GEOL 332 Online Activity 01
Radiocarbon Modeling

Name: ____ **Date**: _______________

Our goal today is to use radiocarbon sample results to interpret the chronostratigraphy of two cores collected adjacent to Humboldt Bay in 2001 (01HB01 and 01HB02). We will correlate buried marsh deposits, interpreted to be evidence for coseismic subsidence, based upon our radiocarbon age interpretations. We will learn:

- How to calibrate and interpret radiocarbon age determinations
- How to calculate sedimentation rates using radiocarbon age estimates
- How to use sedimentation rates to estimate ages of materials with no direct radiocarbon age estimates.

Radiocarbon

Radiometric age control is based on three primary assumptions.

(1) There is a closure time, when the material no longer increases in concentration of a given isotope.
(2) That the isotope decays at a known rate.
(3) That there is no contamination (remains a closed system following the closure time).

The mathematical expression, the age equation that relates radioactive decay to geologic time is:

$$D = D_0 + N(t)\,(e^{\lambda t} - 1)$$

Where,

- t is age of the sample,
- D is number of atoms of the daughter isotope in the sample,
- D_0 is number of atoms of the daughter isotope in the original composition,
- N is number of atoms of the parent isotope in the sample at time t (the present), given by $N(t) = N_o e^{-\lambda t}$, and
- λ is the decay constant of the parent isotope, equal to the inverse of the radioactive half-life of the parent isotope times the natural logarithm of 2.

Radiocarbon age control is a method of determining the time that something died. Living organisms absorb many isotopes during their lifetime. Relevant isotopes for this exercise include ^{12}C and ^{14}C. ^{12}C is a stable isotope, but ^{14}C is radioactive and decays to a daughter isotope at a known rate called the halt life. Once an organism dies, it generally ceases to absorb Carbon.

^{14}C is formed in the atmosphere when cosmogenic nuclides bombard ^{14}N. These ^{14}N isotopes lose neutrons and turn into ^{14}C isotopes. The rate of incoming nuclides varies with (1) the strength of Earth's magnetosphere and (2) the rate that these nuclides are formed. The rate that ^{14}C decays proceeds with a half-life of 5730 years.

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Modern analytical techniques of estimating the amount of ^{14}C in a sample is made by using accelerator mass spectrometry (AMS). AMS counts the atoms of ^{14}C and ^{12}C in a given sample, determining the $^{14}C/^{12}C$ ratio directly. The sample, often in the form of graphite, is made to emit C− ions (carbon atoms with a single negative charge), which are injected into an accelerator. The ions are accelerated and passed through a stripper, which removes several electrons so that the ions emerge with a positive charge. The C3+ ions are then passed through a magnet that curves their path; the heavier ions are curved less than the lighter ones, so the different isotopes emerge as separate streams of ions. A particle detector then records the number of ions detected in the ^{14}C stream, but since the volume of ^{12}C (and ^{13}C, needed for calibration of the instrument) is too great for individual ion detection, counts are determined by measuring the electric current created in a Faraday cup. Faraday cups are located where the isotope labels are placed in **Figure 1**.

When an AMS facility produces results from a set of samples, they calculate the time since the object died based on the half life of ^{14}C. This age is called the "Lab Age" and is reported in "radiocabon years before present." "Present" is defined as 1950 A.D. (Stuiver and Polach, 1977). The lab age is also presented as a normaly distributed data set with 1 and 2 σ uncertainty ranges.

