and therefore may not be affected by geography. However, some studies reveal that various taxa have restricted distribution patterns. Many microbial biogeography studies have been conducted to test for microbial species endemism, but these studies have been conducted in habitats with high dispersion (e.g., aquatic, and specifically oceanic, habitats). Consequently, there have been few studies of microbial biogeography in terrestrial habitats. Karst, in particular, is a discontinuous habitat typified by different hydrostratigraphic units in distinct geologic provinces formed over time. While the karst habitat may be similar in its physicochemical and

geological conditions from one locale to another, microbial groups colonizing karst may reflect biogeography because of genetic exchange limitations. In the separated karst habitats, speciation events could be high. Considering the ubiquity of karst worldwide, understanding the types of microbial communities in cave and karst systems, as well as determining what geologic and geochemical processes may control microbial species distribution and diversity, are critical aspects to preserving the integrity of the karst ecosystem and to predicting ecosystem changes that may occur following disturbances.

The *Epsilonproteobacteria* taxonomic class is an ideal microbial group to investigate endemism, biogeographic diversity, and possible mechanisms controlling bacterial evolution in karst. Members of this class are found in many different sulfur-rich environments, including marine and terrestrial aquatic settings. Although investigated less, *ε-Proteobacteria* from terrestrial settings are potentially

widely distributed. Our previous investigations diagnosed novel evolutionary lineages within the  $\epsilon$ -Proteobacteria from one terrestrial subsurface environment, Lower Kane Cave (LKC) in Wyoming (USA). Two lineages dominated the subterranean communities and were related to organisms identified from other sulfur-rich terrestrial habitats (contaminated groundwater and caves), but not to microbes from marine habitats, including deep-sea hydrothermal vent sites and marine sediments.

Microbial mat samples from six cave and nine karst spring locations were collected, including the Frasassi Caves (Italy) and Movile Cave (Romania). 16S rRNA gene sequences were amplified, cloned, and sequenced from total community DNA extractions using general and  $\epsilon$ -proteobacterial lineage-specific primers. From a total of 336 sequences used for phylogenetic analyses, 71  $\epsilon$ -proteobacterial species-level lineages (operational taxonomic units, OTUs) were identified from cave and spring habitats. We recognize the fact that biogeographic interpretations based on the presence or absence of 16S rRNA genes should be made cautiously. However, five OTUs, consisting of sequences from up to nine locations, came from different continents and from karst systems with varying speleogenetic histories. Analyses of single copy genes (*rpoB* and *acIB*) from selected karst locations are currently underway to test distribution and occurrence pattern differences between the multiple copy genes (e.g., 16S rRNA gene) and single-copy genes. We expect the number of OTUs will be more than that observed with the 16S rRNA gene.

Our initial 16S rRNA gene sequence investigations do not reveal a correlation between the relative speleogenetic age of the cave, the age of the carbonate host rocks, and the microbial group (or OTU). Although most of the systems have formed within the past 500 ka (thousand years) in carbonate rocks ranging up to 400 Ma (millions of years old), all of the cave and spring locations are currently inundated by modern sulfidic waters that are the consequence of distinct regional hydrostratigraphic conditions. These data suggest that extremely ancient, large-scale geological processes and events (e.g., depositional basin sedimentology and geochemistry, plate tectonics, regional karstification events) must have influenced the ancestral distribution of these groups, which were likely marine in origin.

Once  $\epsilon$ -Proteobacteria colonized these terrestrial habitats, limited dispersal capabilities (i.e. no cyst or spore formation) and hydrostratigraphic barriers to genomic exchange led to site-specific lineage evolution. In our analyses, this is indicated by more than 89% of the OTUs consisting of sequence groups from single sampling locations. Furthermore, three OTUs (comprised of sequences from more than one location) were retrieved from the same geographic region, illustrating the potential importance of biogeography in terrestrial  $\epsilon$ -Proteobacteria distribution patterns. The large percentage of site- and region-specific OTUs detected in our study indicates potentially high site-specific endemism effects for some terrestrial  $\epsilon$ -proteobacterial lineages and possibly some recent (on an evolutionary/geologic time scale) exchange on a regional scale.

## RADIATION SCENARIOS FOR AUSTRALIAN CAVE-ADAPTED PLANTHOPPERS

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Cave-adaptation, the shift to a life underground, can provide critical information to understand evolutionary change in general, but the process of cave-adaptation is still not well understood and controversially discussed.

Planthoppers, especially of the family Cixiidae (Insecta: Homoptera: Fulgoromorpha) inhabited caves in many parts of the Tropics and Subtropics independently. These evolutionary lineages are ideally suited models to study the concepts of genetic differentiation and speciation dynamics. One of those planthopper taxa is the Australian genus *Solonaima*. This genus is endemic to Queensland and New South Wales and contains epigean

as well as cavernicolous species. The epigean species occur in the rainforest habitats along the east coast, while the cave-dwelling species are restricted to more arid areas western to the Great Dividing Range (Chillagoe & Mitchell Palmer Karst and Undara Lava Tubes). This relictous pattern seems to be due to the extinction of epigean species in the Outback according to the retreat of habitat starting with the desertification of inner Australia in Miocene, Pliocene.

The observed species display different degrees of troglomorphy, which are incongruent with the age of the caves, as the highest derived species occur in young lava tubes, while less cave-adapted species occur in older

Tower Karsts, which also leads to the assumption of several cave invasion events.

According to the cladogram only two cave-invasions are requisited, one for *S. sullivanii* and one for the other cavernicolous species, although the problem of homoplasy in cave-adaptation has to be considered. If more than one ancestral epigeal *Solonaima* species inhabited once the Outback, from which all cavernicolous species (except *S. sullivanii*) descended, all hints for this are vanished with these hypothetical ancestral species and/or veiled by cave inhabiting conditioned homoplasy.

Hence, morphometrical statistics and variation studies concerning aedeagal characters were conducted additionally, allowing to reconstruct scenarios for the invasion history of the extant populations:

1. Multiple cave-invasion scenario
2. Single initial cave-invasion scenario

To accommodate these results a hypothesis merging the relict hypothesis (Barr 1968) and the adaptive-shift hypothesis (Howarth 1986) had to be formulated.

## CAVE-DWELLING PLANTHOPPERS OF THE GENUS *OLONAIMA* (INSECTA: HEMIPTERA: CIXIIDAE) IN AUSTRALIA: RELICTS OR EXPLORERS?

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The evolution of obligately cavernicolous terrestrial organisms is still controversially discussed. Traditionally, cave colonization has been interpreted as a response to adverse (climatic/ecological) conditions on the surface leading to the extinction of epigeal populations, "trapping" troglomorphic populations inside underground environments. These populations subsequently acquired morphological (troglomorphies) and behavioral alterations. The patterns commonly observed in temperate regions seem to support this assumption. The discovery of terrestrial obligate cavernicolous invertebrates (mainly arthropods) in the tropics, however, with close epigeal relatives still extant, challenged this view. Here, cave colonization and -adaptation could also be the result of an active process, driven by the exploitation of novel food resources, such as roots.

Here we present a model system which allows us to test these hypotheses.

The Australian planthopper genus *Solonaima*, endemic with ca. 15 species in Queensland and New South Wales, contains epigeal as well as facultative and obligatory cavernicolous species. The cave-dwelling species display varying degrees of troglomorphy pertaining to eye- and wing reduction. Epigeal *Solonaima* species occur in rainforest habitats along the East Coast while the cave-dwelling species are restricted to more arid areas west of the Great Dividing Range.

To test the existing hypotheses on our model system, the following criteria should be applied, while these

hypotheses are not necessarily considered to be oppositional:

<i>Relict hypothesis</i>	<i>Adaptive shift hypothesis</i>
- deterioration of climatic conditions on the surface	- stable climatic conditions on the surface
- close epigeal relatives not extant	- close epigeal relatives extant
- cavernicolous taxa are of the same phylogenetic age	- cavernicolous taxa are of different phylogenetic age

The current distribution pattern seems to support the relict hypothesis in the case of the cavernicolous *Solonaima* species: Epigeal and cavernicolous species occur allopatrically. It is conceivable that in the course of the gradual desertification of central Australia during Miocene/Pliocene, when rainforests retreated eastwards, being replaced by a more xerophilic flora, *Solonaima* species survived in (the still moist) cave refugia and subsequently acquired troglomorphies.

The observation, however, of varying degrees of troglomorphies in cavernicolous *Solonaima* species may account for different phylogenetic age of these taxa and thus, be an indication for an adaptive shift. Hence it cannot be excluded that cave colonization and -adaptation in *Solonaima* occurred before the period of desertification, making an initial adaptive shift prior to the development of the extant relictual pattern assumable.

## STYGOFAUNA FROM A KARSTIC ECOSYSTEM IN THE PONOR MOUNTAINS, WESTERN BULGARIA: PRESENT KNOWLEDGE AND RESEARCH CHALLENGES

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The Ponor Mountains (Western Bulgaria) are part of the Balkan Ridge, with altitude 400 - 1473 m a.s.l. and more than 120 caves and chasms. The massif is formed mainly by Mesozoic rocks. Two basic rock complexes can be distinguished regarding to the karstification: Triassic karstic complex, formed by lime and dolomites with maximum depth 600m; and upper Jurassic complex with depth 100-150m. The two aquifers are hydrologically isolated. Basic collector of underground waters is the Triassic complex with annual outflow 2900 dm<sup>3</sup>/s from which 80% is leaving the system through the Iskretski izvori spring. This is the biggest spring in Bulgaria (maximum discharge 35000 dm<sup>3</sup>/s). The Jurassic complex (average outflow 120 dm<sup>3</sup>/s) is lacking superficial outflow which determines its precipitation alimentation.

The stygofauna is very heterogeneously distributed and its composition varies greatly from one station to another. From the aquifer with rocks with Triassic age are found 21 species while from the Jurassic one are found only 7. The common species for the two aquifers are 5 amongst which with higher frequency of occurrence are

*Niphargus bureschi*, *Speocyclops lindbergi* and *Stygoelaphoidella elegans*. At present 25 stygobionts are known from the Ponor Mountains: from Mollusca (2), Hirudinea (1), Acari (1), Copepoda (16), Syncarida (1), Isopoda (1), Amphipoda (3) groups. Crustacean assemblages are natural indicators of the typological characteristics of the system (hydrogeological division of karst, potential subsurface water connections, hydrological regime, contaminants transformation and bioaccumulation). Some of the main challenges to be faced in future concern understanding regional and fundamental functioning and structure of subterranean aquatic ecosystems. The issues to be solved with the help of invertebrate communities are: origin and circulation pattern of groundwater flow in a fractured karstic aquifer; relationships between groundwater hydrodynamics and contamination; connections among the underground areas and understanding differences that may make individual areas unique in terms of fauna; assessment of the contemporary condition and extent of human perturbation on the Ponor Mountains ecosystem; measures for protection and management.

## A CONTEXT FOR EARLY FARMING IN THE CENTRAL DALMATIAN POLJE: EVIDENCE FROM SEDIMENTS AND SOILS

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The formation of and sedimentation processes in poljes (large, elongate, flat-bottomed karstic valleys) are uncertain and may be unique to each polje – dependent on climate, bedrock chemistry, and groundwater. One aim of our work on the Early Farming in Dalmatia Project at the Danilo Bitinjinj and Pokrovnik archaeological sites is to elucidate polje sedimentary history. Analysis of his sediment record will inform the conditions of Neolithic settlement and earliest agriculture. To this end we are examining granulometric and ground-penetrating radar data from these valleys, and reconciling this GPR data with ground-truthing from soil profiles to create a three-dimensional subsurface map. We

will use both the texture and 3-D form of the deposits to reconstruct the geomorphic setting prior to and during Neolithic occupation. We hope that ground-truthing the GPR data, along with textural and soils analyses will enable further interpretations concerning the presence and extent of debris fans, the presence of erosive surfaces in the bedrock and sediments, and evidence for high-energy sedimentation events. Large limestone clasts (5-50 cm) present in valley soils (on- and off-site) may be the product of *in situ* bedrock weathering or the result of high-energy or high-viscosity events. X-ray fluorescence analysis of bedrock and of valley clasts may also help resolve this question.

