Chapter 4

Understanding Dating in Archaeology

YOUR GOALS

You need to understand

- the underlying principles of dating
- the essence of how the more common techniques work
- reasons why particular techniques are appropriate for specific situations
- how to 'read' some of the more common types of charts and diagrams used to present dating data.

Archaeologists have used many different techniques to work out the age of artefacts and sites for which they have no historical dates and the order in which they were used. These dating techniques can be broadly subdivided into two groups:

- **Relative dating** techniques which identify the order in which sites or artefacts were used in a sequence from earliest to latest.
- **Absolute** (or chronometric) **dating** techniques that try to establish an exact or approximate calendar date for a site or artefact.

The techniques selected depend on the specific task and evidence as well as practical considerations such as cost. Many of the scientific techniques are expensive and require high levels of technical skill to use and to interpret. The span of human history studied by archaeologists is so vast and environments so varied that techniques suitable for one place and period may be unsuitable for another.

Periods in archaeology

In the historic period, archaeologists make use of period names which are broader and often different from those used by historians. The fifth to seventh centuries AD are a case in point. In history books the period following Roman Britain is usually referred to as the Saxon Period or the Dark Ages. The latter term has been used to relate to both the decline in Christianity and urban life and the paucity of written documents from the period. To archaeologists it is certainly not 'Dark' since there is a wealth of artefactual evidence. In those further reaches of north-western Europe where the Iron Age was not interrupted by Roman occupation it is often referred to as the later Iron Age because of continuity in technology and society or the 'migration period' because of population evidence. In England 'Early Medieval Period' is sometimes used to indicate discontinuity with the Roman period and greater similarity with later centuries. In general, history will refer to peoples or individual royal families while archaeologists use labels that reflect more gradual changes in material culture and social and economic arrangements.

Archaeologists of European prehistory have, since the adoption of the three age system of stone, bronze and iron in the nineteenth century, used material culture and technology to label periods. A key indicator of the Mesolithic, for example, is the development of microlith technology which can be broadly distinguished from the blade based technology of the Upper Palaeolithic. Within these broad periods of several thousand years, subdivisions are often named after sites where variations in artefactual evidence were first noted. These subdivisions differ across wide regions. For example in France and parts of central Europe the term 'Sauveterrian' is used for part of the early Mesolithic. This is named after the type-site of Sauveterre le Lémance where assemblages containing numbers of geometric microliths were first identified. In Northern Europe a broadly similar period is termed 'Maglemosian' after the type-site of Maglemose in Denmark where flint microliths were used alongside a range of wood and bone tools. For the Palaeolithic some archaeologists, particularly those using environmental data, will refer to climatic periods such as Holocene or particular glaciations such as Devensian. It is worth noting that periods often start and finish at different dates in different areas. For example the Neolithic in south-east Europe occurred earlier than that in the north-west and reflects the gradual spread of agriculture out from the Balkan region. By the time Britain was 'in' the Neolithic the Balkans were 'in' the copper age or Chalcolithic.

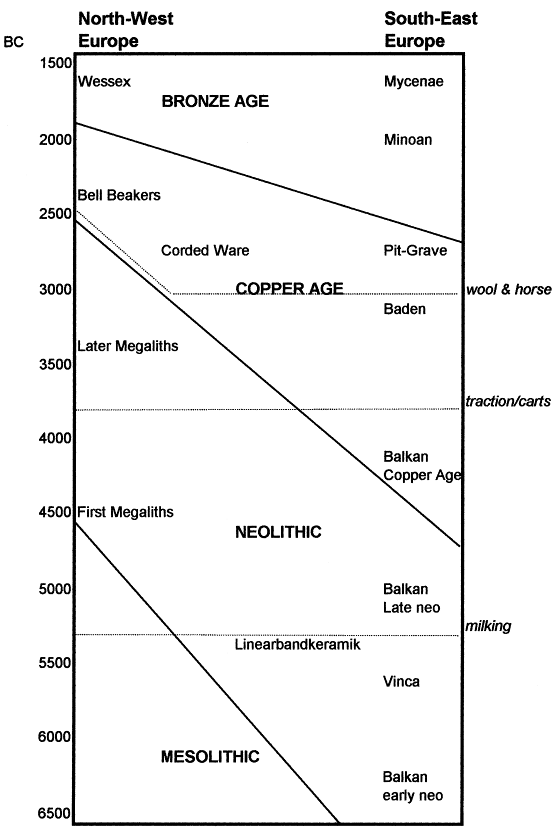


Figure 4.1 *Confusing periods in the past*

This simplified diagram (after Sherratt) illustrates broad patterns between South East and North West Europe during a period where the first metal-using civilisations were developing in the Near East but northern Scandinavians were continuing with the same foraging lifestyle that had been developing since the last Ice Age. So was it the Mesolithic, Neolithic or Bronze Age?

Historical dating

For sites less than 5,000 years old there may be written or artistic evidence which can provide precise dates as long as the original language can be decoded. For example, coins, seals, inscriptions and clay tablets were used by the civilisations of the Mediterranean and Middle

Figure 4.2 *Roman coin from the reign of Nero*

Coins have often been used to establish TPQ dates. In this case, the layer with the coin could not have been earlier than AD 54–68 (the reign of Nero). To help remember the difference between TPQ and TAQ think 'you have to *p*ost a letter before it can *a*rrive'.