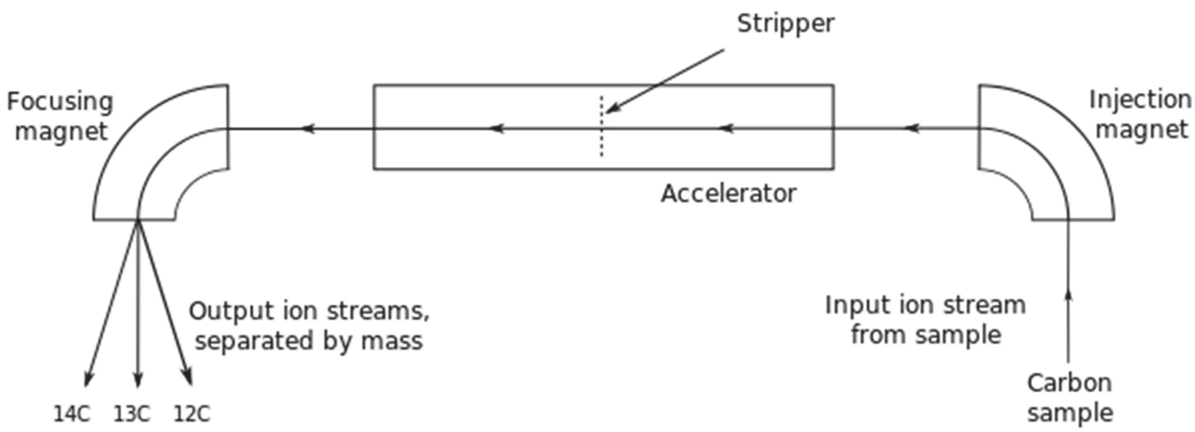

Figure 1. Simplified schematic layout of an accelerator mass spectrometer used for counting carbon isotopes for carbon dating. Aitken (1990)

Because the rate of incoming nuclides has varied through time, we cannot simply apply the half-life to the measured quantity of ^{14}C isotopes to determine the time since that object died. Radiocarbon geochronologists have constructed an empirical calibration curve based upon comparisons between tree ring radiocarbon ages and the count of years back based upon these tree rings (Fairbanks, 2005). The dendrochronologic based calibration curve extends to about 13,000 years before present (1950). Researchers have extended the calibration curve further back using ^{14}C ages paired with high precision Th/U age determinations, back to ~50 ka (Fairbanks, 2005).

There are a number of radiocarbon calibration software applications that one may use to convert a "Lab Age" to a "Calendar Age." These include Calib, OxCal, and Calibrate (Bronk Ramsey, 1995). There are others. These software applications have been developed to also include additional information to help model age results (Bronk Ramsey, 2008). Some of the information that we can use includes: (1) the stratigraphic depth of the samples (2) the superposition of the samples, (3) sedimentation rates, (4) ages from other radiometric techniques (e.g. optically stimulated luminescence, Argon-Argon, etc.), and other information.

