2

What Is Left?

The Variety of the Evidence

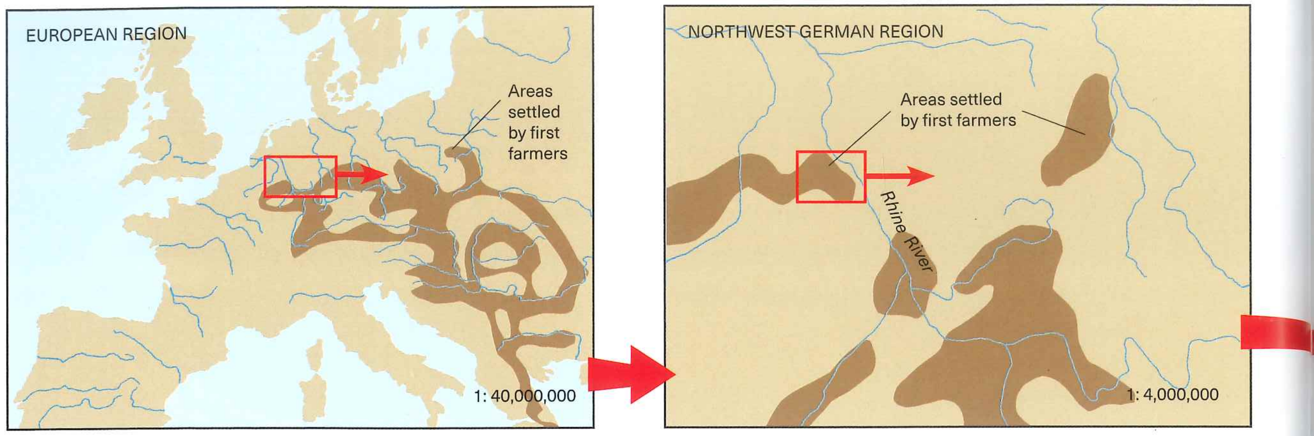
The relics of past human activity are all around us. Some of them were deliberate constructions, built to last, for example the pyramids of Egypt, the Great Wall of China, or the temples of Mesoamerica and India. Others, such as the remains of the Maya irrigation systems of Mexico and Belize, are the visible relics of activities, the aim of which was not primarily to impress the observer, but that still command respect today for the scale of the enterprise they document.

Most of the remains of archaeology are far more modest, however. They are the discarded garbage from the daily activities of human existence: the food remains, the bits of broken pottery, the fractured stone tools, the debris that is formed everywhere as people go about their daily lives.

In this chapter we define the basic archaeological terms, briefly survey the scope of the surviving evidence, and look at the great variety of ways in which it has been preserved for us. From the frozen soil of the Russian steppes, for instance, have come the wonderful finds of Pazyryk, those great chieftains' burials where wood and textiles and skins are splendidly preserved. From the dry caves of Peru and other arid environments have come remarkable textiles, baskets, and other remains that often perish completely. And by contrast, from wetlands, whether the swamps of Florida or the lake villages of Switzerland, further organic remains are being recovered, this time preserved not by the absence of moisture, but by its abundant presence to the exclusion of air.

Extremes of temperature and of humidity have preserved much. So too have natural disasters. The volcanic eruption that destroyed Pompeii in Italy is the most famous of them, but there have been others, such as the eruption of the Ilopango volcano in El Salvador in the second century CE, which buried land surfaces and settlement remains in a large part of the southern Maya area.

Unfortunately most archaeological sites are not in areas subjected to extremes of climate or volcanic activity, and levels of preservation can vary enormously. Our knowledge of the early human past is dependent in this way on the human activities and natural processes that have formed the

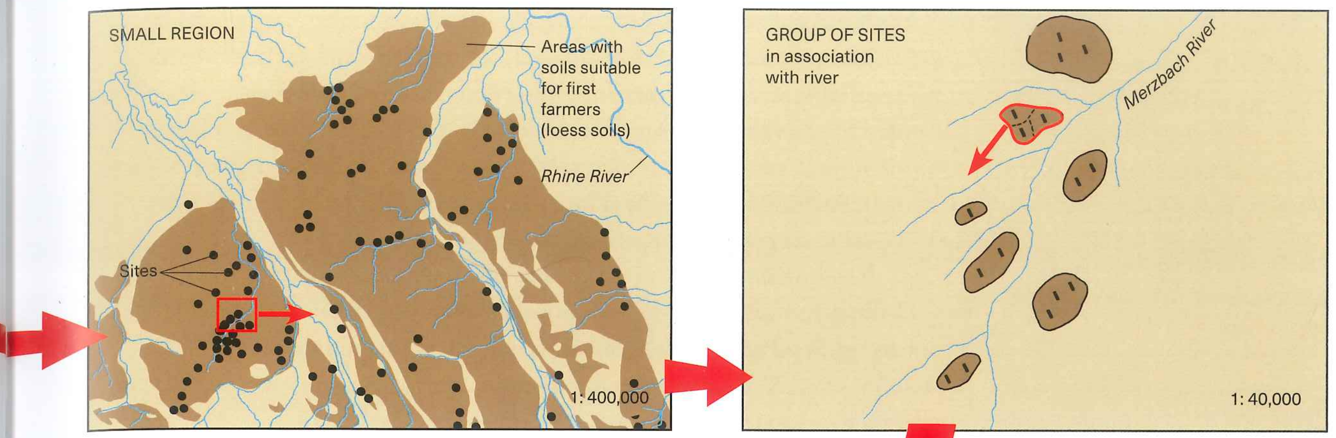


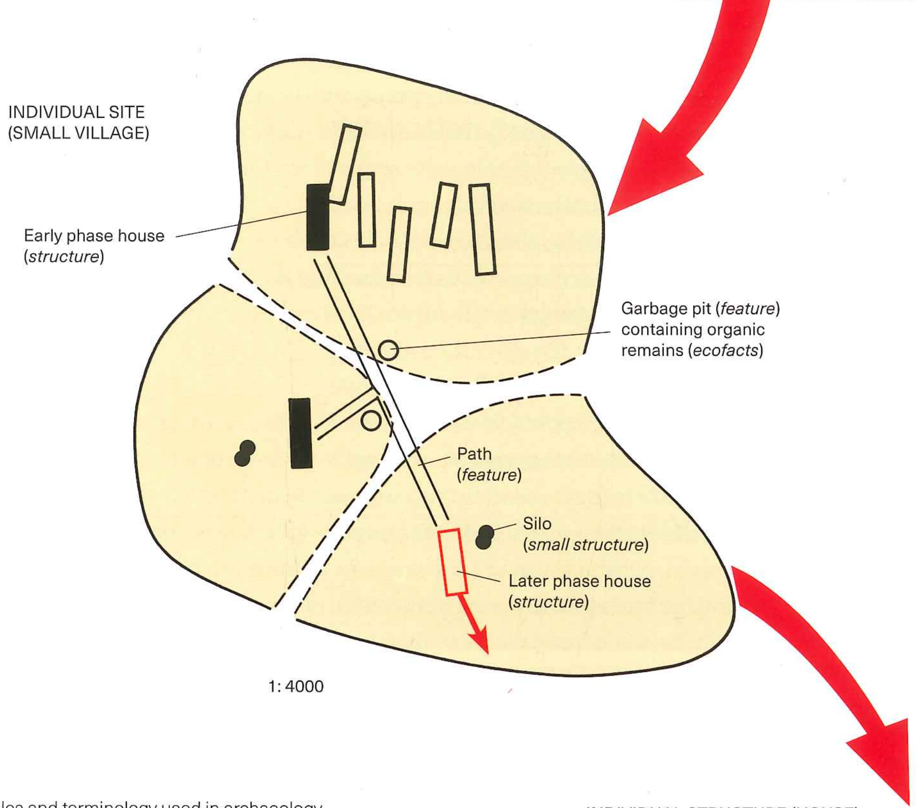
archaeological record, and on those further processes that determine, over long periods of time, what *is* left and what is gone for ever. Today we can hope to recover much of what remains, and to learn from it by asking the right questions in the right way.

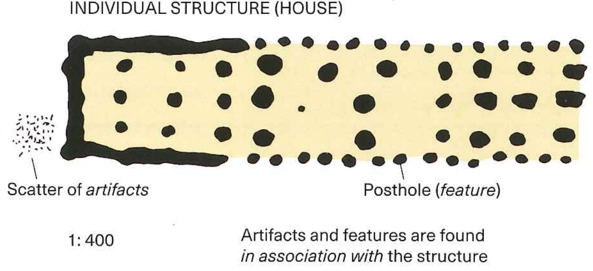
Basic Categories of Archaeological Evidence

The evidence studied by archaeologists very often includes artifacts—objects used, modified, or made by people. But equally important is the study of organic and environmental remains—known as **ecofacts**—that, although not made by humans, can still be very revealing about many aspects of past human activity. Much archaeological research concentrates on the analysis of these artifacts and ecofacts that are found together on sites, which in turn are most productively studied together with their surrounding landscapes and grouped together into regions. Some of these different scales at which archaeologists operate, as well as the terminology they use, are illustrated above and opposite.

Artifacts are humanly made or modified portable objects, such as stone tools, pottery, and metal weapons. But artifacts provide evidence to help us answer all the key questions—not just technological ones—addressed in this book. A single clay vessel or pot can be analyzed in a number of different ways. The clay may be tested to produce a date for the vessel and thus perhaps a date for the location where it was found. It could also be tested to find the source of the clay and thus give evidence for the range and contacts of the group that made the vessel. Pictorial decoration on the pot's surface could help to form or be related to a sequence of design styles (a typology), and it could tell us something about ancient beliefs, particularly if it shows gods or other figures. And analysis of the vessel's shape and any food or other residues found in it can yield information about the pot's use, perhaps in cooking, as well as about ancient diet.







Different scales and terminology used in archaeology, from the continental region (opposite page, top left) to the individual structure (this page, bottom right). In this representation of the pattern of settlement of Europe's first farmers (fifth millennium BCE), the archaeologist might study—at the broader scale—the interesting association between sites and light, easily worked soils near rivers. At the smaller scale, the association—established by excavation—of houses with other houses and with such structures as silos for grain storage raises questions, for example about social organization and permanence of occupation during this period.

Key Concepts
Types of Evidence

Artifacts: portable objects used, modified, or made by humans

Ecofacts: organic and environmental remains not made by humans

Features: non-portable artifacts

Sites: places where artifacts, ecofacts, and features are found together

Some researchers broaden the meaning of the term artifact to include all humanly modified components of a site or landscape, such as hearths, postholes, and storage pits—but these non-portable artifacts are more usefully described as **features**. Such simple features as postholes may themselves, or in combination with remains of hearths, floors, ditches, etc., give evidence for complex features or structures, defined as buildings of all kinds, from houses and granaries to palaces and temples.

Non-artifactual organic and environmental remains, or ecofacts, include human skeletons, animal bones, and plant remains, but also soils and sediments—all of which may shed light on past human activities. They are important because they can indicate, for example, what people ate or the environmental conditions in which they lived.

Archaeological sites may be thought of as the huge variety of places where artifacts, features, structures, and organic and environmental remains are found together. For working purposes we can simplify this still further and define sites as places where significant traces of human activity are identified. Thus a village or town is a site, and so too is an isolated monument, such as Serpent Mound in Ohio. Equally, a surface scatter of stone tools or potsherds may represent a site occupied for no more than a few hours, whereas a Near Eastern **tell** or mound is a site indicating human occupation over perhaps thousands of years.

Key Concepts
Context

Matrix: the material surrounding a find (an artifact, ecofact, or feature)

Provenience: the exact position of a find within the matrix

Association: a find's relationship with other finds

Without context, an artifact loses much of its archaeological value

The Importance of Context

In order to reconstruct past human activity at a site it is crucially important to understand the **context** of a find, whether artifact, ecofact, or feature. A find's context consists of its immediate **matrix** (the material surrounding it, usually some sort of sediment, such as gravel, sand, or clay), its **provenience** (horizontal and vertical position within the matrix), and its **association** with other finds (occurrence together with other archaeological remains, usually in the same matrix). In the nineteenth century the demonstration that stone tools were often associated with the bones of extinct animals in a sealed matrix helped establish the idea of the great antiquity of humankind.

Increasingly since then archaeologists have recognized the importance of identifying and accurately recording associations between remains on sites. This is why it is such a tragedy when looters dig up a site indiscriminately, looking for rich finds, without recording its matrix, provenience, or associations. All the contextual information is lost. A looted vase may be attractive for a collector, but far more could have been learnt about the society that produced it had archaeologists been able to record where it was found (in a tomb, ditch, or house?) and in association with what other artifacts or organic remains (weapons, tools, or animal bones?). Much information about the Mimbres people of the American Southwest has been lost for ever because looters bulldozed their sites, hunting for the superbly painted—and highly sought after—bowls made by the Mimbres 1000 years ago (see box, p. 310).

When modern (or ancient) looters disturb a site, perhaps shifting aside material they are not interested in, they destroy that material's primary context. If archaeologists subsequently excavate that shifted material, they need to be able to recognize that it is in a secondary context. This may be straightforward for, say, a Mimbres site, looted quite recently, but it is much more difficult for a site disturbed in antiquity. Nor is disturbance confined to human activity: archaeologists dealing with the tens of thousands of years of the Paleolithic or Old Stone Age period know well that the forces of nature—encroaching seas or ice sheets, wind and water action—invariably destroy primary context. A great many of the Stone Age tools found in European river gravels are in a secondary context, transported by water action far from their original, primary context.

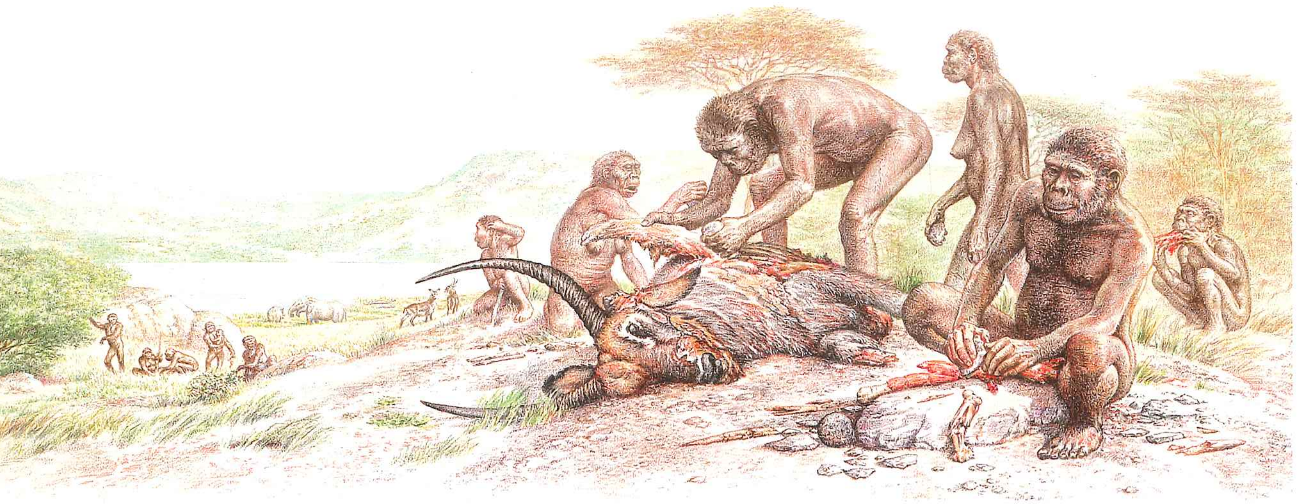
Formation Processes

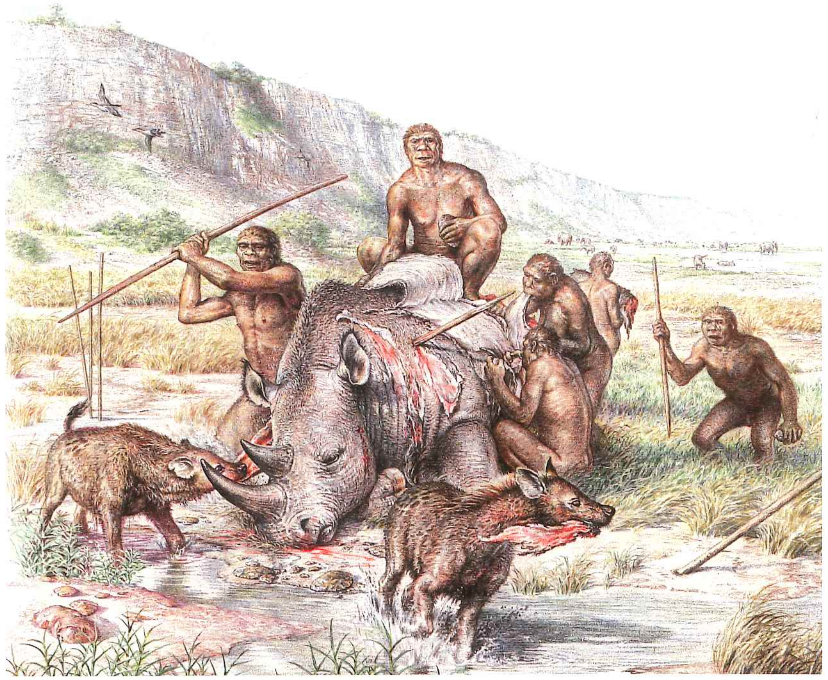
In recent years archaeologists have become increasingly aware that a whole series of **formation processes** may have affected both the way in which finds came to be buried and what happened to them after they were buried. The study of these processes is called **taphonomy**.

A useful distinction has been made between cultural formation processes and non-cultural or natural formation processes. Cultural formation processes involve the deliberate or accidental activities of human beings as they make or use artifacts, build or abandon buildings, plow their fields, and so on. Natural formation processes are natural events that govern both the burial and the survival of the archaeological record. The sudden fall of volcanic ash that covered Pompeii is an exceptional example; a more common one would be the gradual burial of artifacts or features by wind-borne sand or soil. Likewise the transporting of stone tools by river action, referred to above, or the activities of animals—burrowing into a site or chewing bones and pieces of wood—are also examples of natural formation processes.

At first sight these distinctions may seem of little interest to the archaeologist. In fact they are vital to the accurate reconstruction of past human activities. It can be important to know whether certain archaeological evidence is the product of human or non-human (cultural or natural) activity. If, for example, you are trying to reconstruct human woodworking activities by studying cutmarks on timber, then you should learn to recognize certain kinds of marks made by beavers using their teeth and to distinguish these from cutmarks made by humans using stone or metal tools.

Let us take an even more significant example. For the earliest phases of human existence in Africa, at the beginning of the Paleolithic or Old Stone Age period, theories about our primitive hunting ability have been based on the





Early humans as mere scavengers (above) or mighty hunters (right)? Our understanding of formation processes governs the way in which we interpret associations of human tools with animal bones from the fossil record in Africa.

association between stone tools and animal bones found at archaeological sites. The bones were assumed to be those of animals hunted and slaughtered by the early humans who made the tools. But studies of animal behavior and cutmarks on animal bones suggest that in many cases the excavated bones are the remains of animals hunted and largely eaten by other predatory animals. The humans with their stone tools would have come upon the scene as mere scavengers, at the end of a pecking order of different animal species. By no means everyone agrees with this scavenging hypothesis. The point to emphasize here is that the issue can best be resolved by improving our techniques for distinguishing between cultural and natural formation processes—between human and non-human activity. Many studies are now focusing on the need to clarify how to differentiate cutmarks on bones made by stone tools from those made by the teeth of animal predators. Modern experiments using replica stone tools to cut meat off bones are one helpful approach. Other kinds of **experimental archaeology** can be most instructive about some of the formation processes that affect the physical preservation of archaeological material (see box above).