East. Sometimes historical records such as dates, calendars or lists of rulers are available. These have allowed sites such as Egyptian tombs or Mayan temples to be precisely dated. When artefacts from these civilisations appear in non-literate areas they can be used to provide approximate dates in those areas. For more recent periods the exact dates for the introduction of many artefacts from clay pipes to beer bottles are known and can be used to date sites. Where artefacts are used for dating it is critical that their precise position within the stratigraphy is accurately recorded. Such 'indirect dating' of sites provides two types of date:

- *Terminus post quem* (**TPQ**): the earliest possible date for an archaeological deposit
- *Terminus ante quem* (**TAQ**):the latest possible date for the deposit

RELATIVE DATING

Typology

In its simplest form, this involves putting a number of finds into chronological order. On

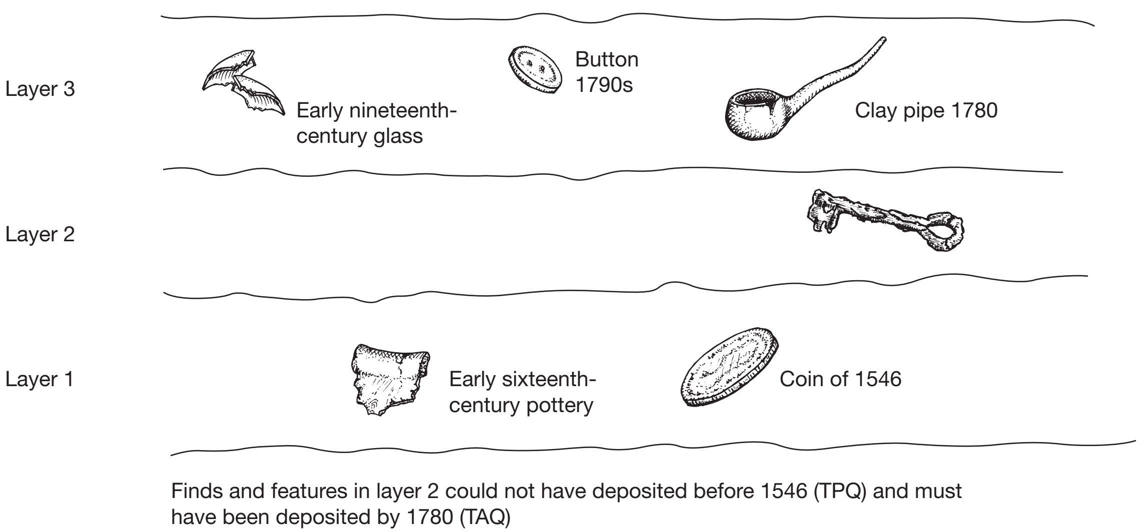


Figure 4.3 *The use of finds to provide earliest and latest dates for a layer. The key can be dated by association (◀ p. 36) to the layer*

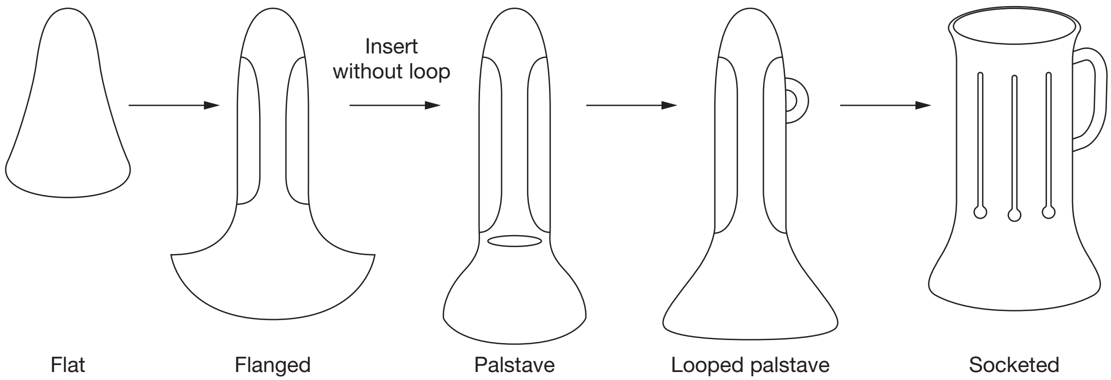


Figure 4.4 *An example of a typological sequence: the development of copper and bronze axes*

a site with a clear and undisturbed stratigraphy, items from lower levels are older than those in higher levels. In the nineteenth century, observations about the types of artefact from different layers led to the creation of a time frame for prehistory known as the '3 age system', based on the introduction of tools made from stone then bronze then iron. Today many flaws are apparent in this scheme but the terms are still used to distinguish different 'periods' in the past. A more sophisticated technique was popularised by Flinders Petrie in the 1900s. He noted that the design and decoration of pottery from the Egyptian tombs he excavated changed gradually over time. He was able to place the different types into a chronological sequence. Once a good typological sequence for an area is established it can be referred to when new finds and sites are discovered and used to 'cross-date' them. In addition to design, the fabric or material used to make the artefact is also analysed. If you take a piece of pottery into your local museum, typology will be used to assign your sherd to a particular period.

Successive groups (or assemblages) of contemporary artefacts, which are commonly found together, have been used to form culture sequences over wide periods. Before the advent of absolute dating techniques this technique enabled a timetable of the spread of 'cultures' across Europe in later prehistory to be constructed, based on changing combinations of grave goods.

Seriation

Most artefact styles appear rarely at first in the archaeological record, then become more common and eventually dwindle in numbers again. This pattern has enabled a sophisticated statistical technique known as seriation (ordering) to be used. Information from a variety of dated sites across a long period is brought together. The frequency with which each form of artefact appears can be plotted as bars on a timeline. Ideally this will produce a shape known as a 'battleship curve' because it looks like an aerial view of a battleship. The changing popularity of each form will appear as a sequence of battleship curves. Other sites can be dated relative to the first site by comparing their seriation.

Problems with these techniques

- Although they can put sites and artefacts into order, they can only be used to provide calendar dates where elements of the sequences are tied to historical data.
- The advent of radiocarbon dating showed that archaeologists had underestimated timespans in prehistory. They had mistakenly

Figure 4.5 *A TRB ceramic assemblage*

This distinctive type of fourth millennium pottery with funnel-neck beakers and a range of stylised containers for liquids is the calling card of the first Neolithic farmers along the Baltic. Debate continues over whether they were incomers or converted foragers (▶ p. 251) but finds of this type provide a relative date for the contexts they are recovered from.

