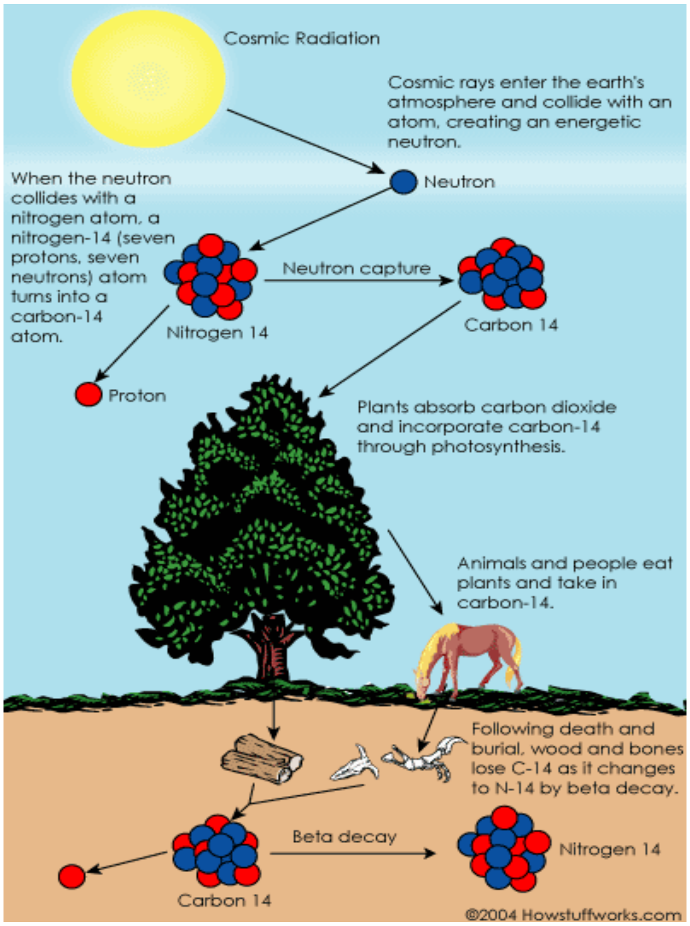
Station 1 - Fossil Dating

RADIOACTIVE DATING

Radiocarbon or **Carbon-14 dating** is a method that utilizes concepts of radioactive decay to determine dates of fossils. This method is used on organic materials such as wood and seeds that are believed to be around 60,000 years old. Carbon-14 dating is a way of determining the age of certain archeological artifacts of a biological origin up to about 60,000 years old. It is used in dating things such as bone, cloth, wood and plant fibers that were created in the relatively recent past by human activities.



The carbon-14 atoms that cosmic rays create combine with oxygen to form carbon dioxide, which plants absorb naturally and incorporate into plant fibers by photosynthesis. Animals and people eat plants and take in carbon-14 as well. The ratio of normal carbon (carbon-12) to carbon-14 in the air and in all living things at any given time is nearly constant. Maybe one in a trillion carbon atoms are carbon-14. The carbon-14 atoms are always decaying, but they are being replaced by new carbon-14 atoms at a constant rate.

As soon as a living organism dies, it stops taking in new carbon. The ratio of carbon-12 to carbon-14 at the moment of death is the same as every other living thing, but the carbon-14 decays and is not replaced. The carbon-14 decays with its half-life of 5,700 years, while the amount of carbon-12 remains constant in the sample. By looking at the ratio of carbon-12 to carbon-14 in the sample and comparing it to the ratio in a living organism, it is possible to determine the age of a formerly living thing fairly precisely.

Because the half-life of carbon-14 is 5,730 years, it is only reliable for dating objects up to about 70,000 years old. However, the principle of carbon-14 dating applies to other isotopes as well. Potassium-40 is another radioactive element naturally found in your body and has a half-life of 1.3 billion years. Other useful radioisotopes for radioactive dating include Uranium -238 (half-life = 4.5 billion years) and Rubidium-87 (half-life = 49 billion years). The use of various radioisotopes allows the dating of biological and geological samples with a high degree of accuracy. However, radioisotope dating may not work so well in the future. Anything that dies after the 1940s, when nuclear bombs, nuclear reactors and open-air nuclear tests started changing things, will be harder to date precisely.

What Did You Learn?