The remainder of this chapter is devoted to a more detailed discussion of the different cultural and natural formation processes.

Experimental Archaeology

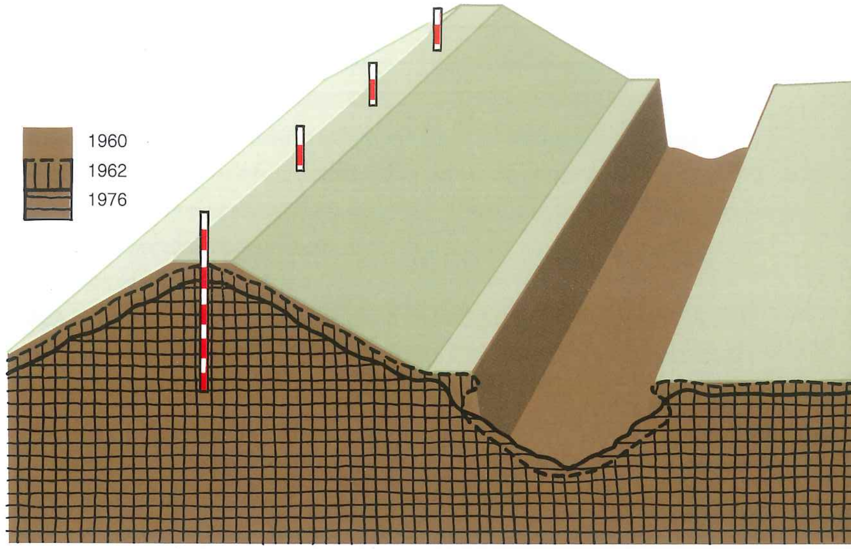
One effective way to study formation processes is through long-term experimental archaeology. An excellent example is the experimental earthwork constructed on Overton Down, southern England, in 1960.

The earthwork consists of a substantial chalk and turf bank, 21 m (69 ft.) long, 7 m (25 ft.) wide, and 2 m (6 ft. 7 in.) high, with a ditch cut parallel to it. The aim of the experiment has been to assess not only how the bank and ditch alter through time, but also what happens to buried materials, such as pottery, leather, and textiles. Sections (trenches) have been—or will be—cut across the bank and ditch at intervals of 2, 4, 8, 16, 32, 64, and 128 years (in real time, 1962, 1964, 1968, 1976, 1992, 2024, and 2088): a considerable commitment for all concerned.

The project is nearing the halfway point, and preliminary results have been interesting. In the 1960s the bank dropped some 25 cm (10 in.) in height and the ditch silted up quite rapidly; since the mid-1970s, the structure has stabilized. As for the buried materials, tests after four years showed that pottery was unchanged and leather little affected, but textiles were already becoming weakened and discolored.

The excavations in 1992 revealed that preservation was better in the chalk bank, which is less biologically active, than in the turf core, where textiles and some wood had completely disappeared. The structure itself had changed little since 1976, though there was considerable reworking and transporting of fine sediment by earthworms.

The experiment has already shown that many of the changes that interest archaeologists occur within decades of burial, and that the extent of these changes can be far greater than had hitherto been suspected.



The bank and ditch as cut in 1960, together with the changes revealed by sections cut across the earthwork in 1962 and 1976.

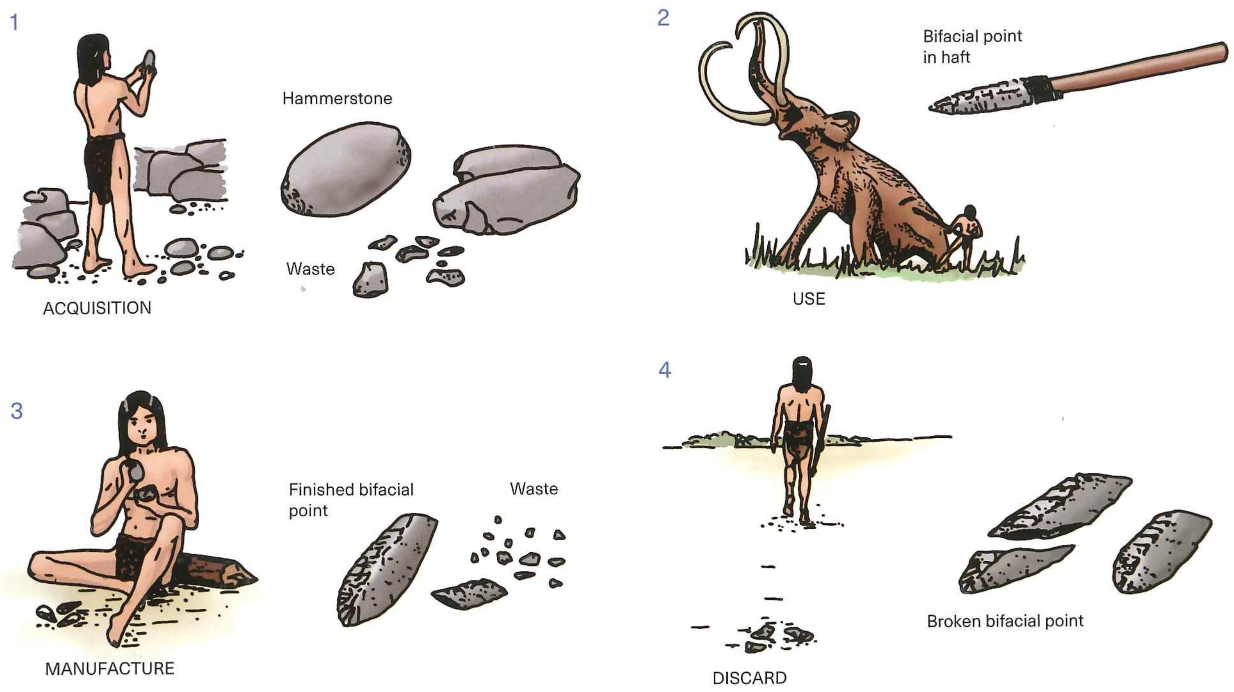
Cultural Formation Processes—How People Have Affected What Survives in the Archaeological Record

We may separate these processes rather crudely into two kinds: those that reflect the original human behavior and activity before a find or site became buried; and those (such as plowing or looting) that came after burial. Now of course most major archaeological sites are formed as the result of a complex sequence of use, burial, and reuse repeated many times over, so that a simple two-fold division of cultural formation processes may not be so simple to apply in practice. Nevertheless, since one of our main aims is to reconstruct original human behavior and activity, we must make the attempt.

Original human behavior is often reflected archaeologically in at least four major activities: in the case of a tool (see diagram below) there may be:

1. acquisition of the raw material;
2. manufacture;
3. use (and distribution); and finally
4. disposal or discard when the tool is worn out or broken.

An artifact, a stone tool in this case, may have entered the archaeological record at any one of these four stages in its life cycle. The archaeologist's task is to determine which stage is represented by the find in question.



(The tool may of course be reworked and recycled, i.e. repeating stages 2 and 3.) Similarly, a food crop, such as wheat, will be acquired (harvested), manufactured (processed), used (eaten), and discarded (digested and the waste products excreted)—here we might add a common intermediate stage of storage before use. From the archaeologist's point of view the critical factor is that remains can enter the archaeological record at any one of these stages—a tool may be lost or thrown out as inferior quality during manufacture, or a crop may be accidentally burnt and thus preserved during processing. In order to reconstruct accurately the original activity it is therefore crucial to try to understand which one of the stages we are examining. It may be quite easy to identify, say, the first stage for stone tools, because stone quarries can often be recognized by deep holes in the ground, with piles of associated waste flakes and blanks, which survive well. But it is much more difficult to know beyond reasonable doubt whether a sample of charred plant remains comes from, say, a threshing area or an occupation area—and this may also make it difficult to reconstruct the true plant diet, since certain activities may favor the preservation of certain species of plant.

Deliberate burial of valuables is another major aspect of original human behavior that has left its mark on the archaeological record. In times of conflict or war people often deposit prized possessions in the ground, intending to reclaim them at a later date but sometimes for one reason or another failing to do so. These **hoards** are a prime source of evidence for certain periods, such as the European Bronze Age, for which hoards of metal goods are common, or later Roman Britain, which has yielded buried treasures of silver and other precious metals. The archaeologist, however, may not find it easy to distinguish between hoards originally intended to be recovered and valuables buried with no reclamation intended, perhaps to placate supernatural powers (placed for example at a particularly dangerous part of a crossing over a bog).

How archaeologists set about trying to demonstrate belief in supernatural powers and an afterlife will be seen in Chapter 9. Here we may note that, in addition to hoards, the major source of evidence comes from burial of the dead, whether in simple graves, elaborate burial mounds, or giant pyramids, usually with such grave-goods as ceramic vessels or weapons, and sometimes with painted tomb-chamber walls, as in ancient Mexico or Egypt. The Egyptians indeed went so far as to mummify their dead—to preserve them, they hoped, for eternity—as did the Incas of Peru, whose kings were kept in the Temple of the Sun at Cuzco and brought outside for special ceremonies.

Human destruction of the archaeological record might be caused by burials of the kind just described being dug into earlier deposits. But people in the past deliberately or accidentally obliterated traces of their predecessors in innumerable other ways. Rulers, for instance, often destroyed monuments or erased inscriptions belonging to previous chiefs or monarchs. Some human destruction meant to obliterate has inadvertently preserved material for the archaeologist to find. Burning, for example, may not always destroy.

It can often improve the chances of survival of a variety of remains, such as of plants: the conversion into carbon greatly increases the powers of resistance to the ravages of time. Clay daubing and adobe usually decay, but if a structure has been fired, the mud is baked to the consistency of a brick. In the same way thousands of clay writing tablets from the Near East have been baked accidentally or deliberately in fires and thus preserved. Timbers too may char and survive in structures, or at least leave a clear impression in the hardened mud.

Today human destruction of the archaeological record continues at a frightening pace, through land drainage, plowing, building work, looting, etc. In Chapter 12 we discuss how this affects archaeology generally and what the potential implications are for the future.

Natural Formation Processes—How Nature Affects What Survives in the Archaeological Record

We saw above how natural formation processes, such as river action, can disturb or destroy the primary context of archaeological material. Here we will focus on that material itself, and the natural processes that cause decay or lead to preservation.

Practically any archaeological material can survive in exceptional circumstances. Usually, however, inorganic materials survive far better than organic ones.

Key Concepts

Survival of Inorganic Materials

Stone tools, fired clay, and some metals, such as gold, silver, and lead, survive very well in nearly all environments

Some metals, such as copper, can corrode depending on the soil conditions, and iron rarely survives in an uncorroded state

Although inorganic materials, particularly stone tools and pottery, are very often found at archaeological sites, these objects may well have been equaled or superseded in abundance and importance by objects that usually do not survive, such as wooden tools or baskets

Inorganic Materials

The most common inorganic materials to survive archaeologically are stone, clay, and metals.

Stone tools survive extraordinarily well—some are more than 2 million years old. Not surprisingly they have always been our main source of evidence for human activities during the Paleolithic period, even though wooden and bone tools (which are less likely to be preserved) may originally have equaled stone ones in importance. Stone tools sometimes come down to us so little damaged or altered from their primary state that archaeologists can examine microscopic patterns of wear on their cutting edges and learn, for example, whether the tools were used to cut wood or animal hides. This is now a major branch of archaeological inquiry.

Fired clay, such as pottery and baked mud brick or adobe, is virtually indestructible if well fired. It is therefore again not surprising that for the periods after the introduction of pottery-making (some 16,000 years ago in Japan, and 9000 years ago in the Near East and parts of South America) ceramics have traditionally been the archaeologist's main source of evidence. As we saw earlier in this chapter, pots can be studied for their shape, surface decoration, mineral content, and even the food or other residues left inside them. Acid soils can damage the surface of fired clay, and porous or badly fired clay vessels or mud brick can become fragile in humid conditions. Even disintegrated mud brick, however, can help to assess rebuilding phases in, for instance, Peruvian villages or Near Eastern tells.

This bronze head from a statue of a Greek male athlete was found off the coast of Croatia in 2001. Bronze survives well in seawater, but some 2000 years of encrustation had to be painstakingly removed by restorers.

Such metals as gold, silver, and lead survive well. Copper, and bronze with a low-quality alloy, are attacked by acid soils, and can become so oxidized that only a green deposit or stain is left. Oxidation is also a rapid and powerful agent of the destruction of iron, which rusts and may similarly leave only a discoloration in the soil.

The sea is potentially very destructive. Underwater remains can be broken and scattered by currents, waves, or tidal action. On the other hand, the sea can cause metals to be coated with a thick, hard casing of metallic salts from the objects themselves; this helps to preserve the artifacts. If the remains are simply taken out of the water and not treated, the salts react with air, and give off acid that destroys the remaining metal. But the use of **electrolysis**—placing the object in a chemical solution and passing a weak current through it—leaves the metal artifact clean and safe. This is a standard procedure in underwater archaeology and is used on all types of objects from cannons to the finds recovered from the *Titanic*.

Organic Materials

Survival of organic materials is determined largely by the matrix (the surrounding material) and by climate (local and regional)—with the occasional influence of such natural disasters as volcanic eruptions, which are often far from disastrous for archaeologists.

The matrix, as we saw earlier, is usually some kind of sediment or soil. These vary in their effects on organic material; chalk, for example, preserves human and animal bone well (in addition to inorganic metals). Acid soils destroy bones and wood within a few years, but will leave telltale discolorations where postholes or hut foundations once stood. Similar brown or black marks survive in sandy soils, as do dark silhouettes that used to be skeletons.

But the immediate matrix may in exceptional circumstances have an additional component, such as metal ore, salt, or oil. Copper can favor the preservation of organic remains, perhaps by preventing the activity of destructive micro-organisms. The prehistoric copper (and salt) mines of central and southeastern Europe, for example, contain many remains of wood, leather, and textiles.

A combination of salt and oil ensured the preservation of a woolly rhinoceros at Starunia, Ukraine, with skin intact, and the leaves and fruits of tundra vegetation around it. The animal had been carried by a strong current into a pool saturated with crude oil and salt from a natural oil

Key Concepts
Survival of Organic Materials

Matrix: the conditions and makeup of the soil or sediment surrounding organic material dictate whether the latter survives

Climate: the local and regional weather conditions in turn affect soils, erosion, flora, and fauna

Natural disasters, such as volcanic eruptions, and **extremes of dry, cold, and wet** conditions, can lead to exceptional preservation of organic materials

seep, which prevented decomposition: bacteria could not operate in these conditions, while salt had permeated the skin and preserved it. Similarly, the asphalt pits of La Brea, Los Angeles, are world famous for the large quantities and fine condition of the skeletons of a wide range of prehistoric animals and birds recovered from them.

Climate plays an important role too in the preservation of organic remains. Occasionally the "local climate" of an environment, such as a cave, preserves finds. Caves are natural "conservatories" because their interiors are protected from outside climatic effects, and (in the case of limestone caves) their alkaline conditions permit excellent preservation. If undisturbed by floods or the trampling feet of animals and people, they can preserve bones and even such fragile remains as footprints.

More usually, however, it is the regional climate that is important. Tropical climates are the most destructive, with their combination of heavy rains, acid soils, warm temperatures, high humidity, erosion, and wealth of vegetation and insect life. Tropical rainforests can overwhelm a site remarkably quickly, with roots that dislodge masonry and tear buildings apart, while torrential downpours gradually destroy paint and plasterwork, and woodwork rots away completely. Archaeologists in southern Mexico, for example, constantly have to battle to keep back the jungle. On the other hand, jungle conditions can be positive, in that they hinder looters from easily reaching even more sites than they do already.

Temperate climates, as in much of Europe and North America, are not good, as a rule, for the preservation of organic materials; their relatively warm but variable temperatures and fluctuating rainfall usually combine to accelerate the processes of decay. In some circumstances, however, local conditions can counteract these processes. At the Roman fort of Vindolanda, near Hadrian's Wall in northern England, more than 1300 letters and documents, written in ink on wafer-thin sheets of birch and alderwood, have been found. Offering a remarkable insight into both military and personal matters on the frontier, the fragments, dating to about 100 CE, have survived because of the soil's unusual chemical condition: clay compacted between layers in the site created oxygen-free pockets (the exclusion of oxygen is vital to the preservation of organic materials), while chemicals produced by bracken, bone, and other remains effectively made the land sterile in that locality, thus preventing disturbance by vegetation and other forms of life.

Natural disasters sometimes preserve sites, including organic remains, for the archaeologist. The most common are violent storms, such as the one that covered the coastal Neolithic village of Skara Brae, in the Orkney Islands, off the north coast of Scotland, with sand; the mudslide that engulfed the prehistoric village of Ozette on America's Northwest Coast (see box, p. 58); or volcanic eruptions, such as that of Vesuvius, which buried and preserved Roman Pompeii under a blanket of ash. Another volcanic eruption, this time in El Salvador in about 595 CE, deposited a thick and widespread layer of ash over a densely populated area of Maya settlement. Work here has uncovered a variety of organic remains at the site of Cerén, including palm and grass roofing, mats, baskets, stored grain, and even preserved agricultural furrows.

Apart from these special circumstances, the survival of organic materials is limited to cases involving extremes of moisture: that is, very dry, frozen, or waterlogged conditions.

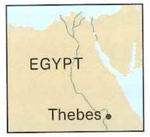
Preservation of Organic Materials: Extreme Conditions

DRY ENVIRONMENTS. Great aridity or dryness prevents decay through the shortage of water, which ensures that many destructive micro-organisms are unable to flourish. Archaeologists first became aware of the phenomenon in Egypt (see Tutankhamun box overleaf), where much of the Nile Valley has such a dry atmosphere that bodies of the Predynastic period (before 3000 BCE) have survived intact, with skin, hair, and nails, without any artificial mummification or coffins—the corpses were simply placed in shallow graves in the sand. Rapid drying out, plus the draining qualities of the sand, produced such spectacular preservative effects that they probably suggested the practice of mummification to the later Egyptians of the Dynastic period.

The pueblo dwellers of the American Southwest (*c.* 700–1400 CE) buried their dead in dry caves and rockshelters where, as in Egypt, natural desiccation took place: these are not therefore true, humanly created mummies, although they are often referred to as such. The bodies survive, sometimes wrapped in fur blankets or tanned skins, and in such good condition that it has been possible to study hair styles. Clothing (from fiber sandals to string aprons) also remains, together with a wide range of goods, such as basketry, feathered ornaments, and leather. Some far earlier sites in the same region also contain organic remains: Danger Cave, Utah (occupied from 9000 BCE onward), yielded wooden arrows, trap springs, knife handles, and other wooden tools, while caves near Durango, Colorado, had preserved maize cobs, squashes, and sunflower and mustard seeds. Plant finds of this type have been crucial in helping to reconstruct ancient diet.

The coastal dwellers of central and southern Peru lived—and died—in a similarly dry environment, so that it is possible today to see the tattoos on their desiccated bodies, and admire the huge and dazzlingly colorful textiles from cemeteries at Ica and Nazca, as well as basketry and featherwork, and also maize cobs and other items of food. In Chile, the oldest deliberately made mummies have been found at Chinchorro, preserved again by the aridity of the desert environment.

