3 Where?
Survey and Excavation of Sites and Features

It has been said that the person with a clear objective and a plan of campaign is more likely to succeed than the person with neither, and this is certainly true of archaeology. The military overtones of the words "objective" and "campaign" are entirely appropriate for archaeology, which often requires the recruitment, funding, and coordination of large numbers of people in complex field projects. It is no accident that two pioneers of field techniques – Pitt-Rivers and Mortimer Wheeler – were old soldiers (box, pp. 31–33). Today, thanks to the impact of such practitioners, and the major influence of the New Archaeology with its desire for scientific rigor, archaeologists try to make explicit at the outset of research what their objectives are and what their plan of campaign will be. This procedure is commonly called devising a ***research design***, which broadly has four stages:

1 ***formulation*** of a research strategy to resolve a particular question or test a hypothesis or idea;
2 ***collecting and recording of evidence*** against which to test that idea, usually by the organization of a team of specialists and conducting of fieldwork;
3 ***processing and analysis*** of that evidence and its interpretation in the light of the original idea to be tested;
4 ***publication*** of the results in articles, books etc.

There is seldom if ever a straightforward progression from stage 1 to stage 4. In real life the research strategy will constantly be refined as evidence is collected and analyzed. All too often, and inexcusably, publication may be neglected (Chapter 14). But in the best planned research the overall objective – the broad question or questions to be answered – will stand even if the strategy for achieving it alters.

In Part II we shall study some of the research strategies archaeologists adopt to answer questions about how societies were organized, what the ancient environment was like, the foods people ate, the tools they made, their trading contacts and beliefs, and indeed *why* societies evolved and changed over time. Chapter 13 examines 4 projects in detail, to show how research is carried out in practice, from start to finish.

In this chapter, however, we will focus on stage 2 of the research process – on the methods and techniques archaeologists use to obtain evidence against which to test their ideas. It should not be forgotten that suitable evidence can often come from new work at sites already the subject of fieldwork: Ian Hodder's renewal and reappraisal of the Çatalhöyük excavations (box, pp. 44–45) demonstrates this point. Much potentially rich and rewarding material also lies locked away in museum and institution vaults, waiting to be analyzed by imaginative modern techniques. It is only recently, for example, that the plant remains discovered in Tutankhamun's tomb in the 1920s (box, pp. 62–63) have received thorough analysis. Yet it remains true that the great majority of archaeological research is still dependent on the collection of new material by fresh fieldwork.

Traditionally, fieldwork used to be seen almost exclusively in terms of the discovery and excavation of sites. Today, however, while sites and their excavation remain of paramount importance, the focus has broadened to take in whole landscapes, and surface survey at sites in addition to – or instead of – excavation. Archaeologists have become aware that there is a great range of "off-site" or "non-site" evidence, from scatters of artifacts to features such as plowmarks and field boundaries, that provides important information about human exploitation of the environment. The study of entire landscapes by regional survey is now a major part of archaeological fieldwork. Archaeologists are becoming increasingly aware of the high cost and destructiveness of excavation. Site surface survey and subsurface detection using non-destructive remote sensing devices have taken on new importance. We may distinguish between ***methods used in the discovery*** of archaeological sites and non-site features or artifact scatters, and those employed ***once those sites and features have been discovered***, which include detailed survey and selective excavation at individual sites.

DISCOVERING ARCHAEOLOGICAL SITES AND FEATURES

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

Nor can one credit archaeologists with the discovery of all those sites that were once lost. No one has ever made a precise count, but a significant number of sites known today were found by accident, from the decorated caves in France of Lascaux, and more recently Cosquer, the underwater entrance to which was discovered by a deep-sea diver in 1985, to the amazing terracotta army of China's first emperor, unearthed in 1974 by farmers digging for a well, as well as the countless underwater wrecks first spotted by fishermen, sponge-gatherers, and sport-divers. Construction workers building new roads, subways, dams, and office blocks have made their fair share of discoveries too – for example, the *Templo Mayor* or Great Temple of the Aztecs in Mexico City (box, pp. 552–53).

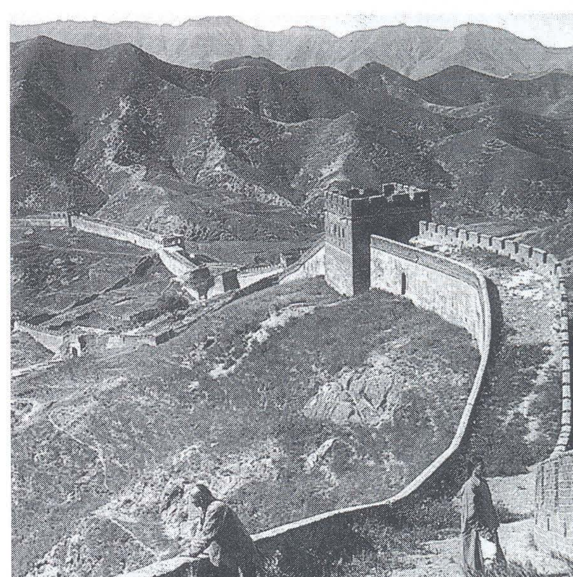
Nevertheless it is archaeologists who have systematically attempted to record these sites, and it is archaeologists who seek out the full range of sites and features, large or small, that make up the great diversity of past landscapes. How do they achieve this?

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***), although any one field project will usually employ both types of reconnaissance.

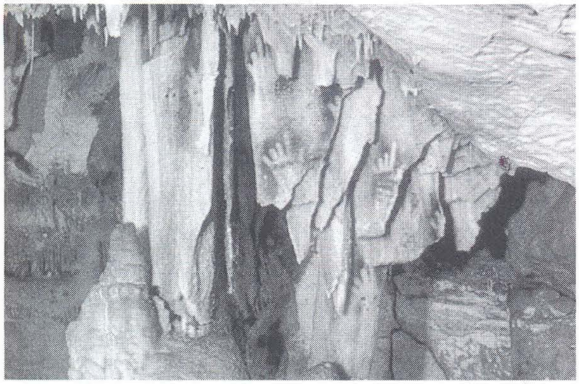
Ground Reconnaissance

Methods for identifying individual sites include consultation of documentary sources and place-name evidence, but primarily actual fieldwork, whether the monitoring of building developers' progress in salvage archaeology, or reconnaissance survey in circumstances where the archaeologist is more of a free agent.

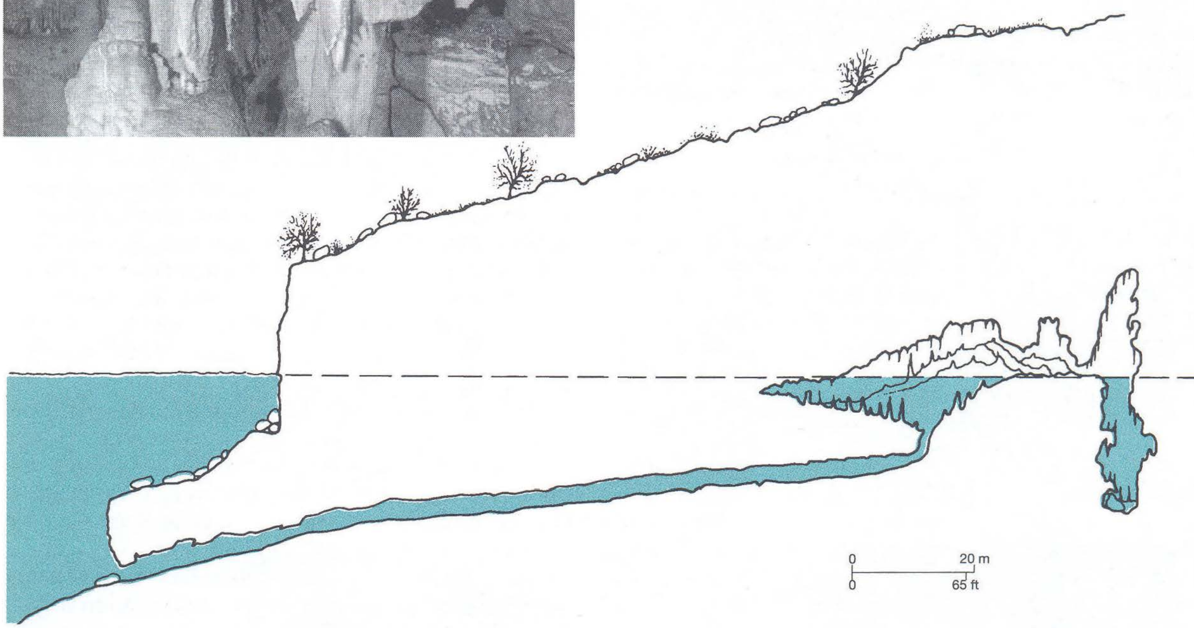
Partially buried but never lost: buildings in the Forum of ancient Rome, as depicted in an 18th-century etching by the Italian artist, Piranesi.



The Great Wall of China, over 2000 km (1250 miles) long, was begun in the 3rd century BC. Like the Forum, it has never been lost to posterity.



The Cosquer cave, discovered by a professional diver in 1985, can now only be entered via an underwater passage, 37 m (122 ft) below the present-day sea level (below). The sloping tunnel leads to a chamber – which has remained partially above water – where Upper Paleolithic wall paintings were noticed in 1991. Among the paintings and engravings on the cave's walls are hand stencils (left).

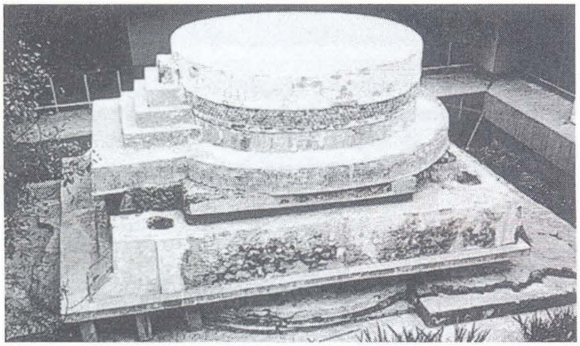


Documentary Sources. In Chapter 1 we saw how Schliemann's firm belief in the historical accuracy of the writings of Homer led directly to the discovery of ancient Troy. A more recent success story of the same kind was the location and excavation by Helge and Anne Stine Ingstad of the Viking settlement of L'Anse aux Meadows in Newfoundland, thanks in large part to clues contained in the medieval Viking sagas. Much of modern biblical archaeology concerns itself with the search in the Near East for evidence of the places – as well as the people and events – described in the Old and New Testaments. Treated objectively as one possible source of information about Near Eastern sites, the Bible can indeed be a rich source of documentary material, but there is certainly the danger that belief in the absolute religious truth of the texts can cloud an impartial assessment of their archaeological validity.

Much research in biblical archaeology involves attempting to link named biblical sites with archaeologically known ones – an effort spurred on in the 1970s by the discovery at Tell Mardikh (ancient Ebla), Syria, by an Italian team, of Bronze Age writing tablets that refer to biblical cities. 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 historic towns. In England, for example, it is possible in the better-documented medieval towns to map many of the streets, houses, churches, and castles back to the 12th century AD, or even earlier, using this kind of evidence. These maps then form a reliable basis on which to decide where it would be most profitable to carry out survey work and excavation.

Salvage Archaeology. In this specialized work – discussed more fully in Chapter 14 – the role of the archaeologist is to locate and record as many sites as possible before they are destroyed by new roads, buildings, or



Salvage archaeology: the Aztec temple of Ehecatl-Quetzalcoatl, discovered during the excavation of the Piño Suarez subway station, Mexico City.

dams, or by peatcutting and drainage in wetland environments. 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 thus discovered may require excavation, and in some cases can even cause construction plans to be altered. Certain archaeological remains unearthed during the digging of subways in Rome and Mexico City were incorporated into the final station architecture.

Reconnaissance Survey. How does the archaeologist set about locating sites, other than through documentary sources and salvage work? A conventional and still valid method is to look for the most prominent remains in a landscape, particularly surviving remnants of walled buildings, and burial mounds such as those in eastern North America or Wessex in southern Britain. But many sites are visible on the surface only as a scatter of artifacts and thus require more thorough survey – what we may call reconnaissance survey – to be detected. Furthermore in recent years, as archaeologists have become more interested in reconstructing the full human use of the landscape, they have begun to realize that there are very faint scatters of artifacts that might not qualify as sites, but which nevertheless represent significant human activity. Scholars such as Robert Dunnell and William Dancey have therefore suggested that these "off-site" or "non-site" areas (that is, areas with a low density of artifacts) should be located and recorded, which can only be done by systematic survey work involving careful sampling procedures (see below). This approach is particularly useful in areas where people leading a mobile way of life have left only a sparse archaeological record, as in much of Africa: see further discussion in Chapter 5.

Reconnaissance survey has become important for another major reason: the growth of regional studies. Thanks to the pioneering researches of scholars such as Gordon Willey in the Virú Valley, Peru, and William T. Sanders in the Basin of Mexico, archaeologists increasingly seek to study settlement patterns – the distribution of sites across the landscape within a given region. The significance of 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 simply to locate an individual site and then to survey it and/or excavate it in isolation from other sites. Whole regions need to be explored, involving a program of survey.

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

Reconnaissance 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 (see box opposite).

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

The area's history of development needs to be examined, not only to familiarize oneself with previous archaeological work and with the local materials but also to assess the extent to which surface material may have been covered or removed by geomorphological

REGIONAL SURVEY ON MELOS

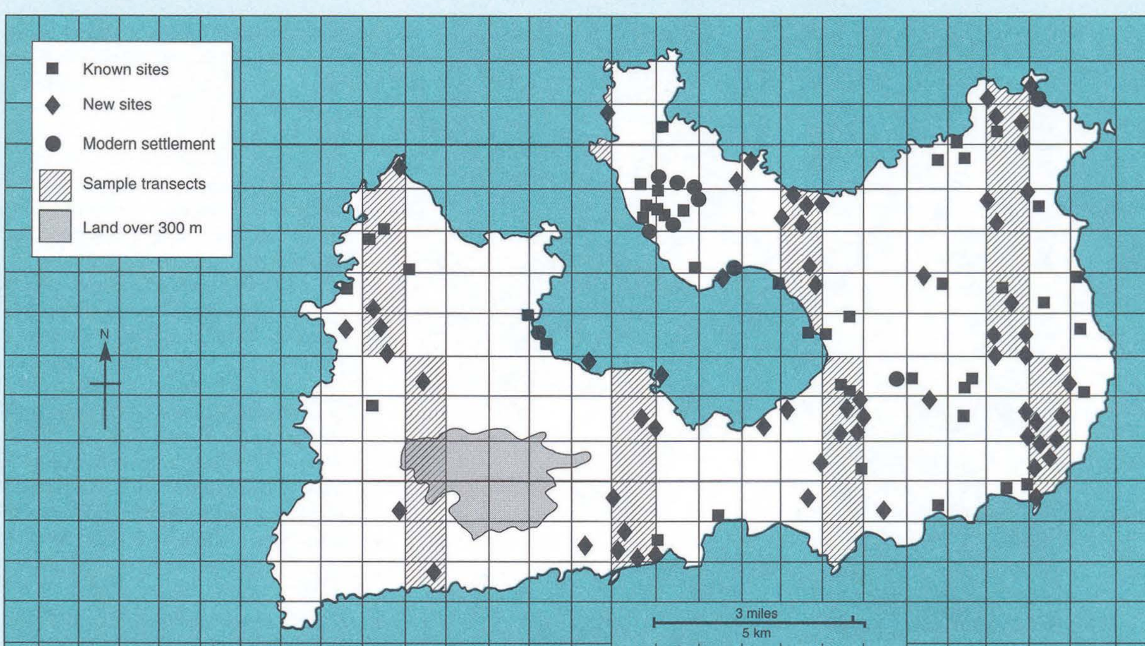
In 1976 and 1977 a team led by John Cherry undertook a survey on the Greek island of Melos in the eastern Mediterranean. The island's relatively small size (151 sq. km or 94 sq. miles) made it an ideal unit for investigation. The survey aimed to study several questions, including how the number, size, and location of sites have changed through time. The investigation was linked to Colin Renfrew's excavations on the island at the Bronze Age site of Phylakopi, and a major aim was to ascertain whether this was the only settlement site on Melos during most of the 2nd millennium BC.

It was decided to undertake an intensive survey of all parts of the island, but severe constraints on time, funds, and personnel meant that only a 20 percent sample was examined. The survey design was a systematic random sample (see box overleaf) made up of transects, the first chosen at random, the rest at intervals of 5 km (3.1 miles) from it. These transects comprised kilometer-wide strips running north-south across the island. Some areas took up to 3 hours to reach, being inaccessible to vehicles. Each transect was examined by groups of 10 to 12 people walking in parallel lines spaced 15 m to 25 m (49–82 ft) apart. In this way an average of 1.5 to 2 sq. km (0.6–0.8 sq. miles) per day was covered.

The location of sites was plotted on detailed maps prepared from air photographs, and their approximate extent and any noteworthy features were also recorded. Further mapping was undertaken using photographs taken by radio-controlled cameras attached to low-level tethered balloons. Little material was collected in order to minimize disturbance of the spatial patterning on the surface (for example, diagnostic potsherds were identified and photographed but left in the field), and most of the sites were revisited in order to expand the data recorded about them.

As a result of the survey, the total number of sites known on Melos increased from 47 to 130 (of all periods), and the island's overall site density proved to be at least six times greater than had been thought, in part through the recognition and recording of small, low-density scatters of material. No other sites of the same date as Phylakopi were found.

Changes in the number and size of sites through time gave evidence of repeated cycles of aggregation and dispersal of settlement, with notable population peaks in the Late Bronze Age and the late Roman period. Throughout the project, close collaboration was maintained with experts in geology, geomorphology, and historical geography.



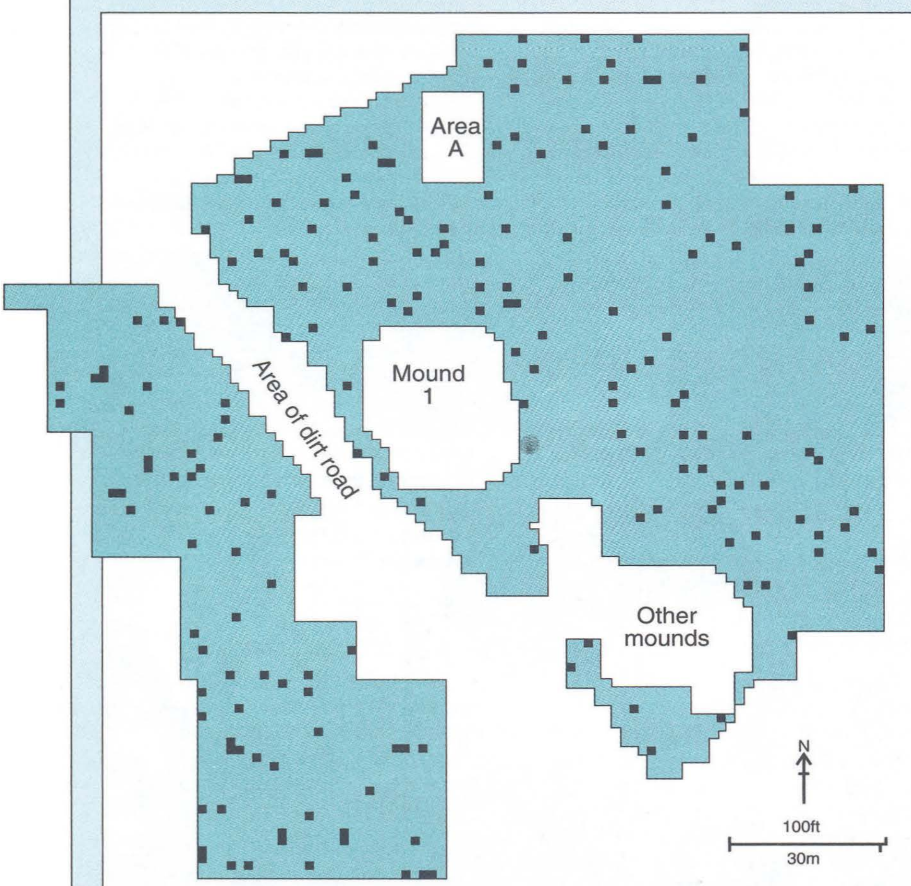
The random sample *transects selected for intensive study.*

SAMPLING STRATEGIES

Archaeologists cannot usually afford the time and money necessary to investigate fully the whole of a large site or all sites in a given region. So some sort of sample is required. But of what kind?

If the objective is to be able to draw reliable general conclusions about the whole site or region from the small areas sampled, one should try to make use of statistical methods. These employ probability theory, hence the term **probabilistic sampling**. Through mathematical means, they attempt to improve the probability that generalizations from the sample will be correct. This is the technique employed by public opinion polls, which may sample fewer than 2000 people yet will extrapolate from the results to generalize about the opinions of millions. Quite often the polls are proved wrong, yet surprisingly often they are more or less right. As with opinion polls, in archaeological work the larger and better designed the sample, the more likely the results are to be valid.

The alternative is to adopt a non-statistical approach: **non-probabilistic sampling**. Some sites in a given region may be more accessible than others, or more prominent in the landscape, which may prompt a less formally scientific research design. Long years of experience in the field will also give some archaeologists an intuitive "feel" for the right places to undertake work. But in order to judge in any quantitative manner how representative the sample is of a site or region, some form of probabilistic sampling needs to be used.

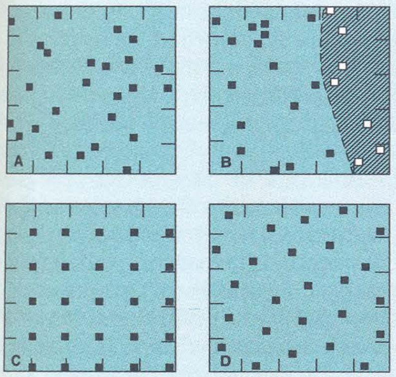


Simple random sample of squares chosen for excavation at Tierras Largas, Mexico.