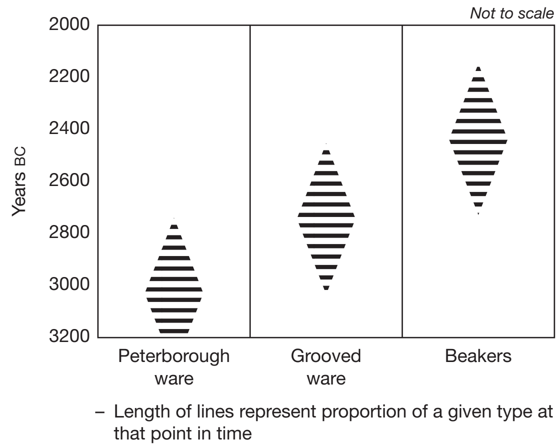


Figure 4.6 *A simplified diagram to show how a model of seriation can be constructed*

The relative proportions of pottery types at a new site would be compared with the seriation chart to give it an approximate date. On our diagram, a site with lots of Grooved ware but only one beaker might be relatively dated to soon after 2800 BC.

constructed sequences to fit their assumptions that all developments happened around the Mediterranean and then spread north and west to 'less civilised' areas.

- One type of artefact doesn't always succeed another. For many years it was thought that pointed hand axes were earlier than oval ones after they were found in lower levels on some sites. However, at Boxgrove both were found together suggesting that other influences on choice were important. Seriation assumes that new artefacts are phased in gradually as others are phased out. This does not always happen.
- **Curation**, the preservation of valued artefacts, can lead to items being deposited a long time after their manufacture. Basing dates on a few isolated artefacts could lead to errors.

Georchaeological dating

For early periods of prehistory archaeologists have borrowed techniques from the earth sciences to reconstruct the environments of early people and also to establish relative chronologies based on environmental changes. As the climate alters, so too do the types and relative numbers of different plants and animals. Where organic preservation is good, changes can be traced by analysing pollen (◀ p. 85) contained in sediments and animal bones. (◀ p. 72) To provide a pollen sequence a core through a deposit such as peat is taken and for each layer the proportions of different types of pollen are identified. Sites within these deposits can then be cross-dated to particular phases of climate history in local sequences. Analysis has to take account of many factors including the different amounts of pollen produced by each plant and the different distances the pollen travels. Similarly, sites can be relatively dated from the type of animal bones

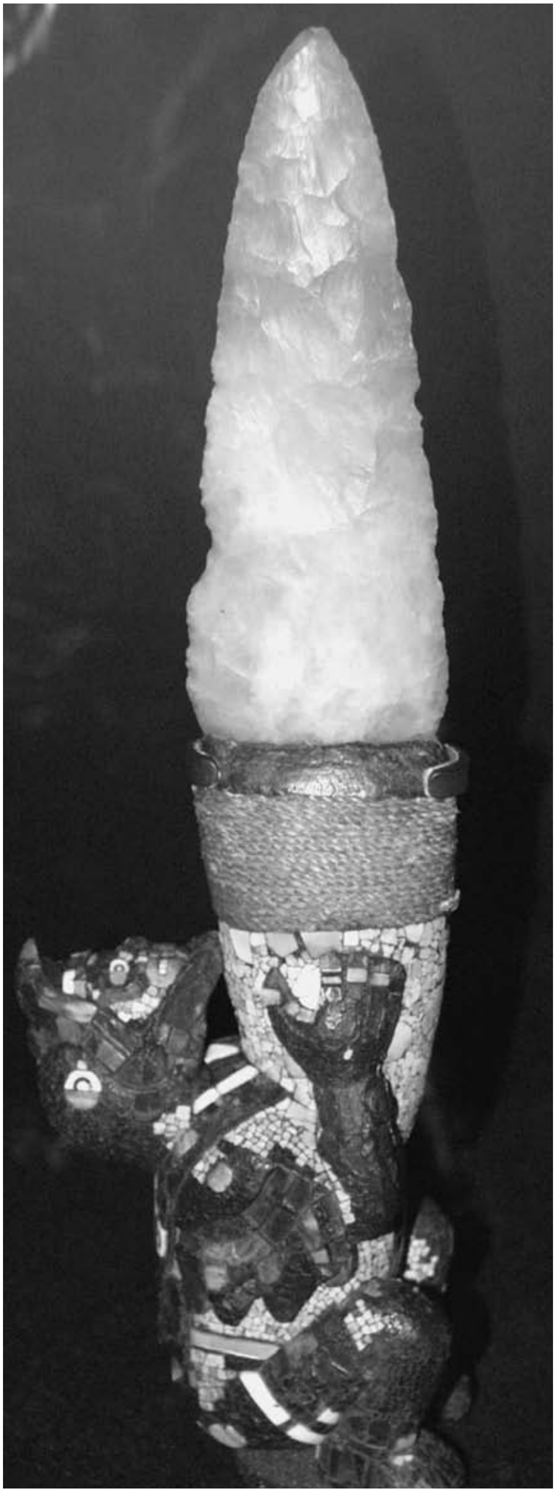


Figure 4.7 *Obsidian blade*

This example is too precious to subject to hydration dating. It illustrates one of the other properties of obsidian – its razor-sharp cutting edge. This Aztec ritual blade was used to remove hearts from sacrificial victims.

present (◀ p. 41). This is particularly useful where the sequence of the appearance or extinction of species (for example mammoths) is known. Absolute techniques are needed to date these sequences. For the relative dating of major climatic sequences, deep sea cores and varves (lake deposits) are used.

Obsidian hydration

Obsidian is a volcanic glass that can be worked to provide razor-sharp cutting edges. In the Middle East and Mesoamerica it performed a similar function to flint in northern Europe. As soon as a piece of obsidian is broken it begins to absorb water from the atmosphere at a known rate (in much the same way as a stick of rock which goes soft on the outside). By measuring how far water has penetrated (hydration) into the obsidian on one site a relative date can be estimated compared to other sites. In some cases, results can be calibrated to provide absolute dates but that requires considerable additional data since the speed of hydration varies with local temperatures and the chemical make-up of the obsidian. This is one of the cheaper laboratory dating techniques.

