# A HIGH-RESOLUTION STABLE ISOTOPE RECORD FROM A PERUVIAN STALAGMITE

Martin van Breukelen[1], Hubert Vonhof [1], Lidia Romero Pittman[2] & Dick Kroon [1]

[1] Vrije Universiteit Amsterdam, Faculty of Earth and Life Sciences, De Boelelaan 1085, 1081HV, Amsterdam, The Netherlands.
phone: +31 (0)20 4447251, fax +31 (0)20 6462457 . E-mail: martin.van.breukelen@falw.vu.nl
[2] Instituto Geológico Minero y Metalúrgico, Avenida Canadá 1470, San Borja, Lima 41, Perú.

## INTRODUCTION

Speleothems are known as carbonate formations in caves. The last few years there is a growing scientific interest in speleothems for climate reconstruction (McDermott, in press; Sancho et al., in press; Jiménez de Cisneros et al., 2003; Genty et al., 2003; Baker et al., 2002; Proctor et al., 2002; Linge et al., 2001; Wang et al., 2001). Speleothems have proven their potential to create a terrestrial high-resolution paleo-temperature record (Schwarcz, 1986). The advantage of caves for paleoclimatic studies is the yearly stability of climatic conditions in the cave (Jiménez de Cisneros et al., 2003). Observations have shown that the temperature in any deep cave is close to the mean annual temperature of the surrounding (Schwarcz et al., 1976; Yonge et al., 1985). This makes speleothems a successful tool paleo-temperature reconstruction (Hendy and Wilson, 1968). The carbonate, of which the speleothem is build, can be used for stable isotope measurements ($\delta^{13}C$ and $\delta^{18}O$). Oxygen isotopes are world-wide used to reconstruct paleo-temperatures, especially for biogenic carbonate in marine cores. Precise age-dating on speleothems can be done by U-Th measurements on TIMS, which makes it possible to calculate absolute ages for the isotope record.

Hendy (1971) describes how the reliability of the isotope measurements on speleothems can be tested. Simultaneous enrichment of $^{13}C$ and $^{18}O$ occurs by kinetic fractionation, which should result in a clear correlation between $\delta^{13}C$ and $\delta^{18}O$. Kinetic fractionation can occur under different circumstances. Rapid loss of $CO_2$ from dripwater causes a kinetic fractionation between $KCO_{3-}$ and $CO_{2(aq)}$, the precipitated carbonate will show a simultaneous enrichment in $^{13}C$ and $^{18}O$. Evaporation of dripwater also causes kinetic fractionation resulting in simultaneous enrichment in $^{13}C$ and $^{18}O$. This takes place due to evaporation or rapid loss of $CO_2$, fractionation occurs within one growth layer of a stalagmite. It takes place in the waterfilm covering the stalagmite. A water film layer thinner then ~1mm exchanges too much $CO_2$ with the atmosphere and shall fractionate from the centre of the stalagmite to the edge. To fulfil the 'hendy' criteria samples of the same growth layer must give the same isotopic values. The isotopic variation within one growth layer is equal to the external reproducibility of the mass-spectrometer.

Figure 1, Map of Peru; Cuevas de Las Lechuzas is marked with a white star.

The speleothem used for this research is a stalagmite from Peru, collected from the cave "Cueva de las Lechuzas". This cave is located in the centre of Peru (S09˚19'44.4", W76˚01'37.5"), near the town of Tingo Maria at ~750 meters above sealevel (Figure 1). The stalagmite is ~20cm long and well layered. The stalagmite is transparent with a yellow colour (figure 2). The humidity in the room is 88% with a temperature of 24.5˚C. Due to the high humidity little evaporation thus fractionation occurs.

## METHODS

Out of the stalagmite collected from Cueva the las Lechuzas a ~1cm thick slice was cut and polished at the Vrije Universiteit Amsterdam (VUA). Thin sections of 300 µm were made and a light microscope was used to check the petrography. No petrographic evidence for diagenetic overprints was found. Periods of growth termination, related with large time-gaps are not found either. After this check five U-Th disequilibrium age-datings were measured on a TIMS. Ages were in chronological order and showed a relatively constant growth pattern of the stalagmite (Figure 3). This supports that the stalagmite had no large hiatuses or diagenetic overprints

0.5 cm sampling resolution was carried out over the complete length of the stalagmite. Two additional high-resolution series at the top were drilled using a Mechantek Micromill microsampler with a resolution of 70 and 50µm respectively. Stable isotope measurements were carried out every 140 and 100 µm. This high-resolution profile was analysed to resolve possible climate variations over the last centuries. $\delta^{18}O$ and $\delta^{13}C$ of the carbonate samples were measured at the VUA on a Finnigan MAT 252 mass-spectrometer, equipped with a Kiel device. GICS carbonate standard is routinely monitored during sample runs. GICS long-term reproducibility lies within 0.07‰ for $\delta^{18}O$ and 0.04‰ for $\delta^{13}C$.

