Introduction to Archaeology

Techniques & Methods

Introduction to archaeology: Techniques & Methods

7. Introduction

Archaeology is the study of human past through its material remains. It is an interdisciplinary undertaking involving the cooperation of scholars from both the humanities and sciences. Archaeology is best known for its detailed excavations of prehistoric and historic places, but archaeologists also regularly use written records, oral histories, geological and geographical data and a host of specialist studies of plant, animal and human remains to document the past. The goal of archaeology is to better understand earlier human life ways and the course of human social development.

Archaeology, (from the Greek words αρχαίος *= ancient and* λόγος *= word/speech/discourse) is the study of human cultures through the recovery, documentation and analysis of material remains and environmental data, including architecture, artefacts, biofacts, human remains, and landscapes.*

The goals of archaeology are to document and explain the origins and development of human culture, understand culture history, chronicle cultural evolution, and study human behaviour and ecology, for both prehistoric and historic societies. It is considered in North America to be one of the four sub-fields of anthropology.

8. Archaeology: the conquest of the past

Since the Roman civilization the antiquarius is a person interested in collecting objects, monuments or stories from the past. Although archaeology as a modern science is a recent discipline which goes back to the mid 19th century, modern archaeologists are the heirs *to the Roman* antiquarii*. The discipline's roots in* antiquarianism *and the study of Latin and Ancient Greek provide it with a natural affinity with the field of history.*

With the Italian Renaissance and the influence of classical Antiquity in the 14^{th}-16^{th} century, Europe opens up for a spectrum of new knowledge such as astronomy, medicine, art, philosophy and theology through the rediscovery of ancient texts mainly Greek and Latin.

From the 16^{th} century, sovereigns, nobles and rich bourgeois make collections of rare objects, both natural and crafted by men, from beneath the ground or from far away countries. In the 17^{th} century, the owners of such collections are called antiquarians*. A century later, these early collections give birth to the first museums and lay the foundations to new disciplines such as zoology, botanic, geology, ethnology and archaeology.*

These collections are composed of:

- *Insects and other animals (zoology)*
- *Plants and flowers (botanic)*
- *Coins and medals (numismatic)*
- *Inscriptions and old documents (epigraphy)*
- *Statues (history of Art)*
- *Pottery (ceramics) (ceramology)*
- *Tools, weapons, costumes etc. (ethnology)*

The craze for new discoveries from the past as well as the growing interest in the New World (extra European countries) becomes a national preoccupation. Each state has an antiquarian *specialised in architecture, history of Art and Antiquity. Kings, aristocrats, nobles and clerics compete in every European state to create vast collections of antiquities and eventually publish their contents. The rediscovery of the past is a matter of intellectual curiosity, social prestige and national pride.*

From the second half of the 17^{th} century, scholars go off to explore the world. They first go to Mediterranean countries (Italy & Greece) and eventually reach Asia. In 1738, the King of Naples in Italy finances the first systematised archaeological excavations in Pompeii and Herculaneum[1]. The finds are now carefully registered and the sites better preserved. With the accumulation of data and objects the first classifications and chronologies appear. Step by step antiquarian collectors become archaeologists.

From the 19^{th} century, antiquarian archaeologists accompany the European conquest and the colonisation of the Word. The Great Western Powers (France, England, Germany, Portugal, Netherlands, Italy) start to colonise new continents (Africa & Asia) appropriating the past of the conquered regions. The military grid of the world is coupled with a scientific grid of new areas. For example, the conquest of India by the British army sees the creation of a service of archaeology.

In 1828, a network of archaeologists, from England, France, Germany, founds in Rome the oldest institute of archaeology in the world (Istituto di Corrispondenza Archaeologica). The discovery of Asia, South America and Africa shows that there are remains of lost civilisations as prestigious as the European Antiquity everywhere in the world.

Antiquity: Ancient Greece and Rome — mid 17^{th} century
Egypt — late 18^{th} century
Mesopotamia — early 19^{th} century
India — mid 19^{th} century

[1] Pompeii: Ancient city in western Italy, south-east of Naples. The city was buried by an eruption of Mount Vesuvius in 79 AD; excavations of the site began in 1738, revealing well-preserved remains of buildings, mosaics, furniture, and the personal possessions of the city's inhabitants. Herculaneum was equally buried by the eruption of Mount Vesuvius and thus largely preserved until its accidental rediscovery by a well-digger in 1709.

South-East Asia *mid 19th century*
Pre-Columbian Americas *mid 19th century*
Prehistory *2nd half 19th century*

National archaeologies *2nd half 19thcentury*

Throughout the whole 19th century, archaeology is essentially preoccupied with the study of imposing monuments and the history of Art and remains an auxiliary discipline to history. It requires deciphering and mastering ancient languages such as Latin, Greek, Sanskrit, Pali, hieroglyphic and cuneiform writings.

But from 1930 onward, archaeology undergoes some important methodological mutations and eventually become a discipline per se *defining itself as the study of human societies through their material remains.*

The first mutation concerns the methods of excavation. Inspired by the reflections of geologists who discover the geological stratification of the Earth, archaeologists in turn pay further attention to the relationship of artefacts and the layers in which they are contained. Archaeological stratigraphy along with typology, which is the classification of artefacts according to type, time and space, is now the focus of any scientific work. Archaeology becomes a full discipline when it can identify the date, the place and the technique of fabrication of its artefacts and then guarantee the conditions of their discovery in the ground.

A second mutation is provided by the development of statistics and information technology. The increasing amount of data collected on an excavating site requires new technologies to treat and analyse all this information.

The contribution of natural sciences constitutes the third mutation. In 1947, Willard Frank Libby perfects radio carbon dating, which remains the most frequent dating technique in archaeology. Other physical and chemical innovations allow the discovery of new sites and the analysis of the components of archaeological objects, establishing their origin, mode of circulation and technique of fabrication.

In the 1960's, the developing collaboration between archaeology and other natural sciences leads to a fourth mutation which sees the creation of a movement called New Archaeology. It is no longer sufficient to formulate interesting hypothesis about the past of such and such society but archaeologists must find a way to prove and validate their theories. Experimental archaeology and ethnoarchaeology are partially created to fill this gap.

1st mutation 1930's	*Excavating methods*	*Stratigraphy & typology*
2nd mutation 1940's	*Statistics & Information technology*	*Data processing*
3rd mutation 1950's	*Natural sciences: physics, chemistry and biology*	*Dating, chemical analysis, geophysical techniques etc.*
4th mutation 1960's	*Theoretical & methodological reflection*	*New Archaeology: experimental & ethno archaeology*

These four mutations, both methodological and theoretical, take place in the second third of the 20th century and eventually lead to a new practice of archaeology. The archaeologist is no longer an antiquarian, an art collector or an auxiliary to the historian. He is an autonomous scientist whose aim is to study human societies through their material remains. Today most developed countries possess archaeological services, university departments and private foundations. As an institutionalised science, archaeology is often dependent on the financial support of the State. Occasionally, *archaeology becomes political and justifies some national or territorial claims. In its worst scenario, the cult of the past serves ideological propaganda.*

Archaeology is thus the result of the quest for Antiquity and if practically all the different cultures in the world have had antiquarians and art collectors, archaeology as a scientific technique of investigating the past is entirely a contemporary western invention. It is directly linked to the development of capitalism, colonialism and the formation of nation states.

9. Archaeological sites: *discovery & location*

What is an archaeological site?	*An archaeological site is a place where buried or submerged material remains can be found and studied by archaeologists.*

9.1 Aerial archaeology

Aerial archaeology consists of looking for vestiges of the past from the air, and then of taking photographs of anomalies, often fleeting, which are clues to sites buried beneath the soil. These photographs are carefully studied, archived, and compared from season to season. An aerial view provides the necessary perspective for a good understanding of the landscape and of certain telling phenomena that are sometimes difficult — and even impossible — to see at ground level.

Aerial archaeology use also satellite imagery and aerial thermography. To perform aerial archaeology means above all, to make archaeological use of this kind of remotely sensed information. The terms "aerial" or "remotely sensed information" already indicate, how aerial archaeology works. It uses the distant view. Archaeological sites show up on the ground surface, depending on their state of preservation, by light-shadow-contrasts (shadow marks), tonal differences in the soil (soil marks) or differences in height and colour of the cultivated cereal (cropmarks). In that way, settlements, graveyards, *fortifications etc. produce specific structures, which can be identified easier from a high viewpoint.*

3.1.1 Aerial photography

In 1858, Gaspard Felix Tournachon took aerial photographs from a captive balloon, having already applied for a patent on the idea of using the photographs for the production of maps. Henry Negretti took the first recorded aerial photographs of Britain in 1863, during a balloon flight over London. The military potential of aviation was soon recognised, however, and this resulted in many technical developments related to flight. The first aerial photograph of Stonehenge was taken from a military balloon in 1906, and archaeologists began to realise the potential of aerial photography during these very early days of aviation. The 1914-18 war saw considerable developments in aviation and produced the pioneers of aerial archaeology, such as O.G.S. Crawford and G.W.G. Allen, who were among the first individuals to regularly record archaeological sites from aircraft.

