2

Fundamentals of Archaeology

Though nothing can bring back the hour
Of splendour in the grass, of glory in the flower;
We will grieve not, rather find
Strength in what remains behind. . . .
William Wordsworth (1770–1850)

In *Intimations of Immortality*, Wordsworth recognized that humanity's hopes of immortality must lie elsewhere than in our physical selves or in our works; for these are transitory; and in the process of decay from the moment of conception. "Shades of the prison house begin to close upon the growing boy," he wrote, intimating that Death's grip is always there, always tightening.

Philosopher Bertrand Russell shared none of Wordsworth's hopes about our prospects of immortality, but he had the same sense of inevitable decay. When asked what he thought would happen to him after death, he cheerfully said, "When I die, I rot."

Perhaps the only people in the world who view the long record of the world's record of rot and decay with hope and optimism are archaeologists. In chapter 1 we reviewed some of the great theories of history and the past—the influential ideas about why history has turned out the way it has. Whatever one thinks of these theories, whatever one's view of the past, to assess these various ideas one must link them to the physical material remains of the past. In this chapter we shall consider the methods that have been developed to apply these great ideas to the material record of the past.

ARCHAEOLOGISTS AND THE PRACTICE OF ARCHAEOLOGY

Before considering in more detail how archaeology is done, let us consider who actually does it. When trapped in airplanes or up against the wall at a party, archaeologists who reveal their occupation often are told, "When I was growing up I wanted to be an archaeologist," or "It must be exciting to be an archaeologist!"

Few non-archaeologists realize, however, that most archaeologists have had to spend 10 years or more in college and graduate school in preparation for their profession, or that for every hour an archaeologist spends excavating, he or she spends hundreds of hours teaching university classes, raising money for research, analyzing artifacts, and writing research reports.

Most professional archaeologists in the United States have a Ph.D., a Doctor of Philosophy degree, the prize for an average of six years of post-graduate study. "Those who can, do, those who can't, teach" does not apply to archaeology: Many professionals hold teaching positions, although a growing proportion of archaeologists are employed by public agencies and private companies. The majority of North American archaeologists have been trained as anthropologists; a minority are language scholars, such as Egyptologists, Assyriologists, Classicists (e.g., specialists in ancient Greek and Roman cultures), art historians, and biblical scholars.

Anthropological archaeologists consider their discipline a social science, whereas language scholars such as Egyptologists often view their studies as part of the humanities. Language scholars tend to be particularly interested in relating archaeological remains to ancient written documents, such as the Bible, Greek and Roman texts, Egyptian hieroglyphic inscriptions, and so on. These different perspectives are not strictly separate, and anthropological concepts are beginning to be incorporated in the humanities, while some anthropologists also have mastered ancient languages. But, as in most academic disciplines, specialization is a necessary part of training. To be well trained in both anthropology and Egyptology, for example, requires at least 8–10 years of graduate study for those hardy few who attempt such extensive preparation.

The majority of North American archaeologists who are anthropologists are generally considered "social scientists," but both this term and "anthropology" are increasingly ambiguous. Anthropology literally means "the science (or study) of man," but that leaves rather a lot to be defined. Anthropology today continues to be divided among several specializations, each of which is at least marginally relevant to the study of world prehistory. *Biological anthropologists*[1] are concerned mainly with the evolution of, and variations in the physical attributes of, humans and primates. Some biological anthropologists search for the fossils of extinct forms of early humans, while others study the genetics of existing human groups; so me are *primatologists*, who analyze the behavior and other characteristics of nonhuman primates; others are specialists in the adaptation of human groups to different environments (especially in extreme environments, such as the high Andes Mountains). *Sociocultural anthropologists* focus on studies of living or recent human societies. They include an extremely diverse range of specialists, such as those who study the languages of nonliterate peoples, and others who do the traditional ethnological studies of human societies, analyzing the lifeways of selected groups, from the hunter-gatherers of the rain forests of the Amazon to the patrons of the bars of south Texas.[2] *Archaeologists* represent a third major specialization within anthropology. Most anthropological archaeologists have some graduate training in the other fields of anthropology, in addition to their concentrations in archaeological methods and theories. Most archaeologists also take advanced courses in statistics, geology, demography, and related disciplines.

The lines that used to separate anthropology, sociology, psychology, and other social sciences have blurred greatly in recent times. The concept of "culture"—the uniquely human intellectual and behavioral capacities (see chapter 3)—has been, and remains, for many anthropologists the connective tissue that incorporates them all in a single discipline, but for many anthropologists there is no strong theoretical structure that unites their discipline.

In Europe, Asia, and Africa, archaeology is often a separate university department—not connected with sociocultural anthropology or biological anthropology, as it is in the

United States. In those countries archaeology is often viewed as a form of history, or, in some cases, as a natural science like paleontology. But contemporary archaeology in the United Kingdom and in some other European countries has become increasingly viewed as social studies, and conversely, in North America, some centers of archaeology have separated and allied themselves more closely with the biological and geological sciences.

Archaeology as a discipline has long been dominated by North American and European scholars,[3] but India, Japan, China, Egypt, Argentina, and many other countries have long and productive traditions of archaeological research, and there is a growing internationalism to archaeology.

THE BASIC DATA OF THE PAST

People are messy animals. More than two million years ago, our ancestors began littering Africa with stone tools and smashed animal bones, and ever since we have been carpeting the world with layer upon layer of our own garbage. All this junk, collectively, from two-million-year-old stone tools to today's eternal aluminum beer cans, as well as the bones of our human ancestors and the remains of the plants and animals they ate, constitute the *archaeological record*.

