References

BASILE I., 1997. Origine des aérosols volcaniques et continentaux de la carotte de glace de Vostok (Antarctique). Laboratoire de Glaciologie et Geophysique de l'Environment (LGGE). Grenoble, Université Joseph Fourier - Grenoble.

BRIAT M., ROYER A., PETIT J.R. and LORIUS C., 1982. Late glacial input of eolian continental dust in the Dome C ice core: additional evidence from individual microparticle analysis. *Annals of Glaciology*, 3: 27-30.

COHMAP, 1988. Climatic changes of the last 18000 years: observations and model simulations. *Science*, 241: 1043-1052.

De ANGELIS M., LEGRAND M., PETIT J.R., BARKOV N.I., KOROTKEVITCH Y.S. and KOTLYAKOV V.M., 1984. Soluble and insoluble impurities along the 950 m deep Vostok ice core (Antarctica) - Climatic implications. *Journal of Atmospheric Chemistry*, 1: 215-239.

De ANGELIS M., BRKOV N.I. and PETROV V.N., 1987. Aerosol concentrations over the last climatic cycle (160 kyr) from an Antarctic ice core. *Nature*, 325 (6102): 318-321.

FUHRER K., WOLFF E.W. and JOHNSEN S.J., 1999. Timescales for dust variability in the Greenland Ice Core Project (GRIP) ice core in the last 100000 years. *Journal of Geophysical Research*, 104(D24): 31043-31052.

GAUDICHET A., PETIT J.R., LEFEVRE R. and LORIUS C., 1986. An investigation by analytical transmission electron microscopy of individual insoluble microparticles from Antarctic (Dome C) ice core samples. *Tellus*, (38B): 250-261.

GAUDICHET A., ANGELIS M.D., LEFEVRE R., PETIT J.R., KOROTKEVITCH Y.S. and PETROV N.V., 1988. Mineralogy of insoluble particles in the Vostok Antarctic ice core over the last climatic cycle (150 Kyr). *Geophysical Research Letters*, 15(13): 1471-1474.

GAUDICHET A., ANGELIS M.D. et al., 1992. Comments on the origin of dust in East Antarctica for present and ice age conditions. *Journal of Atmospheric Chemistry*, 14: 129-142.

HAMMER C.U., CLAUSEN H.B., DANSGAARD W., NEFTEL A., KRISTINSDOTTIR P. and JOHNSON E., 1985. Continuous impurity analysis along the Dye 3 deep core. *Greenland Ice Core: Geophysics, geochemistry and the Environment*, 33: 90-94.

HANNSON M.E., 1994. The Renland ice core. A northern hemisphere record of aerosol composition over 120000 years. *Tellus ser.*, B(46B): 390-418.

JOSSAUME S., 1990. Three-dimensional simulation of the atmospheric cycle of desert dust particles using a general circulation model. *Journal of Geophysical Research*, 95: 1909-1941.

KUKLA G., 1989. Long continental records of climate - an introduction. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 72: 1-9.

MOUNIER L., 1988. Etude des microparticules insolubles deposées dans la glace Antarctique au cours du dernier cycle climatique. LGGE. Grenoble I, Université Joseph Fourier.

PETIT J.R., BRIAT M. and ROYER A., 1981. Ice Age aerosol content from East Antarctic ice core samples and past wind strength. *Nature*, 293(5831): 391-394.

REA D.K., 1994. The paleoclimatic record provided by eolian deposition in the deep sea: the geologic history of wind. *Rev. Geophys.*, 32(2): 159-195.

ROYER A., ANGELIS M.D. and PETIT J.R., 1983. A 30000 year record of physical and optical properties of microparticles from an East Antarctic ice core and implications for paleoclimate reconstruction models. *Climatic Change*, 5: 381-412.

STEFFENSEN J.P., 1997. The size distribution of microparticles from selected segments of the Greenland Ice Core Project ice core representing different climatic periods. *Journal of Geophysical Research*, 102(C12): 26,755-26,763.

YUNG Y.L., LEE T., WANG C.H. and SHIEH Y.T., 1996. Dust: a diagnostic of the hydrologic cycle during the Last Glacial Maximum. *Science*, 271: 962-963.