## MORPHOLOGICAL EVIDENCE OF MULTIPLE CAVE LEVEL DEVELOPMENT IN THE UPPER BASIN OF SOMESUL CALD RIVER, BIHOR MTS., ROMANIA

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The karst on the upper basin of Somesul Cald River is situated in the Apuseni Mts., Romania, on the NE border of Padis karst plateau. It covers a relative small surface, superimposed on the drainage basins of Ponor, Alunu Mic, Alunu Mare and Firii valleys, all right hand affluents of Somesul Cald River.

Two main types of karst are found in the area: slope karst and plateau karst. The slope karst includes numerous caves situated at different elevations on the slopes of the above-mentioned valleys, vertical cliffs and partly denudated caves. The plateau karst is less extended, being present mainly on the northern sector of the area, at the springs of the Firii and Ponor valleys. Numerous dolines punctuate the surface, and some shafts gave access to deep and long cave systems, among them being the Avenul din Poienita-Humpleu karst system, the second longest in Romania.

Down cutting of Somesul Cald river and subsequent lowering of the base level triggered the genesis of a multi-

stage, well-defined karst system, developed along the rivers that cross this area.

Here we report the results of a long-term cave survey project, aiming to correlate cave levels from the upper basin of Somesul Cald river, and construct a chronology of the karstification processes in the area. By combining morphologic observations (both in caves and at the surface) with detailed mapping of the caves we were able to link the Quaternary evolution of the Somesul Cald River and its tributaries with the cave systems presents on the slopes of the rivers, and also establish a relative chronology of the karstification processes that affected the area. Moreover, morphological observations in the caves show that the early stages of cave development took place mainly under phreatic conditions, while later ones were in vadose conditions, as the entire area was uplifted.

## HYDROSTRATIGRAPHY OF THE KARST AQUIFERS OF FLORIDA

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In the United States, two highly-productive carbonate aquifers occur within peninsular Florida: 1) the Floridan aquifer, primarily composed of Eocene to Oligocene carbonates generally unconfined in the northwestern part of the peninsula and confined in the remainder; and 2) the Biscayne aquifer of southeastern Florida, predominately unconfined and mostly Pleistocene in age. Combined, these two aquifers provide potable water for about 17 million Florida residents.

Much of the unconfined Floridan and Biscayne aquifers are in low-lying, coastal, and subtropical environments. Both are composed of karstified eogenetic carbonates that have not been deeply buried and therefore retain substantial primary porosity. Permeability within eogenetic aquifers is highly heterogeneous, with the ma-

trix as much as 107 times as permeable as the matrix of telogenetic carbonates.

The karst features manifest within the unconfined Floridan and Biscayne aquifers offer contrasting examples of cavernous-scale (>2-cm diameter) porosity found within eogenetic karst. Both aquifers, however, differ considerably from epigenic karst in telogenetic limestones, where water flows from sinkholes to springs through fractures and discrete conduits. Groundwater in eogenetic karst similarly can travel through large conduits and fractures, but in contrast, also through mazes of stratibound touching-vugs and rock matrix.

Detailed petrophysical and geophysical studies demonstrate an organization to the hydrostratigraphy of both aquifers. For example, cavernous porosity is com-

monly layered. The origins of the cavernous porosity are primarily associated with fluctuations in sea level. In the unconfined Floridan aquifer, stratiform cavities at 5 m, 12-15 m, 21 m, and 30 m above modern sea level occur at elevations similar to geomorphic terraces in Florida, suggesting cavity formation during higher paleo-altitudes of sea level and water table. Likewise, cavities at depths of 15 m, 40 m, 70 m, and 90-120 m below the modern water

table generally agree with depths of marine terraces submerged in the Gulf of Mexico, which formed at previously lower altitudes of sea level and water table. Distinctly different from the unconfined Floridan aquifer, cavernous porosity in the Biscayne aquifer commonly occurs as horizons of cm-scale, touching-vug porosity within the upper and lower boundaries of depositional cycles.

## A LOCAL DEVELOPMENT OPPORTUNITY FOR A KARST AREA – THE MUNICIPALITY OF ALVAIÁZERE

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Located in the Leiria district (Portugal centre), the municipality of Alvaiázere it has an area of 160 km<sup>2</sup> and it dominates the karst landscape with many characteristic karstic features.

It is an area that presently is facing many problems concerning local development, a decreasing and ageing population are causing a dramatic scenario for its future as a municipality, which implies a big challenge for its own future, concerning economy, social and environmental policies. Other threats like infrastructures are a problem for the cultural, historic and geomorphologic heritage in this area.

Despite this scenario, this area has many characteristics and features that can be a good opportunity for the development of a sustainable development strategy, based in its own values. Its an area in which culture, geomorphology and landscape are closely linked and also an excellent opportunity to develop research at the interface between geomorphology and human sciences.

Many values can also if not identified be lost forever, not only geomorphologic values but also cultural, historic, among many others.

A recent research has showed that this territory has a good potential for the development of a local strategy, similar to a geopark, based in this known and unknown values, but only after being identified this values.

The mountains of Alvaiázere and Ariques are probably the most important area in this municipality concerning to the existence of some of this important values. Karst features like lapiés, caves, doline, a karst valley are present here among many others. Also a rich biodiversity exists here, that's why this area is included in the place Natura 2000 – Sicó/Alvaiázere.

Other value with great importance is the late Bronze Age walled settlement of the mountain of Alvaiázere, one of the largest known habitats from this age in the west of the Iberian Peninsula. Dinosaur footprints are also present in this area, not only in the mountains but also in the surrounding area.

The municipality of Alvaiázere from these values can create and stimulate a global strategy for sustainable territorial development along with geoconservation in this beautiful karst area and a door for the future.

## GEOCHEMICAL AND PHYSICAL PROPERTIES OF STALAGMITES AS A MARKER OF PALEOENVIRONMENTAL CHANGES

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Stalagmites are archives of palaeoclimatic information and many geochemical and physical properties can be used to interpret former environmental conditions that may have occurred during their growth. When calibrated against the present conditions in the cave system, the composition and growth rate of stalagmites can be interpreted in terms of former surface climate.

An extensive 2-year monitoring of the modern cave system shows that isotopic  $\delta^{18}\text{O}$  of the cave drips is equal to the mean annual  $\delta^{18}\text{O}$  of the local precipitation (-7.2‰); the  $\delta^{13}\text{C}$  a product of soil organic matter, whereas Mg and Sr concentration is determined primarily by the dolomitic bedrock. The complex karst hydrology modifies the final drip composition through differential transport, storage and mixing, whilst cave air temperature is seasonally variable due to links with the external atmosphere provided through the cave stream

and multiple entrances, although mean temperature is equal to that above the cave (7.2°C). Cave air  $\text{pCO}_2$  is similarly variable.

A newly sampled stalagmite is analysed together with SU967 a sample previously documented within the literature. The lamina thickness chronology duplicates that of SU967. High-resolution records of  $\delta^{13}\text{C}$  and  $\delta^{18}\text{O}$  are shown together with high and low-resolution Mg and Sr acquired using a variety of new and well-established techniques. Inter and intra-stalagmite variation in  $\delta^{18}\text{O}$ , Sr and Mg is good with excellent replication demonstrated. The  $\delta^{13}\text{C}$  is more variable between samples. Statistically significant co-variations are found between these stalagmite records, instrumental records and climate reconstructions. Finally T/P and summer temperature are reconstructed producing a multi-proxy record of climate for NW Scotland.

## HISTORICAL BIOGEOGRAPHY OF THE GENUS MESONISCUS CARL, 1906

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The genus *Mesoniscus* is a morphologically well-defined group, clearly apart from the other groups of the Oniscidea, with only two species - *Mesoniscus alpicola* (Heller, 1858) and *Mesoniscus graniger* (Frivaldsky, 1865) - and a distribution strictly limited to the Alpino-Carpathic Chain and, as such, particularly interesting from a biogeographical point of view.

The spreading of the genus *Mesoniscus* allows us to notice that the two species are clearly spatially separated: *Mesoniscus alpicola* is found exclusively in the Alps; *Mesoniscus graniger* is spread in the whole Carpathic Chain, from the Northern and the Romanian Carpathians, South-Danube Carpathians, the Dinarids and the Julian Alps.

There are two hypotheses regarding the origin of the species *Mesoniscus graniger*: a Northern Carpathian origin / a Bohemian one (implying a southward spread-

ing along the Carpathic Chain to the Dinarids and the Julian Alps) or, of contrary, an Illyric origin, followed by a northward migration from the Dinarids and the South-Danube Carpathians, through the Romanian Carpathians, up to the Northern Carpathians.

The Northern Carpathian origin hypothesis of the species *Mesoniscus graniger* is argued by an earlier and longer connection between the Alps and the Carpathians and also by a later connection between the Dinarids and the Carpathians.

But recurring land bridges between the Alps and the Dinarian-Pelagonian-Anatolian landmass, anterior to the connection Alps-Bohemian Massif-Carpathians, suggest and argue for an Illyric origin, also sustained by the subsequent isolation of the Dinarids from the Alps and the Carpathians.

## IMPACTS OF ACIDIC PEAT BOG DRAINAGE ON HOLOCENE KARST DEVELOPMENT IN SOUTHEAST ALASKA, USA

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The Tongass National Forest of Southeast Alaska, USA covers nearly 6.9 million hectares of mountainous offshore archipelago with extensive mature temperate rain forests. Because of the accretionary terrane geologic setting, the geology there is extremely complex and heterogeneous, and includes numerous blocks of limestone that have been intensively karstified. These extensive areas of carbonate bedrock are focused mainly on the northern portion of Prince of Wales Island. The last glacial activity in the area occurred with the Wisconsin (Marine Isotope Stage 2) glacial advance during the Pleistocene epoch. This approach strongly influenced the karst landscape. The development of muskeg peatlands has occurred in poor drainage areas where compacted glacial sediments and silts have been deposited over the bedrock below. The decomposition of the Sphagnum mosses leads to highly acidic waters with pH as low as 2.4. The measurement of continuous water chemistry at a muskeg input location and the down gradient karst resurgence

found that the carbonate karst system acts as a buffer for the highly acidic muskeg waters. Over the gradient of the system, the pH increases from 3.89 to 7.22 and the predicted and measured dissolution rates drop from the insurgence to the resurgence of the system. These organic acids from the muskeg waters at the insurgence contribute to the highest recorded dissolution rates for natural karst systems. Depending upon the model used to calculate dissolution, rates ranged from 0.09 cm/yr to 2.5 cm/yr of wall retreat. The karst resurgence does not differ significantly from other karst springs that do not have highly acidic inputs. As such, the acidic muskeg waters are rapidly depleted upon entering the karst system and do not propagate very far down gradient. This is supported by the presence of pits located where the muskeg waters run onto the carbonate areas. These pits have formed since the last glaciation which is backed up by both the dissolution rates and by the geomorphology in the area.

## TIME IN KARST: A BIOSTRATIGRAPHIC PERSPECTIVE

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Almost 150 years ago Louis Agassiz demonstrated that there are only three essential methods by which the natural sciences can operate: comparative, ontogenetic and palaeontologic. Major differences between them are in the way in which the time component of phenomena is considered. The aspect of time is excluded from the scope of the comparative method: an act of comparison as well as its results are the mathematic structures open to further comparisons and testing. They are instant sources of formally objective nomological-deductive hypotheses largely invariant to contextual changes. The *ontogenetic* method operates with the phenomena whose temporality can be eyewitnessed by our personal presence and immediately expressed in terms of a smooth continuous time scale, corresponding to exposure of time in common life. The outputs of the ontogenetic method are the historical-narrative hypotheses whose reliability is entirely de-

termined by the reliability of particular observer and the observation techniques. The *paleontological* method is the way to treat the phenomena for which a temporality is an essential trait of them but stays far beyond the scope of the ontogenetic method. Almost all the phenomena within the scope of this symposium fall in the domain of the palaeontological method and our comprehension of them is thus potentially biased by essential inconsistency of palaeontological method.

These phenomena can be well mutually compared but their temporality can only be derived of the assumption that the difference revealed by an act of comparison is an instant function of time. Of course, the fossil record, including that relevant for study of karst phenomena, is almost never continuous. On contrary, it is fragmentary in more respects and its density exponentially decreases with time distance. Moreover, as pointed out by Eldredge

and Gould (1972), in large time scales, the fossil record exhibits the punctuated equilibria pattern: alternation of sudden large-scale rearrangements with long periods of stasis. In other words, the time scale generated by fossil record is in no way smooth and continuous but discrete and non-linear. Exactly the same is apparently valid for dynamics of karst development and the record that is available for its study.

