

3 Where?

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A major characteristic of archaeology is that it commonly draws evidence from fieldwork, that is, from survey and excavation. Traditionally, fieldwork was seen almost exclusively in terms of the discovery and uncovering of sites. Today, archaeologists are more aware of the high cost and destructiveness of excavation, and so, while sites and their excavation remain of paramount importance, site **surface survey** and **subsurface detection** using nondestructive **remote sensing** devices are now widely used. Indeed, some archaeological projects may not include excavation at all, but focus instead on various forms of survey. The use of noninvasive survey not only leaves the archaeology undisturbed but also helps to answer new questions. For example, the study of entire landscapes by regional survey is now a major part of archaeological fieldwork.

In archaeological fieldwork, we may distinguish between the methods used in the discovery of archaeological sites, and the methods employed once the sites and features have been discovered, which include detailed survey and selective excavation at individual sites. New evidence can often come from new work at sites that are already the subject of fieldwork, such as Ian Hodder's renewal and reappraisal of the excavations at the Turkish tell site of Çatalhöyük (see feature, pp. 42–43). Much potentially rich and rewarding material also lies locked away in museum and institution vaults, waiting to be analyzed using innovative modern techniques. Yet the great majority of archaeological research still depends on the collection of new material by fresh fieldwork.

Discovering Archaeological Sites and Features

One major task of the archaeologist is to find and record the location of sites and features. In this section we shall be reviewing some of the principal techniques used in site discovery. But we should not forget that many monuments have never been lost to posterity: the massive pyramids of Egypt, or those of Teotihuacán near modern Mexico City, have always been known to succeeding generations, as has the Great Wall of China or many of the buildings in the Forum in Rome [3.1, 3.2, p. 77]. Their exact function or purpose may have aroused controversy down the centuries, but their presence, the fact of their existence, was never in doubt.

Nor can we credit archaeologists with the discovery of all the sites that were once lost. A significant number of sites known today were found by accident: the amazing terra-cotta army of China's first emperor was unearthed in 1974 by farmers digging for a well; in France, the decorated cave of Lascaux was stumbled upon in 1940 by teenagers; and the underwater entrance to that of Cosquer



3.1 (Above) Partially buried but never lost: buildings in the Forum of ancient Rome, as depicted in an early nineteenth-century painting by the Italian artist Ippolito Caffi.

3.2 (Below) The Great Wall of China, more than 2,000 km (1,250 miles) long, was begun in the third century BCE. Similarly to Rome's Forum, it has never been lost to posterity.



was discovered by a deep-sea diver in 1985. Countless underwater wrecks have been spotted first by fishing boats, sponge gatherers, and sport divers. Construction workers building new roads, subways, dams, and office blocks have made their fair share of discoveries too—for example, the Templo Mayor (Great Temple) of the Aztecs in Mexico City (see feature, pp. 582–83).

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 discovery conducted at ground level (**ground reconnaissance**) and discovery from the air or from space (**aerial reconnaissance/survey**), although a single field project will usually employ both types of reconnaissance.

Ground Reconnaissance

Methods for identifying individual sites include consultation of documentary sources and place-name evidence, but consist primarily of actual fieldwork, whether it is monitoring building developers' progress in applied or compliance archaeology (often known in the United Kingdom as salvage, or rescue, archaeology) or surveying in circumstances where the archaeologist is more of a free agent.

Documentary Sources and Oral Histories. We saw, in Chapter 1, how Schliemann's firm belief in the historical accuracy of the writings of Homer led directly to the discovery of ancient Troy. In the 1960s the location and excavation by Helge and Anne Stine Ingstad of the Viking settlement of L'Anse aux Meadows in Newfoundland was similarly due, in large part, to clues contained in medieval Viking sagas [3.3, p. 78]. Much of modern biblical archaeology is concerned with the search in Western Asia for evidence of the places, people, and events described in the Old and New Testaments. Treated objectively as a possible source of information about West Asian sites, the Bible can indeed be a rich source of documentary material, but there is a 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 southwest 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."

Early maps and old street names are even more important in helping archaeologists work out the former plans of



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

historic towns. In the better-documented medieval towns in England, it is possible to use this kind of evidence to map many of the streets, houses, churches, and castles back to the twelfth century CE, or even earlier. Such maps then form a reliable basis on which to decide where it would be most profitable to carry out survey work and excavation.

Cultural Resource Management and Applied or Compliance Archaeology. In this specialized work (discussed in Chapter 15), the role of the archaeologist is to locate and record sites before they are destroyed by new roads, buildings, or dams, or by peatcutting and drainage in wetlands. In the United States 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 the developer should allow archaeological survey to take place in advance along the projected line of road or in the path of development. Important sites 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 were incorporated into the architecture of stations.

In the United Kingdom, as in the United States, most excavations and surveys are undertaken in the context of cultural resource management—the influence of the British National Planning Policy Framework has meant that expenditure on archaeology by developers has grown to more than £10 million (\$12 million) annually.

Survey. How does an 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 in Wessex in southern England. But many sites are visible on the surface only as a scatter of artifacts and so require

more thorough survey—what we may call a reconnaissance survey—to be detected.

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 may not qualify as sites but nevertheless represent significant human activity. Some scholars have suggested that these **off-site** or nonsite areas (i.e. areas with a low density of artifacts) should be located and recorded, which can be done only by **systematic survey** work involving careful sampling procedures (see below). This approach is particularly useful in areas where people with a mobile way of life have left only a sparse archaeological record, as in much of Africa (see further discussion in Chapter 5).

Survey has become important for another major reason: the growth of regional studies. Thanks to the pioneering research of scholars such as Gordon Willey in the Virú Valley, Peru, and William T. Sanders (1926–2008) in the Valley of Mexico, archaeologists have increasingly sought to study settlement patterns—the distribution of sites across the landscape within a given region. The significance of this 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 merely to locate an individual site and then to survey and/or excavate it in isolation from other sites. Whole regions need to be explored, and this involves a program of survey.

In the last few decades, reconnaissance 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 has not been forthcoming, or because of a lack of time or funds—modern excavation is slow and costly, whereas survey is cheap, quick, and relatively nondestructive, and requires only GPS (Global Positioning System), 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 could not be answered by excavation.

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 corresponding scale in a way that provides the most information for the least cost and effort. The region to be surveyed needs to be defined: its boundaries may be natural (such as a valley), cultural (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 ourselves 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 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 and semi-arid environments with little vegetation are among the best for this type of work; in equatorial rainforest, survey may be limited to soil exposures along riverbanks, unless time and labor permit the cutting of trails to form a survey grid. Many regions, of course, contain a variety of landscapes, and a single survey strategy is often inadequate to cover them. Flexibility of approach is required, with the area stratified into zones of differing visibility, and an appropriate technique devised for each. Moreover, it must be remembered that some archaeological phases (with **diagnostic** artifacts) 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 agricultural or urban communities (see Chapter 5). All these factors must be taken into account when planning search patterns and recovery techniques.

Another point to consider is whether material should be collected or merely examined for its associations and context (where context is disturbed, as in parts of Africa,

mentioned above, collection is often the most sensible option). And should collection be total or partial? Usually, a sampling method is employed (see feature, p. 82).

There are two basic kinds of surface survey: the unsystematic and the systematic. The former is the simpler, involving walking across each part of the area, 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 and misleading. A walker has an inherent desire to find material, and will therefore tend to concentrate on areas that seem richer, rather than obtaining a sample representative of the whole area that would enable assessment of the varying distribution of material of different periods or types. The method, however, is flexible and will enable the team to focus greater efforts on areas that have proved most likely to contain finds.

Most modern survey is done systematically, employing either a grid system or a series of equally spaced traverses or transects (straight paths) across the area [3.4, 3.5]. The area to be searched is divided into sectors, and these (or a sample of them) are walked. In this way, no part of the area is either under- or overrepresented in the survey. This method also makes it easier to plot the location of finds since one's exact position is always known. Even greater



3.4 (Left) Systematic surface survey in the Egyptian desert. Using GPS, archaeologists sample small areas spaced 100 m (328 ft.) apart, looking for Middle Paleolithic stone tools.

3.5 (Above) Finds are then processed in the field using electronic calipers and handheld computers.

accuracy can be attained by subdividing the traverses into units of fixed length, some of which can then be more carefully examined.

Results tend to be more reliable from long-term projects that cover the region repeatedly because the visibility of sites and artifacts can vary widely from year 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 their ability to recognize and describe sites (the more carefully one looks and the more experience one has, the more one sees); 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, or handheld computers can be used in the field.

It has to be stressed that material found on the surface quite often represents sites beneath, the upper levels of which have been, or are being, removed by plowing, erosion, or later development. Conversely, surface material may also fail to indicate what lies below; for example, if pottery was deposited by manuring or if cultures are aceramic (they do not produce pottery) and hence under-represented in the survey. This is why 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 be done only 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. Outstanding syntheses of regional survey have been produced in parts of Mesoamerica (see Chapter 13) and Mesopotamia, areas that already have a long tradition of this type of work.

In Mesopotamia, for example, the pioneering work by Robert Adams (1926–2018) and others, combining surface and aerial survey, has produced a picture of changing settlement size and spacing through time leading to the first cities: scattered agricultural villages became more clustered as population increased; eventually, by the Early Dynastic period (third millennium BCE), major centers of distribution had arisen, interconnected by routes of communication. The work has also revealed former water-courses and canals, and even probable zones of cultivation.

The Sydney Cyprus Survey Project



From 1992 to 1998 the Sydney Cyprus Survey Project (SCSP), led by Bernard Knapp and Michael Given of the University of Glasgow, undertook an intensive archaeological survey in a 75-sq. km (29-sq. mile) area in the northern Troodos

Mountains of Cyprus [3.6]. This is an area famed for its copper sulfide ore deposits, mined as early as the Bronze Age.

The project examined the human transformation of the landscape over 5,000 years, and placed it in its regional context [3.7]. An interdisciplinary approach integrated such diverse fields as archaeology, archaeometallurgy, ethnohistory, geomorphology, ecology, **geographic information systems (GIS)** (see pp. 96–97, 100), and satellite imagery, without overlooking the human experience of place.

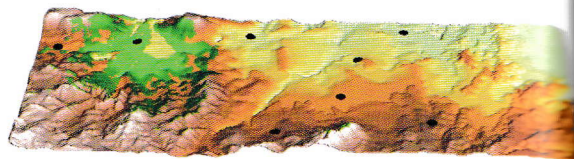
Project Aims and Design

The primary goals of the project were to use archaeological landscape data to analyze the relationship between the production and distribution of agricultural and metallurgical resources through time, and to chart the changing configurations of a **complex society** and the individuals within it.



3.6 (Above) Mapping the medieval settlement of Mitsero Mavrouvouni.

3.7 (Below) Viewshed analysis (see p. 213) of the survey area: black dots indicate medieval to modern settlements and the tinted area shows what is visible from Mitsero.



A multistage research design was adopted, and the notion of the “site” was called into question. The 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. Using the GIS program MapInfo, the photographs were scanned and registered to the UTM (Universal Transverse Mercator) grid with grid lines of 100-m (328-ft.) spacing superimposed on the base map. The Cypriot Lands and Survey Department assisted by giving GPS readings for survey points in the study area.

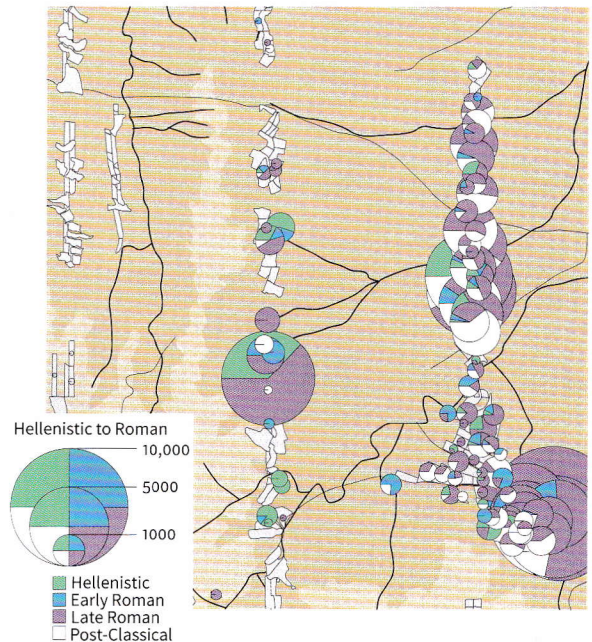
The landscape was divided into single units. In some cases, features in the landscape, such as agricultural plots, defined these units. Otherwise, the main survey approach was to follow a straight line, or transect survey, with the following strategies:

- 1 to walk 50-m (165-ft.) wide transects north-south, with fieldwalkers 5 m (16 ft.) apart, across the survey area at 500-m (1650-ft.) intervals, in order to obtain a broad systematic sample of the survey area;
- 2 to use spatial information entered daily into the GIS to determine which topographic, geological, and land-use factors may have conditioned the occurrence of exposed cultural materials;
- 3 to conduct block survey of special interest areas with extensive evidence of early industrial, agricultural, or settlement activities;
- 4 to investigate, as places of special interest, locales designated by obtrusive remains or high densities of artifacts.

In each unit, a representative sample of cultural material was collected: pottery, chipped stone, ground stone, metals, **slag**, ores and fluxes, glass, and tiles. Other, mainly nondiagnostic, material was simply counted and left in the unit.

A major component of the SCSF consisted of using GIS-derived thematic maps to illustrate the results of the field

3.8 A distribution diagram of pottery (the Pottery Index) in the northeast part of the survey area, showing low-density “carpets” probably derived from manuring, the edge of the city of Tamassos at bottom right, and several density spikes from estates or small settlements.



counting, collecting, and recording strategy. Pottery was the key analytical aspect in assessing the meaning and significance of the survey units, and pottery data (density and distribution) were incorporated into GIS maps. A Pottery Index (PI), adjusted for ground visibility and other factors, was used to indicate the importance of a specific time period within a unit [3.8]. A PI of 500–1,000 was taken to indicate a light scatter of pottery derived from agricultural practices such as manuring; a PI of 5,000 might suggest a low-density habitation, such as a farmstead; whereas a PI of 10,000 suggested the very high densities found on major settlements.

Results

In all, 1,550 survey units were examined, covering 6.5 sq. km (2.5 sq. miles), or 9.9 percent of the survey area. The survey identified eleven special interest areas and 142 places of special interest. The count in the field totaled 87,600 sherds of pottery, 8,111 tile fragments, and 3,092 lithics. About one-third of these were collected and analyzed, and entered into the project's database.

The project concluded that the chronotype cataloguing and information system was integrated with pottery analyses and GIS mapping to present a new perspective on the exploitation of a regional landscape. The Pottery Index sought to bring new rigor to the mapping of regional pottery data. The GIS analytical maps portrayed in a vivid and dynamic way the level and types of materials encountered.

The general conclusion that it took around six years to undertake an intensive survey of roughly 10 percent of an area of only 75 sq. km (29 sq. miles) is of note. Moreover, the chronotype cataloguing system was dependent on reasonably abundant pottery finds that could be classified chronologically according to an already well-established typological system. The availability of a chronologically sensitive indicator of this kind is crucial for any survey analyzing change over time. However, the system also intentionally included a very large range of wares that had not previously been datable by any field project on Cyprus.

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 reconnaissance 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.