Dry Preservation: The Tomb of Tutankhamun



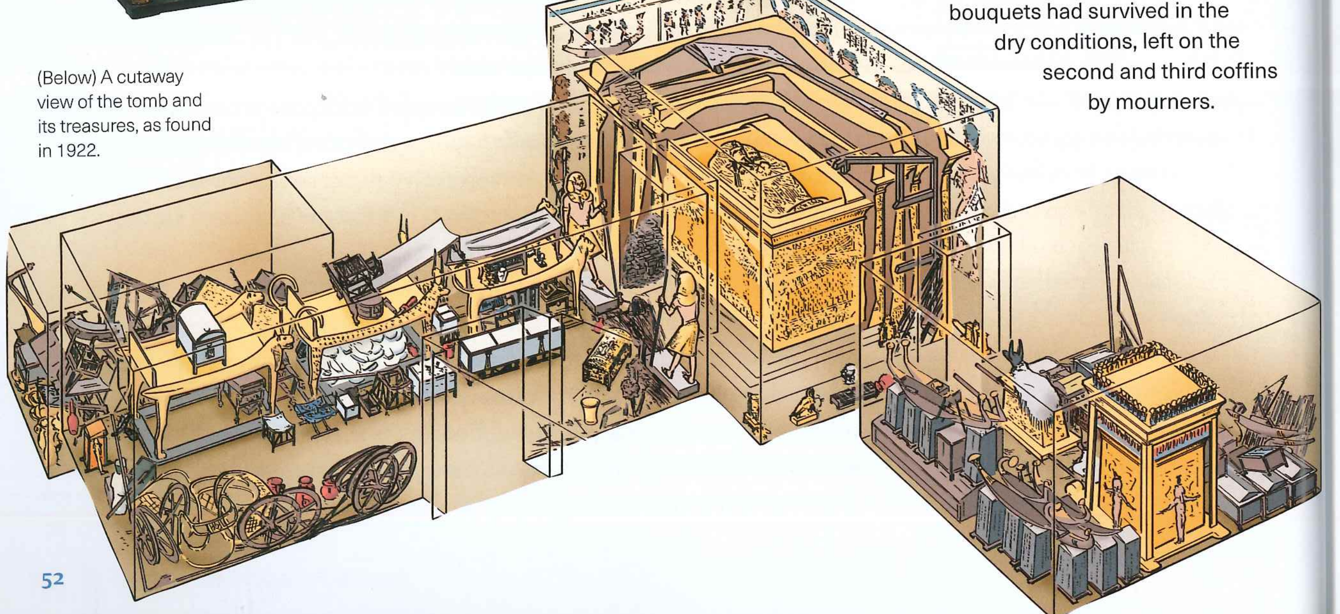
The arid conditions that prevail in Egypt have helped preserve a wide range of ancient materials, ranging from numerous written documents on papyrus (made of the pith of a Nile water plant) to two full-size wooden boats buried beside the Great Pyramid at Giza. But the best-known and most spectacular array of objects was that discovered in 1922 by Howard Carter and Lord Carnarvon in the tomb at Thebes of the pharaoh Tutankhamun, dating to the fourteenth century BCE.

Tutankhamun had a short reign and was relatively insignificant in Egyptian history, a fact reflected in his burial, a poor one by pharaonic standards. But within the small tomb, originally built for someone else, was a wealth of treasure. For Tutankhamun was buried with everything he might need in the next life. The entrance corridor and the four chambers were crammed with thousands of individual grave-goods. They included objects of precious metal, such as jewelry and the famous gold mask, and food and clothing. But wooden objects, such as statues, chests, shrines, and two of the three coffins, made up a large part of the tomb's contents.

The grave furniture was not all originally intended for Tutankhamun. Some of it had been made for other members of his family, and then hastily adopted when the young king died unexpectedly. There were also touching items, such as a chair the king had used as a child, and a simple reed stick mounted in gold labeled as "A reed which His Majesty cut with his own hand." Even wreaths and funerary bouquets had survived in the dry conditions, left on the second and third coffins by mourners.

(Above) The outermost of Tutankhamun's three coffins was made of cypress wood, overlaid with gold foil.

(Left) A gilded ritual couch found remarkably well preserved among the contents of the tomb of Tutankhamun.



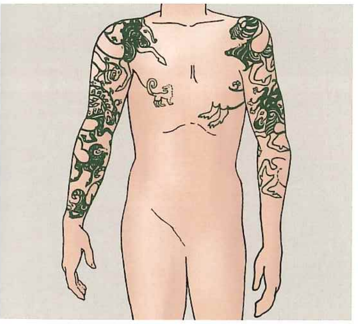
(Below) A cutaway view of the tomb and its treasures, as found in 1922.

A slightly different phenomenon occurred in the Aleutian Islands, off the west coast of Alaska, where the dead were kept and naturally preserved in volcanically warmed caves that were extremely dry. Here the islanders seem to have enhanced the natural desiccation by periodically drying the bodies by wiping or suspension over a fire; in some cases they removed the internal organs and placed dry grass in the cavity.

COLD ENVIRONMENTS. Natural refrigeration can hold the processes of decay in check for thousands of years. Perhaps the first frozen finds to be discovered were the numerous remains of mammoths encountered in the permafrost (permanently frozen soil) of Siberia, a few with their flesh, hair, and stomach contents intact. The unlucky creatures probably fell into crevices in snow, and were buried by silt in what became a giant deep-freeze. The best-known are Beresovka, recovered in 1901, and baby Dima, found in 1977. Preservation can be still so good that dogs will eat the meat and they have to be kept well away from the carcasses.

The most famous frozen archaeological remains are those from the burial mounds of steppe nomads at Pazyryk in the Altai Mountains, southern Siberia, dating to the Iron Age, about 400 BCE. They comprise pits dug deep into the ground, lined with logs, and covered with a low cairn of stones. They could only have been dug in the warm season, before the ground froze solid. Any warm air in the graves rose and deposited its moisture on the stones of the cairn; moisture also gradually infiltrated down into the burial chambers, and froze so hard there during the harsh winter that it never thawed during subsequent summers, since the cairns were poor conductors of heat and shielded the pits from the warming and drying effects of wind and sun. Consequently, even the most fragile materials have survived intact—despite the boiling water that had to be used by excavators to recover them.

The Pazyryk bodies had been placed inside log coffins, with wooden pillows, and survived so well that their spectacular tattoos can still be seen. Clothing included linen shirts, decorated caftans, aprons, stockings, and headdresses of felt and leather. There were also rugs, wall-coverings, tables laden with food, and horse carcasses complete with elaborate bridles, saddles, and other trappings. A further well-preserved burial has been found in the region, containing a female accompanied by six horses, and grave-goods including a silver mirror and various wooden objects.



Frozen conditions in southern Siberia helped to preserve many remarkable finds from the burial mounds of steppe nomads at Pazyryk, dating from about 400 BCE, including this tattoo pattern on the torso and arms of a chieftain.

Similar standards of preservation have also been encountered in other regions, such as Greenland and Alaska. More southerly regions can produce the same effect at high altitude, for instance the Inca-period "mummies" found at a number of high-altitude sites in the Andes; or the 5300-year-old Iceman found preserved in the ice in the Alps near the border between Italy and Austria (see boxes, overleaf and p. 56).

Cold Preservation 1: The Iceman

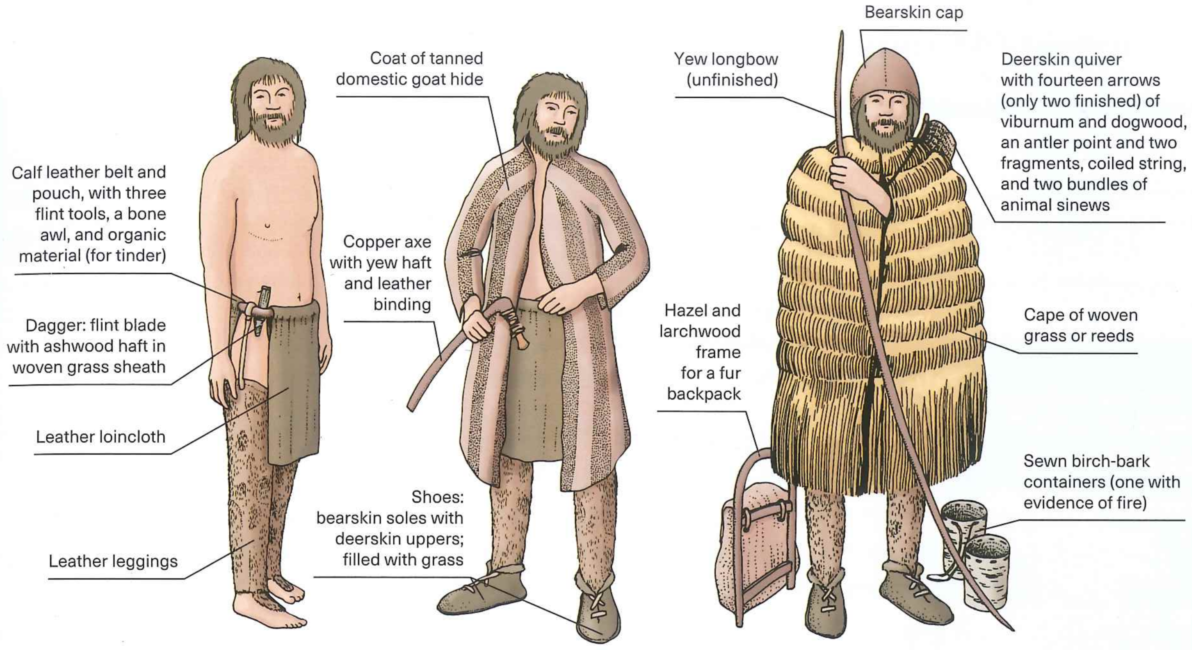
The world's oldest fully preserved human body was found in September 1991 by German hikers near the Similaun glacier, in the Ötztal Alps of South Tyrol. They spotted a human body, its skin yellowish-brown and desiccated, at an altitude of 3200 m (10,500 ft.). The Iceman is the first prehistoric human ever found with his everyday clothing and equipment; other similarly intact bodies from prehistory have been either carefully buried or sacrificed.

The body was placed in a freezer in Austria, but subsequent investigation determined that the corpse—called Similaun Man, Ötzi, or simply the Iceman—had lain *c.* 90 m (300 ft.) inside Italy, and he has been housed there, in a museum in Bolzano, since 1998. Fifteen radiocarbon dates have been obtained from the body, the artifacts, and the grass in the boots: they are all in rough agreement, averaging at 3300 BCE.

It was initially thought the Iceman was overcome by exhaustion—perhaps caught in a fog or a blizzard. After death, he was dried out by a warm autumn wind, before becoming encased in ice. Since the body lay in a depression, it was protected from the movement of the glacier above it for 5300 years, until a storm from the Sahara laid a layer of dust on the ice that absorbed sunlight and finally thawed it out.

(Above right) The body of the Iceman after preservation.

(Right) The Iceman, the oldest fully preserved human, as found in 1991, emerging from the melting ice that had preserved him for more than 5000 years.



The equipment and clothing of the Iceman are a virtual time-capsule of everyday life—more than seventy objects were found associated with him.

He was a dark-skinned male, aged in his mid- to late forties. Only about 1.56–1.6 m (5 ft. 2 in.) tall, his size and stature fit well within the measurement ranges of late Neolithic populations in Italy and Switzerland. Preliminary analysis of his DNA confirms his links to northern Europe.

The corpse currently weighs only about 54 kg (120 lb). His teeth are very worn, especially the front incisors, suggesting that he ate coarse ground grain, or that he regularly used them as a tool. When found he was bald, but hundreds of curly brownish-black human hairs, about 9 cm (3.5 in.) long, were recovered from the vicinity of the body. These had fallen out after death, and it is possible he had a beard.

A body scan has shown that the brain, muscle tissues, lungs, heart, liver, and digestive organs are in excellent condition, though the lungs are blackened by smoke, probably from open fires, and he has hardening of the arteries and blood vessels. Traces of meat have been found in his colon (probably ibex and venison), along with wheat, plants, and plums.

Traces of chronic frostbite were noted in one little toe, and eight of his ribs were fractured, though these had healed or were healing when he died.

Groups of tattoos, mostly short parallel vertical blue lines, were discovered on both sides of his lower spine, on his left calf and right ankle, his wrists, and he had a blue cross on his inner right knee. These marks, probably made with soot, may be therapeutic, aimed at relieving the arthritis that he had in his neck, lower back, and right hip.

His nails had dropped off, but one fingernail was recovered. Its analysis revealed not only that he undertook manual labor, but also that he experienced periods of reduced nail growth corresponding to episodes of serious illness—four, three, and two months before he died. The fact that he was prone to periodic crippling disease supported the view that he fell prey to adverse weather and froze to death. Recent work, however, has revealed what appears to be an arrowhead lodged in the Iceman's left shoulder, cuts on his hands, wrists, and ribcage, and a blow to the head—either from being struck or from falling—which is probably what killed him.

The items found with him constitute a unique time-capsule of everyday life. A great variety of woods and a range of sophisticated techniques of working with leather and grasses were used to create the collection of seventy objects, which add a new dimension to our knowledge of the period.

Cold Preservation 2: Mountain "Mummies"

Since the 1950s, sporadic discoveries have been made of frozen bodies high in the Andes mountains of South America—these finds have become known as mummies, even though they were preserved only by the cold, not by any process of artificial mummification. The Incas of the fifteenth to sixteenth centuries CE built more than 100 ceremonial centers on many of the highest peaks in their empire, since they worshiped the snowcapped mountains, believing that they provided the water for irrigating fields, and hence controlled the fertility of crops and animals.

Among the offerings left for the mountain gods were food, alcoholic drinks, textiles, pottery, and figurines—but also human sacrifices, often young children. In the 1990s, American archaeologist Johan Reinhard carried out a series of expeditions to high peaks in the Andes, and discovered some of the best-preserved ancient bodies ever found, thanks to this "extreme archaeology."

The older, better-preserved Llullaillaco girl had neatly braided hair and wore a selection of ornaments.

On the Ampato volcano, at 6312 m (20,708 ft.), he found a bundle lying on the ice that contained an Inca girl—dubbed the "Ice Maiden" or "Juanita"—who had been ritually sacrificed (by a blow to the head) at the age of about fourteen, and buried with figurines, food, textiles, and pottery. The buried bodies of a boy and girl were later excavated at 5850 m (19,193 ft.).

In 1999, on the peak of Llullaillaco—at 6739 m (22,109 ft.)—he encountered a seven-year-old boy, and two girls of fifteen and six, all with figurines and textiles. So perfect is the preservation of all these bodies that detailed analyses can be carried out on their internal organs, their DNA, and their hair. For example, isotopes in the hair suggest that they chewed coca leaves, a common practice in the region even today.

WATERLOGGED ENVIRONMENTS. A useful distinction in land archaeology (as opposed to archaeology beneath the sea) can be drawn between dryland and wetland sites. The great majority of sites are "dry" in the sense that moisture content is low and preservation of organic remains is poor. Wetland sites include all those found in lakes, swamps, marshes, fens, and peat bogs. In these situations organic materials are effectively sealed in a wet and airless environment that favors their preservation, as long as the waterlogging is more or less permanent up to the time of excavation. (If a wet site dries out, even only seasonally, decomposition of the organic materials can occur.)

It has been estimated that on a wet site often 75–90 percent, sometimes 100 percent, of the finds are organic. Little or none of this material, such as wood, leather, textiles, basketry, and plant remains of all kinds, would survive on most dryland sites. It is for this reason that archaeologists are turning their attention more and more to the rich sources of evidence about past human activities to be found on wet sites. Growing threats from drainage and peatcutting in the wetlands, which form only about 6 percent of the world's total land area, give this work an added urgency.

Excavations at Must Farm in Cambridgeshire, in the east of England, uncovered extensive Bronze Age remains including structures and many objects, among them a well-preserved wheel.

Wetlands vary a great deal in their preservative qualities. Acidic peat bogs preserve wood and plant remains, but may destroy bone, iron, and even pottery. The lake sites of the Alpine regions of Switzerland, Italy, France, and southern Germany, on the other hand, preserve most materials well. Sometimes other forces can help to preserve waterlogged remains, such as the mudslide that buried the Ozette site in Washington State (see box overleaf).

An important recent example of wet preservation is the Must Farm settlement in Cambridgeshire, in the east of England, where some of the best-preserved Bronze Age dwellings in the world have been excavated. The remains include two circular wooden houses dating from 1000–800 BCE, which appear to have been damaged by fire before then sliding into the river, where the fire was extinguished. The buildings and objects within them were then buried and preserved in silt. Many remarkable objects have now been recovered from the site, including pots still containing food, textiles woven from lime tree bark and other plant fibers, and sections of wattle walls. In 2016, a large wooden wheel about 1 m (3 ft.) in diameter was found, the most complete and earliest of its type in Britain. Through its waterlogged preservation, Must Farm offers a rare insight into the everyday life of a Bronze Age village.

Peat bogs, nearly all of which occur in northern latitudes, are some of the most important environments for wetland archaeology. The Somerset Levels in southern England, for example, have been the scene not only of excavations in the early twentieth century to recover the well-preserved Iron Age lake villages of Glastonbury and Meare, but also of a much wider campaign in the last few decades that has unearthed numerous wooden trackways (including

Wet Preservation: The Ozette Site

Cleaning a basket holding a comb and a spindle whorl.

A special kind of waterlogging occurred at the Ozette site, Washington, on the US Northwest Coast. In about 1700 CE, a huge mudslide buried part of a Makah Indian whale-hunting village. Ruins of huge cedar-plank houses lay protected by the mud for three centuries—but not forgotten, for the descendants kept the memory of their ancestors' home alive. Then the sea began to strip away the mud, and it seemed that the site might fall prey to looters. The Makah tribal chairman asked Washington State University archaeologist Richard Daugherty to excavate the site and salvage its remains. Clearing the mud with water pumped from the ocean and sprayed through hoses revealed a wealth of wood and fiber objects.

The houses, where several related families would have lived, were up to 21 m (68 ft. 3 in.) in length and 14 m (45 ft. 6 in.) wide. They had adzed and carved panels (with designs including wolves and thunderbirds), roof-support posts, and low partition walls. There were also hearths, sleeping platforms, storage boxes, mats, and baskets.

More than 55,000 artifacts—mostly wooden—were recovered. They had been preserved by the wet mud, which excluded oxygen. The most spectacular was a block of red cedar, a meter high, carved in the form of a whale's dorsal fin. Even leaves—still green—survived, together with many whale bones.

Field excavation and laboratory preservation continued non-stop for eleven years, an outstanding example of cooperation between archaeologists and indigenous people. Makah elders helped to identify artifacts; young Makah helped to excavate; and a museum now displays the results.

(Below left) A Makah Indian crew member measures a find in one of the Ozette houses.

(Below right) A red cedar carving in the shape of a whale's dorsal fin, inlaid with 700 sea-otter teeth (some forming the shape of a thunderbird holding a serpent, which would stun the whale so that the thunderbird could pick it up in its claws).

The surviving parts of Oldcroghan Man's body are superbly preserved, particularly his hands: the well-kept fingernails and absence of calluses suggest that he may have been an individual of relatively high status. Analysis of his stomach contents revealed a final meal of cereals and buttermilk.

the world's "oldest road," a 6000-year-old 1.6-km (1-mile) stretch of track), and many details about early woodworking skills, and the ancient environment. On the continent of Europe, and in Ireland, peat bogs have likewise preserved many trackways—sometimes with evidence for the wooden carts that ran along them—and other fragile remains. Other types of European wetlands, such as coastal marshes, have yielded dugout logboats, paddles, even fish-nets and fish-weirs.

