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Isotopes freeze images of the ice age

Carbon dating is a method to tell us how old the fossil of a prehistoric animal may be, says S.Ananthanarayanan.

A similar technique can reveal how warm, or cool the earth was when the animal died!

Isotopes

These methods work because the elements can exist as '*isotopes*', or in forms that have a difference in the atomic structure, and yet remain the same element. The nucleus of the Carbon atom, for instance, usually has six protons, or positive particles and six neutrons, or neutral particles. Another form of carbon has not six but seven neutrons in the nucleus. This form is then 'heavier', but it still behaves like carbon, because it is the number of protons that decides chemical behaviour.

Oxygen also exists in different forms. The most abundant has eight protons and eight neutrons or a mass of sixteen. This is referred to as O^{16}. Another form of oxygen has ten neutrons and is called O^{18}.

Carbon dating

This uses the property that C^{13} , which is the kind that has six protons and seven neutrons, or thirteen particles in all, is radioactive, or slowly depletes, getting converted to nitrogen as time goes on. But, as the processes that give rise to C^{13} and the rate of its depletion have struck a balance, the quantity of C^{13}, and hence the ratio of the two forms of carbon in the world, viz, C^{13} and C^{12}, are uniform and constant. All living things, which breathe, drink and eat also have the same ratio of the two forms of carbon in their bodies.

But if the animal should die and get preserved as a fossil, the carbon in its cells stop communicating with the environment to keep up the ratio of C^{12} and C^{13}. The ratio hence gradually changes, as the C^{13} part gets used up through radioactivity.

After some thousands of years, when the fossil is examined, its age can be told by checking how much of C^{13} is left.

The oxygen thermometer

The vast store of water in the earth contains both forms of oxygen, O^{16} and O^{18} in the ratio of about 998 parts of O^{16} to two parts of O^{18}. As neither form is radioactive, the ratio of the two forms in a sample, once isolated, would remain unchanged through the ages. But the exact ratio itself, in the sea, for instance, depends on the temperature, rainfall, climate. This means that if a sample of water, or the oxygen in the water, were preserved for centuries, the ratio of two kinds of oxygen in the sample would be a record of the climate at the time the sample was taken. A kind of photograph!

The way the ratio depends on the climate is like this: As O^{18} is heavier than O^{16}, evaporation tends to carry less of the O^{18} component of seawater up into clouds. Clouds are thus *richer* in O^{16}, which is the lighter component. Now in rainfall, it is again the O^{18} part that detaches from the cloud and descends first. This 'early' rain is usually in the tropics and flows back to the sea. As a result of O^{18} getting bled like this, the clouds that last till they reach the poles, get to the poles even more enriched in O^{16}. The rainfall at the poles, much of which gets fixed as permanent ice, thus has a lot more O^{16} than O^{18}. While in the case of seawater it is the other way about.

During the ice ages

During the ices ages there was heavy accumulation of water with the O^{16} content as polar ice and glaciers. The plants and insects in the sea thus had greater O^{18} in their bodies. When they died, they sank to the bottom of the sea and got preserved in layers that correspond to that time. During warm periods like when the dinosaurs roamed the earth, the polar ice had melted, the oceans had risen and the seawater had a lot more O^{16}. This was also preserved in the shells of sea animals of the time.

Study of these records has shown where the ice formed and melted during and between past ice ages.