Ed Planansky, Hay Springs, NE © 2008

DATIN HISTORY OF ROCK CHRONOMETRIC/RADIOMETRIC G

Educational Objective: To help students become aware of dating techniques used to date very ancient (millions of years) to relatively recent (tens of thousands of years) events in geologic time.

Target Audience: Any science or math class with adaptations for age groups and class setting.

Questions To Be Answered:

1. What is the half-life of a radioactive isotope?

2. How can the half life of an isotope be used to date anything?

3. Which isotope dating method is most likely to give the most accurate dating of a sediment or specimen?

4. Given a hypothetical amount of material present in a sample compared to the amount that was present at formation be able to date events or sediments.

HALF-LIFE

Following World War I and the invention of a device called a mass spectrometer more than 200 isotopes of the 92 naturally occurring elements were found. Isotopes are atoms of elements that have the same atomic number but different atomic masses, they are the same element but have different weights because of different numbers of neutrons in the nucleus of the atom. Because the isotopes are essentially the same element they have the same chemical properties but have different physical properties. For the purposes of dating geologic times the property we are concerned with is radioactive decay.

Each radioactive isotope decays, by emitting alpha or beta particles and becoming a new element many of which are stable and no longer decay. The time it takes for half of a sample to decay into new material(s) is called its half-life.

Many radioactive elements can be used as geologic clocks. Each radioactive element decays at its own unique rate. Once this rate is known, geologists can estimate the length of time over which decay has been occurring by measuring the amount of radioactive (parent) element present and comparing it to the amount of stable (daughter) element present in a sample.

Sample table of some isotopes and their daughter stable daughters and their corresponding half-lives

Radioactive Parent	Stable daughter	Half-life
Potassium 40	Argon 40	1.25 billion years
Rubidium 87	Strontium 87	48.8 billion years
Thorium 232	Lead 208	14 billion years
Uranium 238	Lead 206	4.47 billion years
Uranium 235	Lead 207	704 million years
Carbon 14	Nitrogen 14	5,730 years

The rate of decay is totally independent of intense heat, cold, pressure, or moisture. So by comparing parent to daughter or by graphing parent against time a sample can be dated.

Also since different parent isotopes are produced in different ways the choice of isotope is also dependent on how the formation was produced, i.e. volcanic, organic, sedimentary, etc.

Some examples:

All living materials use carbon dioxide from the atmosphere to produce their living materials either directly through photosynthesis (plants) or by consuming plant matter (animals) that used photosynthesis. All carbon dioxide contain a specific amount of carbon 14, so as long an organism is living the amount of carbon 14 is constant in its matter. Once an organism dies the carbon 14 is no longer replenished and it starts to decay. Carbon 14 is a good way to date things that were once living and probably not over 60,000 years old. Carbon 14 does NOT work for fossils because in fossils the living material has been replaced by other minerals.

To date sedimentary rocks, it is necessary to isolate a few unusual minerals (if present) which formed on the sea floor as the rock was cemented. Glauconite is a good example. Glauconite contains potassium, so it can be dated using the potassium-argon technique. But potassium 40 is usually found only in significant amounts in volcanic rock as the intense heat drives off the argon 40 so it can be assumed that all of the argon 40 in a sample that was once volcanic is present only from the time of cooling of the volcanic rock. So using this technique to date a fossil one could date volcanic activity below and above the fossil to get a relative date for the fossil

The age of the earth itself can be dated from the decay of uranium 238 into lead 206. Uranium-lead dating is often performed on the mineral "zircon" ($ZrSiO_4$), Though it can also be used on other minerals. Zircon incorporates uranium atoms into its crystalline structure as a substitute for the zirconium but strongly rejects lead

Potassium-40 is a good indicator if the rocks are igneous in nature, i.e volcanic or great heat present at formation.

A SIMPLE DATING PROCESS

1. Graph a unit (starting amount) of a radioactive isotope of any material against it's half-life, for example with carbon 14 the graph would incorporate the following X,Y values:

"Y" Amount of C-14	"X" Age of sample	Half-lives
1 unit	0	0
.5	5,730 years old	1
.25	11,460	2
.125	17,190	3
.0625	22,920	4

(Etc)

Using the graph, one has only to find the amount of parent present compared to the amount present at formation (which involves comparing the parent to the daughter). With that Y value go over to the graph and find the corresponding X value, presto you have the age of the sample.

Proposed Situations

1. The dinosaurs disappeared about 64 million years ago the time being referenced by the formation of the K-T boundary. In the Manson, Iowa area 20 to 90 meters below the surface of

the terrain and covered by glacial till lies a structure about 38 kilometers in diameter. It has been determined that a comet or asteroid, 2 kilometers in diameter, struck the Earth at that point. At the time this was the largest meteor impact crater in the northern hemisphere. It was originally hypothesized that this impact was the one responsible for the destruction of the dinosaurs. Since it was volcanic in nature it could be dated by Potassium-40 decay. (Actually Argon-40/Argon-39 ratios were used, but that's another story).

Because the ages here are relatively young for potassium-40 decay use the following units that are very close to the starting value of 1 unit, 1 unit can be any amount it is just what we start with.

Y-axis Amount of Original material	X-axis Age of deposit in millions of years
.9990	17.3
.9980	68.9
.9970	103.4
.9960	138.2

Hint: Start on the lower left Y- axis at .9960 and go up .0001 unit at a time (1 square) until you reach .9990.

Then for X-axis start at the left at 10 (million years) and go 2 squares for 5 million years across the bottom.

Draw a SMOOTH curve. The graph is NOT a straight line rather a curved line.

Be neat and meticulous or this will not work!

It was found that between .9979 and .9978 of the original material was left of the potassium-40. From your graph how old is the crater site?

Could the crater, from your age above, be responsible for the dinosaur extinction?

How much original material would have to have been lift to have been responsible for the Dinosaur extinction? The K-T boundary.

2. In Niobrara, NE a volcanic type deposit (MUCH older than the Ashfall deposites of rhino claim) has been found that resembles a deposit put there by very fast moving water, larger sediments at the bottom of the deposite smaller above and fine silt on the top. The deposit is consistent with a “tsunami”! Nebraksa and Iowa were covered by a large inland sea way from maybe 140 million years ago until its last gasps maybe some 60 million years ago. What maybe could have caused the tsunami?

How could you, or a geologist, verify that the deposit matches your prediction?

Tsunamis, fossils of sea animals, meteor collisions, isn’t geology interesting?

Why do you suspose NO fossils of dinosaurs have been found in Nebraska?

3. The sand hills of Nebraska are the largest in the Western Hemisphere. Not a shifting, blowing sand desert, but stabilized sand dunes. Organic matter toward the bottom of the dunes in the sand hills has been dated. How do you think the material was dated?

Consider that the matter has Carbon-14 emissions of about 2 counts per minute. If living material has approximately 16 cts/min how many half lives has the material gone through?

How old is the material?

Using the 16 cts/min vs the half-life of C-14 graph this decay series (16 vs 0, 8 vs 5730, etc). Charcoal from a Native American camp fire unearthed in sand hill sediments along the Niobrara river was dated at about 10,000 years old. How many cts/minb was the charcoal emitting?

The sand hills are considered to be about 18,000 yrs old. How does this compare to your above prediction?

Other types of radiometric dating:

Argon-Argon | Uranium-Thorium

Fission Track
Helium
Iodine-Xenon
Lanthanum-Barium
Lead-Lead
Lutetium-Hafnium
Neon-Neon
Optically stimulated luminescence
Potassium-Argon
Rhenium_ Strontium
Rubidium-Strontium
Uranium-Lead
Uranium-Uranium

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