Introduction to Archaeology: Notes 8

Chronology, part 1

- Two kinds of dating: relative and absolute
  - **Relative dating** puts things in chronological order, older to younger, without specifying dates in years
  - **Absolute dating** gives ages in years
    - each absolute dating method works only for certain kinds of materials, under certain circumstances
    - they typically involve sending samples to a lab and waiting for the results
    - most absolute dating methods are expensive
    - so we never have enough absolute dates
    - most methods give a probable date range, not an exact year
  - Both kinds of dating are useful
    - don't think that absolute dating has replaced relative dating!
    - in practice, we use relative dating constantly to put things in sequence, then pin down parts of the sequence with a limited number of absolute dates
    - relative dating can be more precise
      - as in strata of garbage that might show sequential changes from summer garbage to the following winter to the following summer…
        - precise to a few months, better than any absolute date
      - or strata from a single big feast, with food preparation debris at the bottom, followed by debris from sweeping out the ashy cooking area afterwards…
        - precise to perhaps a matter of hours!
    - relative dating is often easier and cheaper
      - often can be done right in the field as you dig
      - so you know where you are in time, and relative to other excavation units and sites, without having to wait to export dating samples and get the results of lab work
      - so we rely on relative dating in the field all the time

- Relative dating methods
  - **Stratigraphy** (study of **strata**, or layers of earth)
    - Based on the **law of superposition**
      - When one layer lies on top of another, the upper one must have been placed there after the lower one.
      - As we saw in the discussions of site formation and excavation
  - **Time markers** or **index fossils**
    - fossils in geology and paleontology; artifacts in archaeology
      - archaeologists sometimes refer to certain artifacts as "index fossils", by analogy to index fossils in geology
      - even though it would be more correct to call them "index artifacts"
    - these are fossils (or artifacts) that are characteristic of strata in a certain position in a sequence of strata

    - in geology, strata of rocks, with fossil type A always below strata with fossil type B, which are always below strata with fossil type C
    - sequences like this are found again and again in different locations
    - so if fossil type A is found in a newly-discovered stratum of rocks on another continent, geologists will reasonably assume that those rocks were formed around the same time as the other strata with fossil type A
  - artifacts that are characteristic of a certain point in a sequence of change like this are said to be “**diagnostic**”.
    - example: “Chiribaya style sherds are diagnostic of the Late Intermediate Period”
- One very common kind of relative dating using index fossils (diagnostic artifacts) is **ceramic chronology**
  - Ceramics are useful as time markers
    - ceramics are fairly easy to make, and very useful for cooking, storing, and serving food
      - so many cultures made a lot of pottery
    - ceramics break easily, but the fragments are very durable
      - so the garbage of many cultures is full of broken pottery
    - ceramics can be made and decorated in a virtually infinite variety of ways
      - so fashions or styles of pottery vary from place to place and often change
    - so the styles of pottery can serve as convenient markers of time and social groups that used each style
    - and we can expect to find a lot of pieces of pottery, unlike coins, textiles, etc.
  - There are three main ways to figure out the sequence of pottery styles in a particular region.
    - Stratigraphic sequences:
      - in a site with clear stratigraphic layers, styles in the lowest layer are probably the oldest, followed by styles in higher layers, and so on
      - this method is simple, reliable, and widely used
    - **Seriation** (of collections of things)
      - putting collections of things in order so that the percentages of artifact types or traits in each collection form **battleship curves**
        - “collections of things” might be:
          - surface collections of potsherds, each collection from a different site
          - “grave lots” of artifacts, each collection (or “lot”) from a different burial
        - we must assume that all the artifacts in a given collection are from a single general period
          - this is not always the case
        - battleship curves are patterns of percentages over time that look like a WW I battleship viewed from above: pointy at both ends, wide in the center
          - this represents the changing percentages of an artifact type over time
          - initially, the artifact has not been invented yet
          - when it first appears, it is rare
          - it gains in popularity over time
          - up to some maximum popularity (the fattest part of the battleship)
          - then it declines in popularity