Besides vertical cameras, the early photographers also used hand-held cameras and simply took oblique photographs, at an angle from the aircraft. While this type of photography results in distortion of features caused by perspective, it is still regularly employed by archaeologists as it is flexible and cost efficient. The Second World War also saw great developments in terms of aircraft, camera, and film technology. The use of vertical photography was developed, which results in what amounts to photographic maps of large blocks of the landscape. This is achieved by mounting cameras, which point directly down to the Earth, onto an aircraft and taking a series of overlapping images at regular intervals.

Most of what we now record from the air was originally made by digging into the ground – ditches that defined ownership boundaries, pits cut for storage or burial, and post holes that supported uprights for houses and other structures – although foundations and walls are sometimes also visible. These old holes in the ground, now backfilled, levelled, and invisible to the ground observer, comprise a huge *percentage of the surviving sample of past communities that is available for study.*

The remains of past human activity can be seen from the air in a number of ways. In addition to churches, castles and other old buildings, partly eroded remains of past structures, in the form of earthen mounds and banks, can also be viewed. These sites are known as "earthworks". More elusive, however, are the remains of buried archaeological sites which, in certain conditions, are best viewed from above. When arable fields are ploughed, it is often possible to view the flattened remains of old buildings, roads and field boundaries because of the difference in the soils and materials which make up the remains.

There are 5 clues that reveal buried sites:

- *Landscape anomalies*
- *Low-relief shadows*
- *Crop growth anomalies*
- *Ground moisture anomalies*
- *Soil colour anomalies,*

In arable land, the fill of pot holes, ditches or pits may hold a higher moisture content which can affect the growth of some crops above them, and this differential growth may be recorded on aerial photographs. On some soils, past features may be seen in winter as different coloured soils. The fill of a ditch, for example, may be a dark organically rich soil that shows against a light-toned natural background.

For example, the site of a demolished house might be recognisable from the air due to the concentration of brick, tile and other debris which is visible because of variations of colour and texture. These sites are known as "soil colour anomalies" or "soil marks".

Perhaps the most remarkable type of site, however, are those known as "cropmarks". In this instance, variations in the sub-soil caused by buried archaeological features results in differential crop *growth. In early summer, as crops begin to ripen, the ditches, walls and pits of past settlements, fields and worship places affect the rate at which the crops change colour, and the speed and height to which they grow. For example, the crop over a buried ditch will result in a taller, larger plant because the ditch will contain additional moisture compared to the soils around it. Conversely, the buried remains of a wall will encourage water to drain from the soil, and possibly interrupt the root growth of the plants, therefore resulting in smaller, weaker crops. While most crops can produce marks, cereal crops, and wheat and barley in particular, give marks of especially good definition and resolution. The appearance of cropmarks is enhanced by dry weather when the ripening crops are short of water, and the differences in the condition of the crop can become very marked in drought conditions. From the air, these ditches and pits appear as lines and dots of differently coloured crops, which represent past and usually hidden landscapes of the county.*

In the course of a year, the same levelled-off site will appear often fleetingly, and its appearance will vary widely. Its polymorphism is frankly astonishing. In addition, a very slight change in the shot angle will give two photographs taken at the same moment completely different appearances.

3.1.2 Satellite imagery

Remote sensing satellite is applied in several fields such as agriculture, infrastructure, and military as well as archaeology fields. Both ground and satellite remote sensing techniques contribute to the mapping of the subsurface monuments, the management and protection of archaeological sites and the better exploitation of the natural and cultural environment.

3.1.3 Aerial thermography

In preparation of an archaeological excavation or as part of a subsurface survey, a specific area can be thermally imaged from *aircraft, helicopter or satellite. Variations of temperature observed in the thermal images can be linked to archaeological remains. The reason is that buried houses foundations etc. have a positive influence on the capacity of the ground to store energy, which results in a higher temperature at the surface of the ground above these objects.*

The electromagnetic radiation which is registered by thermography lies within the wavelength region 3-15 μm. For the temperatures found in our normal surrounding the maximum radiation effect lies at 10 μm. This radiation, which is not visible, can be registered by special instruments. In the natural environment, thermal images mainly express the temperature variations of the surface of the ground.

The radiation in the very top layer of the ground is registered by thermography. The conditions deeper in the ground can influence the surface temperature in areas lacking vegetation, because of the heat conduction capacity of the material. If the ground is covered with vegetation the temperature of the upper surface of the vegetation is registered. Therefore vegetation usually makes the possibility of thermography more difficult (air temperature, solar radiation, plant physiological parameters).

Vegetation-free surfaces are thus more likely to reveal archaeological remains concealed in the ground. The ground absorbs energy, mainly radiant energy from the sun and the atmosphere, which is transformed into heat. The heat radiates back in a way that is determined by the thermal qualities of the ground. The supply and the storage of energy result in the temperature at the surface. For an undisturbed soil, water content is the most significant factor in the thermal behaviour of the ground. The thermal inertia of the ground, or in other words how quickly the ground adjusts to temperature changes in the air, is determined mainly by water content. A supply of energy in the ground, which is due to differences in the soil, can be stored for different amounts of time and eventually reveal subsurface structures such as walls, trenches, pits etc.

9.2 Reconnaissance and surface survey (sampling methods)

A modern archaeological project often begins with a survey. Regional survey is the attempt to systematically locate previously unknown sites in a region. Site survey is the attempt to systematically locate features of interest, within a site. Each of these two goals may be accomplished with largely the same methods.

Survey was not widely practiced in the early days of archaeology. Cultural historians and prior researchers were usually content with discovering the locations of monumental sites from the local populace, and excavating only the plainly visible features there.

Survey work has many benefits if performed as a preliminary exercise to, or even in place of, excavation. It requires relatively little time and expense, because it does not require processing large volumes of soil to search out artefacts. (Nevertheless, surveying a large region or site can be expensive, so archaeologists often employ sampling methods.) It avoids ethical issues (of particular concern to descendant peoples) associated with destroying a site through excavation. It is the only way to gather some forms of information, such as settlement patterns and settlement structure. Survey data are commonly assembled into maps, which may show surface features and/or artefact distribution.

The simplest survey technique is surface survey. It involves combing an area, usually on foot but sometimes with the use of vehicles, to search for features or artefacts visible on the surface. Surface survey cannot detect sites or features that are completely buried under earth, or overgrown with vegetation. Surface survey may also include mini-excavation techniques such as augers, corers, and shovel test pits.

9.3 Subsurface geophysical survey

Archaeological geophysics can be the most effective way to see beneath the ground. Magnetometers detect minute deviations in the Earth's magnetic field caused by iron artefacts, kilns, some types of *stone structures, and even ditches and middens. Devices that measure the electrical resistivity of the soil are also widely used. Most soils are moist below the surface, which gives them a relatively low resistivity. Features such as hard-packed floors or concentrations of stone have a higher resistivity.*

Although some archaeologists consider the use of metal detectors to be tantamount to treasure hunting, others deem them an effective tool in archaeological surveying. Metal detectorists have also contributed to the archaeological record where they have made detailed records of their results and refrained from raising artefacts from their archaeological context. In the UK, metal detectorists have been solicited for involvement in the Portable Antiquities Scheme.

Regional survey in underwater archaeology uses geophysical or remote sensing devices such as marine magnetometer, side-scan sonar, or sub-bottom sonar. Archaeological geophysics most often refers to geophysical survey techniques used for archaeological imaging or mapping. More broadly defined, the term could refer to any geophysical techniques applied to archaeology. Remote sensing and marine surveys are also used in archaeology, but are generally considered separate disciplines. Other terms, such as "geophysical prospection" and "geophysical survey" are generally synonymous when used in an archaeological context.

Geophysical survey is used to create maps of subsurface archaeological features. Features are the non-portable part of the archaeological record, whether standing structures or traces of human activities left in the soil. Geophysical instruments can detect buried features when their electrical or magnetic properties contrast measurably with their surroundings. In some cases individual artefacts, especially metal, may be detected as well. Readings taken in a systematic pattern become a data set that can be rendered as image maps. Survey results can be used to guide excavation and to give archaeologists insight into the patterning of non-excavated parts of the site. Unlike other archaeological methods, geophysical survey is not invasive or destructive. For this reason, it is often used where preservation (rather than excavation) is the goal.

Although Geophysical survey has been used in the past with intermittent success, good results are very likely when it is applied appropriately. It is most useful when it is used in a well-integrated research design where interpretations can be tested and refined. Interpretation requires knowledge both of the archaeological record, and of the way it is expressed geophysically. Appropriate instrumentation, survey design, and data processing are essential for success, and must be adapted to the unique geology and archaeological record of each site. In the field, control of data quality and spatial accuracy are critical.

EM conductivity survey

Geophysical methods used in archaeology are largely adapted from those used in mineral exploration, engineering, and geology. Archaeological mapping presents unique challenges, however, which have spurred a separate development of methods and equipment. In general, geological applications are concerned with detecting relatively large structures, often as deeply as possible. In contrast, most archaeological sites are relatively near the surface, often within the top meter of earth. Instruments are often configured to limit the depth of response to better resolve the near-surface phenomena that are likely to be of interest. Another challenge is to detect subtle and often very small features – which may be as ephemeral as organic staining from decayed wooden posts - and distinguish them from rocks, roots, and other natural "clutter." To accomplish this requires not only sensitivity, but also high density of data points, usually at least one and sometimes dozens of readings per square meter.

