Palaeoclimate reconstructions from geochemistry and isotopegeochemistry study of speleothems

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Untill now the most reliable palaeoclimatic records have been derived from stable isotope studies on oceanic foraminifera and on the polar ice caps. However, the link between these results and climatic conditions on the continents has remained tenuous. So far, palaeoclimatic information on the continent was provided nearly exclusively by lake deposits and soil carbonates. Theoretically speleothems provide reliable continental palaeoclimatic information because they are chemically and isotopically rather stable and less affected by post-depositional processes than surficial sediments. Palaeoclimatic curves (timeseries) can be chronologically calibrated by U/Th dating. Speleothems may record in a quantitative way surface air temperatures through $\delta^{18}O$ and floral composition through $\delta^{13}C$, provided they are deposited in isotopic equilibrium with the cave water. The $\delta^{18}O$ of the stalagmite depends on the deposition temperature and on the $\delta^{18}O$ of the dripwater (= w.t. mean rainwater, see below). The rainwater itself depends on different factors among which the surface air temperature and the amount of rainfall are the most important ones. Previous palaeoclimatic reconstructions from speleothems did not yet provide convincing results probably because of a lack of knowledge on the physical chemistry of the cave environment.

Our study was performed in the Belgian Père Noël cave, located in Han-sur-Lesse in the Ardenne massif. The cave opens in the Givetian Fromelenne Formation with subvertical limestone layers which reach a thickness of *c.* 70 m above the cave. A Holocene stalagmite, *c.* 65 cm long, dated 2ka BP to 13 ka BP by TIMS U/Th method was taken at 300 m from the entrance. Since no impermeable formations are present above the cave and since the river does not flow anymore through the Père Noël cave, the water entering the cave consists only of local rain, seeping directly through the limestone. The stalagmite provided a $\delta^{18}O$, $\delta^{13}C$, Mg/Ca and Sr/Ca record throughout the Holocene. Oxygen isotopic analyses were carried out on meteoric waters, present-day seepage waters and present-day calcite in order to better understand the relation between the isotopic and chemical record of the environmental parameters that control it (all values are vs PDB, except for the rainwater which is vs VSMOW).

Results and interpretation

The oxygen isotopic signature of the Holocene stalagmite varies between −6.2 and −4.5‰, with a mean of −5,5‰. An important increase of 0.9‰ around 10.8ka BP (extrapolated U/Th age) can be a record of the Holocene warming. Low values of about −6‰ appear between 13 and 11ka BP (tardiglacial) but also at 7.2 ka BP, during the Atlantic substage, a rather mild but very humid period in Belgium. $\delta^{13}C$ values vary between −8.6‰ and −3.9‰ with a mean of −7.2‰ are not in agreement with expected values for a C_3 vegetation cover. 1000Mg/Ca ratios vary between 6 and 26, with a mean of 10, while 1000Sr/Ca ratios vary between 0.10 and 0.32, with a mean of 0.20.

The important variability of the $\delta^{18}O$ (up to 1.7‰) and the $\delta^{13}C$ (up to 4.7‰) signatures of this stalagmite suggest that other factors than variations in temperature and vegetation affect the isotopic signature of the calcite (all values are vs. PDB, with $2s<\pm0.2‰$). Covariation of the oxygen and carbon

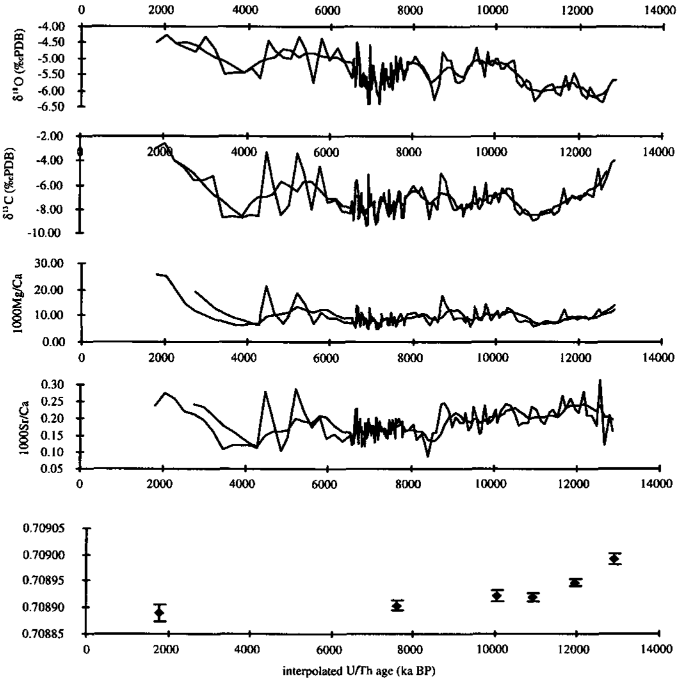

FIG. 1.

isotopic signature along single layers suggests that many parts of the stalagmite were not deposited in isotopic equilibrium with the dripwater. However mean values of $\delta^{18}O$ and $\delta^{13}C$ of the whole stalagmite, i.e. during the Holocene, correspond to those of present-day calcite.

In addition, covariation of $\delta^{18}O$ and $\delta^{13}C$, Mg/Ca and Sr/Ca ratios along the longitudinal axis of the stalagmite (i.e. timeseries) suggests that the isotopic composition as well as the chemical composition of the stalagmite depend on the amount of available water. Measurements of the oxygen isotopic composition of dripwater, soda straws and months old calcite (on glass slides) in the cave lead to following observations:

(1) the dripwater does not exhibit the seasonal effect found in the rainwater and has a mean value of −7.0‰VSMOW which is in agreement with the mean annual value of the rainwater,

(2) the oxygen isotopic composition of the dripwater is very similar at different places in the cave as well as throughout the year at any specific monitored place,

(3) recent calcite, deposited on glass slides exhibit a large range of isotopic compositions in the cave (between −3.3‰ and −6.0‰ PDB),

(4) rapid dripping places seem to produce a lighter calcite than slowly dripping places.

These results confirm the idea that the variation in isotopic composition of the stalagmite is acquired during deposition of the calcite and further support the hypothesis of evaporation and degassing control of the calcite deposition.

A preliminary study of Sr isotopes in the same stalagmite provides an exponentially decreasing 87Sr/86Sr curve with values changing between 0.70899 at 13 ka BP and 0.70889 at 2 ka BP. Progressive leaching of an overlying claycover, possibly accumulated during glacial periods may be suggested as an explanation for this Sr isotopic trend.

As a conclusion, this Belgian Holocene stalagmite rather seems to be a proxy-tool for studying fluctuations in the precipitation amount during the Holocene than it would be for estimating temperature evolution. It also suggests that stalagmites which are not deposited in isotopic equilibrium with the dripwater can still be used for palaeoclimatic studies.

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