NO PREP

Beyond Carbon

Other Ways to Date the Past

Includes: Student reading, case study, differentiated questions, teacher key

Name: Period: Date:

Beyond Carbon: Other Ways to Date the Past

Tree Rings: Nature's Calendar

Of all the dating methods available to archaeologists, dendrochronology, the study of tree rings, may be the most precise. Under the right conditions, it can tell you not just the century or decade, but the exact year, and sometimes even the season, when a piece of wood was cut. The principle is straightforward: trees in temperate climates produce one growth ring per year. In a good year with plenty of rain, the ring is wide. In a drought year, the ring is narrow. This creates a distinctive pattern of wide and narrow rings that is shared by all trees of the same species growing in the same region during the same time period. By matching the ring patterns of living trees to those found in old timbers from buildings, and those in turn to even older wood from archaeological sites, scientists have built continuous tree-ring records stretching back thousands of years. The longest unbroken sequence, based on bristlecone pine trees in the American Southwest, extends more than 8,000 years into the past. In Europe, oak chronologies reach back over 10,000 years.

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Light and Heat: Thermoluminescence Dating

Not everything archaeologists find is organic. Pottery, brick, and burned stone cannot be radiocarbon dated because they contain no carbon-14. For these materials, scientists turn to luminescence dating, a family of methods that measure the energy stored in crystalline minerals since they were last heated or exposed to sunlight. Thermoluminescence, or TL, dating works on materials that have been heated to high temperatures, such as pottery fired in a kiln or stones that were part of a hearth. When mineral crystals in clay or rock are heated above about 500 degrees Celsius, they release all of their stored energy and the clock resets to zero. After that, the crystals begin absorbing energy again from natural background radiation in the surrounding soil. The longer they sit in the ground, the more energy they accumulate. In the lab, scientists heat the sample and measure the light it emits, which is proportional to the amount of stored energy and therefore to the time since it was last fired. A related technique called optically stimulated luminescence, or OSL, works on sediments that have been exposed to sunlight rather than heat. When mineral grains are exposed to sunlight, their stored energy is released, resetting the clock. Once the grains are buried and shielded from light, they begin accumulating energy again. OSL is particularly useful for dating the sediment layers themselves rather than the artifacts within them, which helps archaeologists establish when a layer was deposited. Luminescence dating fills an important gap. It can date materials from roughly 100 years ago to about 500,000 years ago, covering a range that overlaps with radiocarbon dating at the recent end and extends far beyond it at the older end. It is especially valuable in regions where organic materials do not preserve well, such as desert environments where pottery fragments may be the most common finds.

When Carbon Won't Work

For sites older than 50,000 years, which is the upper limit of radiocarbon dating, archaeologists and geologists rely on methods with much longer time ranges. The most important of these is potassium-argon dating, which measures the decay of a radioactive isotope of potassium (potassium-40) into argon gas (argon-40). Potassium-40 has an extremely long half-life of 1.25 billion years, making this method ideal for dating volcanic rocks that are hundreds of thousands to billions of years old. Potassium-argon dating has been essential for understanding human

evolution. Some of the most important early hominin fossil sites in East Africa, such as Olduvai Gorge in Tanzania and sites along the Great Rift Valley in Ethiopia, are located near volcanic formations. When a volcano erupts, the fresh lava contains potassium-40 but no argon-40 because the gas escapes during eruption. After the lava cools and solidifies, the potassium-40 begins decaying into argon-40, which is trapped in the rock. By measuring the ratio of potassium-40 to argon-40, scientists can determine when the volcanic eruption occurred and therefore the age of the rock layer. If fossils or artifacts are found sandwiched between two dated volcanic layers, their age can be bracketed with high confidence. Obsidian hydration is another specialized method. Obsidian is a volcanic glass that was widely used for making sharp cutting tools in many ancient cultures. When a fresh surface of obsidian is exposed, either by fracturing during tool-making or by volcanic eruption, it begins to absorb water from its surroundings, forming a thin hydration layer that grows over time. By measuring the thickness of this layer under a microscope, scientists can estimate how long ago the surface was exposed. The method is less precise than radiocarbon or potassium-argon dating because the rate of hydration varies with temperature and the chemical composition of the obsidian, but it is useful for comparing the relative ages of obsidian tools from the same site.

Putting the Pieces in Order: Seriation

Sometimes archaeologists do not need to know the exact age of something. They just need to know the order in which things were made or used. Seriation is a relative dating technique that arranges artifacts into a chronological sequence based on changes in their style, frequency, or characteristics over time. The principle behind seriation is that styles change gradually. A new pottery style does not appear overnight and disappear just as quickly. It starts rare, becomes popular, and then fades as a newer style replaces it. This creates a pattern that statisticians call a battleship curve because the frequency graph looks like the outline of a battleship viewed from above: narrow at both ends and wide in the middle. By plotting the frequency of different pottery styles across multiple sites or layers, archaeologists can arrange those sites in chronological order even without any absolute dates. Seriation was one of the first systematic dating methods used in archaeology and remains valuable today, particularly in regions where absolute dating methods are difficult to apply. It is especially useful for creating preliminary chronologies that

can later be tested and refined with absolute dating methods. The technique also works on things beyond pottery: changes in grave goods, architectural styles, tool types, and even the chemical composition of metal objects can all be used for seriation. The power of seriation lies in its simplicity and broad applicability. It does not require expensive laboratory equipment or rare sample types. All it requires is a collection of similar artifacts from different contexts and a careful eye for stylistic change. When combined with absolute dating methods, seriation provides the framework on which precise dates can be hung, turning a rough chronological outline into a detailed timeline of the past.

