CHAPTER 5

GENESIS: CONCORDIST INTERPRETATIONS

RADIOMETRIC DATING

High school science students learn about the Periodic Table of Elements and the many types of elements (helium, carbon, iron, oxygen, gold, lead, and so on). They learn that most elements have several different isotopes. For example, carbon-12, carbon-13, and carbon-14 are all different isotopes of carbon. Some isotopes are stable, but other isotopes are unstable and eventually change into other, stable isotopes. (For example, uranium-238 changes into lead-206; carbon-14 changes into nitrogen-14.) This change is called radioactive decay. Radioactive decay is used to measure the age of the earth.

The radioactive isotope that decays is called the parent isotope, and the resulting product is called the daughter isotope. During the decay other energetic particles are released that allow scientists to count the decays one by one.

Radioactive decay is useful for measuring ages because it has a unique pattern over time. The half-life of a radioactive isotope is the time it takes for half of the atoms to decay. For example, nitrogen-13 is an unstable isotope that decays to carbon-13 with a half life of ten minutes. That means that if you start with 16,000 atoms of pure nitrogen-13, after ten minutes you'll only have half that amount left (8,000 atoms) because the other half will have decayed to carbon-13. In the next ten minutes half of the remaining nitrogen decays, and the sample now contains 4,000 atoms of the parent isotope and 12,000 atoms of the daughter isotope. After another ten minutes (now 30 minutes after the start) the sample is 2000 atoms of nitrogen-13 (the parent) and 14,000 atoms of carbon-13 (the daughter).

Scientists can measure the age of a sample even if they haven't been there to watch the whole decay process from the beginning. The age is found by determining how much of the parent isotope has changed into the daughter isotope. In the example given above, if you walked into the lab to see a sample that was one-quarter nitrogen-13 and three-quarters carbon-13, and you knew the sample had no carbon-13 to begin with, you would know that the sample had been decaying for two half-lives. If you also know that the half-life is ten minutes, then you could calculate the age of the sample in the experiment that has been going on for 20 minutes. With a little math it is possible to figure out the age for any ratio of nitrogen-13 to carbon-13, even if you weren't there to watch the decay happen.

A half-life of ten minutes (like nitrogen-13) is too short to be useful for geologists who are interested in time scales of thousands or millions of years. Instead, geologists use isotopes such as carbon-14 (with a half-life of 5,730 years), beryllium-10 (with a half-life 1.52 million years), and uranium-238 (with a half-life of 4.5 billion years). These isotopes decay so slowly that it is impossible to wait around until half of the sample has decayed. But scientists can still measure the half-life. They do so by recording each individual atom that decays, either by the radiation produced in the decay or by counting individual daughter atoms. For something like uranium-238, it might seem like the half-life is too long to see any decays, but the number of atoms in even a small sample is enough to show trillions of decays in a year. Each one can be counted, and the change in rate over the year is used to calculate the half-life.

In order to calculate the age of a rock, geologists need to know

- the half-life of the parent isotope.
- the amount of the parent isotope currently in the rock.
- the amount of the parent isotope in the rock when it was first formed.

The first two can be directly measured; the third is deduced from other information, including the amount of daughter isotope currently in the rock (see the example below). In order for this method to work, the rock must be a closed system from the time it formed till the present, so that no parent or daughter isotope could leave the rock or get into the rock from the outside. Sedimentary rocks are seldom used for radiometric dating because they are generally porous, allowing groundwater with dissolved minerals to get in and out. For this reason, radiometric dating is mainly done on igneous rocks that have not undergone metamorphism. Scientists avoid rocks that are contaminated and use only the interior of the rocks. They don't use rocks that are composites of different types of rock because different portions of the composite could have different ages.

How do scientists know the amount of parent isotope in the rock when it formed? Scientists have various ways to determine this for different kinds of radiometric dating. The simplest way of figuring this out is if there was no daughter isotope in the rock when the rock was formed. In that case, all of the daughter atoms found in the rock today were originally parent atoms, so it is easy to calculate the total amount of parent atoms when the rock formed. Here's one example:

> Some rocks are dated using the decay of the parent potassium-40 to the daughter argon-40. Argon-40 happens to be a gas in molten rock, so it bubbles out of liquid lava. After the lava cools and hardens, all the argon-40 that is produced by radioactive decay of potassium-40 will be trapped in the rock. When scientists study an uncontaminated igneous rock, they know that all of the argon-40 they find is a result of radioactive decays since the initial formation. Thus, they can calculate the original amount of parent isotope and the number of half-lives since it was molten.

When possible, scientists double-check their work by comparing results from different isotopes to make sure that they are consistent with each other. Such double-checking can sometimes be done using multiple isotopes on the *same* rock. Rocks from one formation in western Greenland have had their ages measured more than a dozen times using five different radioactive isotopes. The results were the same for all five isotopes: an age of 3.6 billion years.

Radiometric dating is one of the most important methods of geologists for determining the ages of rocks. It is not the only method; geologists have many other methods for determining ages. Radiometric dating reinforces those other methods, and it is often the most precise method.