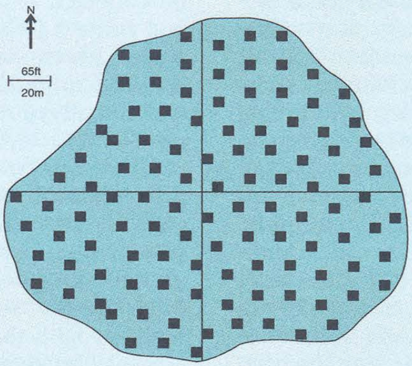
Types of Probabilistic Sampling

The simplest form is a **simple random sample**, where the areas to be sampled are chosen using a table of random numbers. Research at the small Formative-period hamlet of Tierras Largas in the Oaxaca lowlands, Mexico, can serve as an example. Marcus Winter set out to trace this 3000-year-old site's overall layout and house plans in what was simply a plowed field. First he defined the *sample universe* (the site boundaries) from the area of sherd scatter. Next he chose his *sampling units* (the size of the squares, also called quadrats, in his grid). An initial small test excavation suggested that squares 2 m on a side would be large enough to reveal intelligible features beneath the surface.

Finally, Winter needed to determine how large a *sample fraction* would be sufficient (how many squares to investigate). The greater the number of squares, the more precise the predictions. In this case, Winter estimated from the average size of known Formative houses that they would occupy less than 5 percent of the site's area. With an expected rate of occurrence of less than 5 percent in the



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



***Stratified systematic** sample of squares, 5 m on a side, chosen for investigation at Girik-i-Haciyan, Turkey.*

5000 squares of his site grid, he calculated from statistical tables that a sample size of 197 squares would suffice.

The squares were chosen with a table of random numbers. From this sample he was able to estimate the number of houses, pits, burials, and other features which would be found if the entire site were to be exposed.

There are drawbacks to this method. First, it entails defining the site's boundaries beforehand, and these are not always known with certainty. Second, 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 into its natural zones (strata, hence the technique's name), such as cultivated land and forest, and squares are then chosen by the same random-number procedure, except that each zone has the number of squares proportional to its area. Thus, if forest comprises 85 percent of the area, it must be allotted 85 percent of the squares.

Another solution, **systematic sampling,** entails the selection of a grid of equally spaced locations – e.g. choosing every other square (for an adaptation, see the box, Regional Survey on Melos, p. 75). By adopting such a regular spacing one runs the risk of missing (or hitting) every single example in an equally regular pattern of distribution – this is another source of potential bias.

A more satisfactory method is to use a **stratified unaligned systematic sample,** which combines the main elements from all three techniques just described. In collecting artifacts from the surface of a large tell or mound site at Girik-i-Haciyan in Turkey, Charles Redman and Patty Jo Watson used a grid of 5 m squares, but orientated it along the site's main N-S/E-W axes, and the samples were selected with reference to these axes. The strata chosen were blocks of 9 squares (3 x 3), and one square in each block was picked for excavation by selecting its N-S/E-W coordinates from a table of random numbers. Not only does this method ensure an unbiased set of samples, more evenly distributed over the whole site, but it also makes it unnecessary to define the boundaries, since the grid can be extended in any direction.

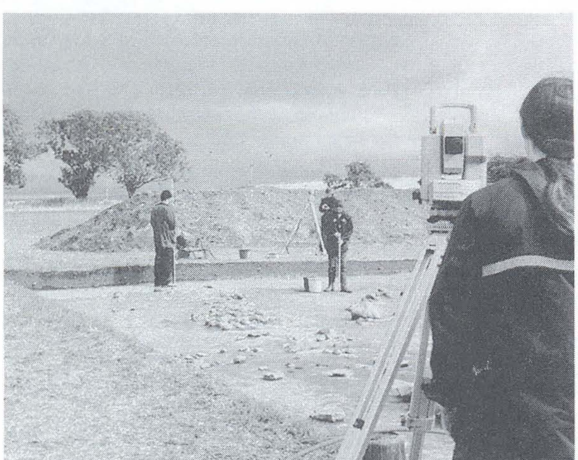
In large-scale surveys, *transects* (linear paths) are sometimes preferable to squares (see box, Regional Survey on Melos, p. 75). This is particularly true in areas of dense vegetation such as tropical rainforest. It is far easier to walk along a series of paths than to locate accurately and investigate 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. On the other hand, squares have the advantage of exposing more area to the survey, thus increasing the probability of intersecting sites. A combination of the two methods is often best: using transects to cover long distances, but squares when larger concentrations of material are encountered.

The four probabilistic sampling methods described above have been tested by Stephen Plog on distribution maps from the Valley of Oaxaca, Mexico, in an attempt to assess their comparative efficiency at predicting the total number of sites from a 10 percent sample. He concluded that systematic and stratified systematic sampling were slightly more efficient than the simple or stratified random sampling techniques – but the differences were not statistically significant and therefore archaeologists could in most circumstances use the simpler methods.

Some allowance needs also to be made for the danger that probabilistic sampling, used on its own in regional survey, might easily fail to reveal a major site – a site that may at one time have dominated the whole region. Where there is likely to be a hierarchy of sites, some larger and more dominant than others, it is therefore only prudent to combine probabilistic sampling with conventional survey to discover prominent sites. For further discussion of this point, see Chapter 5.

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 (dry) and semi-arid environments with little vegetation are among the best for this type of work, whereas in equatorial rainforest survey may be limited to soil exposures along river banks, unless time and labor permit the cutting of trails 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 or pottery styles) are more "visible" than others, and that mobile hunter-gatherer or pastoral communities leave a very different – and generally sparser – imprint on the landscape than do agricultural or urban communities (see Chapter 5). All these factors must be taken into account when planning the search patterns and recovery techniques.



Surveying equipment: a Total Station Theodolite, being used on a site in Scotland, records a point in three dimensions and incorporates an Electronic Distance Measurer (EDM).

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 box, pp. 76–77).

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 (for example, each plowed field), scanning the strip of ground along one's path, 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. Walkers have an inherent desire to find material, and will therefore tend to concentrate on those areas that seem richer, rather than obtaining a sample representative of the whole area that would enable the archaeologist to assess the varying distribution of material of different periods or types.

Most modern survey is done in a systematic way, employing either a grid system or a series of equally spaced traverses or transects. The area to be searched is divided into sectors, and these (or a sample of them, see box, p. 75) are walked systematically. In this way, no part of the area is either under- or over-represented 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 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, since 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 in 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.

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

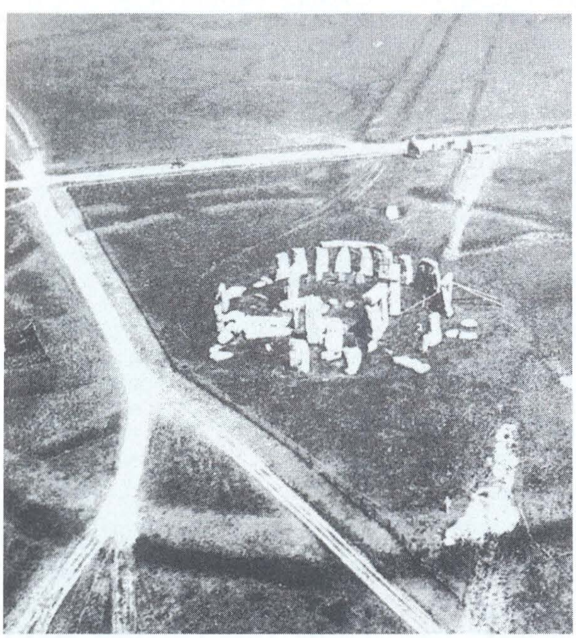
Extensive and Intensive Survey. Surveys can be made more extensive by combining results from a series of individual projects in neighboring regions to produce very large-scale views of change in landscape, land-use, and settlement through time – though, as with individual members of a field crew, the accuracy and quality of different survey projects may vary widely. Outstanding syntheses of regional survey have been produced in parts of Mesoamerica (see Chapter 13) and Mesopotamia, areas which already have a long tradition of this type of work.

In Mesopotamia, for example, the pioneering work by Robert Adams 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, and eventually by the Early Dynastic Period (3rd millennium BC) major centers of distribution had arisen, interconnected by routes of communication. The work has also revealed former watercourses and canals, and even probable zones of cultivation. Alternatively survey can be made more intensive by aiming at total coverage of a single large site or site-cluster – what one might call micro-regional 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, since 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 hugely to our knowledge of the area around the great pyramid-temples (box, pp. 90–91).

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 the air, one of the most important advances made by archaeology this century. In fact, the availability of air photographs can be an important factor in selecting and delineating an area for surface survey.

Aerial Reconnaissance

It must be stressed that aerial reconnaissance, particularly aerial photography, is not merely or even predominantly used for the discovery of sites, being more crucial to their recording and interpretation, and to monitoring changes in them through time.



Two early examples of aerial photography. (Left) The first air photograph of Stonehenge (or of any archaeological site) taken from a balloon in 1906. (Right) Crop-marks reveal massive earthworks at Poverty Point, Louisiana, dating from 1500–700 BC.

ARCHAEOLOGICAL AERIAL RECONNAISSANCE

Archaeologists use aircraft to search the ground for traces of former sites and past landscapes. Photographs are usually oblique and taken by hand-held cameras. Such oblique photography is a selective process, involving archaeological judgment, in contrast to the unselective view obtained by vertical survey. Single-frame shots of a site or feature are usual, although stereoscopic pairs of obliques considerably assist subsequent interpretation. Oblique aerial photographs show sites in the context of the landscape and can also be used for preparing archaeological maps.

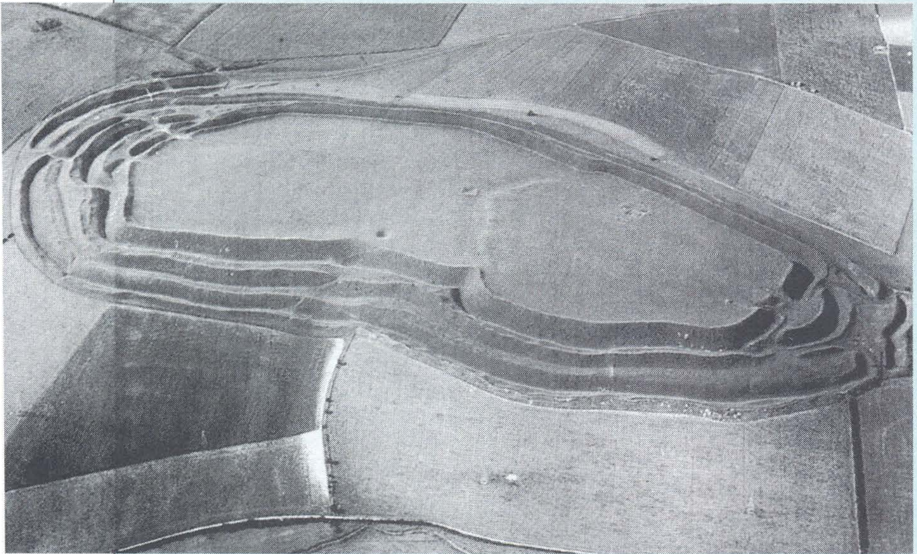
How Sites Show from the Air

A comprehensive knowledge of the ways in which sites show from the air is essential. Those who take and use aerial photographs must understand the means by which the evidence is made visible in order to determine the type of feature that has been recorded. Conventionally, features photographed from the air are often described according to the way they are revealed, rather than by the archaeological reality they represent, thus "earthworks," "soil marks," or "crop-marks." It is more helpful to extend these descriptions, as, for instance, "earthworks showing the ramparts of an enclosure," or "the soil mark of a leveled burial mound," or "crop-marked ditches of a probable settlement."

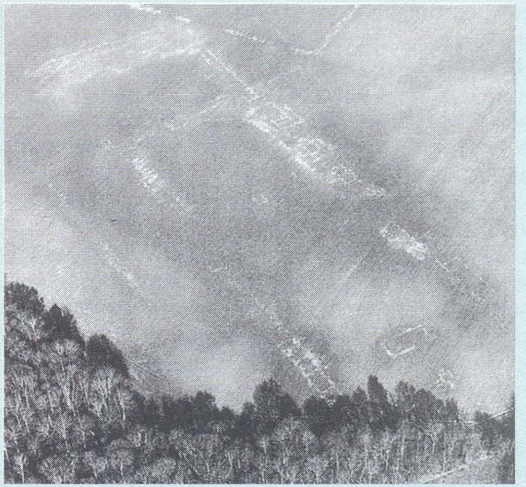
Earthworks is a term used to describe banks and associated ditches, or stone-walled features – in fact, any feature that can be seen in relief. These features are usually revealed from the air as *shadow marks* – an effect that is dependent on the lighting and weather conditions at the time of photography. They also show in relief when viewed as a stereoscopic pair. Such features may also be seen by the differences in vegetation supported by banks and ditches, by differential melting or drifting of snow, or by retention of water in ditches in times of flood. Time of day and time of year are thus important in the discovery and recording of such sites.

Soil-marks reveal the presence of buried ditches, banks, or foundations by the changes in subsoil color caused when a plowshare catches and turns over part of the buried feature, bringing it to the surface. Most soil-marked sites are being destroyed by modern cultivation. They are mostly visible in photographs taken in winter months. Bare soil will sometimes also reveal features through differential moisture retention – *damp marks* – or by differences in thermal properties that affect the melting of snow and frost.

Crop-marks develop when a buried wall or ditch either decreases or enhances crop growth by affecting the availability of moisture and nutrients through changing the depth of soil. Suitable crops, such as wheat, barley, and some root vegetables, provide a perfect medium for revealing features in the underlying soil. This response to buried features is very delicate and dependent on variables such as the type and condition of soil, weather during the growing season, crop type, and agricultural practices. Thus features can stand out strongly in one year and be invisible the next. Knowledge of recent and past land-use in an area can be particularly valuable when assessing the potential of apparently blank modern fields. Some features simply do not produce crop-marked evidence.



Earthwork *seen from the air: the Iron Age hillfort of Maiden Castle, southern England, whose complex ramparts are thrown into relief by shadows cast by massive earthen banks. The air photograph also highlights an interesting earlier feature: a shallow Neolithic ditch running across the middle of the fort.*



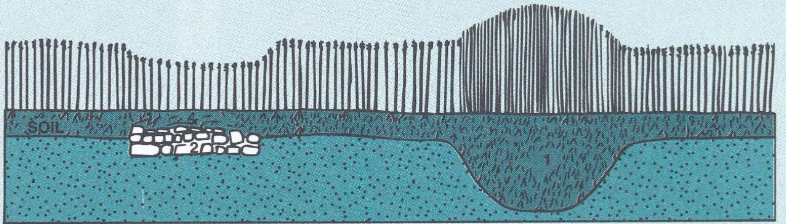
***Winter plowing** has scraped the chalk foundations of this Gallo-Roman villa in France. This process of destruction has in fact revealed the plan of its main structures against the dark soil.*

***Crop-marks** clearly reveal two concentric rings of ditches defining an enclosure at Merzien, Sachsen-Anhalt, Germany. Both ditch circuits are interrupted and may therefore be of Neolithic date.*

Photo Interpretation and Mapping
Interpretation is the process by which features photographed from the air, such as soil-marks, are analyzed in order to deduce the types of archaeological structures causing them. Given that the visibility of features varies from year to year, photos taken over several years need to be studied to compile an accurate plan. Such plans may guide excavation to key points in a structure, place field-collected data in context, or themselves be used as the starting point for new research.

Aerial photos can also be employed to produce a map of known features within a region. Many such records are drawn on to transparent sheets that are overlaid on to maps showing topographical or other information, but more up-to-date systems have converted such information as part of Geographic Information Systems (GIS: see main text).

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



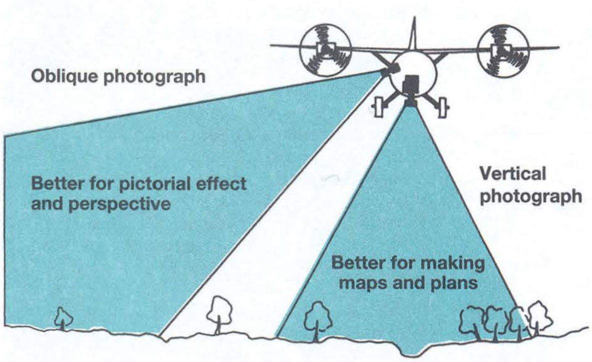
Nevertheless, air photography – together with remote sensing from space (see below) – has been responsible for a large number of discoveries, and continues to find more sites every year.

Aerial Photography. The first major archaeological applications of this technique occurred at the start of the century with photographs of the Roman town of Ostia taken from a balloon, and in 1913 when Sir Henry Wellcome took vertical pictures of his excavations in the Sudan by means of a box kite. World War I gave the technique a great impetus when archaeologists such as O.G.S. Crawford in England discovered the clarity that air photographs taken from aircraft and balloons could provide in their plan view of prehistoric monuments.

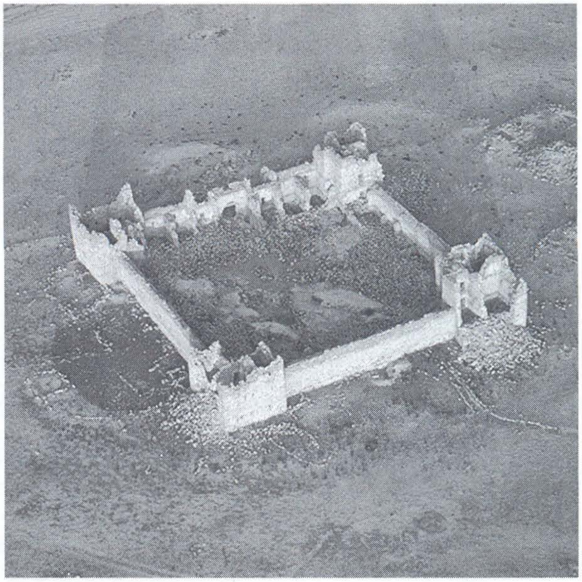
In Syria, from 1925 onward, Father Antoine Poidebard began tracing ancient caravan routes leading to Roman frontier defenses in the desert; using observation from the air, he discovered many new forts and roads. He also showed that underwater sites could be detected from the air, revealing for the first time the ancient harbor beneath the sea at Tyre, Lebanon – a study which was combined with survey by divers and partial excavation. Poidebard's work was paralleled by that of Erich Schmidt over Iran in the 1930s. His photographs documented his excavations in progress as well as sites he was thinking of digging, and he made reconnaissance flights over previously uncharted areas. Similarly, in 1927, military planes photographed Late Bronze Age oak pile structures through the waters of Lake Neuchâtel, Switzerland. In the New World, Alfred Kidder flew in 1929 with pioneer aviator Charles Lindbergh over central and eastern Yucatán, in Mexico, and discovered half-a-dozen new sites within a vast and impenetrable jungle landscape. They also made flights over Arizona and New Mexico looking for ancient villages.

From these beginnings aerial photography has developed into one of the archaeologist's most valued aids. New opportunities have arisen in central and eastern Europe since the fall of the Iron Curtain in 1989. Before that time there were restrictions on flying and no archaeological reconnaissance was allowed. Recently, there has been considerable activity in the air over former Soviet areas which has shown that they were as densely occupied as some of the best-known parts of Britain and western Europe. Whole landscapes are beginning to be recorded by projects that integrate aerial and field survey. Recent work by, for example, the aerial photographer Otto Braasch from Germany and landscape archaeologist Martin Gojda in the Czech Republic has marked the beginnings of aerial survey in those regions. The Aerial Archaeology Research Group has run training weekends in Hungary (1996), and Poland (1998) to introduce aerial photography, interpretation, and mapping primarily to ex-Warsaw Pact countries, with great success.

In Britain and Europe aerial photographs are mainly collected in specialist libraries, which may be held regionally or in major national collections, such as the National Library of Air Photographs in England. This



(Above) Aerial photographs are of two types: oblique and vertical. Obliques are easier to view and understand than verticals but may present more difficulty to the interpreter who must transform the information to plan views.



(Right) Aerial photography is also useful in surveying large or inaccessible areas, such as the eastern frontier of the Roman empire; this is a fort or palace at Qasr Bshir, Jordan.

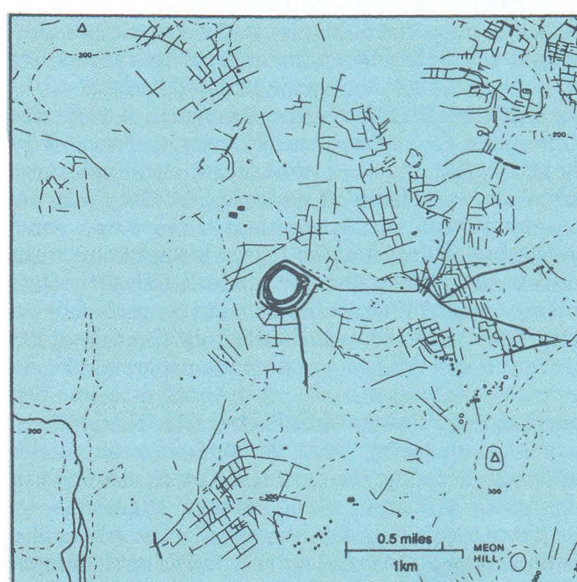
currently holds 0.75 million specialist oblique prints dating from 1906 to the present, and over 3 million vertical survey photographs spanning the years 1940 to 1979.

How Are Aerial Photographs Used? Photographs taken from the air are merely tools; they are means to an end. Photographs do not themselves reveal sites – it is the photographer and the interpreter who do so, by examination of the terrain and the pictures. These are specialized skills. Long experience and a keen eye are needed to differentiate archaeological traces from other features such as vehicle tracks, old river beds, and canals. Indeed, most military intelligence units during the final years of World War II had archaeologists on their staff as interpreters of air photographs. Glyn Daniel's expertise, for example, proved invaluable to British military photo-intelligence, and he ended the war running a large unit in India.