Most commonly applied to archaeology are magnetometers, electrical resistance meters, ground-penetrating radar (GPR) and electromagnetic (EM) conductivity meters. These methods provide excellent resolution of many types of archaeological features, are capable of high sample density surveys of very large areas, and of operating under a wide range of conditions. While common metal detectors are geophysical sensors, they are not capable of generating high-resolution imagery. Other established and emerging technologies are also finding use in archaeological applications.

Electrical resistance meters can be thought of as similar to the Ohmmeters used to test electrical circuits. In most systems, metal probes are inserted into the ground to obtain a reading of the local electrical resistance. A variety of probe configurations are used, most having four probes, often mounted on a rigid frame. Capacatively coupled systems that do not require direct physical contact with the soil have also been developed. Archaeological features can be mapped when they are of higher or lower resistivity than their surroundings. A stone foundation might impede the flow of electricity, while the organic deposits within an outhouse pit might conduct electricity more easily than surrounding soils. Although generally used in archaeology for planview mapping, resistance methods also have a limited ability to discriminate depth and create vertical profiles (see Electrical resistivity tomography).

Electromagnetic (EM) conductivity instruments have a response that is comparable to that of resistance meters (conductivity is the inverse of resistance). Although EM conductivity instruments are generally less sensitive than resistance meters to the same phenomena, they do have a number of unique properties. One advantage is that they do not require direct contact with the ground, and can be used in conditions unfavourable to resistance meters. Another advantage is relatively greater speed than resistance instruments. Unlike resistance instruments, conductivity meters respond strongly to metal. This can be a disadvantage when the metal is extraneous to the archaeological record, but can be useful when the metal is of archaeological interest. Some EM conductivity instruments are also capable of measuring magnetic susceptibility, a property that is becoming increasingly important in archaeological studies.

Magnetometers used in geophysical survey may use a single sensor to measure the total magnetic field strength, or may use two (sometimes more) sensors to measure the gradient of the magnetic field (the difference between the two sensors). In most archaeological applications the latter (gradiometer) configuration is preferred because it provides better resolution of small, near-surface phenomena. Magnetometers may also use a variety of different sensor types. Proton precession *magnetometers have largely been superseded by faster or more sensitive fluxgate, caesium, or overhauser instruments.*

Every kind of material has unique magnetic properties, even those that we do not think of as being "magnetic." Different materials below the ground can cause local disturbances in the Earth's magnetic field that are detectable with sensitive magnetometers. Magnetometers react very strongly to iron of course, and brick, burned soil, and many types of rock are also magnetic, and archaeological features composed of these materials are very detectable. Where these highly magnetic materials do not occur, it is often possible to detect very subtle anomalies caused by disturbed soils or decayed organic materials. The chief limitation of magnetometer survey is that subtle features of interest may be obscured by highly magnetic geologic or modern materials.

GPR survey

Ground-penetrating radar (GPR) is the perhaps the best known of these methods (although it is not the most widely applied in archaeology). The concept of radar is familiar to most people. In this instance, the radar signal – an electromagnetic pulse – is directed into the ground. Subsurface objects and stratigraphy (layering) will cause reflections that are picked up by a receiver. The travel time of the reflected signal indicates the depth. Data may be plotted as profiles, or as planview maps isolating specific depths.

GPR can be a powerful tool in favourable conditions (uniform sandy soils are ideal). It is unique both in its ability to detect some spatially small objects at relatively great depths and in its ability to distinguish the depth of anomaly sources. The principal disadvantage of GPR is that it is severely limited by less-than-ideal conditions. The high electrical conductivity of fine-grained sediments (clays and silts) causes conductive losses of signal strength; rocky or heterogeneous sediments scatter the GPR signal. Another disadvantage is that data collection is relatively slow.

Common metal detectors do not create a logged data set, and thus cannot be used for directly creating maps. Irresponsible (and often illegal) use of metal detectors by artefact collectors or treasure hunters has resulted in extensive damage to the archaeological record, both by the unrecorded removal of artefacts and the destruction of their context by uncontrolled excavation. However when used responsibly and in a systematic manner, they can be a useful tool in archaeological research.

Data collection is broadly similar regardless of the particular sensing instrument. Survey usually involves walking with the instrument along closely spaced parallel traverses, taking readings at regular intervals. In most cases, the area to be surveyed is staked into a series of square or rectangular survey "grids" (terminology can vary). With the corners of the grids as known reference points, the instrument operator uses tapes or marked ropes as a guide when collecting data. In this way, positioning error can be kept to within a few centimetres for high-resolution mapping. Survey systems with integrated global positioning systems (GPS) have been developed, but under field conditions, currently available systems lack sufficient precision for high-resolution archaeological mapping. Geophysical instruments (notably metal detectors) may also used for less formally "scanning" areas of interest.

Data processing and imaging convert raw numeric data into interpretable maps. Data processing usually involves the removal of statistical outliers and noise, and interpolation of data points. Statistical filters may be designed to enhance features of interest (based on size, strength, orientation, or other criteria), or suppress obscuring modern or natural phenomena. Inverse modelling of archaeological features from observed data is becoming increasingly important. Processed data are typically rendered as images, as contour maps, or in false relief. When geophysical data are rendered graphically, the interpreter can more intuitively recognize cultural and natural patterns and visualize the physical phenomena causing the detected anomalies.

The use of geophysical survey is well established in European archaeology, especially in Great Britain, where it was pioneered in the 1940's and 1950's. It is increasingly employed in other parts of the *world, and with increasing success as techniques are adapted to unique regional conditions.*

In early surveys, measurements were recorded individually and plotted by hand. Although useful results were sometimes obtained, practical applications were limited by the enormous amount of labour required. Data processing was minimal and sample densities were necessarily low.

Although the sensitivity of sensors has improved, and new methods have been developed, the most important developments have been automated data logging and computers to handle and process large amounts of data. Continuing improvements in survey equipment performance and automation have made it possible to rapidly survey large areas. Rapid data collection has also made it practical to achieve the high sample densities necessary to resolve small or subtle features. Advances in processing and imaging software have made it possible to detect, display, and interpret subtle archaeological patterning within the geophysical data.

10. Archaeological excavation

Archaeological excavation existed even when the field was still the domain of amateurs, and it remains the source of the majority of data recovered in most field projects. It can reveal several types of information usually not accessible to survey, such as stratigraphy, three-dimensional structure, and verifiably primary context.

Modern excavation techniques require that the precise locations of objects and features, known as their provenance or provenience, be recorded. This always involves determining their horizontal locations and sometimes vertical position as well. Similarly, their association, or relationship with nearby objects and features, needs to be recorded for later analysis. This allows the archaeologist to deduce what artefacts and features were likely used together and which may be from different phases of activity. For example, excavation of a site reveals its stratigraphy; if a site was occupied by a succession of distinct cultures, *artefacts from more recent cultures will lie above those from more ancient cultures.*

Excavation is the most expensive phase of archaeological research. Also, as a destructive process, it carries ethical concerns. As a result, very few sites are excavated in their entirety. Sampling is even more important in excavation than in survey. It is common for large mechanical equipment, such as backhoes (mechanical shovel), to be used in excavation, especially to remove the topsoil, though this method is increasingly used with great caution. Following this rather dramatic step, the exposed area is usually hand-cleaned with trowels or hoes to ensure that all features are apparent.

The next task is to form a site plan and then use it to help decide the method of excavation. Features dug into the natural subsoil are normally excavated in portions in order to produce a visible archaeological section for recording. A feature, for example a pit or a ditch, consists of two parts: the cut and the fill. The cut describes the edge of the feature, where the feature meets the natural soil. It is the feature's boundary. The fill is, understandably, what the feature is filled with, and will often appear quite distinct from the natural soil. The cut and fill are given consecutive numbers for recording purposes. Scaled plans and sections of individual features are all drawn on site, black and white and colour photographs of them are taken, and recording sheets are filled in describing the context of each. All this information serves as a permanent record of the now-destroyed historical site and is used in describing and interpreting the site.

10.1 Sir Mortimer Wheeler (1890-1976)

Mortimer Wheeler was born in 1890 in Glasgow, Scotland. His family moved to Bradford, where he was first educated at Bradford Grammar School then earned a BA and MA at University College, London. While at Bradford Grammar, Wheeler developed a fondness for archaeological excavation and could be found scouring and digging in the countryside for the remains of medieval ovens and fragments of Roman pottery.

Some historians suggest that modern archaeology began with Mortimer Wheeler. He was the first archaeologist to develop a grid system of systematic digging whereby the excavation site was divided into small squares. Each square clearly separated by a narrow baulk that was never excavated. This method permitted an area to be excavated yet preserved a vertical cross-section that revealed the strata of the site as the trench was dug.

Wheeler's box-grid system has been used universally in modern archaeology and although less popular in Europe it is still the most simple method to ensure a systematic approach.