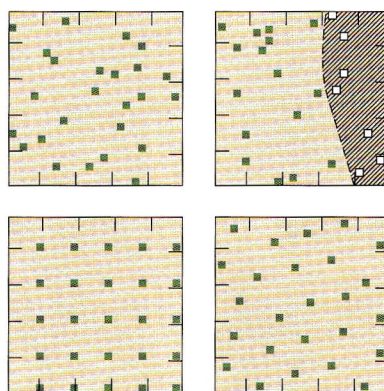
The way archaeologists use sampling is similar to the way it is employed in public-opinion polls, which make generalizations about the opinions of millions of people using samples of just a few thousand. Surprisingly often, the polls are more or less right. This is because the structure of sampled populations 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 probable it is that the results will be valid.

However, some sites in a given region 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

There are four types of sampling [3.9]. The simplest form is a **simple random sample**, where the areas to be sampled are chosen using a table of random numbers. However, the nature of random numbers 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

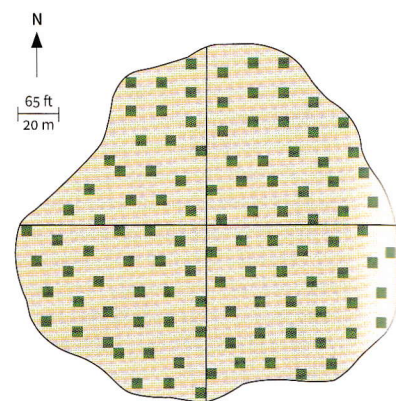


3.9 Types of sampling: (A) simple random; (B) stratified random; (C) systematic; (D) stratified unaligned systematic.

into its natural zones (or strata, hence the technique's name), such as cultivated land and forest, and squares are then chosen by the random-number procedure, except that each zone has the number of squares proportional to its area. Therefore, 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, for example choosing every other square. By adopting such a regular spacing, we run 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 all three techniques just described. In collecting artifacts from the surface of a large tell or mound site at Girik-i-Hacıyan in Turkey, Charles Redman and Patty Jo Watson used a grid of 5-m (16-ft.) squares, but oriented it along the site's main north-south and east-west axes, and the samples were selected with reference to these axes [3.10]. The strata chosen were blocks of nine squares (three by three), and one square



3.10 A stratified unaligned systematic sample of squares, 5 m (16 ft.) on a site, chosen for investigation at Girik-i-Hacıyan, Turkey.

in each block was picked for excavation by selecting its north-south/east-west coordinates from a table of random numbers. This method ensures an unbiased set of samples, more evenly distributed over the whole site.

Transects vs. Squares

In large-scale surveys, transects (straight paths) are sometimes preferable to squares. This is particularly true in areas of dense vegetation such as tropical rainforest. It is far easier to walk along a series of paths than to locate accurately and investigate a large number of randomly distributed squares. In addition, transects can easily be segmented into units, whereas it may be difficult to locate or describe a specific part of a square; and transects are useful not merely for finding sites but also for recording artifact densities across the landscape. At the same time, squares have the advantage of exposing more area to the survey, therefore 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.

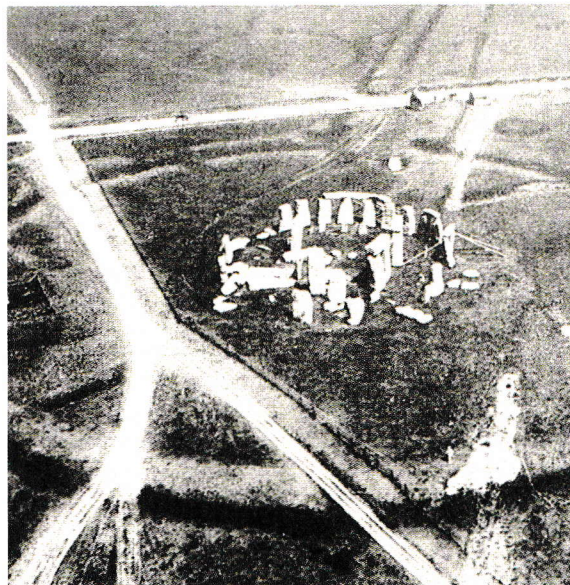
Alternatively, survey can be made more intensive by aiming at total coverage of a single large site or site-cluster—what might be called microregional survey. It is a paradox that some of the world's greatest and most famous archaeological sites have never, or only recently, been studied in this way because attention has traditionally focused on the grandiose monuments themselves rather than on any attempt to place them within even a local context. At Teotihuacán, near Mexico City, a major mapping project initiated in the 1960s has added substantially to our knowledge of the area around the great pyramid-temples (see pp. 100–101).

Surface 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 reconnaissance from above—either from the air or from space. The availability of aerial images can be an important factor in selecting and delineating an area for surface survey.

Aerial and Satellite Survey

Archaeological survey using airborne or spaceborne remote sensing can be divided into two component parts: data collecting, which consists of acquiring photographs or images from aircraft, satellites, or UAVs (uncrewed aerial vehicles, or drones); and data analysis, in which these images are analyzed, interpreted, and (often) integrated with other evidence, such as that collected by field survey, by ground-based remote sensing, or from documents. From the viewpoint of the photo interpreter or image analyst, satellite images, multispectral/hyperspectral data, and traditional aerial photographs are all potentially useful sources, though they differ in scale and resolution and carry different issues of interpretation. These data will collectively be referred to as aerial images.

Millions of aerial images have already been taken [3.11, 3.12]. Many are available for consultation in specialist libraries; a smaller number are freely available online. Most result from area survey, where aerial images are taken in overlapping series to cover predefined areas. A small number are taken each year by archaeologists conducting prospective surveys in light aircraft. Aerial images, even those from prospective survey, are used for a wide range of archaeological purposes, such as the discovery and recording of sites, the monitoring of changes in them through time, and the photographing of buildings and urban (and other) development—in short, the recording of almost anything that may not be there tomorrow. Nevertheless, the making of aerial images from aircraft or satellite and the analysis of these have led to a large number of archaeological discoveries, and the tally grows every year.



3.11, 3.12 Aerial photography, from the earliest to most recent. (Above) The first air photograph of Stonehenge (or of any archaeological site) taken from a balloon in 1906. (Below) The use of a drone in the survey of the Ness of Brodgar, a Neolithic sacred site in Orkney Islands, Scotland.



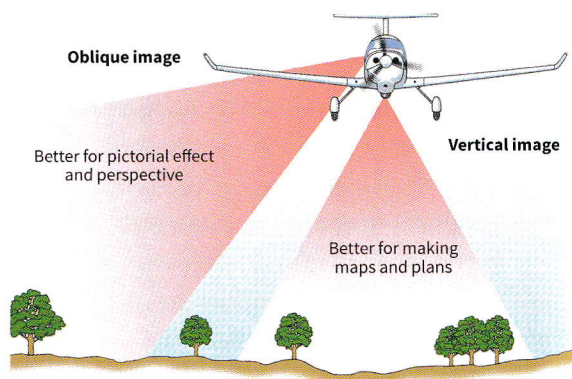
How Are Aerial Images Used? Images taken from the air are merely tools, a means to an end. Images do not themselves reveal sites—it is the image-taker and the interpreter who find sites by examining the terrain and the pictures. These are specialized skills. Experience and a keen eye are needed to differentiate archaeological traces from other features, such as vehicle tracks, old riverbeds, and patterns

produced by modern cultivation. It is a process that benefits from a broad understanding of landscape history, including an awareness of contemporary processes.

Aerial images are of two types—oblique and vertical—each of which has its advantages and drawbacks [3.13]. Oblique images have usually been taken of sites observed from the air by an archaeologist and thought to be of archaeological significance [3.14], whereas most vertical images result from nonarchaeological surveys (e.g. cartographic surveys). Both types of image 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 photographic base map of all the archaeological evidence visible from the air. Such images are a useful tool for informing analytical ground survey.

The ways in which sites are seen from the air and how they are interpreted are discussed in the feature on pp. 86–87. Oblique images are often targeted on archaeological features that may show clearly, while vertical images may need to be examined more thoroughly by an interpreter seeking such information. Both types of image can be rectified and georeferenced using computer programs. This removes the scale and perspective distortions of oblique images and can correct for tilt and off-nadir distortion in vertical views. The use of a digital terrain model (i.e. a three-dimensional model of the ground based on contours or via **LIDAR (light detection and ranging)** or **ALS (airborne laser scanning)** data—see below) in the rectification process produces greater accuracy where the ground is undulating or has high relief. After computer transformation, the resulting image may be layered in graphics software or a GIS (see feature, pp. 98–99) and interpreted by overdrawing the archaeological features that have been identified. Site-specific mapping at scales of 1:2,500 can show considerable detail within a site and can be accurate to less than ± 1 m (± 3 ft.). This allows features to be measured and compared, and is essential in providing precise locations so that excavation trenches can be positioned accurately and cost-effectively (see feature, p. 91). This is the usual method for interpreting and mapping archaeological features from aerial images in Britain and Europe, and may also be a useful tool elsewhere.

The mapping of individual sites from aerial photographs is often necessary in research or salvage (rescue) archaeology, and also forms the foundations of landscape mapping and understanding. The ability to study large areas is often possible only using aerial resources. In Britain,

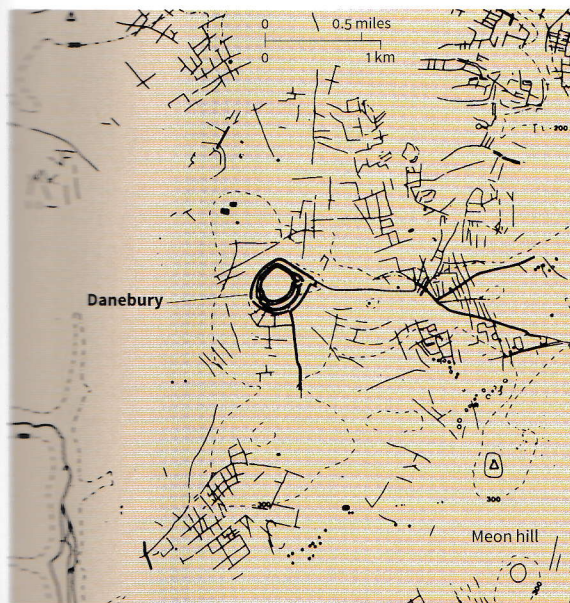


3.13 (Above) Making oblique and vertical aerial images. Obliques are easier to view and understand than verticals, but may present more difficulty to the interpreter who must transform the information to obtain plan views.

3.14 (Below) An oblique aerial image of the earthwork at Great Serpent Mound, near Peebles, Ohio, the largest serpent effigy in the world, built c. 1070 CE.



Rog Palmer used thousands of individual photographs of a 450-sq. km (175-sq. mile) territory around the Iron Age hillfort of Danebury in Hampshire to produce accurate maps [3.15, p. 85]. These show that the site lay within very complex agricultural landscapes, with at least eight other hillforts in the area. Crop marks (explained in the feature, pp. 86–87) and soil marks revealed the presence



3.15 A map of the area around Danebury, an Iron Age hillfort in southern Britain (sixth–second centuries BCE), created from aerial survey, with details of ancient fields, tracks, and enclosures.

of 120 ditched settlement enclosures, hundreds of acres of small fields, regularly arranged, and 240 km (150 miles) of linear ditches and boundary works, many of which were roughly contemporaneous with Danebury, to judge from their forms and from selective excavation by the Danebury Environs Programme.

Although it was known that prehistoric roadways existed within Chaco Canyon in the American Southwest, it was only when a major aerial reconnaissance project was undertaken by the National Park Service in the 1970s that the full extent of the system of roads was appreciated. Using the extensive coverage provided by the aerial images, a whole network of prehistoric roadways was identified and mapped (see p. 412). This was followed by selective ground surveys and some archaeological excavation. From the aerial coverage, it has been estimated that the network, thought to date to the eleventh and twelfth centuries CE, extends some 2,400 km (1,500 miles), though of this only 208 km (130 miles) have been examined at ground level.

Global Positioning Systems. Aerial survey often takes advantage of GPS navigation and flight-path recording by using the digital sensors in precision vertical cameras or in the handheld cameras of airborne archaeologists. The track of a vertical-survey flight is recorded at preset intervals to provide a continuous record that shows the ground that has been overflown and searched. Many handheld cameras can be linked to GPS so that coordinates are recorded

as each photograph is taken. This eases the occasional problem of locating shots when the archaeologist is back on the ground. It is also wise to devise a storage system that allows rapid retrieval of images, is adequately backed up, and takes account of the possible short-term life of digital formats, so as to provide good archival storage of what may be unique data.

Different forms of image, such as vertical photographs and satellite images, are often georeferenced so that they can be layered in a GIS. The application of digital image analysis is now a basic element in the survey archaeologist's toolkit. Just as in excavation and aerial survey, this form of remote sensing research must be well planned and well executed, using a comprehensive methodology.

Recent Developments. New methods and technologies are constantly being developed, and archaeologists are often keen to adopt any technique that promises a new perspective or a more straightforward or cost-effective solution. Automated and semi-automated image analysis is commonplace in disciplines such as environmental remote sensing where work is undertaken on extensive datasets. Aspects of these developments have seen some archaeological application, and researchers are investigating ways in which computers might reliably handle large datasets, such as those that will be generated by hyperspectral surveys. Software can be written to extract features with defined characteristics from data (i.e. pits or mounds) and these should form a useful complement to traditional image analysis. Digital data, such as ALS (see below), respond very well to heavily automated workflows. This is illustrated by a six-year project that surveyed 35,000 sq. km (21,750 sq. miles) of Baden-Württemberg in Germany using supervised automated classification, which identified a possible 600,000 sites. Applications of deep learning are at the cutting edge of automated detection, bringing artificial intelligence to bear in the processes of pattern recognition, especially circles (see feature, p. 89). This demands careful consideration of the ways in which a human observer may work—they draw on experience and knowledge but are constrained by expectation—and of what artificial intelligence is capable of identifying. For example, deep learning has been used to detect more than a hundred Native American shell rings (middens) from LiDAR data in South Carolina.

Drones, or UAVs. The use of drones in combination with structure from motion (SfM) software for recording archaeological sites has become popular in archaeology [3.19, p. 88]. Small battery-powered drones carry a range of instruments and cameras, including thermal and multispectral cameras and LiDAR sensors. They can be programmed to survey an area or take scores of pictures

Identifying Archaeological Features from Above

Features Visible from Above

Successful identification of archaeological sites on aerial images requires knowledge of the types of feature that we may expect to be visible and of formation processes that may have affected them since their abandonment [3.16]. In general, for a site to be detected by a 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), either of which may survive in relief or be completely buried under leveled, cultivated land. Previous fieldwork and excavations in the area of interest should identify the range and characters of archaeological features that may be visible from above, although the smallest of these (postholes, for example) may not be seen on any but the clearest and largest-scale images. Such knowledge of the area or region will also help the interpreter to differentiate between archaeological and nonarchaeological features.

