Malvern U3A Geology Group

Speleothems

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From the Greek spelaion (cave) and thema (deposit), Professor Ian Fairchild described how cave deposits (speleothems) are archives of past environments and climates; and a cave having uses ranging from habitation, to assisting in athletic performance by raising CO2 levels and lithology.

Caves are listening to and recording what happens in the world above, and their deposits reflect what happened in the past. Cave systems are in the climate system. The latter includes: sea ice, glaciers, hydrological cycle, global changes in vegetation and human influences on climate. They are also sensitive indicators of the immediate environment above the cave.

1.(Quaternary) Climates of the past and their investigation.

Records of past climates on land can be detailed and relevant, but are mostly fragmentary. They give a snapshot of climate and are evident in till, lake sediments, fluvial sediments, shelly deposits and aeolian sediments.

For a more continuous record there is a need to look at something developed over a longer period of time e.g. data from the past 1000 years. Data mainly from tree rings suggests that current global warmth is unprecedented in the northern Hemisphere. They can also give us temperature reconstructions.

Ice cores allow investigations even further back in time. In Greenland and Antarctica cores have been removed from the centre of the ice sheets (from 3km deep) which give information about trace impurities and wind strength.

Gas bubbles from within the ice show water molecules with two isotopes of oxygen mostly O_2 wt. 16, but some have 18, which is slower to evaporate and condense as snow – from this the history of the ice can be determined.

O_{18} is used as a thermometer within the ice. During the last ice age there was instability in climate linked to the North Atlantic circulation.

Before the prominent use of ice cores, deep-sea marine cores were used. Climate change was recorded in calcareous oozes (pelagic sediments made up of forams) which accumulated slowly. The record uses past global climate changes and shows warmer periods interrupted by colder periods and is measured by the O_2 isotope in the forams.

The Milankovitch periods of precession and obliquity are the pacemakers of the ice ages, determining when things start and finish. The Milankovitch periodicities in the Earth's orbit affect climate by changing the insolation at different places.

2. How do caves work?

Caves form by limestone or dolomite rock being dissolved. Two stages of cave formation is shown in their morphology.

Young caves are still dissolving, therefore there are no speleothems. Whereas, speleothems form at the end of the life of a cave e.g. Postomia Cave, Slovenia. Gospodiric '76.

The conceptual model of a Karst system is that water rich in CO_2 percolates down. The cave has less CO_2 than the water percolating down, this initiates degassing and $CaCO_3$ is precipitated. Abundant CO_2 in the soil increases carbonate rock dissolution.

Physiologically, caves are therefore places of heat, water and gas exchange.

The conceptual plumbing diagram where the characteristics in the growth of stalactites is recorded, is known as drip hydrology.

The seasons are the drivers of cave ventilation, which works better in the winter with the sinkage of cold air. The degree of ventilation is less in summer when the flow of CO_2 is less.

At the cave entrance cool air coming out of the cave cools the warm air outside and a fog forms.

3. How do speleothems form in caves?

A The speleothem factory model

B Speleothem incubator model

Proof that caves are "working" is exemplified in their products. These include stalagmites where families can grow together in the same place. They can record earthquakes. Flowstone and gour pool deposits. In the Atmosphere Gallery of the Science Museum, the Refugio stalactite from Spain has been cut through.

4. What properties do speleothems display that are useful?

From the annual layers the growth rate can be calculated. The rate of growth depends upon the rate of degassing and the amount of water present. The rate of growth is approximately 10^{th} mm per annum, but this is variable.

In the Ernesto Cave, N E Italy the growth rate is very sensitive to the cave temperature, about 6°C. At the end of the Little Ice Age it was cooler. Warming can be seen in the layers. The growth rings have been further apart recently.

Florescent and chemical signals are recorded in the layers and show distinct seasonal input. Darker layers contain trace elements, Pb and Zn especially, transported in complexed form in the wet, autumn period.

Aerosol deposition from the air or bacteria. The oxygen isotopes varying over time show / record the patterns of the seasons, especially from fracture fed drips.

5. How can we date speleothem deposits?

From the atomic tests between the 1950's and the 1990's, the carbon 14 pulse has been preserved in the stalagmites, and this has been used to prove that the growth layers are annual. Very small errors in dating are achievable. Marine or ice cores cannot be dated using this method.

6. How do speleothems tell us about past environments and climates?

By looking at the structure of stalagmites and working backwards, indications of the climate at the time and subsequent changes can be noted via transfer function.

Example 1. Tartair Cave, NW Scotland.

Tartair is in NW Europe and Gilbraltar in SW Europe, at opposite ends of the North Atlantic Oscillation. Cave deposits demonstrate their sensibility to dry or wet winters with thicker growth in the wetter winter weather in Scotland, thinner layers are found in the dryer winter deposits in Gibraltar and vice-versa.

Example 2. Clamouse, S. France.

Speleothems can be used with other types of archives e.g. trees. Periods of activity can be shown by trace elements in the Mediterranean caves. A drought period nearly 1200 years ago has been identified using chemical changes in two stalagmites from the Clamouse cave.

Example 3. The Holocene event.

The 8·2 Ka event, the coldest snap in the Holocene was the resolution of a short climatic event, the final collapse of the Laurentide Ice Sheet, which resulted in the catastrophic release of meltwater into Hudson Bay. This event meant the surface of the North Atlantic Ocean had more freshwater for a short period. At this time climate was drier, as exemplified in the O_{18} isotope record. Two dips in the record coincide/correlate with two meltwater pulses as found in deposits in Spain, the isotope anomaly being from the freshwater pulses.

Example 4. Records of the monsoons.

The energy of the atmosphere is to be located in records of the monsoons. Monsoons tie in with the start of the ice ages. The amount of heat received from the sun modulates the intensity of the monsoon. Precession every 20,000 years. The overall trend maps out the summer monsoon strength and parallels the decrease in the summer isolation received at these latitudes in the Holocene.

The Milankovitch cycles are mirrored in data from speleothems and air bubbles from the Antarctic Ice Sheet.

Summary – Caves:

1. Have a long history – mostly of gradual growth over perhaps millions of years. Speleothems only form towards the end of their life.
2. Have a physiology acting as a system, for example by maintaining a constant temperature, and by exhaling CO_2 and exchanging it with the outside atmosphere.
3. Can suffer abuse. An excess of visitors, CO_2 damage, vandalism and excessive water loss will ultimately cause collapse and the end of the life of the cave.