The major problem of the paleontologic method and dating karst phenomena lies in absence of a direct feedback control over reliability of the empirical ordinance relations between outputs of comparative analysis and time. Of course, these relations can be biased in many ways and the proposed time datum is never exact but a mere estimate which confidence limits should be specifically discussed in every single case. The methodological syllogism often applied in order to prevent possible dating bias is „count from top stratigraphy“: choosing the upper confidence limit, least distant from now, as a real datum. Traditional application of that technique in „safe“ dating is seemingly the more pertinent the less complete the record is and less robust its dating power is. This may lead to extensive underestimation of the real time span of the phenomena being studied. In dating of karst phenomena the respective bias is even more serious because what is available for study is not the true karstification events and/or the processes producing them but in most instances merely the epiphenomena of their past incidence (infillings of underground cavities, speleothemes etc.). Any data obtained from karst infillings and/or any other karst phenomenon is thus necessarily „a possible minimum age“, i.e. the upper most confidence limit of karstification stage.

Regardless of various instrumental techniques, biostratigraphy remains to be the most significant source of dating particularly for time slices of distant past. Of course, just from them, the fragmentarity of fossil record is greatly pronounced, in general, and any effort of biostratigraphic dating must hence be performed in full respect to this fact.

The procedure of biostratigraphic dating includes the following steps: (i) a careful comparative analysis undertaken both with the morphometric characteristics of all items composing the respective record and with taxonomic and structural composition of the sample. The reliability of the result clearly depends not only on extent of the data obtained from the record under study but even more importantly on the quality and extent of the data taken in comparison (both recent and fossil), (ii) transcription of the specificities of the record revealed by step (i) into terms of its time distance from well dated records. As the rules of the respective transcriptions are essentially quite specific for each particular taxon and even

each trait under study, the procedure (ii) actually results in a large set of different data with greatly variegated confidence limits. The next step should hence include (iii) a comparison of them and application of the techniques discriminating their actual meaning and producing the consensus date. An instant summary of previous comparisons is provided in form of a biostratigraphic system: a set of ordinance rules regarding the phenomena repeatedly revealed in multiple previous analyses. With a formal biostratigraphic system, a practical performance of the step (iii) is essentially simplified namely in that it reduces amount of the comparative effort to be performed onto answering few questions put by definitions of particular units of the respective stratigraphical system. Such an approach works quite well and effectively if the fossil record in study is rich and reliable in respect to representation of particular index fossils and, at the same time, of course, if the biostratigraphic system applied is actually responding to the purpose. This means that its units must be sufficiently well defined and balanced with respect to local and temporal variations in the criteria discriminating them. The finer the time scale on which the biostratigraphic system operates the lesser is its reliability beyond the geographic limits of its type area. Simply said, the absolute reliability is not granted for any biostratigraphic system and its dating power is the smaller the less representative is the actual fossil record. Unfortunately, this is the typical case in the study paleokarst phenomena. Often we obtain only few poor fragments belonging to the taxa not representing real index fossils. Such cases requires application careful case-specific analyses by a well trained palaeontologist, including ad hoc reconsiderations of confidence limits for any possible date that would come in account. It rests upon the karst scientists, of course, to claim such a challenging approach from the palaeontologists cooperating in the study and to expect from them a detailed accounts of the possible confidence limits for the final date they propose. With respecting the above rules, the biostratigraphic approach will undoubtedly continue to play its essential role among the tools by which the information on time in karst is gained.

#### REFERENCES

- Eldredge, N., Gould, S.J., 1972: Punctuated equilibria: An alternative to phyletic gradualism. pp. 82-115 In: Schopf, T.J.M. (ed.): Models in paleobiology. Freeman, Cooper and Co., San Francisco.

## BIOGEOGRAPHY OF STYGOBIOTIC CYCLOPOIDS (CRUSTACEA: COPEPODA) FROM BALKAN PENINSULA FOCUSED ON ACANTHOCYCLOPS KIEFERI LINEAGE

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Evolution of subterranean fauna in Balkan Peninsula has mainly been governed by the geographical patterns of region and its geological history. The Balkan region boasts high level of endemism, particularly in caves, which are well known as Pleistocene glacial refugia. We studied the biogeography of subterranean Cyclopida (Crustacea: Copepoda) of the Balkans on a regional scale. By far the richest sub-region is the Dinaric Mountains, which form the western part of the peninsula (defined by the political borders of the states from former Yugoslavia), followed by the eastern (Bulgaria and S-SE Romania) and the southern Balkans (Greece and Aegean Islands). For the stygobiotic cycloids, the average observed number of species per country is 12.7 and the total diversity is 69. Thus,  $\alpha$ -diversity accounts for 18.4% of the regional diversity and  $\beta$ -diversity contributed for 81.6% to regional diversity. The Cyclopinae fauna is comprised of Nearctic-derived epigeal forms (i.e. *Acanthocyclops*, *Diacyclops*

and *Speocyclops*) of which the most diversified genus is *Diacyclops* with 27 taxa known. The faunistic connection between western and central Europe is supported by the species widespread in Mediterranean region (e.g. Spain and southern France) as well as cosmopolitan stygobionts found throughout Europe. Bray-Curtis similarity coefficients indicate that the Transylvanian Plateau (NW Romania) is closely related to western Balkans (similarity level 41.38%) than to that of northern part of Bulgaria (30.3%).

The *Acanthocyclops kieferi* lineage was analyzed in detail. Thirteen of 17 species in the lineage are endemic to the Balkans. We hypothesize that these 13 species have a common ancestor and arose as a result of vicariant events in the Miocene. These resulted in their isolation in subterranean waters.

## AGE CONSTRAINTS FOR KARST FORMS AND PROCESSES IN APULIA (SOUTHERN ITALY)

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Apulia region, in the south-eastern part of Italy, has three main karst reliefs, named Gargano, Murge and Salento; they show in outcrop a wide part of the apulian foreland (Ricchetti *et al.*, 1992). Their morphological history started in the upper Cretaceous (Luperto Sinni *et al.*, 1991), followed on in the Tertiary age, and developed its major karst forms during the Quaternary (Neboit, 1975; Grassi *et al.*, 1982).

Recently, different kind of researches have been collecting data in Gargano (Sauro, 2000; Caldara & Palmentola, 1993) as in Murge plateau (Sauro, 1991; Bruno *et al.*, 1995; Castiglioni & Sauro, 2000; Palmentola & Iurilli, 2002) and in Salento peninsula (Mastronuzzi & Sansò, 1991; 2001). These recent works, with the help of studies still in progress, are giving further contributions for reconstructing the evolution of karst. For instance, in

hypogean geomorphology and speleological research, karst *morphosequences* (Dramis & Bisci, 1998) are used, relating cave forms with deposits, some of which could be dated (Iurilli *et al.*, 2005).

On the other hand, surface geomorphology can relate karst forms with the local geological setting giving further constraints to apulian karst history (Marsico & Selleri, 2005).

## REFERENCES

- Bruno, G., Del Gaudio, V., Mascia, U. & Ruina, G., 1995: *Numerical Analysis of morphology in relation to coastline variations and karstic phenomena in the southeastern Murge (Apulia, Italy)*. *Geomorphology*, 12, 313-322.
- Caldara, M. & Palmentola, G., 1993: *Lineamenti geomorfologici del Gargano con particolare riferimento al carsismo*. *Bonifica VIII* (3), 43-52.
- Castiglioni, B. & Sauro, U., 2000: *Large collapse dolines in Puglia (Southern Italy): the cases of "dolina Pozzatina" in the Gargano plateau and of "Puli" in the Murge*. *Acta Carsologica* 29/2, 16, p. 83-93.
- Dramis, F. & Bisci, C., 1998: *Cartografia geomorfologica*, p. 105. Pitagora Editore, Bologna.
- Grassi, D., Romanazzi, L., Salvemini, A. & Spilotro, G., 1982: *Grado di evoluzione e ciclicità del fenomeno carsico in Puglia in rapporto all'evoluzione tettonica*. *Geol. Appl. e Idrogeol.*, vol. XVII (2), Bari, 55-73.
- Iurilli, V., Mastronuzzi, G., Palmentola, G. & Selleri, G., 2005: *Indizi di tettonica recente in cavità carsiche della Murgia Meridionale (Puglia)*. Conv. "Montagne e pianure – recenti sviluppi della ricerca in geografia fisica e geomorfologia" AIGEO, Padova 15-17/2/2005, Preprints, 120-121.
- Luperto Sinni, E., Reina, A. & Santarcangelo, R., 1991: *Il ruolo della tettonica nel processo di carsificazione: l'esempio dei giacimenti di bauxite di Spinazzola (Murge baresi, Puglia)*. Proc. Int. Conference on Environmental Changes in Karst Areas. I.G.U. – U.I.S. – Italy 15-27 sept. 1991. Quaderni del Dipartimento di Geografia n. 13, 1991 – Università di Padova, pp. 399-404.
- Marsico, A. & Selleri, G., 2005: *Il paesaggio carsico della Puglia meridionale*. Conv. "Montagne e pianure – recenti sviluppi della ricerca in geografia fisica e geomorfologia" AIGEO, Padova 15-17/2/2005, Preprints, 135-136.
- Mastronuzzi, G. & Sansò P., 1991: *Cenni sul paesaggio carsico della penisola salentina*. *Itinerari Speleologici s.II n.5*, Castellana Grotte (Ba), ????
- Mastronuzzi, G. & Sansò P., 2001: *Pleistocene sea-level changes, sapping processes and development of valley networks in the Apulia region (southern Italy)*. *Geomorphology*, 46 (2002), p. 19-34.
- Neboit, R., 1975: *Plateaux et collines de Lucanie orientale et des Pouilles. Etude morphologique*. Libr. Honore Champion, Paris, 715 p.
- Palmentola, G. & Iurilli, V. (coll.), 2002: *Il carsismo pugliese, problemi e prospettive di ricerca*. Grotte e Dintorni, riv. d. Museo delle Grotte di Castellana (Ba), n. 4, p. 203-220.
- Ricchetti, G., Ciaranfi, N., Luperto Sinni, E., Mongelli, F. & Pieri, P., 1992: *Geodinamica ed evoluzione sedimentaria e tettonica dell'avampaese apulo*. *Mem. Soc. Geol. It.*, 41 (1988), pp. 57-82.
- Sauro, U., 1991: *A polygonal karst in Alte Murge (Puglia, Southern Italy)*. *Zeitschrift für Geomorf.* N. 35 (juni 1991) pp. 207-223.
- Sauro, U., 2000: *Coastal speleogenesis and collapsing by emptying of karst breccia-pipes on the marine cliffs of the Gargano peninsula (Apulia, Italy)*. *Acta Carsologica* 29/2, 16, p. 185-193.

## “AGE OF KARST IN GLACIATED TERRAIN”, WITH EXAMPLES FROM NORWAY AND SVALBARD

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Karstification of the Caledonian metacarbonates in Scandinavia and Svalbard developed in pace with a landscape that was heavily eroded during the Quaternary glaciations. On the Norwegian mainland, nappe tectonics led to the formation of stripe karst, and regional metamorphism effectively destroyed most primary stratigraphic and fabric structures which normally guide cave inception processes. Instead, we are left with coarsely crystalline marbles that are almost as impermeable as granites. Karstification and speleogenesis is therefore dictated by late tectonic fracturing in the brittle regime and by chemical contrasts at lithological contacts. Karstification occurred both during ice cover (*subglacial speleogenesis*) and in ice-free periods. During stadials, water supply

was dictated by the thermal conditions within the ice-sheets. Due to the chemistry and immense water supply in the ice-contact environment, enlargement of pre-existing caves (*speleogenesis sensu lato*) was very efficient, whilst the formation of a proto-cave from a fracture (*speleogenesis sensu stricto*) is slower than in a non-glacial situation. The present-day conditions on Svalbard may serve as a model for how caves developed on the Norwegian mainland during the Quaternary. Most relict caves in the present landscape may be explained by both interglacial and subglacial evolution phases, but a small number of very large passages may have survived since the Tertiary.

