# GEOL 553: Lab 8: Radiocarbon Age Modeling

Radiocarbon age modeling incorporates several processes, each with increasing complexity and assumptions, depending upon the application. We will construct several age models from simple calibrations to several that include depositional models.

$^{14}C$ is generated by cosmogenic bombardment and ensuing decay from $^{14}N$. Due to various controls of incoming cosmogenic radiation, the concentration of $^{14}C$ in the atmosphere has varied through time. Living organisms absorb $^{14}C$ and $^{12}C$ during life so that the concentration of these isotopes is in equilibrium with the atmospheric concentrations of these isotopes. $^{14}C$ decays, but the concentration is re-supported by new absorption (e.g. by eating food that has $^{14}C$ in it). If the organism absorbs an isotopic ratio different than what is represented by the atmosphere at the time it was absorbed, corrections will need to be made (e.g. if the organism lives in sea water, which has older carbon than the atmosphere). When this living organism dies, it stops absorbing $^{14}C$ and $^{12}C$. This is when the clock starts, the time afterwards that we apply the half-life of $^{14}C$ to estimate when that organism died.

$^{14}C$ age determinations are based on the Libby half-life of 5,730 years. Using a mass spectrometer, we can determine the concentration of $^{14}C$ remaining in the sample. Simple age calibrations make the simplest assumptions and are the simplest age models. We can incorporate stratigraphic information into our analyses. These stratigraphic information are known as "priors." For example, based on the principle of superposition, we can include information about what order samples were deposited or died. We can even include information about sedimentologic thicknesses of the geologic units that the samples were collected from. Finally, we can use other forms of stratigraphic correlation to tie field sites together so that we can use $^{14}C$ ages from multiple sites in an age model.

OxCal Help: [https://c14.arch.ox.ac.uk/oxcalhelp/hlp_contents.html](https://c14.arch.ox.ac.uk/oxcalhelp/hlp_contents.html)

**References:**

Bronk Ramsey, C., 2008. Deposition Models for Chronological Records in Quaternary Science Reviews, v. 27, p. 42-60.

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**PART I. AGE CALIBRATION**

We will calibrate an age from a single deposit in a core. The sample came from a single seed. This simple calibration only takes into account the variation of $^{14}C$ through time and the lab age.

<u>Step 1. Single calibrations</u>

Write the OxCal code and calibrate ages for the following $^{14}C$ samples (Table 1). Each sample is listed with a proposed sample name, the lab age and 2 standard deviation error, and the latitude-longitude coordinates from where the sample was obtained.

In the report, include in a table the following: sample name, lab age and error, calibrated age and error. For lab age, use the 2-sigma uncertainty. For the calibrated age, use the 95.4% uncertainty. Also, include the OxCal code from your *.OxCal file. Also include the plot for each age (the plot shows the probability density function of the calibrated age). Include answers to the questions associated with each step.

Table 1. Sample ages Part I.

| # | Sample Name | Latitude (deg) | Longitude (deg) | Lab Age (yrs) | 2 σ Lab Error (yrs) | Sample Material | Depth (m) |
|---|---|---|---|---|---|---|---|
| 1 | 01BR05_332 | 40° 40' 31.5" | 125° 13' 21.5" | 3250 | 50 | Leaf | 3.32 |
| 2 | 01BR05_690 | 40° 40' 31.5" | 125° 13' 21.5" | 6540 | 40 | Seed | 6.90 |
| 3 | 01BR05_720 | 40° 40' 31.5" | 125° 13' 21.5" | 7250 | 60 | Leaf | 7.20 |
| 4 | 01BR05_720 | 40° 40' 31.5" | 125° 13' 21.5" | 7270 | 40 | Leaf | 7.20 |
| 5 | 01BR05_730 | 40° 40' 31.5" | 125° 13' 21.5" | 7330 | 200 | Peat | 7.30 |

QUESTION:

(1) Which samples have calendar (calibrated) years that overlap? Why do you think that is?

Step 2. Combine Ages

We will now use the OxCal function "Combine." Read in the manual about what this function is used for. People do not always use it correctly and there are alternatives if the assumptions are not met. Write the OxCal code to combine samples #3 and #4 from table 1. These samples were both collected from the same stratigraphic unit, so it is reasonable to use the Combine function for this analysis.

In the report, include in a table the following: sample name, lab age and error, calibrated age and error. For lab age, use the 2-sigma uncertainty. For the calibrated age, use the 95.4% uncertainty. Also, include the OxCal code from your *.oxcal file. Also include the plot for each age (the plot shows the probability density function of the calibrated age).

QUESTION:

(1) What is the difference between the results with and without the Combine function?

(2) When would one NOT use the function Combine?

**PART II. RESERVOIR CORRECTION**

Marine organisms absorb carbon from the sea water, which is mixed poorly with the atmosphere. Because the sea water is poorly mixed with the atmosphere, the carbon in the sea water is older than in the atmosphere. The age of sea water varies globally and locally. Due to the global ocean circulation patterns, sea water in the Pacific is older than that in the Atlantic. Also, sea water near the surface is younger that sea water at depth (because it is mixing with the atmosphere).

Sample material from the marine environment are from organisms that have carbon in their body/skeleton. Examples include shells, tests, etc. For example, Foraminifera are single celled organisms that have $CaCo_3$ tests. When Forams die, these tests fall to the sea floor and can be preserved in sediments. Planktic Forams live in surface waters and Benthic Forams live in benthic habitats along the sea floor.