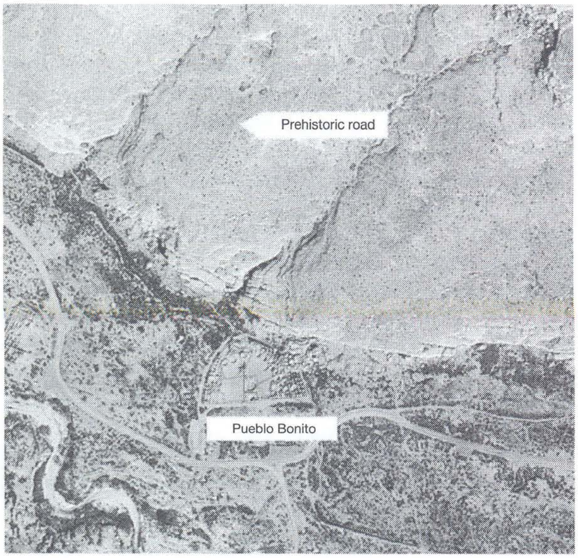
Aerial photographs are of two types: ***oblique*** and ***vertical***. Each has its advantages and drawbacks, but oblique photographs have usually been taken of sites observed from the air by an archaeologist and thought to be of archaeological significance, whereas most vertical photographs result from non-archaeological surveys (for instance, cartographic). Both types can be used to provide overlapping stereoscopic pairs of prints which 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 photographs, which are then processed into a very accurate photogrammetric base map of all the archaeological evidence identified from the air. Analytical ground survey can then proceed on a much surer basis.

The ways in which sites show from the air and how they are interpreted are discussed in the box (pp. 80–81). Oblique photographs show archaeological features clearly on the whole, while vertical photographs may need to be examined by an interpreter seeking such information. Vertical prints show a near-plan view from which it is relatively easy to take measurements or make maps, although if there is a large amount of information, computer rectification methods are more efficient. These programs were initially developed to help transform the scale and perspective distortions of oblique photographs but can just as readily be used to scale interpretations made from vertical prints. Known points are matched on photograph and map and this enables the archaeological information to be rectified to plan view. Computer rectification (georeferencing in the U.S.) is the usual method for mapping archaeological features from aerial photographs in Britain and could be a useful tool elsewhere. Site-specific mapping at scales of 1:2500 can show considerable detail within a site and is usually accurate to within ± 2 m (6 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. Digital terrain modeling can be applied to computer transformations in places where the ground is undulating or has high relief. After computer rectification the resulting plan may be brought to a final form using commercial graphics software or edited and incorporated as a GIS record (Geographic Information Systems – see below).

Mapping of individual sites from aerial photographs is necessary in cases of salvage excavation and also forms the beginning from which landscapes may be mapped and considered. This ability to study large areas is often only possible using aerial resources. In Britain, Roger Palmer used thousands of individual photographs of a 450-sq. km (175-sq. mile) territory around the Iron Age hillfort of Danebury to produce accurate maps which show that the site lay within very complex agricultural landscapes within which there were at least 8 other hillforts. Crop- and soil-marks



Map of the area around Danebury, an Iron Age hillfort in southern Britain (6th–2nd centuries BC), created from aerial survey, with details of ancient fields, tracks, and enclosures.



Chaco Canyon and its system of roads, visible from the air.

(see box, pp. 80–81) revealed the presence of 120 ditched farming 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/or surface finds.

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 photographs a whole network of prehistoric roadways was identified and mapped. This was followed up with selective ground surveys and some archaeological investigation. From the aerial coverage it has been estimated that the network, thought to date to the 11th and 12th centuries AD, extends some 1500 miles (2400 km), though of this only 130 miles (208 km) has been verified by examination at ground level.

Recent Developments in Aerial Photography. New technology is having an impact on aerial photography in different ways. Computer enhancement of pictures can improve their sharpness and contrast. Digital manipulation of images has also been developed and enables a single image, from an oblique or vertical photograph, to be transformed to match the map of the area. Computer programs also exist which allow several images to be transformed and then combined. This is especially useful in cases where a site may lie in two modern fields from which crop-marked information has been recorded in different years. Such plan-form images may help subsequent photo interpretation and mapping. Use of aerial data as a GIS layer may lead to fruitful results from analyses in conjunction with topographic and other archaeological information.

Although black-and-white panchromatic film is still generally used in air photography – because of its cheapness and high resolution – it may be worth employing infrared film as well. This detects radiation just beyond the visible spectrum and has produced some good results over moorland vegetation and in some cereal crops. In Germany false-color infrared film has produced very good results in bare soil conditions by accentuating moisture differences. By contrast, infrared linescan (IRLS) imagery results from equipment that scans from horizon to horizon to detect and record actual temperature differences (thermal prospection) on continuous video tape. Use of IRLS during flights by the British Royal Air Force has led to the identification of a number of new sites, mainly on grass and bare soils in Scotland, but its use is handicapped by the inherent distortion of the image. Computer programs can transform these images to plan views but the resolution cannot match that achieved by conventional photographic films. Recent developments in digital image capture have been advanced by Kodak, who market a system based on a conventional 35mm camera body and lens, but again the achievable resolution is not wholly adequate for capturing the level of detail necessary to record the range of crop- and soil-marked archaeology in Britain and Europe. Most archaeological reconnaissance in these countries is carried out using conventional films, either monochrome or (increasingly) color in order to make high-definition photographs on stock that has good archival permanence.

New World archaeological projects now routinely use the commercially available and cost-effective black-and-white aerial photographs. The 9×9 in negatives can be enlarged considerably before showing grain and thus quite small features such as walls, pits, etc. can be clearly seen. Digital cameras may be used to advantage to acquire images of larger-scale structures and systems, more common in arid and jungle zones.

Remote Sensing from High Altitude. Photographs taken from satellites or the space shuttle have a limited application to archaeology, since their scale is often huge, but images from the LANDSAT (Earth Resources Technology) satellites have proved useful. Scanners record the intensity of reflected light and the infrared radiation from the earth's surface, 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 hominid fossil beds; Space Imaging Radar (which can reveal features beneath 5 m (16 ft) of sand) has been used from the space shuttle to locate ancient riverbeds beneath the deserts of Egypt and hundreds of kilometers of long-abandoned caravan routes in Arabia, many of which converged on a spot in Oman, that may be the lost city of Ubar. Similarly, a radar sensor on the shuttle located ancient watercourses in China's Taklamakan Desert, along which lost settlements can be sought.

In Montana, 8 quarries worked up to 10,000 years ago have been detected by a team from the University of Colorado using the spectral "signatures" of their characteristic geological and vegetational patterns, since different frequencies of radiation detected by satellites provide information about the types of rocks and plants. In Nigeria, Patrick Darling has used both satellite imagery and vertical aerial photographs to carry out major surveys of large areas including swamp forest, tropical rainforest, and savannah, and has identified 1600 walled settlements and more than 16,000 km (10,000 miles) of linear earth boundaries, some surviving to heights of more than 18 m (60 ft) – this has made a huge contribution to the picture of the past that had been put together from piecemeal excavations.

The most remarkable archaeological application so far, however, has been in Mesoamerica. Using false-color LANDSAT imagery, in which natural colors are converted into more sharply contrasting hues, NASA scientists working with archaeologists in 1983 found an extensive network of Maya farmed fields and settlements in the Yucatán peninsula of Mexico. In this expensive experiment, costing $250,000, Maya ruins showed up in false color as tiny dots of blue, pink, and light red – blue for ancient reservoirs cut out of the limestone surface, pink and light red for vegetation on and adjacent to the sites. By looking for examples of blue dots next to pink and light red ones, archaeologists were able to pinpoint 112 sites. They visited 20 by helicopter in order to verify their conclusions.

The project also found an unknown city with twin pyramids, dating to the Classic Maya phase of AD 600–900; and relocated the major city of Oxpemul which had been discovered in the early 1930s but was then lost again in the thick jungle. However, the most important result was the detection of a large network (covering an area 65 km (40 miles) long and 4.8 km (3 miles) wide) of walled fields and house-mounds near Flores Magón, which effectively destroyed the already discredited theory that Maya civilization was based on a shifting type of agriculture, without regularly maintained fields.

Recent advances in satellite sensors have resulted in much improved resolution. Images from LANDSAT Thematic Mapper (TM) comprise pixels which define the ground in 30 × 30 m blocks – the examples above show that this can have archaeological application. Higher definition is available from the French SPOT satellite which has a panchromatic sensor that can achieve 10 m (33 ft) resolution. LANDSAT TM imagery has recently been used by Chris Cox in Britain to define areas of peat in the wetlands of Cumbria while LANDSAT TM and SPOT were used by a team from Durham University to detect and map part of the system of extinct water courses in the East Anglian Fenland. Elsewhere in Britain, Martin Fowler has tested the resolving power of satellite images in his studies of round barrows and other features in the Stonehenge area. The limitations are mainly due to the resolving power of the imagery which is constantly improving. Recently released Russian military imagery uses multi-spectral sensors with a resolution of 5–7 m (16–23 ft), and their panchromatic sensor has a ground resolution of 2–5 m (6.5–16 ft). The American Central Intelligence Agency has allowed some access to its archives of satellite images but is unlikely to make available that of the highest resolution – speculated to be in the order of 5–10 cm (2–4 in) and therefore offering considerable potential for archaeological studies.

Declassified US images can now be browsed on the web (at edcwww.cr.usgs.gov) and ordered as prints or negatives for about $18 per frame – these excellent high-resolution images are on 70 mm film, and are about 1 m (3 ft) in length. Despite the relatively low cost, however, as long as the resolution remains inferior to that of conventional aerial photography, the latter will continue to play a crucial role. As with conventional aerial photographs, satellite images need to be taken at an appropriate time of year for crop-marks and other such features to stand out, but – as is shown by a Russian image of the Stonehenge area – they can sometimes show a remarkable amount of detail, equal to that on conventional 1:10,000 vertical photos.

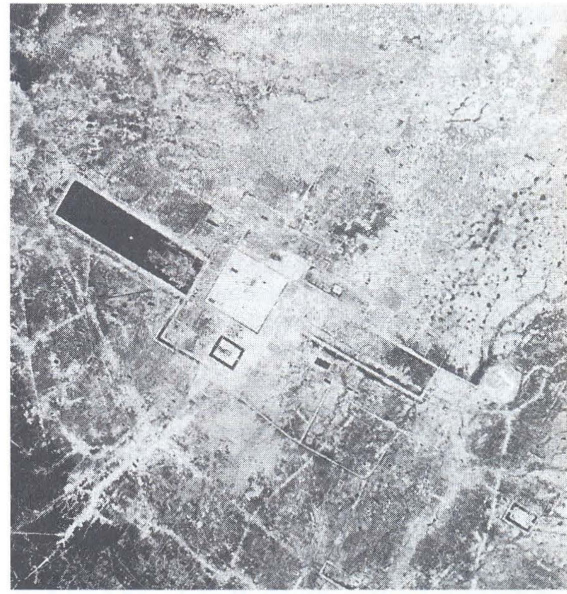
Much of this recent use of satellite imagery has identified the known rather than discovering the unknown but it has shown the capabilities of these very high altitude remotely sensed media. Study of an area of Thailand by J.T. Parry compared features interpreted from conventional vertical aerial photographs, at scales between 1:15,000 and 1:50,000, with those that could be identified on color infrared composite

LANDSAT images. Interpretation of the LANDSAT data was undertaken using projected images that were matched to maps at scales of 1:250,000 or zoomed to 1:50,000. Sites identified were large moated sites, for which LANDSAT was excellent, and smaller mounds (some 75 percent were detected), while canals showed only poorly (23 percent) compared to conventional aerial photographs.

Another remote sensing technique, ***sideways-looking airborne radar*** (SLAR), has also 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 an enormous lattice of grey lines some of which may have been canals, to judge by subsequent inspections by canoe. If field testing – which has scarcely begun – shows that the canals are ancient, it will show that the Maya had an elaborate irrigation and water transport system.

High altitude radar mapping has also helped reveal a hitherto undocumented people in Costa Rica. In 1984–85, Thomas Sever of NASA flew over the area around the volcano of Mount Arenal, which was of interest to archaeologists because local people had found potsherds and tools when roads were cut through the terrain of ash. Sever scanned the area using radar, infrared photographic film, and a device called lidar (light detection apparatus). The resulting images showed roadways radiating from a central graveyard. Subsequent excavation of 62 sites by Payson Sheets revealed that a wandering people had lived in the volcano's shadow since about 11,000 BC, and had settled permanently on the shore of Lake Arenal in 2000 BC. Their campsites, graves, and houses had been buried and protected by a volcanic eruption.

Recently, the vast ruins of the 1000-year-old temple complex of Angkor in northern Cambodia, which cover an area of about 260 sq. km (100 sq. miles) and are shrouded in dense jungle and surrounded by landmines, have been the subject of new studies using high-resolution radar imagery obtained from the space shuttle. The resulting dark squares and rectangles on the images are stone moats and reflecting pools around the temples. The main temple complex of Angkor Wat is readily visible as a small square bounded with black. 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.



A satellite image of the huge ancient site of Angkor in Cambodia: new temples have been discovered in this way.

In addition, British archaeologist Elisabeth Moore has examined both the satellite images and pictures taken from a DC-8 airplane equipped with AIRSAR (Airborne Synthetic Aperture Radar), which makes a three-dimensional map from stereo-images, and discovered some splendid, hitherto unknown temples and mounds, traces of a city predating the great Khmer capital by two or three centuries. She believes that the finds call into question the traditional concepts of the urban evolution of Angkor.

The application of these exciting new techniques to archaeology is only just beginning. So long as they remain expensive, conventional air photography will, however, continue to dominate aerial reconnaissance. But advanced airborne remote sensing techniques will no doubt become cheaper and more widespread in the future.

Recording and Mapping Sites in Reconnaissance Survey

As already noted in the discussion of air photography, the pinpointing of sites and features on regional maps is an essential next step in reconnaissance 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.

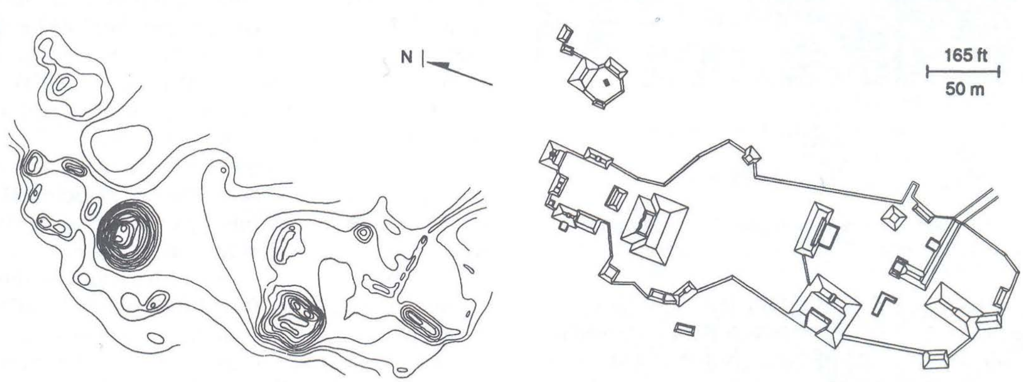
Mapping is the key to the accurate recording of most survey data. For surface features, such as buildings and roads, both topographic and planimetric maps are used. Topographic maps represent differences in elevation or height by means of contour lines and help relate ancient structures to the surrounding landscape. Planimetric maps exclude contour lines and topographic information, concentrating instead on the broad outlines of features, thus 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 – 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 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 59th (or whatever) 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 Paleo-Indian site of Meadowcroft Rockshelter. One of the great values of designating sites using these alpha-numerical systems is that they can be entered easily on computer files, for quick data retrieval, e.g. in salvage archaeology or settlement pattern studies.

Geographic Information Systems

A significant new development in archaeological mapping is the use of GIS (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." A GIS provides a map-based interface to a database; in other words, GIS are designed for the collection, storage, retrieval, analysis, and display of spatial data. GIS developed out of computer-aided design and mapping (CAD/CAM) programs during the 1970s. Some CAD programs, such as AutoCAD, can be linked to commercial databases and have proved valuable in allowing the automatic mapping of archaeological sites held in a computer database. A true GIS, however, also incorporates the ability to carry out a statistical analysis of site distribution, and to generate new information. 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. The software and digital landscape information are fed into a computer, along with (as a standard measurement) the figure of 1 hour for a 5-km walk on the flat. The software then does the calculations, using built-in data on the energy cost of traversing different kinds of terrain. Therefore GIS 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 non-spatial attributes, such as name, date, or material.



Two ways of presenting survey results, as exemplified by the Maya site of Nohmul, Belize. (Left) A topographic map relating the site to its landscape. (Right) A planimetric map showing the individual features of the site.

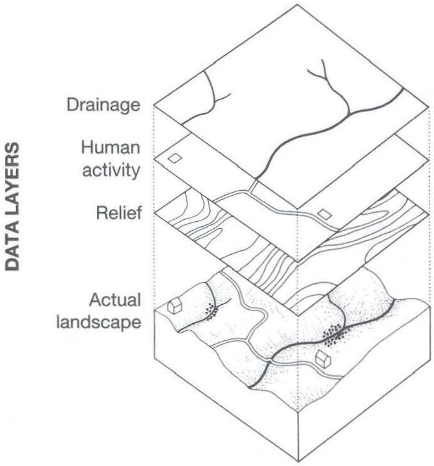
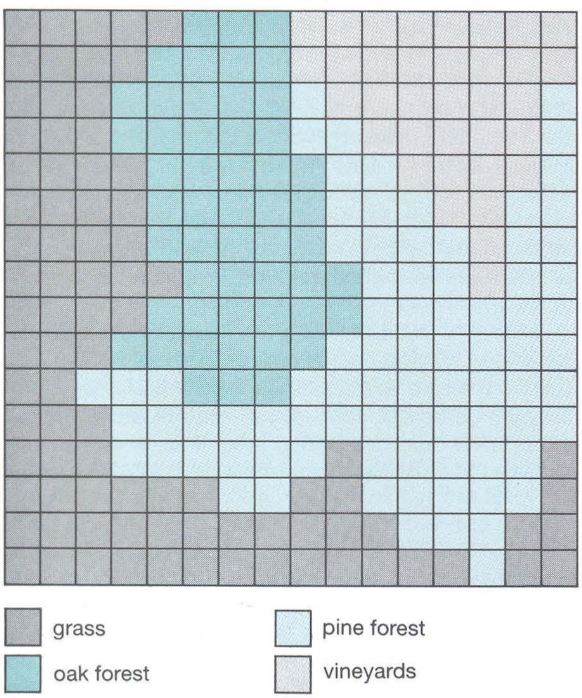


Diagram showing possible GIS data layers.



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

A single archaeological find might therefore be represented by an easting and northing 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 comprise a combination of points, lines, and polygons, along with their non-spatial attributes.

Within a map layer the data may be held in ***vector*** format, as points, lines, and polygons, or they may be stored as a grid of cells, or ***raster*** format. A raster layer recording vegetation, for example, would comprise a grid within which each cell contains information on the vegetation present at that point. Originally, GIS were either raster or vector-based systems and were not compatible. Nowadays, however, most commercial systems will allow these different data structures to be mixed.

Topographic maps represent an enormous amount of environmental data on relief, communications, hydrology etc. In order to make use of this within a GIS environment it is normal to divide the information 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 plans, satellite images, aerial photographs, geophysical survey, as well as maps.

The ability to incorporate satellite and aerial photographs 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 which can be taken directly into a GIS, although considerations of cost, copyright, and the resolution of the data can create obstacles for some GIS projects. Digitizing large numbers of paper maps by hand represents a laborious undertaking. Use can also be made of a handheld Global Positioning System (GPS) to provide a longitude and latitude for a position on the ground, by reference to satellites. These are extremely useful where a region is unmapped, or where the maps are old or inaccurate. Although most archaeological applications have so far focused on landscape survey, there is also no reason why a GIS should not be used at a finer scale to examine spatial relationships within an individual site.

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. In addition, GIS can help in predicting site location by combining data layers that each in some way help determine a site's location.

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

An example was developed by the Illinois State Museum for the Shawnee National Forest in southern Illinois. It predicts the likelihood of finding a prehistoric site anywhere within the 91 sq. km (35 sq. miles) of the forest by using the observed characteristics of the 68 sites which are known from the 12 sq. km (4.6 sq. miles) which 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 watertable. 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. This is a probability model whose result is an equation which can be used to predict the probability that any location with known environmental characteristics will contain a prehistoric site.

Recently, 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 also for the protection and management of archaeological remains in cultural resource management (see Chapter 14).

Many GIS applications, especially those based on predictive modeling, have been criticized as being environmentally deterministic, and it is easy to see why. Environmental data such 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 In an attempt to escape from these more functionalist analyses, archaeologists have used the GIS function called viewsheds to try to develop more humanistic appreciations of landscape (see p. 200).

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 the study of settlement patterns, site systems, and landscape archaeology without planning any recourse to excavation.

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

Site Surface Survey

The simplest way to gain some idea of a site's extent and layout is through a site surface survey – by studying the distribution of surviving features, and recording and possibly collecting artifacts from the surface. At the site of Teotihuacán (see box, pp. 90–91), careful survey was used to produce detailed maps of the city.

