Potential effects of agriculture on karst records, a preliminary outlook based on the Milandre test-site (JU, Switzerland)

Jeannin, P.-Y., Eichenberger, U. *Hessenauer, M. & **Meury P.-X.

Swiss Institute for Speleology and Karst-studies (SISKA), La Chaux-de-Fonds, Switzerland

**MFR Géologie-Géotechnique SA, Delémont, Switzerland*

***Géo & Environnement, Delémont, Switzerland*

Introduction

Several processes of the Earth environment evolution are recorded in Karst, making this environment of increasing interest for paleo-environment reconstructions (e.g. Sasowsky & Mylroie 2004). A large number of investigations have been and are still being dedicated to paleoclimate reconstruction, mainly using speleothems for this purpose. Such studies aims at documenting the past natural climate variations of the Earth.

Some authors attempted to observe effects of human activities on karst records. Perette *et al.* (1997) showed in stalactites of the Choranche cave (France) indications of the coal extended use at the beginning of the industrial development. Other authors investigated recent speleothems in order to calibrate investigation methods (Baker & Smart 1995). Frisia *et al.* (2005) used sulfur variations in speleothems to identify a strong sulphate variation in the atmosphere since 1850.

Observations

Our investigations in the Milandre cave tend to demonstrate some effects of agriculture on karst and caves. If we hypothesize that agriculture increases soil erosion and CO_2 production in soils, we can expect to see consequences in caves. This short note attempts to synthesise preliminary observations made in Milandre. A description of the cave can be found in Gigon & Wenger (1986).

Silt and clay deposits

The most striking feature in Milandre cave is its clogging by silt and clay, especially in the downstream part of the cave. The origin of this material is clearly the soils (unpublished reports). Equipments in the cave entrance part have been installed since the end of the 19th century and deeper in the cave in the 1960ies. Some equipment is now covered by more than 20 cm of sediment, which seems to have been deposited mainly since the 1970ies. A first study of the sediment deposition dynamic in the cave, shows the process to be quite complex, because highly variable in space and time. In space, parts of the cave are being progressively filled up by sediment, because they are flooded during high water stages, but not traversed by significant flow velocity at any time. Other parts are more or less in equilibrium, i.e. erosion compensates the deposition. Finally, some channels are continuously traversed by a flow velocity high enough to prevent any sedimentation of fine material. Deposition also strongly varies in time because the flow velocity depends on the flow conditions (range of variation in the order of 1 to 100 between low and high water stages), but also on the hydraulics of flow (the flooding of passages during high water conditions induces a strong increase of the flow cross-section and therefore a very low flow velocity). In fact two types of accumulations are observed. The first type is represented by pools in permanently active conduits where flow velocity is low during low water conditions with accumulation of sediment mainly during the summer season. During high water event, sediments are eroded by high flow velocity. Only long term monitoring of the discharge rates and heads (pressure) in the system may provide data for really documenting any change in this system.

The second type is represented by flooding zones where no flow (dry conduits) occurs at low water stages and flooding, with much water but large flow cross-section and therefore low velocity, occurs during high water events. Along the last 40 years, it seams that this type of accumulation increased. This will be confirmed or rejected by sedimentological observations, which are currently in progress.

Particle fluxes

Particles in groundwater are being monitored since about 10 years within the framework of the environmental impact study related to the transjurane highway (A16), which is being built on top of the Milandre cave. Particle fluxes are measured continuously using water turbidity at several locations along the underground stream. Particles are also trapped and analysed with respect to their composition.

A first quantification of the particle flux in the underground river suggests an erosion rate of 3 to 5 mm of soil per year, which is close to the highest rates given in the literature for soils having a vegetation cover (Lamontagne 2005).

Although many data are available it is very difficult to identify a real evolution of the particle flux because our time series is too short and subject to very high natural variations compared to the expected evolution.

Speleothems coated by mud

Milandre cave is one of the most decorated caves in Switzerland, most speleothems develop in the part of the cave which is not flooded during high water conditions. However many speleothems appear to be coated by thin mud deposits, which look quite recent. At some places it could be related to extremely high flood events, however it cannot be assumed in all places.