Archaeologists see cosmic significance in the archaeological record. There is a "truth" of sorts embedded in the archaeological record, and archaeologists seek to clarify that truth. The major premise of archaeology is simple and unassailable: It is that much of what we will ever know about our origins, our nature, and even our destiny must be read in the patterns inherent in these layers of debris. Archaeologists assume that they can see in the contents, spatial arrangements, and depositional sequence of the world's garbage the reflections of the factors that have shaped our physical and cultural evolution.

This material archaeological record is the *only* evidence we have to understand more than 99 percent of our past—the period before written languages appeared. And even for the historical era, when we have written records of our past, the archaeological record is important: Whereas historical documents may be full of the usual human lies, propaganda, and misconceptions, the material remains are a physical record of what *did* happen, not what someone said happened or thought happened or wanted to have happened.

Artifacts, Features, and Sites

All academic disciplines have their own jargon, and archaeology is no exception. Archaeologists analyze the archaeological record primarily in terms of *artifacts*, which can be defined as things that owe any of their physical characteristics or their place in time and space to human activity. Thus, a beautifully shaped stone spear-point from a 20,000-year-old campsite in France is an artifact (Figure 2.1), but so is an undistinguished stone flake that some weary Native American pitched out of a Mississippi corn field a thousand years ago.

Nor do things cease to be artifacts because of their recent origins. For many years, archaeologist William Rathje[4] and numerous archaeology students at the University of Arizona studied the artifacts added each day to the Tucson municipal dump and littered along city roads, trying to discern how things are thrown away and what they say about the community that created the trash—and the implications such patterns of discard have for

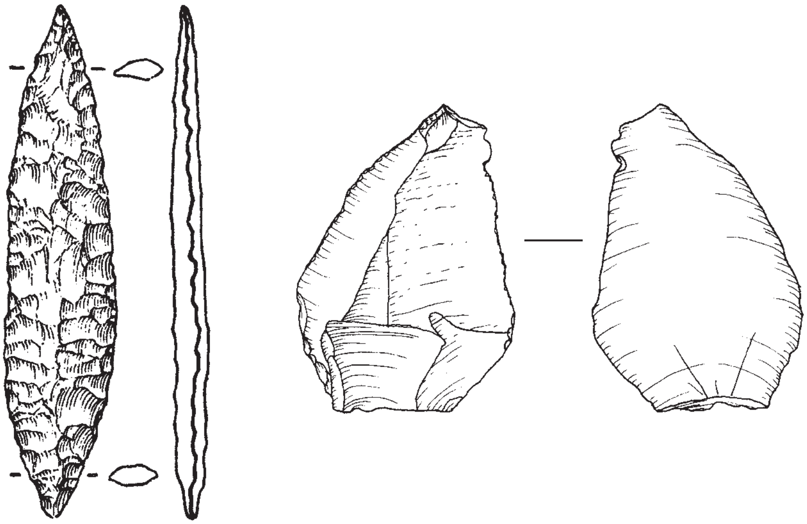

FIGURE 2.1 Stone artifacts include highly worked pieces such as the Solutrean point on the left, as well as undistinguished pieces such as the flake on the right.

understanding the patterns of discard in the past (they learned, among other things, that the average Tucson resident wastes astounding amounts of food; that in rural road litter, unsurprisingly, beer cans and contraceptives are often found together; and that food, newspapers, and other debris preserve extraordinarily well for years in municipal dumps).

These can include footprints left several million years ago when a few of our earliest bipedal ancestors strolled across a volcanic plain at Laetoli, in Tanzania (Figure 2.2)—or the astronauts' footprints on the moon.

Another common archaeological term is *feature*, which refers to a modification to a site that is not portable. They also can be the remains of a hearths, or a storage bin set into the corner of a complex of mudbrick walls (Figure 2.3). Features usually reflect inferred specific, sometimes repeated, activities, such as quarries and latrines.[5]

Perhaps the most common archaeological term is *site*, an imprecise term generally used to refer to relatively dense concentrations of artifacts and features. The ancient city of Babylon, in Iraq (Figure 2.4), which today comprises a huge mound of slowly dissolving baked brick buildings, millions of pottery fragments (known as "sherds" to archaeologists), and all the other debris of an ancient city is a site. But so too is any one of the many areas in Olduvai Gorge, Tanzania, where a few score stone tools and animal bones mark spots where 1.7 million years ago a few of our ancestors hungrily disassembled a killed or scavenged antelope.

Ancient village and town sites are often hard to miss because they are usually marked by remnants of walls and massive quantities of pottery and other debris. It is convenient to think of the archaeological record in this case as composed of many discrete sites representing different settlements, but, in truth, the whole world is littered with artifacts and features: What varies is simply the relative density of artifacts.

In recent years, archaeologists have also become interested in "nonsite" approaches.[6] This method records not only traditional, high-density sites, but also the intervening areas between sites where artifact density is low or nonexistent. By discovering what lies between sites, archaeologists can better understand the full range of behaviors across a landscape.

My colleagues and I (Olszewski), for example, use a nonsite landscape approach for our archaeological survey project (Abydos Survey for Paleolithic Sites, or ASPS) in the high desert of Middle Egypt. Stone artifacts of the Paleolithic period are extremely visible on the barren reaches of this landscape. We record the density of artifacts by taking a sample every 100 m that we walk. At each of these sample spots, we establish a circle of 2 m diameter and then collect every stone artifact that falls into that circle (Figure 2.5). Sometimes these sample circles are devoid of artifacts, in which case, we record a density of zero. The location of each sample circle is logged using a global positioning system (GPS) (see the section "Locating and Excavating Sites"). We then plot the density data for each circle and the circle's location using a mapping program, which allows us to examine patterning in the landscape. Our survey results from the 2002/2003 field season, for example, show that locations along the Wadi Umm al-Qaab[7] were preferentially used (higher density) compared to areas to the west, in the direction of the Wadi al-Jir (Figure 2.6). This may relate to the fact that the Wadi al-Jir is deeply entrenched and thus difficult to use as a pathway from the Nile Valley corridor into the high desert, while the Wadi Umm al-Qaab is a lot easier to walk. Looking at artifact density compared to features of landscape topography creates one layer than can be used in Geographic Information System (GIS) analyses (see the section on "Quantification and Computers in Archaeology").