Upstanding Sites

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

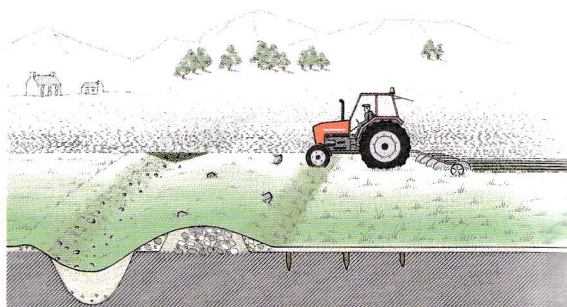
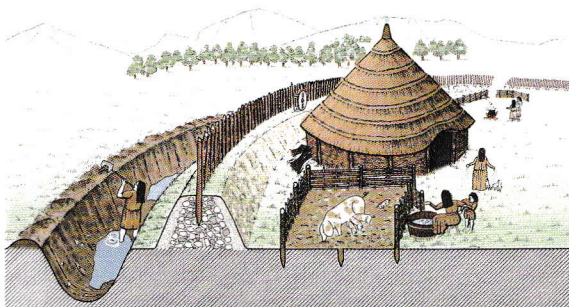
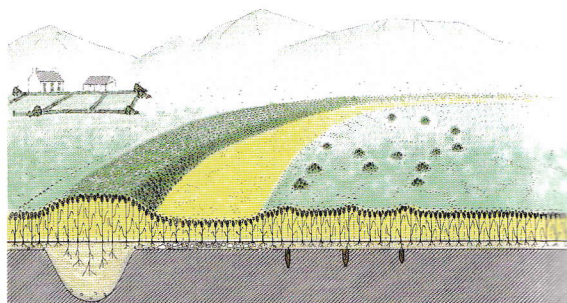
Sections cut through the experimental earthwork on Overton Down in southern England (see p. 54) found that, in an undisturbed chalk landscape, grass colonization had stabilized the slumping of the bank into the ditch after about sixteen years. Similar earthworks can be seen in relief in aerial photographs from many parts of the world, suggesting that such sites can become fossilized only a few years after abandonment.

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 images. Obtaining images taken at different times maximizes the information visible through light and shade. This is one of the advantages of using LiDAR (ALS) (see pp. 88 and 90): software allows a viewer to move the direction and azimuth of the sun so that more information can be provided than can be identified on aerial images. Vertical aerial photos and satellite images should be viewed with shadows falling toward the user, otherwise inverse relief may be perceived.

Leveled Sites

In some parts of the world, most archaeological sites have been leveled and now lie in arable land [3.17]. 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 as aerial

3.16 The simplified process of site formation. The drawing (at right) shows what may be visible today in a field that has been leveled by cultivation. Cereal crops respond to different depths of soil to produce crop markings that may be photographed from above. In an unplowed landscape (bottom right) the major elements of the site survive in slight relief. It is easier to see these from above or on the ground as a hollowed bank and a raised stony band where a former bank or rampart lay. From this evidence we have to imagine what type of features are represented by different crops or slight relief. The original site (bottom left) consisted of a bank and ditch surrounding a roundhouse with its associated domestic stock pen and other fenced areas. Different aspects of the original site may be identified in relief and when it has been completely leveled, while some will never be recovered by this method of detection.



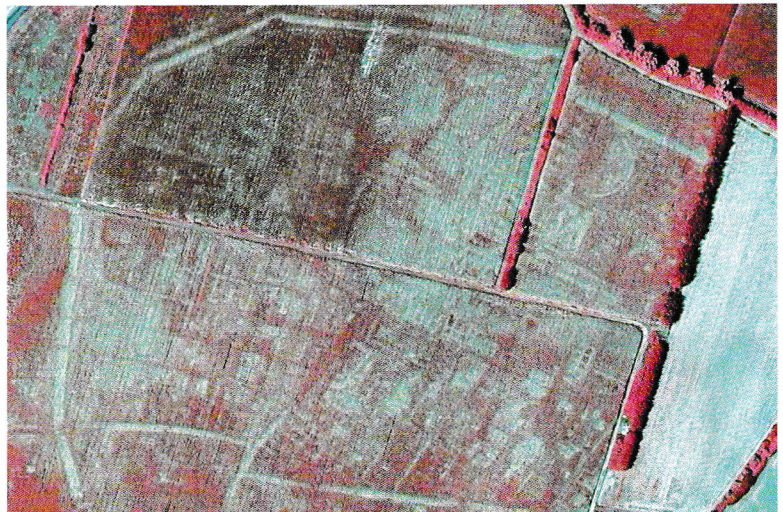


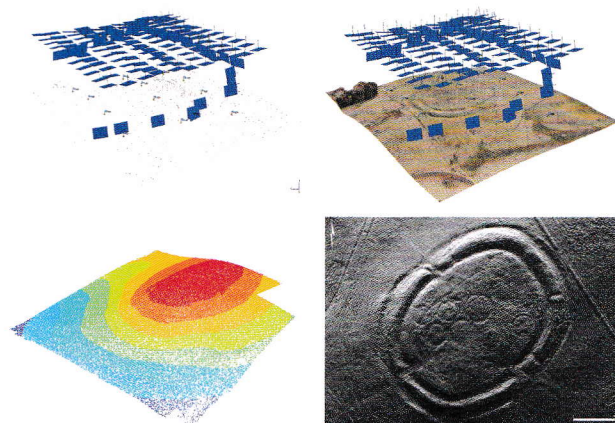
3.17 (Above) Features in relief on the left of this oblique photograph reveal the subsurface remains of a Romano-British farm at Holbeach in the East Anglian fens of England. Ditches were cut to form field and property boundaries, define tracks, and drain the land. These features continue into the field on the right, which has been leveled and is now a cereal field. The track (A-B) that runs across the upper part of the left field can be seen to the right (C-D), 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.

3.18 (Right) The vanished Roman harbor town of Altinum, near Venice, Italy, was mapped in 2007 when a severe drought caused crop-marks to develop over buried structures. The unusual colors in this vertical image show that it was taken in near-infrared wavelengths.

images. In summer months, certain crops may grow differently above different soils and above different depths of soil, and can therefore indicate the presence of underlying archaeological and natural features [3.18]. These crop differences, or crop marks, have been the main media through which aerial survey has recorded the presence of archaeological features; indeed, more features have been

discovered in this way than with any other form of prospection. The majority of crop marks appear in cereal crops, but in drought conditions grass sometimes responds to differences below the ground, as at Stonehenge in July 2013 when parching showed previously unidentified stone holes that may have completed the sarsen circle (see Chapter 5).

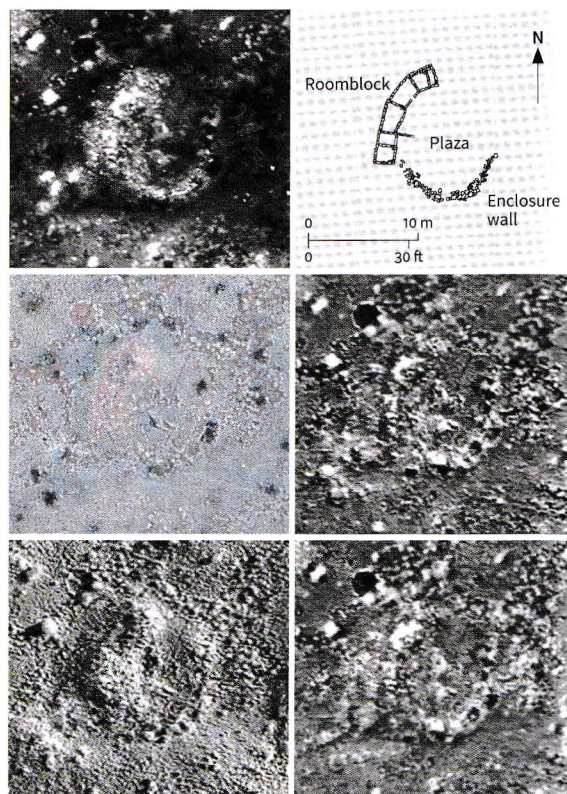




3.19 The earthworks of the later prehistoric settlement at Braidwood, in southern Scotland, were documented by Historic Environment Scotland with photographs taken from a drone. Image-based modeling software first geometrically corrected the photographs to the appropriate scale and aligned them with a sparse point cloud of coordinates of the landscape (**top left**). Texture was then added from the photos (**top right**). Finally, a dense point cloud of coordinates (**bottom left**) was used to produce a multi-direction hillshade model (**bottom right**).

that produce an overlapping set, recording a site, feature, or excavation from all angles. SfM software can combine these images to produce a three-dimensional model and, in so doing, create a set of orthophotos—geometrically corrected images representing an exact likeness of the Earth—that can later be georeferenced and used for making accurate drawings. One recent experiment run by Jesse Casana and his colleagues used a drone carrying optical and thermal cameras to record parts of the Chaco-period (900–1180 CE) Blue J site in New Mexico [3.20]. Flights followed a predetermined course synchronized with times of day when thermal responses were expected from different ground features. Images from each sensor were combined to produce an orthophoto mosaic that was tied to ground control points and could be precisely compared with others. The Blue J site is well known from ground and other survey, so providing a good test environment for the method. The thermal imagery did reveal almost all the known archaeological features, suggesting that it could prove a useful tool in areas where similar remains might be expected.

LiDAR and SLAR. Use of LiDAR (light detection and ranging)—also known as ALS (airborne laser scanning)—has proved extremely valuable in the past twenty years. This technique uses an aircraft, the exact position of which is known through use of a differential 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 three-dimensional point cloud is



3.20 A Chaco-period house compound at Blue J, New Mexico. Thermal imagery collected by a drone at 5:18 a.m. (**top left**) reveals a room block, enclosure wall, and plaza area, all of which have been confirmed by conventional survey and test excavation (**top right**). These features are not visible in a color photograph (**center left**), and are difficult to see through vegetation noise in thermal imagery from 9:50 p.m. (**center right**) or 6:18 a.m. (**bottom right**). Thermal imagery collected just after sunrise at 7:18 a.m. (**bottom left**) reveals the subtle topography of the house compound.

created, which can be processed to produce precise digital elevation models (or digital surface models (DSMs)) and a wide range of different visualizations of the data [3.22, p. 90]. LiDAR provides archaeologists with two great advantages over conventional aerial photography: tree canopies can be eliminated where the laser is able to penetrate to the ground surface through gaps in the vegetation; and the three-dimensional terrain models can be visualized in many ways, simply by moving the angle and azimuth of the sun to enable ground features to be viewed under optimal (and sometimes naturally impossible) lighting. Both facilities have been used effectively 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. In Russia, drone-mounted LiDAR sensors were used in a four-year

AI and Archaeological Survey

The amount of data produced through LIDAR and satellite imagery is so enormous that it is outstripping the capacity of archaeologists to analyze them. However, these unknown archaeological features, left unexamined, are vulnerable to loss. The use of **machine learning** and artificial intelligence (AI), or the ability for computers to mimic the problem-solving and decision-making capabilities of humans, is addressing this problem. This has profound implications for how archaeologists detect and classify archaeological features.

AI for archaeology developed from experiments in the early twenty-first century that sought to use image recognition software on satellite images to make detections of simple shapes using predefined templates. This approach proved time consuming and inflexible, and generated high numbers of false identifications. This all changed in 2016 with the introduction of image recognition using deep convolutional neural networks (CNNs). This approach is based on machine learning, in which the AI is presented with a large dataset of images of known sites or objects so that it can learn the features that are important for identification. Once the AI has learned the key features, it can examine unseen data. In this process the AI makes

predictions (i.e. that there is an X at this location) and gives a numerical value to the confidence of that prediction. This is similar to how humans learn with reference to known examples, building up expertise by seeing more and more examples, and learning from others.

For this approach to be effective, large datasets to train the AI are vital. This is one of the key challenges in applications of AI to archaeological remote sensing, as training datasets have so far been small. Even if this approach is not always possible, it still encourages archaeologists to be explicit in how they define and classify features and sites. There is no suggestion of automating archaeology, whereby we humans are cut out of the loop, but we have a challenge to consider how a tool that may outperform us in some tasks can be used.

Working with AI on Arran

What does machine learning in archaeology look like in practice? Arran, a small island in Scotland, has become something of a test environment for AI approaches. One project, led by Iris Kramer, is training an AI model on examples of prehistoric roundhouses, medieval shieling huts, and small clearance cairns defined by archaeologists from Historic

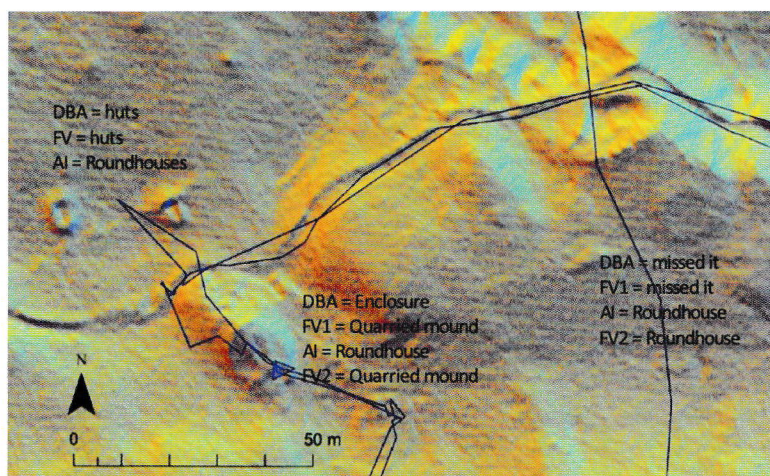
Environment Scotland (HES). This is work in progress, but an approach that combines the AI outputs with feedback from human expertise and field investigation is proving fascinating. Introducing landscape knowledge is helping to reduce dramatically the incidence of false positives, while instances where desk- and field-based investigation missed sites that were found by the AI demonstrate the value of systematic examination of landscape data by an AI [3.21]. These developments mean that AI-led analysis of remote sensing datasets may be embedded to build up more systematic information about the disposition and character of archaeological remains, and to enhance information about Scotland's national heritage.

What Next?

AI is a rapidly developing field. As with other aspects of new technology or methods, it is crucial that careful thought is given to how such developments are assimilated into routine practice. This is important because, while implementing AI currently requires technical skills, it will soon become more accessible as a research tool, though not one that replaces the archaeologist.

Iris Kramer

3.21 Human-computer interaction on the Isle of Arran, illustrated against a LIDAR-derived multi-direction hillshade visualization. Desk-based assessment (DBA) of the visualizations by archaeologists identified sites and features of interest that were subsequently visited in the field (FV – walking tracks recorded by GPS). The Arran data were then used to train and run an AI model (AI). The AI's detections were subsequently visited in the field (FV2). This iterative process has revealed how archaeologists missed the footings of the roundhouse in the top right of the image, while both desk-based assessment and the AI mis-classified the quarried mound in the center left of the image. This is a valuable process to help understand how archaeologists can work with AI to improve documentation and understanding of the archaeological features in our landscapes. Image: Dave Cowley, contains LIDAR for Scotland Phase 3. Crown copyright Scottish Government, SEPA and Fugro (2020).





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

3.23 A view of the Lesnaya barrow group in Russia using drone-mounted LiDAR sensors.



survey that resulted in the discovery of many groups of burial mounds [3.23] that are now in forested areas, as well as hillforts and even the foundations of a nineteenth-century church. A good example of the practical application of LiDAR to an archaeological site comes from the Maya city of Caracol in Belize (see feature opposite). One variant of ALS, green LiDAR, can penetrate shallow water and has successfully been used to identify and record submerged remains in parts of the Mediterranean Sea.

Another remote sensing technique, **SLAR (side-looking airborne radar)**, 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 its high-resolution air photos and satellite images, or to buy copies of them. For example, a desert camp used by Lawrence of Arabia in World War I (1918) was recently located in Jordan as a result of Google Earth being used to examine a likely location shown in contemporary photographs [3.28, 3.29, p. 92].