Bog bodies, however, are undoubtedly the best-known finds from the peat bogs of northwestern Europe. Most of them date from the Iron Age. The degree of preservation varies widely, and depends on the particular conditions in which the corpses were deposited. Most individuals met a violent death and were probably either executed as criminals or killed as a sacrifice before being thrown into the bog. For example, in 2003 the huge (1.91 m (6 ft. 3½ in.) tall) Oldcroghan Man was recovered from a peat bog in Ireland: he had been stabbed, decapitated, and tied down to the bottom of a bog pool.

The best-preserved specimens, such as Denmark's Tollund Man, were in a truly remarkable state, with only the staining caused by bog water and tannic acid as an indication that they were ancient rather than modern. Within the skin, the bones have often disappeared, as have most of the internal organs, although the stomach and its contents may survive. In Florida, prehistoric human brains have even been recovered.

Occasionally, waterlogged conditions can occur inside burial mounds. The oak-coffin burials of Bronze Age northern Europe, and most notably those of Denmark dating to about 1000 BCE, had an inner core of stones packed round the tree-trunk coffin, with a round barrow built above. Water infiltrated the inside of the mound, and, by combining with tannin from the tree trunks, created acidic conditions that destroyed the skeleton but preserved the skin (discolored like the bog bodies), hair, and ligaments of the bodies inside the coffins, as well as their clothing and such objects as birch-bark pails.

A somewhat similar phenomenon occurred with the ships that the Vikings used as coffins. The Oseberg ship in Norway, for example, held the body of a Viking queen of about 800 CE, and was buried in clay, covered by a packing of stones and a layer of peat that sealed it in and ensured its preservation.

Lake-dwellings have rivaled bog bodies in popular interest ever since the discovery of wooden piles or house supports in Swiss lakes more than a century ago. The range of preserved material is astonishing, not simply wooden structures, artifacts, and textiles but, at Neolithic Charavines in France for example, even nuts, berries, and other fruits.

Perhaps the greatest contribution to archaeology that lake-dwellings and other European wetland sites have made in recent years, however, is to provide abundant well-preserved timber for the study of tree-rings, the annual growth rings in trees, for dating purposes. In Chapter 4 we explore the breakthrough this has brought about in the establishment of an accurate tree-ring chronology for parts of northern Europe stretching back thousands of years.

Another rich source of waterlogged and preserved timbers can be found in the old waterfronts of towns and cities. Archaeologists have been particularly successful in uncovering parts of London's Roman and medieval waterfront, but such discoveries are not restricted to Europe. In the early 1980s archaeologists in New York excavated a well-preserved eighteenth-century ship that had been sunk to support the East River waterfront. Underwater archaeology itself is, not surprisingly, the richest source of all for waterlogged finds (see pp. 100–102).

The major problem with waterlogged finds, and particularly wood, is that they deteriorate rapidly when they are uncovered, beginning to dry and crack almost at once. They therefore need to be kept wet until they can be treated or freeze-dried at a laboratory. Conservation measures of this kind help to explain the enormous cost of both wetland and underwater archaeology. It has been estimated that "wet archaeology" costs four times as much as "dry archaeology." But the rewards, as we have seen above, are enormous.

The rewards in the future, too, will be very great. Florida, for example, has about 1.2 million ha (3 million acres) of peat deposits, and on present evidence these probably contain more organic artifacts than anywhere else in the world. So far the wetlands here have yielded the largest number of prehistoric watercraft from any one region, together with totems, masks, and figurines dating as far back as 5000 BCE. In the Okeechobee Basin, for instance, a first-millennium BCE burial platform has been found, decorated with a series of large carved wooden totem posts, representing an array of animals and birds. After a fire, the platform had collapsed into its pond. Yet it is only recently that wet finds in Florida have come to us from careful excavation rather than through the drainage that is destroying large areas of peat deposits and, with them, untold quantities of the richest kinds of archaeological evidence.

Study Questions

1. What is the difference between an artifact and an ecofact?
2. Why is it important for archaeologists to distinguish between cultural and natural formation processes?
3. Why is the context of an artifact so very important to archaeologists?
4. Why do inorganic materials survive better than organic materials?
5. Why are archaeologists particularly interested in wet or waterlogged sites?
6. What is experimental archaeology?

Summary

THE ARCHAEOLOGICAL EVIDENCE available to us depends on a number of important factors:

WHAT PEOPLE, PAST AND PRESENT, have done to it (cultural formation processes).

WHAT NATURAL CONDITIONS, such as soil and climate, have preserved or destroyed (natural formation processes). Inorganic materials usually survive far better than organics, but the latter can be well preserved in a range of special environments—the dry, the cold, and the waterlogged.

OUR ABILITY to find, recognize, recover, and conserve it.

WE CAN DO NOTHING about the first two factors, being at the mercy of the elements and previous human behavior. But the third factor, which is the subject of this book, is constantly improving, as we understand better the processes of decay and destruction, and design research strategies and technical aids to make the most of what archaeological evidence actually survives.

Further Reading

Good introductions to the problems of differential preservation of archaeological materials can be found in:

Aldhouse-Green, M. 2015. *Bog Bodies Uncovered: Solving Europe's Ancient Mystery*. Thames & Hudson: London & New York.

Binford, L. R. 2002. *In Pursuit of the Past: Decoding the Archaeological Record*. University of California Press: Berkeley & London.

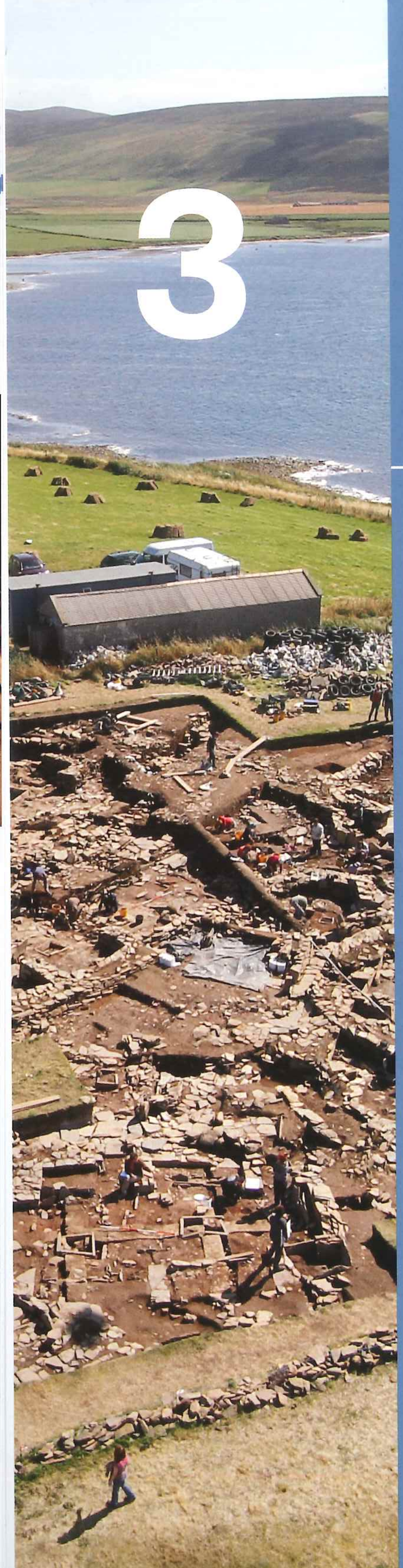
Lillie, M. C. & Ellis, S. (eds). 2007. *Wetland Archaeology and Environments: Regional Issues, Global Perspectives*. Oxbow Books: Oxford.

Menotti, F. & O'Sullivan, M. 2012. *Oxford Handbook of Wetland Archaeology*. Oxford University Press: Oxford.

Schiffer, M. B. 2002. *Formation Processes of the Archaeological Record*. University of Utah Press: Salt Lake City.

Sheets, P. D. 2006. *The Ceren Site: An Ancient Village Buried by Volcanic Ash in Central America* (2nd ed.). Wadsworth: Stamford, CT.

[See p. 345 for a list of useful websites]



3

Where?

Survey and Excavation of Sites and Features

Traditionally, archaeologists are known for finding and excavating sites, but today, while sites and their excavation do remain of paramount importance, the focus has broadened. Archaeologists have become aware that there is a great range of **off-site** or **non-site evidence**, from scatters of artifacts to such features as plowmarks and field boundaries, that provides important information about the past. The study of entire landscapes by regional survey, for example, is now a major part of archaeological fieldwork.

It should also not be forgotten that suitable evidence for study often comes from new work at sites already the subject of fieldwork. Much potentially rich and rewarding material also lies locked away in museum and institution vaults, waiting to be analyzed by imaginative modern techniques. It is only recently, for example, that the plant remains discovered in Tutankhamun's tomb in the 1920s have received thorough analysis. Yet it remains true that the great majority of archaeological research is still dependent on the collection of new material by fresh fieldwork. The main way that archaeologists find this new material—in other words new sites and features—is by survey, either on the ground or from the air.

In the early days of archaeology the next step would have been to excavate. But when archaeologists excavate a site, digging through the layers of evidence, uncovering features and removing artifacts that may have been lying undisturbed for thousands of years, it is important to remember that this is essentially a destructive act—there is just one chance to record exactly what is found and the "experiment" can never be repeated. Excavation is also very expensive, but after the digging the excavators must be prepared to put considerable time, effort, and money into the conservation and storage of their finds, and into the interpretation and publication of their results. Non-destructive means of assessing the layout of sites and features, using, for example, site **surface survey** or **remote sensing** devices, have therefore taken on a new importance, often providing enough information for archaeologists to interpret features at a site, and making large-scale excavation unnecessary.

Key Concepts
Research Design

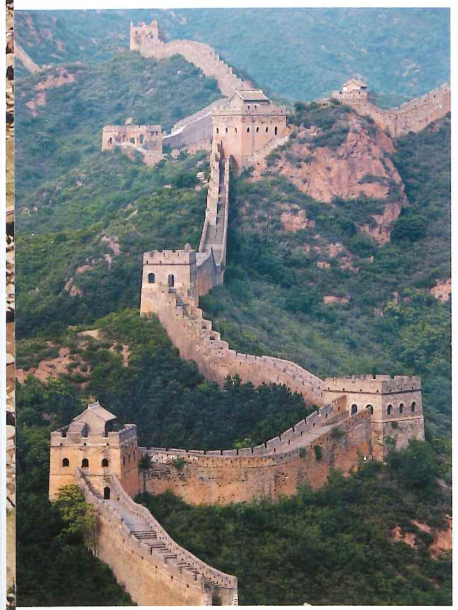
Formulation of a research strategy to resolve a particular question or test a hypothesis or idea

Collecting and recording of evidence against which to test that idea, usually by organizing a team of specialists and conducting fieldwork—whether survey or excavation or both

Processing and analysis of that evidence and its interpretation in the light of the original idea to be tested

Publication of the results in articles, books, etc.

The Great Wall of China, more than 2000 km (1250 miles) long, was begun in the third century BCE. Like the pyramids of Egypt, it has never been lost to posterity.



Although excavation does remain a very important aspect of archaeology, archaeologists are becoming increasingly aware that it should not be undertaken lightly, and that it is only absolutely vital where sites would otherwise be destroyed by modern development or natural erosion.

Before any archaeological fieldwork begins, archaeologists try to make explicit what their objectives are and what their plan of campaign will be. This procedure is commonly called devising a **research design**, which broadly has four stages (listed in the box at left). There is seldom if ever a straightforward progression through these stages. In real life the research strategy will constantly be refined as evidence is collected and analyzed. All too often, and inexcusably, publication may be neglected. But in the best-planned research the overall objective—the broad question or questions to be answered—will stand, even if the strategy for achieving it alters.

In this chapter we are focusing on stage 2 of the research process—on the methods and techniques archaeologists use to obtain evidence against which to test their ideas. We will distinguish between methods used in the discovery of archaeological sites and non-site features or artifact scatters, which include a variety of ground-based and aerial survey techniques, and those employed once those sites and features have been identified, which include detailed survey and selective excavation at individual sites.

Locating Archaeological Sites and Features

One major task of the archaeologist is to locate and record the whereabouts of sites and features. In this section we will be reviewing some of the principal techniques used to locate sites. But we should not forget that many monuments have never been lost: the massive pyramids of Egypt have always been known to succeeding generations, as has the Great Wall of China. Their exact function or purpose may indeed have aroused controversy down the centuries, but their presence, the fact of their existence, was never in doubt.

And not all those sites that were once lost were discovered by archaeologists. No one has ever made a precise count, but a significant number of sites known today were found by accident, from the decorated French cave of Lascaux, and more recently Cosquer, the underwater entrance to which was discovered by a deep-sea diver in 1985, to the amazing terracotta army of China's first emperor, unearthed in 1974 by farmers digging for a well, as well as the countless underwater wrecks first spotted by fishermen, sponge-gatherers, and sport-divers. Construction workers building new roads, subways, dams, and office blocks have made their fair share of discoveries too.

Nevertheless, it is archaeologists who have systematically attempted to record these sites, and it is archaeologists who seek out the full range of sites and features, large or small, that make up the great diversity of past landscapes. How do they achieve this?

A practical distinction can be drawn between site identification conducted at ground level (**ground survey**) and identification from the air or from space (**aerial survey**), although any one field project will usually employ both types of survey.

Ground Survey

Methods for identifying individual sites include the consultation of documentary sources and place-name evidence, but primarily actual fieldwork, whether the monitoring of building developers' progress in "applied archaeology" (see pp. 324–27), or survey in circumstances where the archaeologist is more of a free agent.

DOCUMENTARY SOURCES. In the nineteenth century, Homer's account of the Trojan Wars in his narrative poem the *Iliad* fired the imagination of German banker Heinrich Schliemann, sending him on a quest for the city of Troy; with remarkable luck and good judgment he successfully identified it in western Turkey. A more recent success story of the same kind was the location and excavation by Helge and Anne Stine Ingstad of the Viking settlement of L'Anse aux Meadows in Newfoundland, thanks in large part to clues contained in the medieval Viking sagas. Much of modern biblical archaeology concerns itself with the search in the Near East for evidence of the places—as well as the people and events—described in the Old and New Testaments. Treated objectively as one possible source of information about Near Eastern sites, the Bible can be a rich source of documentary material, but there is certainly the danger that belief in the absolute religious truth of the texts can cloud an impartial assessment of their archaeological validity.

Much research in biblical archaeology involves attempting to link named biblical sites with archaeologically known ones. Place-name evidence, however, can also lead to actual discoveries of new archaeological sites. In southwestern Europe, for example, many prehistoric stone tombs have been found thanks to old names printed on maps that incorporate local words for "stone" or "tomb."

The low mounds at L'Anse aux Meadows turned out to be the remains of huts with walls of piled turf and roofs of turf supported by a wood frame—those seen here have been reconstructed for visitors. Lack of evidence for rebuilding indicates that this was a short-lived settlement.

CULTURAL RESOURCE MANAGEMENT AND APPLIED ARCHAEOLOGY. In this specialized work—discussed more fully in Chapter 12—the archaeologist's role is to locate and record sites, in some cases before they are destroyed by new roads, buildings, or dams, or by peatcutting and drainage in wetlands.

In the USA a large number of sites are located and recorded in inventories every year under Cultural Resource Management (CRM) laws, which were considerably broadened and strengthened in the 1970s. Proper liaison with a developer should allow archaeological survey to take place in advance along the projected line of road or in the path of development. Important sites thus discovered may require excavation, and in some cases can even cause construction plans to be altered. Certain archaeological remains unearthed during the digging of subways in Rome and Mexico City, for instance, were incorporated into the final station architecture.

SURVEY. How does the archaeologist set about locating sites, other than through documentary sources and salvage work? A conventional and still valid method is to look for the most prominent remains in a landscape, particularly surviving remnants of walled buildings, and burial mounds, such as those in eastern North America or Wessex in southern Britain. But many sites are visible on the surface only as a scatter of artifacts and thus require more thorough survey—what we may call survey—to be detected.

Furthermore, in recent years, as archaeologists have become more interested in reconstructing the full human use of the landscape, they have begun to realize that there are very faint scatters of artifacts that might not qualify as sites, but that nevertheless represent significant human activity. Some scholars have suggested that these off-site or non-site areas (that is, areas with a low density of artifacts) should be located and recorded, which can only be done by **systematic survey** work involving careful sampling procedures (see p. 69). This approach is particularly useful in areas where people leading a mobile way of life have left only a sparse archaeological record, as in much of Africa.

Survey has become important for another major reason: the growth of regional studies. Thanks to the pioneering researches of such scholars as Gordon Willey in the Virú Valley, Peru, and William T. Sanders in the Basin of Mexico, archaeologists increasingly seek to study settlement patterns—the distribution of sites across the landscape within a given region. The significance of such work for the understanding of past societies is discussed further in Chapter 5. Here we may note its impact on archaeological fieldwork: it is rarely enough now simply to locate an individual site and then to survey it and/or excavate it in isolation from other sites. Whole regions need to be explored, involving a program of surveys.

In the last few decades, survey has developed from being simply a preliminary stage in fieldwork (looking for appropriate sites to excavate) to a more or less independent kind of inquiry, an area of research in its own right that can produce information quite different from that achieved by digging. In some cases excavation may not take place at all, perhaps because permission to dig was not forthcoming, or because of a lack of time or funds—modern excavation is slow and costly, whereas survey is cheap, quick, relatively non-destructive, and requires only maps, compasses, and tapes. Usually, however, archaeologists deliberately choose a surface approach as a source of regional data in order to investigate specific questions that interest them and that excavation could not answer.

Survey encompasses a broad range of techniques: no longer just the identification of sites and the recording or collection of surface artifacts, but sometimes also the sampling of natural and mineral resources, such as stone and clay. Much survey today is aimed at studying the spatial distribution of human activities, variations between regions, changes in population through time, and relationships between people, land, and resources.

SURVEY IN PRACTICE. For questions formulated in regional terms, it is necessary to collect data on a regional scale, but in a way that provides a maximum of information for a minimum of cost and effort. First, the region to be surveyed needs to be defined: its boundaries may be either natural (such as a valley or island), cultural (such as the extent of an artifact style), or purely arbitrary, though natural boundaries are the easiest to establish.

The area's history of development needs to be examined, not only to familiarize oneself with previous archaeological work and with the local materials but also to assess the extent to which surface material may have been covered or removed by natural processes. There is little point, for example, in searching for prehistoric material in sediments only recently laid down by river action. Other factors may have affected surface evidence as well. In much of Africa, for example, great animal herds or burrowing animals will often have disturbed surface material, so that the archaeologist may be able to examine only very broad distribution patterns. Geologists and environmental specialists can generally provide useful advice.

This background information will help determine the intensity of the surface coverage of the survey. Other factors to take into consideration are the time and resources available, and how easy it is actually to reach and record an area. Arid (dry) and semi-arid environments with little vegetation are among the best for this type of work, whereas in equatorial rainforest, survey may be limited to soil exposures along river banks, unless time and labor permit the cutting of trails. Many regions, of course, contain a variety of landscapes, and more than one strategy for survey is often needed. Moreover, it must be remembered that some archaeological phases (with easily distinguishable artifacts or pottery styles, for example) are more visible than others, and that mobile **hunter-gatherer** or pastoral communities leave a very different—and generally sparser—imprint on the landscape than do agricultural or urban communities. All these factors must be taken into account when planning search patterns and recovery techniques.

There are two basic kinds of survey: the unsystematic and the systematic. The former is the simpler, involving walking across each part of the area (for example, each plowed field), scanning a strip of ground, collecting or examining artifacts on the surface, and recording their location together with that of any surface features. It is generally felt, however, that the results may be biased: walkers have an inherent desire to find material, and will therefore tend to concentrate on those areas that seem richer, rather than obtaining a sample representative of the whole area that would enable the archaeologist to assess the varying distribution of material of different periods or **types**. On the other hand, the method is flexible, enabling the team to focus greater efforts on the areas that have proved most likely to contain sites or finds.

