Quantitative Annual Speleothem Records of Temperature, Precipitation and Solar Insolation in the past – A Key for Characterisation of past climatic systems

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Abstract

We studied luminescence of speleothems from Cold Water cave, Iowa, US and Rats Nest cave, Alberta, Canada. A reconstruction of the past annual precipitation rates for the last 280 years for Kananaskis country, Alberta, Canada has been obtained from speleothem annual growth rates.

In dependence on the soil surface exposition we measure either solar sensitive or temperature sensitive paleoluminescence speleothem records:

- In case of Cold Water cave, Iowa, US we obtained high correlation coefficient of 0.9 between the luminescence record and Solar Luminosity Sunspot index and reconstructed sunspot numbers since 1000 AD with a precision within the experimental error of their measurements;

- in case of Rats Nest cave, Alberta, Canada we measured correlation coefficient of 0.67 between luminescence intensity and air temperature record for the last 100 years and reconstructed annual air temperatures for last 280 years at the cave site with estimated error of 0.35 ^{0}C, while the error of the direct measurements is 0.1 ^{0}C.

Introduction

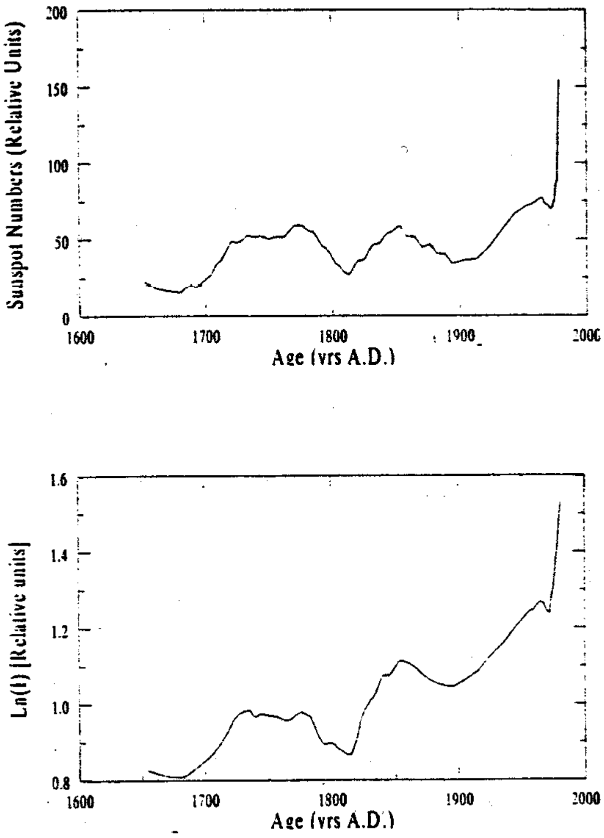
Calcite speleothem luminescence depends exponentially upon soil temperatures that are determined primarily by solar radiation in the case when that cave is covered only by grass or upon air temperatures in case that cave is covered by forest or bush. In the first case, microzonality of luminescence of speleothems can be used as an indirect Solar Insolation (SI) index, but in the second - as an paleotemperature proxy. So, in dependence on the cave site we may speak about "solar sensitive" and "temperature sensitive" paleoluminescence speleothem records like in tree ring records, but in our case record may depend either only on temperature or on solar irradiation.

Methods and Material Studied

Speleothem growth rate variations represent mainly rainfall variations (SHOPOV et al.1992, 1994). Speleothem luminescence visualises annual microbanding (SHOPOV, 1987, SHOPOV et al. 1991). We used it to derive proxy records of annual precipitation at the cave site by measuring the distance between all adjacent annual maxima of the intensity of luminescence. The resultant growth rates correlate with the actual annual precipitation (summed from August to August). We studied the top of a 35 mm long stalagmite from Rats Nest cave (RNC), Alberta, Canada to measure quantitative records of annual temperature and precipitation. For this purpose we obtained a stacked 66000 data points paleotemperature record from Rats Nest cave, Kananaskis karst region, Alberta, Canada. It covers last 1450 yrs with average resolution of about 8 days. Paleoclimatic records has been derived from speleothem luminescence, calibrated by actual climatic records from near climatic station in Banff, Alberta. The sample was dated by two14-C dates, TIMS U/Th dating, autocalibration and annual bands counting dating. All produced consistent age, best estimated as 1450 +/- 80 years. The 14-C data were corrected for “dead” carbon, by its measurement in modern speleothem calcite.

Results and Analyses

We obtained high correlation coefficient of 0.9 between a luminescence record from Cold Water cave, Iowa, US and Solar Luminosity Sunspot index (Fig.1) and reconstructed sunspot numbers since 1000 AD with precision within the experimental error of their measurements. This luminescence record is a part of a 7075 +/- 295 yrs record well dated by 5 U/Th TIMS dates (SHOPOV et al., 1994).