    - and eventually goes out of use entirely
  - if you can put sites (or graves, etc.) in an order such that most of the artifacts form battleship curves…
    - it is almost certain that you have put them in chronological order
    - see the slides!
  - proof that this can work, at least sometimes: James Deetz's Colonial tombstone project
    - tombstones have both decoration and dates carved on them
    - sure enough, if you arrange a lot of Colonial tombstones by year…
      - the different kinds of decoration fall into roughly battleship-shaped patterns
  - Proof that this does *not* always work: my own attempt with surface collections from the Upper Mantaro Valley, Peru
    - it was impossible to put the collections in any order that formed battleship curves for more than one or two pottery types
    - that is, the order suggested by clumping any one type would divide up most or all of the others
    - reason: the surface collections are apparently mixtures of sherds from different periods
      - a site or collection that represents a single period is called a **single-component** site or collection
      - one that mixes material from multiple periods is **multi-component**
    - think about it: this method cannot work with multi-component collections
- **Seriation** (of individual artifacts, each with a set of traits)
  - seriation can also work on individual artifacts, if they have multiple traits
    - like fancy pottery, which might have colors, shapes, decoration, handles, and so on that all vary
    - if the artifacts can be put in an order such that the various traits clump together…
      - it is almost certain that you have put them in chronological order
      - same reasoning as with battleship curves: traits are invented, used for a while, then go out of use
      - Again, see the slides for an illustration
- A note on seriation
  - seriation is not used much anymore
  - the requirement that surface collections include only a single period is rarely met; people tend to return to the same places to live at different periods, creating mixed collections
  - but in certain circumstances, it does work
    - for example, an artifact seriation of decorated ceramics from the south coast of Peru is still a mainstay of chronology there
      - absolute dating shows that it is valid overall
      - and the detail of the order of the styles of pots appears to allow us to place the pots in time periods as tight as perhaps twenty or thirty years
      - better than radiocarbon can do
- **Association** with absolute dates:

      - radiocarbon dates (or other absolute dates) associated with pottery styles indicate the order and duration of each style.
        - artifacts that are found in the same context (the same stratum, burial, etc.) are **associated**
        - they were evidently in use and deposited around the same time
          - roughly, with most strata, since a stratum might accumulate over a period of time
          - quite exactly, in the case of burials, since the artifacts were probably all placed in the burial on a single day
        - so a radiocarbon date on a wooden artifact from a burial also tells us about when a pot from that burial was in use
          - unless the wooden artifact was made from a very old tree, had been kept a long time as an antique, etc.
          - so we generally want a number of good associations with similar dates before we fully trust the conclusions
      - Example:
        - In the area where I work, there is a pottery style called the Tumilaca style.
        - I have run radiocarbon dates on cloth mummy wrappings from numerous tombs that contained Tumilaca style pots
        - the dates all fall from about 950 to 1200 AD.
        - so, when I find Tumilaca style potsherds on the surface of a site, I can be pretty sure that it was occupied during the "Tumilaca period", from 950 to 1200 AD, without having to run more radiocarbon dates.
      - dating ceramics by association with absolute dates is straightforward, reliable, and widely used
    - Once a sequence of ceramic styles is established, if you find pottery of one of the known styles at a site, you know that the site was occupied during that part of the time sequence
    - So we often divide time up into periods that correspond to fashions in pottery style

- Absolute dating methods
  - historical dates (coins, dated inscriptions, etc.)
  - **dendrochronology** (tree ring dating)
    - the best, most precise method there is
    - Most trees grow by adding one layer or "ring" of wood per year: a low-density, light-colored part in the rainy season, and a high-density, dark-colored part in the dry season
    - The thickness of the rings varies depending on the climate each year
    - If you count the rings inwards from the bark of a tree, the widths of the rings are a record of the climate of each year back to when the tree sprouted
      - This is done using a narrow core drilled out of the tree, rather than cutting the tree down
    - Any given period of years has a unique pattern of ring widths
    - If you have a piece of wood with numerous rings (usually a minimum of 20), you can match its ring width pattern to an old tree and tell exactly which years your piece grew in
    - The pattern can be extended back further into time by finding older logs that have ring width patterns that overlap