## THREE-DIMENSIONAL ARCHITECTURE AND ASSOCIATED STRUCTURES WITHIN A LOWER ORDOVICIAN ELLENBURGER COALESCED, COLLAPSED PALEOCAVE SYSTEM

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The three-dimensional, interwell-scale architecture of a Lower Ordovician Ellenburger coalesced, collapsed-paleocave system was constructed by integrating ground-penetrating radar (GPR), shallow core, and outcrop data. The data were collected near Marble Falls in central Texas over an ~800- × ~1,000-m area. Integration of rock facies from core descriptions with GPR-reflection response identified several paleocave facies that can be deciphered and mapped using GPR data alone: (1) continuous reflections image undisturbed strata; (2) relatively continuous reflections (tens of meters or more), characterized by faults and folds, image disturbed strata; and (3) chaotic reflections having little to no perceptible continuity image heterogeneous, collapsed, cave-related facies that cannot be individually resolved using GPR data. These latter facies include highly disturbed strata,

coarse-clast chaotic breccia, fine-clast chaotic breccia, and sediment fill.

The three-dimensional architecture of the coalesced, collapsed-paleocave system, according to core and GPR data, indicates that trends of brecciated bodies are as much as 350 m wide, 1,000+ m long, and tens of meters high. These brecciated bodies are coalesced, collapsed paleocaverns. Between the brecciated bodies are areas of disturbed and undisturbed host rock that are jointly as much as 200 m wide. As a cave system is buried, many structural features form by mechanical compaction, such as folds, sags, and faults. The folds and sags measure from a few meters to several hundreds of meters in width. Collapse-related faults are numerous and can have several meters of throw. Most are normal faults, but some reverse faults also occur.

## RESERVOIR-MODEL ANALOGS AND PORE-NETWORK SUMMARY FOR ELLENBURGER COALESCED, COLLAPSED-PALEOCAVE SYSTEMS

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Paleocave systems are not easy to describe, and no simple description can be applied to these reservoir types. Edges of the productive karsted reservoirs are generally structurally controlled, extent and magnitude of porosity are difficult to define, and pore networks evolve with depth.

Collapsed-paleocave reservoirs commonly display an internal rectilinear pattern in which trends of porous breccias (chaotic and crackle breccias) are separated by tighter rock. The pattern probably reflects penecontemporaneous-karst regional fracture patterns. The breccias may be several thousands of meters across, kilometers long, and 100+ meters thick. These scales are larger than individual caves, indicating the collapse and coalescing of cave systems that formed at composite unconformities.

A detailed description of a paleocave system in central Texas can be used as an analog for understanding

breccia (reservoir) distribution and reservoir heterogeneity. The three main facies are undisturbed host rock, disturbed host rock (crackle brecciated), and collapsed cave passages (chaotic breccias). The brecciated reservoir zones are separated by tighter, nonbrecciated zones.

A complication in understanding paleocave reservoirs is that the pore network evolves from a megapore system near the surface to a crackle-breccia-dominated pore system with deep burial. Delineation of reservoir burial history, therefore, helps us comprehend the pore network present. The reservoir may be fairly well connected because of the large amount of fracturing, and strong heterogeneity of reservoir quality should be expected. Fortunately, many Ellenburger reservoirs are dolomitized, and the dolomite promotes preservation of pores into the very deep subsurface (>7,000 m).

## BIODIVERSITY OF BELGIAN GROUNDWATERS AND CHARACTERIZATION OF THEIR STYGOBIOTIC FAUNA FROM A HISTORICAL AND ECOLOGICAL PERSPECTIVE

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In spite of its supposedly protection from major climatic changes, the subterranean domain in northern Europe seems to have been badly affected by the Quaternary glacial activity during the Pleistocene, resulting in a impoverished fauna.

In Belgium, two complementary processes ("dispersal" and "refugial"), of unknown relative explanatory value, have probably played a role in shaping the composition of post-glacial groundwater fauna. Faunal and ecological characterizations of the Belgian groundwater biodiversity were carried out in order to assess in what extent the present-day stygobiotic fauna can be attributed to one of these processes.

A total of 202 sampling sites were selected in four hydrogeographic basins within the catchment basin of

the Meuse River. Sites were equally divided among the saturated and unsaturated zones of fractured aquifers (karst) and within the hyporheic and the phreatic zones of porous aquifers. Selected environmental parameters were gathered in parallel (17 variables).

More than 140 species were recorded inhabiting Belgian groundwater environment, with representatives of the Amphipoda, Cladocera, Copepoda, Hydrachnidia, Isopoda, Oligochaeta, Ostracoda, Mollusca, Syncarida and Nematoda. Thirty stygobiont species were identified. To date, the total number of stygobiotic species recorded in Belgium is 41, of which 10 species were new to the Belgian fauna.

The number of occurrences for stygobiotic species was always low; and 40% of sampled sites had no stygobi-

onts. A few species were exclusive to one zone although no statistically significant differences were observable in species richness between the different stratification levels considered (basin, aquifer-type, and hydrological zone).

It appeared justified to consider the stygobiotic fauna of Belgium as species-poor and mostly constituted of widely distributed species, with broad ecological tol-

erance. This corresponds to the view of a post-glacial colonisation of the Walloon karst by eurytopic species dispersed from refugia south of the ice and permafrost (Dispersal hypothesis). The nearly absence of endemic species suggests that the scenario of an ancient fauna having survived in local refugia (Refugial hypothesis) remains marginal.

## MTDNA ANALYSIS IN THE GROUNDWATER AMPHIPOD NIPHARGUS FROM THE MEUSE VALLEY (BELGIUM)

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*Niphargus* is a widespread stygobiont amphipod genus, of which six species are known to occur in Belgium. These species are: *N. schellenbergi*, *N. fontanus*, *N. kochianus dimorphopus*, *N. virei*, *N. aquilex* and *N. pachypus*. (The animals can be caught in wells, caves, sources and resurgences.) Belgian *Niphargus* populations live close to the north or north-western border of the species' distributions. Peripheral populations often show a decrease in genetic diversity relative to central populations, from which they may also be more or less isolated. In addition, they may be subject to different selection pressures, possibly reinforcing genetic differentiation and in some cases even speciation. Therefore, we want to investigate to what extent the Belgian *Niphargidae* are genetically comparable and/or differentiated from populations elsewhere in Europe. This information is required to assess the conservation value of the Belgian populations and to uncover eventual cryptic diversity.

We started this research with a mtDNA analysis of Belgian *N. schellenbergi*, *N. fontanus* and *N. kochianus dimorphopus*. Individual DNA was extracted with the QIAamp DNA Mini kit (Qiagen), using the legs from one side of a specimen, so that the remainder of the body could still be used for morphological study. Several sets of primers were tested for the mitochondrial gene fragments cytochrome oxidase c subunit I (COI), cytochrome B (cytB), 12S and 16S. The COI primers (LCO 1490: 5'-GGTCAACAAATCATAAAGATATT GG-3'; HCO 2198: 5'-TAAACTTCAGGGTGACCAAAAATCA-3') yielded successful amplifications in the three species. The standard primers for cytB (UCytB 151F: 5'-TGT GGRGCNACYGTWATYACTAA -3' and UCytB 270R: 5'-AGGAARTAYCAYTCNGG YTG-3') only worked for *N. schellenbergi* and *N. kochianus dimorphopus*, and the 12S primer pair (kindly provided by P. Trontelj) only

yielded good amplification products in *N. schellenbergi*. Hence more primers will have to be tested.

Amplified DNA fragments were purified using a GFX DNA and Gel Band Purification Kit (Amersham Biosciences) or the Wizard SV Gel and PCR Clean-up System (Promega), according to the manufacturers' protocols. Sequencing was performed using an automated DNA sequencer (Applied Biosystems 3130 Genetic Analyzer). In this way we screened (up till now) 150 individuals for COI (approximately 650 bp long), 60 individuals for cytB (app. 350 bp long) and 140 individuals for 12S (app. 510 bp long).

For COI, we found 12 haplotypes within *N. schellenbergi* (18 populations, sequence divergence (p-distance) within the species 0,14%), 2 haplotypes within *N. kochianus dimorphopus* (one population, sequence divergence 6,3 %) and one haplotype within *N. fontanus* (one population). The divergence found in the *N. kochianus dimorphopus* population (sequence divergence 6,3 %) is high compared to the other species studied and to some other subterranean amphipods, especially since we only analysed one population. Finston *et al.*, (Mol. Ecol. 16 (2007): 355-365) found sequence divergences for COI of less than 1,8 % between subterranean amphipod populations (genus *Pilbarus*) caught within a tributary. The three taxa that we studied were well-differentiated by sequence divergences of 31,1 % between *N. schellenbergi* and *N. fontanus*, 37,5 % between *N. schellenbergi* and *N. kochianus dimorphopus*, and 22,9 % between *N. fontanus* and *N. kochianus dimorphopus*.

For 12S, we found 9 haplotypes within *N. schellenbergi* (18 populations) with an overall mean sequence divergence of 1,2 %. So the sequence divergence for 12S is tenfold higher than the sequence divergence for COI, within the same populations.

While amplifying *cytB*, we often obtained a pattern that looked like a 'double' sequence within a single individual. Sometimes one of both was readable and so it turned out that there were indeed two kinds of sequences, with a sequence divergence between the two groups of

15,1 % (sequence divergence within the groups are 1,1 % and 0,6 %). Whether these two kinds of sequences represent a case of heteroplasmy or involve nuclear *cytB* copies (numts) remains to be investigated.

## QUANTIFYING PALEOCAVE COLLAPSE FROM 3D SEISMIC DATA: EXAMPLES FROM THE PALEOZOIC SECTION IN THE NORTHERN FORT WORTH BASIN, TEXAS

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The Lower Ordovician Ellenburger Group of western and central Texas displays excellent paleokarst, both in outcrop and subcrop (e.g., cores), reflecting multiple exposure events. In the northern Fort Worth Basin, circular collapse structures representing suprastratal deformation above these collapsed-paleocave systems are well-known drilling hazards for tight-shale gas wells (Lower Carboniferous Barnett Formation). It is, consequently, important to understand their geometries in detail; the collapse features are therefore imaged using 3D seismic data. This study provides quantitative analysis of the timing of collapse and geometrical characteristics of these largely concentric structures. Concentric faults extend vertically 760 to 1,060 m from the Lower Ordovician Ellenburger Group. The largest structures remained active longer, influencing deposition of a younger, Upper Carboniferous

fluvial system. A defining parameter of these features is the upward-narrowing trough of the sag zone. A rectilinear paleokarst system is identified, with coalesced passage and cavern systems aligning along NW-SE and NE-SW trends. This orthogonal trend reflects the rectilinear fracture and joint system within the Ellenburger Group that was preferentially exploited by karst weathering processes. Collapse appears to have been incremental, with significant collapse occurring after about 300 m of overburden had been deposited. A set of criteria are outlined for quantifying the geometries of collapse-generated sag structures identified on seismic data (as opposed to sags generated by other processes—e.g. pull-apart basins). This template provides valuable information for defining seismically resolvable karst-collapse features worldwide.

## STYGOBIOTIC ISOPODA: A TOOL TO ASSESS WORLD CHANGES

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The fauna of the subterranean aquatic realm is rich, widely distributed and certainly underestimated, in number and, moreover, in the potential to provide a good insights into the evolution of each taxon, of the environment they colonize and of the paleogeographic events that shaped them. Within this fauna the Isopoda constitute an important portion. They are present in all the subterranean environments so far explored. Several different taxa of various families do colonize different areas with several species whose number is mostly related to the research

effort. The populations are composed mostly by endemic species, a common aspect of the subterranean habitats, due in general to the long time since each of them have colonised these ecosystems. Some of these taxa are ancient relicts, while others are more recent colonisers. We will concentrate on few of these.

### Relict taxa:

1. Calabozoidea, South American, restricted to few localities in Venezuela, and Brazil.

2. Phreatoicoidea, colonizing Australia, in a great variety of freshwater habitats, wells and caves in India, and caves and riverbeds in South Africa.

3. Stenassellidae widely distributed, they colonize different subterranean ecosystems from the Far East to America, accounting for an old conquest of the subterranean aquatic habitats.

#### Ancient and recent colonisers:

the Mediterranean genera of the Cirrolanidae with strict relationships to genera of other regions. The family has different levels of endemic areas, is widely distributed with several stenoendemic genera.