For artifacts and other objects collected or observed during surface survey, it may not be worth mapping their individual locations if they appear to come from badly disturbed secondary contexts. Or there may simply be too many artifacts realistically to record all their individual proveniences. In this latter instance the archaeologist will probably use sampling procedures for the selective recording of surface finds (see box, pp. 76–77). However, where time and funds are sufficient and the site is small enough, 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 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, although some objects

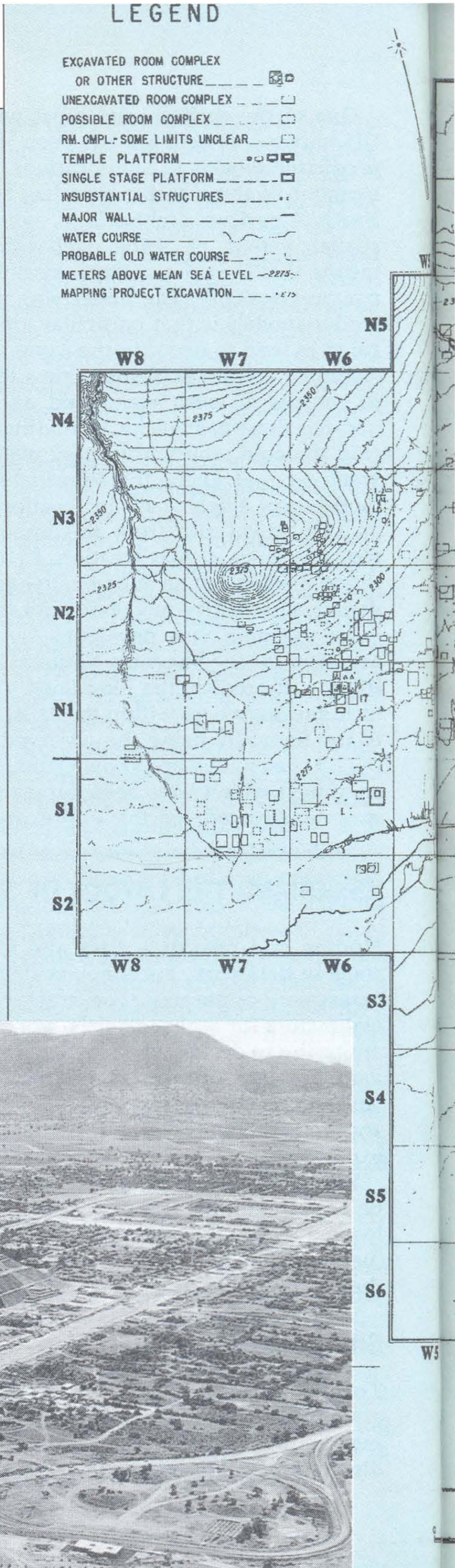
TEOTIHUACAN MAPPING PROJECT

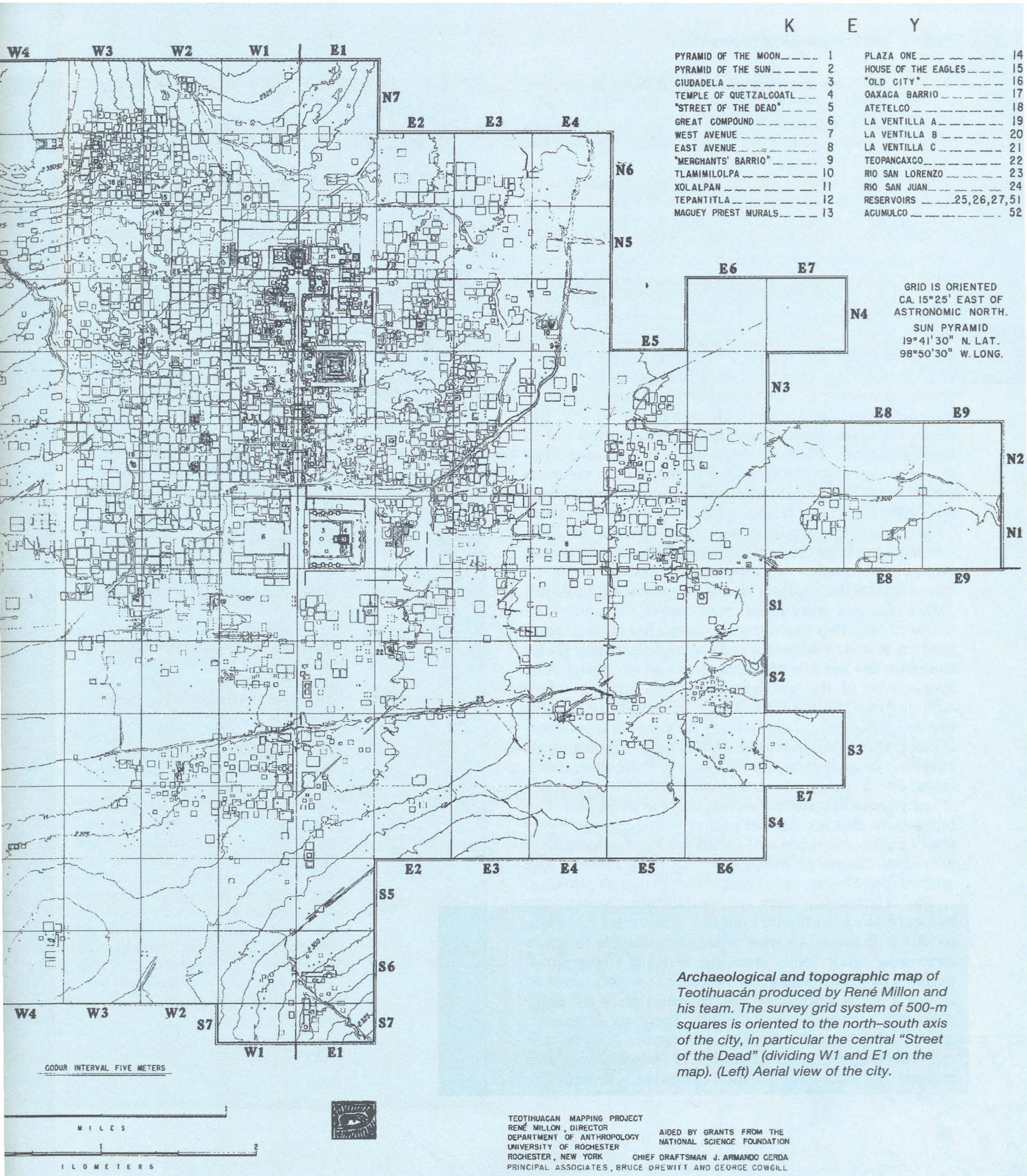
In 1962 the University of Rochester initiated a project, directed by René Millon, to map the pre-Columbian city of Teotihuacán. Located 40 km (25 miles) northeast of Mexico City, the site had been the largest and most powerful urban center in Mesoamerica in its heyday from AD 200 to 650. The layout and orientation of the city had intrigued scholars for decades; however, they considered the grandiose pyramid-temples, 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, and the grid plan of the city were discovered and defined.

Fortunately, structural remains lay just beneath the surface, so that Millon and his team were able to undertake the mapping from a combination of aerial and surface survey, with only small-scale excavation. The survey began with low-altitude aerial photography and preliminary ground reconnaissance to establish a survey grid made up of 147 squares, each 500 m on a side and each with its own map data sheet to be filled in. Using the grid, the city's irregular boundary, enclosing about 20 sq. km (*c.* 8 sq. miles), was defined by walking the perimeter. The city area itself was then intensively surveyed and mapped, and surface collections made. Individual structures were plotted for each 500-m square, and surface data recorded on special forms. Millions of potsherds were collected, and over 5000 structures and activity areas recorded. Small-scale excavations were also conducted to test the survey results. Eventually Millon and his colleagues combined the architectural interpretation of all this information on to the base map of the whole site, which they then published in conjunction with an explanatory text.

Teotihuacán had been laid out on a regular plan, with four quadrants orientated on the great north–south "Street of the Dead" and another major avenue running east–west across it. Construction had occurred over several centuries, but always following the master plan. The northern quadrant was the oldest residential area, with certain neighborhoods (*barrios*) here and elsewhere in the city apparently reserved for particular craft specialists, as shown by concentrations of obsidian, pottery, and other goods.

Since 1980, a new multi-disciplinary team directed by Rubén Cabrera Castro of the Mexican Institute of Archaeology and History (INAH) has been enlarging the picture, so successfully established by the Teotihuacán Mapping Project. 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, undertaken by a team from the National Autonomous University of Mexico led by Linda Manzanilla, were used to create a 3-D reconstruction of subsurface contours.





Archaeological and topographic map of Teotihuacán produced by René Millon and his team. The survey grid system of 500-m squares is oriented to the north–south axis of the city, in particular the central "Street of the Dead" (dividing W1 and E1 on the map). (Left) Aerial view of the city.

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 flint-working, seed-grinding, and butchering. These areas served as guides for subsequent excavation.

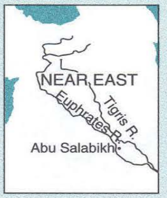
A similar surface survey was conducted at the Bronze Age city of Mohenjodaro in Pakistan. Here, a team of archaeologists from Pakistan, Germany, and Italy investigated the distribution of craft-working debris and found, to their surprise, that craft activities were not confined to a specific manufacturing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

Reliability of Surface Finds. Archaeologists have always used limited surface collection of artifacts as one way of trying to assess the date and layout of a site prior to excavation. However, now that surface survey has become not merely a preliminary to excavation but 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.

One 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 one might predict that multi-period, deep sites such as Near Eastern tells or village mounds would show few if any traces on the surface of the earliest and deepest levels. 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 collected with care, are truly multi-period, reflecting many phases of a site's use, not just the latest one. The reasons for this are not yet entirely clear, but they certainly have something to do with the kind of formation processes discussed in Chapter 2 – from erosion and animal disturbance to 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 meter squares) to assess a site's horizontal extent, ultimately by more thorough excavation (see below). There are, 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.

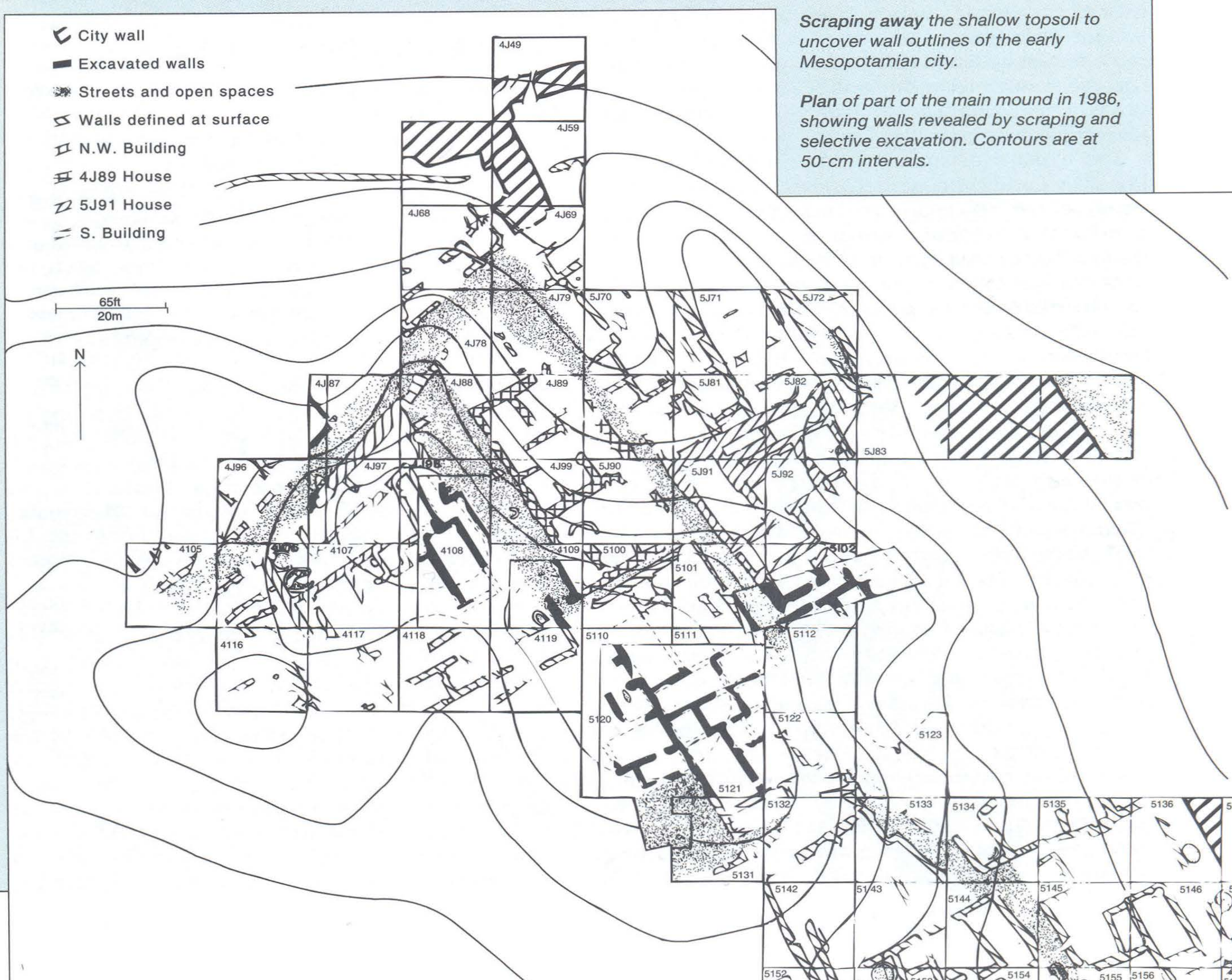
SURFACE INVESTIGATION AT ABU SALABIKH



An effective and simple site investigation strategy has been adopted at Abu Salabikh, Iraq, by Nicholas Postgate. He wanted to study the large-scale layout of an early Mesopotamian city – a considerable challenge, since many of the relevant archaeological deposits lie buried deep within multi-period mounds. However, at Abu Salabikh Postgate found a series of low mounds where occupation layers of a suitably early date lay conveniently just beneath the surface. The site was of a size to daunt most archaeologists (50 ha or 124 acres), but Postgate and his team found that they could obtain good results over wide areas simply by scraping away the shallow topsoil. Exposed immediately beneath were quite clear wall lines which could then be mapped almost as accurately as after actual excavation, and far more quickly.

Potsherds and other artifacts littering the surface were collected, and these were used to suggest earlier or later dates for different parts of the plan. These results could be confirmed by selective excavation.

Surface deposits of a mound on the western side of the site belonged to about 2900 BC, and displayed large, thick-walled, self-contained compounds, each containing separate rectangular houses with courtyards, storerooms, and drainage, as well as fire installations. The main mound, however, revealed houses of *c.*2500 BC packed tightly side by side, separated by an occasional narrow street. Although only part of the site has been uncovered in this way, it nevertheless represents the largest area of housing known from any 3rd millennium site in southern Iraq.



Scraping away *the shallow topsoil to uncover wall outlines of the early Mesopotamian city.*

Plan *of part of the main mound in 1986, showing walls revealed by scraping and selective excavation. Contours are at 50-cm intervals.*

Subsurface Detection

Probes. The most traditional technique is that of probing the soil with rods or borers, 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. Probing of this type is still employed routinely by some archaeologists – for example, to gauge the depth of the midden at the Ozette site in Washington State (pp. 60–61) or by Chinese archaeologists to plot the 300 pits remaining to be investigated near the first emperor's buried terracotta army. In the mid-1980s, the American archaeologist David Hurst Thomas and his team used over 600 systematically spaced test probes with a gasoline-powered auger in their successful search for a lost 16th-century Spanish mission on St Catherine's Island off the coast of Georgia in the U.S. Augers are also used by geomorphologists studying site sediments. However, there is always a risk of damaging fragile artifacts or features.

One notable advance in this technique was developed by Carlo Lerici in Italy in the 1950s for Etruscan tombs of the 6th century BC. Having detected the precise location of a tomb through aerial photography and soil resistivity (see below), he would bore down into it a hole 8 cm (3 in) in diameter, and insert a long tube with a periscope head and a light, and also a tiny camera attached if needed. Lerici examined some 3500 Etruscan tombs in this way, and found that almost all were completely empty, thus saving future excavators a great deal of wasted effort. He also discovered over 20 with painted walls, thus 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 Cheops (Khufu), in Egypt. This lies adjacent to another pit, excavated in 1954, that contained the perfectly preserved and disassembled parts of a 43-m (141-ft) long royal cedarwood boat of the 3rd millennium BC. The $250,000 probe revealed that the unopened pit does indeed contain all the dismantled timbers of a second boat but that the pit was not airtight – thus dashing hopes of analyzing the "ancient" air to see whether carbon dioxide in the atmosphere had increased over the millennia, and which component of the air preserves antiquities so efficiently.

Projects of this kind are beyond the resources of most archaeologists. But in future, funds permitting, probes of this type could equally well be applied to other Egyptian sites, to cavities in Maya structures, or to the many unexcavated tombs in China.

The Great Pyramid itself has recently been the subject of probes by French and Japanese teams who believe it may contain as yet undiscovered chambers or corridors. Using ultrasensitive microgravimetric equipment – which is normally employed to search for deficiencies in dam walls, and can tell if a stone has a hollow behind it – they detected what they think is a cavity some 3 m (10 ft) beyond one of the passage walls. However, test drilling to support this claim has not been completed and all tests have been stopped by the Egyptian authorities until their potential contribution to Egyptology has been established.

Ground-Based Remote Sensing

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

Seismic and Acoustic Methods. The simplest way to pass energy through the ground is to strike it. In *bosing* the earth is struck with a heavy wooden mallet or a lead-filled container on a long handle. Recording the resulting sound helps to locate underground features, since a dull sound indicates undisturbed ground, while buried ditches or pits produce a more resonant effect. This crude technique has now been made virtually obsolete through technological advances.

A more refined method, developed by the U.S. Army, has recently been applied to archaeological projects in Japan by Yasushi Nishimura. This *standing wave technique* employs a device which produces and amplifies so-called Rayleigh waves by striking the ground softly and repeatedly. A striker weighing 20 kg (44 lb) can reach depths of 10 m (33 ft), but bigger machines can reach 70 m or even 100 m (230–330 ft). The speed of the waves can be calculated by having two pick-up points a fixed distance apart. Since the waves move fast in hard materials, more slowly in clay or soft materials, features such as buried land surfaces can be detected.

UNDERWATER ARCHAEOLOGY

Underwater archaeology is generally considered to have been given its first major impetus during the winter of 1853–54, when a particularly low water level in the Swiss lakes laid bare enormous quantities of wooden posts, pottery, and other artifacts. From the earliest investigations, using crude diving-bells, it has developed into a valuable complement to work on land. It encompasses a wide variety of sites, including wells, sink holes, and springs (e.g. the great sacrificial well at Chichén Itzá, Mexico); submerged lakeside settlements (e.g. those of the Alpine region); and marine sites ranging from shipwrecks to sunken harbors (e.g. Caesarea, Israel) and drowned cities (e.g. Port Royal, Jamaica).

The invention in recent times of miniature submarines, other submersible craft, and above all of scuba diving gear has been of enormous value, enabling divers to stay underwater for much longer, and to reach sites at previously impossible depths. As a result, the pace and scale of discovery have greatly increased over the last few decades. More than 1000 shipwrecks are known in shallow Mediterranean waters, but recent explorations using deep-sea submersibles have begun to find Roman wrecks at depths of up to 850 m (2790 ft), and two Phoenician wrecks packed with amphorae discovered off the coast of Israel are the oldest vessels ever found in the deep sea.

Underwater Reconnaissance

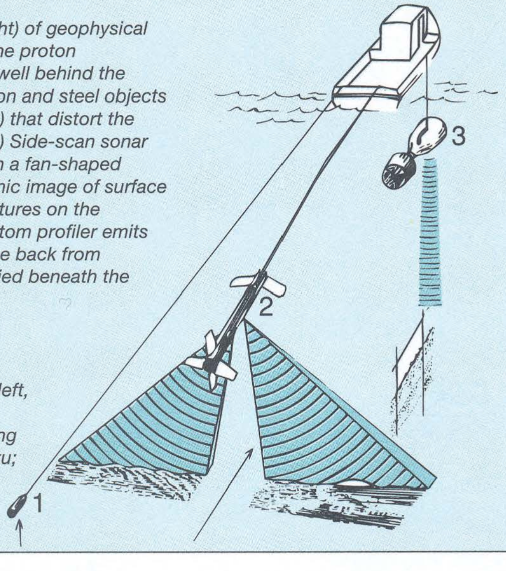
Geophysical methods are as useful for finding sites underwater as they are for locating land sites (see diagram). For example, in 1979 it was magnetometry combined with side-scan sonar that discovered the *Hamilton* and the *Scourge*, two armed schooners sunk during the War of 1812 at a depth of 90 m (295 ft) in Lake Ontario, Canada.

Nevertheless, in regions such as the Mediterranean the majority of finds have resulted from methods as simple as talking to local sponge-divers, who collectively have spent thousands of hours scouring the seabed.

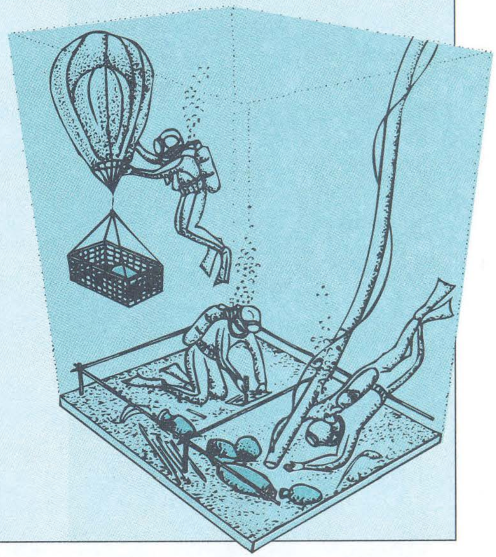
Underwater Excavation

Excavation underwater is complex and expensive (not to mention the highly demanding post-excavation conservation and analytical work that is also required). Once underway, the excavation may involve shifting vast quantities of sediment, and recording and removing bulky objects as diverse as storage jars (amphorae), metal ingots, and cannons. George Bass, founder of the Institute of Nautical Archaeology in Texas, and others have developed many helpful devices, such as baskets attached to balloons to raise objects, and air lifts (suction hoses) to remove sediment (see diagram). If the vessel's hull survives at all, detailed drawings must be made so that specialists can later reconstruct the overall form and lines, either on paper or in three dimensions as a model or full-size replica (see box, pp. 96–97). In some rare cases, like that of England's *Mary Rose* (16th century AD), preservation is sufficiently good for the remains of the hull to be raised – funds permitting.

