STABLE ISOTOPES IN SPELEOTHEMS AS PROXIES OF PAST ENVIRONMENTAL CHANGES IN THE ALPS

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Abstract. This short communication presents preliminary results and interpretations from an ongoing research project in the Obir Cave of southeast Austria. This cave system hosts abundant calcite dripstones many of which are actively forming today. The stable isotopic composition of a Holocene stalagmite dated by U-series TIMS techniques shows rather stable values throughout most of the last eight millennia, except for the last few hundred years when both C and O isotope values strongly increase (probably due to changes in the cave air circulation as a result of mining activity).

1. INTRODUCTION

Data of environmental change in the Alps are confined largely to the Late Glacial and Postglacial, because glaciations effectively obliterated older sedimentary records. Cave calcites (speleothems) hold a high promise of providing critically needed paleoenvironmental information complementing the surface sedimentary record and extending it back in time up to several hundreds of thousands of years. We are currently using the stable isotopic composition of alpine speleothems dated by U-series thermal ionization mass spectrometry (TIMS) techniques to infer paleo-environmental changes in the recharge area of the karst systems and in particular in high-mountain sites where existing surface paleodata are rare.

2. SAMPLING SITE AND STRATEGY

Based on a reconnaissance study of caves in Austria we selected four caves for further study placing particular emphasis on sites with modern dripstone formation. In addition to sampling dripwaters at regular intervals we also take milligram samples of wet stalagmite tops for stable isotope analysis. Cave air pCO_2 and relative humidity are being measured using portable instruments and the air temperature is automatically logged. Here we present preliminary data from one of these sites, Obir Caves.

The Obir massif is located in the northern segment of the Karawanken, a mountain range stretching E-W along the Austrian-Slovenian border. The caves developed in Middle and Upper Triassic platform carbonates and were only discovered during mining activities [1-3], mostly during the 18^{th} century (the mines were finally closed in 1913 – [4-6]). No known natural entrances to the caves exist. Parts of the Obir caves have recently been adapted as a show cave [7], but other parts of the extensive system are virtually untouched by tourist activities. We selected a neighboring cave (Rassl system, approximately 1100 m a.s.l.) which can only be accessed through an abandoned mining adit [8]. This cave is characterized by vadose shafts, narrow subhorizontal passages and chambers with abundant active speleothem deposition. Climatic conditions in the cave are virtually constant throughout the year (air temperature 5.4°C, relative humidity in excess of 97%). The partial pressure of CO_2 varies seasonally with low values during winter and spring (500-600 ppmv) and high values during summer and late fall (up to 1800 ppmv). Active speleothem deposition encompasses flowstones, stalagmites, stalactites and soda straws and pool deposits.

3. METHODS

Speleothem samples, both inactive and active were examined using a combination of thin-section petrography, Th-U dating and stable isotope analysis. Thin sections were examined both using standard transmitted light microscopy and uv-and blue light epifluorescence microscopy. The mineralogical composition of individual samples was checked using powder X-ray diffractometry. Age dating was performed by TIMS measurements of ^{238}U, ^{234}U, ^{232}Th, and ^{230}Th using 0.5-1 g of sample. Measurements were performed on a multi-collector Finnigan MAT 262 RPQ utilizing the double filament technique (for analytical details see [9]).

Samples for stable carbon and oxygen isotope analyses were microdrilled and measured with an on-line, automated, carbonate preparation system linked to a triple-collector gas-source mass spectrometer. Results are reported in the usual per mil notation relative to the VPDB standard. Standard deviations (1-sigma) of replicate analyses of standard materials are less than 0.10‰ for both C and O.

A variety of seepage waters were collected in the cave and analyzed for temperature, pH, electrical conductivity, and major cations and anions. Chemical speciation and saturation states are calculated using PHREEQC. The O isotopic compositions are reported on the VSMOW scale.