## THE RECONSTRUCTION OF THE PLIOCENE PALEOENVIRONMENT OF THE UNROOFED CAVES WITH FOSSIL REMAINS OF *MARIFUGIA CAVATICA* FROM THE ČRNOTIČE QUARRY, PODGORSKI KRAS, W SLOVENIA

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From the morphology of the caves, cave sediments and remnants of fossil cave animals and other fossils reconstructions of the paleoenvironments in which they were formed can be made. However it is difficult not to mix the evidences from different environmental settings which followed during the whole speleogenesis of a cave.

Here we present the reconstruction of the early Pliocene paleogeography of the Podgora karst and caves with fossil remains of cave animal *Marifugia cavatica*.

The unroofed caves and other caves discovered in Črnotiče quarry on the edge of the Podgora karst show a very complex speleogenesis and proved to be very important for the understanding of the evolution of SE part of the Kras plateau. Fill in the largest of fossil horizontal unroofed caves was roughly dated back to 4.2–5.2 Ma (Bosak *et al.*, 1999). Later work in the quarry reveal a new part, a side passage of the same cave in which the cave animal serpulid *Marifugia cavatica* tubes attached to the walls were preserved (Mihevc 2000, Mihevc *et al.*, 2001, 2002). Sediments were dated by paleomagnetic methods to 2.5–3.6 Ma (Bosak *et al.*, 2004).

Most important part of the cave is phreatic or epiphreatic, more than 17 m high and 4–8 m wide water passage. There are large scallops on the walls of the passage with attached *Marifugia cavatica* tubes indicating rather slow flow and stable environment. It was located in low position with small gradient and was already a result of a long speleogenesis. Water with discharge several hundred litres per second flowing through the cave system was coming from a sinking river, ponors of the river were close to the preserved part of the cave. At least part of catchment area of the sinking river was on Eocene flysch

marls. There were fish living in a river and floods were washing in drowned small mammals.

Filling of the passage which preserved the sessile tubes of *Marifugia* followed was probably a result of a fast change, maybe collapse in other part of the cave. Later gradient both outside and in karst enlarge, the fine sediments in the upper part of the profile were eroded and replaced by coarser sediments. In that part of the cave wall no serpulid tubes were found. Water left the cave and in a dry passage more than 7 m thick flowstone layer was deposited.

Today the surface is at 420 m a.s.l. and is cutting the flowstone fill of the passage exposing it on the surface as a typical unroofed cave. Nearest water table caves where *Marifugia cavatica* still lives are karst springs about 2 km away in elevation about 50 m a.s.l.

#### REFERENCES:

- Bosák, P., Mihevc, A., Pruner, P., Melka, K., Venhodová, D. & Langrová, A., 1999: Cave fill in the Črnotiče Quarry, SW Slovenia: Palaeomagnetic, mineralogical and geochemical study. – *Acta Carsologica*, 28/2, 15–39, Ljubljana.
- Bosák, P., Mihevc, A. & Pruner, P., 2004: Geomorphological evolution of the Podgorski Karst, SW Slovenia: contribution of magnetostratigraphic research of the Črnotiče II site with *Marifugia* sp. *Acta carsol.*, 2004, letn. 33, št. 1, str. 175–204, ilustr.
- Mihevc, A., 2000: Fosilne cevke iz brezstope jame – verjetno najstarejši ostanki jamskega cevkarja *Marifugia* (Annelida: Polychaeta). – *Acta Carsologica*, 29/2, 261–270, Ljubljana.

Mihevc, A., Sket, B., Pruner, P. & Bosák, P., 2001: Fossil remains of a cave tube worm (Polychaeta: Serpuliidae) in an ancient cave in Slovenia. Proc., 13th International Speleological Congress, Brasilia, 2001, str. 20-24, Brasilia.

Mihevc, A., Bosak, P., Pruner, P. & Vokal, B., 2002: Fossil remains of the cave animal *Marifugia cavatica* in the unroofed cave in the Černotiče quarry, W Slovenia. *Geologija*, 45, 2, str. 471-474.

## FORMATION AND EVOLUTION OF THE PERI-MEDITERRANEAN KARST DURING THE MESSINIAN SALINITY CRISIS AND THE PLIOCENE: EVIDENCE FROM THE ARDÈCHE VALLEY, SOUTHERN FRANCE

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During the Messinian–Pliocene eustatic cycle, the Mediterranean Sea was characterized by a short lived (5.95–5.32 Ma) sealevel fall, which attained –1500 m in some areas. The study of benchmark levels permits the chronology and dynamics of this event to be established. In the Rhône’s middle valley, our investigations allow a new interpretation for the genesis of the Ardèche endokarst. A fall in base-level was responsible for both the incision of the so-called Messinian canyons as well as a deep karst development. Karst systems were formed in association with the Messinian canyons of the Ardèche and Rhône Rivers. During the flooding of the Mediterranean Basin (5.32 Ma), these karst systems were filled by water and plugged by sedimentary infilling of the rias. This

mechanism pushed groundwater backward through the karst system, which in turn formed diagnostic “chimney-shafts”.

These pathways were geometrically connected to the position of the Pliocene benchmark levels. Consequently, the Messinian Salinity Crisis was responsible for two karst responses. The first was concomitant with the crisis itself and corresponds to the formation of a karst system. The second followed the Messinian Salinity Crisis and corresponds to the *per ascensum* adaptation of this karst system in Vauclusian karsts by the formation of “chimneyshafts”.

## THE CARBONATE HYDROGEOCHEMISTRY OF THE KRKA RIVER, CROATIA

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The Krka River is incised into a broad plateau underlain by folded carbonate rocks along the Dalmatian coast of Croatia. The Krka River drains a surface watershed of ~2,610 km<sup>2</sup>, and receives flow contributions from a network of interconnected subsurface watersheds of unknown configuration. At eight separate locations, tufa structures have developed across the river perpendicular to flow, and have grown to a size that interferes with that flow.

The purpose of this investigation is to characterize the hydrogeochemical condition of the Krka River to define the geometry of subsurface components of the

watershed, the chemistry of the water delivered by those individual components, and the effect of subsurface contributions on the process and location of tufa precipitation.

To determine the mechanisms responsible for tufa precipitation, we investigated the carbonate chemistry, temperature, pH, and topography of the Krka. We determined the carbonate content by in situ titration every ~2.0 km along the 72-km length of the Krka. Values of pH ranged from 7.4 to 8.4; the concentration of total carbonate ranged from 300 to 500 ppm. We collected 32 samples of modern tufa from sites close to the titration stations,

and analyzed those samples by X-Ray Diffraction. Within limits of analytical precision, all samples were identical in mineralogy, with calcite the predominant mineral. Aragonite, magnesium calcite, magnesite, stononite, and quartz were identified at much smaller percentages.

In tufa-precipitating river systems with well characterized hydrologic inputs, such as Havasu Creek, AZ, pH and carbonate content follow a systematic trend of rising pH and decreasing carbonate content with distance from the source. In the Krka system, that simple pattern is not

realized; sequential subsurface inputs apparently alter the hydrochemistry and, ultimately, the process of tufa precipitation. Within the Krka system, we identified three short segments of the river through which systematic rise of pH and decline in total carbonate content document distance downstream from a discrete subsurface source. Those segments are separated by reaches in which variation of those chemical parameters follows no clear pattern, suggesting that subsurface inputs to the Krka vary both in space and time.

## DJARA CAVE (WESTERN DESERT OF EGYPT) AS A PALEOENVIRONMENTAL, AND PALEOCLIMATIC INDICATOR

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Djara Cave is one of the few caves in the Western Desert of Egypt containing speleothems. It is located close to the Farafra-oasis in western Egypt and was first visited by the German GERHARD ROHLFS on 24<sup>th</sup> December 1873, who found an extensive speleothem (stalactites, stalagmites and flowstones) development in this cave, part of them are covered by sand. The cave was then visited and studied by many research groups (geological, geomorphological and archeological) due to its importance as a paleoclimatic indicator for the desert. The cave is located on an Eocene plateau to the west of the Nile valley, which consists of highly fractured carbonates of the Naqb Formation. Today, the Western Desert of Egypt, where the cave is located, is part of the hyperarid Eastern Sahara and belongs to the subtropical desert climate zone. High temperatures, low humidity and strong winds cause high potential evaporation rates in excess of 5000mm per year. In contrast, the interpolated annual precipitation sum is less than 5mm with sparse rain on only 1–5 days per year on average. The cave temperature is 23°C year-round and appears to stay very close to the external mean temperature.

U/Th datings of speleothems by  $\alpha$ -spectrometry yielded ages ranging from  $140 \pm 15.9$  kyr to  $283 \pm 56$  kyr (Brook *et al.*, 2002). One TIMS date yielded  $201.05 \pm 2.1$  kyr. A number of samples was beyond the U/Th dating limit ( $\sim 500$  kyr for TIMS dating,  $\sim 350$  kyr for  $\alpha$ -spectrometry) (Holzkämper, 2004). Isotopically depleted values, which were also measured within earlier investigations, suggest that enhanced African summer monsoon and westerly circulation during the winter months advected precipitation to the Western Desert enabling speleothems to form in the recently hyper-arid region. A number of covered hearths in the close vicinity of the cave have been found by previous expeditions, some of which were dated with the radiocarbon method. These and additional datings of ostrich egg shells yielded ages between 9.7 kyr to 5.5 kyr, indicating that wetter conditions prevailed in the area during this time interval. So Djara Cave is a great source of information for the paleoclimate of the Sahara, showing the change from wet, dry to hyperarid conditions through time.

## MORPHOMETRIC ANALYSIS OF THE LEPTODIRINAE BEETLES WITH RESPECT TO THEIR HYPOTHETIC SUCCESSIVE HISTORICAL COLONISATION OF SUBTERRANEAN HABITATS IN SLOVENIA

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The animal morphology is, besides recent molecular investigations, still an unavoidable classical approach in the analysis of taxonomic groups in space and time. The understanding of the adaptatiogenesis for living in hypogean habitats can contribute to the research of the karst evolution. In Slovenia, within the subfamily Leptodirinae (Cholevidae = Leiodidae), three morphological groups have been established representing unique lineages with respect to their adaptations to preferred habitats. Three species of the epigeal lineage live in moos and litter, while two troglobitic lineages have been recognized among 34 species and 38 subspecies. Most of them belong to the bathyscioid type sensu Jeannel with an ovoid body and relatively robust short appendages resembling adaptations in edaphic beetles. The second troglobitic leptodirine lin-

eage represents the ultra evolved leptodiroid type sensu Jeannel with specially transformed, mostly enlarged body and gracile, long thin appendages. The species of the first troglobitic group live more or less in all karstic regions of Slovenia till Karavanke/Karawanken Mts., known to be the border of the continuous distribution of troglobites in the Central Europe. The species of the second group are limited to the Dinaric Karst. In this study, the morphometric comparisons between selected species of the three groups as well as the outgroup of Cholevinae were carried out to find statistical differences between them. The authors suggest that the detailed analysis of the two evolutionary successive troglobitic lineages can support the discussion about the karst evolution.

## THE TIME WHEN NEANDERTHALS VISITED ROMANIAN CAVES

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### ABSTRACT

Humanoid footprints in the fossil record are rare. A survey of the literature reveals only two well documented, dated cases. The one, from ~325 ka in Italy (Mietto *et al.*, 2003), represents a very early, pre-Neanderthal human. The other, from ~117 ka in Africa (Gore, 1997), is likely a *Homo sapiens sapiens* print. Here we report the first clearly *Homo sapiens neanderthalensis* footprint. It was found in Vârtope Cave, Romania. The person stepped into calcareous mud that later hardened. The 22 cm long print suggests a body height of ~1.46 m; a gap of 1.6 cm marks the separation of big toe and second toe. The date of the footprint is constrained by the date of the deposition of

the mud (~97 ka, dated by U-Th isochron method) and the date on the base of a nearby stalagmite on top of the mud (~64 ka). Thus the Vârtope Cave person lived in Romania sometime between 97 and 64 ka, long before the earliest known *Homo sapiens sapiens* remains in Europe (~35-30 ka) (Carciumaru & Anghelini, 2000; Trinkaus *et al.*, 2003). To our knowledge, this is the first discovered and dated *Homo sapiens neanderthalensis* footprint.