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When calibrating marine ages we use the marine calibration curve which assumes an age of 400 years for the sea water. There is an online database that people use to estimate what the local deviation from the global reservoir is. These “delta R” estimates are created by comparing age estimates of deposits that have paired marine and terrestrial samples. The difference between the age determination of the marine sample and the terrestrial sample will tell us what the delta R is for that site. Unfortunately, most of the delta R data do not extend far back in time. The marine reservoir correction database is here: http://calib.qub.ac.uk/marine/

Step 1. Reservoir Correction

Write the OxCal code and calibrate ages for the following marine $^{14}C$ samples (Table 2). Each sample is listed with a proposed sample name, the lab age and 2 standard deviation error, and the latitude-longitude coordinates from where the sample was obtained. Use the reservoir correction database to select an appropriate ΔR value.

In your report, place in a table the sample name, the coordinates, the lab age and error, and the calibrated age and error. Answer the questions.

Table 2. Sample ages Part II.

| # | Sample Name | Latitude (deg) | Longitude (deg) | Lab Age (yrs) | 2 σ Lab Error (yrs) | Sample Material |
|---|---|---|---|---|---|---|
| 1 | 01TN20_305 | 40° 40’ 31.5” | 125° 00’ 00” | 3650 | 20 | Planktic Foram |
| 2 | 01TN20_670 | 40° 40’ 31.5” | 125° 00’ 00” | 6940 | 20 | Planktic Foram |
| 3 | 01TN20_710 | 40° 40’ 31.5” | 125° 00’ 00” | 7650 | 40 | Planktic Foram |
| 4 | 01TN20_710 | 40° 40’ 31.5” | 125° 00’ 00” | 7950 | 80 | Benthic Foram |

QUESTION:

(1) What is the difference in age results for samples 3 and 4 (which were collected at the same depth)? Why do you think that this might be?

**PART III. TERRESTRIAL DEPOSITIONAL AGE MODEL: SEQUENCE AND P_SEQUENCE**

The simplest depositional age model uses the OxCal function "Sequence." In this model, ages of specified events are assumed to be in the correct order but no use is made of depth information. Read Bronk Ramsey (2008) for more about the Sequence function. There are several other Sequence functions that take into account different assumptions about sedimentation rate and particle size. We will first do a simple Sequence and then perform a P_Sequence analysis.

Step 1. Terrestrial Sequence

Write the OxCal code, using the function "Sequence," and calibrate the ages for the terrestrial samples (Table 1). The sample data are presented as before, but now we use the depth information. Utilize the Combine function for the samples collected at the same depth.

Step 2. Terrestrial P_Sequence

Write the OxCal code, using the function "P_Sequence," and calibrate the ages for the terrestrial samples (Table 1). The sample data are presented as before, but now we have depth information. Utilize the Combine function for the samples collected at the same depth.

QUESTION:

(1) What is the difference in age results between the Sequence and P_Sequence analyses?

**PART IV. MARINE DEPOSITIONAL AGE MODEL: SEQUENCE AND P_SEQUENCE**

We will first do a simple Sequence and then perform a P_Sequence analysis.

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Step 1. Marine Sequence

Write the OxCal code, using the function “Sequence,” and calibrate the ages for the following marine samples (Table 3). The sample data are presented as before, but now we have depth information. Use the reservoir correction database to select an appropriate ΔR value.

Table 3. Sample ages Part III.

| # | Sample Name | Latitude (deg) | Longitude (deg) | Lab Age (yrs) | 2 σ Lab Error (yrs) | Sample Depth (m) |
|---|---|---|---|---|---|---|
| 1 | 108PC_022 | 04° 39’ 35.3” | 93° 08’ 34.1” | 2015 | 15 | 0.22 |
| 2 | 108PC_053 | 04° 39’ 35.3” | 93° 08’ 34.1” | 3035 | 15 | 0.53 |
| 3 | 108PC_061 | 04° 39’ 35.3” | 93° 08’ 34.1” | 4070 | 15 | 0.61 |
| 4 | 108PC_072 | 04° 39’ 35.3” | 93° 08’ 34.1” | 4340 | 20 | 0.72 |
| 5 | 108PC_081 | 04° 39’ 35.3” | 93° 08’ 34.1” | 4625 | 20 | 0.81 |
| 6 | 108PC_089 | 04° 39’ 35.3” | 93° 08’ 34.1” | 4840 | 20 | 0.89 |
| 7 | 108PC_104 | 04° 39’ 35.3” | 93° 08’ 34.1” | 5950 | 20 | 1.04 |
| 8 | 108PC_108 | 04° 39’ 35.3” | 93° 08’ 34.1” | 6115 | 20 | 1.08 |
| 9 | 108PC_112 | 04° 39’ 35.3” | 93° 08’ 34.1” | 6685 | 25 | 1.12 |
| 10 | 108PC_115 | 04° 39’ 35.3” | 93° 08’ 34.1” | 7175 | 20 | 1.15 |

QUESTION:

(1) Which calibrated calendar ages overlap? Why do you think this is?

Step 2. Marine P_Sequence

Write the OxCal code, using the function "P_Sequence," and calibrate the ages for the following terrestrial samples (Table 3). The sample data are presented as before, but now we have depth information. Use the reservoir correction database to select an appropriate ΔR value.

QUESTION:

(1) What is the difference in age results between the Sequence and P_Sequence analyses?