The world's archaeological record is the raw material for the analysis of the past, but to find meaning in it we must bring to bear a wide range of analytical techniques and a body of theories, hypotheses, and ideas of many different kinds.

FIGURE 2.2 A trail of hominin footprints was found preserved in volcanic ash at Laetoli, Tanzania. These prints demonstrate that hominins were fully bipedal by 3.6 million years ago.

The Formation of the Archaeological Record

The "past" in a sense is simply the present archaeological record. This may sound like a Zen *koan* (a riddle without a solution whose purpose is to demonstrate the inadequacy of logical reasoning and provide enlightenment), but, in fact, the past *is* the present, in that we can only see the past in the present archaeological record.

The artifacts, features, and sites constituting the archaeological record vary widely in their contents and ages, but all must be understood to have been formed by a complex interplay not only of the activities of the people who created them but also of natural forces, such as erosion, volcanic deposits, and organic decay.[8] Studying archaeological sites from this perspective is called *taphonomy*.[9]

Any hopes we may have of explaining the past are necessarily linked to our ability to understand how the past—in the sense of the archaeological record—was created.[10]

FIGURE 2.3 This feature is a set of clay-lined hearths from a pithouse (semi-subterranean dwelling) at an Ancestral Puebloan site in the American Southwest.

FIGURE 2.4 Architectural remains, such as these stone room walls at the Neolithic site of Basta in Jordan, are an example of an early farming village site.

Consider as an example the problem of understanding the origins of modern humans —that is, of us, *Homo sapiens sapiens*. Many "models" (i.e., sets of linked hypotheses about the causes of a particular development) of modern human origins have been formulated, but currently only one has the confidence of a majority of scholars: This model—described variously as the "African Origins," "Total Replacement," or "Eve" model[11] —is that modern humans evolved first and only in Africa, just a few hundred thousand years ago or less, and then migrated to the rest of the world, displacing all other hominin forms, and with little or no genetic interchange with them. An alternative model, commonly known as the "Multiregional Evolution" model,[12] and held by a minority of anthropologists, accepts that North Africa was a conduit for hominin migrations for millions of years but contends that modern humans arose out of gene flow among some or all of the many different human populations that had colonized Africa, Europe, and Asia many hundreds of thousands, perhaps millions, of years ago.

The evidence relevant to these "models" of human origins is discussed in chapter 4. The important point here is that to analyze this archaeological record we have to sort out a bewildering array of cultural and natural factors that produced the archaeological record of relevance here. Early *Homo sapiens* in Africa, for example, may have developed a simple advantage in tool-making that made them slightly better than other forms of humans at making a living as hunter-foragers, with the long-term result that this slight advantage allowed them to

FIGURE 2.5 Systematic collection of surface artifacts is shown here as archaeologists establish a size-standardized circular collection unit during the Abydos Survey for Paleolithic Sites project.

supplant other groups. If so, then we should be able to see reflections of this supposed advantage in the stone tools, food remains, and other data of the archaeological record. We might look at the animal bones found in sites associated with early *Homo sapiens* in Africa, for example, and see if they show different, perhaps more efficient, hunting techniques, compared to those of Europe and Asia. The problem, however, is to sort out the natural and cultural factors that created these sites. At various South African sites, for example, human skeletal remains and tools have been found in caves along with animal bones. But we know that leopards and other "natural" predators regularly killed animals and brought them back to these cave dens. So how can we tell which animals were killed by people and which by other animals? One can use a low-power microscope to look at marks on some

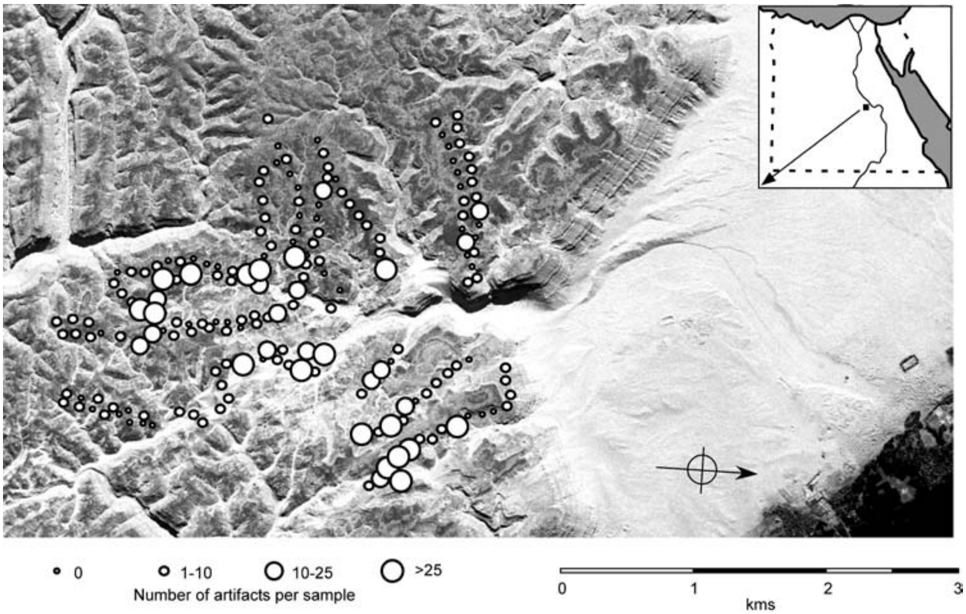

FIGURE 2.6 This map shows the variable density of surface artifacts in the area surrounding the Wadi Umm al-Qaab, Egypt, recorded by the Abydos Survey for Paleolithic Sites project. Such information is a valuable clue to how the landscape was used by prehistoric groups.