Nautical archaeologists have now excavated more than 100 sunken vessels, revealing not only how they were constructed but also many insights into shipboard life, cargoes, trade routes, early metallurgy, and glassmaking. We look in more detail at two projects: the Red Bay Wreck, Canada (pp. 96–97) and the Uluburun Wreck, Turkey (pp. 374–75).

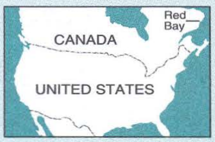


***Three methods** (near right) of geophysical underwater survey. (1) The proton magnetometer is towed well behind the survey boat, detecting iron and steel objects (e.g. cannons, steel hulls) that distort the earth's magnetic field. (2) Side-scan sonar transmits sound waves in a fan-shaped beam to produce a graphic image of surface (but not sub-surface) features on the seafloor. (3) The sub-bottom profiler emits sound pulses that bounce back from features and objects buried beneath the seafloor.*



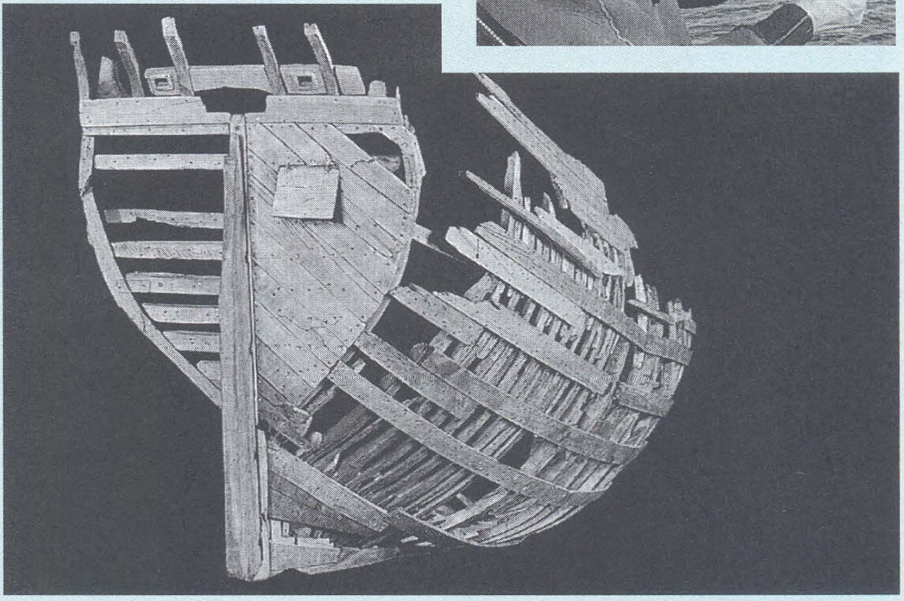
***Underwater excavation** techniques (far right): at left, the lift bag for raising objects; center, measuring and recording finds in situ; right, the air lift for removing sediment.*

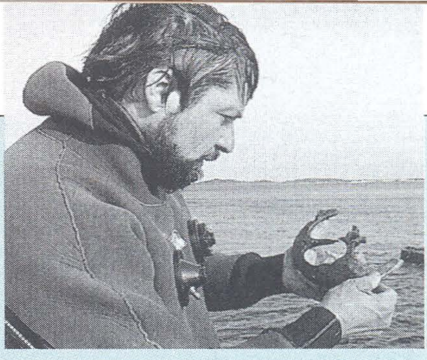
THE RED BAY WRECK: DISCOVERY AND EXCAVATION



Underwater archaeology, in conjunction with archival research and land archaeology, is beginning to yield a detailed picture of whaling undertaken by Basque fishermen at Red Bay, Labrador, in the 16th century AD. The Basques were the largest suppliers to Europe at this time of whale oil – an important commodity used for lighting and in products such as soap.

In 1977, prompted by the discovery in Spanish archives that Red Bay had been an important whaling center, the Canadian archaeologist James A. Tuck began an excavation on the island closing Red Bay harbor. Here he found remains of structures for rendering blubber into whale oil. The next year, the nautical archaeologist Robert Grenier led a Parks Canada team in search of the Basque galleon *San Juan*, which the archives said had sunk in the harbor in 1565.

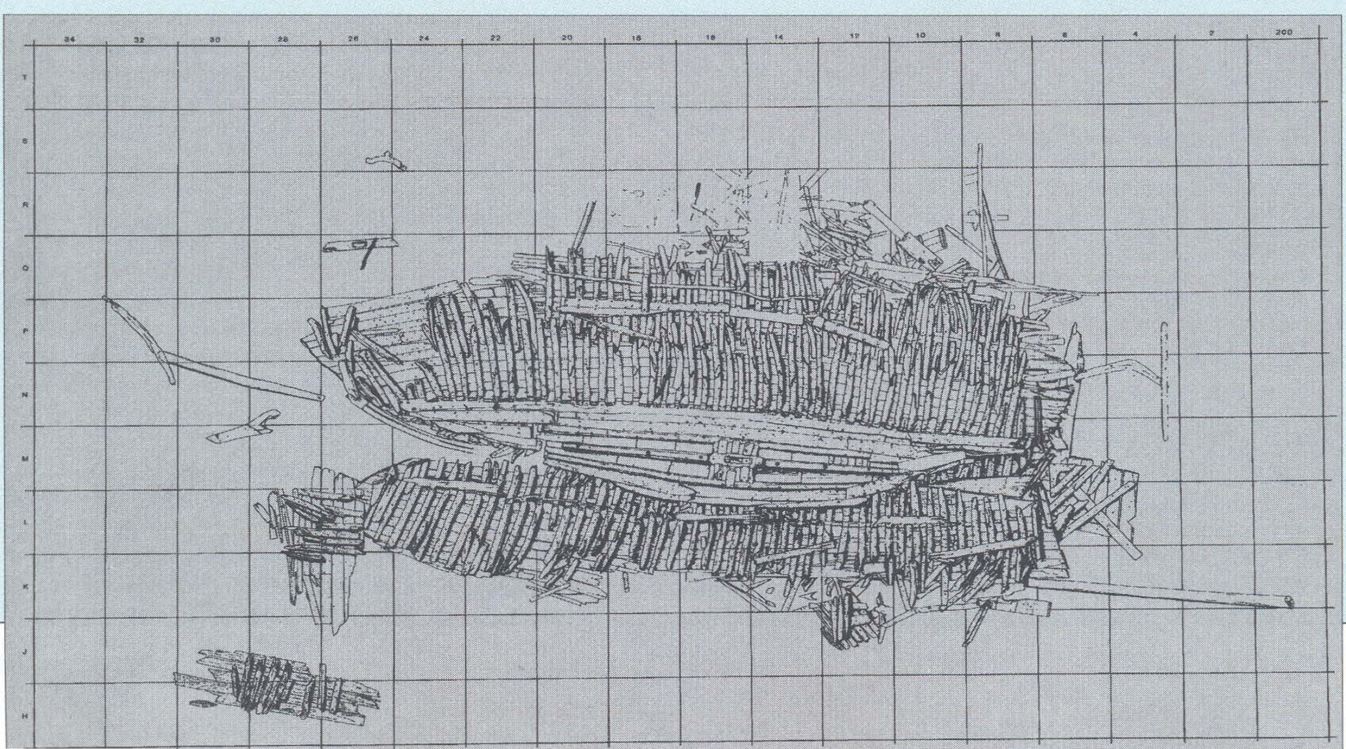




***Model**, at a scale of 1:10, to show how the galleon's surviving timbers may have fitted together.*

***Project director** Robert Grenier (top) examines the remains of an astrolabe (navigational instrument) from Red Bay.*

***Structural plan** of the wreck on the harbor bottom (2-m grid squares).*



Discovery and Excavation

A wreck believed to be that of the *San Juan* was located at a depth of 10 m (33 ft) in 1978, by a diver towed behind a small boat. A feasibility study carried out the following year confirmed the site's potential, and from 1980 to 1984 Parks Canada undertook a survey and excavation project that employed up to 15 marine archaeologists, backed up by 15–25 support staff, including conservators, draftspersons, and photographers. Two more galleons were discovered in the harbor, but only the supposed *San Juan* was excavated.

The dig was controlled from a specially equipped barge, anchored above the site, that contained a workshop, storage baths for artifacts, a crane for lifting timbers, and a compressor able to run 12 air lifts for removing silt. Salt water was heated on board and pumped down through hoses direct to the divers' suits to maintain body warmth in the near-freezing conditions.

An important technique devised during the project was the use of latex rubber to mold large sections of the ship's timbers in position underwater, thereby reproducing accurately the hull shape and details such as toolmarks and wood grain. The remains of the vessel were also raised in pieces to the surface for precise recording, but the latex molds eliminated the need for costly conservation of the original timbers, which were reburied on-site.

Analysis and Interpretation

On the evidence of the meticulous drawings and molds made during the excavation, a 1:10 scale model was constructed as a research tool to help reveal how the vessel had been built, and what she had looked like. Many fascinating details emerged, for instance that the 14.7-m (48-ft) long keel and bottom row of planks (garboard strakes) had – most unusually for this size of ship – been carved from a single beech tree. Nearly all the rest of the vessel was of oak.

In overview, the research model revealed a whaling ship with fine lines, far removed from the round, tubby shape commonly thought typical of 16th-century merchant vessels.

As the accompanying table (below) indicates, a wealth of artifacts from the wreck shed light on the cargo, navigational equipment, weaponry, and life on board the unlucky galleon.

Thanks to the integrated research design of this Parks Canada project – the largest ever conducted in Canadian waters – many new perspectives are emerging on 16th-century Basque seafaring, whaling, and shipbuilding traditions.

CULTURAL MATERIAL RECOVERED AT RED BAY

THE VESSELS

Whaling ship *believed to be the San Juan: Hull timbers (more than 3000) • Fittings: capstan, rudder, bow sprit • Rigging: heart blocks, running blocks, shrouds, other cordage • Anchor • Iron nail fragments*

Two other whaling ships

Four small boats*, some used for whaling*

RECOVERED ARTIFACTS

Cargo-Related: *Wooden casks (more than 10,000 individual pieces) • Wooden stowage articles: billets, chocks, wedges • Ballast stones (more than 13 tons)*

Navigational Instruments: *Binnacle • Compass • Sand glass • Log reel and chip • Astrolabe*

Food Storage, Preparation, and Serving: *Ceramics: coarse earthenware, majolica • Glass fragments • Pewter fragments • Treen: bowls and platters • Basketry • Copper-alloy spigot key*

Food-Related: *Cod bones • Mammal bones: polar bear, seal, cow, pig • Bird bones: ducks, gulls, auk • Walnut shells, hazelnut shells, plum pits, bakeapple seeds*

Clothing-Related: *Leather shoes • Leather fragments • Textile fragments*

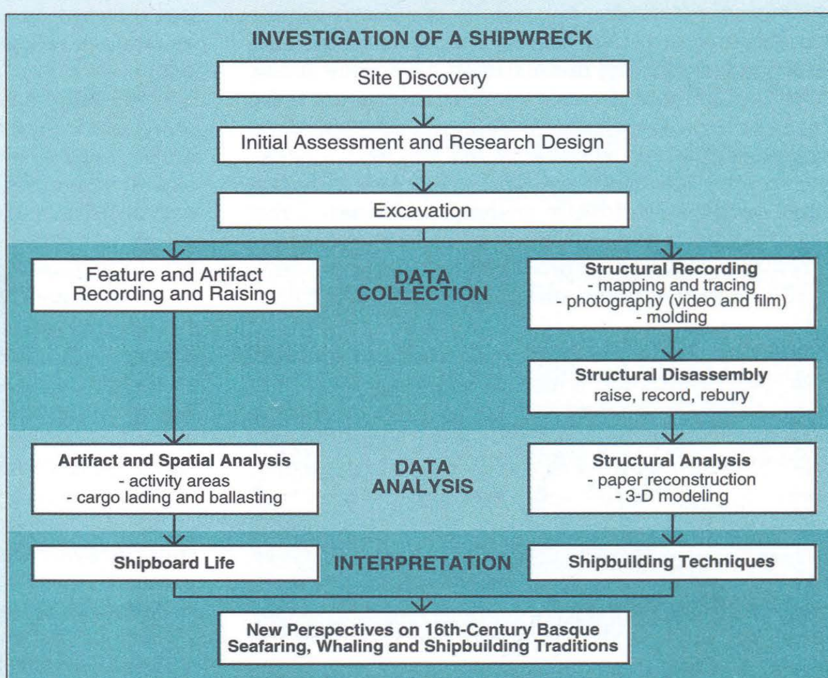
Personal Items: *Coins • Gaming piece • Comb*

Weaponry-Related: *Verso • Lead shot • Cannonballs • Possible wooden arrow*

Tool-Related: *Wooden tool handles • Brushes • Grindstone*

Building Material: *ceramic roof tile fragments*

Whaling-Related: *Whale bones*



The sections produced can then be transformed into a contour map of the subsurface features.

Other types of echo-sounding, such as sonar, have been employed elsewhere. For example, Kent Weeks and a team from the University of California have systematically mapped tombs in the Valley of the Kings at Thebes in Egypt. Using sonar devices in 1987 they successfully relocated a tomb, the position of which had been lost, only 15 m (49 ft) from that of the pharaoh Ramesses II, which is thought to have belonged to 50 of Ramesses' sons. This has recently revealed itself to be the biggest pharaonic tomb ever found, with at least 67 chambers laid out in a T-shape.

Detection of gravitational anomalies, mentioned in the section on probing the pyramids, 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 box p. 95). For example, after a bronze statue of an African boy was brought up in a sponge diver's net off the Turkish coast, George Bass and his colleagues were able to make a successful search for the Roman ship from which it came by means of echo-location systems.

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

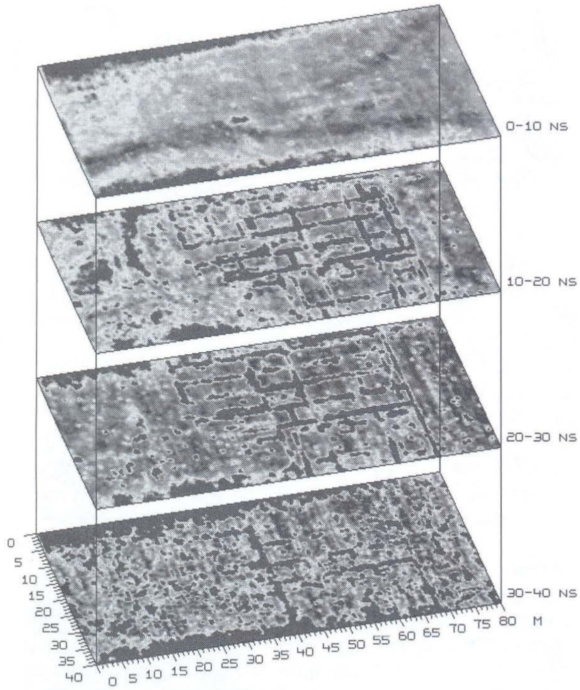
In the field, the technique usually employs a single surface radar antenna which transmits very short pulses of electromagnetic energy (radar waves) down into the ground. A receiver records reflections from the discontinuities encountered, whether these are natural changes in soil horizons or properties, or buried archaeological features. The time it takes radar waves to travel from the surface source to the discontinuity and back to the receiver is measured in nanoseconds (i.e. billionths of a second), and since the wave velocity can be estimated, this indicates the distance involved.

In archaeological exploration and mapping, the radar antenna is generally dragged along the ground at walking speed in transects, sending out and receiving many pulses per second. In the early years of this method, the reflections were printed on paper and interpreted visually, and thus relied heavily on the experience and ability of the operator who had to guess what the buried feature might be from often indecipherable images. Inevitably this led to uncertainties and inconclusive results, with some notable successes and failures. Now, however, the method has greatly improved, and the reflection data can be stored digitally, which enables sophisticated data processing and analysis to be carried out, producing clean, crisp reflection records which are easier to interpret. Powerful computers and software programs make it possible to store and process large three-dimensional sets of GPR data – e.g. a GPR survey of an area 50 m square can generate 500 megabytes of data – and computer advances now permit automated data and image processing which can help to interpret complicated reflection profiles.

One such advance is the use of "time-slices" or "slice-maps." Thousands of individual reflections are separated into horizontal slices, each of which corresponds to a specific estimated depth in the ground, and can reveal the general shape and location of buried features at each depth. A variety of colors (or shades of grey) are used to make a visual image that the brain can interpret more easily – e.g. areas with little or no subsurface reflection may be colored blue, those with high reflection may be red. Each slice therefore becomes like a horizontal excavation, and illustrates many buried components of the site. In fact, the slices do not need to be horizontal, and can be programmed to follow stratigraphic layers, and to have any orientation or thickness required.

For example, in the Forum Novum, an ancient Roman marketplace located about 100 km (62 miles) north of Rome, British archaeologists from the University of Birmingham and the British School of Archaeology in Rome needed a fuller picture of an unexcavated area than they had been able to obtain from aerial photographs and other techniques such as resistivity (see below). A series of GPR slices of the area revealed a whole series of walls, individual rooms, doorways, courtyards – in short, produced an architectural layout of the site which means that future excavation can be concentrated on a representative sample of the structures, thus avoiding a costly and time-consuming uncovering of the whole area.

Parts of the fourth-largest Roman city in England, that of Wroxeter in Shropshire (see box, pp. 100–01), have recently been studied by GPR; "time-slices" from different depths have revealed the town's changing



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

history through 400 years. Together with a very extensive magnetometer survey (see box p. 102), this has shown that the town's streets covered a much bigger area than previously thought – more than 60 ha (150 acres) – with a grid street-pattern, and clear outlines of houses, shops, and workshops.

In Japan, a burial mound at Kanmachi Mandara of about AD 350 was protected from excavation by cultural property laws, so GPR was used to locate the burial area within the mound, and determine its structural design. Radar profiles were taken at 50-cm (20-in) intervals across the mound, with pulses that could penetrate about 1 m (3.3 ft) into the ground.

Other electromagnetic methods available to the archaeologist are those employing soil conductivity meters and pulsed induction meters (see box, p. 102).

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

The technique works particularly well for ditches and pits in chalk and gravel, and masonry in clay. It involves first placing two "remote" probes, which remain stationary, in the ground. Two "mobile" probes, fixed to a frame that also supports the meter, are then inserted into the earth for each reading. A new development is "resistivity profiling," which involves the measurement of earth resistance at increasing depths across a site, by widening the probe spacings and thus building up a vertical "pseudosection". A more sophisticated variant of this method, borrowed from medical science, is electrical tomography, while the future will doubtless see the combination of multiple profiles across a site to create 3-D images of buried surfaces.

One drawback of the technique is that it is rather slow due to the need to make electrical contact with the soil. Mobile resistivity systems, with probe arrays mounted on wheels, have been developed by French geophysicists to increase the speed of survey coverage. Nevertheless, the method is an effective complement to other remote sensing survey methods. Indeed it often replaces magnetic methods (see below) since, unlike some of these, it can be used in urban areas, close to power lines, and in the vicinity of metal. Most things detectable by magnetism can also be found through

Dr Albert Hesse using an experimental automated resistance array at Wroxeter. This should help increase the speed of survey coverage.

GEOPHYSICAL SURVEY AT ROMAN WROXETER

Covering an area of nearly 78 ha (193 acres), Roman Wroxeter, or Viroconium Cornoviorum, was the fourth largest urban center in the province of Britannia and the capital of the Cornovii tribe. It is important today because, unlike so many other Roman towns in Britain, Wroxeter has survived largely without damage and no succeeding modern settlement was built over it.

The city has attracted archaeological attention over the last century, with extensive excavations being carried out on the public buildings of the town by antiquarians. Modern large-scale excavations have been undertaken by Graham Webster and Philip Barker. Excavation is not the only source of information for the development of the town, however. Intensive aerial survey over many years has provided important evidence for the layout of the town and its possible development, and has allowed the compilation of a town plan of considerable detail.

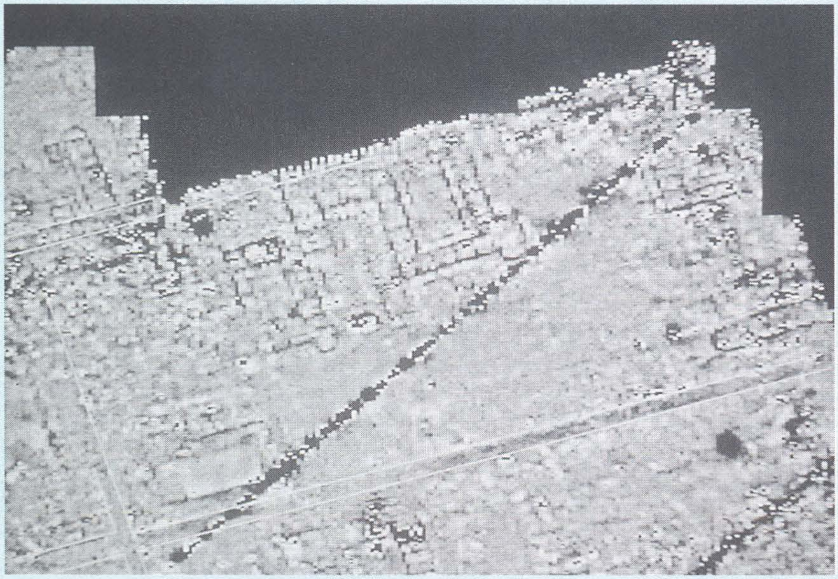
A great deal of information is therefore available for the site and its history, from the construction of a fortress for Roman legions XIV and XX by AD 60, and the foundation of the Civitas Cornoviorum during the 90s, through to the intriguing evidence for post-Roman occupation. The information is, however, extremely variable. Modern excavation has only uncovered a very small part of the site, certainly less than 1 percent of the total, while aerial photography is not effective over the whole area, frequently only reflecting the stone buildings, and not even all of these. Consequently, little was known about large parts of the city and indeed perhaps 40 percent of the best-preserved Roman city in Britain was effectively terra incognita.