4. RESULTS AND DISCUSSION

Sample OBI 12 is a 32 cm high stalagmite which was actively forming at the time of sampling. The stalagmite was dated by seven TIMS dates starting at 8.2 ± 0.29 ka and the youngest date was obtained 10 mm below the top (0.32 ± 0.04 ka). All dates are in stratigraphical order and indicate a mean growth rate of 39 mm per thousand years. We obtained a medium-resolution stable isotope record from this sample (approximately 50-year resolution – Fig. 1). Macroscopic and thin-section microscopic inspection showed no evidence of growth discontinuities suggesting continuous growth since 8.2 ka BP. During most of the past 8.2 ka C isotopes vary only within1.5‰ (Fig. 1). Superimposed are smaller-scale trends, e.g. low C isotope values during a few centuries from about 5.6 to 5.3 ka BP and during an even shorter episode from 4.3 to 4.2 ka BP. We suggest that these periods of low $\delta^{13}C$ values correspond to times of dense forest vegetation and high soil bioproductivity (and probably also high soil moisture) above the cave, giving rise to a high proportion of pedogenically-derived, isotopically light C in the cave seepage waters. This interpretation of a warmer and probably also more humid climate during periods of low $\delta^{13}C$ values is consistent with recent data from east-alpine glaciers showing evidence of strong recession during these time periods (e.g., [10]). Our preliminary data also suggest that the warm phase during the 6th millennium BP — whose end coincided with the death of the famous iceman found in the Tyrolian Alps (cf. [11] – Fig. 2) — was probably the warmest during the past 8 ka (with the possibly exception of the late 20th century).

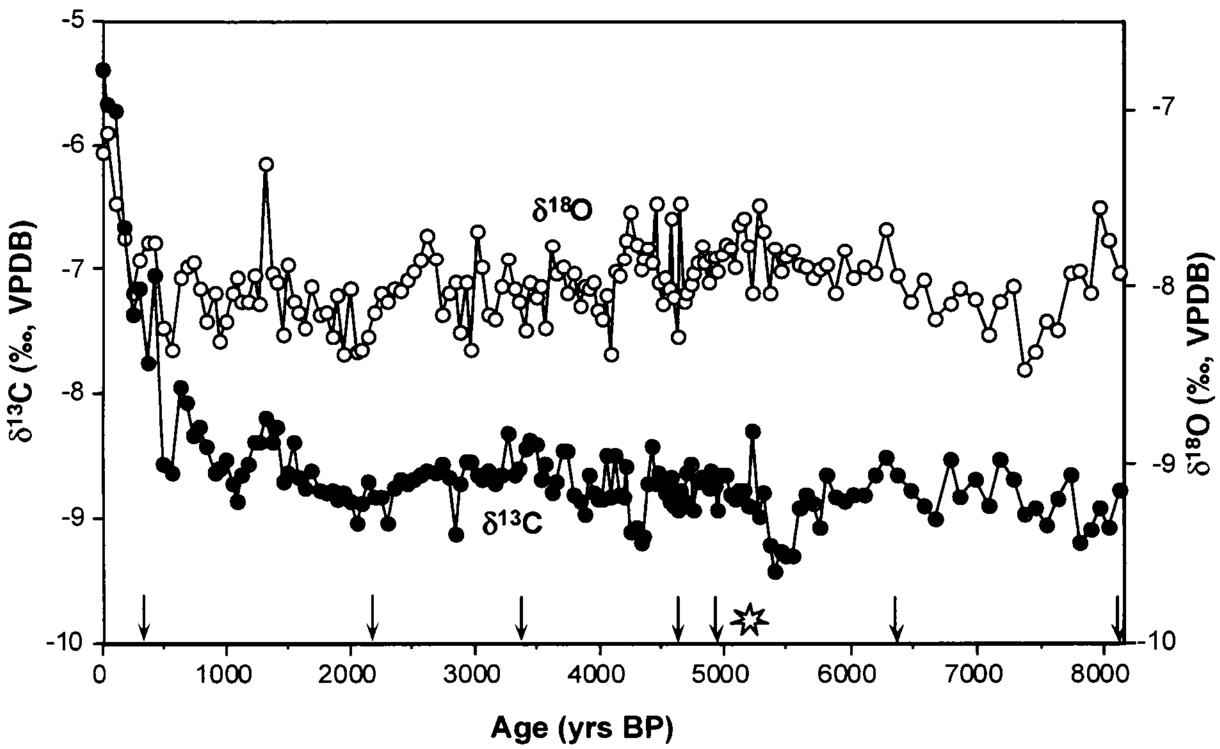

FIG. 1. C and O isotope variation along the extension axis of a Holocene stalagmite (sample OBI 12). Vertical arrows are TIMS Th-U dates and the asterisk indicates the calibrated ^{14}C age of the iceman [11].