bones and see evidence that they were butchered with stone tools, but what if a leopard killed this animal and humans simply scavenged it? While it is not always easy to differentiate marks left on bones by animal teeth from those made by humans with stone or bone tools, precise observations can reduce errors in identification to less than 5 percent.[13]

While we can use taphonomy to address broad questions about hominin behaviors, such as those described earlier, many archaeologists also employ this technique to study the nature of specific archaeological sites. One example is the research at the French site of Cagny l'Epinette.[14] Initial excavations and interpretations here identified a "living floor" of Lower Paleolithic age. This occupation surface was thought to be relatively pristine and was described as containing a thin, but dense, concentration of stone artifacts, as well as evidence for activity areas associated with the butchering of animals and other tasks. In effect, it is analogous to having a mini-version of a Pompeii-like situation, where behaviors are virtually frozen in time.

But is this living floor interpretation the correct explanation? Harold Dibble and his colleagues tested this in their new excavations at the site by carefully recording spatial information for artifacts and animal bones, as well as many details about the stone artifacts and sediments, such as the presence of fine gravel or larger cobbles in the dirt associated with the living floor artifacts and animal bones. Their results, which are supported by several lines of independent evidence, indicate that Cagny l'Epinette (Figure 2.7) is not a living floor, but the result of stream deposition. This can be seen, for example, in the edge damage on stone artifacts resulting from stream transport and the lack of very small stone artifacts, which because they are light in weight were carried farther away by stream action than the larger stone artifacts and animal bones. Other evidence includes the orientation of the artifacts,[15] which are mainly parallel or perpendicular to stream flow rather than randomly oriented as would be expected on a living floor; very little evidence in the form of cut marks on animal bones to indicate butchering; and the size match of the stone artifacts and natural materials such as cobbles. Because these cultural and natural materials are similar in size, and we know that hominins were not depositing the natural materials, this also suggests processes such as stream action. The recent research at Cagny l'Epinette has thus shown that it is not hominin behavior that is directly reflected at this site, but a combination of cultural and natural materials brought together through redeposition. Pompeii-like situations in archaeology are indeed quite rare.

FIGURE 2.7 Excavations at the Lower Paleolithic site of Cagny l'Epinette, France.

There are many other ambiguities in the archaeological record pertaining to modern human origins, and this complexity of disentangling cultural from natural factors is found in almost every archaeological project, whether the site is two million or 200 years old. And to the extent that there is brilliance and great creativity in the practice of archaeology, it is usually expressed in formulating some major problems in terms that can be "tested" effectively with archaeological data, whether from new excavations or from laboratory analyses.

The archaeological record is often viewed as "incomplete" because decay and other factors have changed it. But in a sense, the archaeological record is only incomplete if one looks at it as potentially a perfect reflection of the complete history of actions by the human societies that created it. It is what it is: the product of cultural and natural factors. The archaeological record can never be that perfect reflection; instead, it is itself a product of these forces, and in that sense it is not really "incomplete"—even though our knowledge of these forces must always be incomplete.[16]

Artifact Production and Preservation

> The innocent and the beautiful
> Have no enemy but time.
>
> *W. B. Yeats*[17]

The basic sequence of events that has produced the world's archaeological record is the same for stone tools as it is for today's best DataWhacker computer. In each case, people: (1) acquire the raw materials, (2) make some of these materials into artifacts by changing them (or simply altering their location) in some way, (3) use some of the artifacts, and (4) then discard them.

At each stage of this sequence, a variety of cultural and/or natural factors comes into play. In ancient Mesopotamia, for example, people lived primarily in houses made of mudbricks—made simply by mixing mud with straw and forming bricks by hand or in simple wood molds and leaving them to dry. Mesopotamia's intense sun, occasional rain, strong winds, and ground water seepage then began to degrade these bricks and the buildings created from them. Eventually the buildings were abandoned and a variety of cultural and natural factors continued to operate on them. Wooden roof beams, stone thresholds, and even some mudbricks, for example, were regularly carried away for a variety of reuses.

This process, of making and using—and reusing—things and then discarding them, is really no different today. For example, landfills around the world are currently filling up with the carcasses of typewriters and early generations of computers, many of which have been scavenged for spare parts. Although these machines may last longer than most of the remains of antiquity, all are subject to eventual obliteration through a combination of cultural and natural forces.

How quickly these materials are returned to their elemental chemical state is simply a matter of their composition and the conditions of preservation. The laws of thermodynamics assert that matter is never destroyed nor lost in the universe, but this is little consolation to the archaeologist looking, for example, at the smear of calcium that is all that is left of a corpse buried many millennia ago in the warm, wet soils of the Egyptian Delta. Even in drier, better-preserved contexts, a number of things can destroy archaeological remains. Floods wash them away, glacial ice sheets grind them to bits, rodents go out of their way to burrow through them, earthworms move them, and rivers and winds bury them under silt and sand.

