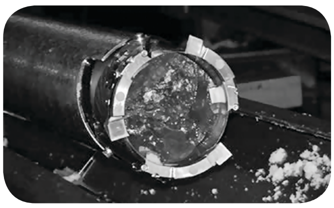
PALEOCLIMATIC EXPLORATION IN THE ARCTIC & ANTARCTIC: SCIENTIFIC DRILLING STATIONS AND ICE CORES AT THE POLES

The ice cores drilled and extracted at the poles bear special witness to the past climate of our planet. These ice cores contain tiny air bubbles that act as samples of the Earth's atmosphere during its history. By drilling down to great depths into the polar ice sheets and analysing the ice back through the ages, scientists have been able to show that it is possible to reconstitute the conditions that existed in the environment in the past. These "archives" have also enabled us to confirm the close relationship that exists between the way the temperature has changed and the levels of the principal greenhouse gases (mainly carbon dioxide and methane). Being able to understand the way the climate has behaved in the past is also a good way to evaluate the changes ahead...



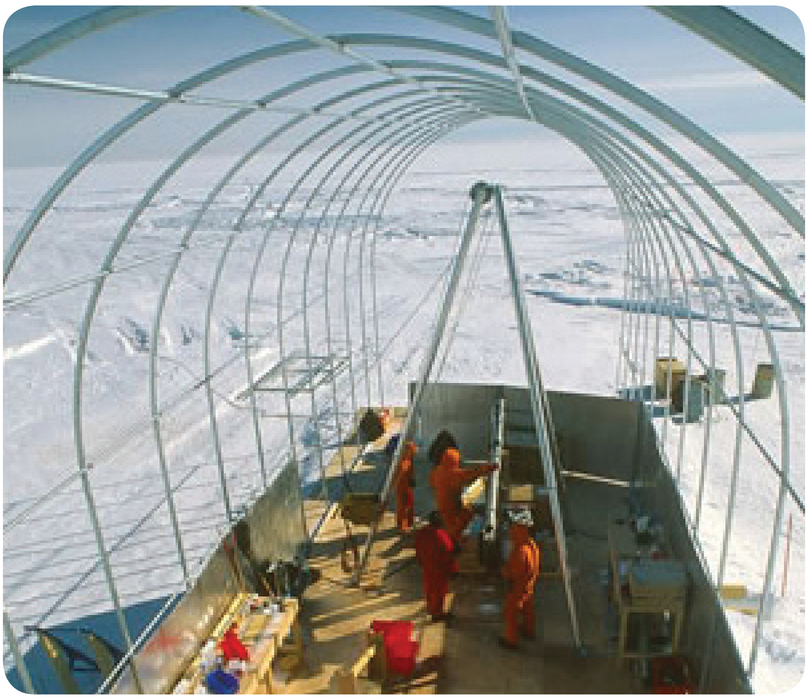


Figure 1a

Ice core taken from polar ice sheets

Figure 1b

Ice core elements allowing to reconstruct paleoclimates

1

Air bubbles; samples from the atmosphere of the past

2

Paleotemperatures calculated with a method comparing ratios of oxygen isotopes (^{16}O & ^{18}O)

3

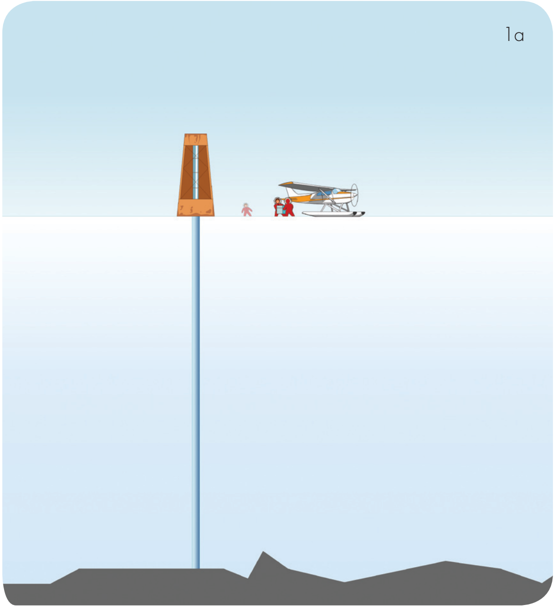
Volcanic ash spewed into the atmosphere during violent eruptions