Much modern survey is done in a systematic way, employing either a grid system or a series of equally spaced transects (straight paths) across the area. The area to be searched is divided into sectors, and these are walked systematically. Because of the constraints of time and money, it is often not possible to survey the entirety of an area in this way, so archaeologists have to employ a sampling strategy (see box opposite) where only certain sectors or transects are picked to be searched. Systematic survey also makes it easier to plot the location of finds since an exact position is always known.

For example, from 1992 to 1998 the Sydney Cyprus Survey Project, led by Bernard Knapp and Michael Given of the University of Glasgow in Scotland, undertook an intensive archaeological survey in a 75-sq. km (29-sq. mile) area in the northern Troodos Mountains of Cyprus. This is an area famed for its copper sulphide ore deposits, exploited as early as the Bronze Age. The project examined the human transformation of the landscape over a period of 5000 years and placed it in its regional context. A first requirement for the systematic intensive survey strategy was good maps. Enlarged aerial photographs were used to create a base map of the entire survey region. The main survey approach was a transect survey with the aim of obtaining a broad systematic sample of the area; areas with extensive evidence of early industrial, agricultural, or settlement activities, and locales with high densities of artifacts, were investigated more closely. It took the team around 6 years to survey just 10 percent of the area. The survey identified 11 Special Interest Areas and 142 Places of Special Interest for investigation. The count in the field totalled 87,600 sherds of pottery, 8111 tile fragments, and 3092 lithics. About one third of these were collected and analyzed and entered into the project's database.

Results tend to be more reliable from long-term projects that cover a region repeatedly, since the visibility of sites and artifacts can vary widely from year

Key Concepts
Locating Sites Using Ground Survey

Documentary Sources: mainly of use in locating Classical, biblical, and relatively recent sites

Cultural Resource Management: sites in areas that may be under threat from development are located, recorded, and sometimes excavated prior to their destruction

Survey: surveys can be either **unsystematic** (where archaeologists randomly search an area on foot for artifacts or evidence of features) or, more commonly, **systematic** (where archaeologists walk an area using carefully laid out grid systems or transects). A **sampling strategy**, where only a representative part of an area is actually searched, is often used to save time and money. Small-scale excavations can be undertaken to check survey results

Sampling Strategies

Archaeologists cannot usually afford the time and money necessary to investigate the whole of a large site or all sites in a given region, so they need to sample the area being researched. In a ground survey this will involve using one of the methods described below to choose a number of smaller areas to be searched, with the objective being to draw reliable conclusions about the whole area.

The way archaeologists use sampling is similar to the way it is employed in public opinion polls, which make generalizations about the opinions of millions of people using samples of just a few thousand. Surprisingly often the polls are more or less right. This is because the structure of sampled populations is well known—for example, we know their ages and occupations. We have much less background information to work with in archaeology, so must be more careful when we extrapolate generalizations from a sample. But as with opinion polls, in archaeological work the larger and better designed the sample, the more likely the results are to be valid.

Some sites in a given region, however, may be more accessible than others, or more prominent in the landscape, which may prompt a more informal sampling strategy. Long years of experience in the field will also give some archaeologists an intuitive "feel" for the right places to undertake work.

Types of Sampling

The simplest form is a simple random sample, where the areas to be sampled are chosen using a table of random numbers. The nature of random numbers, however, results in some areas being allotted clusters of squares, while others remain untouched—the sample is, therefore, inherently biased.

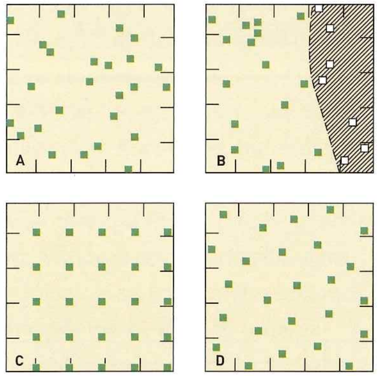
One answer is the stratified random sample, where the region or site is divided into its natural zones (strata, hence the technique's name), such as cultivated land and forest, and squares are then chosen by the same random-number procedure, except that each zone has the number of squares proportional to its area. Thus, if forest comprises 85 percent of the area, it must be allotted 85 percent of the squares.

Another solution, systematic sampling, entails the selection of a grid of equally spaced locations—e.g. choosing every other square. By adopting such a regular spacing one runs the risk of missing (or hitting) every single example in an equally regular pattern of distribution—this is another source of potential bias.

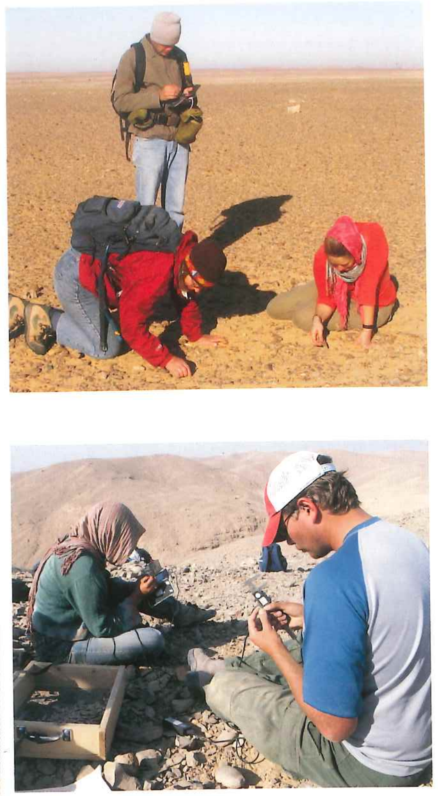
A more satisfactory method is to use a stratified unaligned systematic sample, which combines the main elements from the other techniques. In collecting artifacts from the surface of a large tell or mound site at Girik-i-Haciyan in Turkey, Charles Redman and Patty Jo Watson used a grid of 5-m squares, but orientated the grid along the site's main N-S/E-W axes. The squares were selected with reference to these axes. The strata chosen were blocks of nine squares (3 x 3), and one square in each block was picked for excavation by selecting its N-S/E-W coordinates randomly.

Transects vs Squares

In large-scale surveys, transects (straight paths) are sometimes preferable to squares, particularly in areas of dense vegetation, such as tropical rainforest. It is far easier to walk along a path than to locate accurately and investigate a square. In addition, transects can easily be segmented into units, whereas it may be difficult to locate or describe a specific part of a square; transects are equally useful not merely for finding sites but also for recording artifact densities across the landscape. On the other hand, squares have the advantage of exposing more area to the survey, thus increasing the probability of intersecting sites. A combination of the two methods is often best: using transects to cover long distances, but squares when larger concentrations of material are encountered.



Types of sampling: (A) simple random; (B) stratified random; (C) systematic; (D) stratified unaligned systematic.



Systematic surface survey in the Egyptian desert: using GPS, archaeologists sample small areas spaced 100 m (330 ft.) apart, looking for Middle Paleolithic stone tools (top). Finds are then processed in the field using electronic calipers and handheld computers (above).

to year or even with the seasons, thanks to vegetation and changing land-use. In addition, members of field crews inevitably differ in the accuracy of their observations, and in their ability to recognize and describe sites (the more carefully we look, and the more experience we have, the more we see); this factor can never be totally eliminated, but repeated coverage can help to counter its effects. The use of standardized recording forms makes it easy to put the data into a computer at a later stage; alternatively, handheld computers can be used in the field.

Finally, it may be necessary or desirable to carry out small excavations to supplement or check the surface data (particularly for questions of chronology, contemporaneity, or site function), or to test hypotheses that have arisen from the survey. The two types of investigation are complementary, not mutually exclusive. Their major difference can be summarized as follows: excavation tells us a lot about a little of a site, and can only be done once, whereas survey tells us a little about a lot of sites, and can be repeated.

EXTENSIVE AND INTENSIVE SURVEY. Surveys can be made more extensive by combining results from a series of individual projects in neighboring regions to produce very large-scale views of change in landscape, land-use, and settlement through time—though, as with individual members of a field crew, the accuracy and quality of different survey projects may vary widely. Alternatively survey can be made more intensive by aiming at total coverage of a single large site or site-cluster. It is a paradox that some of the world's greatest and most famous archaeological sites have never, or only recently, been studied in this way, since attention has traditionally focused on the grander monuments rather than on any attempt to place them within even a local context. At Teotihuacan, near Mexico City, a major mapping project initiated in the 1960s has added hugely to our knowledge of the area around the great pyramid-temples (see pp. 82–84).

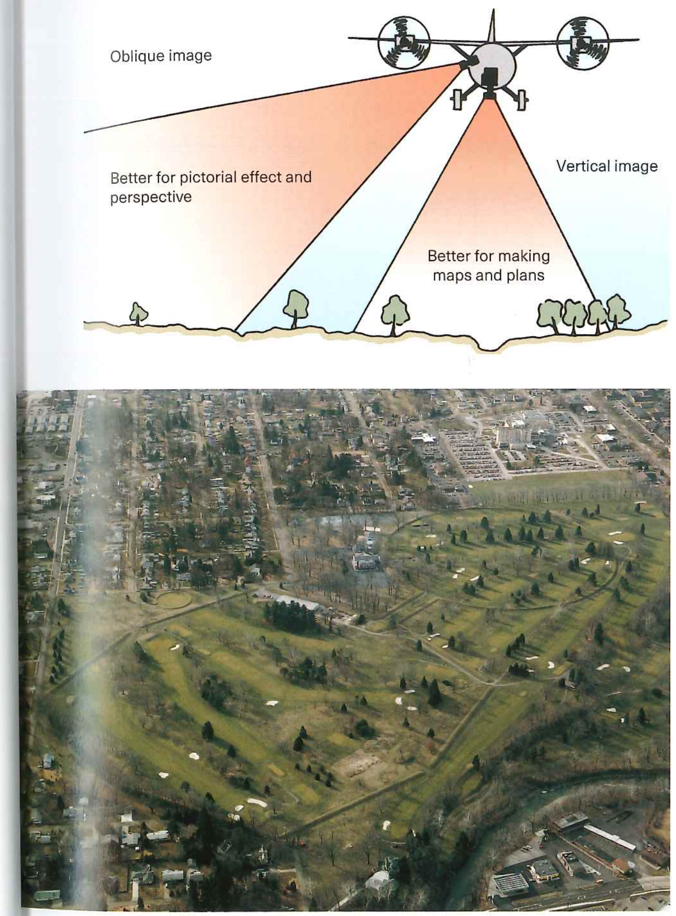
Ground survey has a vital place in archaeological work, and one that continues to grow in importance. In modern projects, however, it is usually supplemented (and often preceded) by survey from the air, one of the most important advances made by archaeology in the twentieth century. In fact, the availability of air photographs can be an important factor in selecting and delineating an area for ground survey.

Aerial Survey

Archaeological survey using airborne or spaceborne remote sensing can be divided into two component parts: data collection, which comprises taking photographs or images from aircraft or satellites; and data analysis, in which such images are analyzed, interpreted, and (often) integrated with other evidence from field survey, ground-based remote sensing, or documentary evidence. From the viewpoint of the photo interpreter or image analyst there is little difference between satellite images, multispectral/hyperspectral data, and traditional air photographs other than that of scale and resolution. The source itself is irrelevant and these data will collectively be referred to as "aerial images."

Millions of aerial images have already been taken: some of these are available for consultation in specialist libraries, and a lesser quantity is freely available online. Most result from "area survey" in which aerial images are taken in overlapping series to cover predefined areas, and a small number are taken each year by archaeologists who undertake prospective surveys using a light aircraft. It must be stressed that aerial images, even those resulting from prospective survey, are used for a wide range of archaeological purposes, from the discovery and recording of sites, to monitoring changes in them through time, photographing buildings, urban (and other) development—and, in fact, recording almost anything that "may not be there tomorrow." Nevertheless, the taking and analysis of aerial images from aircraft or satellite have led to a large number of archaeological discoveries, and the tally grows every year.

Aerial photographs are of two types: oblique and vertical. Obliques are easier to view and understand than verticals but may present more difficulty to the interpreter, who must transform the information to plan views. The photo (bottom) is an oblique aerial photograph of Newark earthworks, Ohio. An octagon and circle joined by a small strip of land are clearly visible, as are the small mounds just inside the octagon's corners.



HOW ARE AERIAL IMAGES USED? Images taken from the air are merely tools; they are means to an end. Images do not themselves reveal sites—it is the image taker and the interpreter who do so, by examination of the terrain and the pictures. These are specialized skills. Long experience and a keen eye are needed to differentiate archaeological traces from other features, such as vehicle tracks, old river beds, and canals. Indeed, most military intelligence units during the final years of World War II had archaeologists on their staff as interpreters of air photographs.

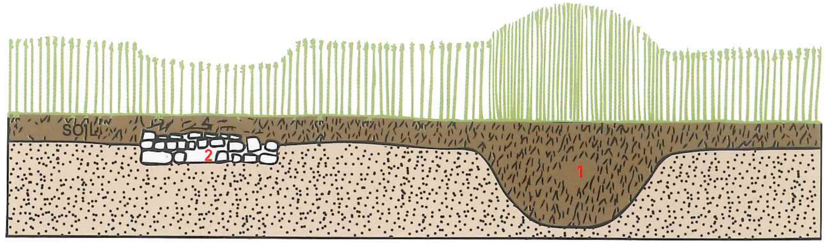
Aerial images are of two types: oblique and vertical. Each has its advantages and drawbacks, but oblique images have usually been taken of sites observed from the air by an archaeologist and thought to be of archaeological significance, whereas most vertical images result from non-archaeological surveys (for instance, cartographic). Both types can be used to provide overlapping stereoscopic pairs of prints that enable a scene to be examined in three dimensions and so add confidence to any interpretation. Stereoscopic pictures taken of the ancient city of Mohenjodaro in Pakistan from a tethered balloon, for example, have enabled photogrammetric—accurately contoured—plans to be made of its surviving structures. Similarly, large areas can be surveyed with overlapping images, which are then processed into a very accurate photogrammetric base map of all the archaeological evidence identified from the air. Analytical ground survey can then proceed on a much surer basis.

Oblique images are often targeted on archaeological features that may show clearly, while vertical images may need to be more thoroughly examined by an interpreter seeking such information. Both types of image can be rectified or georeferenced using computer programs. This removes the scale and perspective distortions of oblique images and can correct for tilt and distortion in vertical views. After computer transformation the resulting image may be layered in graphics software or a **GIS** (**Geographic Information System**—see pp. 79–82) and interpreted by overdrawing the archaeological features that have been identified.

The clearest way to indicate what a person has identified on aerial images is to produce a map that shows their interpretation. Such maps have many uses: to provide a guide for conservation and management; to show the relations between sites and their environment; to give context for field-walking; and to show accurate locations of archaeological features for ground surveys. For example, although it was known that prehistoric roadways existed within Chaco Canyon in the American Southwest, it was only when a major aerial survey project was undertaken by the National Park Service in the 1970s that the full extent of the road system was appreciated. Using the extensive coverage provided by the aerial images, a whole network of prehistoric roadways was identified and mapped. This was followed by selective ground surveys and some archaeological investigation. From the aerial coverage it has been estimated that the network, thought to date to the eleventh and twelfth centuries CE, extends to some 2400 km (1500 miles), though of this only 208 km (130 miles) have been verified by examination at ground level.

IDENTIFYING ARCHAEOLOGICAL SITES FROM ABOVE. Successful identification of archaeological sites on aerial images requires knowledge of the types of feature that might be expected and of the post-depositional (formation) processes that may have affected them since their abandonment. In general, for a site to be detected by any remote sensing method, it needs to have altered the soil or subsoil. These alterations can vary between holes cut into the ground (such as ditches and pits) and features placed upon it (such as banks, mounds, and walls), and these may now survive in relief—i.e. as lumps and bumps on the surface—or be completely buried under leveled cultivated land.

It is important to remember that similar holes and bumps may have been caused by natural disturbances or from recent human activity (leveling field boundaries or digging small quarries, for example), and an experienced image analyst should be able to identify these, and distinguish them from archaeological features, in an area with which they are familiar.



(Right) How crop-marks are formed: crops grow taller and more thickly over sunken features, such as ditches (1), and show stunted growth over buried walls (2). Such variations may not be obvious at ground level, but are often visible from the air, as different-colored bands of vegetation.

(Below) Features in relief on the left of this photograph show the remains of a Romano-British farm at Holbeach in the East Anglian fens of eastern England. Ditches were cut to form field and other property boundaries, flank tracks, and drain the land. These features continue into the field on the right, where they have been filled and are now under a level field growing cereal. The track that runs across the upper part of the left field can be seen to the right, marked by a darker band where crop growth has been boosted by the deeper soil that fills the former ditch. Silted channels of former watercourses show as broad light-toned bands where the crop is growing sparsely in poorer soil. These differences illustrate how changes in crop growth can mark subsurface features.

Aerial images record relief sites through a combination of highlight and shadow, so the time of day and season of the year are important factors in creating the most informative image of such sites. It may be necessary to obtain images taken at different times to maximize the information visible through light and shade, although such new techniques as **LIDAR** (**Light Detection and Ranging**)—also known as **ALS** (**Airborne Laser Scanning**)—allow a viewer to move the position of the sun at will (see overleaf).

In some parts of the world, archaeological sites have been leveled and now lie in arable land. Although these sites have suffered a degree of destruction (and many continue to be destroyed by annual cultivation), these landscapes can be rewarding when examined on aerial images. In summer months, crops may grow differently above different soils and above different depths of soil and can thus indicate the presence of archaeological and natural features. These crop differences, sometimes called crop-marks, have been the main way in which aerial survey has recorded the presence of archaeological features; indeed, more features have been discovered via crop-marks than with any other form of prospection.

RECENT DEVELOPMENTS. New technology is having an impact on aerial survey in different ways. Although the majority of existing images have been taken on film—black and white, color, or false color infrared—primarily digital sensors are now used in precision vertical cameras and the handheld cameras used by airborne archaeologists. Modern flying, be this to capture a series of parallel overlapping strips of vertical photographs or to examine a chosen area by an archaeologist, is usually planned and recorded to take advantage of GPS (Global Positioning System) navigation.

The application of digital image analysis is now a basic element in the survey archaeologist's toolkit. Just as in excavation and aerial survey, remote sensing research must be well planned and well executed, using a comprehensive methodology. Automated and semi-automated image analysis is commonplace in disciplines such as environmental remote sensing, where work is undertaken on extensive datasets. Field observations, archaeological interpretation, and human expertise, however, remain indispensable.

The use of drones (or Unmanned Aerial Vehicles—UAVs) has become increasingly popular. Small battery-powered drones carry a range of instruments and cameras and can take scores of pictures that produce an overlapping set, recording a site, excavation, or feature from all possible angles. Structure from Motion (SfM) software can combine these images to produce a 3D model that can be georeferenced and used for making accurate drawings.

LIDAR AND SLAR. Use of LIDAR has proved extremely valuable in the past few years. This technique uses an aircraft (or drone), whose exact position is known through GPS, carrying a laser scanner that rapidly pulses a series of beams to the ground. By measuring the time taken for these to return to the aircraft an accurate picture of the ground in the form of a digital elevation model (or digital surface model) is created. Software used with LIDAR provides archaeologists with two great advantages over conventional aerial photography: tree canopies can be eliminated by switching off the "first return," so the sensor can see into woodland; and the angle and azimuth of the sun can be moved to enable ground features to be viewed under optimal (and sometimes naturally impossible) lighting. Both facilities have been used to advantage in England where new sites—mostly enlargements to field systems—have been found, and locational corrections made to the existing record of the landscape around Stonehenge.