1. Carbon-14's half life is 5700 years, meaning that within approximately 62,000 years, the material will have no Carbon-14 left. Describe what other options scientists have to use for fossils that they know are older than 62,000 years old (RI 8.3 APPLICATION)
2. Will scientists be able to age materials dated from modern day using these methods? Why or why not? (RI 8.4)

Station 2 - Fossil Dating

FISSION TRACK

Fission track dating was developed in the mid 1960s by three American physicists, who noticed that micrometer-sized damage tracks are created in minerals and glasses that have minimal amounts of uranium. Fission track dating is used to age materials that were once living and non-living. These tracks accumulate at a fixed rate, and are good for dates between 20,000 and a couple of billion years ago. Because of the age range, this method is considered very accurate and is used most often in materials over 60,000 years.

This is a method of age determination that makes use of the damage done by the spontaneous fission of uranium-238, the most abundant isotope of uranium. The fission process results in the release of several hundred million electron volts of energy and produces a large amount of radiation damage before its energy is fully absorbed. The damage, or fission tracks, can be made visible by the preferential leaching (removal of material by solution) of the host substance with a suitable chemical reagent; the leaching process allows the etched fission-track pits to be viewed and counted under an ordinary optical microscope. The amount of uranium present can be determined by irradiation to produce thermal fission of uranium-235, which produces another population of tracks, these related to the uranium concentration of the mineral. Thus, the ratio of naturally produced, spontaneous fission tracks to neutron-induced fission tracks is a measure of the age of the sample.

A wide variety of minerals have been fission-track dated, as have natural and artificial glasses. Fission-track dating has been used for very old samples (*e.g.,* meteorites) and also for the dating of very young specimens (*e.g.,* artifacts from archaeological sites). Fission track dating is based on the microscopic observation and counting of etchable tracks left by the spontaneous fission of uranium in minerals. Since its development in 1963 the method attracted a steadily growing interest from geologists and geochronologists throughout the world. Apart from its relative experimental ease the success must be mainly ascribed to the specific ability of the method of unraveling the thermal and tectonic history of rocks, a potential which only became fully exploited during the last decade with the systematic introduction of track size analysis.

What did you learn?

1. What materials is fission track dating used on? (KNOWLEDGE RI 8.1)
2. This method is relatively new. Why do you think it has taken scientists so long to figure out how to use these radioactive materials? (ANALYSIS 8.3)

Station 3 - Fossil Dating

O S L

<u>Optically stimulated luminescence</u> (OSL) makes use of electrons trapped between the bands in the crystalline structure of certain types of matter (such as quartz, feldspar, and aluminum oxide). The trapping sites are imperfections or defects of the crystal lattice. The ionizing radiation produces electron-hole pairs which when stimulated, emit a light. The photons are detected using a photomultiplier tube. The signal from the tube is then used to calculate the dose that the material had absorbed.

OSL dating occurs in ancient materials such as mainly geological sediments, but also sometimes fired pottery, bricks etc, all younger than 100,000 years old. In order to carry out OSL dating, mineral grains have to be extracted from the sample. Most commonly these are so-called coarse grains - 100-200 μm, or fine grains - 4-11 μm. Occasionally other grain sizes are used.

The difference between radiocarbon dating and OSL is that the former is used to date organic materials, while the latter is used to date minerals. Events that can be dated using OSL are, for example, the mineral's last exposure to sunlight; Mungo Man, Australia's oldest human find, was dated in this manner. It is also used for dating the deposition of geological sediments after they have been transported by air (eolian sediments) or rivers (fluvial sediments). In archaeology, OSL dating is applied to the dating of ceramics: the dated event is the time of their last heating to a high temperature (in excess of 400 °C).

Recent OSL dating of stone tools in Arabia pushed the "out-of-Africa" date hypothesis of human migration back 50,000 years and added a possible path of migration from the African continent to the Arabian peninsula instead of through Europe.

What did you learn?

1. How does OSL work? (COMPREHENSION RI 8.1)
2. Will OSL work for once living materials? Explain why or why not. (APPLICATION RI 8.3)
3. Why do scientists need more than one method to age fossils? (EVALUATION RI 8.1)

Station 4 - fossil dating

ICE CORES

Ice cores, cylinders of ice drilled out of glaciers and polar ice sheets, have played an important role in revealing what we know so far about the history of climate. The United States scientists embarked on a new ice coring project in Greenland with a wide range of state of the art analyses in the hopes of resolving questions about how the climate system functions. Drilling for The Greenland Ice Sheet Project Two* (GISP2) began in 1989. When they reach the bottom of the ice sheet, 3000+ meters thick, in 1992 they will have recovered the longest, most detailed, continuous record of climate available from the northern hemisphere stretching back 200,000 years or more through two glacial/interglacial (cold/warm) cycles.

How can a history of climate be reconstructed from an ice core? When snow falls it carries with it the compounds that are in the air at the time, compounds ranging from sulfate, nitrate and other ions, to dust, radioactive fallout, and trace metals. When snow falls in a place where temperatures above freezing are rare (there is only a hint of any melting at the GISP2 site in the 750 year record recovered to date), such as in polar regions or at high altitude, the snow from one year falls on top of the previous year without melting.