Speleothems and Upper Pleistocene Climate - New Results from Caves in Germany

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ABSTRACT. Here we present and discuss new dating results obtained from speleothems of caves in southern Germany. So far, four stalagmites from three caves have been dated by the Uranium-series TIMS (Thermion Mass Spectrometry) method. Their dates range from MIS 5e to MIS 2. Two stalagmites from the Klaus-Cramer Cave in the Bavarian Alps yielded ages around 125 ka BP. The Upper Pleistocene part of a stalagmite from the Sontheimer Cave (Swabian Alb) grew throughout MIS 5. A stalagmite from the Hintere Kohlhalden Cave (Swabian Alb) started to grow 21 ka BP, i. e. during the Dansgaard/Öschger Interstadial 2.

KEY WORDS: speleothems, Uranium-series (TIMS) dating, Upper Pleistocene climate, South Germany.

Introduction

In 1999 our two groups (Kempe and Rosendahl, Univ. of Technol. Darmstadt; Eisenhauer, GEOMAR, and Wiegand, Univ. of Göttingen) began to cooperate in a project entitled "Sinter and Palaeoclimate in Central Europe during the Pleistocene". The project mainly focuses on the analysis of speleothemes from caves in different German karst regions (Kempe and Rosendahl, 1999). To start we focused on samples from southern Germany, i.e. the Franconian- Swabian Alb (with more than 6000 recorded caves the largest and one of the best-known karst areas of Germany) and the Bavarian Alps.

Methods and material studied

The samples were taken from four complete stalagmites of various sizes. In order to establish the time of onset and end of the growing phases, we first dated the base and the tip of each stalagmite by the Uranium-series/TIMS (thermal ionisation mass spectrometry) method.

Two small stalagmites, 4 cm wide and 6–8 cm long, (KCH-A and KCH-B) were taken in the Klaus-Cramer Cave in the Bavarian Alps (Allgäu/Gottesackerplateau), 2000 m a.s.l. (Rosendahl, 1997). The cave is rich in speleothems in some places and shows at least three different generations of growth. First dates of around 200 ka BP suggest that the oldest generation is of Middle Pleistocene age (MIS 7) (Rosendahl et al., 1998).

Two stalagmites were taken from two caves in the Swabian Alb. The first sample, a 30 cm long and 15 cm wide stalagmite (SHSi1), was collected from a pit in the Sontheimer Cave, which was primarily filled with breccia-like sediments (Höhlenverein Sontheim, 1997). The second sample, a candle-like stalagmite (HKHSi1) with a total length of 150 cm, comes from the Hintere Kohlhalden Cave, 100 m S of the Sontheimer Cave (Höhlenverein Sontheim, 1997). Each of the stalagmite was cut into two halves. We took dating samples from one of the halves and used the other one for geochemical (O, C and Sr isotopes, AAS), mineralogical (FTIR-Spectroscopy) analyses and layer counting.

Results and analyses

The stalagmite KCH-B yielded an age of 126,540 +739/-743 years BP. Stalagmite KCH-A was dated to 155,270 +458/-460 years BP. This sample, however, has lost uranium secondarily so that its age is probably too old and we have to assume that KCH-A has the same age as KCH-B. The internal structure of stalagmite SHSi1 shows two different growing phases. The older one (phase 1; SHSio) suffered secondary loss of uranium and cannot be dated. The first layers of the second phase (SHSia) yielded an age of 125,746 ± 1018 years BP. Three further age determination above that sample yielded ages of 109,484 ± 4553 years BP (SHSib) and 79,264 ± 2744 years BP (SHSic). The layer closest to the surface gave, however, an older age again, i.e. 139,720 ± 9076 years BP (SHSid). From the 150 cm long stalagmite HKHSi1 we have so far only ages for its base and tip. The base yielded an age of 21,000 ± 975 years BP, and the tip an age of 2772 ± 101 years BP. The geochemical and mineralogical analyses are still being processed.