The high-resolution images publicly available from the IKONOS (about 1 m/3 ft. resolution) and QuickBird (60-cm/24 in.) satellites offer data comparable with aerial photographs, while Google Earth has basic world cover from NASA's LANDSAT series (28.5 m/94 ft.) but also incorporates IKONOS, QuickBird, and GeoEye images, some other satellite imagery, and conventional aerial photographs. IKONOS and QuickBird provide both multispectral (MS) and panchromatic (PAN) high-resolution imagery in which such details as buildings are easily visible. The imagery can be imported into remote sensing image-processing software, as well as into GIS packages for analysis.

Some useful early work was done using images from the LANDSAT series. Scanners record the intensity of reflected light and the infrared radiation from the Earth's surface.

Lasers in the Jungle



One of the best examples of the application of LiDAR (or ALS) to archaeology is at Caracol, a Maya

city in Belize that flourished between 550 and 900 CE. Arlen and Diane Chase of the University of Central Florida have been excavating at this site for more than twenty-five years, during which time researchers on the ground managed to map 23 sq. km (9 sq. miles) of settlement, despite the dense tropical forest [3.24]. 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).

John Weishampel, a biologist from the same university, designed the project's use of LiDAR. Having used lasers to study forests and other vegetation for years, he now applied this technique to the recording of an archaeological ruin under a tropical rainforest. The laser signals penetrate the jungle cover and are reflected from the ground below. 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 made more than 4 billion measurements of the landscape below. This was then followed by three weeks of analysis by remote sensing experts [3.25, 3.26].

Caracol's entire landscape can now be viewed in three dimensions [3.27], which has led to the discovery of new ruins, agricultural terraces, and stone causeways leading to

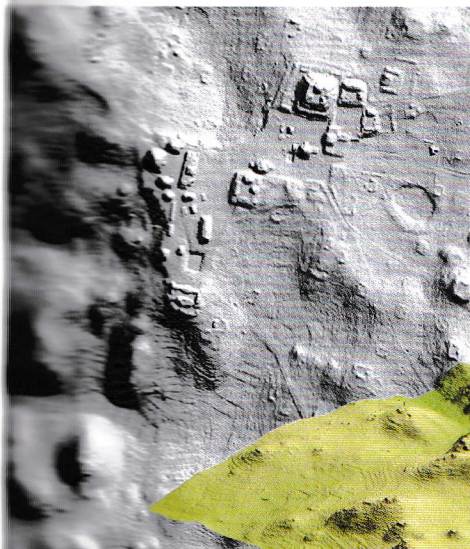
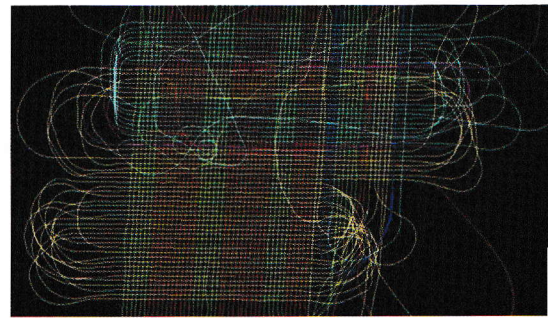
more distant settlements. This was the first application of LiDAR to such a large archaeological site, and it is clear that the technique will radically transform research on sites in challenging environments of this kind. Just as excavation alone can verify the findings of ground-based remote sensing, so the data produced from the air at Caracol will need to be confirmed on the ground.

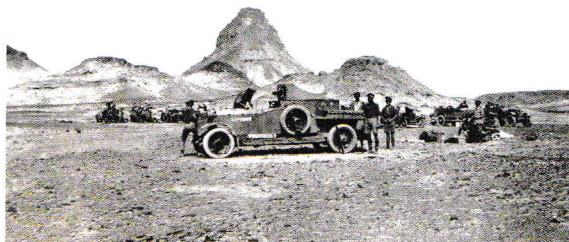
3.24 (Above) Plaza A at Caracol; only a tiny proportion of the city's total area has been cleared.

3.25 (Left) A LiDAR image of the center of Caracol with jungle cover removed; agricultural terraces show up as ripples in valleys and hillsides.

3.26 (Right) The plane's route over its twenty-four hours of flight time, during which billions of measurements of the landscape were taken.

3.27 (Below) The 3D projection of the Caracol LiDAR survey, showing the features beneath the canopy.





3.28, 3.29 The black-and-white photograph above, together with Colonel T. E. Lawrence's own writings, which refer to a "toothed hill" at which his team made camp, helped a Bristol University team identify the site at which Lawrence stopped overnight while campaigning in northwestern Arabia.



and convert these electronically into photographic images. LANDSAT images have been used to trace large-scale features such as ancient levee systems in Mesopotamia and an ancient riverbed running from the deserts of Saudi Arabia to Kuwait, as well as sediments around Ethiopia's Rift Valley that are likely to contain hominin fossil beds.

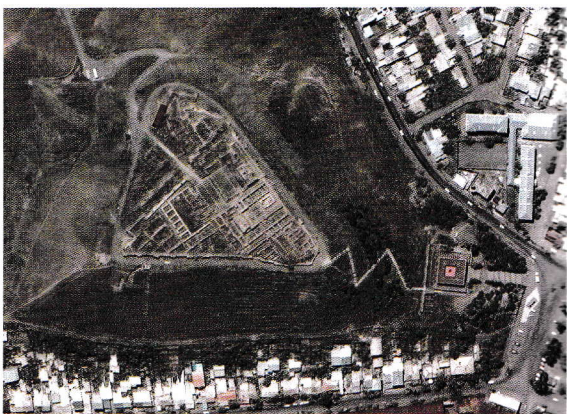
The introduction of Google Earth has been a true aerial revolution, since it offers every archaeologist the opportunity to examine the ground and look for archaeological sites. It is being used, for example, by paleontologists in Africa to hunt for fossils, and in 2008 it revealed five hundred new caves in South Africa alone, including the one that yielded the bones of *Australopithecus sediba* (see p. 172). Hundreds of new archaeological sites in Afghanistan and thousands of tombs in Saudi Arabia are also being discovered by this method. But the same rules of visibility apply to those images as to conventional aerial photos, and the absence of evidence on a particular date is not evidence of absence. Microsoft's web search engine Bing offers a more restricted range of aerial images, but these are sometimes different from those used in Google Earth and so complement this material. NASA's World Wind also offers worldwide cover but at lower resolutions or using aerial images available elsewhere. It is important to note, however, that most users have never been trained

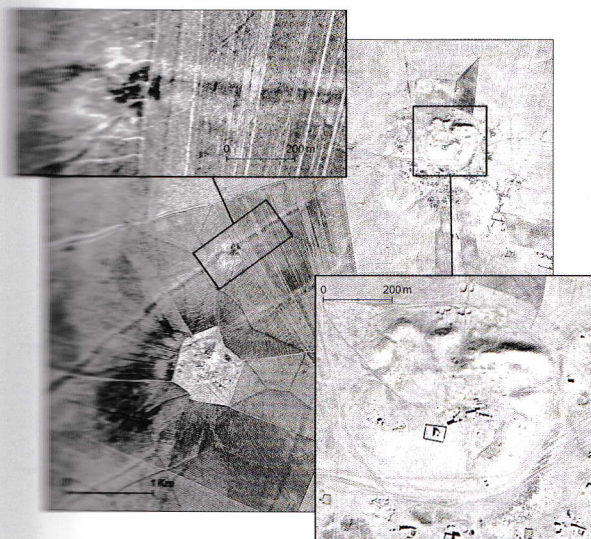
to interpret such images and many expect sites to be visible at all times.

Both QuickBird and IKONOS images are stored in image libraries and can be accessed for a low cost. It is also possible to have photographs taken to order, although the minimum cost may be high. In parts of the world where maps are still considered confidential documents 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/6 ft. 6in. resolution) [3.30, 3.31]. These provide a useful base map and allow provisional interpretation of sites, which can later be checked by fieldwork. CORONA images have led to the detection and detailed mapping of numerous kinds of archaeological remains, such as ancient roads, ruins, and

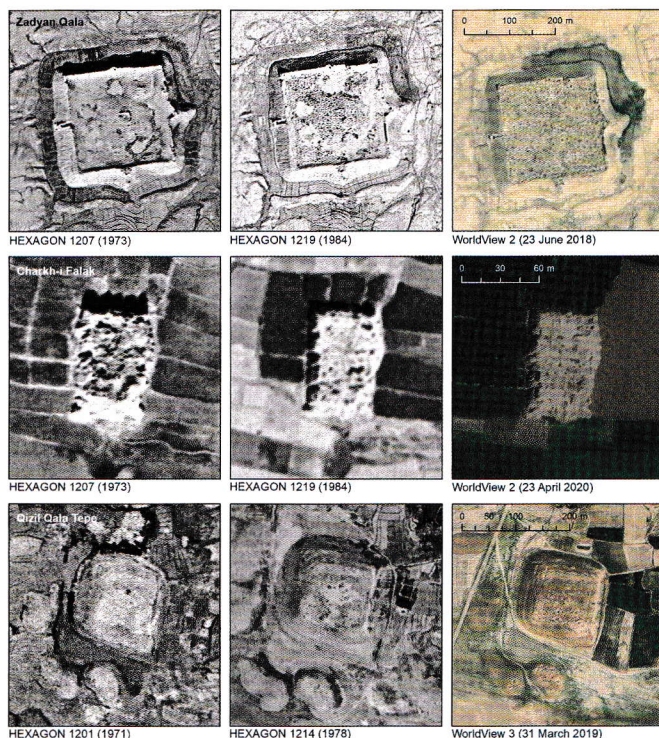
3.30, 3.31 Two satellite images of the Urartian citadel of Erebuni, near Yerevan, Armenia, founded in 782 BCE. (Below) An image from the American CORONA series taken in 1971, with resolution of about 2 m (10 ft. (Bottom) A higher-resolution screenshot from Google Earth of a QuickBird image taken in 2006. Both are displayed with south to the top, so shadows assist photo-reading of topography and structures.





3.32 (Above) A HEXAGON photograph of the Early Bronze Age city of Hamoukar (Syria), showing details of the site's main mound and a hollow way feature to the southwest.

3.32 (Right) A time series of HEXAGON images, 1971–1984, showing the increasing extent of looting at Zadyan Qala, Charkh-i Falak, and Qizil Qala Tepe, Balkh Oasis (Afghanistan).



irrigation networks. CORONA takes two images of the same spot, which can be processed to produce a stereoscopic view and a three-dimensional digital surface model.

Jason Ur of Harvard University has used CORONA satellite photography to examine linear trackways across northern Mesopotamia (Syria, Turkey, and Iraq). These broad and shallow features (often called hollow ways) were formed over time as people walked from settlement to settlement, and from settlements to fields and pasture. Because depressed features collect moisture and vegetation, they are easily visible on CORONA images. Some 6,025 km (3,750 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 the region was home to several major centers, all intersite and interregional movement was through a chain of smaller settlements; no direct tracks existed between the major centers. Political centralization was probably weak, and authority was likely to have been consensual: even the elite had to respect local systems of land tenure as they moved about.

In recent years more declassified US spy photographs have been released, from U2 missions and the HEXAGON satellite [3.32, 3.33]. The latter has considerably better

resolution than CORONA, and a number of archaeological studies have already used it, for example, on the Roman camps and siege works at Machaerus (Jordan) and Masada (Israel).

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. One of SAR's 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, nondestructive alternative to surface survey that does not involve the collection of artifacts and can, therefore, save a great deal of time and effort in some circumstances.

The international Greater Angkor Project has found that the vast ruins of the 1,000-year-old temple complex of Angkor in northern Cambodia may cover an area of up to 3,000 sq. km (1,150 sq. miles). The ruins, shrouded in dense jungle and surrounded by landmines left over from the civil war, have been the subject of studies using

	Technique	Uses	Pros	Cons	Open Access
Air photographs	Oblique	Recording archaeological features by an observer	Provides clear views of sites Makes good illustrations	Features need to have been recognized prior to being photographed	Specialist aerial photograph libraries
	Vertical	Recording whole landscapes Historic photographs can be used to document land use and development and to identify threats to archaeological sites	Millions of existing images Photographs usually taken to be examined stereoscopically	Many photographs are not taken at optimum times to record archaeological information Good interpretation requires expertise	Google Earth, Microsoft Bing, Geoportal websites for many EU countries USGS Earth Explorer has some free downloads of parts of the data Some collections have online access to thumbnails at least
	Very low altitude (drone, UAV, kite, balloon, pole)	Recording a known site, excavation or small predetermined area	Relatively cheap Good for illustration Software can produce 3D models from appropriate photographs	Most current aviation laws do not permit out-of-sight flight, therefore remote survey is not (yet) possible	Private collections, often research-driven
Visible wavelengths (satellite imagery)	CORONA	Provides a historic view (1960s–70s)	Cheaply available Best resolution is about 2 m (6 ft)	Cover is not worldwide Severe image distortion due to collection technique	USGS Earth Explorer enables searches to be made. Thumbnails can be inspected for cloud cover
	WorldView/Quickbird/IKONOS/GeoEye	Provides a high-resolution image in places where air photographs are not available	Much is freely available on the Internet Sub-meter resolution allows identification of many types of archaeological features	Can be fairly expensive	DigitalGlobe's website carries an overview, gallery, and lets searches be made via an image finder
	LANDSAT	Visible and non-visible wavelength data collection active since 1972	Worldwide repeated cover on many dates	Coarse resolution	Scenes can be inspected and downloaded from LANDSAT's website
	Airborne Laser Scanning (ALS) or LiDAR	Provides accurate models of upstanding features and their terrain	Very high resolution Software can remove forest canopy to provide accurate terrain model	Expensive Experience needed to decide optimum ground resolution before data capture Survey produces huge point clouds of data that need skillful processing	In the USA, there is a National LiDAR Program undertaken by USGS. Point density can be too low for archaeology, but useful for general topography. In Europe, national environmental agencies may have data
Non-visible wavelengths (airborne/spaceborne)	Multispectral/hyperspectral	Investigates phenomena that are detected in visual and infrared wavelengths	Potential for merging data from separate wavelengths to optimize information	Masses of data that may need initial analysis using automated processing	DigitalGlobe has spaceborne multispectral scenes
	SLAR/SAR/SIR-C	Provides accurate topographic map and terrain model Can record large upstanding archaeological features In specific conditions can provide images of sub-surface features	Sub-meter resolution from airborne sensors Software can remove forest canopy to provide accurate terrain model	Spaceborne data can have fairly coarse resolution	NASA and USGS hold archive data
	Thermal radiometry	Records objects that have different thermal properties Data collection from space, aircraft or very low altitude	May detect surface and some sub-surface remains	Early airborne data was of low resolution Spaceborne data (ASTER) is too coarse for detection of all but monumental archaeological remains	Private collections, often research driven

3.34 A table summarizing the main techniques used in aerial survey.



3.35 A SAR satellite image of the huge ancient site of Angkor, Cambodia. The largest temple, Angkor Thom, is visible through the jungle cover as a large green square, with the smaller Angkor Wat beside it. The large dark rectangles are reservoirs.

high-resolution radar imagery obtained from NASA satellites [3.35]. The resulting dark squares and rectangles on the images are stone moats and reflective pools of water 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), which irrigated rice fields and fed the pools and moats. They were probably also used to transport the massive stones needed for constructing the complex. Recent LiDAR survey of this area has considerably supplemented the information derived from satellite sources.