Wheeler's influence has extended well into Asia. He excavated at numerous sites in India and Pakistan. After being knighted for his contribution to archaeology he spent many years furthering public education through his television shows Animal, Mineral, Vegetable; Buried Treasure; and Chronicle.

10.2 Open Area

The open area is a type of excavation in which large horizontal areas are opened especially where single period deposits lie close to the surface. This means that the excavation is done through natural stratigraphic layers on a larger scale without maintaining large walls along opened grid squares of the excavation area.

The opening up of large horizontal areas for excavation is usually used where single period deposits lie close to the surface. It is the excavation of as large an area as possible without the intervention of baulks and a grid system. This technique allows the recognition of much slighter traces of ancient structures than other methods. On multi-period sites, however, it calls for much more meticulous recording since the stratigraphy is revealed one layer at a time. In this method of excavation, the full horizontal extent of a site is cleared and large areas are open while preserving a stratigraphic record in the balks between large squares. A gradual vertical probe may then take place. This *method is often used to uncover houses and prehistoric settlement patterns.*

10.3 Stratigraphy

The underlying principle of stratigraphic analysis is that of superposition. This term means that older items are usually found below younger items. When an archaeological site is excavated the sides of the unexcavated baulk reveals layering of subsequent settlements and activity. Stratigraphic excavation is the recording and study of these different strata as they are removed from the area.

In archaeology, especially in the course of excavation, stratification is a paramount and base concept. It is largely based on the Law of Superposition. When archaeological finds are below the surface of the ground (as is most commonly the case), the identification of the context of each find is vital in enabling the archaeologist to draw conclusions about the site and about the nature and date of its occupation. It is the archaeologist's role to attempt to discover what contexts exist and how they came to be created. Archaeological stratification or sequence is the dynamic superimposition of single units of stratigraphy, or contexts.

Contexts are single events or actions that leave discreet, detectable traces in the archaeological sequence or stratigraphy. They can be deposits (such as the back-fill of a ditch), structures (such as walls), or "zero thickness surfaciques," better known as "cuts." Cuts represent actions that remove other solid contexts such as fills, deposits, and walls. An example would be a ditch "cut" through earlier deposits. Stratigraphic relationships are the relationships created between contexts in time, representing the chronological order they were created. One example would be a ditch and the back-fill of said ditch. The temporal relationship of "the fill" context to the ditch "cut" context is such that "the fill" occurred later in the sequence; you have to dig a ditch before you can back-fill it. A relationship that is later in the sequence is sometimes referred to as "higher" in the sequence, and a relationship that is earlier, "lower," though this does not refer *necessarily to the physical location of the context. It is more useful to think of "higher" as it relates to the context's position in a Harris matrix, a two-dimensional representation of a site's formation in space and time.*

The Law of Superposition

In a series of layers and interfacial features, as originally created, the upper units of stratification are younger and the lower are older, for each must have been deposited on, or created by the removal of, a pre-existing mass of archaeological stratification.

Law of Original Horizontal

Any archaeological layer deposited in an unconsolidated form will tend towards a horizontal disposition. Strata which are found with tilted surfaces were so originally deposited, or lie in conformity with the contours of a pre-existing basin of deposition.

Law of Original Continuity

Any archaeological deposit, as originally laid down, will be bounded by the edge of the basin of deposition, or will thin down to a feather edge. Therefore, if any edge of the deposit is exposed in a vertical plane view, a part of its original extent must have been removed by excavation or erosion: its continuity must be sought, or its absence explained.

Law of Stratigraphic Succession

Any given unit of archaeological stratification takes its place in the stratigraphic sequence of a site from its position between the undermost of all units which lie above it and the uppermost of all those units which lie below it and with which it has a physical contact, all other superpositional relationships being regarded as redundant.

Understanding a site in modern archaeology is a process of grouping single contexts together in ever larger groups by virtue of their relationships. The terminology of these larger clusters varies depending *on the practitioner, but the terms interface, sub-group, and group are common. An example of a sub-group could be the three contexts that make up a burial; the grave cut, the body, and the back-filled earth on top of the body. Sub-groups can then be clustered together with other sub-groups by virtue of their stratigraphic relationship to form groups, which in turn form "phases." A sub-group burial could cluster with other sub-group burials to form a cemetery, which in turn could be grouped with a building, such as a church, to produce a "phase". Phase implies a nearly contemporaneous archaeological horizon representing "what you would see if you went back to time X". The production of phase interpretations is the first goal of stratigraphic interpretation and excavation.*

The potential flaws in relative dating are obvious; for example, by assuming that an object is older because it was found in a lower player. There are many instances of deep holes being dug for rubbish pits or to locate well water that protrude into the record of older strata injecting more modern material as they are filled in over time. Landslides and slips can completely change the topography of an entire site burying what was once on top by that which is much older, hence reversing the strata layers.

10.4 Data recording

Archaeologists attempt to study the archaeological record in order to understand the human interaction at a particular location across the history of time. There are two sources of information (material data and intangible data) that the archaeologist uses from a digging site with the aim of making conclusions about past human behaviour.

Once artefacts and structures have been excavated, or collected from surface surveys, it is necessary to properly study them, to gain as much data as possible. This process is known as post-excavation analysis, and is normally the most time-consuming part of the archaeological investigation. It is not uncommon for the final excavation reports on major sites to take years to be published.

At its most basic, the artefacts found are cleaned, catalogued and compared to published collections, in order to classify them typologically and to identify other sites with similar artefact assemblages. However, a much more comprehensive range of analytical techniques are available through archaeological science, meaning that artefacts can be dated and their compositions examined. The bones, plants and pollen collected from a site can all be analyzed (using the techniques of zooarchaeology, paleobotany, and palynology), while any texts can usually be deciphered. These techniques frequently provide information that would not otherwise be known and therefore contribute greatly to the understanding of a site.

Artefacts

Artefacts are material remains but they differ from the larger architectural remains often better called 'features'. The non-movable objects, such as buildings, that have been constructed or modified by people, must be left in situ*. Remnants of objects such as the remains of decayed organic materials are sometimes referred to as 'stains' in the archaeological record. These, too, must usually be left* in situ*.*

The remains of significant objects that were built on location pose few problems to the archaeological data collector as to its original measurement, direction, and association. It is the smaller, portable objects that, although easy to first quantify in the field, pose the greater difficulties when it comes to interpretation.

Material Data		*Intangible Data*
Artefacts	*Ecofacts*	
Artis facta *or "Effects of Art". Any object produced by human activity: e.g. architectural features, jewellery, tools, weapons, pottery, stoneware, cloth, leather, coins,*	*Any organic material or "stains" induced by human activity: e.g. burned or decayed wood, ashes, grains, kerns, bones, plants, pollens etc.*	*Measurements such as height, width, length, weight, density, material, colour & texture of the object. But also its altitude, orientation and relationship with other artefacts or*

paintings, statues etc.		*ecofacts.*

Material Data

These are the physical items located such as artefacts (ecofacts) and include objects like jewellery, pottery, stoneware, tools, weapons, clothing, and architectural items like walls, floors, columns, pillars, lintels, doors, gates, roads, wells, and even holes in the ground for rubbish pits.

Intangible Data

This is solely information based. Unlike the tangible objects that are classed as 'material remains' descriptive data is an intangible factual reality that helps to lock the artefact in a location with context. Examples of archaeological data are measurements, direction, perhaps orientation, and/or associations.

Measurement

This not only includes the obvious need to quantify the artefact as to height, width, and length, but also weight, mass, and density can be determined along with measuring colour and texture against known registers. Measurements within the archaeological site itself would include calculating its area, the areas of separate fields, strata heights according to sea level (HASL) and attributing HASL to excavated artefacts.

Direction

Artefacts collected or described without providing directions is not nearly as useful. Basically, compass bearings are used that provide the analyst with north, south, east and west alignments. For example, gates or entrances to settlements will be noted as facing NE or some other direction. Roads, streets, and walls will be stated to run N-S or perhaps SE – NW. For large items the usual 360 degrees of the standard compass will normally suffice.

Direction for smaller objects is usually confined to recording its orientation. That is; was the object standing up or lying down, etc. In *the case of human remains the record will show the posture, orientation, and direction.*

Association

This information seeks to position the artefact in relation to its surroundings. This might include noting other similar or dissimilar artefacts found together and will also include the artefact's relationship to walls, human remains, and any other objects that are in the vicinity. On a wider scale, association may mean the relationship of one field site to another or even one or more settlements to each other.

Interpretation of Data

Transportable items may have been deposited at their discovery position because they were inadvertently dropped, deliberately stolen from elsewhere or some other reason totally unknown to us. Often, only a single piece of pottery is discovered. It could be the only remains of an item once at that location or it could have been brought in from elsewhere for a special purpose yet unknown.

Archaeologists need to be ever mindful of their interpretations of the collected data from the often vague and ambiguous archaeological record. Stone and ceramics are materials that preserve well. Artefacts of organic origin such as human or animal bones, skins, and hair, or items made of wood or plant matter do not survive long in moisture laden soils or soils with high acidity.

Therefore, the lack of discovered organic artefacts may not necessarily suggest that there were few originals and the data analyst must factor in the soil types and the climate conditions also taking consideration of any climatic changes to the site over time.