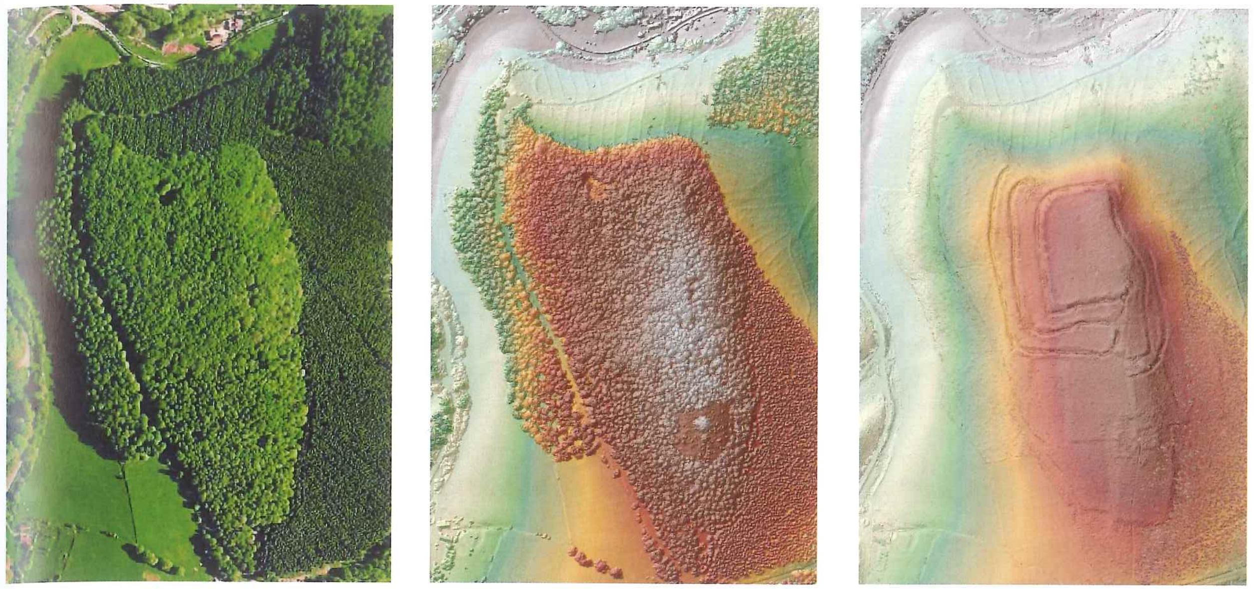
Key Concepts
Locating Sites Using Aerial Survey

Aerial Photography: aerial photographs can be either oblique (better for pictorial effect and perspective) or vertical (better for maps and plans). Features visible from the air are classed as either earthworks, soil-marks, or crop-marks

Drones: Unmanned Aerial Vehicles (UAVs) are now commonly used to produce overlapping sets of pictures and 3D models of sites

LIDAR: a new laser-scanning technique that can accurately map whole landscapes, even beneath tree cover. Resulting digital plans can be manipulated to reveal such subtle features as the remains of ancient field systems

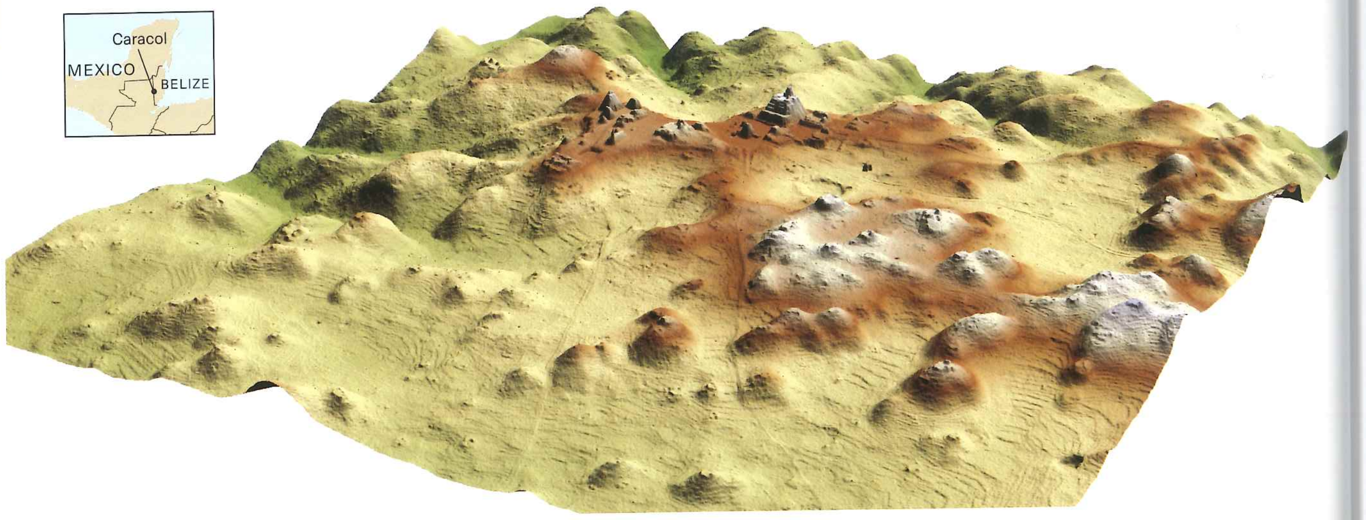
Satellite Photography: useful primarily at the largest scales, for example mapping very large sites or tracing ancient irrigation systems



LIDAR in operation: the Iron Age hillfort of Welshbury in the Forest of Dean, England, is almost invisible in conventional aerial photographs (left). The initial LIDAR image shows little improvement (center) but once reflections from leaves and trees (the "first return") have been filtered out using a software algorithm the earthworks are clearly visible (right).

An excellent example of the practical application of LIDAR to an archaeological site comes from Caracol, a Maya city in Belize that flourished between 550 and 900 CE. Arlen and Diane Chase of the University of Nevada have been excavating at this site for more than twenty-five years, and during that time, despite the dense tropical forest, had managed to map 23 sq. km (9 sq. miles) of settlement. Survey from the air, however, enabled them within a few weeks to surpass the results of those twenty-five years, by covering a far larger area and discovering that the city actually extended over 177 sq. km (68 sq. miles). Images taken at the end of the dry season in 2009 took about four days (twenty-four hours of flight time) to capture, the small aircraft passing back and forth over the city, and making more than 4 billion measurements of the landscape below. This was then followed by three weeks of analysis by remote sensing experts.

Caracol's entire landscape can now be viewed in 3D, which has led to the discovery of new ruins, agricultural terraces, and stone causeways leading to more distant settlements (see illustration overleaf). This was the first application of LIDAR to such a large archaeological site, and it is clear that the technique will radically transform research on sites in challenging environments of this kind. However, just as only excavation can verify the findings of ground-based remote sensing, so the data produced from the air at Caracol will need to be confirmed on the ground.



Only a tiny proportion of the city of Caracol's total area has been cleared of jungle—the photo (top) shows Plaza A at the site, closely surrounded by thick vegetation. A 3D LIDAR projection of the site (above), however, reveals the features beneath the jungle canopy; agricultural terraces show up as ripples in valleys and hillsides.

Another remote sensing technique, Side-Looking Airborne Radar (SLAR), has yielded evidence suggesting that Maya agriculture was more intensive than previously imagined. The technique involves recording in radar images the return of pulses of electromagnetic radiation sent out from a flying aircraft. Since radar will penetrate cloud cover and to some extent dense rainforest, Richard Adams and his colleagues were able to use SLAR from a high-flying NASA aircraft to scan 80,000 sq. km (31,200 sq. miles) of the Maya lowlands. The SLAR images revealed not only ancient cities and field systems, but also an enormous lattice of gray lines, some of which may have been canals, to judge by subsequent inspections by canoe. If field testing reveals that the canals are ancient, it will show that the Maya had an elaborate irrigation and water transport system.

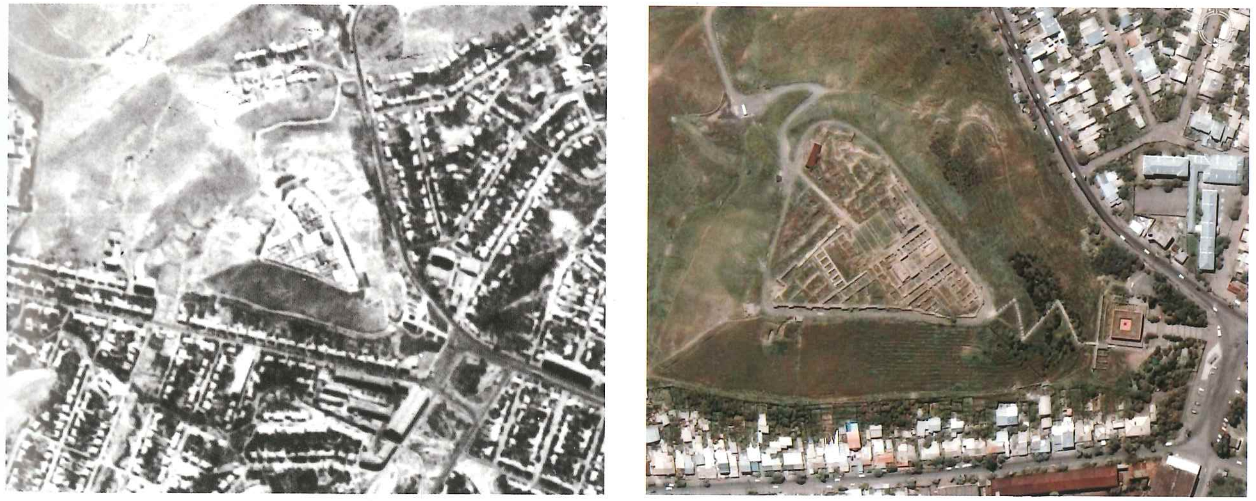
SATELLITE IMAGERY AND GOOGLE EARTH. It is now routine to access Google Earth and use the high-resolution air photos and satellite cover there, or to buy copies of them. The high-resolution images available from the IKONOS (about 1 m resolution), QuickBird (60 cm), and GeoEye (40 cm) satellites offer data comparable with aerial photographs, while Google Earth has basic world cover from NASA's LANDSAT series (28.5 m) but includes blocks of IKONOS, QuickBird, and GeoEye images, some other satellite imagery, and some conventional aerial photographs. The imagery can be imported into remote sensing image-processing software, as well as into GIS packages for analysis.

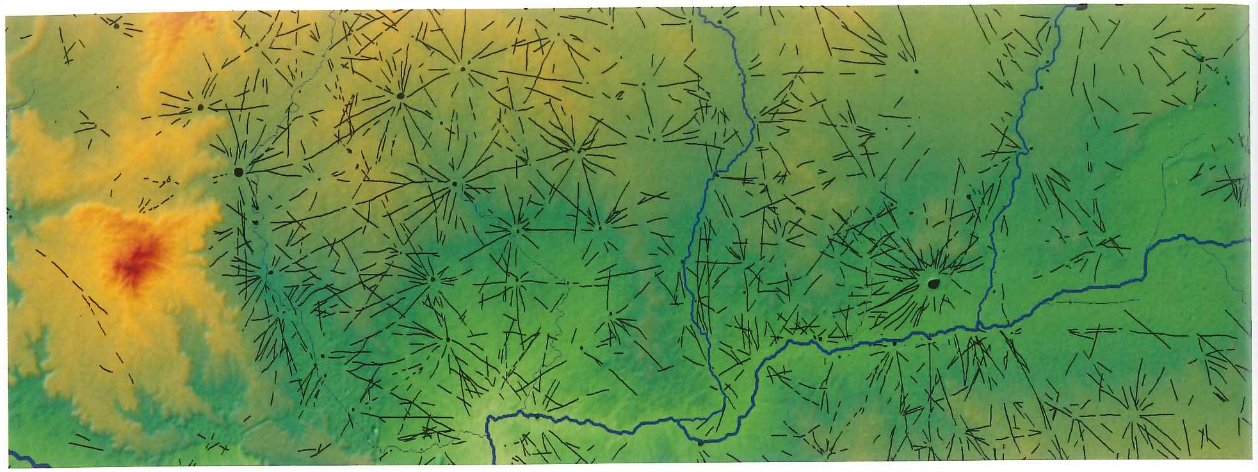
The introduction of Google Earth has been a true aerial revolution, since it offers every archaeologist the opportunity to examine the ground and look for archaeological sites—for example, it is being used by paleontologists in Africa to hunt for fossils, and in 2008 it revealed 500 new caves in South Africa, including the one that yielded the bones of ***Australopithecus** sediba* (see p. 135); and hundreds of new archaeological sites in Afghanistan are also being discovered by this method. But the same rules of visibility apply to those images as they do to conventional aerial photos, and absence of evidence on one particular date is not evidence of absence. Most users have never been trained to interpret such images and many expect sites to be visible at all times.

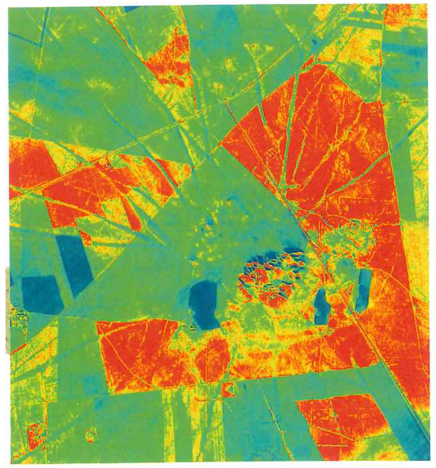
QuickBird and IKONOS/GeoEye images can be taken to order, although the minimum cost may be high for some archaeological projects. Libraries of older images are lower in price. In parts of the world where maps are still regarded as secret or do not exist, an up-to-date satellite image may be the only way to provide a base map for archaeological investigations.

Much use has been made of the Cold War CORONA satellite photographs (at best about 2 m resolution), and these too provide a useful base map and allow provisional interpretation of sites that can later be checked by

Two satellite images of the Urartian citadel of Erebuni, near Yerevan, Armenia, founded in 782 BCE: on the left, with resolution of about 2 m (10 ft.), is an image from the American CORONA series taken in 1971; on the right is a higher resolution screen shot from Google Earth of a QuickBird image taken in 2006. Both images are displayed with south to the top so that shadows assist photo-reading of topography and structures.







CORONA photograph (above, with false color added) of radial trackways around Tell Brak, northeastern Syria, dating from around 2600 to 2000 BCE. Thousands of miles of trackways in the region have been mapped by Jason Ur using a GIS database. The area shown at top is about 80 km (50 miles) wide. Tell Brak is at center right, north of the Khabur River.

fieldwork—for example, CORONA images have led to the detection and detailed mapping of numerous kinds of archaeological remains, such as ancient roads, ruins, irrigation networks, and so forth.

Jason Ur of Harvard University has used CORONA imagery to examine linear trackways ("hollow ways") across northern Mesopotamia (Syria, Turkey, and Iraq). These broad and shallow features were formed over time as people walked between settlements, and from settlements to fields and pasture. Because depressed features collect moisture and vegetation, they are easily visible on CORONA images. Some 6025 km (3750 miles) of premodern features have been identified, primarily dating to a phase of Bronze Age urban expansion from around 2600 to 2000 BCE. Most commonly, trackways radiated out 2–5 km (1–3 miles) from sites, in a spoke-like pattern. Although there were several major centers, all movement was done by moving from place to place; no direct tracks existed between the major centers. From that we can deduce that political centralization and authority was probably weak.

OTHER SATELLITE TECHNIQUES. Another recent addition to the archaeologist's arsenal is SAR (Synthetic Aperture Radar), in which multiple radar images (usually taken from space, but also from aircraft) are processed to yield extremely detailed high-resolution results that can provide data for maps, databases, land-use studies, and so forth. SAR records height information and can provide terrain models of territory being surveyed. One of its many advantages is that, unlike conventional aerial photography, it provides results day or night and regardless of weather conditions. It can be used with multispectral data from satellites to make inventories of archaeological sites in a survey area—a rapid, non-destructive alternative to surface survey that does not involve the collection of artifacts and can thus save a great deal of time and effort in some circumstances.

A satellite image of the huge ancient site of Angkor in Cambodia.

The international Greater Angkor Project has found that the vast ruins of the 1000-year-old temple complex of Angkor in northern Cambodia may cover an area of up to 3000 sq. km (11,500 sq. miles). The ruins, shrouded in dense jungle and surrounded by landmines, have been the subject of studies using high-resolution SAR imagery obtained from NASA satellites. The resulting dark squares and rectangles on the images are stone moats and reflecting pools around the temples. The most important discovery for archaeologists so far has been the network of ancient canals surrounding the city (visible as light lines) that irrigated rice fields and fed the pools and moats. They were probably also used to transport the massive stones needed for constructing the complex.

ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer) is an imaging instrument that flies on Terra, a satellite launched in 1999 as part of NASA's Earth Observing System (EOS), and is used to obtain detailed maps of land surface temperature, reflectance, and elevation.

Satellite remote sensing projects carried out by those with backgrounds in both remote sensing and archaeology have much to offer, but satellite archaeology should not be regarded as a substitute for archaeological excavation or survey work. It is just one among a number of tools that archaeologists may want to employ in their research. Besides revealing the presence of (sub)surface archaeological features (even in areas previously surveyed), satellite remote sensing can place archaeological sites in a much larger context, showing past social landscapes in all their complexity and helping greatly with quality assessment. Analysis of satellite imagery may further aid in determining where to excavate and may precede archaeological survey. Archaeologists will therefore need to rethink their surveying and excavation strategies in light of this new information, especially as image resolution continues to increase.

Geographic Information Systems

The standard approach to archaeological mapping is now the use of Geographic Information Systems (GIS), described in one official report as "the biggest step forward in the handling of geographic information since the invention of the map." A GIS is a collection of computer hardware and software and of geographic data, designed to obtain, store, manage, manipulate, analyze, and display a wide range of spatial information. A GIS combines a database with powerful digital mapping tools. GIS developed out of computer-aided design and computer-aided mapping (CAD/CAM) programs during the 1970s. Some CAD programs, such as AutoCAD, can be linked to commercial databases and have proved valuable in allowing the automatic mapping of archaeological sites held in a computer database. A true GIS, however, also incorporates the ability to carry out a statistical analysis of site distribution, and to generate new information.

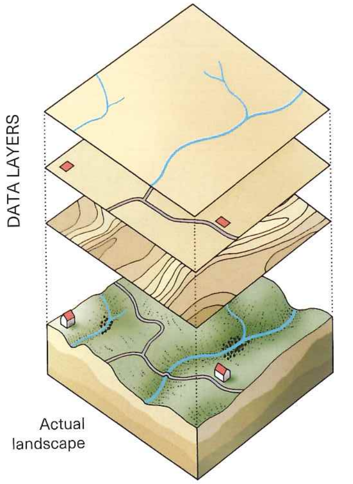


Diagram showing possible GIS data layers: from top to bottom, drainage, human activity, and relief.

A GIS may include an enormous amount of topographic and environmental data on relief, communications, hydrology, etc. To make the information easier to handle, it can be divided into different layers, each representing a single variable (see illustration at left). Archaeological data may themselves be split into several layers, often so that each layer represents a discrete time-slice. As long as they can be spatially located, many different types of data can be integrated, including site plans, satellite images, aerial photographs, geophysical survey, as well as maps. A good example of many different types of data being incorporated into a GIS is the Giza Plateau Mapping Project in Egypt (see box opposite).

