Appendix B
Core Lab Activities

Core Lab 1 - Radiometric Dating

The age of fossils and rocks intrigues almost everyone. Students not only want to know how old a fossil is, but they want to know how that age was determined. Some very straightforward principles are used to determine the age of fossils. Students should be able to understand the principles and have that as a background so that age determinations by paleontologists and geologists do not seem like black magic.

There are two types of age determinations. Geologists in the late 18th and early 19th century studied rock layers and the fossils in them to determine relative age. William Smith was one of the most important scientists from this time who helped to develop knowledge of the succession of different fossils by studying their distribution through the sequence of sedimentary rocks in southern England. It was well into the 20th century that enough information had accumulated about the rate of radioactive decay that the age of rocks and fossils in number of years could be determined through radiometric age dating.

Purpose and Outcomes

The students will

- explain how half-lives of radioactive elements are used in estimating ages of materials.
- interpret patterns in data and infer relationships between variables.
- observe that individual runs of statistical processes are less predictable than the average of many runs.

Materials Required

- 100 M & M's (or coins) per group
- large cup or other container in which M & M's can be shaken
- graph paper
- watch or clock that keeps time to seconds (A single watch or clock for the entire class will do.)
- piece of paper marked TIME and indicating either 1, 2, 3, 4 or 5 minutes
- 128 small cards or buttons that may be cut from cardboard or construction paper, preferably with a different colour on opposite sides, each marked with "U-235" on one side and "Pb-207" on the opposite side

Radiometric Age-Dating

Some elements have forms (called isotopes) with unstable atomic nuclei that have a tendency to change, or decay. For example, U-235 is an unstable isotope of uranium that has 92 protons and 153 neutrons in the nucleus of each atom. Through a series of changes within the nucleus, it emits several particles, ending up with 82 protons and 125 neutrons. This is a stable condition, and there are no more changes in the atomic nucleus.

A nucleus with that number of protons is called lead (chemical symbol Pb). The protons (82) and neutrons (125) total 207. This particular form (isotope) of lead is called Pb-207. U-235 is the parent isotope of Pb-207, which is the daughter isotope.

Many rocks contain small amounts of unstable isotopes and the daughter isotopes into which they decay. Where the amounts of parent and daughter isotopes can be accurately measured, the ratio can be used to determine how old the rock is, as shown in the following activities.

At any moment there is a small chance that each of the nuclei of U-235 will suddenly decay. That chance of decay is very small, but it is always present and it never changes. In other words, the nuclei do not >wear out' or get >tired'. If the nucleus has not yet decayed, there is always that same, slight chance that it will change in the near future.

Atomic nuclei are held together by an attraction between the large nuclear particles (protons and neutrons) that is known as the "strong nuclear forces", which must exceed the electrostatic repulsion between the protons within the nucleus. In general, with the exception of the single proton that constitutes the nucleus of the most abundant isotope of hydrogen, the number of neutrons must at least equal the number of protons in an atomic nucleus, because electrostatic repulsion prohibits denser packing of protons. But if there are too many neutrons, the nucleus is potentially unstable and decay may be triggered. This happens at any time when addition of the fleeting "weak nuclear force" to the ever-present electrostatic repulsion exceeds the binding energy required to hold the nucleus together.

Very careful measurements in laboratories, made on VERY LARGE numbers of U-235 atoms, have shown that each of the atoms has a 50:50 chance of decaying during about 704,000,000 years. In other words, during 704 million years, half the U-235 atoms that existed at the beginning of that time will decay to Pb-207. This is known as the half-life of U-235. Many elements have some isotopes that are unstable, essentially because they have too many neutrons to be balanced by the number of protons in the nucleus. Each of these unstable isotopes has its own characteristic half life. Some half lives are several billion years long, and others are as short as a ten-thousandth of a second.

Part 1

A tasty way for students to understand about half life is to give each team 100 pieces of >regular' M&M candy. On a piece of paper or Bristol board each piece should be placed with the printed M (heads or tails if you are using coins) facing down. This represents the parent isotope. The candy should be poured into a container large enough for them to bounce around freely, it should be shaken thoroughly, then poured back onto the paper so that it is spread out instead of making a pile. This first time of shaking represents one half-life, and all those pieces of candy that have the printed M facing up represent a change to the daughter isotope. Then, count the number of pieces of candy left with the M facing down. These are the parent isotope that did not change during the first half life. (An alternative would be to use coins with heads as the parent isotope and tails as the daughter isotope.)

The teacher should have each team report how many pieces of parent isotope remain, and the first row of the decay table should be filled in and the average number calculated. The same procedure of shaking, counting the "survivors", and filling in the next row on the decay table should be done seven or eight more times. Each time represents a half life.

Each team should plot on a graph the number of pieces of candy remaining after each of their shakes and connect each successive point on the graph with a light line. On the same graph each team should plot the average values for the class as a whole and connect that by a heavier line. And, on the same graph, each group should plot points where, after each shake the starting number is divided by exactly two and connect these points by a different coloured line. This line begins at 100; the next point is 50; the next is 25 and so on. This line represents the theoretical values after each half life period.

Graph

Run	Number of Parent Isotope Atoms									Class Total	Class Av.
	Gp.1	Gp.2	Gp.3	Gp.4	Gp.5	Gp.6	Gp.7	Gp.8	Gp.9		
1											
2											
3											
4											
5											
6											
7											
8											
9											
10											

After the graphs are plotted, the teacher should guide the class into thinking about:

- Why each group did not get the same results?
- Which follows the mathematically calculated line (theoretical line) better? Is it the single group's results, or is it the line based on the class average? Why?
- Did students have an easier time guessing (predicting) the results when there were a lot of pieces of candy in the cup, or when there were very few? Why?