All archaeological research should incorporate an historical background investigation. This will compliment the data recorded during the excavation and allow analysts to 'see' the artefacts in the context of what happened at that site before and after the date of the artefact.

11. Dating techniques

Archaeological scientists have two primary ways of telling the age of artefacts and the sites from which they come: relative dating and absolute dating.

Relative dating presumes the age of an object in relation to and comparison with other objects found in its vicinity, usually in the same archaeological stratum. Relative dating cannot provide an accurate year or a specific date of use. The style of the object and its location in the stratigraphy are required to suggest a relative date.

A more precise and accurate system is known as absolute dating and can in most circumstances provide a calendar year to the object. Since 1950 there has been a transformation in the dating techniques of archaeologists. Absolute dating is nevertheless highly dependant on laboratory analysis.

The greatest problem with dating an object from antiquity is that nearly every absolute dating process requires the destruction of at least a piece of the object in conducting the analysis. There are relatively few dating laboratories and having an artefact dated can be an expensive exercise especially if the artefact is not of great scientific value itself.

11.1 Relative dating: typology & seriation

The shape and style of an object changes through time although its function may remain the same. The changing styles of pottery, glass, stoneware, and metal objects provide the analysts with known progressive sequences. Once an artefact is compared to its known development date then whenever that item reappears in the archaeological record, of that or any other site, it can quickly be dated.

Seriation as a dating technique in archaeology was first used, and probably invented by the archaeologist Sir William Flinders-Petrie in 1899. Seriation (also called sequence dating) is based on the idea that artefacts change over time. Artefacts styles and characteristics change over time, coming into fashion, and then fading in popularity.

Generally, seriation is manipulated graphically. The standard graphical result of seriation is a series of "battleship curves," which are horizontal bars representing percentages plotted on a vertical axis. Plotting several curves can allow the archaeologist to develop a relative chronology for an entire site or group of sites.

Assume you are studying six junkyard deposits, and you are interested in determining how old each of the junkyards are, relative to one another; i.e., which was opened first, which second, etc. You notice that each junkyard has a collection of discarded musical recordings, ranging from 78 rpm record fragments right up through CD-ROMs. You count all the musical data from each junkyard, and work out the percentages of each type of recording.

1. *Seriation Step 1: Collect the Data*
2. *Seriation Step 2: Graph the Data*
3. *Seriation, Step 3: Assemble Your Battleship Curves*

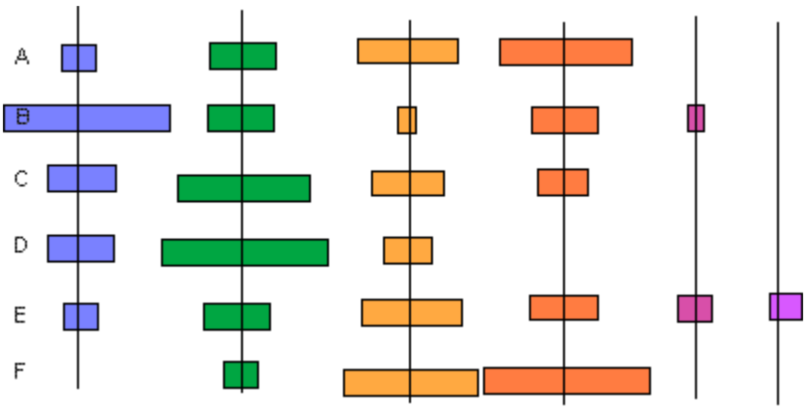
Seriation Step 1: Collect the Data

	78 rpm	33 1/3 rpm	45 rpm	8 track	Cassette	CD-Rom
Junkyard A	10	20	30	40		
Junkyard B	50	20	5	20	5	
Junkyard C	20	40	25	15		
Junkyard D	35	50	15			
Junkyard E	10	20	30	20	10	10
Junkyard F		10	40	50		

Data on junkyard contents for seriation study
Kris Hirst (c) 2006

You next convert the percentages to a bar graph, with each row representing a junkyard (A through F), and each column representing a type of recording medium. Hence, a narrow bar means a small percentage of the total musical deposit for a given junkyard; and a wide bar represents a large percentage.

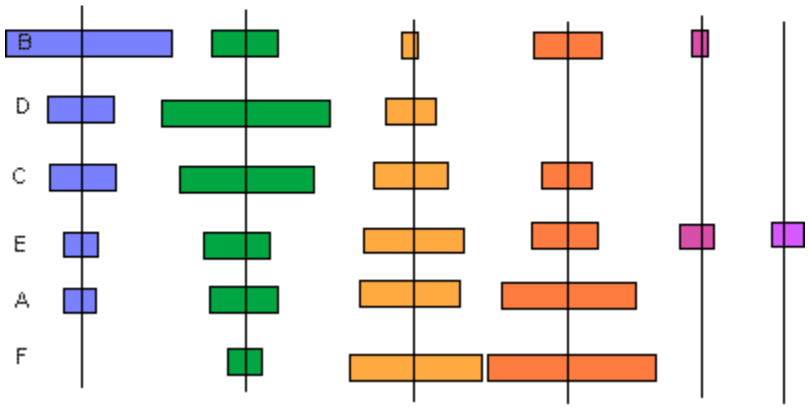
Seriation Step 2: Graph the Data



Seriation bar graph of junkyard data
Kris Hirst (c) 2006

For the next iteration you switch around the junkyard data until each column resembles a battleship, narrow at both ends, when the media shows up less frequently in the deposit, and fatter in the middle, when it occupies the largest percentage of the junkyard deposits. In this example, Junkyard B was likely the first opened, because it has the largest quantity of the oldest artefact, and lesser amounts of the others; and Junkyard F is likely the last, because it has none of the oldest type of artefact, and a preponderance of the more modern types. What the data doesn't provide is absolute dates, or length of use, or any temporal data other than the relative age of use.

Seriation, Step 3: Assemble Your Battleship Curves



Seriation bar graph, second iteration
Kris Hirst (c) 2006

11.2 Absolute dating

11.2.1 Carbon dating

Radiocarbon dating uses the biological assumption that all living things absorb carbon, both ordinary carbons, ^{12}C, and radioactive carbon, ^{14}C, into their living tissue. At the moment of death the ^{14}C begins to decay at a rate that scientists already know from other experiments. The missing amount can then determine how long it took to be lost and therefore date the object to a precise period. ^{14}C dating can only be used on organic matter such as wood, coal, peat, bones, leather, cloth or grains.

Radiocarbon dating is a radiometric dating method that uses the naturally occurring isotope carbon-14 (^{14}C) to determine the age of carbonaceous materials up to about 60,000 years. Raw, i.e. uncalibrated, radiocarbon ages are usually reported in radiocarbon years "Before Present" (BP), "Present" being defined as AD 1950. Such raw ages can be calibrated to give calendar dates.

The technique of radiocarbon dating was discovered by Willard Frank Libby and his colleagues in 1947 during his tenure as a professor at the University of Chicago. Libby estimated that the steady state radioactivity concentration of exchangeable carbon-14 would be about 14 disintegrations per minute (dpm) per gram. In 1960, he was awarded the Nobel Prize in chemistry for this work.

Carbon has two stable, nonradioactive isotopes: carbon-12 (^{12}C), and carbon-13 (^{13}C). In addition, there are tiny amounts of the unstable isotope carbon-14 (^{14}C) on Earth. Carbon-14 has a half-life of 5730 years and would have long ago vanished from Earth were it not for the unremitting cosmic ray impacts on nitrogen in the Earth's atmosphere, which forms more of the isotope. When cosmic rays enter the atmosphere, they undergo various transformations, including the production of neutrons. The resulting neutrons participate in the following nuclear reaction on nitrogen atoms of nitrogen molecule (N_2) in the atmosphere air.

The highest rate of carbon-14 production takes place at altitudes of 9 to 15 km (30,000 to 50,000ft), and at high geomagnetic latitudes, but the carbon-14 spreads evenly throughout the atmosphere and reacts with oxygen to form carbon dioxide. Carbon dioxide also permeates the oceans, dissolving in the water. For approximate analysis it is assumed that the cosmic ray flux is constant over long periods of time; thus carbon-14 is produced at a constant rate and the proportion of radioactive to non-radioactive carbon is constant: ca. 1 part per trillion (600 billion atoms/mole). In 1958, Hessel de Vries showed that the concentration of carbon-14 in the atmosphere varies slightly over time. For the most accurate work, the temporal variations are compensated by means of calibration curves. When these curves are used, their accuracy and shape are the factors that determine the accuracy and age obtained for a given sample.

Plants take up atmospheric carbon dioxide by photosynthesis, and are eaten by animals, so every living thing is constantly exchanging carbon-14 with its environment as long as it lives. Once it dies, however, this exchange stops, and the amount of carbon-14 gradually decreases through radioactive beta decay.