## REFERENCES

- Ford, D.C. & Williams, P.W., 1989: Karst Geomorphology and Hydrology. London. Unwin Hyman. 601 pp. (Times New Roman, 11, single spaced, fully justified)
- Cârciumaru, M. & Anghelinu, M., 2000: The Carpathian Mousterian and the transition from middle to upper Palaeolithic in southern Romania. in *Neanderthals and modern humans -- discussing the transition: Central and Eastern Europe from 50,000 - 30,000 B. P.* (J. Orschiedt, G.-C. Weniger, Eds.) Mettmann, Neanderthal Museum, pp. 190-195.
- Gore, R., 1997. The dawn of humans: tracking the first of our kind. *National Geographic Magazine*. 192: 92-99
- Mietto, P., Avanzini, M. & Rolandi, G., 2003. Human footprints in Pleistocene volcanic ash. *Nature*. 422: 133.
- Trinkaus, E., Moldovan, O., Milota, S., Bilgar, A., Sarcina, L., Athreya, S., Bayley, S.E., Rodrigo, R., Gherase, M., Higham, T., Ramsey, C.B. & van der Plicht, J., 2003. An early modern human from the Pesteră cu Oase, Romania. *Proc. Natl. Acad. Sci. U.S.A.* 100: 11231-11236.

## ISOTOPIC INVESTIGATIONS OF CAVE DRIP WATERS AND PRECIPITATION: APPLICATIONS TO HYDROGEOLOGICAL AND PALEOCLIMATE STUDIES IN FLORIDA, USA

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Precipitation and in-cave drip waters from speleothems at three caves that transect the Gulf coast of the Florida peninsula from North to South have been collected to satisfy three research goals. 1) Quantify the variability of the isotopic signal of precipitation and drip waters at each cave and isolate the primary factors that control that isotopic variability both at the site and regional scale. 2) Determine the fraction of meteoric waters that originate in the Atlantic Ocean and Gulf of Mexico at each site. 3) Calculate the recharge rates through the vadose zone of the aquifer matrix at each site. In addition to weekly water samples, instrumentation inside and outside each cave monitors hourly data on temperature and relative humidity; acoustic loggers acquire data on drip rates beneath active speleothems attached to unfractured blocks of the aquifer matrix. The relationship between the isotopic composition ( $\delta^{18}\text{O}$  and  $\delta^2\text{H}$ ) of cave waters and meteoric sources is critical for reconstructing paleoclimates using speleothem data. This study will serve as a first of its kind in the southeastern US where the impacts of con-

founding variables such as temperature, vapor source, storm frequency and intensity, distance from shore, and soil/water/rock interactions are poorly understood.

Determining precipitation sources will shed light on how the climate of the Florida Peninsula is affected by regional weather patterns such as the Atlantic Multi-decadal Oscillation, El Niño, and the Intertropical Convergence Zone. For example, rainfall from tropical systems in the summer show a depleted  $\delta^{18}\text{O}$  signal when compared to frontal precipitation events during the winter.

Calculating recharge rates will help us better understand the transport of meteoric waters through the epikarst and into the underlying Floridan Aquifer. All three caves formed in the eogenetic Ocala limestone where matrix permeabilities are high,  $10^{-11}$  m<sup>2</sup> to  $10^{-13.8}$  m<sup>2</sup>. The lag times between precipitation events and changes in drip rate from the aquifer matrix are short at all three caves, on the order of days to weeks, compared to caves in the telogenetic, low-permeability limestones of the mid-continent.

## SPELEO-FAUNA OF THE MONTI SIMBRUINI REGIONAL NATURAL PARK

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In the region of Lazio there live 50% of total Italian species due to its environmental variety.

A sampling and a study about speleo-fauna has been done for two years (starting in 2002) in 30 different caves (24 of them biospaeologically unknown) in the Central Appennino in the Monti Simbruini Natural Park.

During this research probably new species belong of Orders of Araneae and Coleoptera are to be found. The Coleoptera is a Curculionidae *Otiiorhynchus* (*Lixorhynchus*) similar in morphological characters to *O. gianquin-toi* (F. Solari, 1936) (det. G. Osella); the Spider is a Centromerus considered, from Dr. P. Pantini, similar to *C. puddui* (known only in a Sardegna's cave). This sample needs a comparison with samples of *C. cinctus* (known in Corsica and Algeria).

Specialization level of cave fauna of Monti Simbruini and Volsci, in particular Monti Lepini (the better biospaeologically known mountains complex in central Italy). The Specialization Index (Sbordoni *et al.* 1977) has been calculated. This Index uses the report between the number of troglobiontes and the total of eutrglobious species (the total of troglobiontes and trglophilus). This

index appears independent both of cave morphology and development.

From preliminary observations it is seen that troglobiontes of Monti Simbruini are fewer than the troglobiontes of Lepini. Moreover in Monti Lepini endemic species are more and with areas of endemicity larger than the Simbruini's species. The specialization Index is higher for Monti Lepini fauna than for Monti Simbruini.

The different kinds of cave fauna in the two mountains complex could be due to two different reasons, probably together:

**1) The geological kinematics of the zone:** The mountain chain of Volsci emerged 1.5 million years before than Monti Simbruini, and so cave fauna of Monti Simbruini could be in a more in arrears evolutive level than Volsci one.

**The different climatic conditions:** In Volsci is usual to find uncovered karst with mediterranean clima. This condition simplify the separation between fauna of humid environment, typical of caves, and external fauna; so allopatric division is favoured and speciation too.

## GENESIS AND AGE OF ICE ACCUMULATIONS IN CAVES

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Perennial ice exists in a significant number of caves in Europe and elsewhere in the world. Ice in caves accumulates through complex freezing and melting processes, which eventually lead to the development of laminated deposits, with clear ice layers alternating with impurity-rich ones. This deposition style offers good perspectives for the use of ice accumulations in caves as paleoclimatic archives, as they contain a large number of climatic proxies: O, H and C stable isotopes, pollen, beetle remains etc. However, in order to be able to make best use of these proxies, a good age model is needed for the hosting ice.

Using present-day ice formation as a model, we propose a genetic and evolutionary model for the formation of ice deposits in selected caves from Apuseni Mountains, Romania.

In order to achieve our goal, we firstly developed a model for the present-day accumulation of ice, using glaciological, meteorological and geochemical (tritium dating) analyses. We found that the ice has a well structured response to external climatic forcing, its melting or building-up being controlled mainly by variations in precipitation (i.e., availability of dripping water), while temperature is acting as a second order controller (e.g., dripping water can determine the accumulation of ice, if air temperature is bellow 0°C, or can lead to ice melting, if air temperature is above 0°C). Air temperature itself has a limited influence on the dynamics of ice, due to peculiar morphology of caves, witch do not allow warm air penetration inside the caves during summer (cold air traps). Winter air is entering the cave at a high rate, but in

the absence of dripping water has a reduced influence on the dynamics of ice. This model, combined with detailed stratigraphic measurements of the existing ice bodies enabled us to reconstruct the past dynamics of the ice. By

plotting the data obtained against  $^{14}\text{C}$  values, we were able to build a good age-depth scale for the last 1000 years, as basis for further paleoclimatic reconstructions, using ice in caves as sources of information

## PALEOCLIMATIC SIGNIFICANCE OF THE MAMMAL CAVE FOSSILS

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The importance of the fossils from caves sediments is obviously from the paleoclimatic interpretations point of view.

The paleontological studies above the mammals from the Upper Pleistocene from Romania reveal a distinct particularity in comparison with other mammals associations from the rest of the Europe.

We will reconstruct the paleoenvironment from the last glacial cycle (Wurm) on the basis of the mammal cave fossils discovered in few cave from Romania. The research made in carstic deposits from the last glacial cycle, is based on systematic survey in few of the most important paleontological sites.

The remains accumulated here have different origins: bones abandoned here by the primitive hunters, scavengers and from natural causes (death) when the cave was used like shelter (*Ursus spelaeus* and *Crocuta spelaea*). For the small mammals the main remains sources was the existence, next to the entrance of the caves, of the carnivorous bird's nests. The remains was accumulated in chronological positions and represent a mirror for the mammalian associations from the outside, especially for the small mammals.

## OPTICALLY STIMULATED LUMINESCENCE ANALYSIS OF THE SPELEOTHEMS IN CROATIA

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The luminescence dating covers a range of analytical methods that can be applied over different time periods in different minerals and in different environmental conditions. The optical stimulation allows very small luminescence signals to be detected. In most cases the minerals analyzed with this method were quartz and feldspars, because they are able to store energy in a crystal structure. This energy is deposited mainly by ionising

radiation from environment and by cosmic radiation. The analysis of this energy is the base of the luminescence dating method. In our work we have analyzed the speleothems mainly consist of calcite or aragonite. The sources for the optical stimulated luminescence were the laser coherent light and the non coherent light emitting diodes (LED) sources.

## KARST AS A MODEL SYSTEM TO EXAMINE TERRESTRIAL MICROBIAL BIOGEOGRAPHY PATTERNS THROUGH TIME

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The evolutionary mechanisms that govern the distribution of microbes on Earth are poorly understood. Continental plate motion and geologic processes have changed the distribution of terrestrial and marine life throughout Earth's history. Confinement to certain locations has resulted in speciation events and even endemism. For microscopic life, however, the concept that geographic isolation plays a role in microbial species diversity is controversial. Because microbes are small in size, are metabolically tenacious, and are overwhelmingly abundant on Earth, microbes may be distributed everywhere and therefore may not be affected by geography. Many microbial biogeography studies have been conducted to test for microbial species endemism, but these studies have been conducted in habitats with high dispersion (e.g., aquatic, and specifically oceanic, habitats). There have been rela-

tively few studies to characterize microbes living in terrestrial habitats where it is assumed that there has been limited dispersal due to the geographic and hydrostratigraphic barriers. Hypothetically, similar to what has been observed for organisms living on islands, microbial communities in the terrestrial subsurface, and specifically in caves and karst settings, would have had less opportunity to exchange genetic information because of barriers to gene flow and exchange; therefore, speciation events would be higher. Considering the ubiquity of karst worldwide, understanding the types of microbial communities in cave and karst systems, as well as determining what geologic processes may control microbial species distribution and diversity, are critical aspects to preserving the integrity of karst ecosystem and to predicting changes in ecosystem that may occur following disturbances.

## SPELEOGENESIS IN 15 DAYS

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Although corrosion is very important from the speleogenetical point of view field measurements of corrosion are still very scarce. While the number of long-lasting speleogenetical interpretations and evolution modeling of karst aquifers still grows, actual values of corrosion are not yet well established. One should ask, if these interpretations of cave development fit into the field acquired data. On the basis of this question we started to measure the intensity of corrosion at several different underground streams, which flow in the epiphreatic zone. Measurements were done with limestone tablets as their preparation is easy and accuracy of the method (up to 0.0001 mm) is precise enough to detect measurable changes in one year.

Due to significant improvement of the methodology, which allows to measure corrosion in streams with velocities over 3 m/s, in the period from 2005 to 2006 corrosion at 68 different sites was measured. The average measured intensity was -0.02 mm/a. Gathered values are in accordance with measurements accomplished by dr. A. Mihevc, who measured corrosion on cave walls with micro-erosion meter. Measurements gave us insight into

the activity of caves from the view of corrosion – some cave systems were recognized as corrosively active, while others have fossil cave rocky relief. On 29 locations the intensity of corrosion is greater than 0.005 mm/a. This means that at such places corrosion can be measured in 15-day intervals. This is so short period of time, that we can recognize the influence of individual hydrological event, *i.e.* at low, medium or high water conditions. If the intensity of corrosion was almost the same through the year, in 6 separate cave systems we could measure it daily.

On the basis of annual measurements we decided to place 78 limestone tablets in the following caves: Križna jama, Nova Križna jama, Lekinka, Pivka jama, Tkalca jama and Jelovička jama. In these caves we are measuring spatial and temporal differences of corrosion in 15-, 30- and 50-day intervals. Although the caves have quite different recent speleogenesis our results show that in the period of low water levels corrosion does not occur at any experimental sites. Unexpectedly, at some places important flowstone deposition was observed. It seems that the

majority of corrosion is done during medium high water levels, which are relatively frequent. The highest corrosion efficacy is certainly characteristic for high waters, but such hydrological events are quite rare. In the ponor cave Lekinka at medium high water level influence of the

distance from the cave entrance was very well observed, namely the corrosion intensity in 65 m water course fell from 0.003 mm in 15 days to 0.002 mm in the same period.