- this is extremely accurate and precise – to the exact year – but very time-consuming to create the master sequence
  - someone must find chunks of old wood that overlap, with no gaps, from the present back to the period of interest
- every region and type of tree requires its own, different master sequence
  - some areas have no suitable trees
  - or the climate does not vary enough from year to year
  - or the microclimates vary so much from place to place in the region that no single sequence would work widely enough to be worth setting up
  - or the work just has not been done yet
- sometimes the best we can do is a "**floating chronology**"
  - that is a tree-ring sequence that does not extend to a known date
  - pieces of wood that grew during the period covered can be precisely dated relative to others, say "tree A was felled 32 years before tree B"
  - but the starting date of the whole sequence is unknown
- only relatively large chunks of wood with quite a few rings can be dated
  - if you don’t have beams, posts, good-sized wooden artifacts, or large chunks of firewood at your site, you can’t use this method
- the real trick, as with all methods, is ensuring a meaningful archaeological association of the date with an event that interests us
  - we care about human behavior, not when a certain bit of wood grew
  - dendrochronology is most useful for logs that are preserved all the way out to the bark, or to the smooth surface with beetle damage just under it
    - because the year that this last ring grew is the year that the tree died
    - which is probably when someone cut it down
    - which is probably near to when it was used to build a house, for firewood, etc.
  - but:
    - what if the tree died naturally, and was collected later for use?
    - what if the tree was cut down and left for years to dry before it was used?
    - what if a log in the building we want to date was not cut down for that building, but instead was salvaged from an old, abandoned structure?
  - if the trunk was squared up into a beam, or planks were cut from the log, or artifacts were carved from pieces of the log, we can’t tell how close the wood was to the outermost ring of the tree
    - we can date the growth of the wood in the object, but if it came from deep inside the tree, that wood might have grown long before the tree was cut down and used
    - even so, that gives us a date *after which* the artifact must have been made
      - the object cannot be older than the tree rings present in it
      - a *terminus post quem* (TPQ)
      - this can help us bracket events in time, but we have to be careful not to confuse a *terminus post quem* with the actual age of the thing
      - all we know is that it was made an unknown time after the *terminus post quem*.
- range of dating:
  - varies by region; up to 10000 years ago in northern Europe

  - but most regions still lack good master sequences
    - the US Southwest is an exception, because the preservation is so good
  - still, this method is important, because it provides a positive check to verify and adjust radiocarbon dates
- **radiocarbon dating**: the main points
  - It works. No serious scientist doubts the method
    - although it sometimes fails due to contamination of the samples or other problems
  - it is not precise, that is, radiocarbon dates give a range, not a specific year
    - like 550 AD ± 40
      - meaning the true date has a 68% chance of being between 510 AD and 590 AD
      - 68% is only about a 2/3 chance; there is still a 1/3 chance that the actual date falls outside of this range
  - a radiocarbon date tells you how long it has been since the tissue of a living thing died
    - How it works is explained below and in a separate reading posted on the class website
  - only organic materials can be dated
    - that is, things that were once alive:
      - wood, seeds, corn cobs, wine residues, or other plant material
      - bone, leather, hair, teeth, or other animal material
      - shell
      - textiles made from wool (hair), cotton, flax, silk, etc.
    - unfortunately, organic materials are scarce in most archaeological sites
    - but carbonized wood (charcoal) often survives even when other organic materials have decayed away
      - so charcoal is the most commonly dated material
      - of course, charcoal is only found where there was a fire…
  - inorganic things like pottery, stone tools, etc. cannot be radiocarbon dated themselves
    - if you want to know the age of an inorganic object, you hope some organic material that can be radiocarbon dated was found together with it
  - works on samples up to about 45,000 years old
  - dates are destructive and expensive
    - the sample is purified and converted into a standard form such as liquid benzene or graphite
      - although now with Accelerator Mass Spectrometry (AMS) radiocarbon dating, the sample can be as small as a grain of wheat or a few centimeters of thread
    - AMS dates now cost $325 each with a National Science Foundation grant, or $475 without, or even more for commercial purposes
      - you always want at least two or three agreeing dates for any given period or event, to avoid possible errors
      - and you typically want to date numerous events for any given project
      - that adds up to a lot of money
    - so we never have enough of them
  - How radiocarbon dating works
    - (see the posted reading for a bit more detail)