By emitting an electron and an anti-neutrino, carbon-14 is changed into stable (non-radioactive) nitrogen-14. This decay can be used to get a measure of how long ago a piece of once-living material died. However, aquatic plants obtain some of their carbon from dissolved carbonates which are likely to be very old, and thus deficient in the carbon-14 isotope, so the method is less reliable for such *materials as well as for samples derived from animals with such plants in their food chain.*

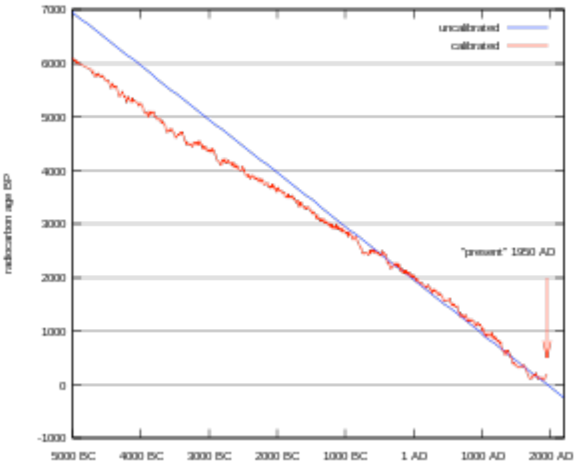
Measurements are traditionally made by counting the radioactive decay of individual carbon atoms by gas proportional counting or by liquid scintillation counting, but these are relatively insensitive and subject to relatively large statistical uncertainties for small samples (below about 1g carbon).

Raw radiocarbon ages (i.e., those not calibrated) are usually reported in years "before present" (BP). This is the number of radiocarbon years before 1950, based on a nominal (and assumed constant - see "calibration" below) level of carbon-14 in the atmosphere equal to the 1950 level. They are also based on a slightly off historic value for the half-life maintained for consistency with older publications.

Radiocarbon labs generally report an uncertainty, e.g., 3000±30BP indicates a standard deviation of 30 radiocarbon years. Additional error is likely to arise from the nature and collection of the sample itself, e.g., a tree may accumulate carbon over a significant period of time. Such old wood, turned into an artefact some time after the death of the tree, will reflect the date of the carbon in the wood.

The current maximum radiocarbon age limit lies in the range between 58,000 and 62,000 years. This limit is encountered when the radioactivity of the residual ^{14}C in a sample is too low to be distinguished from the background radiation.

The need for calibration



Calibration curve for the radiocarbon dating scale. Data sources: Stuiver et al. Samples with a real date more recent than AD 1950 are dated and/or tracked using the N- & S-Hemisphere graphs.

A raw BP date cannot be used directly as a calendar date, because the level of atmospheric ^{14}C has not been strictly constant during the span of time that can be radiocarbon dated. The level is affected by variations in the cosmic ray intensity which is affected by variations in the Earth's magnetosphere caused by solar storms. The level has also been affected by human activities—it was almost doubled for a short period due to atomic bomb tests in the 1950s and 1960s and has been reduced by the release of large amounts of CO_2 from ancient organic sources where ^{14}C is not present—the fossil fuels used in industry and transportation, known as the Suess effect.

Calibration methods

The raw radiocarbon dates, in BP years, are therefore calibrated to give calendar dates. Standard calibration curves are available, based on comparison of radiocarbon dates of samples that can be independently dated by other methods such as examination of tree growth rings (dendrochronology), ice cores, deep ocean sediment cores etc.

Relatively recent (2001) evidence has allowed scientists to refine the knowledge of one of the underlying assumptions. A peak in the amount of carbon-14 was discovered by scientists studying speleothems in caves in the Bahamas. Stalagmites are calcium carbonate deposits left behind when seepage water, containing dissolved carbon dioxide, evaporates. Carbon-14 levels were found to be twice as high as modern levels. These discoveries improved the calibration for the radiocarbon technique and extended its usefulness to 45,000 years into the past.

Uranium – Lead Dating

Lithic items cannot be dated by ^{14}C methods but the same principle can be used using radioactive uranium. Rocks, when formed by volcanic reaction or other cataclysmic event, contain a minute quantity of radioactive substance. From the day of the rock's creation *this radioactivity begins to deplete. Like ^{14}C, by measuring the loss, a scientist can attribute an age according to known loss rates.*

11.2.2 Dendrochronology

Dendrochronology or tree-ring dating is the method of scientific dating based on the analysis of tree-ring growth patterns. This technique was developed during the 20th century. The technique can date wood to exact calendar years.

Many trees in temperate zones grow one growth ring each year, the newest ring being adjacent to the bark. For the entire period of a tree, a year-by-year record or ring pattern is formed that reflects the climatic conditions in which the tree grew. Adequate moisture and a long growing season result in a wide ring. A drought year may result in a very narrow one. Trees from the same region will tend to develop the same patterns of ring widths for a given period. These patterns can be compared and matched ring for ring with trees growing in the same geographical zone and under similar climatic conditions. Following these tree-ring patterns from living trees back through time, chronologies can be built up, both for entire regions, and for sub-regions of the world. Thus wood from ancient structures can be matched to known chronologies (a technique called cross-dating*) and the age of the wood determined precisely. Cross-dating was originally done by visual inspection. Nowadays, computers are used to do the statistical matching.*

To eliminate individual variations in tree ring growth, dendrochronologists take the average of the tree ring widths of multiple tree samples to build up a ring history. This process is termed replication. A tree ring history whose beginning and end dates are not known is called a floating chronology*. It can be anchored by cross-matching either the beginning or the end section against the end sections of another chronology (tree ring history) whose dates are known. Fully anchored chronologies which extend back more than 10,000 years exist for river oak trees from South Germany (from the Main and Rhine rivers). A fully anchored chronology which extends* *back 8500 years exists for the bristlecone pine in the Southwest US (White Mountains of California).*

In areas where the climate is reasonably predictable, trees develop annual rings of different properties depending on weather, rain, temperature, etc. in different years. These variations may be used to infer past climate variations.

Timber core samples are used to measure the width of annual growth rings. By taking samples from different sites and different strata within a particular region, researchers can build a comprehensive historical sequence that becomes a part of the scientific record; for example, ancient timbers found in buildings can be dated to give an indication of when the source tree was alive and growing, setting an upper limit on the age of the wood and a Terminus Post Quem *to the archaeological structure in which the piece of wood was used.*

While archaeologists can use the technique to date a piece of wood and when it was felled, it may be difficult to definitively determine the age of a building or structure that the wood is in. The wood could have been reused from an older structure, may have been felled and left for many years before use, or could have been used to replace a damaged piece of wood.

The dendrochronologist faces many obstacles, however, including some species of ant which inhabit trees and extend their galleries into the wood, thus destroying ring structure.

11.2.3 Thermoluminescence

Artefacts that are made from crystalline materials can be dated using luminescence analysis. Crystalline minerals when subjected to intense heat will burn with differing colours of flame. Mostly used to date pottery the method is very effective but costly.

Thermoluminescence dating was invented around 1960 by physicists, and is based on the fact that electrons in all minerals emit *light (luminesce) after being heated. It is good for between about 300 to about 100,000 years ago, and is a natural for dating ceramic vessels.*

Thermoluminescence dating is used for rocks, minerals and pottery. It dates items between the years 300-100,000B.P. It is based on the fact that almost all natural minerals are thermoluminescent. Energy absorbed from ionizing radiation frees electrons to move through the crystal lattice and some are trapped at imperfections. Later heating releases the trapped electrons, producing light.

Measurement of the intensity of the luminescence can be used to determine how much time has passed since the last time the object was heated. The light is proportional to the amount of radiation absorbed since the material was last heated. Natural radioactivity causes latent thermoluminescence to build up so the older an object is the more light is produced. Therefore, thermoluminescence dating is actually determining the last time a crystal was heated and electrons were released. The minerals that are used for thermoluminescence dating are quartz, feldspar, diamond and calcite.

The last time a crystal was reheated and its electrons were released is known as a clock resetting event. This usually occurs when the items are heated to 350 degrees Celsius. Therefore, in archaeology, thermoluminescence dating works best for ceramics, cooking hearths, incidentally fire-cracked rocks and deliberately fire treated rocks such as flint.

When collecting samples for thermoluminescence dating, several samples from different vessels not smaller than 1 gram should be taken. Samples should not be exposed to heat and powdery examples should not be exposed to bright light. A sample of the earth also needs to be collected so environmental radiation can be tested. The wetness of the soil and sample should also be recorded. Samples should be placed in a polyethylene bag and sealed with electrical tape.

To test the date, three steps are taken:

1. *Measure sample's intensity of luminescence*

2. *Relate luminescence intensity to radiation dose (irradiate sample with a calibrated radioactive source)*
3. *Determine the dose per year that the sample has been exposed to*

The formula used in this equation is:

$$\textit{Age} = \frac{\textit{accumulated dose}}{\textit{dose rate}}$$

Dose Rate=dose accumulated each year

11.2.4 Archaeomagnetism

Archaeomagnetism is a method of utilizing magnetic polar wander to date materials containing magnetic minerals. Archaeological materials that contain magnetic particles are kilns, pots, hearths and most sediment. Heating and cooling such materials (or depositing in air or water in the case of sediments) causes the geomagnetic field to be recorded by the magnetic particles present. This recorded magnetization can be measured many years later and so give a date that is directly related to anthropogenic activity. The technique can be applied in the last 3000 years in the UK. However, it is not an independent method of dating and requires a reference curve to convert the magnetic direction measured into a date. The geomagnetic field is subject to secular and spatial variation. Secular variation is fundamental to this dating technique but the spatial variation requires that calibration be localized to within 1000km of the calibration curve.