Surveying the City

The Wroxeter Hinterland Project set out to study the effect of the town on its hinterland, and as part of this work it was realized that a more complete plan of the interior was essential. It was decided to carry out a geophysical survey of the whole of the available city – given the size of area, a radical solution was required to achieve this. The project was undertaken over several years by an international team of British and foreign geophysicists, including national bodies such as English Heritage and commercial groups including GSB Prospection. Their activities and results are impressive: nearly 63 ha (156 acres) were covered by gradiometer survey, representing over 2.5 million data points, and nearly 15 ha (37 acres) by resistance survey. Over 5 ha (12 acres) of ground penetrating radar data are now available for use in time-slicing software (to provide information on the depth of features, see p. 99), and a myriad other techniques, including seismics, conductivity, and caesium magnetometry, were used. Some techniques were employed to a lesser extent but still provide invaluable comparative results.

Results

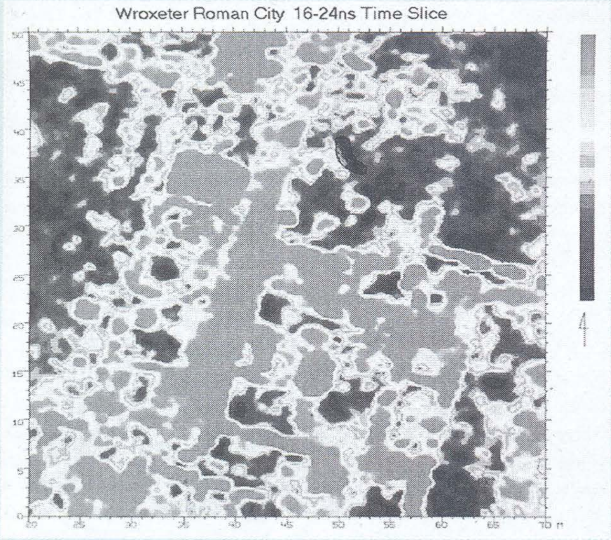
The result of this work is the most extensive and complete plan currently available for a Romano-British civitas

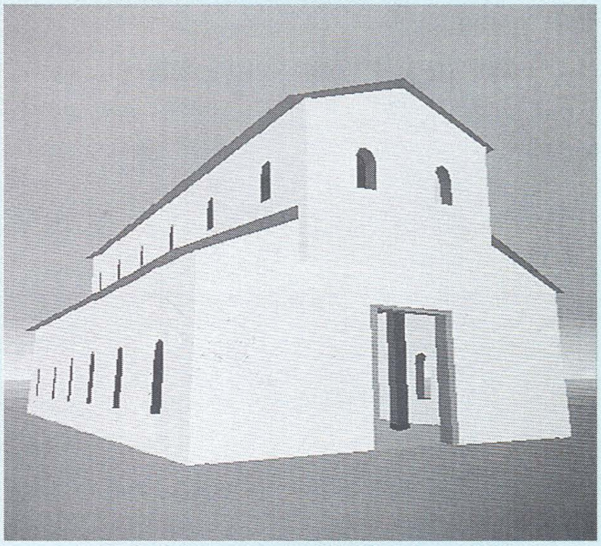


***The magnetometry** data for the area south of the bath insula (left). A large courtyard house and an apsidal building interpreted as a church can be seen.*

(Opposite above) A composite plan of the time-sliced radar plot of one building (left) and a web-based virtual reality reconstruction of the apsidal building interpreted as a possible church (right): see also http://www.bufau.bham.ac.uk/ for further examples.

(Opposite below) A detail of the plan of Roman Wroxeter derived from David Wilson's aerial photographic study and the magnetometer survey (left). The team at Wroxeter (right) setting up equipment for a ground penetrating radar survey.



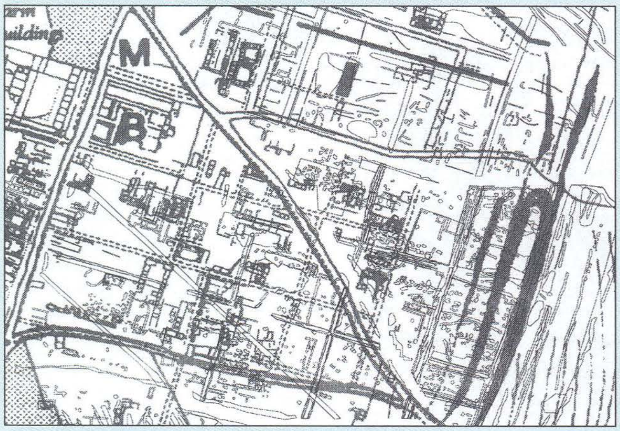


capital. There is evidence for central areas of elite buildings surrounded by artisan quarters and it is possible to identify specialized industrial areas. Dense pitting in the northwestern quarter of the town may relate to agro-industrial activities, such as tanning. A space in the eastern central area may be interpreted as the *forum boarium* (cattle market).

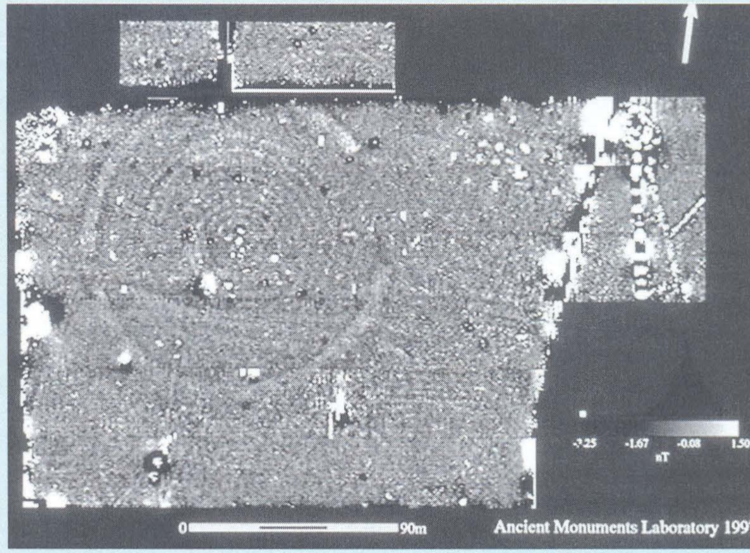
A number of features deserve specific comment. One large stone building, 27 m (88.5 ft) in length, oriented east–west and with an apse at its eastern end, is possibly a church. Equally important, among the gradiometer data, is the phenomenon of "reversed" magnetic data in the northeastern quarter of the town. This seems most reasonably interpreted as evidence for a major fire which swept across the town, causing changes in the magnetic properties of the building stone as it was burnt.

Geophysics has also provided a glimpse into the prehistory of the site: a number of ring ditches can be recognized within the survey data, and a small enclosure and associated fields appear to underlie the defenses and may represent the preceding Iron Age landscape.

The plan derived through geophysics at Wroxeter is exceptional: it is the most detailed of a Roman city ever produced in Britain – but without any expensive and destructive spadework. It is now being used as a basis for a virtual reality reconstruction of the town, which will be available to schools on CD-Rom. However, the study is not important simply because of the extent or even the quality of the data, but because it is an integral part of a larger research program.



MEASURING MAGNETISM



***Results of a magnetometer survey** of the site of Stanton Drew in Somerset. This revealed the existence of a wooden henge structure consisting of nine concentric rings of timbers that had completely disappeared above ground.*

The main instruments for tracing buried features using magnetic methods are magnetometers. Metal detectors can detect metals and some soil features as well.

The **proton precession magnetometer** consists of a sensor (a bottle of water) encircled by an electrical coil, mounted on a staff and connected by a cable to a small portable box of electronics. The device can detect small but sharp differences in magnetic field intensity caused by buried objects and features.

Proton magnetometers are usually employed using a grid divided into squares 1 m to 3 m on a side. Unfortunately their rate of operation is somewhat slow. Other drawbacks which they share with all other kinds of magnetometer include the fact that the operator cannot wear any iron: all buckles, watches, bootnails, metal pens, etc. must be kept several meters away; there must be no wire fences or corrugated sheeting in the vicinity. Proton magnetometers are also susceptible to interference from overhead cables. In a small, crowded country such as Japan, where one is never far from electrified rail lines or other direct current power lines, two magnetometers have to be used simultaneously (i.e. differential proton magnetometers, using two sensors) in order to overcome the "noise" that causes fluctuations in the magnetic field.

Fluxgate magnetometers have the advantage of sensors which give a continuous reading, but they are more complex to set up and operate – this is a directional instrument, and all measurements must be made with the sensor pointing in precisely the same direction (usually by hanging it vertically).

The most favored type of fluxgate magnetometer, the **fluxgate gradiometer**, uses two sensors in a light, self-contained instrument which produces a continuous output, and records differences in magnetic intensities on a meter. This can be combined with automatic trace recording and computer processing – consequently it can do fast, accurate surveys of large areas. A survey team using two fluxgate magnetometers can provide detailed coverage of at least two hectares per day. Such rapidity, and the responsiveness of such instruments to a wide range of archaeological features, has led to their increased use in archaeological evaluations, for instance in advance of the building of roads. Along one stretch of the future M3 highway in England, it found 8 sites in 10 km (6.2 miles).

The **caesium magnetometer** is a highly sensitive portable magnetometer that can detect minute magnetic variations, down to about one millionth of the earth's magnetic field. It is being increasingly used to detect weakly magnetized features such as postholes, and more deeply buried sites. Mounted on wheels, it can achieve rates of ground coverage comparable to fluxgate gradiometer surveys.

Metal detectors employ both magnetism and conductivity – they respond to the high electrical conductivity of all metals and to the high magnetic susceptibility of ferrous metals. There are two main instruments. The **soil conductivity meter** comprises a radio transmitter and receiver in continuous operation, and detects subsurface features by measuring the distortion of the transmitted field caused by changes in the conductivity or susceptibility of the soil. Metals, for example, produce strong anomalies, while pits produce weak ones. The **pulsed induction meter** can find metal objects and magnetic soil anomalies such as pits by applying pulses of magnetic field to the ground from a transmitter coil – the larger the coil, the deeper the penetration. Similar devices are also employed in underwater archaeology (see box, p. 95).

resistivity; and in some field projects it has proved the most successful device for locating features (see box). Techniques based on magnetism are, however, still of great importance to archaeologists.

Magnetic Survey Methods. These are among the most widely used methods of survey, being particularly helpful in locating fired clay structures such as hearths and pottery kilns; iron objects; and pits and ditches. Such buried features all produce slight but measurable distortions in the earth's magnetic field. The reasons for this vary according to the type of feature, but are based on the presence of iron, even if only in minute amounts. For example, grains of iron oxide in clay, their magnetism randomly orientated if the clay is unbaked, will line up and become permanently fixed on the direction of the earth's magnetic field when heated to about 700°C (1292°F) or more. The baked clay thus becomes a weak permanent magnet, creating an anomaly in the surrounding magnetic field. (This phenomenon of thermoremanent magnetism also forms the basis for magnetic dating – see Chapter 4.) Anomalies caused by pits and ditches, on the other hand, occur because the so-called magnetic susceptibility of their contents is greater than that of the surrounding subsoil.

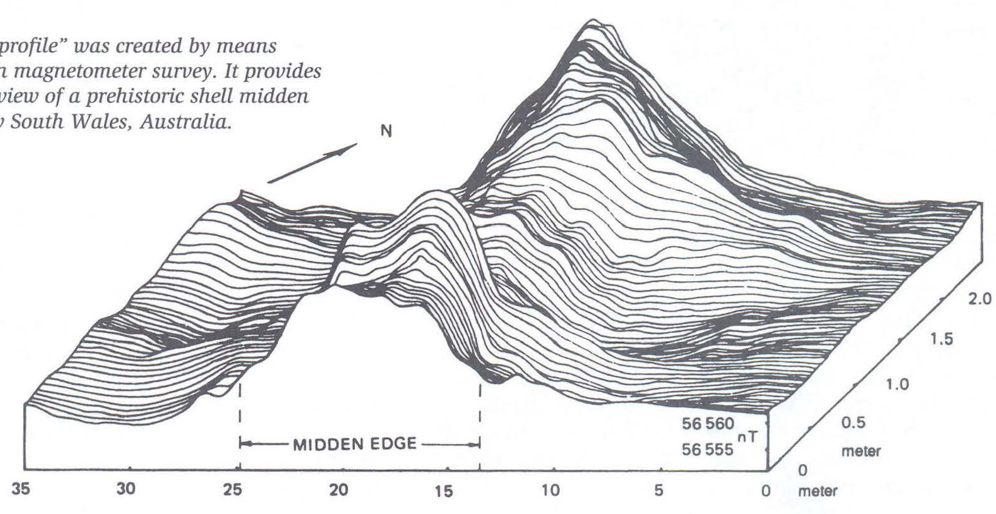
All the magnetic instruments can produce informative site plans which help to delimit archaeological potential (see box). Common means of presentation are contour, dot density, and gray-scale maps, all also used to display resistivity survey results. In the case of magnetic survey, the contour map has contour lines that join all points of the same value of the magnetic field intensity – this successfully reveals separate anomalies, such as tombs in a cemetery. In dot-density mapping, individual magnetometer readings are plotted as dots on a plan, with shading dependent on the magnetic intensity, the blacker areas therefore represent the highest anomalies in the local magnetic field. This makes it easier to pick up regular features, even where changes may be slight.

New developments in image processing by computer make it possible to manipulate geophysical datasets in order to reduce spurious effects and highlight subtle archaeological anomalies. For example, "directional filtering" allows a data "surface" of any chosen vertical scale to be "illuminated" from various directions and elevations to make subtle anomalies visible. Such processing mimics the revealing effects of low sunlight on earthworks, but with the added flexibility of computer manipulation.

An alternative, simpler mapping method has been devised which presents the data as a series of stacked profiles. Each traverse with the equipment is plotted as a curved profile. These are then placed in order, parallel to each other but aligned on an oblique plan, so that one obtains a kind of 3-D image of the site's magnetic variations.

Metal Detectors. These electromagnetic devices are also helpful in detecting buried remains – and not just metal ones. 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. Features such as pits, ditches, walls and kilns can also sometimes be recorded with these instruments because of their different magnetic sus-

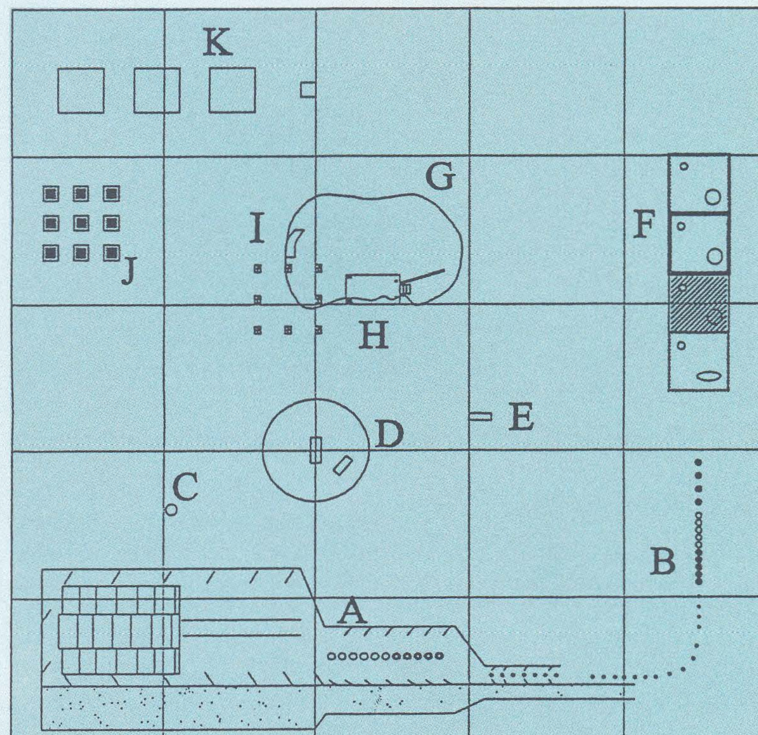
This "stacked-image profile" was created by means of a proton precession magnetometer survey. It provides a three-dimensional view of a prehistoric shell midden at Stuarts Point, New South Wales, Australia.



CONTROLLED ARCHAEOLOGICAL TEST SITE

As this chapter shows, we now have many different ways of "looking" under the ground, but problems start when one tries to interpret what is revealed by the scanners, because an infinity of things could send out the same signal. In an effort to make the assessment of these data more than an educated guess, a Controlled Archaeological Test Site (CATS) has been constructed by the US Army's Construction Engineering Research Labs (CERL) in Urbana, Illinois, for research and training in geophysical applications in archaeology.

This "controlled archaeological test-bed" covers 2500 sq. m (26,910 sq. ft) of land near the campus of the University of Illinois. A meter beneath the surface, four contiguous house floors have been created; there are also hearths, roasting pits, refuse pits, and artifact clusters; mortuary features such as pig and dog burials in mounds, under house floors and in isolated pits; a matrix of clay bricks of various compositions, buried at different depths; an earth oven with remains of cooked chicken and yams inside; clamshells; and palisades, postholes, ditches, and embankments – the latter in segments of different dimensions and composition. In other words, the site replicates the kind of ephemeral features commonly left in the sub-plowzone by the indigenous cultures of the American Midwest, which are often hard to distinguish from the surrounding soil with the methods outlined in this chapter. There is also a matrix of wooden rods, metal pipes, and other objects in various configurations and depths.



Plan of the CATS, showing the buried features: A *ditch and embankment;* B *palisade;* C *roasting pit;* D *mound;* E *burial;* F *house complex;* G *midden;* H *historical cellar;* I *limestone piers and brick sidewalk;* J *brick matrix;* K *matrix of wood and metal objects.*

Since the location and depth of every feature in the CATS are known to within a millimeter, and their geophysical attributes are also known, there is no need for future excavations to check results. Experiments are now planned to apply non-destructive investigative techniques to the site which should lead to far more precise ways of locating and identifying what lies beneath the soil.

ceptibilities as compared to the surrounding soil or subsoil (see box, p. 102, for types of equipment).

Metal detectors can be of great value to archaeologists, particularly in providing quick general results and locating modern metal objects that may lie near the surface. They are also very widely used by non-archaeologists, most of whom are responsible enthusiasts, but some of whom vandalize sites mindlessly and often illegally dig holes without recording or reporting the finds they make. There are now 30,000 metal detector users in Britain alone.

Other Techniques. There are a few other prospection methods which are not often used but which may become more widely adopted in the future, particularly geochemical analysis, discussed below.

Both *radioactivity* and *neutron scattering* have been tried out in remote sensing tests, but it was found that both work only if the soil cover is very thin. Most soils and rocks have some radioactive content, and, as with resistivity and magnetic surveying, in the radioactivity technique readings measure discontinuity between buried ditches or pits and the surrounding earth. In the neutron method, a probe that is both a source of fast neutrons and a detector of slow ones is inserted into the soil: measurement of their rate of slowing and scattering through the ground is taken. Stone produces a lower count rate than soil, so buried features can sometimes be detected.

Thermal prospection (thermography), which has already been briefly mentioned in the section on aerial photography above, is based on weak variations in temperature (as little as tenths of a degree) which can be found above buried structures whose thermal properties are different from those of their surroundings. The technique has mostly been used from an airplane, but ground-based thermal imaging cameras do exist; these have not yet seen much application to archaeological features, though they can be effective in detecting concealed variations within a building, such as infilled doorways in churches. So far, thermography has been used primarily on very long or massive structures, for instance prehistoric enclosures or Roman buildings.

The mapping and study of the *vegetation* at a site can be very informative about previous work – certain species will grow where soil has been disturbed, and at Sutton Hoo, for example, an expert on grasses was able to pinpoint many holes that had been dug into this mound site in recent years.

Geochemical analysis involves taking samples of soil at intervals (such as every meter) from the surface of a site and its surroundings, and measuring their phosphate (phosphorus) content. It was fieldwork in Sweden in the 1920s and 1930s that first revealed the close correlation between ancient settlement and high concentrations of phosphorus in the soil. The 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. Subsequently, the method was used to locate sites in North America and northwest Europe: Ralph Solecki, for example, detected burials in West Virginia by this means.

Recent phosphate 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 are accurately reflected in the topsoil. In the past, topsoil was considered to be unstratified and hence devoid of archaeological information; it was often removed mechanically and quickly without investigation. Now, however, it is becoming clear that even a site that appears totally plowed-out can yield important chemical information about precisely where its occupation was located. The phosphate method is also invaluable for sites with no apparent internal architectural features. In some cases it may help clarify the function of different parts of an excavated site as well. For example, in a Romano-British farmstead at Cefn Graeanog, North Wales, J.S. Conway took soil samples at 1 m (3 ft 4 in) 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.

Investigations of this type are slow, because one has to lay down a grid, collect, weigh, and analyze the samples. But they are becoming increasingly common in archaeological projects, since they can reveal features not detected by other techniques. Like magnetic and resistivity methods (to which they are complementary), they help to construct a detailed picture of features of special archaeological interest within larger areas already identified by other means such as aerial photography or surface survey.

In concluding this section on subsurface detection, we may refer in passing to a controversial technique that has a few followers. *Dowsing* (in the U.S. witching) – the location of subsurface features by holding out a twig, copper rod, coathanger, pendulum, or some such instrument and waiting for it to move – has been applied to archaeological problems for at least 50 years, but without being taken seriously by most archaeologists.

In the mid-1980s, however, it was used in a project to trace medieval church foundations in Northumberland, England, and the skeptical archaeologists involved became convinced of the technique's validity. While keeping an open mind, most archaeologists remain extremely doubtful. Only excavation can test the predictions made, and in the church project digging confirmed some of the dowser's predictions, but not all of them; this is hardly surprising, since a dowser often has a good chance of being right – either the feature is there or it is not. Tests by the physicist Martin Aitken to find a correlation between dowsing responses and magnetic disturbance in a Romano-British pottery kiln proved entirely negative.

For the moment, therefore, until overwhelming proof of the validity of dowsing and other unconventional methods is forthcoming, archaeologists should continue to put their faith in the ever-growing number of tried-and-trusted scientific techniques for obtaining data about site layout without excavation.