- Carbon in the environment:
  - there are 3 isotopes of carbon: ^{12}C, ^{13}C, ^{14}C
    - ^{12}C is the common isotope of carbon
      - 6 protons and 6 neutrons in its nucleus
      - stable
      - 99% of all carbon in the Earth's environment
    - ^{13}C has an extra neutron
      - 6 protons, 7 neutrons
      - stable
      - 1% of carbon in the environment
    - ^{14}C has two extra neutrons
      - 6 protons, 8 neutrons
      - unstable (radioactive; it decays)
      - called "radiocarbon"
      - 1/trillionth of the carbon in the environment
      - ^{14}C decays to ^{14}N, ordinary nitrogen: most of the atmosphere
      - ^{14}C has a half life of 5730 years
    - So all the ^{14}C should long since have decayed away…
      - but ^{14}C is constantly produced in the upper atmosphere by cosmic rays (mostly from the sun) striking ^{14}N
  - the rate of production and decay balance to a constant amount in the atmosphere
- Carbon in the life cycle:
  - Land plants get all their carbon from carbon dioxide in the atmosphere
    - none from the soil, water, etc.
  - Land animals get all their carbon from the plants they eat
    - and the animals they eat that have eaten plants
  - While the tissue is alive, the carbon stays in equilibrium with the atmosphere
    - that is, a living land plant or animal contains about the same proportion of ^{14}C as the atmosphere around it
    - because biological processes keep destroying and recreating the carbon compounds in most tissues, incorporating fresh carbon into them
  - When the tissue dies, these biological processes stop replenishing the ^{14}C
    - which decays away at its known rate
    - starting with about the proportion of ^{14}C in the atmosphere, and getting less and less over time
- Calculating the time since death:
  - we know the percentage of ^{14}C in the tissue at death
    - about the same percentage as is in the atmosphere
  - we can measure the current percentage of ^{14}C in the tissue
  - we know the rate of decay
  - so we can calculate how long it has been decaying away
  - that is, how long it has been since the tissue died
- Two ways to measure the percentage of ^{14}C in a sample

    - **Conventional radiocarbon dating**: measure how radioactive the sample is
      - each time a ^{14}C nucleus decays into ^{14}N, it releases a high-energy particle
      - conventional dating detects these decay events
      - the more ^{14}C in the sample, the more often a ^{14}C nucleus will decay
      - so the number of decay events in a given period of time tells you how many ^{14}C nuclei are present
      - this requires a fairly large sample, in order to observe a significant number of decay events in a reasonable period of time
        - Dry wood: a sphere slightly larger than a pool ball
          - this is conservative; you can often get results with less
    - **Accelerator Mass Spectrometer (AMS) radiocarbon dating**: literally count ^{14}C and ^{12}C nuclei in a tiny sample
      - can work with much smaller samples
      - because it is based on all the ^{14}C nuclei in the sample, not just the few that happen to decay while we are watching
      - typical sample size for dry wood: a sphere about the size of a pea
        - this is conservative; you can often get results with less
        - single grains of wheat, a few cm of thread, etc.
      - typically provides a smaller uncertainty term than conventional dating, too
        - like 500 ±35 cal AD, versus 500 ±60 cal AD
    - with both methods, the older the sample, the more material you need
      - because there is less ^{14}C left to measure
- Understanding the **error term**, or **uncertainty**
  - Both methods are based on a measurement of the amount of ^{14}C present
    - Like all measurements, these have some degree of uncertainty
    - So radiocarbon dates come with an error term
    - Like 500 BP ± 40
  - The error term is the **standard deviation** (often called **sigma**, or **σ**) of the probability distribution (a “normal” or “bell” curve) of the estimated date
    - The “500 BP” is the mean, or center, of that distribution
    - The error term “± 40” is an indication of how wide the central portion of the probability distribution is
  - The error term tells us that there is a 68.26% chance that the true date falls in the indicated range (in this example, 460 to 540 BP)
    - That still leaves almost a 1 in 3 chance that the date falls outside that range
  - In order to be more certain, people sometimes double the error estimate (they give the “two sigma” error term)
    - There is a 95% chance that the true date falls within this wider range
    - That still leaves a 5% (1 in 20) chance that the true date is outside this range
  - One way to reduce this uncertainty is run numerous dates
    - There are statistical methods for combining multiple dates of the same event in order to narrow the range of uncertainty
- Some wrinkles in radiocarbon dating