- http://www.peak.org/~obsidian/

Hydration also occurs in other rocks and the potential of quartz for dating is currently being explored. Experiments on artefacts with known dates including Olmec pendants in Mexico has led to claims that quartz hydration may be able to date artefacts between 100 and 100,000 years old. However not all archaeologists currently accept this method.

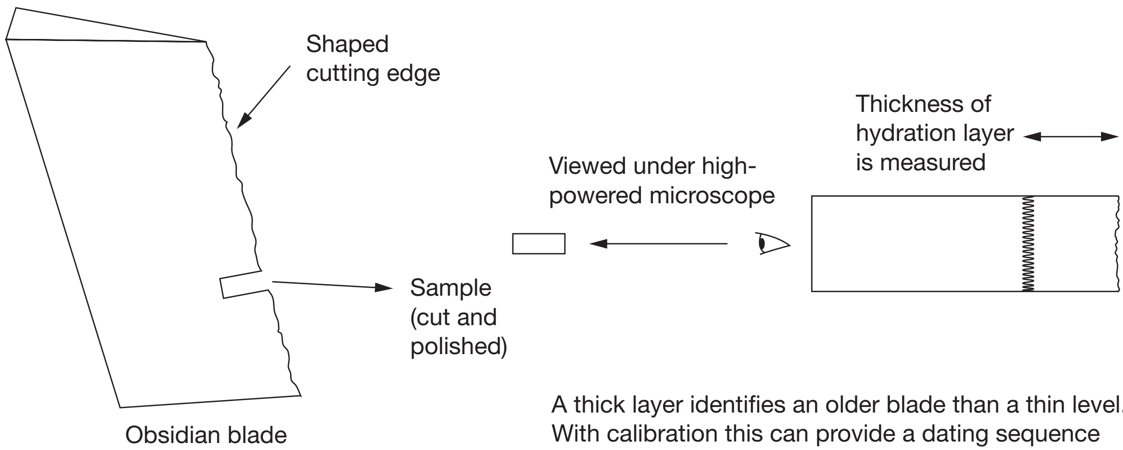


Figure 4.8 *How obsidian hydration works*

Chemical dating of bones

Buried bones absorb fluorine and uranium from water in the ground whilst their nitrogen content declines as collagen in the bones decays. These processes occur at uniform rates so it is possible to establish the relative age of different bones by measuring the proportions of these chemicals.

ABSOLUTE OR CHRONOMETRIC DATING

Since the middle of the twentieth century new methods have been used to provide calendar dates. With the exception of dendrochronology, they all have margins of error and are expensive to use.

Dendrochronology (tree ring dating)

This is the most accurate chronometric dating method. Early in the annual growing season trees produce thin-walled 'earlywood' cells. Towards the end of the year thick-walled 'latewood' cells are produced. This cycle produces a visible 'ring' in the wood each year under the bark. The rings are wider in good weather conditions than in poor ones and can provide a record of local climatic variation. Trees in the same area will have similar ring patterns which means wood from different periods can be matched in overlapping sequences. These are tied to historical dates by modern trees. Californian Bristlecone Pines, which live for 4,000 years, were used to construct sequences over 7,000 years in the USA while oaks preserved in bogs have been used in Europe to create master sequences going back 11,000 years. The precision of the method is such that the felling date of the central stump of Seahenge (▶ p. 119) which had its bark attached has been pinpointed to between April and June 2050 BC.

Dendrochronology does have some limitations. Sometimes carpenters discard the softer sapwood just under the bark. This is important as in England there may be 15–55 or so 'sapwood' rings on an oak. In such cases researchers can only estimate an 'earliest possible felling date'. Not all areas have sufficiently varied seasons or enough surviving timber to be able to construct sequences. To effectively date wood around fifty years of tree rings are needed. Since this represents quite a thick piece of wood, the technique is better for dating building timbers than artefacts. Its direct use is from the Neolithic onwards when buildings were used and it has

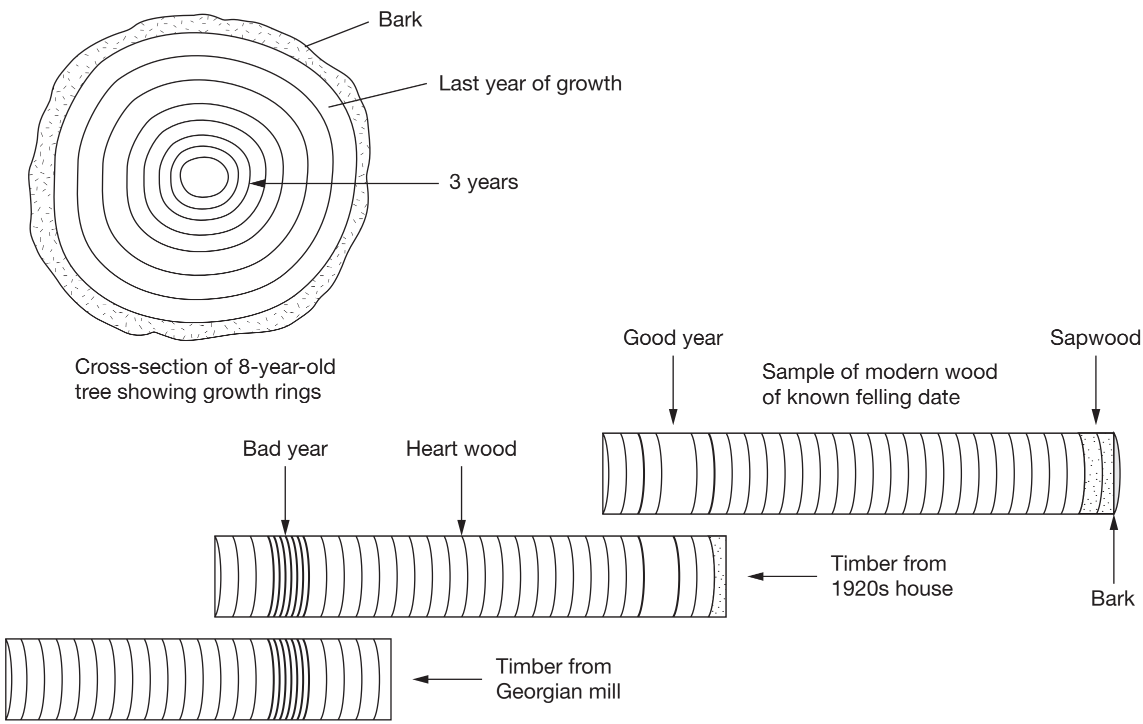


Figure 4.9 *The key principles of dendrochronology*

Principle of tree ring dating: overlaps are matched to take the sequence back from a known date to date old timbers. Samples are taken at 90 degrees to the grain and numbers of rings and their thickness measured by eye or computer.

been widely used on medieval ships and buildings. Dendrochronology actually dates when the tree died or was felled. Where wood has been reused, as often happened with structural timbers in the past, this method can overestimate the age of a structure.