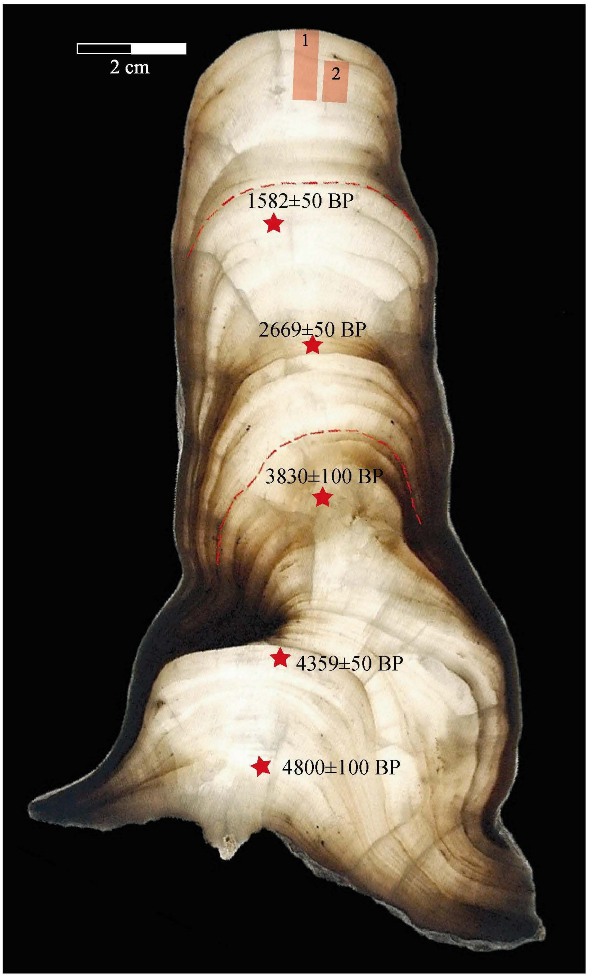

Figure 2, Transparent 1cm thick slap of the stalagmite CLL-1 collected from Cueva de Las Lechuzas. Series 1 & 2 are drilled in the shaded red area

In figure 3 the Uranium-Thorium ages are plotted versus distance. This gives an indication of the growthrate of the stalagmite and the time-resolution of our isotopic measurements. For the five intervals between the U-Th ages the growthrate is calculated in table 1.

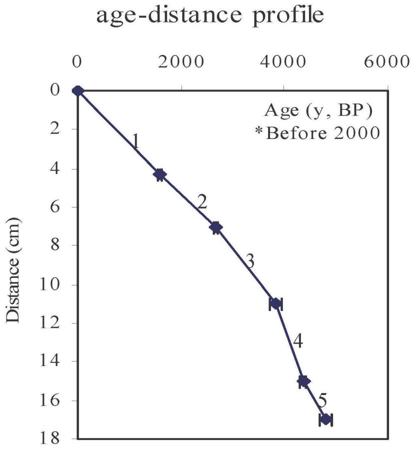

Figure 3, U-Th ages versus distance. Three periods are marked. Growth rates can be found in table 1.

| Distance (cm) | U-Th-age (BP=2000) | Error | Period | Growth-rate µm/year |
|---|---|---|---|---|
| 4.25 | 1582 | 50 | 1 | 27 |
| 7 | 2669 | 50 | 2 | 25 |
| 11 | 3830 | 100 | 3 | 34 |
| 15 | 4359 | 50 | 4 | 76 |
| 17 | 4800 | 100 | 5 | 45 |

Table 1, U-Th ages and growthrates.