  - a number of things make the real application of radiocarbon dating a little more complicated
  - but we can either deal with them, or avoid them
  - these are not problems that call the radiocarbon method into question, but just realities that we have to understand to use it successfully
- Wrinkle #1: **de Vries effects**: need for **calibration**
  - the amount of ^{14}C in the atmosphere has not been absolutely constant
    - apparently due to variations in solar radiation
    - so the percentage of ^{14}C that a sample started with has sometimes been a little more or less than the modern concentration of ^{14}C in the atmosphere
  - this variation has been measured by radiocarbon dating many individual tree rings
    - so we now know the apparent radiocarbon age of wood from specific years back to 10,000 BC
  - we use this to correct the measured age in **radiocarbon years** to a **calibrated** date in calendar years
    - written like 500 **cal** BC
    - see the slides for illustrations
  - in some places, the calibration curve is flattish or has a dip in it
    - this has the effect of spreading the out the probability distribution of some dates, increasing the range of probable dates
    - calibrated dates cannot be expressed as simple x ± y years
      - instead, they are complicated probability distributions
      - for simplicity, often given as a range in which 68% of the probability falls, like 1495 to 1610
  - this “wrinkle” is well understood and easily dealt with by using computer programs to calibrate dates
- Wrinkle #2: the **marine carbon reservoir effect**
  - Carbon dioxide(CO_2) dissolved in seawater is partially isolated from the atmosphere
    - only contacts the atmosphere at the sea’s surface
    - deep seawater has no contact with the atmosphere
    - so the ^{14}C in the atmosphere diffuses into seawater only slowly
  - so ^{14}C in seawater decays away at the same rate as in the atmosphere, but is replaced at a lower rate
    - so there is less ^{14}C in marine CO_2 than in the atmosphere
    - the CO_2 in seawater looks about 400 years “older” than the CO_2 in the atmosphere
  - this “marine carbon reservoir” is **depleted** in ^{14}C
    - the depletion varies depending on depth, currents, etc.
    - because it depends on mixing deep, more depleted water and surface water that has picked up more ^{14}C from the atmosphere
  - marine plants get their carbon from CO_2 dissolved in seawater
    - marine animals get their carbon from those plants
    - or other animals that have eaten them
  - so marine plants and animals start off with less ^{14}C than land plants and animals do
    - making them look older than they really are

  - but how *much* less?
  - we can estimate the starting concentration of ^{14}C by radiocarbon dating shells, fishbone, etc. of known age
    - like shells collected live before the first atomic bomb test in 1945
  - then calculate backwards to figure out how much ^{14}C the sample started with
    - typically, the seawater has an apparent age of about 400 years
    - but in different places, it varies from less than 100 to over 1000 years…
  - then assume that the seawater in that location has always had that same apparent age
    - and use that as the starting point for other dates on shell, etc.
    - but if currents have changed, the apparent age of the seawater could have been different
  - This makes dates on marine materials less precise than terrestrial materials
    - because the starting concentration of ^{14}C is less precisely known
      - the error term will be larger
    - and if currents have changed, the calculated starting concentration of ^{14}C might be incorrect
  - so marine samples like shell or fish bone are a second choice material for radiocarbon dating
    - samples from land plants or animals give dates with smaller error terms and less chance of being seriously wrong
    - but we do date shell and other marine materials when there is no good alternative
- Wrinkle #3: **Mixed carbon reservoir effects**
  - humans near a coastline may eat a mix of land and marine foods
    - they get some carbon with the atmospheric percentage of 14C
    - and some carbon with the lower, marine percentage of 14C
  - but we don’t know how much of each
  - so if we date human remains from a coastal area, we don’t know the starting point to calculate the decay from
  - this can introduce errors of up to several centuries when dating human remains from coastal areas
    - no good answer for this
    - better to just avoid dating coastal human remains, unless you want just a very rough age estimate
      - for very ancient human remains such as the initial settlers of Australia or the New World, knowing a date within plus or minus 500 years might be good enough
      - in that case, an uncertainty of a few centuries would not be a problem
    - find something else that got all its carbon from land sources!
- Wrinkle #4: **Southern Hemisphere atmospheric carbon reservoir effect**
  - the atmosphere does not mix fully between northern and southern hemispheres
  - air in the southern hemisphere contains slightly less ^{14}C than does air in the northern hemisphere
  - so radiocarbon dates in the southern hemisphere come out about 40 years “older” than dates from the northern hemisphere