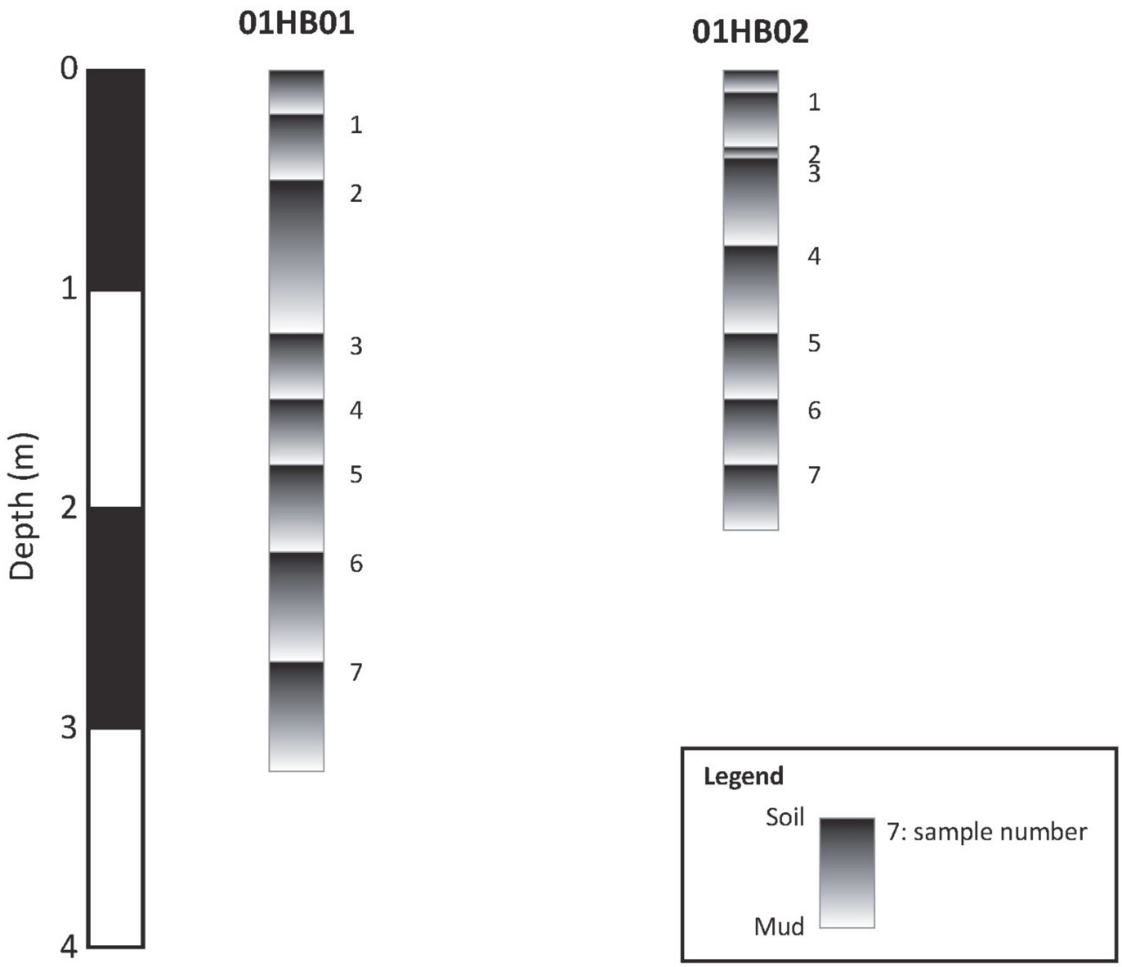

Figure 2. Sediment cores 01HB01 and 01HB02. Marsh deposits (dark gray) are overlain by muds (light gray). Sample locations are numbered, but not every sample location has a radiocarbon result.

Part I. OxCal Calibration

As a group, we will log on to OxCal and calibrate a couple ages together. Enter the results in the Table below. The samples that we will calibrate are the ones that have lab ages, but no calendar ages.

Part II. Sedimentation Rate Calculations

We will now calculate the sedimentation rates for each samples that have a direct radiocarbon age estimate. Use the sample depth as a proxy for the amount of sediment overlying each radiocarbon age, along with that radiocarbon age, to calculate a sedimentation rate at those depths. Then, calculate the mean sedimentation rate by using the sedimentation rate calculated at each radiocarbon age. Fill in the answers in the table below.

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Part III. Calculated Age Estimates

We could use a statistical age model to perform this task. If people know how to do this, feel free to attempt this. Otherwise, we will simply use the mean sedimentation rate and the sample depths to calculate an age estimate for some of the deposits interpreted to be marsh soils buried during earthquakes.

Part IV. Correlation

Finally, we would like to correlate the buried marsh deposits between each core. First, write the radiocarbon ages next to each sample number on the core diagram. Next, draw correlation tie-lines between the tops of the buried marsh deposits that you interpret to correlate with each other, based upon the radiocarbon ages. Label the tie-lines with buried horizon numbers, beginning with BH-1 for the uppermost buried marsh deposit. Enter the number of buried marsh deposits here: ____________

Table 1. Radiocarbon age determination results for cores 01HB01 and 01HB02.

Core 01BR01							
Sample Number	**Depth (cm)**	**Lab Age**	**2 σ Error**	**Calendar Age**	**95.4% Error**	**Sedimentation Rate (cm/yr)**	**Calculated Age**
1	20	220	40	210	220		
2	50	880	40	820	100		
3	120						
4	150						
5	180	1570	40				
6	220						
7	270	2770	40				
						Mean Rate:	

Core 01BR02							
Sample Number	**Depth (cm)**	**Lab Age**	**2 σ Error**	**Calendar Age**	**95.4% Error**	**Sedimentation Rate (cm/yr)**	**Calculated Age**
1	10						
2	35						
3	40	890	40	830	100		
4	80	1020	40	930	140		
5	120						
6	170	1920	40				
7	200	2200	40				
						Mean Rate:	

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