## A MAMMAL-DATED MID-EOCENE CAVE COLLAPSE IN THE QUERCY PALEOKARST, SW FRANCE

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The largest part of the Quercy regional area, SW France, is made of a thick Jurassic limestone platform, which contains a dense net of karstic voids. These voids are filled with clay deposits, within which phosphatic crusts developed. Intense mining of this ore, in the last 19<sup>th</sup> century quarter, revealed the fossiliferous richness of the fillings, mostly with terrestrial vertebrate remains. Their study, renewed for the last forty years, produced a corpus of fossil data and their bearing into various fields: knowledge of groups from amphibians to mammals, evolution of lineages, biochronology, paleoecology, paleoenvironments, and so forth. The fossil documented period in the Quercy phosphatic area now extends through 30 million years, from the early Eocene up the early Miocene. Studied mammal lineages allowed numerical dating (Escarguel *et al.*, 1997).

The Laprade net (Tarn-et-Garonne dept.) is mostly an unroofed cave, this resulting from the strong plio-quadernary erosion of the platform. Since mining, infilling red clay still occur in restricted parts. At the N-W end, this clay yielded a vertebrate fauna, the age of which is Mid-Eocene, MP 14 of the European mammal scale (Sudre *et al.*, 1990). Its numerical dating is – 41.35 M.a. ± 0.426. In the NW underground gallery, the E wall at entrance consists of chaotic superposition of large limestone blocks, some of metric size. This results from a vault and/or wall local collapse. The infilling red clay between the blocks simply extends the bearing-fauna one outside.

Its age postdates the collapse, without significant time between collapse and filling. Similar collapses often occur in active karst systems, most of time without clear cause. However, the Laprade filling dating sent back us to another paleokarstic place in Quercy, the Prajoux one (Lot dept.). There, few mammal remains predate a fault movement, at ca – 41.5 M.a. (Astruc *et al.*, 2000). The closeness of the two datings is best understood as relating to the same intense tectogenic and seismic period of the pyrenean orogen, effects of which being distally preserved. The Laprade collapse together with the Prajoux fault support such interpretation. Here, the dating method relies on evolutionary data of mammal lineages. While other, chemical dating methods, will soon be settled and allow checking.

### REFERENCES

- Astruc, J. G., Escarguel, G., Marandat, B., Simon-Coinçon, R. & Sigé, B., 2000: *Geodinamica Acta*, 13: 271-280.
- Escarguel, G., Marandat, B. & Legendre, S., 1997: Actes du Congrès Biochrom'97, Mém. EPHE, Inst. Montpellier, 21: 443-460,
- Sudre, J., Sigé, B., Remy, J.A., Marandat, B., Hartenberger, J.-L., Godinot, M. & J.-Y. Crochet, 1990: *Palaeovertebrata* 20 (1): 1-32.

## VARIATIONS IN SPELEOTHEM TRACE ELEMENTS AND $\delta^{13}\text{C}$ IN CENTRAL FLORIDA: POTENTIAL FOR PALEOCLIMATE RECONSTRUCTION

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A stalagmite collected from Briar Cave in central Florida, provided the first Late Holocene Paleoclimatic record for Florida using speleothems. The stalagmite was analyzed for trace elements Sr and Mg and for carbon isotopes. Thermal ionization mass spectrometry of uranium-thorium isotopes indicate the speleothem was precipitated during the last 4200 years. When Sr/Ca and Mg/Ca time series data is combined with Uranium series dating techniques, the age of paleoclimate variations may be deduced. Using Sr/Ca and Mg/Ca ratios to learn past climatic data is under debate. Many academics believe temperature, effective rainfall, recharge rates, and vegetation patterns can be found from trace elements in speleothems, others argue that only the speleothem growth

rate may be obtained from trace elements. Results showed that Sr concentrations are negatively correlated with  $\delta^{13}\text{C}$ , a relationship we inferred to record changes in soil productivity. Magnesium concentrations were not found to be significantly correlated with hemispheric temperature, however results suggest the residence time of percolation waters maybe the controlling factor. Coeval changes in the Sr content and  $\delta^{13}\text{C}$  signals, as induced by soil productivity, can only be explained by changing precipitation above the cave. Both proxies record a 170-180 year solar cycle that has also been found in the Gulf of Mexico marine records. Consequently, this result provides evidence of an extra-terrestrially driven modulator of precipitation in central Florida.

## DETERMINATION OF PAST FLOW REGIMES FROM SCALLOPS OF BEYYAYLA CAVE (BILECIK – TURKEY) BY USING BOOTSTRAP HYPOTHESIS TESTING METHOD

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Caves provide natural archives of records of the palaeo-hydrologic conditions. Scallops are among the corrosion – morphologies that may provide such records. In this paper scallops at the walls of the passage of the Beyyayla Cave in Turkey were measured and statistically analysed to infer about the past hydrologic conditions. The cave is located within a dissected – relict karst, and it exhibits

poly phase passage morphology. Relicts of scallops on the passage walls vary in shape and size. Data collected in the cave were analyzed by the bootstrap hypothesis test to determine the number of modes in the multimodal histogram, which is obtained over the collected data set. The results of analyses revealed that the cave had been affected by at least two flow regimes.

## URANIUM-SERIES DATING OF SPELEOTHEMS: ESTABLISHING TIME AND FORCING OF CARBONATE DEPOSITION IN KARST SYSTEMS

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Over the last few years cave science has seen an strong increase in interest from other academic disciplines as well

as from the general public. This development is largely due to the growing awareness of the importance of karst

systems as groundwater resources in many regions of the world as well as the recognition that within these sub-surface environments information about past climate and hydrology is reliably recorded in carbonate deposits. Paleoclimate scientists currently are very keen to study speleothems and some regard them even as valuable as ice cores from Polar regions.

Although most speleothem studies are currently targeted toward providing high-quality records of climate and environmental change outside cave networks, these results are also undoubtedly of great significance for a better understanding of long-term dynamics within karst systems. Examples include the frequency of cave flooding recorded as detrital-rich layers in stalagmites,

drought periods as indicated by narrowly spaced speleothem laminae and/or microhiatus, overgrowths of marine organisms on speleothems in near-coastal caves during sea-level highstands, and the occurrence of intermittent speleothem deposition in cold-climate caves prone to freezing. These studies therefore provide critical data for assessing the role of climate forcing of karst hydrological processes on timescales ranging from annual to millennial. Given the inherently complex nature of karst systems and the fact that these systems evolve over time, results obtained from individual speleothem samples, however, will require thorough validation to arrive at robust interpretations.

## KARST DEVELOPMENT AT THE RACISZYN AREA (KRAKÓW – WIELUŃ UPLAND, S POLAND) – PRELIMINARY RESULTS.

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In September 2005 in a quarry near Raciszyn (Kraków-Wieluń Upland, S Poland) we discovered a new small cave. The entrance was placed on the bottom of the lowest exploitation level. Both geographical and geological position of the cave allows us to expect new data on evolution and development of karst in this part of Poland. The cave is a part of larger geological structure i.e. a large slit that runs along the whole quarry. During the exploration about 20 samples of speleothems from the cave and other parts of quarry have been collected to the further

Th/U analysis. We have found at least three generations of speleothems separated by erosion surfaces and clastic sediments (mostly clays). This indicates complicated history of the cave and radical changes of hydrogeological conditions during Pleistocene in this area. The oldest discovered speleothems are older than 350 ka, and probably older than 1.2 Ma, and exceeds the method's range. Next generation of speleothems developed between 233 and 118 ka. The youngest speleothems were Holocene age.

## A COMPARATIVE REVIEW OF FOREST MANAGEMENT HISTORY IN SOME HUNGARIAN KARST AREAS

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Vegetation is one of the karstecological factors. As such it directly affects microclimate and soil and thus indirectly the whole system. Due to their geographical position, the potential vegetation of Hungarian karsts is mixed-stand deciduous forest so forest management methods in the past and present are a key issue in today's karst surface

development. On the other hand karst is a special environment with characteristic surface features and special water balance, which needs special considerations in management. This study aims to reveal the similarities and differences of past forest management in the different karst regions of Hungary.

## THE KARSTIC REJUVENATION PROCESSES ON THE ALADAG MOUNTAIN (EASTERN OF CENTRAL TAURUS MOUNTAINS, TURKEY) SINCE THE LAST GLACIAL MAXIMUM

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The karstic processes had been ruled in Aladağ region with the continental conditions for the beginning of the Paleocene-Eocene era in the area. The trace of this term and the later karstification as Later Miocene can be seen on the paleokarstic ore deposits at Aladag region. The morphologic development surfaces can be seen since the Upper Miocene on the area. The Aladag Karst Plateau that bounded with Zamanti River and Ecemiş strike slipped fault zone is also an uplift area on the border of the Central and Eastern Taurus Belts. The plateau consists of two main different parts which are as high altitude karst area and lower fluviokarstic area. The high altitude karst area has been intensively affected from the Quater-

nary glacial processes. The most of glacial were as valley type but also traces of ice cap glacial have been found on the mountain. The resignation of the last glacial was continued till the 7000 year BP. The landforms of epikarst were scraped and plugged through the last glacial period while the glacial were using the mature karstic basin. This processes affected the karst hydrological system and morphological structure as hanged karst springs, un-walled shafts, unroofed caves and polycyclic dolines on the area. The rapid uplift of the plateau according to close region and the glacial flow also caused to deep incision of the Aladag Mountain.

## KARST IN THE CORDISBURGO REGION, MINAS GERAIS STATE, BRAZIL

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The Karst in Cordisburgo is considered to be one of the most significant karst regions in Minas Gerais State, Brazil. It is distinguished for both the magnificent potential of its endokarst and the important archaeological, paleontological, historical and tourist sites it offers. Minas Gerais, the third most important industrial area in Brazil, has intensive farming and mining activities as well. According to the Instituto Brasileiro de Geografia e Estatística (2001), about 35.83% of the economically active population is employed in farming, cattle raising, planting and fishing; 40.70% in the general services; 15.07% in the industrial sector and 8.40% in small commerce sectors, which is basically primary needs-oriented. Although there are some exceptions, this scenario leads to problems with natural resources management, especially in karst areas. Cordisburgo is located at about 110 km north of Belo Horizonte, the Minas Gerais State

capital city, on the Late Proterozoic metasedimentary carbonate rocks of Grupo Bambuí (600-500 Ma B.P.). The predominant climate is typical of tropical regions: two well defined seasons, a characteristic of the Cerrado. The annual temperature average is 22° C and the annual rainfall average is 1230 mm. This particular karst area is characterized by elongated massive limestone reliefs in the E-W direction (maximum height of 1055 m), intercalated by *poljés* (minimum height of 715 m) with temporary lagoons. The endokarst is developed in four main caves with horizontal development equal or superior to 1000 m (Gruta da Morena - 4620 m; Lapa Nova do Maquiné - 1312 m; Gruta do Salitre - 1098 m; Gruta do Toboga - 1000 m). There are also 10 other caves that are developed in limestone. The city of Cordisburgo was first discovered by the 17<sup>th</sup> century explorers called *Bandeirantes*, and later became a settlement which was officially

established by a priest in 1883. The toponym reinforces the sacred meaning of the place: *Cordis* = heart; *Burgo* = city, an allusion to the Sacred Heart of Jesus. In the 19<sup>th</sup> century, this area was studied by Peter Wilhelm Lund, who found important paleontological sites there, such as the Lapa Nova do Maquiné cave (1834). It is important to notice that Lund discovered important evidences of the pre-historic South American fauna from the Pleistocene in this cave. This cave is also known as the first Brazilian touristic cave. In the 20<sup>th</sup> century (1956) the area was described in famous novels by an important Brazilian writer (Guimaraes Rosa), when he wrote about the relationship between farmers and the *sertanejos*, the 'cerrado cowboys' and the landscape. Traditionally the population used the karst waters as their primary resource for agriculture, farming and domestic usage. According to COPASA, the company that provides for water distribution and sewage treatment in the county, the supply comes from a 20.0 l/s outflow well. As a result of the intensive agricultural and farming activities, the drinking water supply of the municipality may be significantly exploited and contaminated. Nowadays, the municipality is investing much more in tourism. Besides all this, there is another important element that points out to the importance of that area conservation: the quarry expansion towards it, which is about to become a reality. Due to these threats, the conservation of this speleological and natural patrimony is urgent. Now the region is being studied by Travassos & Kohler, who are developing a map of the karst phenomena, intended to be the basis for the geo-environmental compartmentation of that region, offering important subsidies for the sustainable management of that environmental scenario, especially for the susceptibility of the karst aquifer to contamination. Processes that are similar to those mentioned by Kovačič and Rav-

bar (2005) take place at Cordisburgo. The presence of a thin soil cover leads to rapid water percolation in plantations and pastures, accelerating the contamination of the aquifer. Other distant areas of non-carbonated rocks may act as allogenic recharge areas that concentrate pollutants from different human activities as well. There are no sanitary landfills to protect groundwater from the leachates in that area. The only solid waste disposal process is an inappropriate site. So, it is important to establish systematic studies in the area and, according to Kranjc (2000, p.123), also invest in the education of all inhabitants, from politicians and experts to pupils who may be of influence to the threat and the protection of karst areas and the water supply. As a starting move "*the most important task is to fill the gap between the karst specialists with their knowledge and "non-karst" specialists, also highly educated, with sometimes striking ignorance of karst and karst water.*" (KRANJC, 2000, p.123).