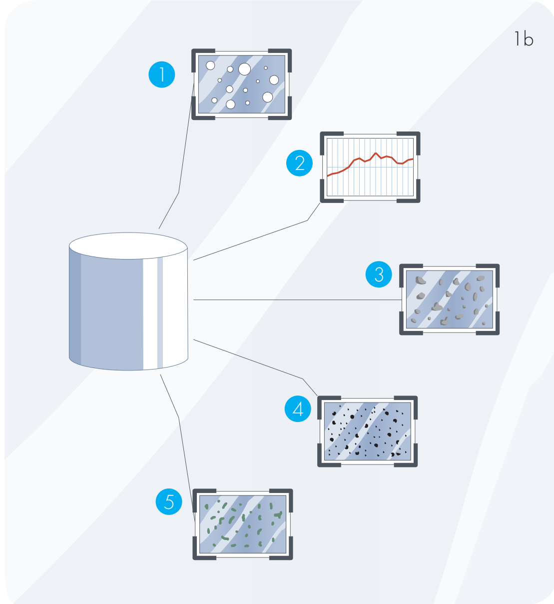
4

Aerosols: airborne particles, grains of sand, particles of sea salt, etc.

5

Pollen





1) WHAT IS AN ICE CORE?

An ice core is a long, cylindrical sample of ice taken from the ice sheets covering Antarctica and Greenland, as well as other expanses of ice in the Polar Regions (such as the ice caps in the Canadian Archipelagos or in Iceland) or glaciers in mountainous areas. This thick crust of ice is the result of the accumulation, year after year, of the layers of snow that have fallen and become compacted over very long periods of time (several thousands of years in the case of the ice sheets).

The deeper we drill, the older the layers of ice are. This makes it possible to go back along a time line. As they accumulated and were transformed into ice, the snow crystals also trapped tiny bubbles of air, which provide us with dependable samples of what the atmosphere was like at the time the snow became ice. Once trapped inside the ice, these air bubbles became totally cut off from the atmosphere and have not changed since, making it possible to use ice cores as climate "archives". Studying these archives has contributed a great deal to the science of paleoclimatology, which consists of reconstituting the way our climate has evolved using various proxy methods, including studying ice cores and marine (lake and ocean) sediments..

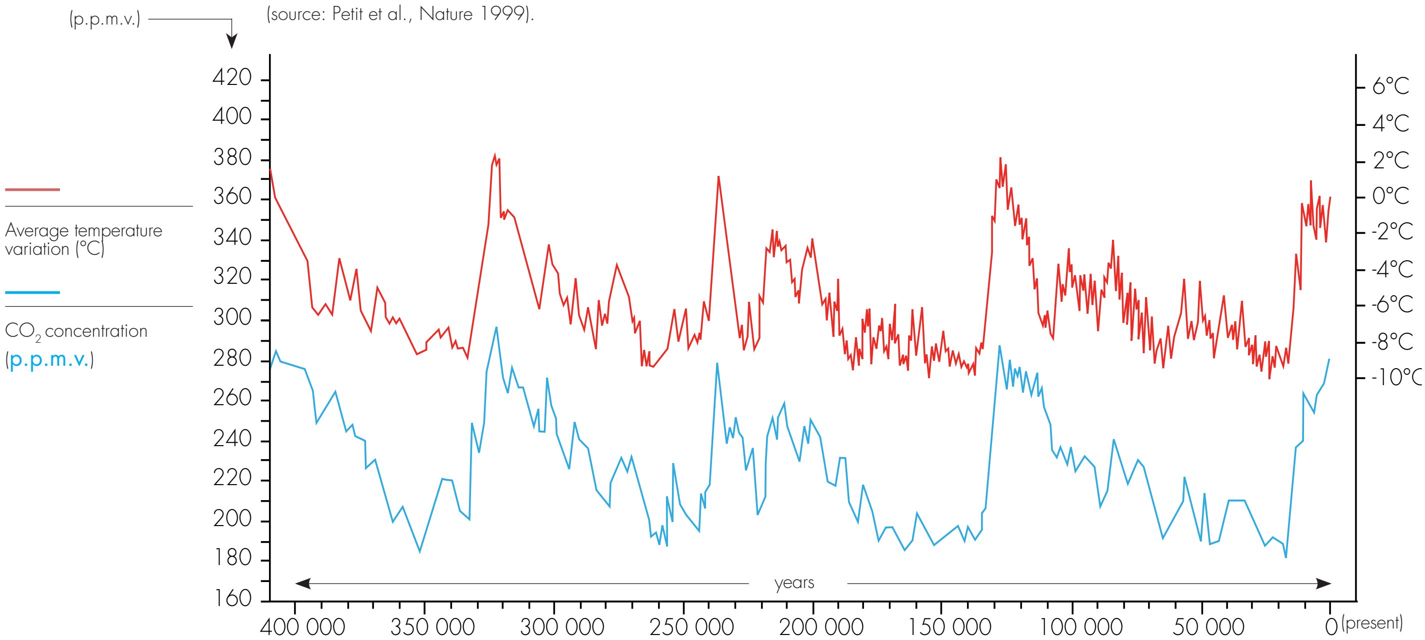
Drilling ice cores enables us to go back up to 110,000 years in the ice of the Greenland Ice Sheet and as much as 800,000 years in the ice of the Eastern Antarctic Ice Sheet.