The ability to incorporate aerial imagery can be particularly valuable for site survey, as it can provide detailed and current land-use information. Many topographic data already exist in the form of digital maps that can be taken directly into a GIS. Knowing exact ground coordinates is essential in archaeological practice for mapping purposes and learning about distribution patterns. This is done by means of a handheld GPS, which allows archaeologists to map their ground position (in some cases to within as little as 3 cm) by connecting to a global satellite system. A minimum of four satellites has to be communicating with the GPS to provide close X and Y data, which can display the received information in longitude/latitude (degrees, minutes, seconds), or to a UTM (Universal Transverse Mercator) coordinate system that provides data in eastings and northings. These data are extremely useful where a region is unmapped, or where the maps are old or inaccurate.

Once the basic outlines of a site have been mapped with reasonable accuracy by means of the GPS, and control points placed around the site, standard practice is to use a **total station** to record its more detailed features to a greater degree of accuracy. This instrument is an electronic theodolite integrated with an electronic distance meter, used to read distances to a particular point. Angles and distances are measured from the total station to points under survey and the coordinates (X, Y, Z, or northing, easting, and elevation) of the surveyed points relative to the total station position are calculated. These data can then be downloaded from the total station to a computer to generate a map of the surveyed area. All the information is recorded and then submitted as GIS data to the client or sponsoring organization of the work as a matter of course.

Once data are stored within a GIS it is relatively straightforward to generate maps on demand, and to query the database to select particular categories of site to be displayed. Individual map layers, or combinations of layers, can be selected according to the subject under investigation.

One of the earliest, and most widespread, uses of GIS within archaeology has been the construction of predictive models of site locations. Most

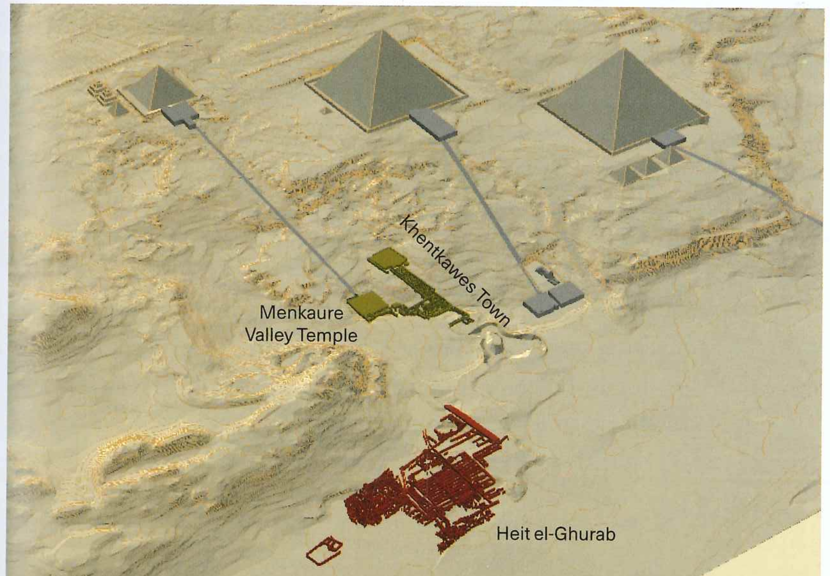
Survey and Excavation on the Giza Plateau

For nearly thirty years American Egyptologist Mark Lehner has been systematically exploring Egypt's Giza Plateau in an effort to find the settlements that housed the workforce that built the pyramids. To the south of the Great Sphinx, 4500-year-old paved streets have been uncovered, as well as various buildings, from barracks to bakeries. The Giza Plateau Mapping Project (GPMP) has so far exposed a vast urban center attached to the pyramids, sometimes known as the "Lost City of the Pyramid Builders."

Directed by Camilla Mazzucato and Rebekah Miracle, GIS is being used to integrate all the project's drawings, forms, survey data, and artifact databases into a single organized digital archive. This enables the team to map patterns of architecture, burials, artifacts, and other materials, such as foodstuffs: for example, it has been found that the people who resided in the bigger houses ate the best meat (beef) and fish (perch), while the others ate more pig and goat. Color-coded graphs and charts can be produced, representing the densities and distributions of various artifact types in different areas, buildings, rooms, or even features.

Data collected over almost 30 years, incorporated in the GIS:

- over 6000 field drawings
- over 19,000 archaeological features
- survey and remote sensing data
- aerial and satellite imagery
- historical maps
- artifact/ecofact distribution information



(Above left) The Giza Plateau Mapping Project began with an extremely accurate survey of the cultural and natural features of the entire area. The survey grid is centered on the Great Pyramid.

(Left) Using digitized 1-meter contours of the plateau and CAD data depicting the architectural components of the pyramid complex, the GPMP GIS team created a nearly three-dimensional surface called a TIN, or triangulated irregular network, over which they can lay other data layers, such as maps. Here (left), the GPMP survey grid is draped over the surface of the plateau. The "Lost City of the Pyramid Builders," Heit el-Ghurab, is clearly visible in the foreground.

of the development of these techniques has taken place within North American archaeology, where the enormous spatial extent of some archaeological landscapes means that it is not always possible to survey them comprehensively. The underlying premise of all predictive models is that particular kinds of sites tend to occur in the same kinds of place. For example, certain settlement sites tend to occur close to sources of fresh water and on southerly aspects, because these provide ideal conditions in which humans can live (not too cold, and within easy walking distance of a water source). Using this information it is possible to model how likely a given location is to contain an archaeological site from the known environmental characteristics of that location. In a GIS environment this operation can be undertaken for an entire landscape, producing a predictive model map for the whole area.

An example was developed by the Illinois State Museum for the Shawnee National Forest in southern Illinois. It predicts the likelihood of finding a prehistoric site anywhere within the 91 sq. km (35 sq. miles) of the forest by using the observed characteristics of the 68 sites that are known from the 12 sq. km (4.6 sq. miles) that have been surveyed. A GIS database was constructed for the entire area and the characteristics of the known sites were compared with the characteristics of the locations known not to contain sites. This resulted in a model that can be used to predict the likelihood that any location with known characteristics will contain a prehistoric site.

Assessing the Layout of Sites and Features

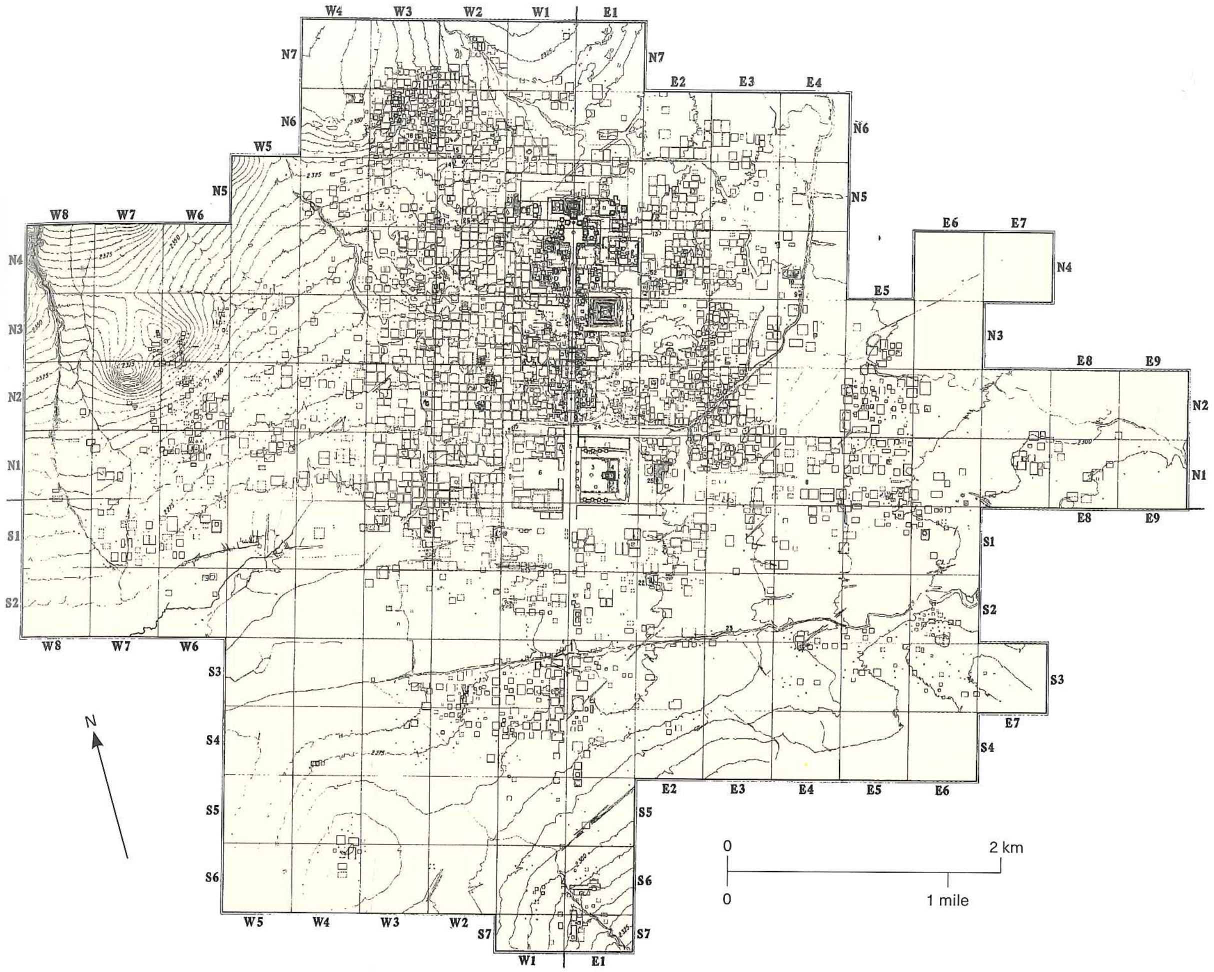
Finding and recording sites and features is the first stage in fieldwork, but the next stage is to make some assessment of site size, type, and layout. These are crucial factors for archaeologists, not only for those who are trying to decide whether, where, and how to excavate, but also for those whose main focus may be site management, the study of settlement patterns, site systems, and **landscape archaeology**, and who are not planning to carry out any excavation.

We have already seen how aerial images may be used to plot the layout of sites as well as helping to locate them in the first place. What are the other main methods for investigating sites without excavating them?

Site Surface Survey

The simplest way to gain some idea of a site's extent and layout is through a site surface survey—by studying the distribution of surviving features, and recording and possibly collecting artifacts from the surface.

The Teotihuacan Mapping Project, for instance, used site surface survey to investigate the layout and orientation of the city, which had been the largest and most powerful urban center in Mesoamerica in its heyday from 200 to 650 CE. The layout and orientation of the city had intrigued scholars for decades; however, they considered the grandiose pyramid-temples, plazas,



(Above) Archaeological and topographic map of Teotihuacan produced by the Teotihuacan Mapping Project. The survey grid system of 500-m squares is oriented to the north–south axis of the city, in particular the central "Street of the Dead" (dividing W1 and E1 on the map).

(Right) View south along the Street of the Dead, with the Pyramid of the Sun prominent on the left, echoing the shape of the mountain behind.

and the major avenue—an area now known as the ceremonial center—to be the entire extent of the metropolis. It was not until the survey conducted by the Teotihuacan Mapping Project that the outer limits, the great east–west axis, and the grid plan of the city were discovered and defined.

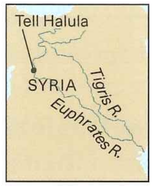
Fortunately, structural remains lay just beneath the surface, so that the team were able to undertake the mapping from a combination of aerial and surface survey, with only small-scale excavation to test the survey results. Millions of potsherds were collected, and more than 5000 structures and activity areas recorded. Teotihuacan had been laid out on a regular plan, with four quadrants orientated on the great north–south "Street of the Dead" and another major avenue running east–west across it. Construction had occurred over several centuries, but always following the master plan.

For artifacts and other objects collected or observed during site surface survey, it may not be worth mapping their individual locations if they appear to come from badly disturbed secondary contexts. Or there may simply be too many artifacts to record all their individual proveniences. In this latter instance the archaeologist will probably use sampling procedures for the selective recording of finds. Where time and funds are sufficient and the site is small enough, however, the collection and recording of artifacts from the total site area may prove possible.

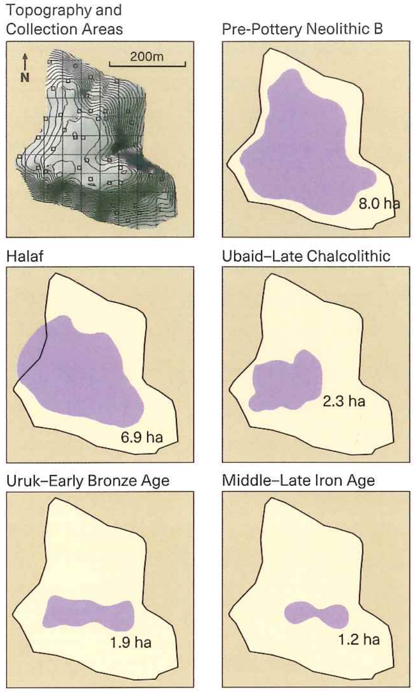
For example, a site surface survey was conducted at the Bronze Age city of Mohenjodaro in Pakistan. Here, a team of archaeologists from Pakistan, Germany, and Italy investigated the distribution of craft-working debris and found, to their surprise, that craft activities were not confined to a specific manufacturing zone within the city, but were scattered throughout the site, representing assorted small-scale workshops.

RELIABILITY OF SURFACE FINDS. Archaeologists have always used limited surface collection of artifacts as one way of trying to assess the date and layout of a site prior to excavation. However, now that surface survey has become not merely a preliminary to excavation, but also in some instances a substitute for it—for cost and time reasons—a vigorous debate is taking place in archaeology about how far surface traces do in fact reflect distributions below ground.

We would logically expect single-period or shallow sites to show the most reliable surface evidence of what lies beneath. Equally one might predict that multi-period, deep sites, such as Near Eastern village mounds, would show few if any traces on the surface of the earliest and deepest levels. This is by no means always true, however—for example, at Tell Halula in northern Syria, a survey was carried out by an Australian team in 1986, involving the collection of such artifacts as potsherds and stone tools from the surface, using **stratified random sampling** procedures based on a grid system. 46 squares in this grid were sampled, amounting to 4 percent of the 12.5-ha (31-acre) site area. Typological analysis of the artifacts made it possible to identify ten major occupation phases, representing fifteen different cultural periods.



(Left) The survey and collection team at Tell Halula using a theodolite.



(Above) Plan of Tell Halula showing the layout of collection squares, plus outline plans showing the changing location and size of settlement during five of the ten occupation phases.

(Left) CORONA satellite image of the Halula district, showing the location of the tell and the boundary of the sampling area.

Those who support the validity of surface survey, while agreeing that there is bound to be a quantitative bias in favor of the most recent periods on the surface, nevertheless point out that one of the surprises for most survey archaeologists is how many of their sites, if collected with care, are truly multi-period, reflecting many phases of a site's use, not just the latest one. The reasons for this are not yet entirely clear, but they certainly have something to do with the kind of formation processes discussed in Chapter 2—from erosion and animal disturbance to such human activity as plowing.

The relationship between surface and subsurface evidence is undoubtedly complex and varies from site to site. It is therefore wise wherever possible to try to determine what really does lie beneath the ground, perhaps by digging test pits (usually meter squares) to assess a site's horizontal extent, or by more thorough excavation (see below, pp. 91–105). There is, however, a whole battery of **subsurface detection** devices that can be used before—or indeed sometimes instead of—excavation, which of course is destructive as well as expensive.

Subsurface Detection

PROBES. The most traditional technique is that of probing the soil with rods or augers, and noting the positions where they strike solids or hollows. Metal rods with a T-shaped handle are the most common, but augers—large corkscrews with a similar handle—are also used, and have the advantage of bringing samples of soil to the surface, clinging to the screw. Many archaeologists use hand-held probes that yield small, solid cores. Probing of this type was used, for example, by Chinese archaeologists to plot the 300 pits remaining to be investigated near the first emperor's famous buried terracotta army. There is always, however, a risk of damaging fragile artifacts or features.

One notable advance in this technique was developed by Carlo Lerici in Italy in the 1950s as part of the search for Etruscan tombs of the sixth century BCE. Having detected the precise location of a tomb through aerial photography and **soil resistivity** (see pp. 88–89), he would bore down into it a hole 8 cm (3 in.) in diameter, and insert a long tube with a periscope head and a light, and also a tiny camera attached if needed. Lerici examined some 3500 Etruscan tombs in this way, and found that almost all were completely empty, thus saving future excavators a great deal of wasted effort. He also discovered more than twenty with painted walls, thus doubling the known heritage of Etruscan painted tombs at a stroke.

SHOVEL-TEST PITS (STPS). To gain a preliminary idea of what lies beneath the surface, small pits may often be dug into the ground at consistent distances from each other; in Europe these are usually in the form of meter-squares, but in some parts of North America small round holes are dug, about the diameter of a dinner-plate and less than a meter deep. These pits help show what an area has to offer, and help identify the extent of a possible site, while analysis and plotting of the material retrieved from them by sieving of the soil can produce maps showing areas with high concentrations of different kinds of artifacts. This method is commonly employed as part of site surveys for CRM projects in areas of the USA with poor surface visibility, such as forested areas of the east coast.

PROBING THE PYRAMIDS. Modern technology has taken such work even further, with the development of the endoscope and miniature TV cameras. In a project reminiscent of Lerici's, a probe was carried out in 1987 of a boat pit beside the Great Pyramid of Cheops (Khufu), in Egypt. This lies adjacent to another pit, excavated in 1954, that contained the perfectly preserved and disassembled parts of a 43-m- (141-ft.-) long royal cedarwood boat of the third millennium BCE. The 1987 probe revealed that the unopened pit contained all the dismantled timbers of a second boat. In 2008 a team from Waseda University in Tokyo, Japan, inserted a second miniature camera to reexamine the boat's condition and ascertain whether it could be safely lifted.The covering stone blocks and boat's timbers were duly removed in 2011. Robot probes with miniature cameras have been sent up two of the so-called "airshafts" of the Great Pyramid to discover whether or not they link up to hidden chambers—tantalizingly, stone blocking part-way up hinders further investigation.

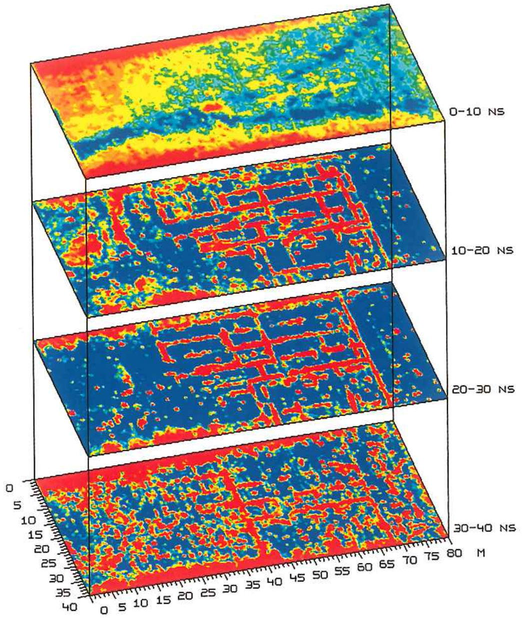
Projects of this kind are beyond the resources of most archaeologists. But in future, funds permitting, probes of this type could equally well be applied to other Egyptian sites, to cavities in Maya structures, or to the many unexcavated tombs in China. The Great Pyramid itself has been the subject of further probes by French and Japanese teams, who believe it may contain as yet undiscovered chambers or corridors. Using ultrasensitive microgravimetric equipment—which is normally employed to search for deficiencies in dam walls, and can tell if a stone has a hollow behind it—they detected what they think is a cavity some 3 m (10 ft.) beyond one of the passage walls. Test drilling to support this claim has not been completed, however, and all tests are carefully monitored by the Egyptian authorities until their potential contribution to Egyptology has been established.