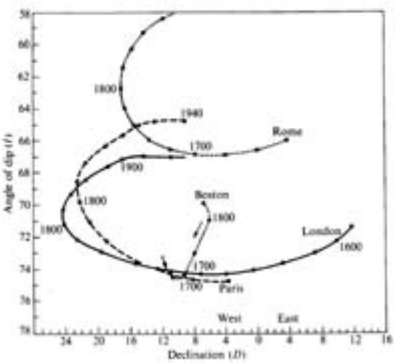


Illustration showing how the magnetic direction has chanced since

1600AD in London, Paris, Rome and Boston, taken from Aitken, 1990: Figure 9.3

How it works

Heating a material to a temperature greater than its Curie point and then cooling it allows magnetic grains to align themselves along the direction of an external magnetic field during cooling to ambient temperature. The grains will now remain orientated in this direction unless they are reheated. Therefore this method is dating the last time a hearth or kiln was heated to over its Curie temperature.

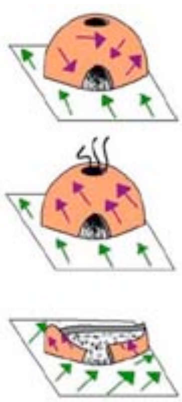


Illustration showing how a kiln acquires magnetic direction, courtesy of Zoe Outram

In order to obtain a date by this method it is necessary to establish true north and the horizontal level on site. Therefore the changes in the recorded magnetization can be compared to the current geomagnetic field. It is important that the material to be sampled has been heated and remained "in-situ" or undisturbed since it was last heated. The samples then have the recorded magnetic direction (inclination and declination) measured in the laboratory and the results are calibrated to give dates.

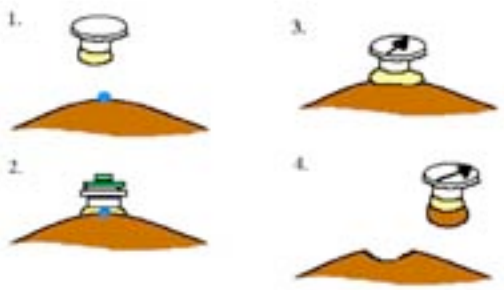
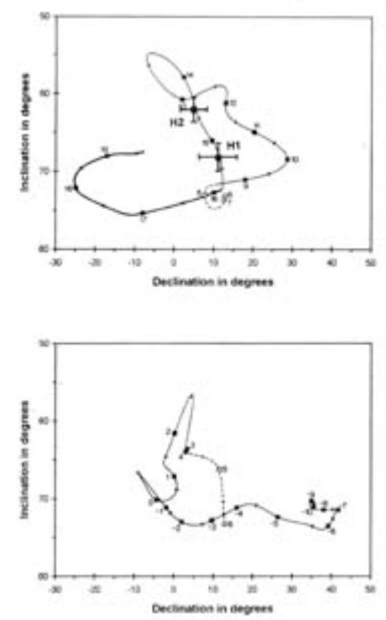


Illustration showing how samples are taken, courtesy of Zoe Outram.

How the curve was compiled

From post medieval times the secular variation of the geomagnetic field in the UK has been measured with reasonable reliability and measurements on fired clays dated by other methods have allowed the extension of this time scale into prehistoric times. Due to the spatial variation in the magnetic field all the data are localized to Meriden (52.43°N, 1.62°W) before it could be included in the calibration curve. Clark et al, in 1988 were the first to bring most of the available data together in the British calibration curve.



The British Archaeomagnetic calibration curve normalized to Meridian showing 600AD - 1975AD (upper) and 1000BC - 600AD (lower), taken from Clarke et al, 1988.

12. Environmental studies

12.1 Biological anthropology

Anthropological fields

- *Biological anthropology (also physical anthropology)*
  - *Primatology*
- *Cultural anthropology (also social anthropology)*
  - *Anthropology of religion*
  - *Feminist anthropology*
  - *Psychological anthropology*
  - *Ethnology*
  - *Evolutionary Anthropology*
- *Linguistic anthropology*
  - *Anthropological linguistics*
- *Archaeology*
  - *Experimental archaeology*
  - *Historical archaeology*
  - *Public archaeology*
  - *Zooarchaeology*
  - *Evolutionary archaeology*

Biological anthropology, or physical anthropology, studies the mechanisms of biological evolution, genetic inheritance, human adaptability and variation, primatology, primate morphology, and the fossil record of human evolution.

Physical anthropology developed in the 19th century, prior to the rise of Alfred Wallace and Charles Darwin's theory of natural selection, and Gregor Mendel's work on genetics. Physical anthropology was so called because all of its data was physical (fossils, especially human bones). With the rise of Darwinian theory and the modern synthesis, anthropologists had access to new forms of data, and many began to call themselves "biological anthropologists."

Some of the early branches of physical anthropology, such as early anthropometry, are now rejected as pseudoscience. Metrics such as the cephalic index were used to derive behavioural characteristics. Two of *the earliest founders of scientific physical anthropology were Paul Broca and Franz Boas.*

- *Primatology, the study of primates,*
- *Population genetics, the study of biological human variability and diversity (related to evolutionary biology)*
- *Human adaptation, the study of human adaptive responses (physiological, developmental, and genetic) to environmental stress and variation (see also biomedical anthropology).*
- *Human anatomy the study of the anatomy and physiology of humans and their ancestors.*
- *Human evolution including:*
    - *Paleoanthropology, the study of fossil evidence for human evolution.*
    - *Human behavioural ecology, the study of behavioural adaptations such as foraging, reproduction, and ontogeny from an evolutionary ecological perspective (see also behavioural ecology).*
- *Neuroanthropology, the study of the evolution of the human brain, and of culture as a neurological adaptation of the species to its environment.*

The study of human evolution often involves other specializations:

- *Human osteology, the study of skeletal material. Experts in osteology are able to apply their skills and knowledge to other areas:*
    - *Paleopathology, which studies the traces of disease and injury in human skeletons*
    - *Forensic anthropology, the analysis and identification of human remains in the service of coroners or medical examiners. This research often provides law enforcement with important evidence.*

12.2 Paleobotany (palynology & carpology)

Paleobotany (from the Greek words paleon *= old and* botanikos *= of herbs) is the branch of paleontology dealing with the recovery and identification of plant remains from geological contexts, and their use in the reconstruction of past environments and the history of life. A closely related field is palynology, the study of fossil and extant spores and pollen. Paleobotany includes the study of terrestrial plant fossils, as well as the study of marine autotrophs, such as algae.*

Paleobotany is important in the reconstruction of prehistoric ecological systems and climate, known as paleoecology and paleoclimatology respectively, and is fundamental to the study of plant development and evolution. Paleobotany has also become important to the field of archaeology, primarily for the use of phytoliths in relative dating and in paleoethnobotany,

Ethnobotany

*Though the term "ethnobotany" was not coined until 1895 by the US botanist Harshberger, the history of the field begins long before that. In AD 77, the Greek surgeon Dioscorides published "*De Materia Medica*", which was a catalog of about 600 plants in the Mediterranean. It also included information on how the Greeks used the plants, especially for medicinal purposes. This illustrated herbal contained information on how and when each plant was gathered, whether or not it was poisonous, its actual use, and whether or not it was edible (it even provided recipes). Dioscorides stressed the economic potential of plants. For generations, scholars learned from this herbal, but did not actually venture into the field until after the Middle Ages.*

*In 1542 Leonhart Fuchs, a Renaissance artist, lead the way back into the field. His "*De Historia Stirpium*" cataloged 400 plants native to Germany and Austria.*

*John Ray (1686-1704) provided the first definition of "species" in his "*Historia Plantarum*": a species is a set of individuals who give rise through reproduction to new individuals similar to themselves.*

In 1753 Carl Linnaeus wrote "Species Plantarum", which included information on about 5,900 plants. Linnaeus is famous for inventing the binomial method of nomenclature, in which all species (mineral, vegetable or animal) get a two part name (genus, species).

The 19th century saw the peak of botanical exploration. Alexander von Humboldt collected data from the new world, and the famous Captain Cook brought back information on plants from the South Pacific. At this time major botanical gardens were started, for instance the Royal Botanic Gardens, Kew.

Edward Palmer collected artifacts and botanical specimens from peoples in the North American West (Great Basin) and Mexico from the 1860s to the 1890s.

Once enough data existed, the field of "aboriginal botany" was founded. Aboriginal botany is the study of all forms of the vegetable world which aboriginal peoples use for food, medicine, textiles, ornaments, etc.

The first individual to study the emic perspective of the plant world was a German physician working in Sarajevo at the end of 19th Century: Leopold Glueck. His published work on traditional medical uses of plants done by rural people in Bosnia (1896) has to be considered the first modern ethnobotanical work.

Other scholars analyzed uses of plants under an indigenous/local perspective in the early 20th century: e.g. Matilda Coxe Stevenson, Zuni plants (1915); Frank Cushing, Zuni foods (1920); and the team approach of Wilfred Robbins, JP Harrington, and Barbara Freire-Marreco, Tewa pueblo plants (1916).