- http://www.ltrr.arizona.edu/

Radiocarbon dating

All living things absorb several types of carbon isotope from the atmosphere in similar ratios. About 1 per cent of this carbon is an unstable isotope known as carbon 14 (C-14) which decays at a known rate. The half-life of radiocarbon is 5730 years which is the length of time it takes for half the C-14 to decay. By comparing the amount of C-14 remaining with amounts of other carbon isotopes (which do not decay) in organic samples it is possible to work out how much C-14 has decayed. This indicates how long it has been since decay began (and the creature or plant was alive). For many years it was thought that the dates produced by radiocarbon dating were precise. However the original half-life estimate of 5568 has been shown to be too little and the amount of carbon in the atmosphere has varied over time. As a result many dates for the last 8000 years were underestimated. For 5000 BC this was by around 1000 years! To get round this problem, radiocarbon dates are calibrated. More recently scientists have also identified a 'marine reservoir' effect. Carbon in the food chain in the sea is up to 400 years older than that on land with the result that dates based on bones of populations which ate a lot of marine food may be inaccurate.

The usual method of calibrating radiocarbon dates is dependent upon dendrochronology. Even after calibration there is a margin of error that is calculated statistically. This usually means that there is a 68 per cent chance or 'level of confidence' (LOC) that the real date is within the range indicated and a 95 per cent LOC that it is within twice the range. C-14 is mainly used to date organic materials including bone, shell and plant remains. It does not work on cremated bone although it will work for charred bone. It is more precise with wood samples from twigs and nuts than from trees that may have lived for hundreds of years. Radiocarbon's practical use is for periods from 200 to about 10,000 years with less reliability to around 40,000 years. Until recently at least 10 grams of charcoal or 200 grams of bone were needed for results. The development of accelerator mass spectrometry (AMS) has enabled samples as tiny as one grain