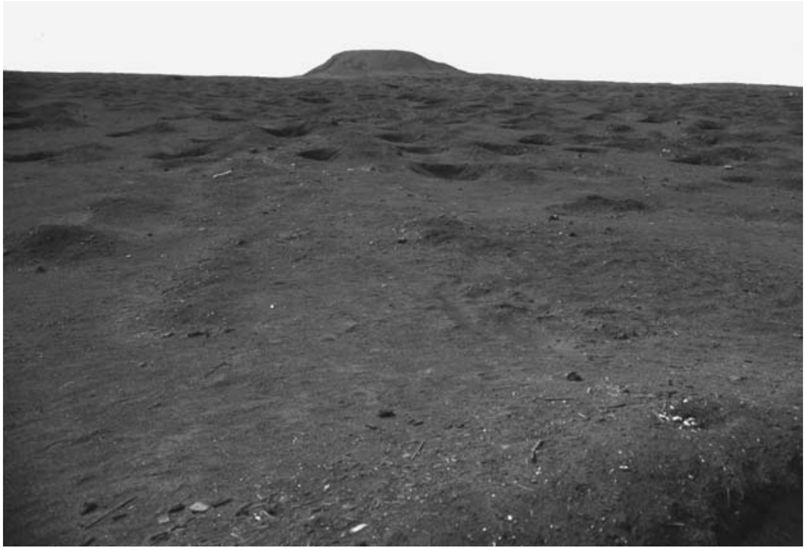

FIGURE 2.8 Looting of archaeological sites removes artifacts from their context and destroys sites. Seen here are the results of grave robbing at the site of el Brujor in Peru.

The greatest destruction, however, is caused by people. The gleaming limestone sheaths that originally enclosed each of the Egyptian pyramids were looted in medieval times and used as building materials. All over the ancient world, in fact, successive settlements were built on—and of—the remnants of earlier occupations. Still, our own generation is perhaps the worst despoiler of antiquities. In Rome, New York, and many other cities, for example, nearly every construction project disturbs the archaeological record of earlier times.

Industrialization at least has some possible benefits, but the same cannot be said for the other great destroyer of the past, looting. Illegal antiquities from around the world are openly on sale around the world. It is sad to relate, but even the mild fines and other penalties currently in force in some countries are only occasionally applied to people convicted of looting. And in many countries the primary looters are impoverished peasants who are simply trying to make a minimal living.

Looting destroys the only hope we have of analyzing cultural processes in the archaeological record because it obliterates the *context* of artifacts and features (Figure 2.8). Thus, for example, to study the origins of the first civilizations of Mexico, it is crucial to excavate sites in such a way that the goods people were buried with and the contents of their houses are meticulously recorded, so that the distribution of wealth in the community can be estimated. But once a looter has ripped through house floors to loot graves of their contents, the anthropological significance of the site is lost forever.

Context involves not only the relationship of specific artifacts and features to each other at a site but also their relationships to other types of data such as plant remains and animal bones. These spatial data provide valuable additional information about the organization of activities at sites.

Natural decay processes affect sites too, but if a site is not looted the effects of these natural processes can be discerned and taken into account in interpretations. Stone tools are almost indestructible, but organics—bones, hides, wood, plants, people, and so on—rot. The best preservation of organic remains occurs where there is not enough water, heat, pH balance, or oxygen for the chemistry of decay to occur. The best preservation is in dry caves, under thick layers of volcanic ash, or in peat bogs, permafrost, or deep, dark, cold water. Entire mammoths have been retrieved from frozen pits in Siberia, and well-preserved human corpses thousands of years old have been recovered from peat bogs (Figure 2.9), swamps, and in one case, a glacier in Europe.

No one knows how powerful the analytical equipment of the future will be, so archaeologists must consider the option of not digging some fraction of extremely important sites, in hopes that someday we will have equipment and techniques of vastly greater sophistication.

Archaeological Research Design

No matter what an archaeologist's academic orientation, anyone who metaphorically or actually dons the pith helmet chooses where to excavate or survey and then interpret what is found. Choosing the place to dig, for example, is usually not so speculative a procedure as imagined by non-archaeologists, who frequently ask, "How do you know where to look?" In modern archaeology, one rarely sets out on expeditions to remote places on the Micawberish assumption that something interesting will turn up—although many ancient remains are still found by accident or unsystematic exploration. But increasingly, archaeological remains are identified through a process of systematic survey. It does not take a trained archaeologist to find the pyramids of Egypt or Mexico, but most archaeological remains are less evident and accessible, such as those covered by drifting sand or alluvial soils, buried beneath contemporary settlements, or located in remote, untravelled areas.

FIGURE 2.9 "Tollund man," a 2,000-year-old hanging victim from the peat bogs of Denmark, illustrates the "pickling" properties of weakly acidic environments.

Many archaeological surveys and excavations are done within the context of a specific intellectual question or problem. If one were interested in the origin of maize agriculture in ancient Mexico, for example, one would read the numerous articles on this subject, and then examine maps of where early varieties of maize have been found. One might then hypothesize some possible causes of the transition to maize agriculture. This process of hypothesis formation is one of the more creative aspects of the discipline. The goal for the archaeologist is to develop some novel ideas or ways of looking at a problem that lead him or her to look for certain kinds of data. One might, then, hypothesize that for various reasons maize was domesticated in lowland coastal areas and in the context of certain kinds of communities. One could then identify where relevant remains might be found and then design a program of surveys and/or excavations to study this problem in this area.

Only some archaeological research is in this *problem-oriented* format. Many contemporary archaeologists believe that such an approach unnecessarily limits archaeology to a dubious kind of empirical science. Instead they seek to understand the archaeological record in the terms they speculate the ancient peoples themselves viewed their world.

Archaeologists James Brady and Wendy Ashmore,[18] for example, focused on the conceptual world of the ancient Maya, of Mesoamerica. In their view the physical world of the Maya, especially the mountains, caves, and water sources, combine in the form of an animate and sacred landscape that continuously renews and re-creates the core beliefs and cosmic processes that the ancient Maya considered fundamental to their universe. They suggest that the ancient Maya built many structures in forms and placements that reinforced the king's power and the religious beliefs of the kingdom. Stone pyramids, for example, were considered forms of sacred hills, and artificial caves through which flood waters were channeled reinforced the notion of the king as an agent of the gods who governs life-giving irrigation waters.