ASTER (the 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. It goes beyond LANDSAT in that it captures data in fourteen bands, from the visible to the thermal infrared wavelengths, and also provides a stereo viewing capability for the creation of digital elevation models. As the best ground resolution is 15 m (50 ft.), ASTER is useful for examining terrain rather than for detecting sites, unless they are very large, such as the tell settlements typical in Southwest Asia.

The European Space Agency's UTM-2 comprises two satellites capable of recording locations in the globe's mid-latitudes every two to three days using multispectral sensors. Images are added to the ESA's website and can be used to monitor crop development to help select optimal dates for commissioning higher-resolution aerial cover or to check vegetation cover prior to field survey visits.

Satellite remote sensing projects carried out by archaeologists 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 help archaeologists determine where to excavate and may precede archaeological survey.

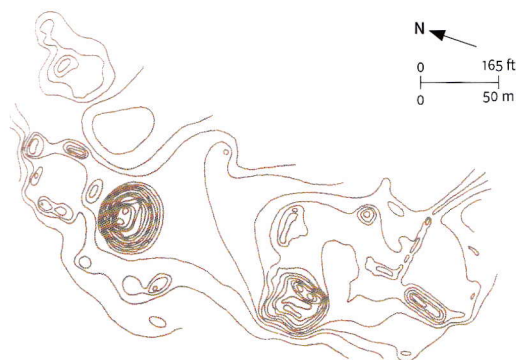
Archaeologists will need to persist in rethinking their surveying and excavation strategies in light of this new information, especially as image resolution continues to increase with technological advances [3.34, opposite].

Recording and Mapping Sites in Survey

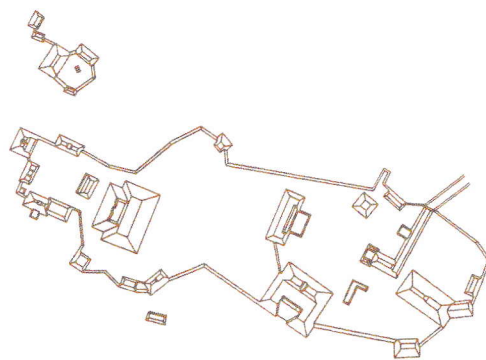
As already noted in the discussion of aerial survey, the pinpointing of sites and features on regional maps is an essential next step in survey. To have discovered a site is one thing, but only when it has been adequately recorded does it become part of the sum total of knowledge about the archaeology of a region.

Mapping is the key to the accurate recording of most survey data. For surface features, such as buildings and roads, both topographic and planimetric maps are used [3.36, p. 96]. Topographic maps represent differences in elevation or height by means of contour lines and help relate ancient structures to the surrounding landscape. Planimetric maps exclude contour lines and topographic information, concentrating instead on the broad outlines of features, therefore making it easier, for example, to understand the relationship of different buildings to each other. On some site maps the two techniques are combined, with natural relief depicted topographically and archaeological features planimetrically.

In addition to plotting a site on a map—including its exact latitude, longitude, and map grid reference (or a metric UTM reference)—proper recording entails giving the site some kind of locational designation and entering this on a site record form, along with information about who owns the site, its condition, and other



3.36 Two ways of presenting survey results, as exemplified by these representations of the Maya site of Nohmul, Belize.



(Above left) A topographic map relating the site to its landscape. (Above) A planimetric map showing the individual features of the site.

details. Locational designations vary in different parts of the world. In the United States, they usually consist of a two-digit number for the state, a pair of letters for the county, and a number indicating that this is the *n*th site discovered in that county. Thus, site 36WH297 designates the 297th site discovered in Washington County (WH), in the state of Pennsylvania (36). This is the locational designation for the famous Paleoamerican Meadowcroft Rockshelter. One of the great values of designating sites using these alphanumerical systems is that the information can be easily entered on computer files for quick data retrieval, for example in salvage archaeology or settlement-pattern studies.

Geographic Information Systems

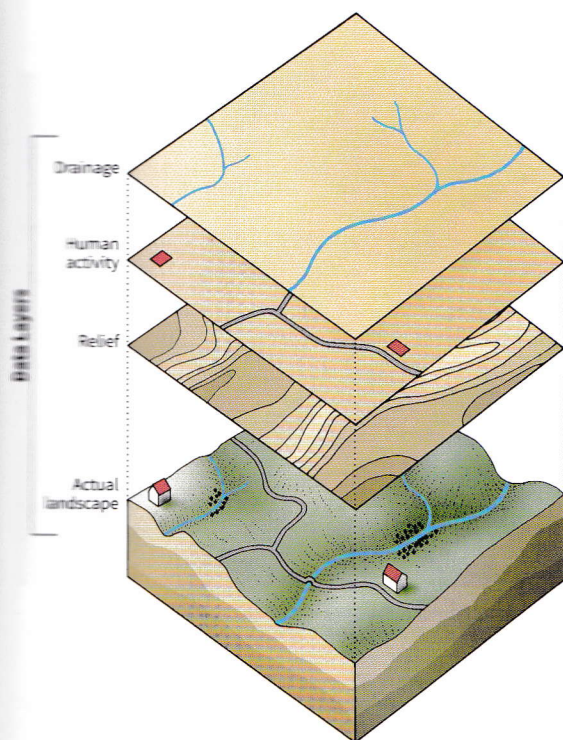
The standard approach to archaeological mapping is now the use of geographic information systems, described in one official report as “the biggest step forward in the handling of geographic information since the invention of the map.” GIS are collections of computer hardware and software and of geographic data, designed to obtain, store, manage, manipulate, analyze, and display a wide range of spatial information. Developed out of computer-aided design and mapping (CAD/CAM) programs during the 1970s, they combine a database with powerful digital mapping tools. 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, can also carry out a statistical analysis of site distribution and generate new information. Given information about slope and distance, for example, a GIS can also be used for cost surface analysis, mapping catchment areas and site territories, taking the surrounding terrain into account. Here, the software and digital landscape information are fed into a computer, along with (as a standard measurement) the

figure of one hour for a 5-km (3-mile) walk on the flat. The software then does the calculations, using built-in data on the energy cost of traversing different kinds of terrain. GIS, therefore, have applications far beyond recording and mapping, and we shall return to their analytical capabilities in Chapters 5 and 6.

A GIS will hold information on the location and attributes of each site or point recorded. Spatial data can be reduced to three basic types: point, line, and polygon (or area). Each of these units can be stored, along with an identifying label and a number of nonspatial attributes such as name, date, or material. A single archaeological find might therefore be represented by an easting and northing coordinate and a find number, while an ancient road would be recorded as a string of coordinate pairs and its name. A field system could be defined as strings of coordinates following each field boundary, along with reference names or numbers. Each map (sometimes described in a GIS as a layer or coverage) may consist of a combination of points, lines, and polygons, together with their different nonspatial attributes [3.37, p. 97].

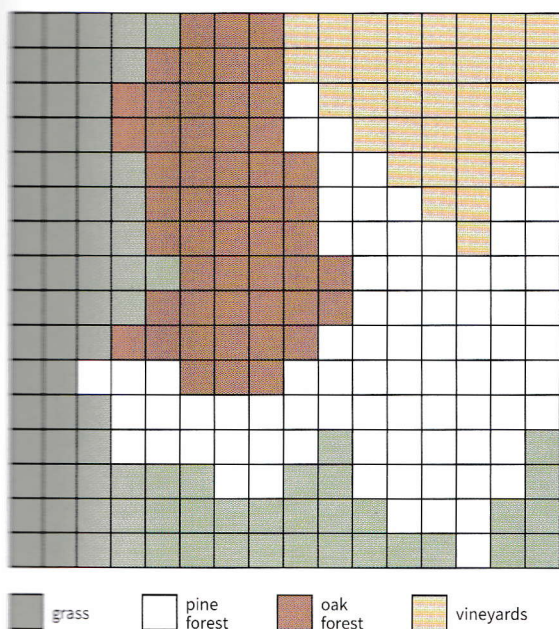
Within a map layer, the data may be held in vector format, as points, lines, and polygons, or stored as a grid of cells, in raster format [3.38, p. 97]. A raster layer recording vegetation, for example, would consist of a grid within which each cell contains information on the vegetation present at that point. Nowadays, most commercial systems will allow these different data structures to be mixed.

A GIS may include an enormous amount of environmental data on relief, communications, hydrology, and so on. To make all this information easier to handle, it is normal to divide it into different map layers, each representing a single variable. Archaeological data may themselves be split into several layers, most 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 in a GIS. These can include site



3.27 (Above) Diagram showing possible GIS data layers.

3.28 (Below) Raster representation of a data layer showing vegetation: each cell is coded according to the main vegetation type.



plans, artifact distributions, aerial images, and **geophysical** survey results, as well as maps. A good example of many different types of data being incorporated into a GIS is the Giza Plateau Mapping Project (GPMP) in Egypt (see feature, pp. 98–99).

The ability to incorporate aerial images into a GIS can be particularly valuable for site reconnaissance as they 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 of archaeological material culture. This is done by means of a handheld GPS, which allows archaeologists to map their ground position (in some cases within as little as 3 cm/1 in.) by connecting to a global satellite system. A minimum of four satellites must be communicating with the GPS to provide precise *x* and *y* data, which can display the received information in longitude and latitude (degrees, minutes, seconds), or in a UTM coordinate system, which 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*, and *z*, or northing, easting, and elevation) of the surveyed points relative to the Total Station positions 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. The ability of GIS to incorporate archaeological data within modern development plans allows a more accurate assessment of their archaeological impact.

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

GIS and the Giza Plateau



For nearly thirty years, the American Egyptologist Mark Lehner has been systematically exploring a site at the

edge of Egypt's Giza Plateau that was home to the workforce that built the pyramids [3.39]. This vast urban center is known as Heit el-Ghurab (Wall of the Crow) or the Lost City of the Pyramid Builders [3.40]. Since 2005, Lehner's Ancient Egypt Research Associates (AERA) have also been working southwest of the Sphinx in the area around the Menkaure Valley Temple and the town attached to the tomb of Queen Khentkawes.

Directed by Rebekah Miracle, AERA's GIS is being used to integrate the project's drawings, forms, survey data, and artifact databases into a single organized digital archive [3.41, 3.42]. This enables the team to map patterns of architecture, burials, artifacts, and other materials such as foodstuffs [3.43]. For example, it appears that the residents of large houses ate the most desirable animal foods, beef from young cattle and Nile perch, while others ate predominantly sheep, goat, and pigs.

Data collected over almost thirty years, all of which are being incorporated in the GIS [3.44], include:

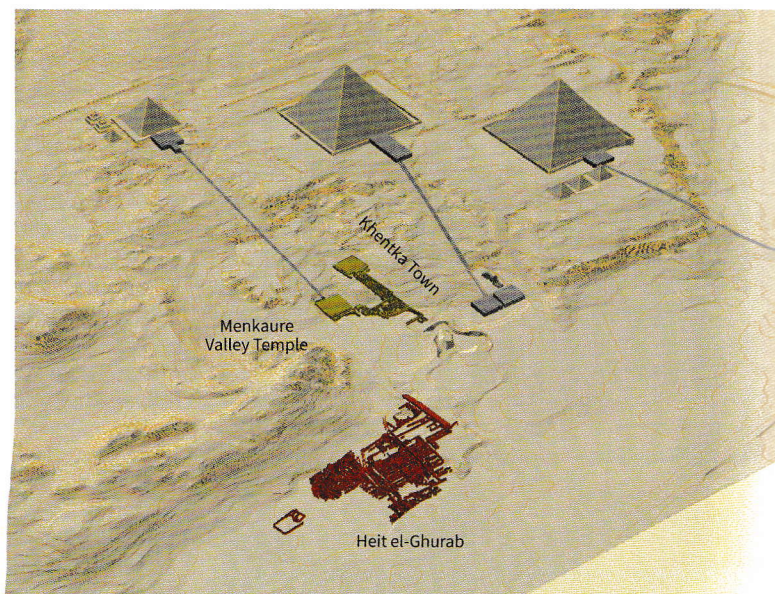
- more than 19,000 archaeological features
- more than 6,000 field drawings
- survey and remote sensing data
- aerial and satellite imagery
- historical maps
- artifact/ecofact distribution information.

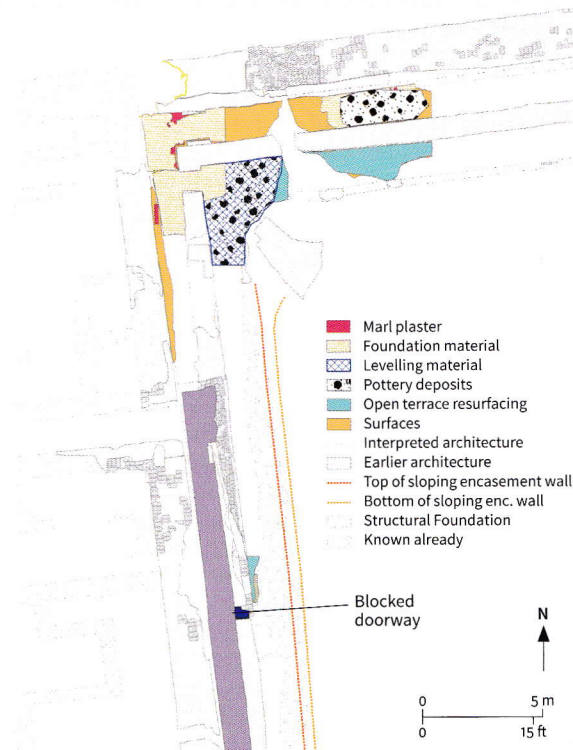
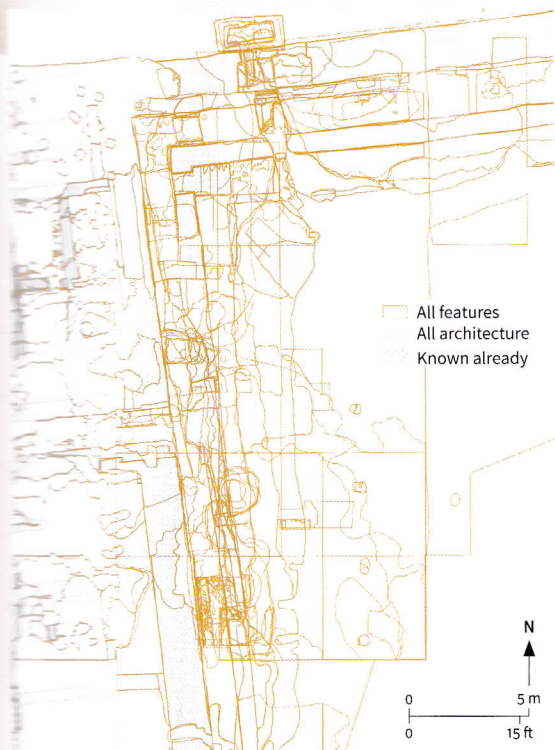
Eventually, AERA hopes to make all of these data available in an online database and GIS that can be accessed by researchers worldwide.



3.39 (Above) The Giza Plateau Mapping Project (GPMP) 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.

3.40 (Below) Using digitized 1-m (3-ft.) 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, the GPMP survey grid is draped over the surface of the plateau. The Lost City of the Pyramid Builders is clearly visible in the foreground.