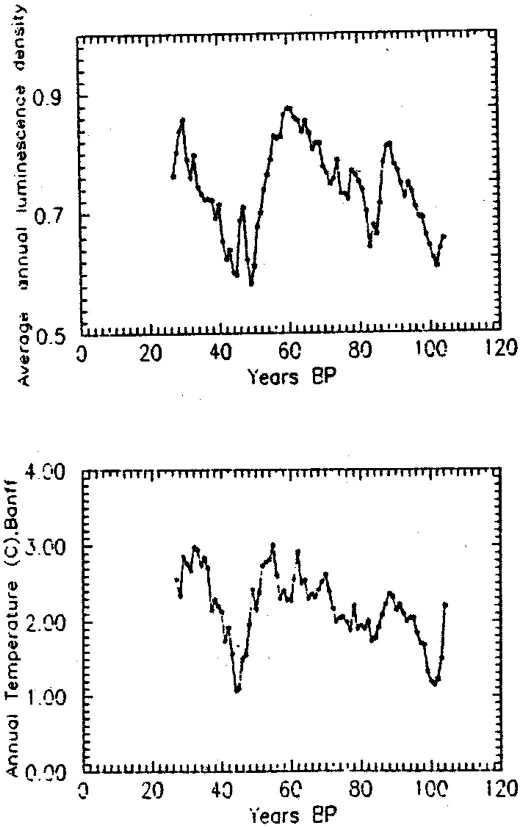
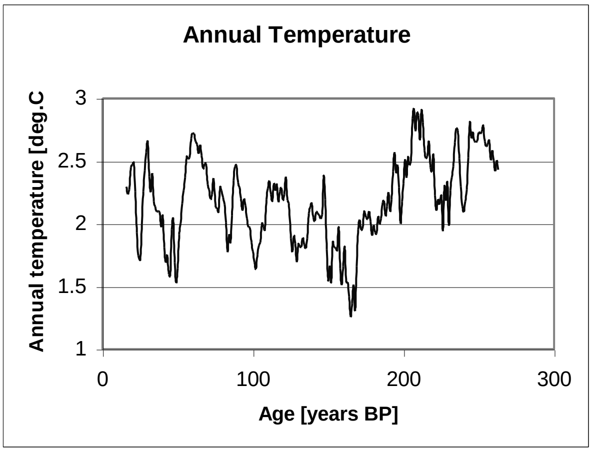


Fig.1. (left up)- Twenty year average sunspot records since 1700 AD, (left down)- Optical density of luminescence of a speleothem from Coldwater Cave, Iowa (USA).
Fig.2. (right up)- Average annual luminescence density of a speleothem from Rats Nest Cave (Canada) (right down)- Annual temperature, Banff , Alberta (Canada).

A reconstruction of the past annual temperature for the last 280 years has been obtained from average annual speleothem luminescence intensity calculated from the 66000 px record, calibrated by actual temperature record from near climatic station in Banff, Alberta, Canada. We obtained reasonably good correlation (correlation coefficient of 0,68) between the annual temperature for the last 105 years (recorded at the closest weather station - Banff, located in the same valley, 50 km northern of the cave) and the average annual speleothem luminescence intensity (Fig.2). We used obtained regression coefficients to reconstruct annual temperature for the last 280 years at the cave site (Fig.3). The estimated statistical error is 0.35 ^{o}C. Intensity of luminescence was not dependent on actual precipitations and sunspot numbers (zero correlation).

Speleothem growth rate variations represent mainly rainfall variations. A reconstruction of the past annual precipitation rates for the last 280 years has been obtained from speleothem annual growth rates, derived from the distance between annual speleothem luminescence bands, calibrated by actual precipitation record from near climatic station in Banff, Alberta, Canada. We obtained reasonably good correlation (correlation coefficient of 0,57) between the annual precipitations (from Banff, Alberta) and the annual growth rate of the speleothem. We used obtained regression coefficients to reconstruct annual precipitations for the last 280 years at the cave site (Fig.4). The estimated statistical error is 80 mm/ year. Annual speleothem growth rate was independent on the intensity of luminescence, on annual temperature and on solar luminosity for the same time span (zero correlation).

Speleothem luminescence visualizes annual microbanding we used to derive proxy records of annual precipitations for the cave site. Annual luminescence microbanding was used very successfully for relative and absolute dating of speleothems by Autocalibration dating. This dating method appear to be more precise than TAMS ^{14}C and AMS U/Th dating for relative dating of short time intervals and only dating method for speleothems with little uranium, younger than 2000 years.



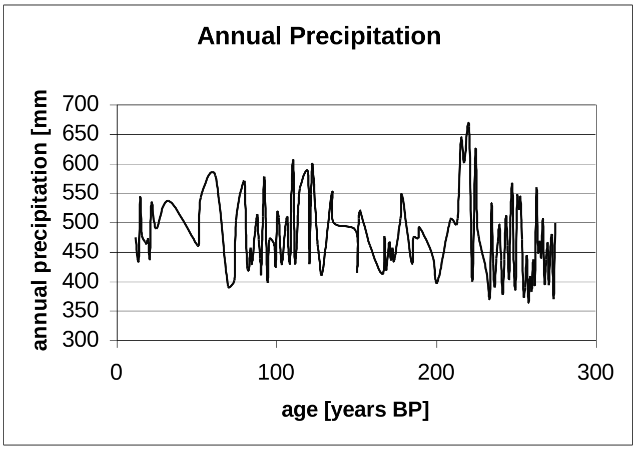


Fig. 3 ***Fig. 4***

Fig.3 (Up) Annual temperature in the last 280 years for Kananaskis country, Alberta, Canada derived from annual intensity of luminescence of a stalagmite from Rats Nest cave, Alberta, Canada

Fig.4 (Down) Annual precipitation (from August to August) in the last 280 years for Kananaskis country, Alberta, Canada derived from annual growth rate of a stalagmite from Rats Nest cave, Alberta, Canada

Conclusion

It is demonstrated, that speleothems can be used as natural climatic stations with annual resolution for purposes of climatology and agrometeorology for a time span far exceeding all historic records.

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