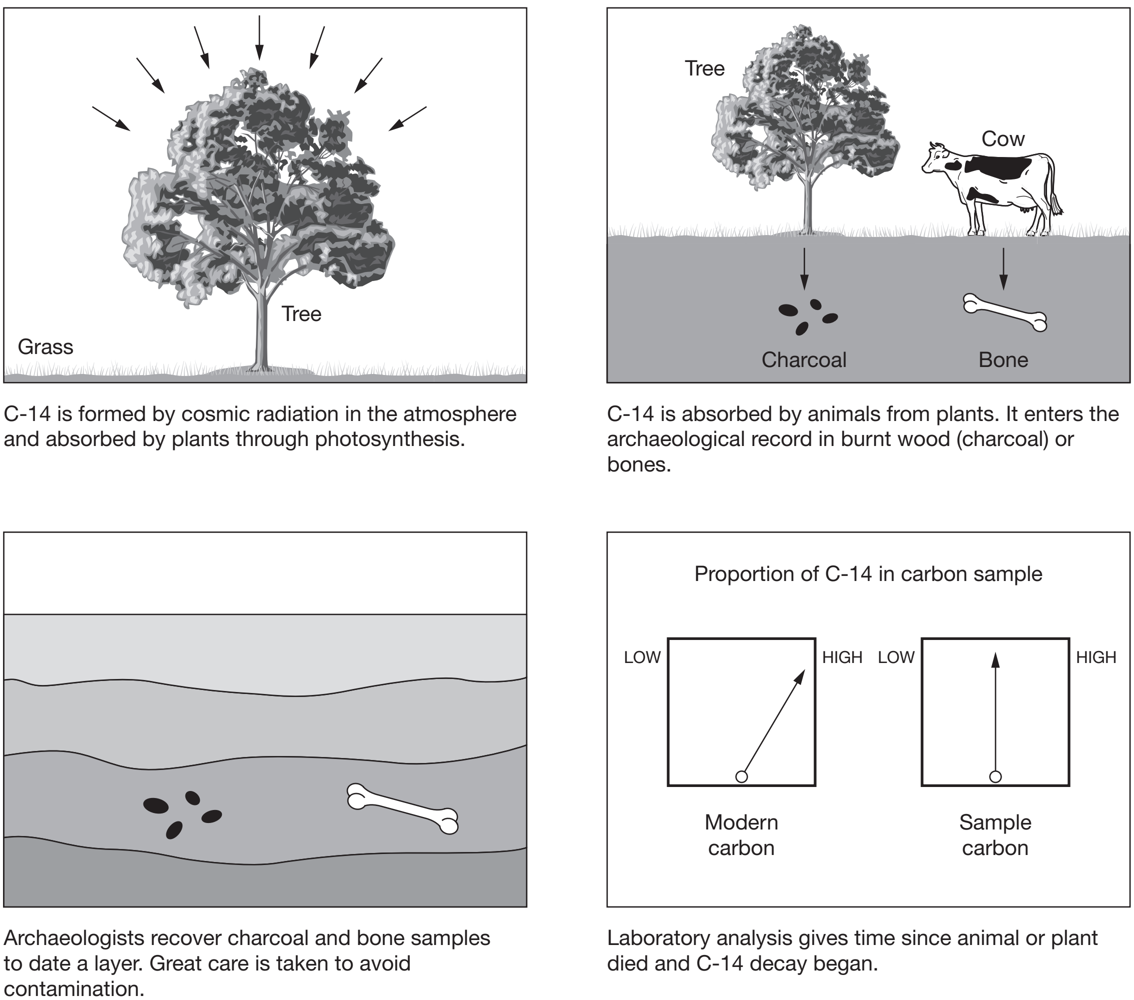


Figure 4.10 *How radiocarbon reaches the archaeological record*

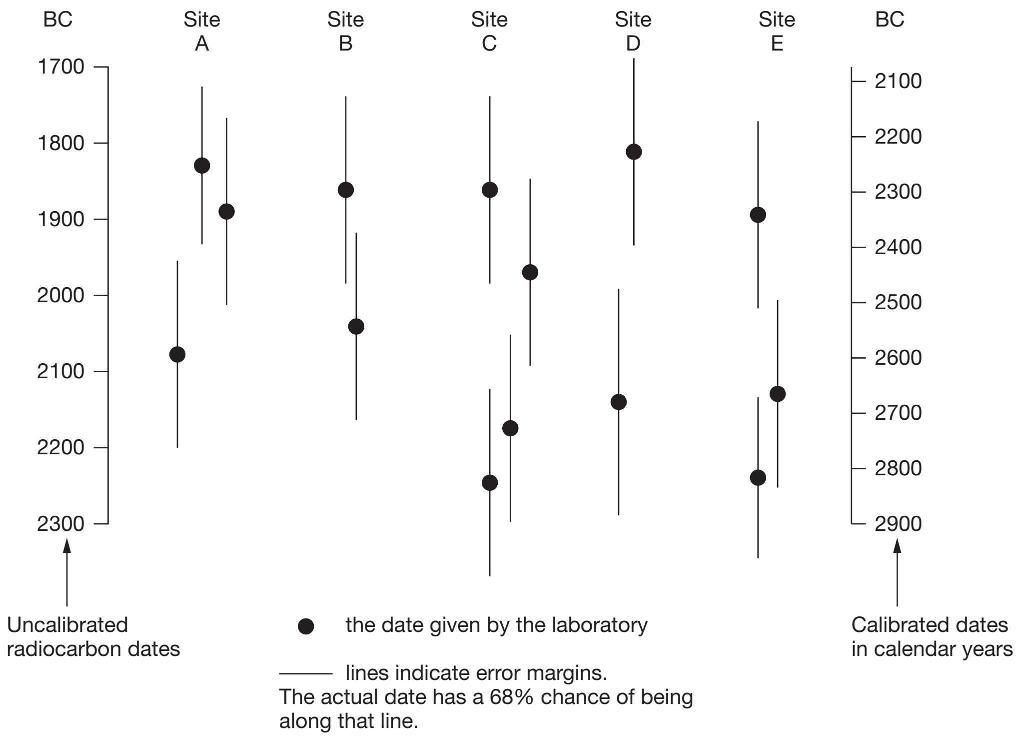


Figure 4.11 *Reading a radiocarbon table*

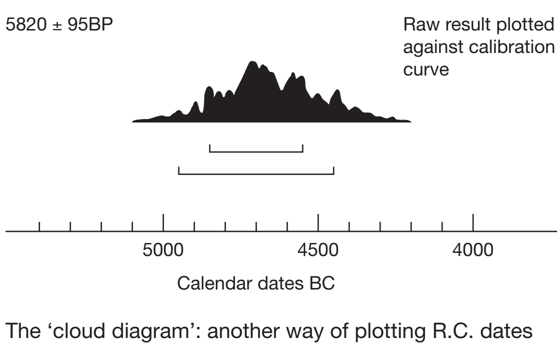


Figure 4.12 *A 'cloud' diagram*

An alternative mode of plotting RC dates shows the date range graphically. Lines underneath indicate 1 and 2 LOC.

of cereal to be dated. This expensive technique uses energy to accelerate the carbon molecules in such a way that they can be separated by weight and then counted.

- http://www.radiocarbon.org/
- http://www.radiocarbon.org/Info/#labs

C-14 dates are expressed in the following ways:

- Lower case letters are often, but not always, used to show that dates are uncalibrated, whereas capitals should mean they have been calibrated. Increasingly 'Cal' is added to a calibrated date to avoid any confusion.
- Calendar dates are expressed as ad or bc (uncalibrated) and BC, AD, Cal BC, Cal AD (calibrated)
- Radiocarbon dates are expressed as BP or Cal BP (calibrated). BP means 'before present' (1950) and is often preferred for early prehistoric periods for which BC and AD are relatively meaningless.

KEY TERM

Calibration

Calibration involves turning measures of time into calendar dates by comparing results from one method with dates from a more precise method. Dendrochronology is the most widely used method for calibration. Essentially, wood of a known age is tested for its C-14 date and the two dates compared. Once a large range of comparisons has been made a chart can be produced which enables scientists to read off a calendar year against a sample date. Calibration curves are modified as new data on ancient wood is published.

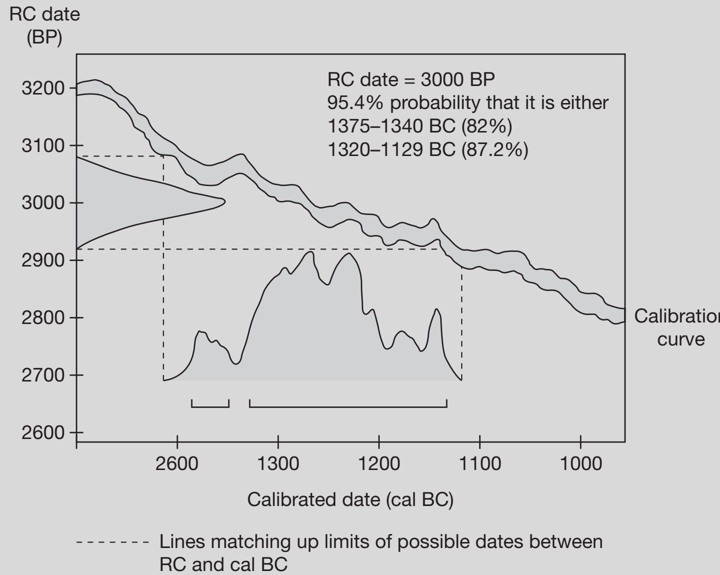


Figure 4.13 *How calibration works*

This diagram is intended simply to illustrate principles. In the example plotted you can see that where the calibration curve is steeper, raw dates are converted to a relatively short range of calibrated dates while where the curve is shallow the range would be much longer.