    - now that this has been well documented, it is easily fixed by subtracting 40 years from the radiocarbon age
- Wrinkle #5: Other **reservoir effects**
  - some river and spring water contains carbon dissolved from limestone
    - this carbon is so old that there is no ^{14}C left in it at all
    - “dead carbon”
    - a plant or animal that gets its carbon from such water will start off depleted in ^{14}C
      - like aquatic plants or river fish that eat them
    - so it will look older than it really is
  - and some other processes can affect the ^{14}C content of the carbon reservoir that living things draw from
  - these are just special cases we just have to look out for
    - each must be noticed, figured out, and corrected for
    - in some cases, they may keep us from getting good radiocarbon dates on certain materials in certain regions
- Wrinkle #6: **Isotopic fractionation** effects
  - Chemical reactions involve physical movement of nuclei
  - Heavier nuclei (^{13}C and ^{14}C) have more inertia
    - so they move a little slower
    - so they perform chemical reactions a little slower
  - Say you surround a plant with carbon dioxide with a 50-50 mix of ^{12}C and ^{13}C
    - the plant tissues will end up with a little more of the lighter ^{12}C, and a little less of the heavier ^{13}C
    - this change in proportions of isotopes due to different reaction rates is isotopic fractionation
    - the tissues are depleted in ^{13}C relative to the atmosphere
  - There are three different chemical pathways for photosynthesis
    - C3: used by most plants
    - C4: used by some arid-adapted plants like corn
    - CAM: used by some desert plants like cacti
  - each has a different number of reaction steps
  - plants with longer photosynthetic pathways end up with less of the heavier isotope
    - since the heavier isotope reacts more slowly at each step
    - C4 plants incorporate ^{14}C in only slightly less concentration than it has in the atmosphere
    - C3 plants incorporate less ^{14}C than C4 plants
    - CAM plants incorporate variable amounts of ^{14}C, depending on the climate, ranging from similar to C3 to similar to C4
  - so C3 plants start off more depleted in ^{14}C than do C4 plants
    - if we did not correct for this somehow, C3 plants would look older, because they started with less ^{14}C
  - Solution:
    - the amount of depletion of a heavier isotope is proportional to the weight of the nuclei

    - So we measure the depletion of ^{13}C (one extra neutron) compared to the atmosphere
    - the depletion of ^{14}C (two extra neutrons) must have been exactly twice as much
    - we use this to calculate a starting percentage of ^{14}C that takes into account whatever fractionation occurred
      - we don’t even have to know what caused the fractionation
      - different photosynthetic pathways, rainfall effects, etc.
      - because the depletion of ^{13}C tells us exactly how much fractionation actually occurred, regardless of its cause
    - bottom line: by measuring ^{13}C, any potential fractionation effect can be fully corrected
- The old wood problem
  - In some climates, trees, branches, etc. can last for decades, even many centuries
  - people may collect firewood that has been dead for centuries
    - especially the first to arrive, before it has all been picked up
  - if we date charcoal from their fire, we get dates that are
    - correct for the death of the tree
    - but far too old for the fire, which is what we care about
  - people will collect wood regardless of when it died
    - so dates from different pieces of firewood or different fires may vary widely
    - may be out of stratigraphic order
  - if we only run a few dates, we might not notice...
    - but if we run a bunch of dates and they come out widely variable in no particular order, we suspect “old wood”
    - if we run a bunch of dates and they all pretty well agree, there is almost no chance that we are dating “old wood”
  - this is actually not a problem with radiocarbon dating itself
    - it would also affect tree-ring dates on the same firewood
    - this is a problem of assuming an *association* between what we actually date – the death of a tree – and what we want to date – when some people built a fire
- Radiocarbon sample sizes
  - Depends on material, age, and preservation
    - Must have enough carbon in total to measure
    - the older the sample, the less 14C left, so the larger it must be to get a good measurement
  - Conventional dating
    - Charcoal: 15-30 g (handful)
    - Wood: 25-100 g (5-20 pencils; pool-ball size)
    - Wool textiles: 50-100 g (large handful)
    - Bone: 300-500 g (1-3 human long bones)
  - AMS dating
    - Charcoal or wood : 5-50 mg (grain of wheat to pea size)
    - Wool textile: 5-50 mg (2 inch thread to postage-stamp area)
    - Bone: 1 gram (1 to 3 inches of human rib)
- Summary of the process of radiocarbon dating

- Collect the sample
  - avoid marine materials if possible
  - avoid mixed marine/terrestrial samples if at all possible
- Export legally if in another country
- Send to lab
  - request 13C measurement to control for fractionation
- Lab returns a radiocarbon age in radiocarbon years
  - corrected for fractionation using 13C measurement
  - like “1200 ± 35 BP” in radiocarbon years
- If in southern hemisphere, subtract 40 from the age
- Calibrate the date using a program like Oxcal
  - “693-941 cal AD, 2 sigma” (95% confidence)
- Plot dates, compare to others, interpret