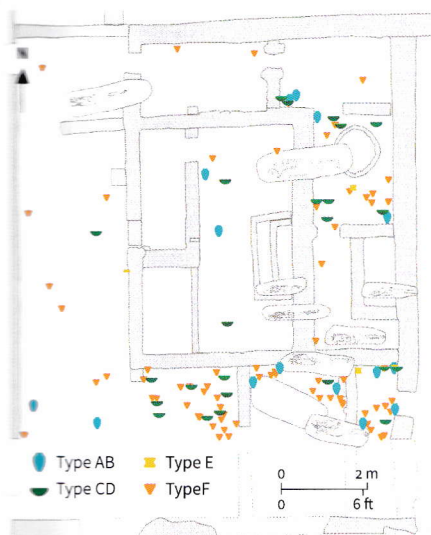




3.41, 3.42 (Above, left and right) GIS presentation of the features that have been digitally recorded in the Royal Administrative Building (RAB), one of the GPMP's largest and most complex excavation areas.

3.43 (Below) The spatial distribution of finds is easy to represent within the GIS. Here, the distribution of four different pottery types (shown in blue, green, yellow, and orange) is displayed in an area of the Heit el-Ghurab settlement known as the Eastern Town House. Also displayed are later burials that have cut through the house's walls.

3.44 (Right) Survey and excavations since 1988 have been concentrated on the area known as Heit el-Ghurab, or The Lost City of the Pyramid Builders, some 400 m (1,300 ft.) south of the Sphinx. This detailed plan of the settlement, which was abandoned at the end of the 4th dynasty (2575–2465 BCE), the period of Giza pyramid building, now forms part of the GIS.



models is that particular kinds of archaeological site 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 from the known environmental characteristics of a given location how likely it is to contain an archaeological site. In a GIS this operation can be done for an entire landscape and a predictive model map produced for the whole area.

An example developed by the Illinois State Museum for the Shawnee National Forest in southern Illinois 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 sixty-eight sites, which are known from the 12 sq. km (4.6 sq. miles) that have been surveyed. A GIS database was constructed for the entire area including data themes for elevation, slope, aspect, distance to water, soil type, and depth to the water table. The characteristics of the known sites were compared with the characteristics of the locations known not to contain sites, using a statistical procedure known as logistic regression, a probability model resulting in an equation that can be used to predict the probability that any location with known environmental characteristics will contain a prehistoric site.

The potential value of predictive modeling with GIS has also become apparent outside North America, particularly in the Netherlands and in Britain. Such models can be of value both in understanding the possible distribution of archaeological sites within a landscape and for the protection and management of archaeological remains in cultural resource management (see Chapter 15).

Many GIS applications, especially those based on predictive modeling, have been criticized as being environmentally deterministic, and it is easy to see why. Such data as soil types, rivers, altitude, and land use can be measured, mapped, and converted into digital data, whereas cultural and social aspects of landscape are much more problematic. To escape from these more functionalist analyses, archaeologists have used the GIS function called **viewsheds** to try to develop a more humanistic appreciation of landscape (see pp. 207 and 213, and feature, pp. 208–209).

Assessing the Layout of Sites and Features

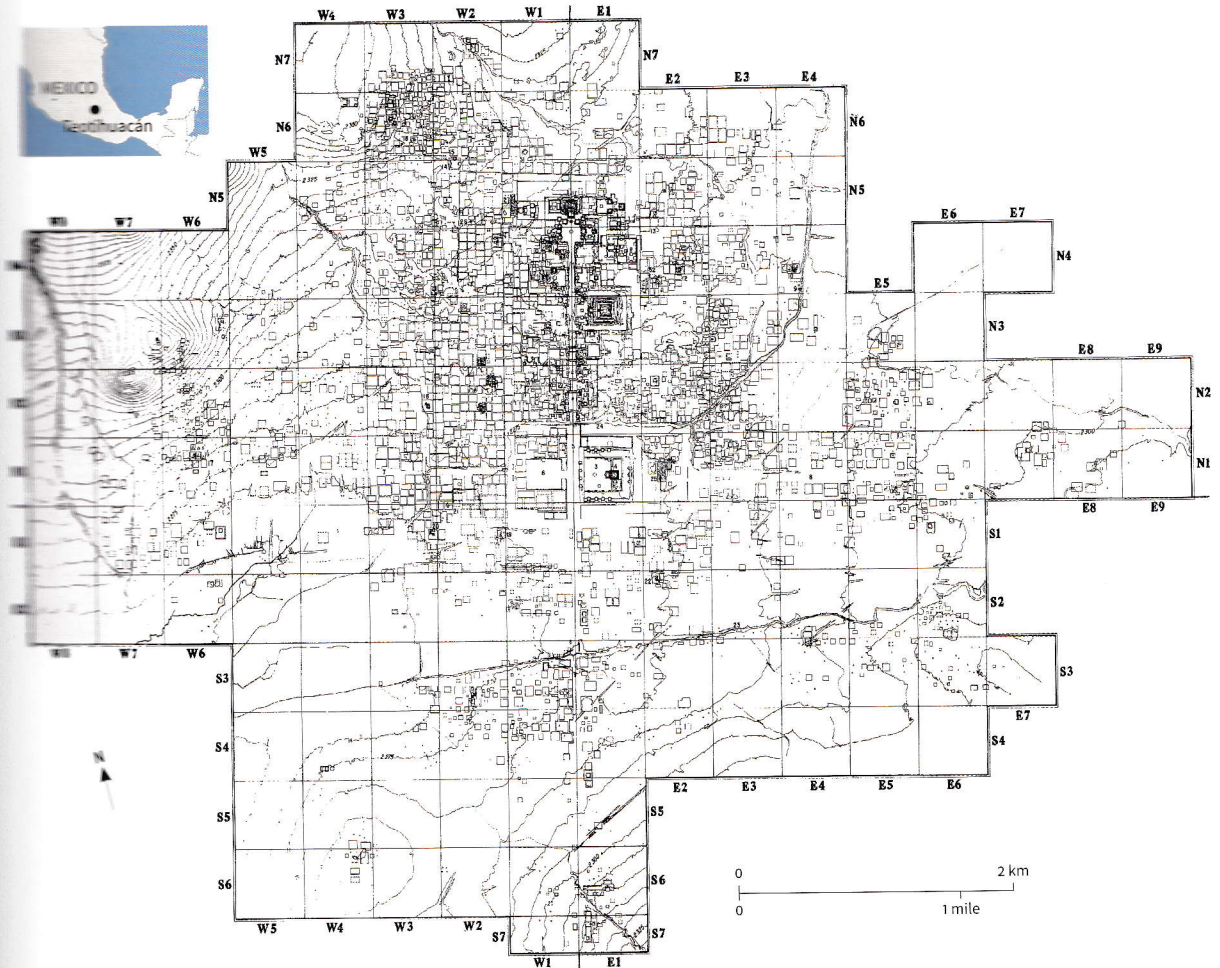
Finding and recording sites and features is the first stage in fieldwork, but the next stage is to make some assessment of site size, type, and layout. These are crucial factors for archaeologists, not only for those who are trying to decide whether, where, and how to excavate, but also for those whose main focus may be site management or the study of settlement patterns, site systems, and landscape archaeology without planning any recourse to excavation.

We have seen how aerial images may be used to locate and plot the layout of sites and how the experimental use of drones and machine learning have begun to locate, record, and classify pottery scatters, for example in north-east Greece. But 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 Teotihuacán Mapping Project, for instance, used site surface survey to investigate the layout and orientation of the city, which was the largest and most powerful urban center in Mesoamerica in its heyday from 200 to 650 CE [3.45, 3.46]. The layout and orientation of the city had intrigued scholars for decades; however, they considered the grandiose pyramid temples, the plazas, 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 Teotihuacán Mapping Project that the outer limits, the great east–west axis (see p. 413), and the grid plan of the city were discovered and defined. Fortunately, structural remains lay just beneath the surface, and so the team were able to undertake the mapping from a combination of aerial and surface surveys, with only small-scale excavation to test the survey results. Millions of potsherds were collected, and more than 5,000 structures and activity areas recorded. Since 1980, a team from the Mexican Institute of Archaeology and History (INAH) has been enlarging the picture so successfully established by the Teotihuacán project survey. Other teams employed geophysical methods to map a system of caves and tunnels used for extracting construction material, as well as for burials and rituals. Magnetometer and resistivity surveys (see pp. 105 and 110), undertaken by a team from the National Autonomous University of Mexico led by Linda Manzanilla, were used to create a three-dimensional reconstruction of subsurface contours.



3.45 (Above) An archaeological and topographic map of Teotihuacán produced by the Teotihuacán Mapping Project. The survey grid system of 500-m (1,650-ft.) 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).



3.46 (Left) A 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.

Tell Halula: Multiperiod Surface Investigations



Surface investigations by Australian archaeologist Mandy Mottram at Tell Halula in northern Syria in 1986 aimed to establish the occupation

history of this multiperiod site by identifying the different cultures represented, as well as the location and extent of their settlements [3.47, 3.48]. Earlier investigations of the site using **nonprobabilistic sampling** (based on the judgment of the sampler) methods implied a principal occupation during the Halaf period, c. 5900–5200 BCE, followed by several lesser occupations. The subsequent discovery of materials belonging to a preceramic phase of the Neolithic suggested that the occupation history of the site might be far more complex than had hitherto been suspected.

After the extent of the site had been determined, artifacts such as potsherds and stone tools were collected from the surface using stratified random sampling procedures based on a grid system [3.49]. Forty-six squares in this grid were sampled, amounting to 4 percent of the 12.5-ha (31-acre) site area. Typological analysis of the artifacts enabled Mottram to identify ten major occupation phases, representing fifteen different cultural periods. The

3.47 The survey and collecting team at Tell Halula using a theodolite.



3.48 A CORONA satellite image of the Halula district, showing the location of the tell and the boundary of the sampling area.

presence of transitional-type artifacts indicated that occupation was often continuous from one phase to another, testifying to long-term political and economic stability.

To establish where the different settlements were located on the tell, GIS software was used to map the distribution of artifacts belonging to each occupation phase. The resulting contour maps of artifact density were then overlaid on a

relief map of the site and on each other, enabling the distributions to be interpreted in the light of both surface topography and the probable stratigraphic relations of the parent deposits. Integral to this process was the application of a noise estimate, which helped to screen out materials that probably reached their current locations as a result of random rather than long-term processes.

Results of the Survey

As well as indicating the number, size, and chronology of the different settlements, an important result of this work was the identification of some of the processes involved in the mound's formation and how these affected what remained on the surface. One important discovery was that the site was originally composed of two tells—one to the southeast and the other to the northwest. The maps also revealed that the site is severely eroded, a situation evidently exacerbated in recent times by the clearance of surface architecture.

The later occupation deposits have been severely degraded, leaving earlier levels widely exposed. Many of the later settlements are therefore likely to have been more extensive than is indicated by any remains. At the same time, it is now certain that the site was most extensively

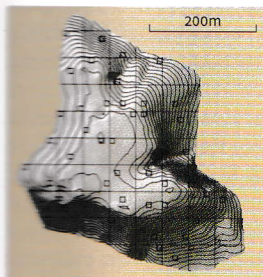


occupied during the Pre-Pottery Neolithic, dating to c. 7900–6900 BCE, rather than during the Halaf period, as previously thought.

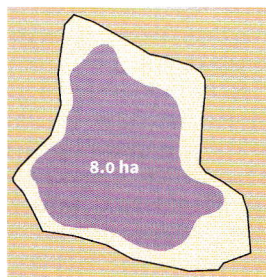
Another important discovery was that the site was finally abandoned only at the end of the Hellenistic (or start of the Roman) period—in around 60 BCE. All later materials were found to be the product of manuring of the area by the inhabitants of an adjacent site, indicating that, over the last two millennia or more, Tell Halula's main use has been as agricultural land.

It thus proved possible from surface survey, combined with GIS, to obtain a clearer understanding of the complex occupation sequence of this multiperiod site and to discover previously unknown details of its history.

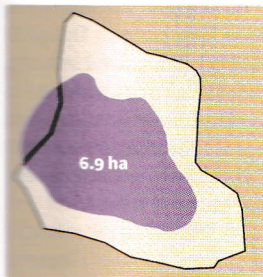
3.49 A plan of Tell Halula showing the layout of collection squares, plus outline plans of the tell showing the changing location and size of settlement during five of the ten occupation phases.



Topography and Collection Areas



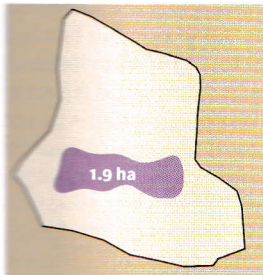
Pre-Pottery Neolithic B



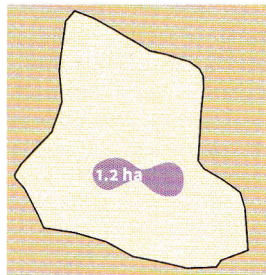
Halaf



Ubaid–Late Chalcolithic



Uruk–Early Bronze Age



Middle–Late Iron Age

Artifacts and other objects may be collected or observed during surface survey, but if they appear to come from badly disturbed secondary contexts it may not be worth mapping their individual locations. 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 surface 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, Frank Hole and his colleagues picked up everything from the entire surface of a 1.5-ha (3.7-acre) open-air prehistoric site in the Valley of Oaxaca, Mexico, plotting locations using a grid of 5-m (16-ft.) squares. They transformed the results into maps with contour lines indicating not differences in elevation but relative densities of various types of materials and artifacts. It then became clear that, while some objects (such as projectile points) were evidently in a secondary context displaced down slopes, others seemed to lie in a primary context and revealed distinct areas for flintworking, seed-grinding, and butchering. These areas served as guides for subsequent excavation.

A similar 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 craftworking 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. Now that surface survey has become not merely a preliminary to excavation but, in some instances, a substitute for it—for cost and other reasons, as outlined earlier in this chapter—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—an assumption that seems to be borne out by the shallow site of Teotihuacán, or Frank Hole's Oaxaca site mentioned above. Equally, we might predict that multiperiod, deep sites, such as West Asian tells or mounds, would show few if any traces on the surface of the earliest and deepest levels. Yet this is by no means always true, as shown by surface survey work at Tell Halula in Syria (see feature opposite).

Proponents of 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 examined with care, are truly multiperiod, reflecting many phases of a site's use, not just the latest one. The reasons for this certainly have something to do with the kind of formation processes discussed in Chapter 2—from erosion and animal disturbance to human activity, such 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 1-m/3-ft. squares) to assess a site's horizontal extent, or ultimately by more thorough excavation (see pp. 111–134). There is, however, a whole battery of subsurface detection devices that can be brought into play before—or indeed sometimes instead of—excavation, which of course is destructive as well as expensive to undertake.