Beginning in the 20th century, the field of ethnobotany experienced a shift from the raw compilation of data to a greater methodological and conceptual reorientation. This is also the beginning of academic ethnobotany.

Today the field of ethnobotany requires a variety of skills: botanical training for the identification and preservation of plant *specimens; anthropological training to understand the cultural concepts around the perception of plants; linguistic training, at least enough to transcribe local terms and understand native morphology, syntax, and semantics.*

Palynology

Palynology is the science that studies contemporary and fossil palynomorphs, including pollen, spores, dinoflagellate cysts, acritarchs, chitinozoans and scolecodonts, together with particulate organic matter (POM) and kerogen found in sedimentary rocks and sediments.

The term palynology *was introduced by Hyde and Williams in 1944, following correspondence with the Swedish geologist Antevs, in the pages of the Pollen Analysis Circular (one of the first journals devoted to pollen analysis, and produced by Paul Sears in North America). Hyde and Williams chose* palynology *on the basis of the Greek words* paluno *meaning 'to sprinkle' and* pale *meaning 'dust' (and thus similar to the Latin word* pollen*).*

Palynology is an interdisciplinary science and is a branch of earth science (geology or geological science) and biological science (biology), particularly plant science (botany). Stratigraphical palynology is a branch of micropalaeontology and paleobotany which studies fossil palynomorphs from the Precambrian to the Holocene.

Palynomorphs are broadly defined as organic-walled microfossils between 5 and 500 micrometers in size. They are extracted from rocks and sediments both physically, by wet sieving, often after ultrasonic treatment, and chemically, by using chemical digestion to remove the non-organic fraction. For example, palynomorphs may be extracted using hydrochloric acid (HCl) to digest carbonate minerals, and hydrofluoric acid (HF) to digest silicate minerals in suitable fume cupboards in specialist laboratories.

Samples are then mounted on microscope slides and examined using light microscopy or scanning electron microscopy. Once the pollen grains have been identified they can be plotted on a pollen diagram *which is then used for interpretation. Pollen diagrams are useful in giving evidence of past human activity (anthropogenic impact), vegetation history and climatic history.*

Palynology uses many techniques from other related fields such as geology, botany, palaeontology, archaeology, pedology, and geography.

Palynology is used for a diverse range of applications, related to many scientific disciplines:

- *Biostratigraphy and geochronology. Geologists use palynological studies in biostratigraphy to correlate strata and determine the relative age of a given bed, horizon, formation or stratigraphical sequence.*
- *Palaeoecology and climate change. Palynology can be used to reconstruct past vegetation (land plants) and marine and freshwater phytoplankton communities, and so infer past environmental (palaeoenvironmental) and palaeoclimatic conditions.*
- *Organic palynofacies studies, which examine the preservation of the particulate organic matter and palynomorphs provides information on the depositional environment of sediments and depositional palaeoenvironments of sedimentary rocks.*
- *Geothermal alteration studies examine the colour of palynomorphs extracted from rocks to give the thermal alteration and maturation of sedimentary sequences, which provides estimates of maximum palaeotemperatures.*
- *Limnology studies. Freshwater palynomorphs and animal and plant fragments, including the prasinophytes and desmids (green algae) can be used to study past lake levels and long term climate change.*
- *Taxonomy and evolutionary studies.*
- *Forensic palynology- the study of pollen and other palynomorphs for evidence at a crime scene.*
- *Allergy studies. Studies of the geographic distribution and seasonal production of pollen, can help sufferers of allergies such as hay fever.*

- *Melissopalynology - the study of pollen and spores found in honey.*
- *Archaeological Palynology examines human uses of plants in the past. This can help determine seasonality of site occupation, presence or absence of agricultural practices or products and plant-related activity areas within an archaeological context. Bonfire Shelter is one such example of this application.*

Because the distribution of acritarchs, chitinozoans, dinoflagellate cysts, pollen and spores provides evidence of stratigraphical correlation through biostratigraphy and palaeoenvironmental reconstruction, one common and lucrative application of palynology is in oil and gas exploration.

Palynology also allows scientists to infer the climatic conditions from the vegetation present in an area thousands or millions of years ago. This is a fundamental part of research into climate change.

12.3 Ethnoarchaeology

Ethnoarchaeology is the ethnographic study of peoples for archaeological reasons, usually focusing on the material remains of a society, rather than its culture. Ethnoarchaeology aids archaeologists in reconstructing ancient lifeways by studying the material and non-material traditions of modern societies. Archaeologists can then infer that ancient societies used the same techniques as their modern counterparts given a similar set of environmental circumstances.

Ethnography can provide insights of value to archaeologists into how people in the past may have lived, especially with regard to their social structures, religious beliefs and other aspects of their culture. However, it is still unclear how to relate most of the insights generated by this anthropological research to archaeological investigations. This is due to the lack of emphasis by anthropologists on the material remains created and discarded by societies and on how these material remains vary with differences in how a society is organised.

This general problem has led archaeologists (for example, London [2000]) to argue that anthropological work is not adequate for answering archaeological problems, and that archaeologists should therefore undertake ethnoarchaeological work to answer these problems. These studies have focused far more on the manufacture, use and discard of tools and other artefacts and have sought to answer such questions as what kinds of objects used in a living settlement are deposited in middens or other places where they may be preserved, and how likely an object is to be discarded near to the place where it was used.

One good example of ethnoarchaeology is that of Brian Hayden (1987), whose team examined the manufacture of Mesoamerican quern-stones, providing valuable insights into the manufacture of prehistoric quern-stones.

Ethnography (□θνος ethnos = people and γράφειν graphein = writing) is the genre of writing that presents varying degrees of qualitative and quantitative descriptions of human social phenomena, based on fieldwork. Ethnography presents the results of a holistic research method founded on the idea that a system's properties cannot necessarily be accurately understood independently of each other. The genre has both formal and historical connections to travel writing and colonial office reports. Several academic traditions, in particular the constructivist and relativist paradigms, claim ethnographic research as a valid research method.

12.4 Experimental archaeology

Experimental archaeology employs a number of different methods, techniques, analyses, and approaches in order to generate and test hypotheses or an interpretation, based upon archaeological source material, like ancient structures or artefacts. It should not be confused with primitive technology which is not concerned with any archaeological or historical evidence, living history or historical re-enactment, which is generally undertaken as a hobby, for entertainment or to demonstrate a romantic atmosphere of a specific *(pre)historic era. Experimental Archaeology is "Within the context of a controllable imitative experiment to replicate past phenomena in order to generate and test hypotheses to provide or enhance analogies for archaeological interpretation" (Mathieu, 12)*

One of the main forms of experimental archaeology is the creation of copies of historical structures using only historically accurate technologies. This is sometimes known as reconstruction archaeology. However, the product of experimental archaeology is data, not the constructed house, axe, pot or whatsoever. A good example is Butser Ancient Farm in the English county of Hampshire which is a working replica of an Iron Age farmstead where long-term experiments in prehistoric agriculture, animal husbandry and manufacturing are held to test ideas posited by archaeologists. In Denmark, the Lejre Experimental Centre carries out even more ambitious work on such diverse topics as artificial Bronze Age and Iron Age burials, prehistoric science and stone tool manufacture in the absence of flint.

Other examples include:

- *The Kon-Tiki, a balsa raft built by Thor Heyerdahl and sailed from Peru to Polynesia to demonstrate the possibility of cultural exchange between South America and the Polynesian islands.*
- *Attempts (so far unsuccessful) to transport large stones like those used in Stonehenge from their probable original location in Pembrokeshire to the site on Salisbury Plain, using only technology that would have been available at the time.*
- *The reconstruction of part of Hadrian's Wall at Vindolanda, carried out in limited time by local volunteers.*
- *Greek triremes have been reconstructed by skilled sailors from plans and archaeological remains and have been successfully tried out at sea.*
- *Attempts to manufacture steel that matches all the characteristics of Damascus steel, whose original manufacturing techniques have been lost for centuries.*
- *Experiments in Ancient Roman Coin Minting.*

In recent years, experimental archeology has been featured in several television productions, such as BBC's "Building the Impossible" and the Discovery Channel's "Secrets of Lost Empires". On television shows, the serious scientific benefits of the techniques are somewhat lessened by imposing strict deadlines on the team.

Other types of experimental archaeology may involve burying modern replica artefacts and ecofacts for varying lengths of time to analyse the post-depositional effects on them. Other archaeologists have built modern earthworks and measured the effects of silting in the ditches and weathering and subsidence on the banks to understand better how ancient monuments would have looked.

The work of Flintknappers is also a kind of experimental archaeology as much has been learnt about the many different types of flint tools through the hands-on approach of actually making them. Experimental archaeologists have equipped modern professional butchers, archers and lumberjacks with replica flint tools to judge how effective they would have been for certain tasks. Use wear traces on the modern flint tools are compared to similar traces on archaeological artefacts, making probability hypotheses on the possible kind of use feasible. Hand axes have been shown to be particularly effective at cutting animal meat from the bone and jointing it.

13. Conclusion