Key Information: Dating Methods Beyond Radiocarbon

Method	Key Details
Dendrochronology	Dates wood by matching tree-ring patterns; can provide exact year; master chronologies extend 8,000+ years
Thermoluminescence (TL)	Dates heated materials like pottery and hearth stones; effective range 100 to 500,000 years
Optically Stimulated Luminescence (OSL)	Dates sediments last exposed to sunlight; useful for dating soil layers themselves
Potassium-Argon Dating	Dates volcanic rocks; effective range hundreds of thousands to billions of years; half-life of 1.25 billion years
Obsidian Hydration	Measures water absorption layer on obsidian tools; less precise but useful for comparing relative ages
Seriation	Arranges artifacts in chronological order based on stylistic change; does not require laboratory equipment
Cross-Dating	Using a known-date sequence in one area to date materials in another region by matching patterns

Case Study: Dr. Yazzie's Pueblo Puzzle

Dr. Ben Yazzie carefully removed a blackened wooden beam from the collapsed roof of an ancient pueblo in northeastern Arizona. His team had been excavating the multi-room structure for two field seasons, trying to determine when this section of the pueblo was built and how long it had been occupied. The site had no pottery that could be confidently linked to a known time period, and there were no volcanic deposits nearby for potassium-argon dating. But the roof beams were well-preserved, their ring patterns clearly visible under the dry desert conditions. Dr. Yazzie photographed the beam's cross-section and sent high-resolution images to a dendrochronology lab at the University of Arizona. "We have twelve beams from this room," he told his colleague Dr. Thompson on the phone. "If even half of them match the master chronology, we can nail down the construction date." Two weeks later, Dr. Thompson called back with results. "Eight of your twelve beams match. The cutting dates range from 1084 to 1089 CE. But here is what is interesting: two of the beams have cutting dates in the 960s CE. They are over a hundred years older than the rest." Dr. Yazzie smiled. "Recycled timber. They probably pulled those beams from an older structure when they built this room. That means there is an earlier occupation phase we have not found yet."

1. Using information from the reading, explain why dendrochronology is particularly well-suited for dating this pueblo site. Why would other dating methods be less effective in this situation?

2. Dr. Yazzie concludes that two beams are recycled timber from an older structure. How does this connect to the reading's discussion of what tree-ring dates actually measure? What does this finding suggest about the history of the site?

Multiple Choice

1. How can dendrochronology be so precise in determining when a piece of wood was cut?

    a) It measures the weight of the wood

    b) It measures the amount of water absorbed by the wood during long-term storage

    c) It matches the pattern of wide and narrow growth rings to a master chronology

    d) It counts the total number of cells in the wood

2. Potassium-argon dating is most useful for dating which type of material?

    a) Wooden beams from ancient buildings

    b) Organic materials like bone and charcoal

    c) Volcanic rocks near fossil sites

    d) Pottery and ceramic objects

3. What is the principle behind seriation as a dating method?

    a) Styles change gradually over time, creating predictable patterns of popularity

    b) Chemical decay rates determine the age of pottery and other clay-based artifacts

    c) Artifacts deeper in the ground are always older

    d) All artifacts from the same site are the same age

Matching

Write the letter of the correct definition on the line next to each term.

Term	Definition
1. ___ Dendrochronology	A) A relative dating technique that arranges artifacts chronologically based on changes in style or frequency
2. ___ Thermoluminescence	B) A method that dates volcanic rocks by measuring the decay of potassium-40 into argon-40 gas
3. ___ Potassium-Argon	C) A method that estimates the age of volcanic glass tools by measuring the thickness of a water absorption layer
4. ___ Seriation	D) A method that dates heated materials by measuring the light energy stored in crystals since they were last fired
5. ___ Obsidian Hydration	E) A dating method that uses the pattern of annual tree growth rings to determine the exact year wood was cut

Fill-in-the-Blank

1. The longest unbroken tree-ring record, based on bristlecone pines in the American Southwest, extends more than _____ years into the past.

2. Potassium-40 has an extremely long half-life of _____ billion years, making potassium-argon dating ideal for very old volcanic rocks.

3. In seriation, the frequency pattern of a style over time is called a _____ curve because its shape resembles the outline of a warship.

Short Answer

Answer each question in 2-4 complete sentences.

1. Why is dendrochronology considered the most precise dating method in archaeology? What conditions must be met for it to work, and what are its limitations?

2. Explain why potassium-argon dating has been so important for studying human evolution in East Africa. What is it about the geology of that region that makes this method particularly useful?

3. How does seriation differ from the other dating methods discussed in this reading? In what situations would an archaeologist choose seriation over a laboratory-based method?