2) WHAT IS AN ISOTOPE AND WHAT PART DOES EXAMINING THEM PLAY IN PALEOCLIMATOLOGY?

Numerous chemical elements in the periodic table have several isotopes. Isotopes of the same element have the same number of protons in their nucleus but have different numbers of neutrons. This is true for carbon, for example, which has many isotopes, two of which are naturally occurring and stable: carbon 12 (^{12}C) and carbon 13 (^{13}C). However one carbon isotope, carbon 14 (^{14}C) is a naturally occurring radioisotope that undergoes slow yet predictable radioactive decay, which means the atom decays over time by emitting electromagnetic radiation and subatomic particles.

The predictable rate of radioactive decay of ^{14}C can be useful in determining the age of organic material. The time required for half of a given quantity of a radioisotope to undergo radioactive decay is called its half-life. This is the principle used in carbon 14 dating. The radioactive isotope ^{14}C is produced in the upper atmosphere when nitrogen gas is bombarded by cosmic rays (^{14}C represents only around 1×10^{-10} % of the carbon isotopes found in Earth's atmosphere). Found in trace quantities on the Earth's surface, living organisms absorb carbon 14 during their lifetime. After an organism dies, the amount of ^{14}C in its body decreases a predictable rate. It is therefore possible to date organic material by measuring its residual level of ^{14}C to determine the time needed for the quantity of remaining ^{14}C to diminish to the value measured.

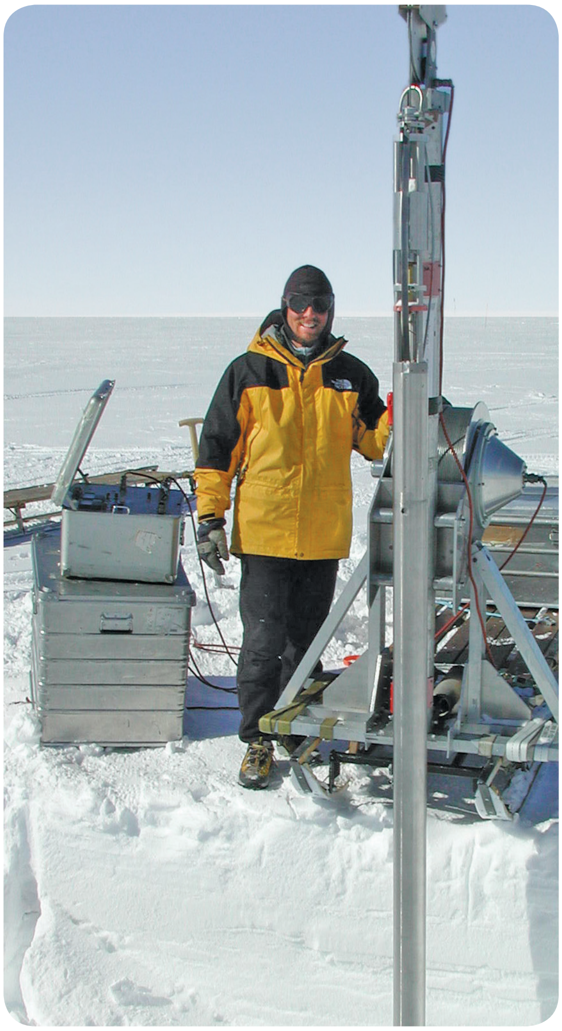
Figure 2: Information gathered from an ice core taken near Vostok Station in Antarctica:
Evolution of the carbon dioxide (CO_2) concentration and of the variation in average temperature during the last 400,000 years (source: Petit et al., Nature 1999).