Ground-based Remote Sensing

Probing techniques are useful, but inevitably involve some disturbance of the site. There are, however, a wide range of non-destructive techniques ideal for the archaeologist seeking to learn more about a site before—or increasingly often without—excavation. These are geophysical sensing devices, which can be either active (i.e. they pass energy of various kinds through the soil and measure the response in order to "read" what lies below the surface); or passive (i.e. they measure such physical properties as magnetism and gravity without the need to use energy to obtain a response).

ELECTROMAGNETIC METHODS. The ground-penetrating (or probing) radar (GPR) method employs radio pulses. An emitter sends short pulses through the soil, and the echoes not only reflect back any changes in the soil and sediment conditions encountered, such as filled ditches, graves, walls, etc., but also measure the depth at which the changes occur on the basis of the travel time of the pulses. Three-dimensional maps of buried archaeological remains can then be produced from data processing and image-generation programs.

In archaeological exploration and mapping, the radar antenna is generally dragged along the ground with the aid of a low trolley at walking speed in transects, sending out and receiving many pulses per second. The reflection data are stored digitally, which enables sophisticated data processing



Amplitude slice-maps from the Forum Novum site, Italy. The top slice, at 0–10 ns (nanosecond, equivalent to 0–50 cm) reveals a Y-shaped anomaly, reflecting two gravel roads. As the slices go deeper, the Roman walls begin to emerge very clearly, showing a well-organized plan of rooms, doors, and corridors. The deepest slice shows the actual floor levels of the rooms and the objects preserved on them.

and analysis to be carried out, producing records that are relatively easy to interpret. Powerful computers and software programs make it possible to store and process very large three-dimensional sets of GPR data, and computer advances now permit automated data and image processing that can help to interpret complicated reflection profiles.

One such advance is the use of time-slices or slice-maps. Thousands of individual reflections are combined into a single three-dimensional dataset that can then be "sliced" horizontally, each slice corresponding to a specific estimated depth in the ground, and revealing the general shape and location of buried features at successive depths. A variety of colors (or shades of gray) are used to make a visual image that the brain can interpret more easily—e.g. areas with little or no subsurface reflection may be colored blue, those with high reflection may be red. Each slice therefore becomes like a horizontal surface, and can illustrate the buried components of the site.

For example, at Forum Novum, an ancient Roman marketplace about 100 km (60 miles) north of Rome, archaeologists from the University of Birmingham in England and the British School of Archaeology in Rome needed a fuller picture of an unexcavated area than they had been able to obtain from aerial photographs and other techniques, such as resistivity (see below). GPR slices of the area revealed a whole series of walls, rooms, doorways, and courtyards—in short, they produced an architectural layout of the site that means that future excavation can be concentrated on a representative sample of the structures, thus avoiding a costly and time-consuming uncovering of the whole area.

EARTH RESISTANCE SURVEY. A commonly used method that has been employed on archaeological sites for several decades, particularly in Europe, is **earth resistance survey**. The technique derives from the principle that the damper the soil the more easily it will conduct electricity, i.e. the less resistance it will show to an electric current. A **resistivity meter** attached to electrodes in the ground can thus measure varying degrees of subsurface resistance to a current passed between the electrodes. Silted-up ditches or filled-in pits retain more moisture than stone walls or roads, and will therefore display lower resistivity than stone structures.

The technique works particularly well for ditches and pits in chalk and gravel, and masonry in clay. It usually involves first placing two remote probes, which remain stationary, in the ground. Two mobile probes, fixed to a frame that also supports the meter, are then inserted into the earth for each reading. A variation of the method is resistivity profiling, which involves the measurement of earth resistance at increasing depths by widening the probe spacings and thus building up a vertical "pseudosection" across a site.

Key Concepts
Assessing the Layout of Sites and Features

Site Surface Survey: the study of the distribution of surviving features at a site (such as earthworks or traces of structures), and the recording and sometimes collection of artifacts (often pottery or stone tools) from the surface

Subsurface Detection: the use of probes and shovel-test pits (and sometimes miniature TV cameras and endoscopes) to find and map subsurface features

Ground-based Remote Sensing: the use of non-destructive techniques, such as ground-penetrating radar and magnetometry, to find and map subsurface features

MAGNETIC SURVEY METHODS. These are particularly helpful in locating such fired-clay structures as hearths and pottery kilns; iron objects; and pits and ditches. Such buried features all produce slight but measurable distortions in the Earth's magnetic field. The reasons for this vary according to the type of feature, but are based on the presence of minute amounts of iron. For example, grains of iron oxide in clay, their magnetism randomly orientated if the clay is unbaked, will line up and become permanently fixed in the direction of the Earth's magnetic field when heated to about 700°C (1292°F) or more. The baked clay thus becomes a weak permanent magnet, creating an anomaly in the surrounding magnetic field. Anomalies caused by pits and ditches, on the other hand, occur because the so-called magnetic susceptibility of their contents is greater than that of the surrounding subsoil.

Magnetic instruments, such as **fluxgate magnetometers** (see box overleaf), can produce informative site plans that help to delimit archaeological potential. Today, multiple types of sensors—both electromagnetic and magnetic—are often integrated on moving platforms or mobile arrays, which allow for simultaneous measurements. Color and grayscale maps are produced that, along with contour maps, are used to display earth resistance survey results. In the case of magnetic survey, the contour map has lines that join all points of the same value of the magnetic field intensity—this can reveal separate anomalies, such as tombs in a cemetery.

METAL DETECTORS. These electromagnetic devices are also helpful in detecting buried remains. An alternating magnetic field is generated by passing an electrical current through a transmitter coil. Buried metal objects distort this field and are detected as a result of an electrical signal picked up by a receiver coil. Metal detectors can be of great value to archaeologists, particularly as they can provide general results and are able to locate modern metal objects that may lie near the surface. They are also very widely used by non-archaeologists, most of whom are responsible enthusiasts. Some, however, vandalize sites mindlessly and often illegally dig holes without recording or reporting the finds they make, which are therefore without context.

So far, we have discovered sites and mapped as many of their surface and subsurface features as possible. But, despite the growing importance of survey, the only way to check the reliability of surface data, confirm the accuracy of the remote sensing techniques, and actually see what remains of these sites is to excavate them. Furthermore, survey can tell us a little about a large area, but only excavation can tell us a great deal about a relatively small area.

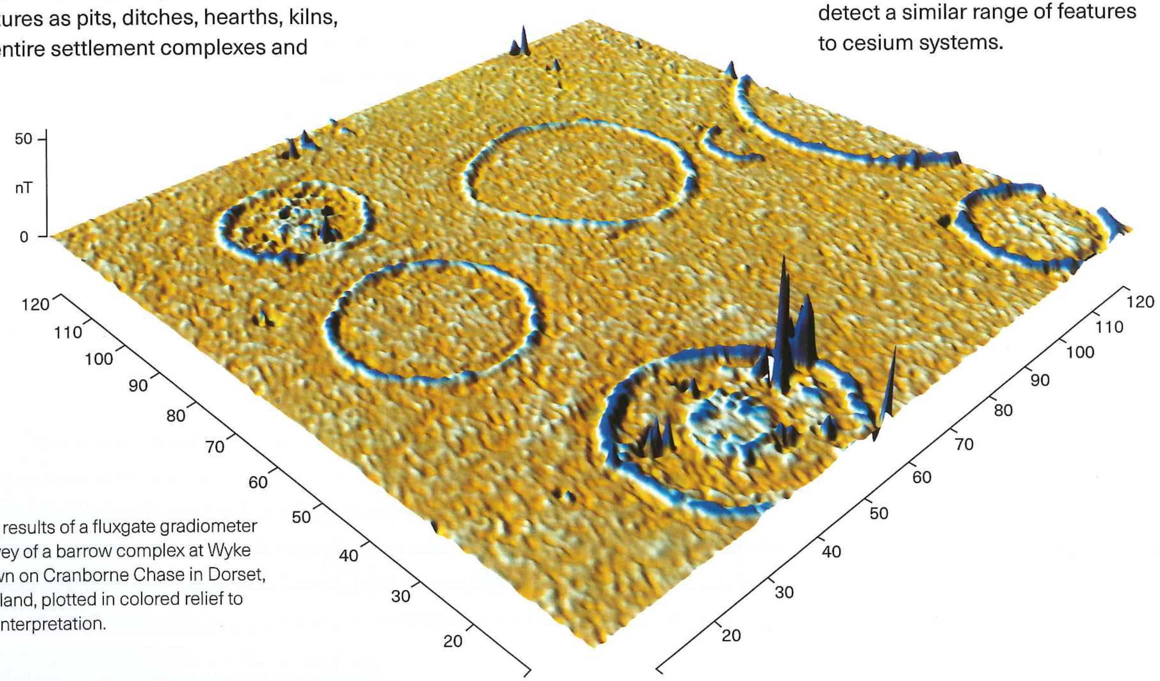
Measuring Magnetism

Most terrestrial magnetometer surveys are undertaken either with fluxgate or with alkali-metal vapor magnetometers.

Fluxgate instruments usually comprise two sensors fixed rigidly at either end of a vertically held tube, and measure only the vertical component of the local magnetic field strength. The magnetometer is carried along a succession of traverses, usually 0.5–1.0 m apart, tied in to an overall pre-surveyed grid, until the entire site is covered. The signal is logged automatically and stored in the instrument's memory, to be downloaded and processed later. To speed up the coverage of large areas, two or more fluxgate instruments can be moved across the site at once—either on a frame carried by the operator, or sometimes on a wheeled cart. In this way, many hectares of ground can be covered quite quickly, revealing such features as pits, ditches, hearths, kilns, or entire settlement complexes and their associated roads, trackways, and cemeteries.

An alternative and sometimes more effective magnetometer is the alkali-metal vapor type, typically a cesium magnetometer. Although more expensive and quite difficult to operate, an advantage these magnetometers have over fluxgate types is that they are more sensitive and can therefore detect features that are only very weakly magnetic, or more deeply buried than usual. Such instruments have been used for many years with great success in continental Europe and are finding favor elsewhere. Unlike a fluxgate gradiometer they measure the total magnetic field (but can be operated as a total-field gradiometer if configured with two vertically mounted sensors). It is also usual for two or more of these sensors to be used at once—often mounted on a non-magnetic wheeled cart. Surveys with such systems can cover up to about 5 ha (12 acres) each day at a high resolution sampling interval (0.5 m × 0.25 m). Arrays of fluxgate sensors are now also being introduced, but many surveys are conducted with a dual sensor system (as in the photograph above) with a sample interval of *c*. 0.1 m × 0.25 m. Fluxgates are often favored for their lower cost, versatility, and ability to detect a similar range of features to cesium systems.

The Bartington Grad601-2 single-axis, vertical-component, high-stability fluxgate gradiometer system.



The results of a fluxgate gradiometer survey of a barrow complex at Wyke Down on Cranborne Chase in Dorset, England, plotted in colored relief to aid interpretation.

Excavation

Excavation retains its central role in fieldwork because it yields the most reliable evidence for the two main kinds of information archaeologists are interested in: (1) human activities at a particular period in the past; and (2) changes in those activities from period to period. Very broadly we can say that contemporary activities take place horizontally in space, whereas changes in those activities occur vertically through time. It is this distinction between horizontal slices of time and vertical sequences through time that forms the basis of most excavation methodology.

In the horizontal dimension, archaeologists demonstrate that activities occurred at the same time by proving through excavation that artifacts and features are found in association in an undisturbed context. Of course, as we saw in Chapter 2, there are many formation processes that may disturb this primary context. One of the main purposes of the survey and remote sensing procedures outlined in earlier sections is to select for excavation sites, or areas within sites, that are reasonably undisturbed. On a single-period site, such as an East African early human camp site, this is vital if human behavior at the camp is to be reconstructed at all accurately. But on a multi-period site, such as a long-lived European town or Near Eastern village mound, finding large areas of undisturbed deposits will be almost impossible. Here archaeologists have to try to reconstruct during and after excavation just what disturbance there has been, and then decide how to interpret it. Clearly, adequate records must be made as excavation progresses if the task of interpretation is to be undertaken with any chance of success. In the vertical dimension archaeologists analyze changes through time by the study of stratigraphy.

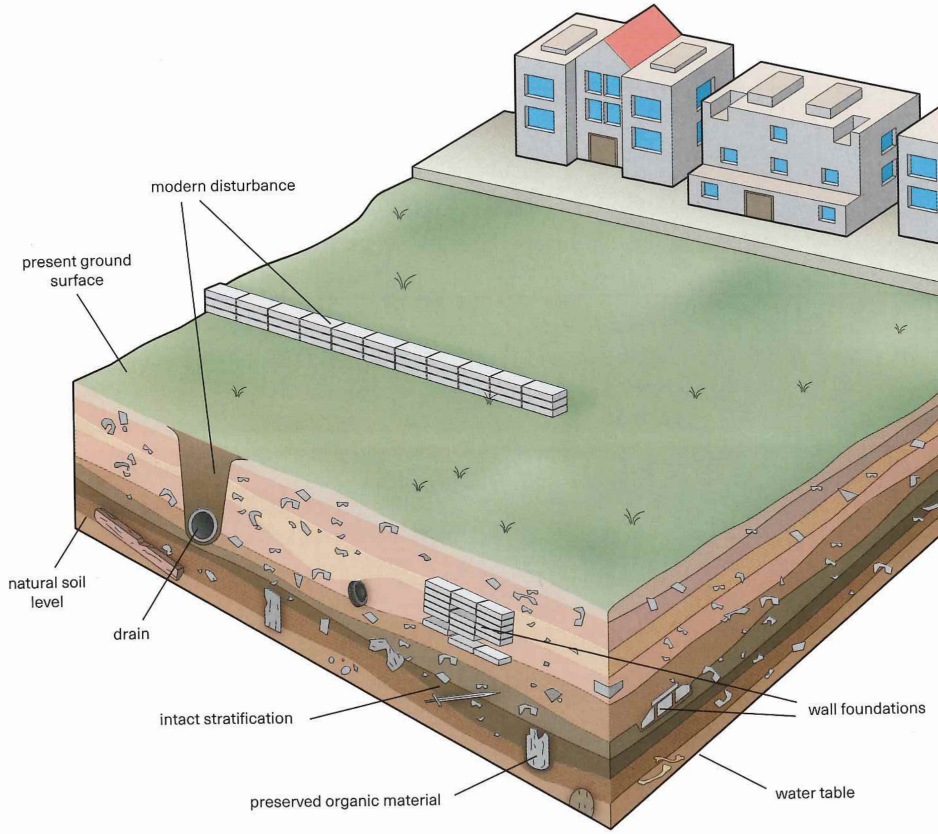
Stratigraphy

As we saw in Chapter 1, one of the first steps in understanding the great antiquity of humankind was the recognition by geologists of the process of stratification—that layers or strata are laid down, one on top of the other, according to processes that still continue. Archaeological strata (the layers of cultural or natural debris visible in the side of any excavation) accumulate over much shorter periods of time than geological ones, but nevertheless conform to the same law of superposition. Put simply, this states that where one layer overlies another, the lower was deposited first. Hence, an excavated vertical profile showing a series of layers constitutes a sequence that has accumulated through time.

Chapter 4 explores the significance of this for dating purposes. Here we should note that the law of superposition refers only to the sequence of deposition, not to the age of the material in the different strata. The contents of lower layers are indeed usually older than those of upper layers, but the archaeologist must not simply assume this. Pits dug down from a higher layer or burrowing animals (even earthworms) may introduce later materials into lower levels. Moreover, occasionally strata can become inverted, as when they are eroded all the way from the top of a bank to the bottom of a ditch.

Archaeologists have developed an ingenious and effective method of checking that artifacts—so far mostly of stone or bone—discovered in a particular deposit are contemporaneous and not intrusive. They have found that in a surprising number of cases flakes of stone or bone can be fitted back together again: reassembled in the shape of the original stone block or pieces of bone from which they came. At the Mesolithic (Middle Stone Age) site of Hengistbury Head in southern England, for example, reanalysis of an old excavation showed that two groups of flint flakes, found in two different layers, could be **refitted**. This cast doubt on the stratigraphic separation of the two layers, and demolished the original excavator's argument that the flints had been made by two different groups of people. As well as clarifying questions of stratification, these refitting or **conjoining** exercises are transforming archaeological studies of early technology (see Chapter 7).

The complexity of stratification varies with the type of site. This hypothetical section through an urban deposit indicates the kind of complicated stratigraphy, in both vertical and horizontal dimensions, that the archaeologist can encounter. There may be few undisturbed stratified layers. The chances of finding preserved organic material increase as one approaches the water table, near which deposits may be waterlogged.



Key Concepts
Excavation

Excavation yields evidence of contemporary activities (which are found horizontally through space) and changes through time (which are found vertically in sequences)

Stratigraphy is the study of archaeological layers found during excavations. The law of superposition states that where one layer overlies another, the lower was deposited first. This forms the basis of the way archaeologists investigate changes through time

Excavation methods should be adapted to the site and the particular questions that need to be answered. The two main strategies are the Wheeler box-grid and open-area excavation; a combination of both is often used. A sampling strategy of some kind can be required to save time and money

Stratigraphy, then, is the study and validating of stratification—the analysis in the vertical, time dimension of a series of layers in the horizontal, space dimension (although in practice few layers are precisely horizontal).

What are the best excavation methods for retrieving this information?

Methods of Excavation

Excavation is both costly and destructive, and therefore never to be undertaken lightly. Wherever possible, non-destructive approaches (outlined earlier) should be used to meet research objectives in preference to excavation. But assuming excavation is to proceed, and the necessary funding and permission to dig have been obtained, what are the best methods to adopt?

This book is not an excavation or field manual, but although such things do exist, a few days or weeks spent on a well-run dig are worth far more than reading any book on the subject. Nevertheless, some brief guidance as to the main methods is given here. In addition, we look at the excavation of one site, the Jamestown settlement in Virginia, in a little more detail (see box overleaf).

It goes without saying that all excavation methods need to be adapted to the research question in hand and the nature of the site. It is no good digging a deeply stratified urban site, with hundreds of complex structures, thousands of intercutting pits, and tens of thousands of artifacts, as if it were the same as a shallow Paleolithic open site, where only one or two structures and a few hundred artifacts may survive. On the Paleolithic site, for example, it may be possible to uncover all the structures and record the exact position or provenience, vertically and horizontally, of each and every artifact. On the urban site there is no chance of doing this, given time and funding constraints. Instead, we have to adopt a sampling strategy, and only key artifacts, such as coins (important for dating purposes: see Chapter 4), will have their provenience recorded with three-dimensional precision, the remainder being allocated simply to the layer and perhaps the grid-square in which they were found (sites are usually divided up into grid-squares, just like maps are, in order to aid in accurate recording; naturally, the size and number of the grid squares will depend on the type, size, and likely depth of the site).

It should be noted, however, that we have already reintroduced the idea of the vertical and horizontal dimensions. These are as crucial to the methods of excavation as they are to the principles behind excavation. Broadly speaking we can divide excavation techniques into:

1. those that emphasize the vertical dimension, by cutting into deep deposits to reveal stratification; and
2. those that emphasize the horizontal dimension, by opening up large areas of a particular layer to reveal the spatial relationships between artifacts and features in that layer.