The problem many archaeologists face in this regard is that, on the one hand, we have ample evidence that the physical worlds of the ancients *were* invested with symbolic significance that is far different from our own; but, on the other hand, we have face enormous difficulties in ever verifying our interpretations. In fact, many archaeologists believe that we can never verify, in an empirical sense, our attempts to reconstruct the symbolic significance of the Maya landscape or any other ancient place and time.

Often archaeological research is simply exploratory. One might select an area and do surveys to see if any important remains can be found there. Also, in recent years "problem-oriented" archaeological research has been complemented by rapid growth in "public" archaeology, or "CRM"—that is, cultural resource management. In many countries, governments stipulate that new construction must be preceded by an analysis of its impact on the historical and archaeological record, and then research is undertaken if significant remains are found. These efforts mitigate—offset—the destruction of portions of the archaeological record through the preservation of some sites from destruction or the careful excavation of those sites that will be destroyed. Hundreds, perhaps thousands, of archaeologists now are employed around the world as "public archaeologists" to do this kind of work.

"Public archaeology" is usually well funded by the relevant government, but other archaeological approaches are a different matter. Interesting ideas about the past are in no short supply in archaeology, but money to do the relevant research certainly is. In the United States, for example, an archaeologist can submit a written proposal for research funds to the U.S. National Science Foundation or the National Endowment for the Humanities, explaining precisely what kinds of archaeological evidence he or she hopes to find and why it is important. This proposal will be judged by a group of one's peers, and if it is successful (in recent years only about 15 percent of National Science Foundation archaeology proposals were funded), one then would receive the money and conduct the field research.[19] Most archaeologists who direct long-term research projects must spend months of each year trying to obtain funds to continue the project by writing proposals, administering grants received, requesting funds from corporations and private donors, and so on.

LOCATING AND EXCAVATING SITES

Actually locating sites might involve walking surveys, where 5 or 10 archaeologists, working from maps or aerial photographs, simply line up and walk over a selected area, recording sites as they are found. Aerial photographs and other photogrammetric techniques can often be used to reveal ancient agricultural fields, roads, and other features not visible from the ground. The CORONA satellite images (Figure 2.10), for example, which are a type of remote sensing, have recently been used to understand the history of settlement and ecology of Mesopotamia. Other remote sensing techniques include magentometry, and ground-penetrating radar that send signals that "bounce" off subsurface anomalies such as structures, burials, or other features. Archaeologists can thus map these anomalies, often showing enough of the outline of the features so that their type can be identified, for example, a residential dwelling, without necessarily excavating.

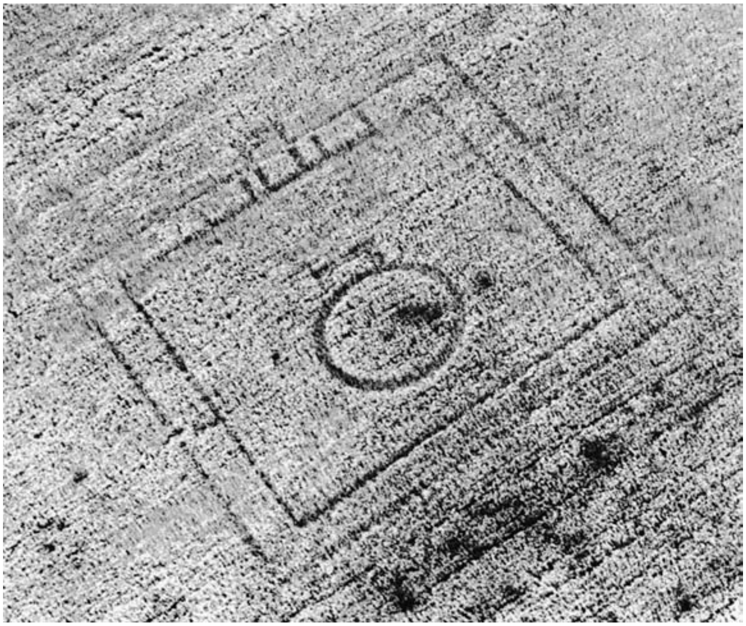

FIGURE 2.10 Aerial photographs often reveal archaeological remains that are not directly visible from ground level, as in the outline of this Roman temple on Hayling Island, Hampshire, England. Stone walls just below ground surface caused parching of grain just above them during the 1976 drought, revealing the outline of the temple wall.

Until recently, many archaeologists relied on placing marks (such as dots or Xs) on topographic maps or aerial photographs to record the location of the sites they found on surveys. This has dramatically changed, however, with the wide availability of GPS. GPS reads locational data by triangulating signals from orbiting satellites and thus records highly accurate spatial information, such as the universal transverse mercator (UTM) coordinates or, alternatively, longitude and latitude.[20] Moreover, GPS units are relatively inexpensive, portable and thus easy to use in the field, and capable of digitally storing information. At the end of each field day, these data are downloaded into computer software programs, a process that decreases the chance of error associated with handwriting data and later keyboarding that information into a computer application.

However they are located, archaeological sites can either be simply mapped and recorded, or they can be excavated—depending on the project's resources and objectives. The methods used to excavate archaeological sites depend on the kind of remains involved and the objectives of the archaeologist. Normally the first step is to make a careful map of the site so that objects and features found can be given precise three-dimensional coordinates, the *provenience* (Figure 2.11). Then the site is gridded into, say, 5-by-5 m blocks, and a sample of these blocks is selected for excavation. Actual digging is done with dental tools, paint brushes, trowels, shovels, bulldozers, or dynamite—depending, again, on the objectives and context.

Although many of the hand tools that archaeologists dig with at sites have remained the same for more than a hundred years, one of the most significant advances in recording information during excavation has come about due to the total station. A total station

FIGURE 2.11 The Lower and Middle Paleolithic site of Abri Vaufrey, France, during excavations. Note the grid system demarcated using weighted strings suspended from above.