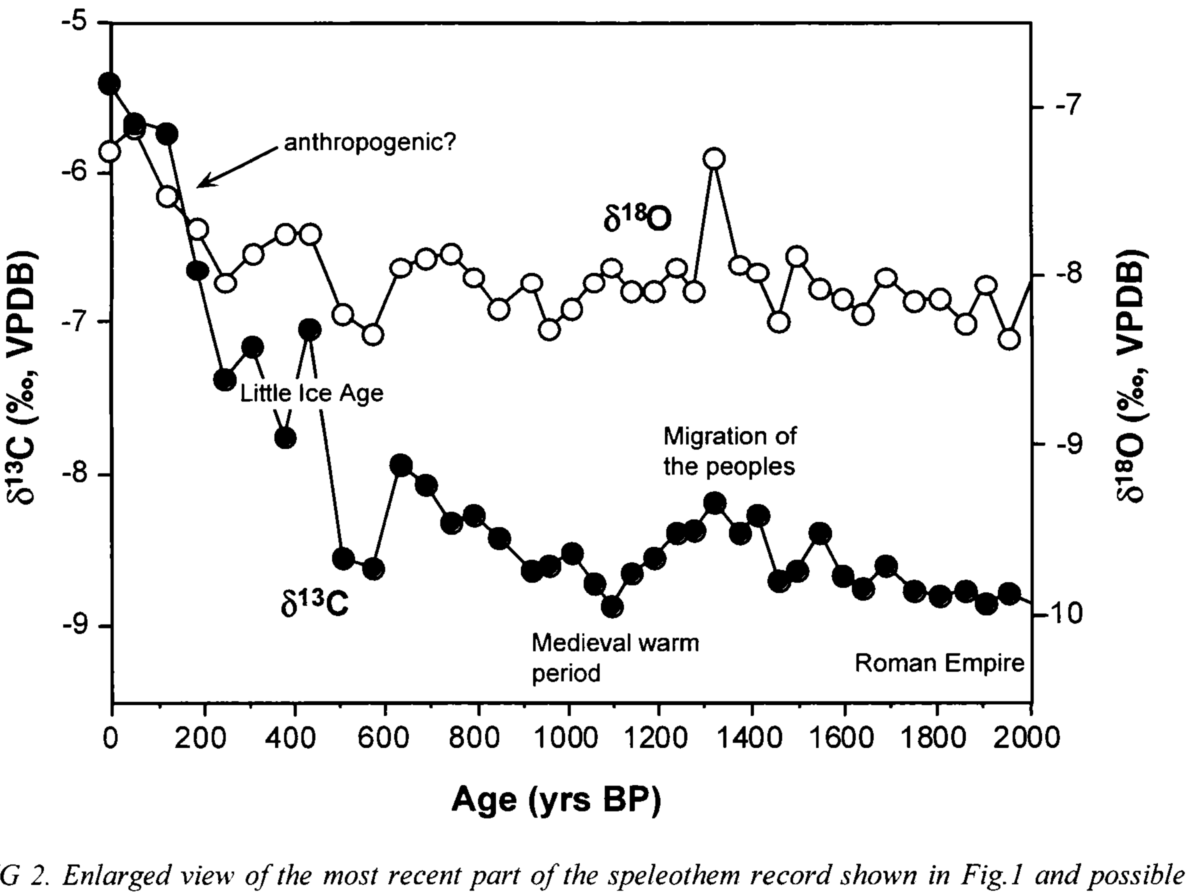

FIG 2. Enlarged view of the most recent part of the speleothem record shown in Fig.1 and possible correlation with historical events.