As each year's snowfall is buried by successive years' snowfall, the constituents contained in the snow are buried along with it. By drilling down from the surface of an ice sheet and analyzing snow from greater and greater depths, a history of the compounds in the air can be obtained. Further, snow that is deeper than 80 meters at the GISP2 site turns into ice from the weight of the snow above it, and trapped in the ice are small bubbles of air. Thus, in addition to trapping compounds from the air, an ice sheet traps a small sample of the air itself. This trapped air is also analyzed and provides information about the composition of the atmosphere at the time the ice formed. Sediments also accumulate very slowly relative to snow on an ice sheet. This results in much longer records from sediment cores, but a much-reduced ability to resolve short-term changes. While periods of hundreds to thousands of years might be resolved in a sediment core, annual and even seasonal resolutions are possible with ice cores. On the other hand, sediment cores can provide records, which are as long as several million years compared with the several hundred thousand years of ice cores. Because of these differences, sediment cores and ice cores provide complimentary climate information; ices cores provide high resolution, direct information and sediment cores lower resolution, less direct records, but from much longer time periods.

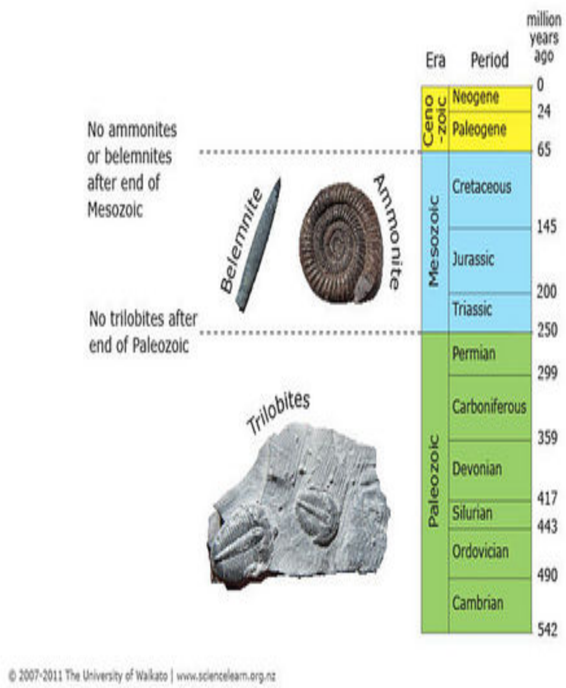
What did you learn?

1. Describe how ice cores work (COMPREHENSION RI 8.1)
2. What can the climate tell about the living things in an environment (APPLICATION RI 8.3)?
3. Why is it useful to be able to describe the climate in addition to age the material in an environment? (ANALYSIS RI 8.3)

Station 5

F O S S I L   D A T I N G

Relative dating is used to arrange geological events, and the rocks they leave behind, in a sequence. The method of reading the order is called stratigraphy (layers of rock are called strata). Relative dating does not provide actual numerical dates for the rocks. Fossils are important for working out the relative ages of sedimentary rocks. Throughout the history of life, different organisms have appeared, flourished and become extinct. Many of these organisms have left their remains as fossils in sedimentary rocks. Geologists have studied the order in which fossils appeared and disappeared through time and rocks. This study is called biostratigraphy.



Fossils can help to match rocks of the same age, even when you find those rocks a long way apart. This matching process is called correlation, which has been an important process in constructing geological timescales.

Some fossils, called index fossils, are particularly useful in correlating rocks. For a fossil to be a good index fossil, it needs to have lived during one specific time period, be easy to identify and have been abundant and found in many places. For example, ammonites lived in the Mesozoic era. If you find ammonites in a rock in the South Island and also in a rock in the North Island, you can say that both rocks are Mesozoic. Different species of ammonites lived at different times within the Mesozoic, so identifying a fossil species can help narrow down when a rock was formed.

Correlation can involve matching an undated rock with a dated one at another location. Suppose you find a fossil at one place that cannot be dated using absolute methods. That fossil species may have been dated somewhere else, so you can match them and say that your fossil has a similar age. Some of the most useful fossils for dating purposes are very small ones. For example, microscopic dinoflagellates have been studied and dated in great detail around the world. Correlation with them has helped geologists date many New Zealand rocks, including those containing dinosaurs.

What did you learn?

1. How do index fossils work? (COMPREHENSION 8.1)
2. Does relative dating provide accurate and precise information? Explain why or why not. (ANALYSIS RI 8.2)