Discussion and conclusions

The stalagmites KCH-A and KCH-B as well as the oldest layers of the second phase in sample SHSi1 correspond to the onset the last Interglacial (MIS 5e), the Eemian. The further dates of sample SHSi1 fall into the range of the Brörup - (MIS 5c) and of the Odderade - Interstadial (MIS 5a). The date of the outer layer is obviously too old. The surface shows traces of solution and corrosion and the stalagmite has been covered with sediments. This suggests, that it has been subject to dissolution and secondary Uranium leaching.

Within the Phase 2 layer of SHSi1 no growth hiatus can be seen, suggesting, that it grew continuously from MIS 5e to MIS 5a. The sediments, which covered the stalagmite and caused leaching and corrosion in its outer layer, could have entered the cave by solifluction during the colder climate of MIS 4 or 3. The stalagmite HKHSi1 from nearby Hintere Kohlhalden Cave stood on the same kind of sediments caused by solifluction. Its date of 21 ka BP for the onset of its growth came as a surprise since it is close to the Last Glacial Maximum. At this time we do not have reason to believe that it is a measurement artefact, nevertheless it must be viewed with caution. We would have expected that the Upper Pleistocene climate 25 to 15 ka ago would have sustained deep-seated permafrost in the region of the Swabian Alb. Under such conditions, speleothem formation should have ceased If, however, our date proves to be correct, then either the period of permafrost was shorter than so far assumed or permafrost coverage may have been discontinuous. Meanwhile a similar date has been obtained from a stalagmite from the Arbeitslosen Cave/Swabian Alb (personal communication T. Abel, Tübingen), which supports our conclusion of an early demise of the continuous permafrost coverage. Onset and fading of permafrost presumably is responsible for the termination and beginning of sinter formation periods in Central Europe. Furthermore, ice formation caused wide-spread damage to cave sinter, effectively removing all pre-Holocene stalactites from the cave ceilings and breaking and overthrowing even large stalagmites (Kempe, 1989).

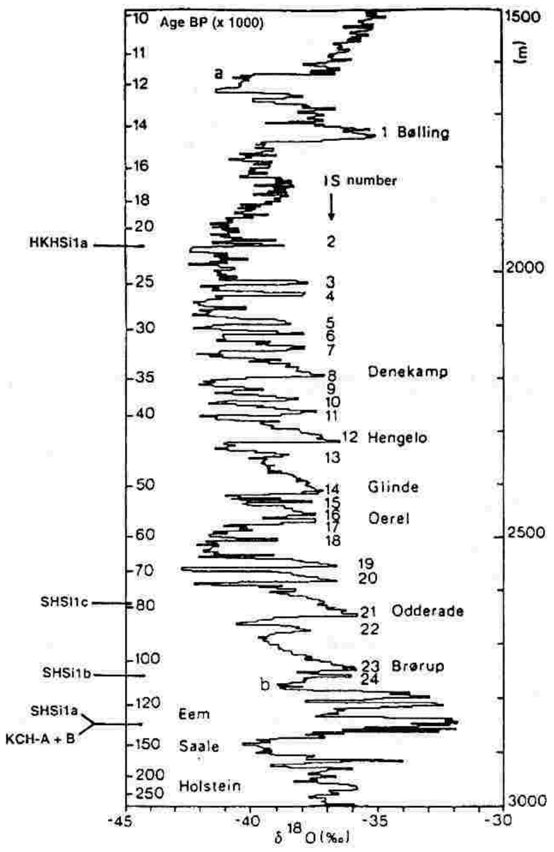

Fig. 1. Oxygen-isotope ($^{18}O/^{16}O$) record from the GRIP ice core (after Dansgaard et al., 1993) and the positions of the reported speleothem data.

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References

DANSGAARD W., JONSEN S.J., CALUSEN H.B., DAHL-JENSEN D., GUNDESTRUP N.S., HAMMER C.U., HIVDBERG C.S., STEFFENSEN J.P., SVEINBJÖRN-DOTTIR A.E., JOUZEL J. and BOND G., 1993. Evidence for general instability of past climate from a 250-kyr ice-core record. *Nature*, 364: 218-220.

HÖHLENVEREIN SONTHEIM e.V. (Hrsg.), 1997. Führer durch die Sontheimer Höhle. Heroldstatt.