Soil PCO_2 and the deposition of speleothems

Data from Perrin (2003) showed that CO_2 partial pressure in cultivated soils of the Milandre area is much higher (3 to 5 %) than that of forest soils (0.5 to 1.5 %). In the cave, values up to 2.5 % have been measured (Perrin, 2003 and our own measurements). Perrin (2003) also observed that percolation water into the cave is supersaturated with respect to calcite at all analysed water inlets (at ten different locations). As agriculture probably increased the average soil pCO_2 above the cave, speleothems are supposed to grow faster than before and cave atmosphere to be enriched in CO_2. As we don't have CO_2 measurements in the cave prior to 2001 we cannot document any evolution in this value at present.

In some places speleothems are corroded by water inlets. This can be due either to a decrease in the soil CO_2 partial pressure or to an increase of the cave CO_2 partial pressure, or both simultaneously. Chemistry and origin of these percolation waters should be investigated in further details.

Water characteristics and speleothems

Groundwater characteristics are obviously different below forests, pastures and cultivated lands respectively (Perrin, 2003). Enrichments in NO_3^-, SO_4^{2-}, CL^- and somehow in $Mg^{2+,}$ Na^+ and K^+ are observed below cultivated land compared to forested areas. This is very probably recorded in speleothems, but was not measured in Milandre cave so far.

Although soil pCO_2 are strongly contrasted between forest and cultivated soils, the hardness (or TDS) of the water percolation does not present significant differences between the two types of regions. This fact is unexpected and not explained so far.

Outlook

This short note provides a series of indications concerning the very probable effects of agriculture on karst, and especially on environmental records in karst. These effects are mainly:

- an increase of silt and clay deposition rates in caves on speleothems, which is related to soil erosion enhanced by agriculture;
- a change in the chemical content of infiltration water, inducing variations (growth rate and composition) in the deposition of calcite in speleothems.

Although quite preserved from the outside activities caves are linked to landsurface and especially soil characteristics. If recent activities appear to have left very clear indications in cave records, one can expect to be able to identify human implementation all over a (karst) region by studying cave sediments in more details (e. g. McFarlane 2005).

REFERENCES

Sasowsky, I. D. & Mylroie, J. (2004): Studies of cave sediments, physical and chemical records of paleoclimate. Kluwer Academic/Pelnum Publishers, New York: 329 p.

Perette, Y., Delannoy, J.-J., Genty, D., Destombes, J.-L. & Quinif, Y. (1997): Enregistrement de l'activité charbonnière dans les spéléothèmes de Choranche (Vercors, France). Proc. 12th Congr. of Speleol., Switzerland, vol. 1 : 61-64.

Baker, A. & Smart P. L. (1995): Recent flowstone growth rates: Field measurements in comparison to theoretical predictions. Geology, vol. 122: 121-128.

Frisia, S., Borsato, A., Fairchild, I. & Susini, J. (2005): Variations in atmospheric sulphate recorded in stalagmites by synchrotron micro-XRF and XANES analyses. Earth and Planetary Science Letters, 235 (2005), 729-740.

Gigon, R. & Wenger, R. (1986): Inventaire spéléologique de la Suisse, tome II, canton du Jura. SHSN, Porrentruy : 291 p.

Lamontagne Denys, 2005: Cours sur l'érosion des sols, http// :thot.cursus.edu/rubrique.asp?no=22063.

Perrin, J. (2003) : A conceptual model of flow and transport in a karst aquifer based on spatial and temporal variations of natural tracers. PhD Thesis, University of Neuchâtel, available at http://www2.unine.ch/Jahia/site/biblio/op/edit/pid/4367.

Mc Farlane, D., Lundberg, J. & Cordingley, J. (2005): E brief history of stalagmite growth measurements at Ingelborough Cave, Yorkshire, United Kingdom. Cave and Karst Science, vol 31, Nr 3: 113-118.