FIGURE 2.12 The use of total stations has revolutionized archaeological recording for both accuracy and speed. On the left, a crew member uses a small computer to coordinate information received from the total station. On the right, another crew member holds the prism pole at the point being recorded by the total station.

combines a theodolite (a survey instrument that measures horizontal and vertical angles) with an electronic distance meter (EDM) (Figure 2.12). The EDM shoots a laser beam to a reflective prism that is held at a specific point, for example, on a stone tool that has been uncovered. The prism bounces the laser beam back to the EDM, which uses the horizontal and vertical angle measurements from the theodolite and calculates the exact three-dimensional Cartesian coordinates (grid coordinates) of the point being measured.[21] Total stations can be linked to small computers, which automatically store the data, thus eliminating errors that occur when data have to be handwritten in field notebooks. Of course, these data can be downloaded into a mapping program each day. Being able to "see" the site (stone tools, animal bones, features, etc.) in plan and profile views as it is excavated on a daily basis is a great boon to decision-making in the field. Total stations can also be used to accurately map the surface of sites, for example, foundations of dwellings and other features, the natural topography of the site and its surrounding area, and the distribution of sites across the landscape.

Like every other profession, archaeology has its variants of Murphy's Laws: Veteran field workers know that the most important find will likely be made on the last day of the season, when there is no time or money to continue the excavations, and that particularly important finds are usually located in the most inaccessible places. Archaeology is also a lot of hard work, usually, and much of it takes place at uncongenial hours of the day and seasons of the year. Anyone who has dug a backyard trench for a sewer pipe on a hot August day has already experienced many of the thrills of field archaeology.

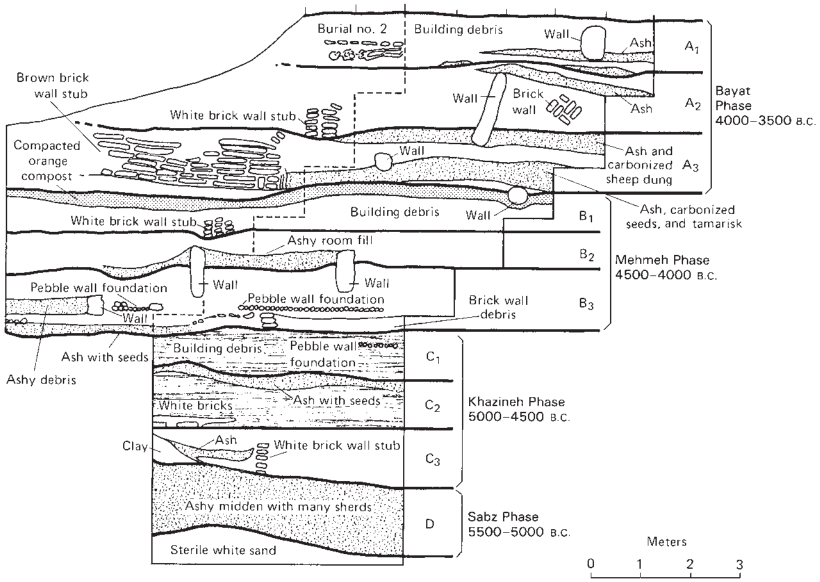

FIGURE 2.13 This profile drawing shows the depositional history of a community at Tepe Sabz, near Deh Luran, Iran, from about 5500 to 3500 B.C. Skill in field archaeology is largely the ability to discern and interpret such cultural layers in the confusing jumble of mudbrick, stones, ash, and other debris.

The simple mechanics of excavation are within the range of abilities of almost any healthy adult. The best field archaeologists tend to be those who have a good sense of spatial relationships and enormous patience. "God is in the details," said a great architect,[22] and the same is true of archaeology. One usually tries to excavate according to the *stratigraphy* (Figure 2.13) of the site, so that the different layers of debris are removed in the reverse sequence in which they were deposited—as opposed to simply digging the site by arbitrary levels and removing successive layers, each, say, 25 cm thick.

Thomas Jefferson may have conducted the first scientific stratigraphic archaeological excavation in history.[23] In 1784 he excavated a trench through a Native American burial mound near his home in Virginia and recognized that it had been built up over time by many burials and reburials. Jefferson was able to read a time sequence in the stratigraphy of the site, and he related the differences in preservation of the human bones to the relative time these people had been buried. Jefferson also applied his research to a specific problem: In Jefferson's time many people thought that the "mound-builders" were ancient Europeans, not Native Americans; Jefferson concluded that Native Americans may have been the builders of these mounds.

Modern stratigraphic excavation techniques are based on the same logic as Jefferson's. In Tabun Cave in Palestine, for example, Neandertals came each year for a few months and built fires, made tools, butchered animals, and generally lived out their presumably unremarkable lives. Rocks falling from the ceiling and animals bringing their prey back to the cave when people were not there added to the layers of debris. Thus the excavators,[24] who were interested in subtle changes in diet and tool manufacture over the whole history of the cave's occupation because they were looking for evidence regarding the relationship of the Neandertals to ourselves, had to tease apart layer after layer of debris, trying to separate layers that were the result of short time intervals. The excavators were, in effect, trying to see *change* in the way the Neandertals lived over thousands of years.

Aaron Copland described listening to one of Ralph Vaughn William's symphonies as like staring at a cow for 45 minutes, and although studying archaeological strata is even less eventful, it is one of the most important activities in archaeology. Stratigraphic analyses require that the analyst reconstruct the many different processes that produced the sequence of deposits, and this can require considerable skill, patience, and experience. In cave sediments, for example, one must try to discern faint traces of burrowing animals that may have tunneled in from the surface and whose burrows were subsequently filled with charcoal, ash, and artifacts that date to periods long after their stratigraphic position would suggest. Some of the most complex stratigraphy is found in the remains of early villages and towns in the Middle East, where mudbrick buildings were built and rebuilt and replaced in the same area over many centuries, so that the last, most recent community sat (or sits) atop 10 or more meters of compacted debris representing the remains of thousands of years of building and then abandoning houses, walls, streets, latrines, hearths, and the other facilities of ancient daily life.