However, on account of its very short half-life on the scale of geological time (only 5730 years), the ^{14}C method of carbon dating can only be applied to material younger than approximately 50,000 years, since before this time no traces of the isotope can be detected.

In the same way, analysing two oxygen isotopes, the "light" isotope ^{16}O and the "heavy" isotope ^{18}O, enables us to measure the isotope fractionation, or ratio of ^{18}O to ^{16}O, and use it as a kind of paleothermometer. This is how the temperature curve in figure 2 was obtained. It shows the variation in average temperature for the period sampled in the ice taken from Vostok (going back 400,000 years). We can also see that the curve of carbon dioxide (CO_2) concentrations lines up very well with this temperature curve).

Using the shells of foraminifers (planktonic microorganisms) taken from ocean sediment cores as a proxy , it is possible to reconstitute the average temperature of the surface water even further back in time (~ 200 million years).



SHEET N°5

GLOSSARY:

Aerosol: n. Ecology. – Tiny solid or liquid particles (micron size) suspended in the air that can act as condensation nuclei for water droplets to form clouds.

Core: n. Glaciology or sedimentology. – Sample of ice or marine sediment obtained using a cylinder several centimetres in diameter, usually in a section of 3 to 5 metres. These samples enable us to deduce a range of information about paleoclimates.

Carbon 14 dating: Nuclear physics. - Dating technique that uses the radioactive decay timeline of the radioactive isotope 14C. The proportion of this isotope decreases steadily over time.

Half-life: n. Nuclear physics. – Period after which half of the radioactive nuclei initially present have disappeared by radioactive decay.

Isotope fractionation: n. Chemistry. – Ratio of the respective proportions of two different isotopes of the same element in a given environment. In the case of oxygen, the ratio of the levels of the two isotopes ^{16}O and ^{18}O found in the water molecules in polar ice makes it possible to work out temperatures from past eras (paleotemperatures), when the ice was formed from fresh snow.

Paleoclimatology: n. Climatology. – Area of climatology that studies ancient climates.

ppmv: n. Chemistry. – Concentration of a given substance corresponding to one part per million in volume (ppmv), which is equivalent to 1 cm^3/m^3.

Radioactivity: n. Nuclear physics. – The emission of electromagnetic radiation and subatomic particles through the radioactive decay of certain unstable or radioactive atoms. Radioactive decay results in the release of energy and often the formation of other chemical elements. Uranium and plutonium are two examples of radioactive elements.

Periodic table (Mendeleev's table): Chemistry. – Table showing all chemical elements classified in ascending order of atomic number. In this way, the elements are ordered in lines (periods) and columns (blocks), which determines their physical and chemical properties

WEB:

See the animations on "Climate Archives" and "Ice Caps and Ice Sheets", as well as the teaching dossier on "Polar Science" on EDUCAPOLES, the educational website of the International Polar Foundation (IPF):
http://www.educapoles.org

Other websites containing interesting information related to this subject:

http://www.antarctica.ac.uk/images/video/player.php?id=cf71156c

http://earthobservatory.nasa.gov/Features/Paleoclimatology_IceCores/

http://www2.cnrs.fr/en/1201.htm

http://www.esf.org/index.php?id=855

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