## REFERENCES

- Kohler, H.C., 1989: *Geomorfologia cárstica na Região de Lagoa Santa-MG*. Doctorate Dissertation. p.113, São Paulo.
- Kovačič, G.; Ravbar, N., 2005: Mapping of hazards to karst groundwater on the Velika Planina Plateau (Slovenia). *Acta Carsologica*, 34/1, p.74-85, Ljubljana.
- Kranjc, A., 2000: Karst water research in Slovenia. *Acta Carsologica*, 29/1, p.117-125, Ljubljana.
- Palmer, A.N., 2001: Dynamics of cave development by allogenic water. *Acta Carsologica*, 30/2, p.13-32, Ljubljana.
- Ravbar, N., 2004: Drinking water supply from karst water resources (The example of the Kras Plateau, SW Slovenia). *Acta Carsologica*, 33/1, p.73-84, Ljubljana

## COMPARATIVE ANALYSIS OF CAVE-PLANTHOPPER RADIATIONS IN AUSTRALIA AND HAWAII — PRELIMINARY RESULTS (HEMIPTERA: FULGOROMORPHA: CIXIIDAE)

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Ongoing studies have revealed numerous cases of parallel evolution of cavernicolous planthoppers all over the world in tropical and subtropical caves. Given that concepts of genetic change and speciation dynamics are subject to review by natural model systems, the comparative

study of these independent evolutionary lineages and radiations can provide critical information.

We survey species complexes from Australian and Hawaiian caves exhibiting different degrees of troglomorphy. In Australia (Qld), *Solonaima* and *Undarana*

species have colonized old karst caves as well as young lava tubes. On the Hawai'ian Islands, the cave-dwelling *Oliarus* species represent at least seven independent cave colonizations on three islands of different age, including the *Oliarus polyphemus* species complex from various, partly still active volcanic systems on Hawai'i Island .

The diversity of external factors (e.g., resource availability and stability, migration possibilities, macro- and microclimatic changes, predators) as well as internal factors (e.g., genetic variability, population structure and density) allows us to incorporate these into concepts of time and mode of evolutionary change in cave organisms.

## THE EARLIEST TIME OF KARST CAVE FORMATION

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Karst cave development in carbonate rock is predicated by the existence of such rock, so the earliest a cave can form is synchronous with carbonate deposition. A hierarchy of cave development conditions can be established based on the postdepositional evolution of carbonate porosity into three time-porosity stages that conform to the rock cycle as stated by Choquette and Pray (1970, p. 215): "the time of early burial as eogenetic, the time of deeper burial as mesogenetic, and the late stage associated with erosion of long-buried carbonates as telogenetic". In diagenetic order, from immature to mature host rock, a progression can be established:

A) Eogenetic Caves - The carbonate rock is in its environment of deposition; cave development can be presented as three progressive stages:

1) Constructional - Caves formed by deposition of a soluble rock at the instant the rock is deposited. Example: Tufa caves; the rock is the end product of earlier carbonate dissolution but the void itself not produced by dissolution.

2) Syndepositional - Caves formed by dissolution while rock deposition is occurring. Examples: Caves formed in lagoonal carbonate sands when beach sands prograde over them, or eolian calcarenites deposited across existing surface stream channels.

3) Syngenetic - Caves formed subsequent to deposition by dissolution while rock lithification is occurring. Examples: Eolian calcarenites invaded by a fresh-water lens and mixing zone, or subtidal carbonates exposed to meteoric water by uplift associated with tectonics and/or glacioeustasy.

B) Mesogenetic Caves - The carbonate rock is buried, isolated from surficial processes, and undergoing diagenetic maturation. By definition, all karst caves developed in mesogenetic rocks are hypogenic.

C) Telogenetic Caves - The carbonate rock is diagenetically mature and exposed to the surficial weathering environment.

A fourth category, *metamorphic*, could address caves formed in carbonates that have been metamorphosed into marbles. The hierarchy does not require a fixed chronology. Geologic processes operate at different rates in different areas. For example, some New Zealand Oligocene carbonates are telogenetic as a result of the vigorous tectonic burial and uplift, while rocks of similar age in Florida are still eogenetic. The age of the rock can be misleading, what is important is the diagenetic character of the rock at the time of cave genesis.

## THE DINARIC KARST EVOLUTION – THE CAVE SHRIMPS’ MOLECULAR AND GEOLOGICAL POINT OF VIEW

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The cave dwelling shrimps of the genus *Troglocaris* show a disjunct distribution in European karstic groundwaters: in the Dinaric Karst on the Balkan Peninsula, on the West Caucasus and in South France. The phylogenetic relationships within the genus based on the sequences of two mitochondrial and one nuclear gene showed a monophylum with two main lineages constituted of the Dinaric and Caucasian taxa. Both lineages have geographically largely separate ranges: one is extending from Italy to Bosnia and Herzegovina and the other from Bosnia and Herzegovina and Montenegro over Caucasus. Absolute dating of phylogenetic events is possible by using calibration points from the fossil record or vicariant events. In the atyid shrimps, or even more ideally in the *Troglocaris* group, points like that are not available. Therefore the molecular clock approach has been used to estimate the divergence dates among the clades. The divergence dates were estimated using substitution rate divergences previously defined in other decapods. The split between *T. inermis* from France and the surface-living *Dugastella valentina* from Spain is about 10 Myr old, but they had common predecessor with Dinaric and Caucasian *Troglocaris* taxa in the middle Miocene, about

15 Myr ago. The most unexpected is a relatively young split between Caucasian and Dinaric *Troglocaris* populations that was estimated at 6-11 Myr. The Dinarides represent a complex land formed during the Tertiary and Quaternary. The tectonics strongly controlled the formation of many small Neogene basins within the Dinarides which were geological characterized by fresh-water sedimentation. The analysis of faunal characteristics which occurred in sediments in the Neogene fresh-water basins within the Dinarides showed many similarities between North Croatian Basin and Northern Bosnia region. The higher number of deep splits within the cave shrimps in the southern Dinaric Karst might be a result of the Miocene Dinaride lake system geographically comprising parts of Croatia, Bosnia-Herzegovina and Montenegro, where *Troglocaris* lineages are taxonomically more diverse than in the NW part of Dinaric Karst. Younger lineages within *Troglocaris* are congruent with hydrographically isolated areas in the Dinaric Karst. All age estimates are rough, calibration point within the Dinaric Karst would enable us to develop a more precise dating of a cladogenic events for *Troglocaris* and other cave taxa in the area.

## CHANGE DETECTION AND TIME-SERIES FROM AERIAL-, AND SATELLITE IMAGES ON THE BÜKK-PLATEAU (BÜKK-FENNCSÍK), HUNGARY

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The most common form of land use in Hungarian karsts is woodland. An integrated forest management taking into account considerations of environmental protection as well could insure the conservation of karsts in a near-natural state. Before World War II, the forests of the Bükk Mountains were owned by the state. While earlier the forests were mainly cut down to increase the area suitable for grazing, after the war deforestation followed due to a highly increased claim for wood production. The exploitation of forests also had an impact on

their age composition. The foundation of the Bükk National Park in 1977 meant a turning point in the history of the area's forests, introducing the concept of sustainable management.

In this study we compared time-series of aerial images in order to follow changes in the investigation area. These images were taken by the military cartography in the years 1956, 1965, 1975, 1987, 1988, 2004, related to the revision of earlier maps. We define the horizontal and vertical changes of the area such as increase the net of the

forestry roads which is close-textured that even before, and the height of forest based on digital surface models which contain the height of the trees above the digital

elevation model. The species composition of the stands was defined by the supervised classification of Landsat satellite imagery.

## TIME RECORDED IN CAVE DEPOSITS – 10 YEARS OF PALEOMAGNETIC RESEARCH IN SLOVENIAN CAVES

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The palaeomagnetic and magnetostratigraphic research of karst deposits has been carried out since October 1997 in 17 caves and 2 surface sites located in different geological units and geographical settings of Slovenia. Totally 33 sedimentary profiles and more than 2,000 samples have been sampled and processed by the standard palaeomagnetic analyses (thermal and alternating field demagnetisation, magnetic susceptibility measurements, etc.).

After the last massive marine transgression during Eocene, when thick pile of flysch siliciclastics deposited, in the most of the area studied, there is no evidence of younger marine sediments, even if they have been expected by some authors (e.g., Rögl 1998). The area was thus exposed to denudation. Correlate sediments preserved in isolated basins in vicinity, belonging to Miocene Paratethys deposits, are about 6-10 Ma old (e.g., Márton *et al.*, 2002).

Cave karst deposits (both clastic and chemogenic) offer the record of processes, which evidences have not been preserved on the surface of most of karst regions of Slovenia and can help to decipher the younger geological and tectonic history.

The start of our paleomagnetic and magnetostratigraphic research was framed by chronostratigraphic models of cave infilling compiled by Rado Gospodarič (e.g., 1981, 1985, 1988) from different sources and applied methods. He dated cave deposits to period up to 350 ka and only some deposits were expected to be older (ca 600-900 ka; e.g. Gospodarič 1985). But later data of Th/U dating of speleothems from different Slovenian caves (Zupan 1991, Mihevc 2001) indicate that a lot of speleothems are older than explained by Gospodarič. Even much greater age of caves and karst surfaces suggest the studies of unroofed caves. With assumption that the caves were developed deep below surface and considering recent denudation rate these caves and sediments in them can be 1 – 5 Ma years old (Mihevc 1996, 2001).

Performed paleomagnetic and magnetostratigraphy studies, combined by numerical dating methods, mineralogical, petrological, geochemical, paleontologi-

cal and geomorphological analyses, offered surprisingly new time frame for cave depositional processes – they proved that most of analyzed sediments can be up to several millions of years old, including sites studied by Rado Gospodarič. The oldest paleontologically correlated ages have been found in the Račiška pečina Cave in the Classical Karst – about 3.5 Ma.

The obtained data of correlated- and numerical-ages of cave/karst deposits supported the new trends and ideas concerning the evolution of karst surfaces especially in the region of the Classical Karst, indicated that cave deposits occurring now in different altitudes can be of the same age, and proved that deposits in caves, now unroofed, are very ancient.

### REFERENCES

- Gospodarič, R., 1981: Sinter generations in Classical Karst of Slovenia. *Acta Carsologica*, 9, 87-110, Ljubljana.
- Gospodarič, R., 1985: On the spelogenesis of Divaška jama and Trhlova Cave. *Acta Carsologica*, 13, 5-32, Ljubljana.
- Gospodarič, R., 1988: Paleoclimatic record of cave sediments from Postojna Karts. *Ann. Soc. geol. Belg.*, 111, 91-95.
- Márton, E., Fodor, L., Jelen, B., Márton, P., Rifelj, H. & Kevric R., 2002: Miocene to Quaternary deformation in NE Slovenia: complex paleomagnetic and structural study. *J. Geodynam.*, 34, 627-651.
- Mihevc, A., 1996: Brezstropa jama pri Povirju. *Naše jame*, 38, 65-75, Ljubljana.
- Mihevc, A., 2001: Speleogenesis of the Divača Karst. The Publishing House of the Scientific Research Center of SASA, 180 pp, Ljubljana.
- Rögl, F., 1998: Palaeogeographic Considerations for Mediterranean and Paratethys Seaways (Oligocene to Miocene). *Ann. Naturhist. Mus. Wien*, 99 a, 279-310, Wien.
- Zupan, N., 1991: Flowstone datations in Slovenia. *Acta Carsologica*, 20, 187-204, Ljubljana.

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