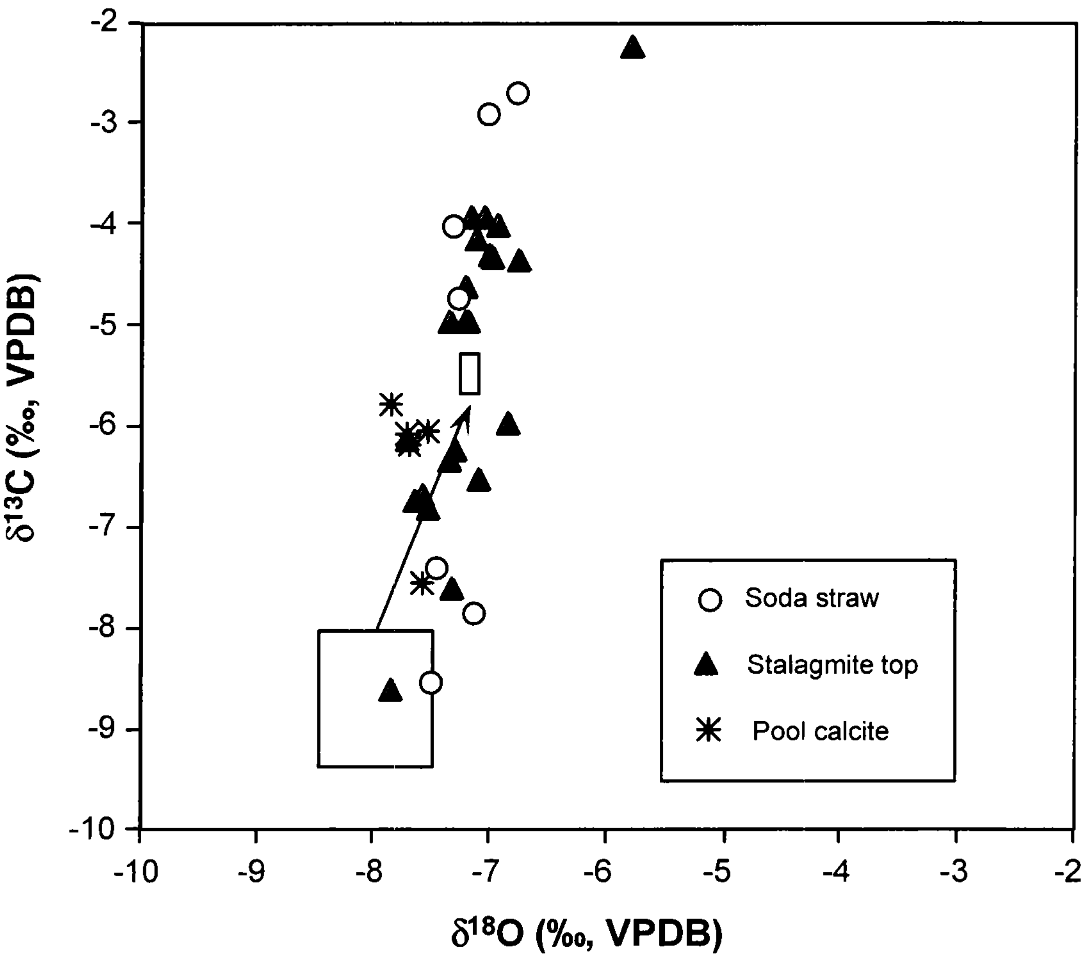

FIG. 3. Stable isotopic composition of modern calcite precipitates in Obir cave. The lower rectangular box indicates the stable isotopic composition of the Holocene stalagmite OBI 12, except for its youngest part, indicated by the smaller box.

The O isotope values vary only by about 1‰ during most of the Holocene, again suggesting fairly stable climatic and hydrologic conditions. Periods of low $\delta^{13}C$ values do not clearly correlate with relatively high $\delta^{18}O$ values, probably suggesting that the O isotopes are effectively rock-buffered. This interpretation is consistent with the relatively thick rock overburden of 80-100 m at the sampling site.

The most recent segment of the stable isotope curves shows an interesting and well known pattern reflected mostly in the C isotope data starting with the generally warm climate during Roman times up to the Little Ice Age (Fig. 2). This correlation between the $\delta^{13}C$ values and the well known cultural trends, though striking, warrants further high-resolution dating and stable isotope analyses and should be regarded as preliminary only. Since the Little Ice Age the C isotopic composition increased to values significantly higher than at any time during the past 8.2 ka. Although less well pronounced, the O isotope values also increased during the last few hundred years (Fig. 2). In order to better constrain the significance of this dramatic increase in the C isotopic composition we analyzed tips of soda straws, modern pool deposits and tops of stalagmites in this cave (Fig. 3). The C isotope values vary from -8.5 to as high as –2.3‰ and delineate an evolutionary trend toward high values. The O isotopic compositions increase only slightly by about 1‰. A possible explanation for this covariance is kinetic isotope fractionation [12], i.e. a slight decrease in relative humidity in the cave interior causing enhanced degassing of carbon dioxide and mild evaporation. This hypothesis is difficult to test in the modern cave environment, but available instrumental data suggest that the cave interior (where the samples were taken) is close to condensation all year round.

Frisia et al. [13] studied a Holocene stalagmite record from the south-alpine Grotta di Ernesto (Trento) and observed a similar increase in the C isotopic composition during the last few hundred years which they tentatively attributed to extensive wood-cutting above the cave. Anthropogenic changes of the vegetation above Obir cave is a possibility, although we found no historical reports of extensive deforestation in this area. We speculate, however, that the onset of the mining activity may have had a strong impact on the overall air circulation in these caves (which lack natural entrances large enough to be surveyed by man) giving rise to either a lower pCO_2 in the interior cave air and/or a slight decrease in the water vapor saturation. Evaporation, however, is considered to be insignificant in the present-day cave environment. This is supported by the observation that most actively precipitating calcite is in near isotopic equilibrium with the parent dripwater.

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