## DISCUSSION AND CONCLUSION

The 0.5 cm resolution series shows a rapid shift to lighter $\delta^{18}O$ values around 4000 BP (figure 4). We interpret this as a shift to wetter conditions because the $\delta^{18}O$ of rainwater in western Amazonia is mainly controlled by the amount of precipitation (e.g. Grootes, 1993). Haug et al. (2001) shows a shift to drier climate at 4000 BP in the Caribbean, which he explains by a southward migration of the ITCZ. This hypothesis implies that Western Amazonia got wetter during this transition which fits well with the observed shift to lower $\delta^{18}O$ values in our profile at 4000 years BP. The apparent change to drier conditions around 1600 BP, with an additional spike at ~700 BP in our speleothem data has not be matched to any other proxy record yet.

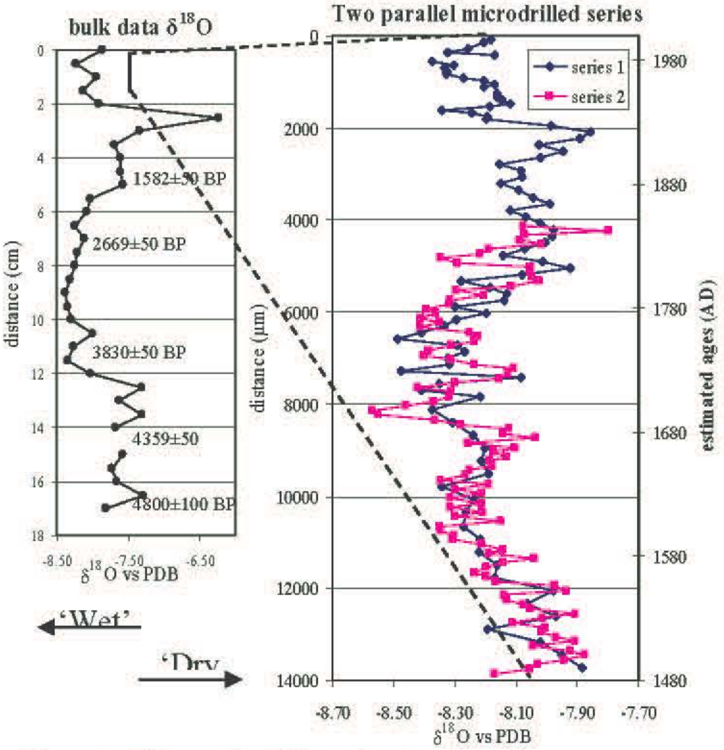

Figure 4, $\delta^{18}O$ profile of the stalagmite. Note the same values for series 1 and series 2.

Both microdrilled series lie in the same range for the oxygen isotope measurements and shown the same overall pattern (figure 4). Both series show a shift to lower $\delta^{18}O$ values, thus a wetter period, around 1500 and 1850 (AD). This period is world wide recognized as the 'little Ice Age'. Haug et al. (2001) recognises the 'little Ice Age' over exactly the same time-span at Cariaco Basin. In our records the transition from drier to wetter conditions around 4000 years BP and the 'little ice age' is interpreted as a period of increased precipitation due to the southward migration of the Intertropical Convergence Zone (ITCZ). Haug et al., 2001 has proven the same southward migration of the ITCZ in Cariaco Basin, which led to reversed climate conditions in Cariaco Basin compared to our record.

Small scale cycles observed in the isotopic record, cover a timespan between ~10 and ~16 years. These cycles may be related with solar activity, which have 11-year cyclicity. Another explanation for these cycles can be the variability of the Sea Surface Temperature (SST) of the tropical North Atlantic. This region is namely characterized by a main SST variability at 12.8 y (Melice and Roucou, 1998)

## FUTURE RESEARCH

Improvement on paleo-temperature calculations can be made by measuring the isotopic composition of fluid inclusion in speleothems (Matthews et al., 2000; Schwarcz et al., 1976). New techniques make it possible to measure µl amounts of water on $^2H$ and $^{18}O$ (Dennis et al., 2001). Using this technique provides the original $\delta^{18}O$ signal of the dripwater; therefor the $\delta^{18}O$ signal of the carbonate can be calibrated and checked against the original $\delta^{18}O$ of the dripwater. In this way it is possible to check if the carbonate was precipitated in equilibrium with the dripwater. Nowadays a monitoring project is set up in the Cueva de las Lechuzas to collect dripwater from different locations in the cave to receive a seasonal overview of the $\delta^{18}O$ changes in the dripwater for the period of one year.

## REFERENCES

BAKER, A., PROCTOR, C.J., AND BARNES, W.L., 2002. Stalagmite lamina doublets; a 1000 year proxy record of severe winters in Northwest Scotland?: International Journal of Climatology, v. 22, p. 1339-1345.

