



QUESTION FROM THE CLASSROOM

By Bob Becker

Q. I was reading an article about global warming that described scientists analyzing samples of air from 800,000 years ago. From this analysis, they found that current carbon dioxide levels in the atmosphere are at their highest level in more than 800,000 years. How do scientists find samples of 800,000-year-old air?

A. They find them in tiny bubbles that are trapped at the bottom of ice sheets, sometimes as much as 3.5 kilometers thick. These ice sheets formed over the years, as snowfall upon snowfall accumulated in areas such as Antarctica, Greenland, and in high-altitude mountain ranges like the Andes in South America.

What scientists do to extract and analyze ice core samples is pretty remarkable. They set up camp in these extremely cold regions and spend years drilling through the ice with large hollow coring drills. The technique allows them to bring up ice core samples that are typically 2–6 meters long, carefully remove them from the drill, and then send the drill down for more.

It is interesting to note that beyond 300 meters, the ice is under such great pressure that it tends to flow and deform. (Even though ice is a solid, it is considered a plastic material and deforms under substantial pressure.) This deformation would close off the hole each time a core sample is removed. To avoid this problem, the hole must be filled to within 100 meters from the surface with a fluid—typically a hydrocarbon, which is a compound made of carbon and hydrogen atoms (such as *n*-butyl acetate)—to supply equal pressure outward and keep the hole from sealing off.

This drilling fluid must not freeze at these subzero temperatures; is environmentally safe, nontoxic and nonhazardous; is relatively inexpensive; can be easily cleaned off the core samples and recovered for reuse; and must have just the right density to match that of the ice so that the pressures inward and outward are equalized.

Although no liquids meet all these require-

ments, *n*-butyl acetate ($C_6H_{12}O_2$) comes fairly close. Kerosene (a mixture of hydrocarbons ranging from $C_{10}H_{22}$ to $C_{16}H_{34}$) can also be used, but it must be mixed with an additive—typically a halogenated hydrocarbon, in which one or more hydrogen atoms in a hydrocarbon molecule are replaced by halogen atoms,

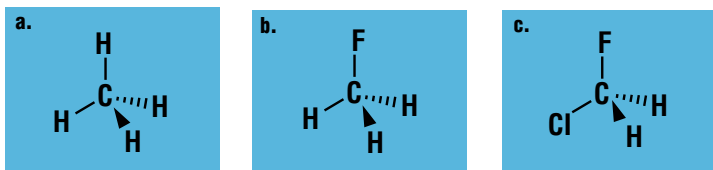


Figure 1. Methane (a) and two examples of halogenated hydrocarbons: fluoromethane (b) and chlorofluoromethane (c).



Ice core extracted from the Andes in Bolivia.

such as fluorine, chlorine, or bromine (see Fig. 1)—to increase its density.

Once they are ready to be analyzed, the ice core samples are placed in an ultra-clean and very cold flask, where they are crushed up into tiny pieces to release the trapped air bubbles. This air and the ice from which it came can then be analyzed to obtain a wealth of information.

So how can scientists have any idea of what the temperatures were back when the snow fell hundreds of thousands of years ago? One clue involves the ratio of oxygen-18 to oxygen-16.

More energy is needed to get the heavier water molecules into the atmosphere and keep them there. This means that the isotopic content of water falling as rain or snow depends on the temperature of the sea from which

it evaporated and on the air that carried the water vapor. So, the isotopic content is related to temperature, and the higher the ratio of oxygen-18 to oxygen-16, the warmer the year. By measuring the ratio of these two isotopes in the ice samples, researchers can track how temperatures change over the years.

Also, you would think that dating the air would be as simple as dating the ice in which the bubbles are imbedded. But snow remains

porous for quite some time and to depths of up to 100 meters. As it gets compacted beneath more and more layers of snow, this porosity decreases, and the bubbles of air eventually seal themselves off, but scientists have determined that this can create a lag time between the age of the air and the age of the ice in which it is imbedded.

This lag time can be anywhere from 50 to 500 years. In other words, the age of trapped air can only be linked to the time at which the bubbles completely sealed themselves off under the pressure of all the snow above. This sealing off time introduces some degree of uncertainty into the information the scientists obtain.

Uncertainty is a part of any scientific research, and although 500 years may not seem like much in comparison with 800,000 years, it does make it challenging to show direct correlations between periods of rapid temperature change—determined from the ice itself—and periods of carbon dioxide increases in the ice-embedded bubbles occurring at the same time.

There is a lot of discussion these days about greenhouse gases and global warming. Among all of these discussions, it is easy to lose sight of the fact that dedicated men and women are working tirelessly and meticulously in bitter cold trenches in the middle of Antarctica and above the Arctic Circle to help us understand how climate has changed in the past and how it is changing now. ▲