Subsurface Detection

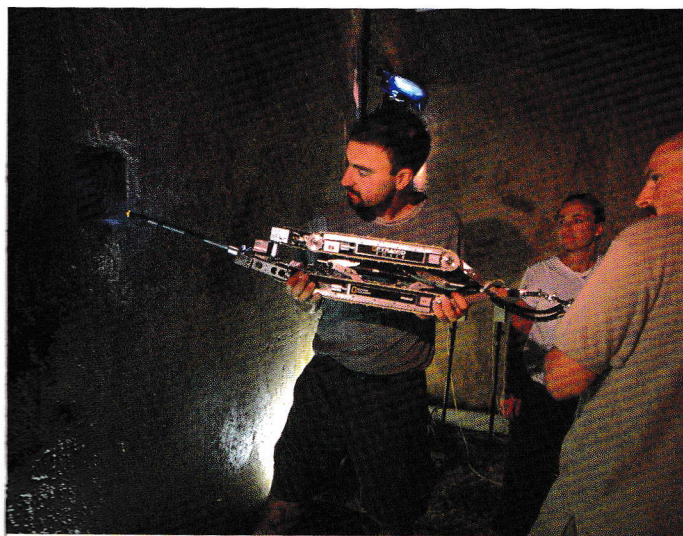
Probes. The most traditional technique is that of probing the soil with rods or augers and noting the positions where they strike solids or hollows. Metal rods with a T-shaped handle are the most common, but augers—large corkscrews with a similar handle—are also used, and have the advantage of bringing samples of soil to the surface, clinging to the screw. Many archaeologists routinely use handheld probes that yield small solid cores. Probing of this type was used, for example, to gauge the depth of the midden at the Ozette site in Washington State (pp. 60–61) and by Chinese archaeologists to plot the hundreds of

pits yet to be investigated near the first emperor's famous buried terra-cotta army. In the mid-1980s the American archaeologist David Hurst Thomas and his team used more than six hundred systematically spaced test probes with a gasoline-powered auger in their successful search for a lost sixteenth-century Spanish mission on St. Catherine's Island off the coast of Georgia in the United States. Augers are also used by geomorphologists studying site sediments. There is, however, always a risk of damaging fragile artifacts or features.

One notable advance in this technique was developed by Carlo Lerici (1890–1981) 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 below), he would bore down into it, creating a hole 8 cm (3 in.) in diameter, and insert a long tube with a periscope head and light, with a tiny camera attached if needed. Lerici examined some 3,500 Etruscan tombs in this way, and found that almost all were completely empty, saving future excavators a great deal of wasted effort. He also discovered more than twenty with painted walls, thereby doubling the known heritage of Etruscan painted tombs at a stroke.

Probing the Pyramids. Modern technology has taken this kind of work even further with the development of the endoscope (see Chapter 11) and miniature TV cameras. In a project reminiscent of Lerici, a probe was carried out in 1987 of a boat pit beside the Great Pyramid of Khufu (Cheops) in Egypt. This lies adjacent to another pit, excavated in 1954, which contained the perfectly preserved and disassembled parts of a 43-m (141-ft.) long royal cedarwood boat of the third millennium BCE (see p. 341). The 1987 probe revealed that the unopened pit did indeed contain all the dismantled timbers of a second boat. In 2008 a team from Waseda University inserted a second miniature camera to re-examine the boat's condition and ascertain whether it could be safely lifted. The covering stone blocks and the boat's timbers were duly removed in 2011.

Robot probes with miniature cameras have been sent up the so-called airshafts of the Great Pyramid to discover whether or not they link up to hidden chambers [3.50]. For example, the Pyramid Rover was able to reach and drill through a previously discovered stone slab that blocked one of these shafts, revealing another doorway behind. Further probes have been used by French and Japanese teams, who believe the Pyramid may contain as yet undiscovered chambers or corridors; using ultrasensitive



3.50 Robots were first used to explore and clear the Great Pyramid's airshafts in 1993. In 2002 the Pyramid Rover re-entered two of these shafts for more thorough investigation, navigating turns that the previous unit could not.

microgravimetric equipment—normally employed to search for deficiencies in dam walls, as it 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, however, has not been completed. All tests are carefully monitored by the Egyptian authorities until their potential contribution to Egyptology has been established. 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.

Ground-Based Remote Sensing

Probing techniques are useful, but inevitably involve some disturbance of the site. Geophysical methods offer a range of non-destructive techniques ideal for the archaeologist seeking to learn more about a site before—or increasingly often without—excavation. These methods measure the physical properties of the soil to help infer what lies unseen below the surface. Geophysical instruments either passively measure variations in naturally occurring magnetic or gravitational fields (e.g. magnetometer survey) or actively transmit energy into the ground and measure the response (e.g. Ground Penetrating Radar).

While hand-carried, single-sensor instruments have been used for many years, recent advances in electronics have enabled a new generation of multisensor arrays mounted on carts or towed behind vehicles allowing for multiple simultaneous measurements. Such arrays usually incorporate a GPS/GNSS antenna so there is no need to stake out a survey grid in advance, making landscape-scale geophysical survey possible.

Advances in computer processing allow data to be manipulated to suppress unwanted effects, highlight subtle archaeological anomalies, and offer new ways to display the results. For instance, directional filtering allows the data to be viewed as if it were a surface illuminated from various directions and elevations, which makes subtle anomalies more visible. Such processing mimics the revealing effects of low sunlight on earthworks, but with the added flexibility that the direction of illumination can be chosen.

Magnetic Survey Methods. These are among the most useful methods of archaeological survey because a wide variety of remains, such as iron objects, kilns, hearths, pits, and ditches, can all create a detectable magnetic signature. By far the most common technique is magnetometer survey, which measures slight distortions in the Earth's magnetic field caused by buried archaeological features. The reasons for these distortions vary according to the type of feature, but depend on the presence of

magnetic minerals, even if only in minute amounts. For example, structures such as kilns and hearths can become permanently magnetized because grains of iron oxide in the constituent clay, which has randomly orientated magnetism when the clay is unbaked, will line up and become permanently fixed in the direction of the Earth's magnetic field when heated above a threshold temperature. The baked clay therefore becomes a weak permanent magnet, creating an anomaly in the surrounding magnetic field. (This phenomenon of thermoremanent magnetism, or TRM, also forms the basis for magnetic dating—see Chapter 4.) By contrast, pits and ditches can cause magnetic anomalies because the magnetic susceptibility of their contents is greater than that of the surrounding subsoil. Magnetic susceptibility is the ability of materials that are not permanently magnetized to enhance the strength of an externally generated magnetic field, such as the Earth's, where it passes through them. A second magnetic technique, magnetic susceptibility survey, is designed specifically to detect variations in soil magnetic susceptibility using an instrument that creates its own magnetic field then measures the amount by which it is enhanced.

Different feature types each create magnetic anomalies with varying strengths and forms, allowing informative site plans to be produced (see feature, p. 106). Magnetometers are also well suited to deployment in multisensor arrays as measurements are rapid and no contact with the ground is needed.

Seismic and Acoustic Methods. Some types of **echo-sounding**, such as sonar, have been employed in archaeology. For example, detection of anomalies can find cavities such as caves. Seismic methods normally used by oil prospectors have helped to trace details of the foundations of St. Peter's Basilica in the Vatican in Rome.

One of the most important archaeological applications of echo-sounding techniques, however, is in underwater projects (see p. 118–19). In one case, after a bronze statue of an African boy was brought up in a sponge-diver's net off the Turkish coast, George Bass (1932–2021) and his colleagues were able to locate the Roman ship from which it came by means of echo-location systems. The use of multibeam sonar can gather huge amounts of data from wreck sites for the creation of three-dimensional terrain models; it covers the seabed below and to either side of the survey vessel, and derives continuous and well-positioned spot heights for thousands of points on the seabed as the vessel moves forward. Recently, experiments have begun in acoustic mapping of submerged Stone Age sites. Using reflection-seismic methods, this has made possible the noninvasive detection of unknown underwater sites through an acoustic response from humanly knapped

Measuring Magnetism

Although several types have been developed, most archaeological surveys use either **fluxgate magnetometers** or alkali-metal vapor magnetometers.

Fluxgate sensors need relatively little power to run and are lower cost, but can be susceptible to more sources of measurement noise. Such errors can be due to temperature changes or, as fluxgate sensors measure the magnetic field in just one direction, variations in the orientation of the sensor. To compensate, they are usually deployed in vertical gradiometer mode, where two fluxgate sensors are mounted one above the other in a tube and the difference between their measurements, or vertical gradient, is recorded. Both sensors respond similarly to sources of noise but the lower sensor, being closer to the ground, responds more strongly to magnetic variations caused by buried objects. Subtracting the signal of the upper sensor from the lower tends to remove measurement errors while preserving the response to any buried archaeological.

Alkali-metal vapor sensors measure the total strength of magnetic field regardless of direction and are typically less susceptible to measurement noise but usually require

more power and are more expensive. They can be favored in situations where features are only weakly magnetic, or more deeply buried than usual.

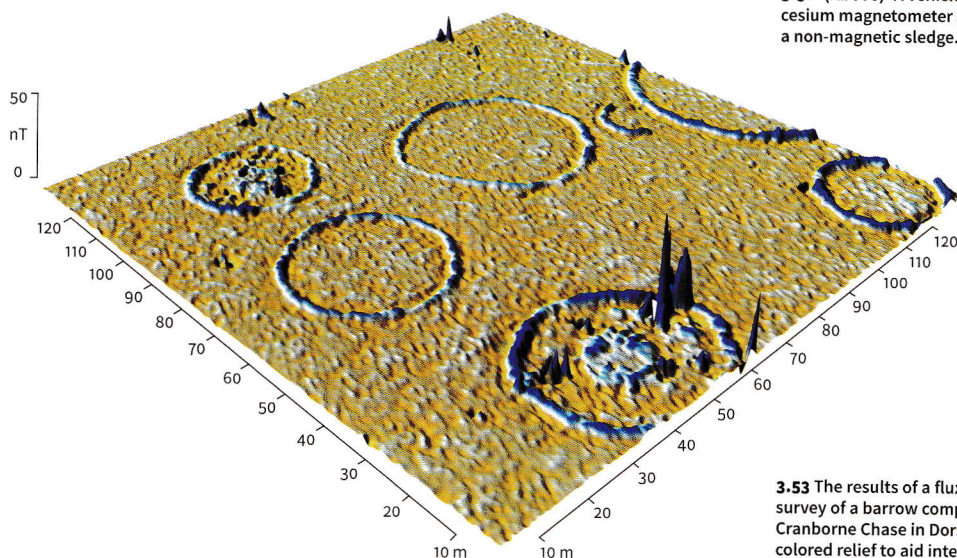
Many magnetometer surveys are carried out using hand-held instruments, where the magnetometer is carried along a succession of traverses, usually 0.5–1.0 m (20–40 in.) apart, tied into an overall pre-surveyed grid, until the entire site is covered [3.51]. The signal is logged automatically and stored 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 [3.52].

A more recent development, however, has been the integration of GPS/GNSS so the position of each measurement can be logged automatically without the need for a pre-surveyed grid. With this capability, arrays of magnetometers can be combined on non-magnetic hand-operated carts or vehicle-towed platforms. Surveys with such systems can cover up to about 10 ha (24 acres) each day at a high-resolution sampling interval (0.5 m × 0.25 m / 20 × 10 in.) [3.53].



3.51 (Top) The Bartington Grad 601-2 single axis, vertical component, high-stability fluxgate gradiometer system.

3.52 (Above) A vehicle-towed array of six cesium magnetometer sensors mounted on a non-magnetic sled.



3.53 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.

lithics. Field tests have been carried out with planted objects, but the technique has also been tried out at sites in Israel, Florida, Sweden, Switzerland, and Denmark with very encouraging results. The method is known as HALD (Human Altered Lithic Detection). Archaeologists have been examining the precise sounds made from lithics when they are knapped. This led researchers to explore how these stones can be excited by a similar acoustic signal.

In one experiment, a knapped Coastal Plains chert core was placed 1 m (3 ft.) away from a loudspeaker and microphone. The loudspeaker was programmed to emit sine burst signals with center frequencies ranging from 4 to 13 kHz. The acoustic waves traveled from the speaker to the chert core and the microphone detected and measured the resulting acoustic excitation signals.

Ground Penetrating Radar. A method similar to seismics, which also employs an active source of energy to image the ground, is ground penetrating (or probing) radar (GPR). Rather than using vibrational seismic energy, a GPR transmitter sends either short pulses or a continuous series of radio waves through the soil utilizing electromagnetic radiation in a range from 30 MHz to 8 GHz. Changes in the physical properties of the soil and sediments, often associated with a variation in soil conductivity encountered over filled ditches, graves, walls, etc., can produce a reflection of the incident radio wave energy. The reflected wave is recorded by a receiver co-mounted in the GPR antenna that can measure the amplitude, phase and two-way travel time from the transmitter through the soil to the target feature and back to the surface. A grid of parallel GPR profiles can then provide a three-dimensional map of the buried archaeological remains using the

two-way travel time to estimate the depth at which the changes occur, and a combination of the amplitude and phase can provide information on material properties of the features, for example high amplitude reflections from buried walls.

In the field, the antenna is towed by a vehicle or dragged manually along the ground [3.54, 3.55], sending out and receiving many pulses per second, often from an array of multiple transmitter and receiver elements. Recent developments have trialed the use of radar antennas mounted from both Uncrewed Aerial Vehicles (drones) and robotically controlled agricultural tractors.

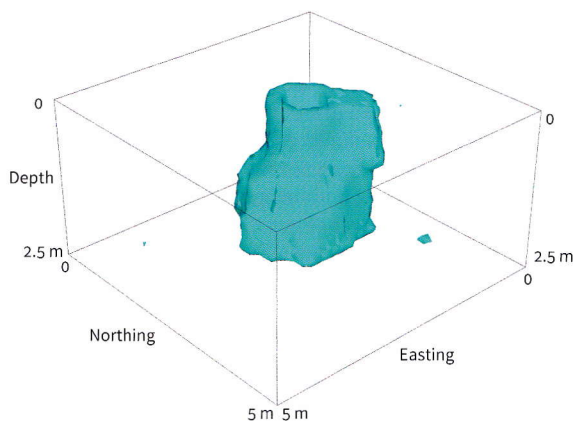
The precise location of each measurement is determined through either a GNSS receiver or tracking theodolite prism co-mounted on the radar antenna, and the data are collated together into a three-dimensional model or cube. The data can be visualized as a vertical profile, showing reflections through the ground from a single traverse across the site, or by combining thousands of individual reflections into a single three-dimensional dataset that can then be sliced horizontally. Each slice corresponds to a specific estimated depth in the ground, revealing the general shape and location of buried features at successive depths. The depth can be estimated from the recorded two-way travel time of the reflected radar pulse and the velocity of the pulse through the ground surface. Both the velocity and the maximum penetration depth of the radar pulse will vary between different sites due to the nature of the geology and soils, and the center frequency of the antenna. Lower frequencies may penetrate deeper

3.54 (Left) A GPR antenna array mounted on a hand-pushed cart. In this case, eight individual channels are collected and displayed in real-time simultaneously. The position of the readings is recorded by a robotic total station that tracks the location of the prism mounted on the cart.

3.55 (Below) Larger area surveys may be undertaken using vehicle towed GPR antenna arrays, here collecting twenty separate channels at a spacing of 0.075 m (3 in.). A GNSS receiver is co-mounted on the array to provide positional control and the trailing odometer wheel is used to trigger the measurement sequence as the GPR system is maneuvered across the site.



into the ground, but with a reduced spatial resolution and the attenuation of the radar signal in some soils may even preclude the use of the technique entirely. The whole three-dimensional data model can also be visualized as an iso-surface volume, where a contour is drawn around a suitable anomaly. For example, when a hole opened up in farmer's field in the Avebury World Heritage site in the south of England, a radar survey revealed evidence of an underlying megalithic chamber. The iso-volume extracted from the data shows the collapse opening leading from

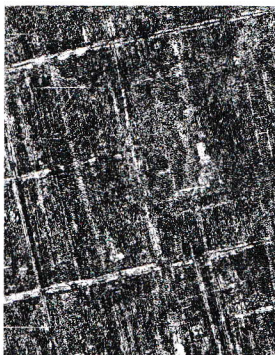


3.56 (Above) The iso-surface volume of a Neolithic cist burial within the Avebury World Heritage site, UK. The collapsed hole from the surface into the cist has been imaged by the GPR data and opens into a larger 2 m × 1 m (3 × 6 ft.) stone-lined chamber at a depth of 1.25 m (4 ft.). The data can be further explored by rotating and zooming in to the iso-surface volume.