KEMPE S., 1989. Sinterschäden: verursacht durch Permafrost oder Erdbeben? *Mitt. Verb. Höhlen u. Karstforsch.*, 35: 87-90.

KEMPE S. and ROSENDAHL W., 1999. Speläotheme als pleistozäne Klimaarchive in Mitteleuropa. *Mitt. Verb. dt. Höhlen u. Karstforsch.*, 45(2): 100-101.

ROSENDAHL W., 1997. Höhlen- und Karstforschung am Hochifen-Gottesackerplateau/Allgäu. Kongressakten zum 10. nat. Kongress der Schweizer Gesellschaft für Höhlenforschung (SGH) in Breitenbach 1995, Birkhäuser Verlag, Basel, pp. 180-182.

ROSENDAHL W., EISENHAUER A. and WIEGAND B., 1998. Erste Ergebnisse von TIMS U/Th-Datierungen an Speläothemen aus einem Höhlensystem des Gottesackerplateaus (Kleinwalsertal/ Allgäuer Alpen). *Mitt. Verb. dt. Höhlen u. Karstforsch.*, 44(4): 134-138.

Oxygen Isotope Climatic Record in a Carbonate Flowstone Layer from a Medieval Underground Mine in the Kutná Hora Ore District

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ABSTRACT. The 37 cm thick carbonate flowstone layer found in a gallery of abandoned medieval mine in the Kutná Hora ore district (65 km E of Prague) started to grow about 500 years ago. Re-opening of the gallery in the 1960s terminated its growth. The relationship of calcite $\delta^{18}O$ to climatic changes was studied in a vertical profile (42 samples), covering the whole thickness of the flowstone layer. Assuming constant growth rate, an arbitrary time scale was attributed to individual sampling points. The oxygen isotopic data of flowstone were compared with temperature data published by Brázdil (1994) and Mann et al. (1999), and with isotope temperature obtained from $\delta^{13}C$ values for tree-rings from the Black Forest (Lipp et al., 1991). These comparisons show that changes in the $\delta^{18}O$ values of flowstone were dominantly controlled by changes in $\delta^{18}O$ values of water feeding the gallery. A good agreement between the $\Delta\ \delta^{18}O$ curve and the curve for summer temperature indicates that summer precipitation was the main source of water penetrating into gallery.

KEY WORDS: carbonate flowstone, oxygen isotopes, climate, medieval mine.

Introduction

In 1967, a hydrological 22 m deep shaft located in the historical centre of the mining town Kutná Hora (65 km E from Prague) revealed partly flooded underground passages of a medieval mine in the Osel ore belt. One of the important phenomenons observed in the medieval gallery was the presence of rich calcite dripstone decoration including floor flowstones up to 37 cm thick. Samples of the flowstone were taken for a stable isotope investigation.

Medieval galleries of the Ag (± Zn, Pb, Cu) ore zone Osel discovered in 1967 were later partly drained by cleaning of a medieval adit about 250 m long, which today represents the only entrance into the mine (Pechoèová and Hoffmanová, 1991). This adit, 0.5–1.0 m wide and 1.5–2.5 m high, is nearly horizontal and follows a local first-order geological and hydrological boundary between the folded, high-grade metamorphosed and faulted gneissic basement and the overlying horizontally layered Cretaceous platform sediments. At the boundary a transgression horizon of Cretaceous conglomerates is typically developed. The total thickness of Cretaceous rocks above the studied mine level varies between 12 and 20 m. The Cretaceous rocks are represented mainly by sandstone with calcite cement, containing from 15 to 30 wt.% calcite. Dripping water penetrates into the gallery in many places, locally forming larger inflows of up to 0.3 l/sec. Today, the entire system is drained through the old draining adit; deeper levels are filled with water. The area above the studied mine belongs to the historical town centre.

Methods and material studied

The flowstone, which was precipitated on the gallery floor, is composed of several white-yellowish layers formed by hard, porous, dendritic calcite crystals with indistinct banding. Calcite crystals grew under water. Two block samples (A and B) were cut out from different places of the flowstone and used for