U-235 is found in most igneous rocks. Unless the rock is heated to a very high temperature, both the U-235 and its daughter Pb-207 remain in the rock. A geologist can compare the proportion of U-235 atoms to Pb-207 produced from it and determine the age of the rock.

Part 2

Each team receives 128 flat pieces, with U-235 written on one side and Pb-207 written on the other side. Each team is given a piece of paper marked TIME, on which is written either 1, 2, 3, 4 or 5 minutes.

The team should place each marked piece so that U-235 is showing. This represents Uranium-235, which emits a series of particles from the nucleus as it decays to Lead-207 (Pb-207). When each team is ready with the 128 pieces all showing U-235, a timed one-minute interval should start. During that time each team turns over half of the U-235 pieces so that they now show Pb-207. This represents one “half-life” of U-235, which is the time for half the nuclei to change from the parent U-235 to the daughter Pb-207.

A new one minute interval begins. During this time the team should turn over half of the U-235 that was left after the first interval of time. Continue through a total of 4 to 5 timed intervals.

However, each team should stop turning over pieces at the time marked on their TIME papers. After all the timed intervals have occurred, teams should exchange places with one another as instructed by the teacher. The task now for each team is to determine how many timed intervals (that is, how many half-lives) the set of pieces they are looking at has experienced. The half-life of U-235 is 704 million years. Both the team that turned over a set of pieces and the second team that examined the set should determine how many million years are represented by the proportion of U-235 and Pb-207 present, compare notes, and haggle about any differences. (Each team must determine the number of millions of years represented by the set that they themselves turned over. PLUS the number of millions of years represented by the set that another team turned over.)

Core Lab 2 - Carbon Dioxide and Global Warming

Introduction

Although carbon dioxide (CO_2) represents only about 0.036 percent of the gases that make up the atmosphere, scientists believe it to be contributing greatly to global warming. Its importance is its transparency to in-coming short wave solar radiation and its absorbency of outgoing long wave terrestrial radiation. A portion of the energy leaving the ground is absorbed by carbon dioxide and subsequently re-emitted partially back to the ground, keeping the area near the ground warmer than normal and resulting in global warming. Measurements show an increase in levels from 315 parts per million (ppm) to 360 parts per million from measurements taken at Mauna Loa Observatory in Hawaii in 1958 to the present date.

In this lab you will study both the short term trends and the long term trends of this increase in carbon dioxide in our atmosphere and identify some of the causes and effects of global warming.

Purpose and Outcomes

The students will

- graph the changes in the level of CO_2 in the atmosphere and to interpret these changes.
- correlate trends in the concentration of CO_2 to future climate changes.
- construct and interpret lines or curves of best fit.

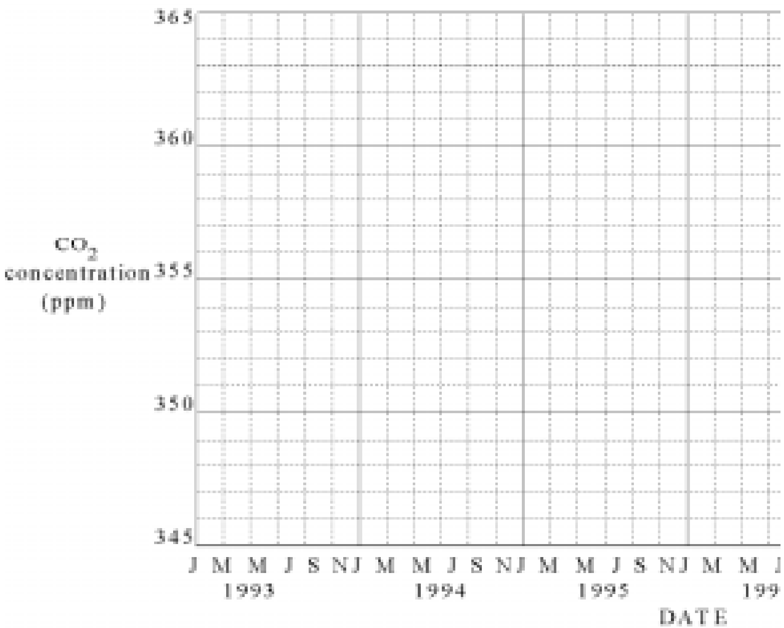
Materials Required

- pencils and other graphing utensils

Method

Date	1993	1994	1995	1996	1997	1998
Jan.	349.2	351.2	353.7	354.7	353.6	356.6
Mar.	350.6	353.1	354.7	356.6	358.1	359.1
May	352.9	355.2	356.7	358.1	360.0	361.2
Jul.	350.8	353.6	354.8	355.5	357.1	360.0
Sept.	347.4	349.8	350.8	352.0	353.2	355.2
Nov.	348.7	351.1	352.3	353.7	354.2	354.8

The table below contains data on CO_2 concentrations in parts per million (ppm) for the six-year period from



1993 to 1998. Use this data to plot CO_2 concentrations as a function of date on the graph grid provided. Draw a smooth best-fit curve between your data points.

Analysis

1. What short-term trend(s) occur between CO_2 concentrations and the dates?
2. What long-term trends occur between CO_2 concentrations and the dates?
3. During which month of each year were the CO_2 concentrations the highest? the lowest?
4. Explain the "cyclic" nature of the CO_2 concentrations using the following:

   (a) photosynthesis

   (b) the burning of fossil fuels (coal, oil, gasoline etc.)
5. The destruction of our forests and the other forests of the world have a profound effect on the CO_2 concentrations. Explain how.
6. Briefly explain two ways in which the present CO_2 concentrations could be reduced.
7. If these levels of CO_2 concentrations continue to increase, predict the effects on the following:

   (a) the polar ice caps,

   (b) sea levels,

   (c) coastal communities.