3.57 (Below) Selected amplitude slice maps from Silchester Roman Town, UK. From left to right: the near-surface slice, between 1.2 and 2.4 ns (nanoseconds; at this site equivalent to 0.6–0.12 m/2.4–4.7 in.) reveals areas of gravel or rubble, broadly aligned with the known orientation of the town street plan. As the slices go deeper, a network of both Roman roads and building walls begin to emerge very clearly, showing a well-organized plan of rooms with a high level of internal detail surrounding the central, open market space. The deepest slice shows a range of rooms previously obscured by building rubble, together with a compacted gravel layer with a network of drains.



1.2–2.4 ns (0.06–0.12 m)



6.0–7.2 ns (0.3–0.36 m)



13.2–14.4 ns (0.66–0.72 m)



20.4–21.6 ns (1.02–1.08 m)

the surface to the buried chamber. Subsequent excavation suggests this is the remains of a Neolithic cist burial, formed of a small stone-lined grave [3.56].

On a larger scale, the Forum Basilica, a combined large market place and public buildings, has been mapped in great detail by GPR survey in the center of the abandoned walled Roman town at Silchester, located approximately 80 km (50 miles) east of London. Extensive magnetometer survey and targeted excavation has been conducted at the site by the University of Reading and analyzed together with aerial photography. GPR slices helped to reveal the whole architectural layout over substantial areas of the site where the majority of excavation evidence relied on the work of Victorian archaeologists [3.57].

Low-frequency EM methods. A range of geophysical instruments make use of low-frequency electromagnetic fields below 300 kHz, emitting a continuous wave from a transmitter coil. The transmitted signal creates secondary fields within any buried electrical conductors or magnetic features, and these are recorded by one or more separate tuned receiver coils. Both the conductivity and magnetic susceptibility of the sub-surface can be determined from the amplitude and phase of the received signal. The depth to the feature can be estimated from the separation and orientation of the transmitter and receiver coils.

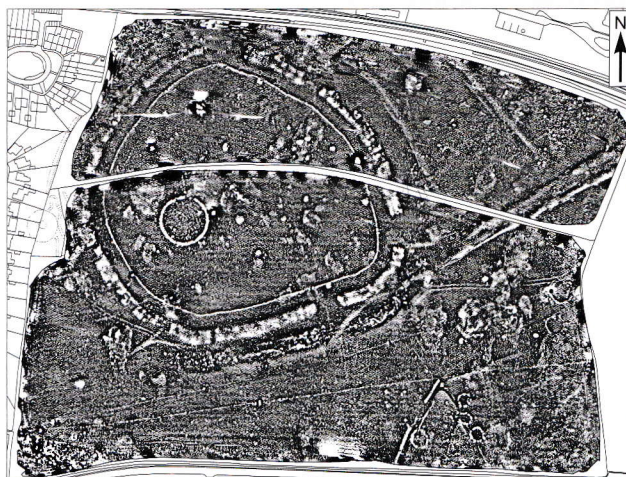
As the coils of the instrument do not have to make contact with the ground surface, they offer the advantage of rapid field data acquisition, and may be carried either by hand or towed by a vehicle. For most archaeological applications a coil spacing of 1 m (3 ft.) will suffice, but instruments with multiple coil spacings are available and allow simultaneous conductivity and magnetic measurements to be made from different depths. The results may vary with the underlying geology and soils, but a good correlation can often be demonstrated when compared with earth resistance and magnetic data sets. Geomorphological features, such as palaeochannels and changes in soil type, can also be mapped successfully using wider coil spacings across expansive landscapes.

Mount Pleasant Henge

Mount Pleasant is a large Neolithic ditch-and-bank monument comparable in size to other mega-henges, such as Avebury and Durrington Walls in Wiltshire, but that remains almost hidden from view under arable fields to the east of Dorchester in Dorset, UK. Much is known about the henge from previous excavations conducted between 1970 and 1971, and aerial photography that shows areas of soil erosion on the raised banks on its southern side.

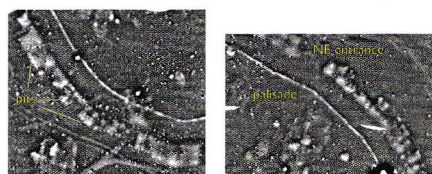
Geophysical survey was conducted using both a vehicle-towed magnetometer array and multichannel GPR system to assess the survival of the prehistoric remains and variation in the depth of soil cover protecting the archaeology. The magnetometer data was collected at a sample interval of 0.15×0.5 m (6×20 in.) and the GPR readings measured at 0.075×0.075 m (3×3 in.) with the position of both systems recorded by a GNSS receiver mounted on the instrument array.

The magnetic survey [3.58] has mapped the outer ditch of the henge together with the palisade, a ring of large internal postholes supporting an enclosing structure of timbers inside the ditch. There is evidence in the data for the apparent gang-digging of the ditch, which appears to have been constructed in an irregular, segmented form. When viewed in detail it appears each segment may have been enlarged from an original circle of pits to mark out the course of the ditch [3.59 (a)]. Entrances to the henge have been detected as breaks across the course of the ditch and bank, including a previously unrecognized entrance to the northeast [3.59 (b)] together with a possible



3.58 (Above) Magnetic survey data showing the whole of the main henge.

3.59 (Right) Details of the main henge ditch showing evidence of gang-digging.



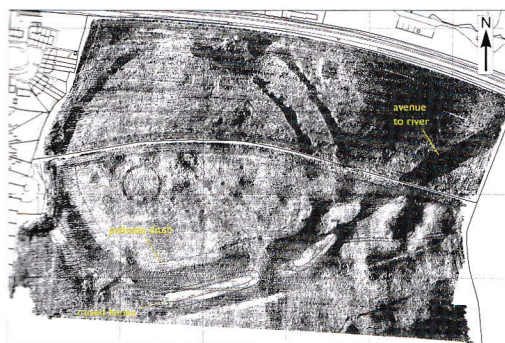
outer work and an avenue leading towards the River Frome also detected in the GPR survey [3.60].

Although completely excavated in the 1970s, the penannular (almost fully circular) ditched feature with internal postholes, known as Site IV, found on a raised plateau within the center of the main henge can still be discerned in the magnetic results, although the corresponding GPR data suggests the topsoil protecting the archaeology is as shallow as 0.2 m (8 in.) in places. There is also a pattern of deeper plough scours visible in the underlying chalk geology [3.61] that suggests deeper, historic steam ploughing rather than the modern agricultural regime.

Several Bronze age barrow groups are known from aerial photography surrounding the main henge and the

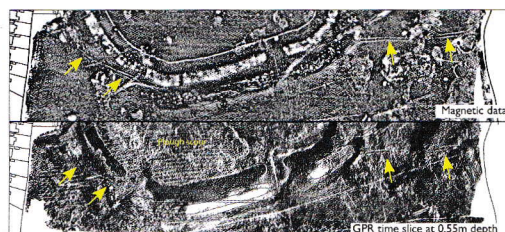
geophysical survey has provided new detail, including evidence for an additional ring ditch and the suggestion that three of the barrows are in fact pit circles, which could represent earlier small henge-type monuments or mortuary enclosures.

Both geophysical techniques also reveal a parallel double ditch that crosses the site from east to west and partially follows the circuit of the henge bank to the south [3.61]. The two ditches are too wide apart to be modern vehicle tracks and appear to be more than 2 m (79 in.) in depth. They are obscured by raised sections of the bank to the south of the henge, perhaps suggesting a more significant prehistoric boundary contemporary with, or even marking out, the earlier phases of the main monument.



3.60 (Left) GPR data over the henge at a depth of 0.3 m (12 in.).

3.61 (Below) A parallel linear ditch anomaly found with both geophysical techniques. The plough scours detected by the GPR are also indicated.



Earth Resistance Survey. The first geophysical technique to be used to search for buried archaeology was earth resistance (or **electrical resistivity**) survey, which Richard Atkinson successfully employed in 1946 to detect infilled ditches and pits dug into gravel at Dorchester-on-Thames in England. The technique is based on the principle that water in soil pores will conduct electricity, so the wetter the soil the less it will resist the passage of an electrical current. For accurate measurements, a **resistivity meter** is attached to four electrodes in the ground, two of which pass an electrical current through the soil while the other two measure the electrical resistance. Different probe arrangements can be used, but the twin electrode (or twin probe) array is well suited to archaeological prospection. Two mobile probes are fixed to a frame that also supports the meter and these are inserted into the ground for each measurement. A cable connects the meter to the other two remote probes set at a fixed reference position some distance away. The technique works particularly well for detecting buried masonry, which tends to be drier than the surrounding soil and so has a high electrical resistivity, but it can also detect silted-up ditches and filled-in pits, which retain more moisture and therefore have lower resistivity.

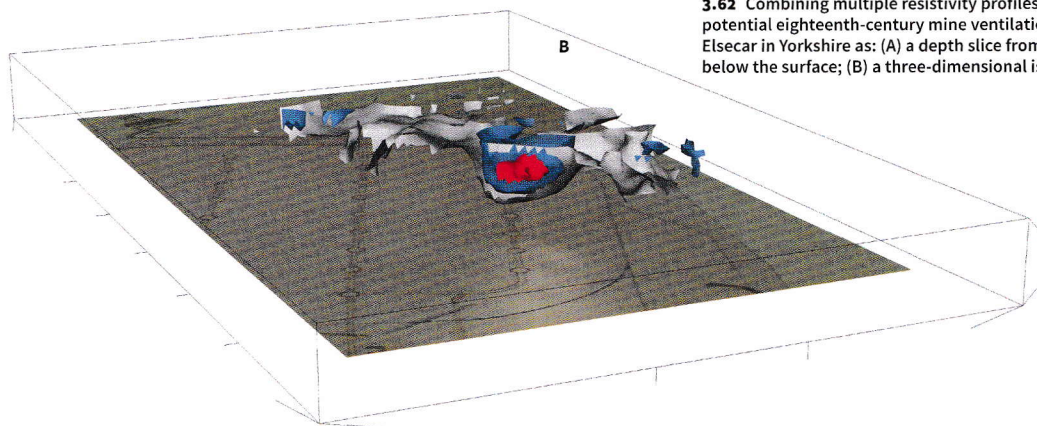
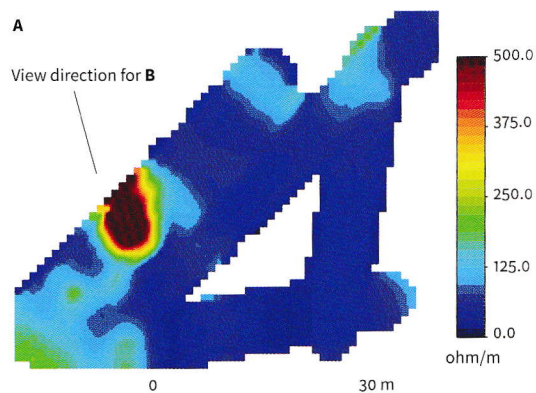
Increasing the separation between the electrodes causes the electric current to penetrate deeper beneath the surface, leading to a variation of the method called resistivity profiling. Employing a large array of electrodes laid out in a line, measurements are made at increasing probe spacings to create a vertical electrical profile or pseudosection. A combination of multiple profiles across a site can be used to create three-dimensional images of buried surfaces (and horizontal depth-slices comparable to those produced for GPR data).

One drawback of **earth resistance survey** is that it is relatively slow because it needs to make electrical contact with the soil. To increase the speed of coverage, mobile earth resistance systems have been developed using spiked wheels as electrodes, which can either be hand- or vehicle-towed. Problems can also be encountered if the soil

is too hard or too dry as the electric current may have difficulty passing into the ground owing to high contact resistance. The method, however, offers the advantages that it can be used in urban areas and in the vicinity of ferrous structures, which can cause problems for magnetic methods, and on uneven ground, which can cause difficulties for GPR survey. It is therefore an effective complement to other remote sensing methods and in some field projects it has proved the most successful means for locating buried features [3.62].

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 nonarchaeologists, most of whom are responsible enthusiasts, but some of whom vandalize sites mindlessly, and often illegally



3.62 Combining multiple resistivity profiles over a potential eighteenth-century mine ventilation shaft at Elsecar in Yorkshire as: (A) a depth slice from 3 m (10 ft) below the surface; (B) a three-dimensional iso-surface



3.63 Part of the Staffordshire hoard, the largest Anglo-Saxon hoard of gold and silver metalwork ever found. Unearthed in July 2009 by a metal detectorist (working with the landowner's permission), it comprises more than 1,500 high-quality pieces, mostly linked to weaponry, such as sword pommels. Thought to date to the seventh or eighth century CE, the hoard contained 5 kg (11 lb.) of gold and 1.3 kg (2.9 lb.) of silver. It has been valued at £3.2 million (nearly \$4 million).

dig holes without recording or reporting the finds they make, which are therefore without context. There are now thirty thousand metal detectorists in Britain alone. The official British Portable Antiquities Scheme (see feature, p. 587) seeks to harness their enthusiasm for archaeological benefit. One of the great successes of recent years of the Portable Antiquities Scheme has been the discovery by an amateur detectorist of the remarkable Staffordshire hoard of Anglo-Saxon gold and silver metalwork [3.63].

Geochemical Analysis. Geochemical analysis involves taking samples of soil at intervals (such as every 1 m/3 ft.) from the surface of a site and its surroundings, and measuring their elemental content. In the past, topsoil was considered to be too disturbed and unstratified, and so devoid of archaeological information; it was often removed mechanically and quickly, without investigation. Now, it is clear that even the surface of an archaeological site that appears totally disturbed can yield important chemical information. Organic components of occupation debris may disappear, while the inorganic ones remain: of these, magnesium or calcium can be analyzed, but it is the phosphates that are the most diagnostic and easily identified. High phosphate concentrations may be the only surface sign of an archaeological site. Tests on sites in England, examining samples taken at 20-cm (8-in.) intervals from the surface downward, have confirmed that undisturbed archaeological features in the subsoil can be accurately reflected in the topsoil.

The phosphate method can also be valuable for the interpretation of sites with no apparent internal architectural features, and can help clarify the function of different parts of an excavated site. For example, in a Romano-British farmstead at Cefn Graianog, North Wales, J. S. Conway took soil samples at 1-m (3-ft.) intervals from the floors of excavated huts and from neighboring fields, and mapped their phosphorus content as contour lines. In one building, a high level of phosphorus across the middle implied the existence of two animal stalls with a drain for urine running between them. In another, the position of two hearths was marked by high readings.

Geochemical methods can also reveal what processes or activities were being carried out in the past. Portable infrared spectrometers first appeared in the late 1980s, and today, portable instruments, such as **X-ray fluorescence (XRF) spectrometers** and scanners, are routinely employed to give a detailed analysis of the chemical composition of soils, pigments, calcite, limestone, plaster, ash, and so on, without the need to take samples. One major advantage of handheld devices is that such instruments avoid a reliance on off-site laboratories where samples previously had to be sent for analysis, often causing months of delay.

Excavation

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 remote sensing techniques, and actually see what remains of these sites and obtain dates, is to excavate them. As mentioned before, survey can tell us a little about a large area, but only excavation can tell us a great deal about a relatively small area.

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 speaking, 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 contemporaneity—that activities did indeed occur at the same time—by proving to their satisfaction 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