DENNIS, P.F., ROWE, P.J., AND ATKINSON, T.C., 2001. The recovery and isotopic measurement of water from fluid inclusions in speleothems: Geochimica et Cosmochimica Acta, v. 65, p. 871-884.

GENTY, D., BLAMART, D., OUAHDI, R., GILMOUR, M., BAKER, A., JOUZAL, J., AND VAN-EXTER, S., 2003. Precise dating of Dansgaard-Oeschger climate oscillations in western Europe from stalagmite data: Nature (London), v. 421, p. 833-837.

GROOTES, P.M., 1993. Interpreting continental oxygen isotope records, *in* Swarts et al., eds., Climate change in continental isotopic records., AGU Geophys. Monograph 78.

HENDY, C.H., AND WILSON, A.T., 1968. Palaeoclimatic data from speleothems: Nature (London), v. 219, p. 48-51. Hendy, C.H., 1971, The isotopic geochemistry of speleothems; 1, The calculation of the effects of different modes of formation on the isotopic composition of speleothems and their applicability as paleoclimatic indicators: Geochimica et Cosmochimica Acta, v. 35, p. 801-824.

JIMÉNEZ DE CISNEROS, C., CABALLERO, E., VERA, J.A., DURÁN, J.J., AND JULIÁ, R., 2003. A record of Pleistocene climate from a stalactite, Nerja Cave, southern Spain: Palaeogeography, Palaeoclimatology, Palaeoecology, v. 189, p. 1-10.

LINGE, H., LAURITZEN, S.E., LUNDBERG, J., AND BERSTAD, I.M., 2001. Stable isotope stratigraphy of Holocene speleothems; examples from a cave system in Rana, Northern Norway: Palaeogeography, Palaeoclimatology, Palaeoecology, v. 167, p. 209-224.

MATTHEWS, A., AYALON, A., AND BAR-MATTHEWS, M., 2000. H ratios of fluid inclusions of Soreq Cave (Israel) speleothems as a guide to the eastern Mediterranean meteoric line relationships in the last 120 ky: Chemical Geology, v. 166, p. 183-191.

MCDERMOTT, F., Palaeo-climate reconstruction from stable isotope variations in speleothems: a review: Quaternary Science Reviews, v. In Press, Corrected Proof.

MELICE, J.L., AND ROUCOU, P., 1998. Decadal time scale variability recorded in the Quelccaya summit ice core delta 18O isotopic ratio series and its relation with the sea surface temperature: Climate Dynamics, v. 14, p. 117-132.

HAUG, G.H., HAUGHEN, K.A., SIGMAN, D.M., PETERSON, L.C., AND ROEHL, U., 2001. Southward migration of the Intertropical Convergence Zone through the Holocene: Science, v. 293, p. 1304-1308.

PROCTOR, C.J., BAKER, A., AND BARNES, W.L., 2002. A three thousand year record of North Atlantic climate: Climate Dynamics, v. 19, p. 449-454.

SCHWARCZ, H.P., 1986. Geochronology and isotopic geochemistry of speleothems, *in* Fritz, and Peter ; Fontes, eds., The terrestrial environment, B.: Amsterdam, Netherlands, Elsevier, p. 271-303.

SCHWARCZ, H.P., HARMON, R.S., THOMPSON, P., AND FORD, D.C., 1976. Stable isotope studies of fluid inclusions in speleothems and their paleoclimatic significance: Geochimica et Cosmochimica Acta, v. 40, p. 657-665.

SANCHO, C., PENA, J.L., MIKKAN, R., OSACAR, C., AND QUINIF, Y., Morphological and speleothemic development in Brujas Cave (Southern Andean Range, Argentine): palaeoenvironmental significance: Geomorphology, v. In Press, Corrected Proof.

WANG, Y.J., CHENG, H., EDWARDS, R.L., AN, Z.S., WU, J.Y., SHEN, C.C., AND DORALE, J.A., 2001, A high-resolution absolute-dated late Pleistocene monsoon record from Hulu Cave, China: Science, v. 294, p. 2345-2348.

YONGE, C.J., FORD, D.C., GRAY, J., AND SCHWARCZ, H.P., 1985. Stable isotope studies of cave seepage water: Chemical Geology; Isotope Geoscience Section, v.58, p. 97-105.