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

Purposes of Excavation

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

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

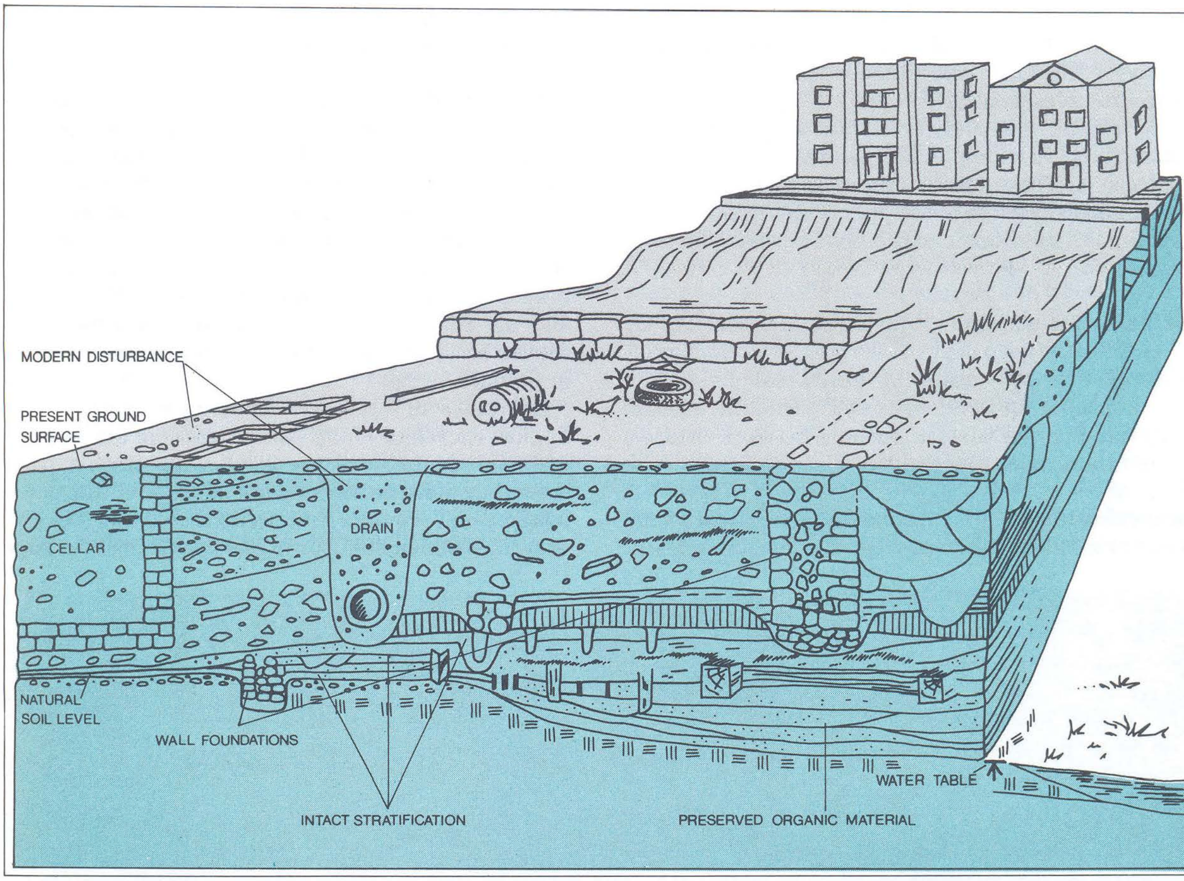
Stratigraphy. As we saw in Chapter 1, one of the first steps in comprehending the great antiquity of humankind was the recognition by geologists of the process of stratification – that layers or strata are laid down, one on top of the other, according to processes that still continue. Archaeological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

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

In recent years, archaeologists have developed an ingenious and effective method of checking that artifacts – so far mostly of stone or bone – discovered in a particular deposit are contemporaneous and not intrusive. They have found that in a surprising number of cases flakes of stone or bone can be fitted back together again: reassembled in the shape of the original stone block or pieces of bone from which they came. At the British Mesolithic (Middle Stone Age) site of Hengistbury Head, for example, reanalysis of an old excavation showed that two groups of flint flakes, found in two different layers, could be refitted. This cast doubt on the stratigraphic separation of the two layers, and demolished the original excavator's argument that the flints had been made by two different groups of people. As well as clarifying questions of stratification, these refitting or conjoining exercises are transforming archaeological studies of early technology (Chapter 8).

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

What are the best excavation methods for retrieving this information?



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

Methods of Excavation

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

This book is not an excavation or field manual, and the reader is referred for detailed information to the texts listed at the end of this chapter and in the bibliography. In fact, a few days or weeks spent on a well-run dig are worth far more than reading any book on the subject. Nevertheless some brief guidance as to the main methods can be given here.

It goes without saying that all excavation methods need to be adapted to the research question in hand and the nature of the site. It is no good digging a deeply stratified urban site, with hundreds of complex structures, thousands of intercutting pits, and tens of thousands of artifacts, as if it were the same as a shallow Paleolithic open site, where only one or two structures and a few hundred artifacts may survive. On the Paleolithic site, for example, one has some hope of uncovering all the structures and recording the exact position, vertically and horizontally – i.e. the ***provenience*** – of each and every artifact. On the urban site one has no chance of doing this, given time and funding constraints. Instead, one has to adopt a sampling strategy (see box, pp. 76–77) and only key artifacts such as coins (important for dating purposes: see Chapter 4) will have their provenience recorded with three-dimensional precision, the remainder being allocated simply to the layer and perhaps the grid-square in which they were found.

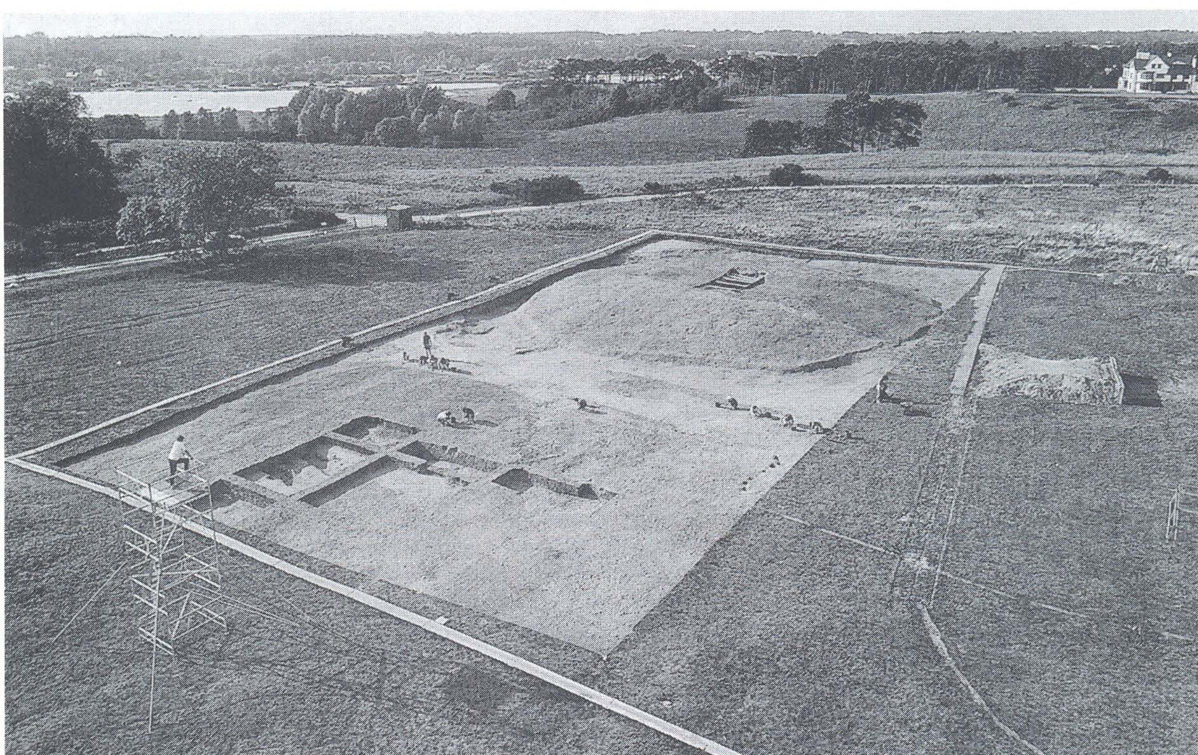
One should note, however, that we have already reintroduced the idea of the vertical and horizontal dimensions. These are as crucial to the methods of excavation as they are to the principles behind excavation. Broadly speaking one can divide excavation techniques into:

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

Most excavators employ a combination of both strategies, but there are different ways of achieving this. All presuppose that the site has first been surveyed and a grid of squares laid down over it to aid in accurate recording.

The ***Wheeler box-grid*** – developed, as we saw in Chapter 1, from the work of General Pitt-Rivers – seeks to satisfy both vertical and horizontal requirements by retaining intact baulks of earth between the squares of the grid so that different layers can be traced and correlated across the site in the vertical profiles. Once the general extent and layout of the site have been ascertained, some of the baulks can be removed and the squares joined into an open excavation to expose any features (such as a mosaic floor) that are of special interest.

Advocates of ***open-area excavation***, such as the English excavator Philip Barker, criticize the Wheeler method, arguing that the baulks are invariably in the wrong place or wrongly orientated to illustrate the relationships required from sections, and that they prevent the distinguishing of spatial patterning over large



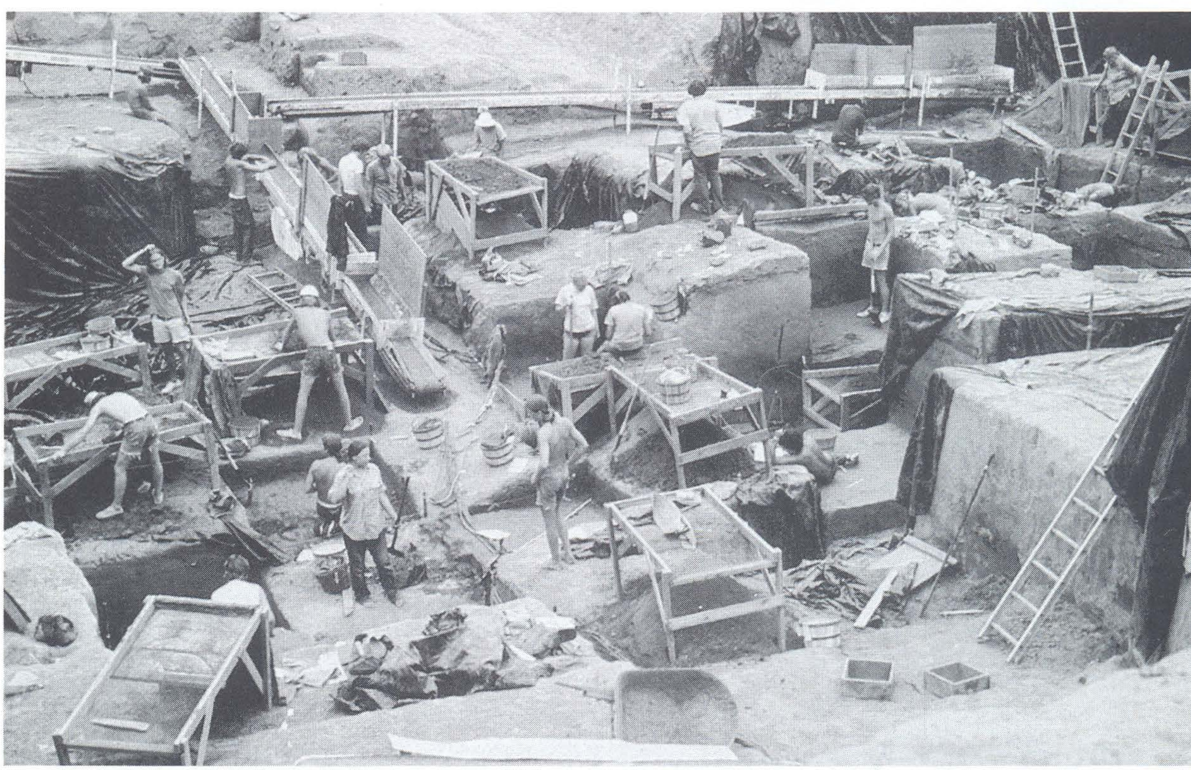
Open-area excavation at Sutton Hoo, eastern England. A large area, 32 × 64 m, was uncovered to establish the perimeters of two burial mounds. Detailed stratigraphy was then studied in smaller squares. Immediately below the topsoil lay early medieval features, recorded using overhead color photographs to emphasize soil variations, and plotted on site plans at scales of 1:10 and 1:100.

areas. It is far better, these critics say, not to have such permanent or semi-permanent baulks, but to open up large areas and only to cut vertical sections (at whatever angle is necessary to the main site grid) where they are needed to elucidate particularly complex stratigraphic relationships. Apart from these "running sections," the vertical dimension is recorded by accurate three-dimensional measurements as the dig proceeds and reconstructed on paper after the end of the excavation. The introduction since Wheeler's day of more advanced recording methods, including field computers, makes this more demanding open-area method feasible, and it has become the norm, for instance, in much of British archaeology. The open-area method is particularly effective where single-period deposits lie near the surface, as for instance with remains of Native American or European Neolithic long houses. Here the time dimension may be represented by lateral movement (a settlement rebuilt adjacent to, not on top of, an earlier one) and it is essential to expose large horizontal areas in order to understand the complex pattern of rebuilding.

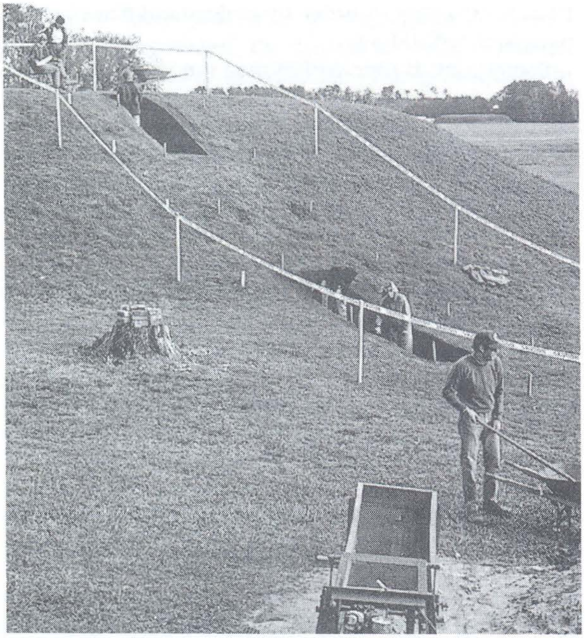
Sometimes, if time and money are short, and structures lie sufficiently close to the surface, the topsoil can simply be scraped away over large areas, as has been done to good effect at Tell Abu Salabikh (box, pp. 92–93).

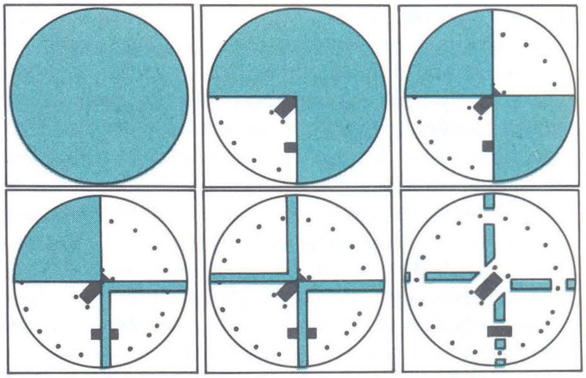
No single method, however, is ever going to be universally applicable. The rigid box-grid, for instance, has rarely been employed to excavate very deep sites, such as Near Eastern tells, because the trench squares rapidly become uncomfortable and dangerous as the dig proceeds downward. One solution commonly adopted is ***step-trenching***, with a large area opened at the top which gradually narrows as the dig descends in a series of large steps. This technique was used effectively at the Koster site, Illinois.

Another solution to the problem of dangerously deep excavations, successfully adopted on the salvage excavations at Coppergate, York (see case study,

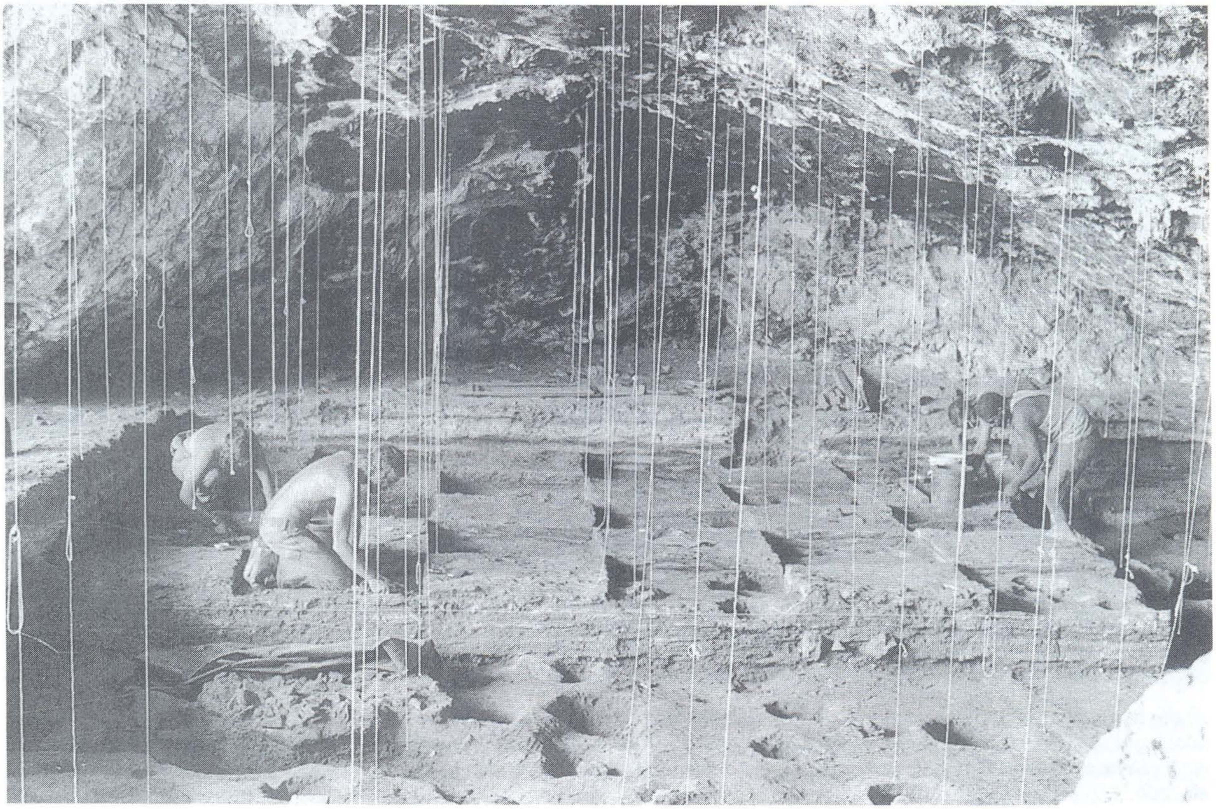


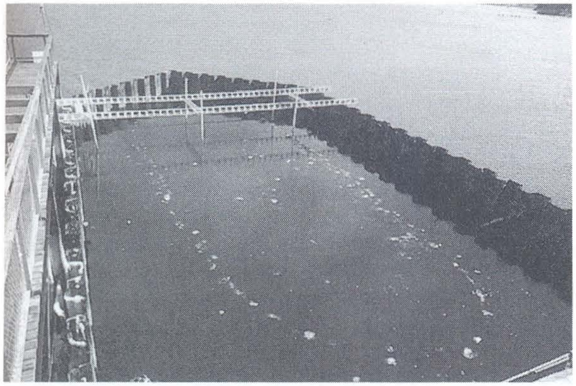
At the American Indian site of Koster, in the Illinois River Valley, large horizontal areas were uncovered in order to locate living floors and activity zones. However, so that the vertical dimension could also be analyzed at this deep site, vertical sections were cut as steps as the excavation descended. At this complex site 14 occupation levels were identified, stretching from c. 7500 BC to AD 1200.





Excavation methods. (Left) Sectioning a burial mound at Moundville, Alabama (see box, pp. 212–13). (Above) Six stages of the quadrant method for excavating burial mounds. The objective is to expose subsurface features while retaining four transverse sections for stratigraphic analysis. (Below) Excavation of 70,000 years of deposits at Boomplaas Cave, South Africa (see Chapter 6), demanded meticulous recording controls, using grid lines attached to the cave roof.





Excavation using a cofferdam: the wreck – visible as air bubbles – of the merchant brig designated YO 88 at Yorktown, Virginia, scuttled during the War of Independence.

Chapter 13) and Billingsgate, London, is to build a ***cofferdam*** of sheet piling around the area to be dug. Cofferdams have also been used in shipwreck excavations, either simply to control the flow of water – as on a War of Independence wreck at Yorktown, Virginia – or to pump out the water altogether. Cofferdams are expensive and the dig must be well funded.

Whatever the method of excavation – and the accompanying illustrations show other techniques e.g. for the excavation of burial mounds and cave sites – a dig is only as good as its methods of recovery and recording. Since excavation involves destruction of much of the evidence, it is an unrepeatable exercise. Well thought out recovery methods are essential, and careful records must be kept of every stage of the dig.

Recovery and Recording of the Evidence

As we saw above, different sites have different requirements. One should aim to recover and plot the three-dimensional provenience of every artifact from a shallow single-period Paleolithic or Neolithic site, an objective that is simply not feasible for the urban archaeologist. On both types of site, a decision may be made to save time by using heavy mechanical diggers to remove topsoil (but see above, p. 105), but thereafter the Paleolithic or Neolithic specialist will usually want to screen or sieve as much excavated soil as possible in order to recover tiny artifacts, animal bones, and in the case of wet sieving (see Chapter 6), plant remains. The urban archaeologist on the other hand will only be able to adopt sieving much more selectively, as part of a sampling strategy, for instance where plant remains can be expected to survive, as in a latrine or refuse pit.