A SECOND DATING REVOLUTION? THE APPLICATION OF BAYESIAN STATISTICAL ANALYSIS

Radiocarbon results often contain very broad ranges of possible dates. E.g. 3500 ± 125 years means that the data has a 68 per cent chance of being somewhere within a 250 year period and a 95 per cent chance of lying within a 500 year period. These broad date ranges have meant that archaeologists have been unable to discuss particular events and discussions of sequences and changes have often been at a very general level. The application of a new statistical technique to radiocarbon dates offers the possibility of much greater precision. It is also challenging current beliefs about many periods in the past.

The Rev. Thomas Bayes was an eighteenth century amateur mathematician. He developed a statistical model based on accumulating evidence in order to assess the probability of a given hypothesis being correct. This involves other observations and common-sense knowledge being used to modify probability statements. To take an extreme and simplified example: there might be a 5 per cent chance in any given year of snow falling on 25th December. However if we know that it snowed on 23rd and 24th, the probability of snow falling on the 25th would increase significantly.

If we take our 250-year date range, there are 250 potential outcomes which have equal probability of being the right date. Bayesian inference might lead us to update this hypothesis using other information available to us. For example other dating evidence derived from stratigraphy might lead us to reject one part of the date range. As a result of combining different types of evidence we might update the hypothesis by stating that it was probable that another part of the range contained the probable actual date. In this case we might then believe that the possible date range spanned 30 years rather than 250.

This advance is possible because of recent developments in computer-based simulations and complex mathematical methods of translating archaeological data into formats where it can be analysed statistically. There is some criticism of the approach because it contains elements of subjectivity but it has generally been embraced by dating specialists. Although first applied to radiocarbon dates, Bayesian statistics are being used in a range of other dating methods including thermoluminescence to improve the resolution of dates and in other areas of archaeometry where results are expressed in terms of probability.

English Heritage have illustrated the potential of this technique by using it to carry out a re-dating of skeletal remains from a number of neolithic long barrows in southern England. Previous data from Wayland's Smithy had given a span of dates over a thousand years. This suggested a long period of little change with episodic reuse of the monument. The new data on 14 skeletons narrowed the range to a few decades from 3590 to 3560 BC. This opens up the possibility that the monument was related to one event or series of events. Evidence of injuries on the skeletal remains could suggest that it relates to conflict. Re-processing of radiocarbon dates from four other long barrows including West Kennet and Hazleton revealed that the final burials in each of them date to around 3625 BC. Alex Bayliss who leads the English Heritage team has suggested that instead of seeing the Neolithic as a relatively timeless period, we may now start to be able to identify specific events and change within it.

Figure 4.14 *The façade of Wayland's Smithy*

Fourteen skeletons were excavated in the 1960s from this chambered long barrow in Oxfordshire. Recent forensic examination suggests that three of them may have been killed by arrows. Two of the skeletons may have been scavenged by dogs or wolves as they lay in the open before being recovered and buried. This may suggest that the people were killed at the same time in a raid or feud. Combined with the new dates it may mean that the middle of the fourth millennium BC was a time of social tensions.

Thermoluminescence (TL)

Radioactive decay in the quartz crystals found in clay leads to a build up of electric charge at a known rate. The electrical charge is released as light (luminescence) when the crystals are heated. Each reheating resets the clock. When pottery is discarded it also acquires (gamma) radiation from the surrounding soil. Essentially this means that the flash of light energy released by a given weight of ceramic sample (palaeodose) can be measured in a laboratory to calculate the number of years since the pottery was fired. The more light the longer the time since the 'clock setting event'.

$$\frac{\text{Palaeodose (acquired since last heating)}}{\text{Annual dose}} = \text{Age}$$

The technique can be used for materials such as glass and burnt flint or stone for periods from the present to around 400,000 years ago. It is significantly less accurate than C-14 dating and can give false readings due to radiation from the soil or if the initial firing was at low temperature. However, it is useful for older periods and instances where there are no organic remains such as dating Upper Palaeolithic figurines from Dolni Vestonice. A similar principle underlies **Optically Stimulated Luminescence (OSL)**. Electrons from decaying radioactive elements are trapped in crystals of quartz or feldspar which form part of many sediments. When stimulated with light, the electrons free themselves, giving off luminescence (light energy) in the process. The amount released can be used to date the last 'clock setting event'. Dates from 50 to a million years can be calculated with more accuracy than TL. OSL measures the time since sediments were last exposed to sunlight or in the case of ceramics when they were last heated to over 400°C.

- http://www.uic.edu/labs/ldrl/

Potassium–argon dating

As potassium in rock crystals decays it produces argon gas at a known rate. Measuring the amounts and ratios in a laboratory provides a date at which the crystal was formed. It has been used in volcanic regions to date layers of rock which sandwich human remains. For instance, at Koobi Fora in East Africa early hominid remains were dated to 1.89 million years BP ±0.01 million years. The technique can be used for periods from around 200,000 to several million years ago but it is limited to sites with the right geology.

Other absolute dating techniques

Figure 4.17 covers less commonly used methods, some of which are still at an experimental stage. You do not need to know them in detail although you should be aware of the situations where they might be used. Like radiocarbon dating, most of them rely on data showing known rates of chemical change or decay that can be measured in laboratories. Several of them measure the age of layers rather than the archaeological deposits themselves and are thus limited to particular types of geology. Most methods are used in combination to cross-check dates.

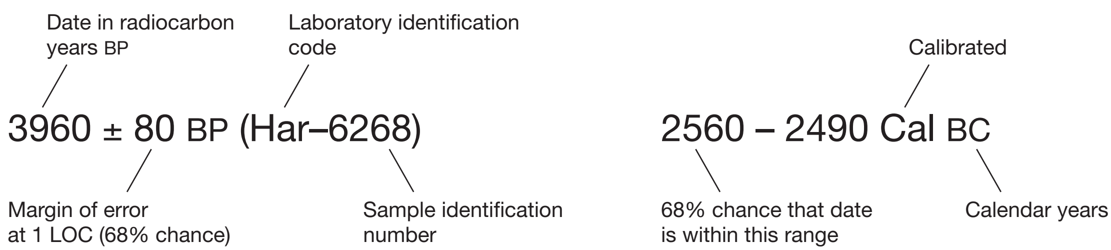
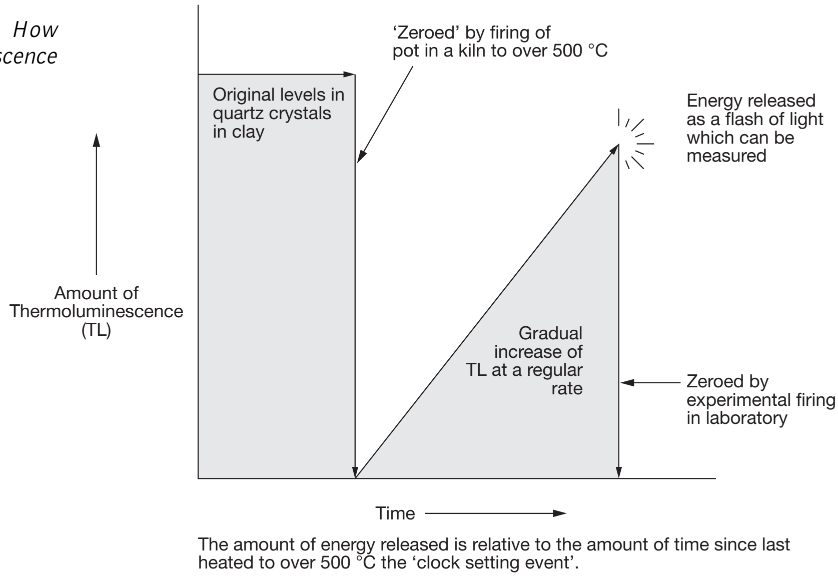


Figure 4.15 *Understanding a radiocarbon date*

Figure 4.16 *How thermoluminescence works*



KEY TASK

Test your grasp of dating methods

1 Which methods might you use to date the following? Check your answers on p. 429.

- A wooden spear tip from 20,000 years ago
- Shells from a Mesolithic midden
- Seeds from a Roman well
- Burnt flint from a palaeolithic hearth
- Walls made from baked mud bricks from an ancient house
- Human bones from a Saxon cemetery
- An Aztec kiln site from Mexico
- Bison bones found in cave deposits
- A terracotta figurine from a Roman temple
- Timbers from a Bronze Age boat

2 Construct a bar chart to show which methods are useful for which period in the past.

- List each method on the vertical axis at regularly spaced intervals.
- List the following dates (in years BP) on the horizontal axis at regularly spaced intervals: 0, 100, 500, 1,000, 5,000, 10,000, 50,000, 100,000, 500,000, 1,000,000, 5,000,000.
- Shade the period for which each method is useful in the relevant row.

	How it works	*What it can be used for*	*What periods it is used for*	*Comments/limitations*	*Examples*
Amino acid racemization	The chemical structures of the amino acids found in all living things change slowly over time at a known rate	Bones, teeth and shell	1000 to 1 million years	Must not be cooked Needs calibrating Varies with climate	Ostrich eggs on Palaeolithic sites in Africa
Archeomagnetism	The earth's magnetic field changes over time. When iron oxide is heated to around 600 °C and cools, it records the magnetic field at that time. Variations in the earth's field have been calculated which enables the date of initial heating to be established	Ceramics, lava, hearths and kilns that contain iron oxide	Up to 5,000 years	Local variations in magnetism Sites must be undisturbed when measured. Needs to be calibrated, e.g. by varves Can provide inaccurate dates where the same polarity occurred more than once	Clay ovens in south-west USA
Electron spin resonance (ESR)	Electrical charges build up at a known rate in some crystal structures. The time since the process began can be calculated by measuring the charge	Teeth enamel, shells calcite deposits in caves	50,000 to 1 million years	Works best in dry environments Wide error margins	Palaeolithic sites in Israel and Africa
Fission track dating	Uranium decays regularly through fission (splitting) which releases energy and damages crystalline structures, leaving a 'track'. Tracks or holes are counted to estimate the time the process of decay has taken	Glass, burned obsidian, heated stones containing uranium Sites sandwiched between volcanic layers	Mainly 100,000 to several million years although some recent glass has been dated	Difficulty in differentiating tracks from crystal defects Over 10% error margins	Homo habilis bones at Olduvai Gorge from around 2 million years ago
Uranium series	Uranium isotopes U235 and U238 are soluble in water and decay to produce deposits of thorium and protactinium at known rates. By measuring the ratios of the elements the date at which the deposits were laid down can be established	Analysing calcium carbonate deposits where water containing uranium has seeped into caves and been deposited (e.g. as stalactites) Teeth enamel, shells	Early human sites in Europe 50,000 to 500,000 years	Prone to ambiguous results Needs a high uranium content	Dentine on Neanderthal/ early human teeth in Israel
Varves	Melt-water from glaciers lays down different sediment at different times of year. This creates annual layers like tree rings. Changing climate will lead to changing deposits which can then be cross-referenced over large areas	Analysing cores taken from ancient lake beds. Where they contain pollen they can be tied to geoarchaeological sequences	Up to 20,000 years	Key dating role is by calibrating other techniques such as radiocarbon and archaeomagnetism	A sequence of 17,000 years has been established in Scandinavia and 20,000 in the USA

Figure 4.17 *Comparison of other major scientific dating methods*