Once an artifact has been recovered, and its provenience recorded, it must be given a number which is entered in a catalog book or field computer and on the bag in which it is to be stored. Day-to-day progress of the dig is recorded in site notebooks, or on data sheets preprinted with specific questions to be answered (which helps produce uniform data suitable for later analysis by computer).

Unlike artifacts, which can be removed for later analysis, features and structures usually have to be left where they were found (*in situ*), or destroyed as the excavation proceeds to another layer. It is thus imperative to record them, not simply by written description in site notebooks, but by accurately scaled drawings and photography. The same applies to vertical profiles (sections), and for each horizontally exposed layer good overhead photographs taken from a stand or tethered balloon are also essential.

It is the site notebooks, scaled drawings, photographs and computer disks – in addition to recovered artifacts, animal bones, and plant remains – that form the total record of the excavation, on the basis of which all interpretations of the site will be made. This post-

Screening: archaeologists at the Maya site of Cozumel, Mexico, screen excavated dirt through a mesh to recover tiny artifacts, animal bones, and other remains.

The ultimate value of an excavation lies in the records produced during actual fieldwork. Good organization is essential. Here we show the step-by-step methods adopted by the Museum of London. (Right) A flow diagram of procedures for the excavator to follow once a context (deposit) has been identified during the dig. (Below) Recording sheets must be meticulously completed as work proceeds. Most features are excavated and thus destroyed, so post-excavation analysis and layer-by-layer reconstructions of the site depend entirely on accurate field notes. (Opposite) The Roman baths at Huggin Hill in London. A Museum of London archaeologist uses a theodolite to measure the accurate position of a column base on which another archaeologist holds a survey rod (range pole). Their measurements will later form the basis for a detailed plan.

CLEAN AREA

IDENTIFY LIMITS OF CONTEXT

CHECK WITH SUPERVISOR AS TO NEED OF PHOTOGRAPH

IDENTIFY NUMBER OF GRID SQUARES IN WHICH FEATURE LIES

TAKE SHEET(S) OF PERMATRACE FROM FILE IN SITE OFFICE

DRAW A PLAN OF FEATURE AT A SCALE OF 1:20 UNLESS OTHERWISE ADVISED

TAKE RELEVANT TYPE OF CONTEXT SHEET FROM FILE IN SITE OFFICE

TAKE CONTEXT NUMBERS FROM SITE CONTEXT REGISTER

RECORD CONTEXT NUMBER ON PLAN(S)

TAKE LEVELS; MARK SPOT HEIGHTS ON PLAN, RECORD BACKSIGHT AND FORESIGHTS ON REVERSE OF CONTEXT SHEET

REDUCE LEVELS TO O.D. AND TRANSFER TO PLAN

DESCRIBE CONTEXT

OBTAIN FINDS BAG AND LABEL, AND ENTER SITE CODE AND CONTEXT NUMBER ON LABEL

CHECK WITH SUPERVISOR AS TO SUITABLE METHOD OF EXCAVATION, NEED FOR SAMPLING AND METHOD OF FINDS COLLECTION

EXCAVATE CONTEXT, AMENDING AND ADJUSTING DESCRIPTION AS NECESSARY

TAKE FINDS TO APPROPRIATE PLACE

DETERMINE RELATIONSHIPS OF NEWLY RECORDED CONTEXT TO PREVIOUSLY EXCAVATED STRATIGRAPHY BY OVERLAYING PLANS

CROSS-REFERENCE RELATIONSHIPS ON CONTEXT SHEET AND FILL IN MATRIX

ENTER DATE AND INITIALS ON CONTEXT SHEET

PLACE PLAN AND CONTEXT SHEET IN RELEVANT "TO BE CHECKED" FILES

[ALL PLANS, CONTEXT SHEETS AND RELATIONSHIPS SHOULD BE CHECKED BEFORE LEAVING SITE]

CONTEXT RECORDING SHEET

Grid Square(s)	Area/Section	Context type	Site Code	Context
110 – 115/210	B	DEPOSIT	XYZ | 89	138

DEPOSIT
1. Compaction
2. Colour
3. Composition / Particle size (over 10%)
4. Inclusions (under 10%) occa / mod / freq
5. Thickness & extent
6. Other comments
7. Method & conditions

1) VARIES FROM LOOSE TO COMPACT
2) DARK GREYISH BROWN
3) SAND (40%) SILT (60%)
4) FREQUENT LARGE FRAGMENTS OF POTTERY AND TILE; FREQUENT MEDIUM AND SMALL FRAGMENTS OF BONE, OCCASIONAL MEDIUM AND SMALL FRAGMENTS OF LEATHER, SMALL FRAGMENTS METAL, AND WHOLE OYSTER SHELLS (ALL INCLUSIONS WELL SORTED)
5) THICKEST AT NORTH (25mm) SLOPING DOWN TO THE SOUTH/EAST (10mm) THE LOWER BOUNDARY TO THE NEXT HORIZON IS IRREGULAR
6) OCCASIONAL LENSES OF ORGANIC MATERIAL
7) WEATHER DRY, EXCAVATED WITH MATTOCK

CUT
1. Shape in plan
2. Corners
3. Dimensions/Depth
4. Break of slope- top
5. Sides
6. Break of slope- base
7. Base
8. Orientation
9. Inclination of axis
10. Truncated (if known)
11. Fill nos
12. Other comments

Draw profile overleaf

PTO

Stratigraphic matrix

121 | 135

This context is 138

154 | 157 | 148

Your interpretation : ~~Internal~~ External ~~Structural~~ ~~Other (specify)~~

A DUMPED DEPOSIT, (PROBABLY REFUSE)

Your discussion :

LARGE QUANTITY OF POTTERY AND BONE PLUS OTHER MATERIAL AND WELL SORTED NATURE SUGGEST IT IS A DUMP OF REFUSE MATERIAL.
(MIGHT BE ASSOCIATED WITH STRUCTURE 95)?

Context same as :

PTO

Plan nos : P 138 (X2)	Site book refs :	Initials & date NH 24/8/89
Other drawings : S/E	Matrix location : C3	Checked by & date BP 2/9/89
Photographs : ☐ Card nos :		

Levels on reverse

Tick when reduced and transferred to plans : ✓

Highest : Lowest :

Finds (tick)

None	Pot	Bone	Glass	Metal	CBM	Other BM	Wood	Leather
	✓	✓		✓	✓			✓

Environmental samples

Sample nos & type : 23 BULK SAMPLE FOR SIEVING – FISH BONES etc.

Other finds (specify) : 1 WHOLE CERAMIC VESSEL

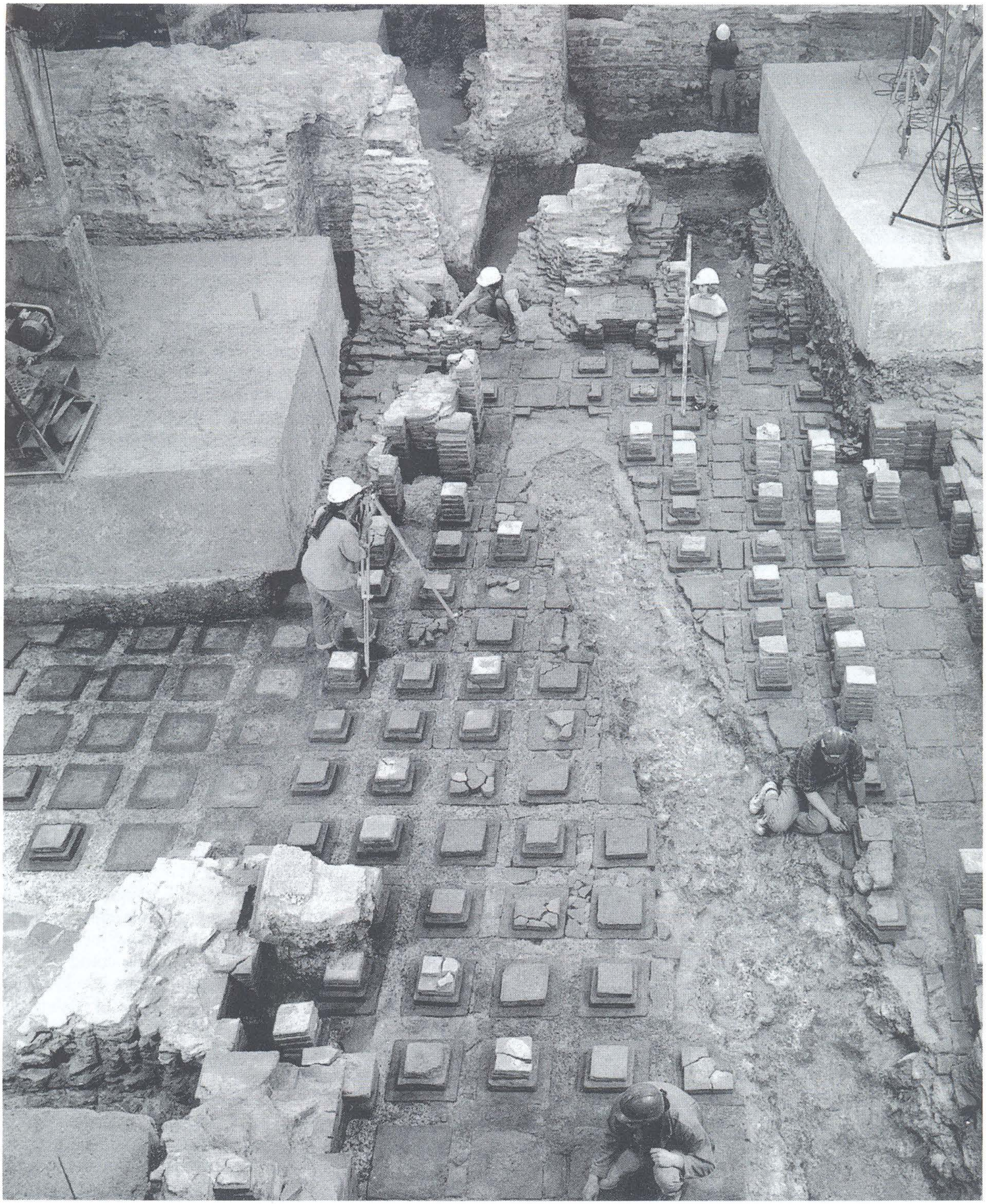
Finds sample (BM) nos :

Checked Interpretation :

PTO

Provisional period	Group	Initials & date

MUSEUM OF LONDON



excavation analysis will take many months, perhaps years, often much longer than the excavation itself. However, some preliminary analysis, particularly sorting and classification of the artifacts, will be made in the field during the course of the excavation.

Processing and Classification

Like excavation itself, the processing of excavated materials in the field laboratory is a specialized activity that demands careful planning and organization. For example, no archaeologist should undertake the excavation of a wet site without having on hand team members expert in the conservation of waterlogged wood, and facilities for coping with such material. The reader is referred for further guidance to the many manuals now available that deal with conservation problems confronting archaeologists.

There are, however, two aspects of field laboratory procedure that should be discussed briefly here. The first concerns the cleaning of artifacts; the second, artifact classification. In both cases we would stress the need for the archaeologist always to consider in advance what kinds of questions the newly excavated material might be able to answer. Thorough cleaning of artifacts, for example, is a traditional part of excavations worldwide. But many of the new scientific techniques discussed in Part II make it quite evident that artifacts should *not* necessarily be cleaned thoroughly before a specialist has had a chance to study them. For instance, we now know that food residues are often preserved in pots and possible blood residues on stone tools (Chapter 7). The chances of such preservation need to be assessed before evidence is destroyed.

Nevertheless most artifacts eventually have to be cleaned to some degree if they are to be sorted and classified. Initial sorting is into broad categories such as stone tools, pottery, and metal objects. These categories are then subdivided or classified, so as to create more manageable groups that can later be analyzed. Classification is commonly done on the basis of three kinds of characteristics or ***attributes***:

1 surface attributes (including decoration and color);
2 shape attributes (dimensions as well as shape itself);
3 technological attributes (primarily raw material).

Artifacts found to share similar attributes are grouped together into artifact types – hence the term ***typology***, which simply refers to the creation of such types.

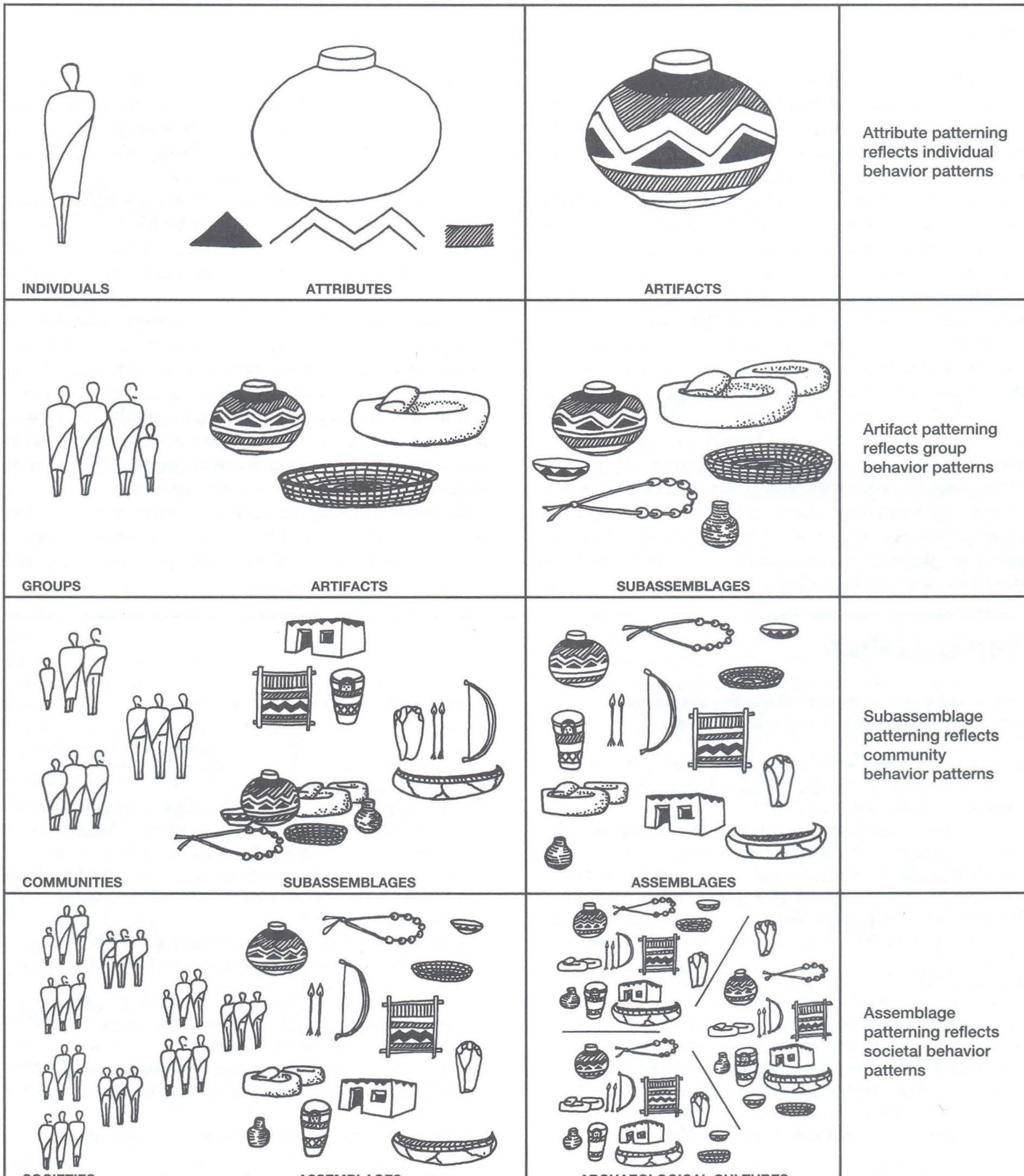
Typology dominated archaeological thinking until the 1950s, and still plays an important role in the discipline. The reason for this is straightforward. Artifacts make up a large part of the archaeological record, and typology helps archaeologists create order in this mass of evidence. As we saw in Chapter 1, C.J. Thomsen demonstrated early on that artifacts could be ordered in a Three Age System or sequence of stone, bronze, and iron. This discovery underlies the continuing use of typology as a method of dating – of measuring the passage of time (Chapter 4). Typology has also been used as a means of defining archaeological entities at a particular moment in time. Groups of artifact (and building) types at a particular time and place are termed ***assemblages***, and groups of assemblages have been taken to define ***archaeological cultures***.

As we shall see in Part II, the difficulty comes when one tries to translate this terminology into human terms and to relate an archaeological culture with an actual group of people in the past.

This brings us back to the purpose of classification. Types, assemblages, and cultures are all artificial constructs designed to put order into disordered evidence. The trap that former generations of scholars fell into was to allow these constructs to determine the way they thought about the past, rather than using them merely as one means of giving shape to the evidence. We now recognize more clearly that different classifications are needed for the different kinds of questions we want to ask. A student of ceramic technology would base a classification on variations in raw material and methods of manufacture, whereas a scholar studying the various functions of pottery for storage, cooking etc. might classify the vessels according to shape and size. Our ability to construct and make good use of new classifications has been immeasurably enhanced by computers, which allow archaeologists to compare the association of different attributes on hundreds of objects at once.

In a salvage project in the late 1980s – involving the survey, testing, and excavation of some 500 sites along the 2250-km (1400-mile) route of a pipeline from California to Texas – Fred Plog, David L. Carlson, and their associates developed a computerized system using a video camera for automatic recording of different attributes of artifacts. Four to six people could process 1000–2000 artifacts a day, some 10 times quicker than normal methods. The standardization of recording methods allows rapid and highly accurate comparisons to be made between different artifact types.

In conclusion, it cannot be stressed too strongly that all the effort put into survey, excavation, and post-excavation analysis will have been largely wasted unless the results are published, initially as interim reports and subsequently in a full-scale monograph (see Chapter 14).



Terms used in archaeological classification, from attributes (shape, decoration) of a pot to the complete archaeological culture: a diagram developed by the American archaeologist James Deetz. The columns at left and right give the inferred human meaning of the terms. The extent to which one can draw behavioral inferences from such classification is discussed in Chapter 12.

SUMMARY

Until the present century, individual sites were the main focus of archaeological attention, and the only remote sensing devices used were a pair of eyes and a stick. The developments of aerial photography and reconnaissance techniques have shown archaeologists that the entire landscape is of interest, while geophysical and geochemical methods have revolutionized our ability to detect what lies hidden beneath the soil.

Today archaeologists study whole regions, often employing sampling techniques to bring ground reconnaissance (surface survey) within the scope of individual research teams. Having located sites within those regions, and mapped them using aerial reconnaissance techniques and now GIS, archaeologists can then turn to a whole battery of remote sensing site survey devices able to detect buried features without excavation. The geophysical methods almost all involve either passing energy into the ground and locating buried features from their effect on that energy or measuring the intensity of the earth's magnetic field. In either case, they depend on contrast between the buried features and their surroundings. Many of the techniques are costly in both equipment and time, but they are often cheaper and certainly less destructive than random test-pits or trial trenches. They allow archaeologists to be more selective in deciding which parts of a site, if any, should be fully excavated.

Excavation itself relies on methods designed to elucidate the horizontal extent of a site in space, and the vertical stratification representing changes through time (though time can be represented by horizontal movement of the site as well). Good recording methods are essential, together with a well-equipped field laboratory for processing and classifying the finds. Classification based on selected attributes (decoration, shape, material) of each artifact is the fundamental means of organizing the excavated material, usually into types – hence typology. But classification is only a means to an end, and different schemes are needed for the different questions archaeologists want to address.

However, little of the material retrieved during survey and excavation will be of much use unless it can be dated in some way. In the next chapter we turn to this crucial aspect of archaeology.

FURTHER READING

Useful introductions to methods of locating and surveying archaeological sites can be found in the following:

Allen, K.M.S., Green, S.W. & Zubrow, E.B.W. (eds.). 1990. *Interpreting Space: GIS and Archaeology*. Taylor and Francis: London & New York.

Clark, A. 1996. *Seeing Beneath the Soil: Prospecting Methods in Archaeology*. (2nd ed.) Routledge: London.

Colwell, R.N. (ed.). 1983. *Manual of Remote Sensing*. (2nd ed.) Society of Photogrammetry: Falls Church, Virginia.

Flannery, K.V. (ed.). 1976. *The Early Mesoamerican Village*. Academic Press: New York. (Helpful examples of surface survey.)

Lock, G. & Stančič, Z. (eds.). 1995. *Archaeology and Geographical Information Systems: A European Perspective*. Taylor and Francis: London & Bristol, Penn.

Lyons, T.R. & Avery, T.E. 1977. *Remote Sensing: A Handbook for Archaeologists and Cultural Resource Managers*. U.S. Dept of the Interior: Washington, D.C.

Tite, M.S. 1972. *Methods of Physical Examination in Archaeology*. Seminar Press: London & New York.

Among the most widely used field manuals are:

Barker, P. 1993. *Techniques of Archaeological Excavation*. (3rd ed.) Routledge: London; Humanities Press: New York. (British methods.)

Connah, G. (ed.). 1983. *Australian Field Archaeology. A Guide to Techniques*. Australian Institute of Aboriginal Studies: Canberra. (Australian methods.)

Hester, T.N., Shafer, H.J., & Feder, K.L. 1997. *Field Methods in Archaeology*. (7th ed.) Mayfield: Palo Alto, Calif. (American methods.)

Joukowsky, M. 1980. *A Complete Manual of Field Archaeology*. Prentice-Hall: Englewood Cliffs, N.J. (American methods.)

Scollar, I., Tabbagh, A., Hesse, A. & Herzog, I. (eds.) 1990. *Remote Sensing in Archaeology*. Cambridge University Press: Cambridge and New York.

Spence, C. (ed.). 1990. *Archaeological Site Manual*. (2nd ed.) Museum of London. (British methods.)

And the journal *Archaeological Prospection* (since 1994).

Also useful for beginners, and well illustrated:

McIntosh, J. 1999. *The Practical Archaeologist*. (2nd ed.). Facts on File: New York; Thames & Hudson: London.