Excavation techniques and stratigraphic analyses in such sites reward patience, work, and imagination. British archaeologist Sir Leonard Woolley, for example, while excavating Ur, in Mesopotamia, removed some debris and saw two holes in the ground where something had apparently rotted away. He poured them full of plaster and when the plaster had hardened, Woolley unearthed an almost complete cast of an ancient wooden musical instrument that had long since disintegrated (Figure 2.14). One of the pioneers in devising the techniques of excavating ancient cities was Sir Mortimer Wheeler, a British archaeologist whose excavations at sites in the Indus Valley (modern Pakistan) were done with great care to reveal a stratigraphic record that would allow him to understand how these cities grew and changed over time.[25]

Stratigraphic analyses are a fundamental part of field archaeology because they provide the primary data for looking at change over time in all aspects of cultures. The archaeologist knows that if he or she can detect disturbances and read the strata correctly, the lowest strata can be assumed to be earlier than the ones above it, and thus a form of "time" can be read in a stratigraphic sequence. Understanding the nature of these changes, however, requires analyses of the materials and artifacts found in these strata.

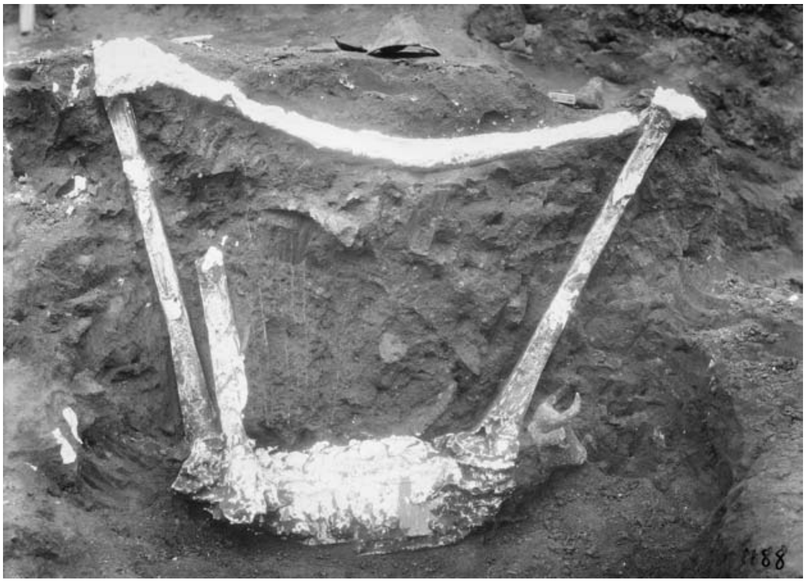

FIGURE 2.14 Sir Leonard Woolley's innovation of pouring plaster into a couple of unusual holes in the ground at the Mesopotamian site of Ur resulted in the recovery of a cast of a lyre.

ANALYSES OF THE PAST

A century ago, most archaeologists were "generalists" in that they were all broadly trained academically and could do most of the analyses their research required, including the excavations and laboratory analyses. The extreme specialization of modern culture, however, has had its impact on archaeology too, and today almost every professional has some kind of technical specialization or area of research in which she or he is particularly qualified. Every archaeological site is unique and nonrenewable, and many technical specialists are required to make the most of the evidence unearthed. Most excavation staffs today include geologists, botanists, palynologists (experts on plant pollen), architectural draftsmen, faunal experts (specialists in analyzing animal remains), artifact illustrators, and other specialists. Conserving finds once they are discovered has also become a highly technical specialty, requiring advanced training in chemistry and other sciences.[26] A few of these specializations are discussed here; others are considered in the context of specific archaeological problems in later chapters.

Reconstructing Ancient Environments and Cultural Ecologies

Archaeologists usually begin their analyses by trying to reconstruct the physical environments in which a particular segment of the archaeological record was formed. Climates and the world's geomorphology—the shape and constituents of land surfaces—have changed greatly over the several million years we and our ancestors have lived, and each archaeological analysis begins with an effort to reconstruct the physical world of the culture being analyzed.

Ancient climates can often be reconstructed from floral and faunal remains. The study of animal remains, or *faunal analysis*, is a complex discipline in which in most cases the archaeologist is trying to reconstruct human diet and local environments. Taphonomic[27] analyses usually are focused on the factors that decompose and in other ways change animal bones after the animal dies. Faunal analysts generally tally the numbers and kinds of animals represented by the remains they find, and then use statistical methods to estimate food values, the ages and sexes of the animals involved, and changes in diets and the physical characteristics of the animals being exploited.[28] One of the most prolonged and heated arguments in contemporary archaeology now involves analyses of marks (Figure 2.15) left by humans cutting up animals with stone tools: For reasons discussed in chapters 3 and 4, it is important in understanding the origins of our genus to study butchered animal bones to try to distinguish between cases in which people butchered animals they had killed themselves and those in which they butchered animals they scavenged from kills of other animals, such as lions and hyenas.[29]

Throughout the history of our genus, plants have been the main source of food for most humans, and so *floral analyses*—studies of the remains of plants—are an extremely important part of archaeology, particularly in studies of how domesticated plants and animals and agricultural economies evolved.[30] Carbon is chemically quite stable, so charred plants and seeds preserve well. Carbonized plant remains can be retrieved by *flotation*: Excavated sediments are mixed with water or some other fluid and the charred plant

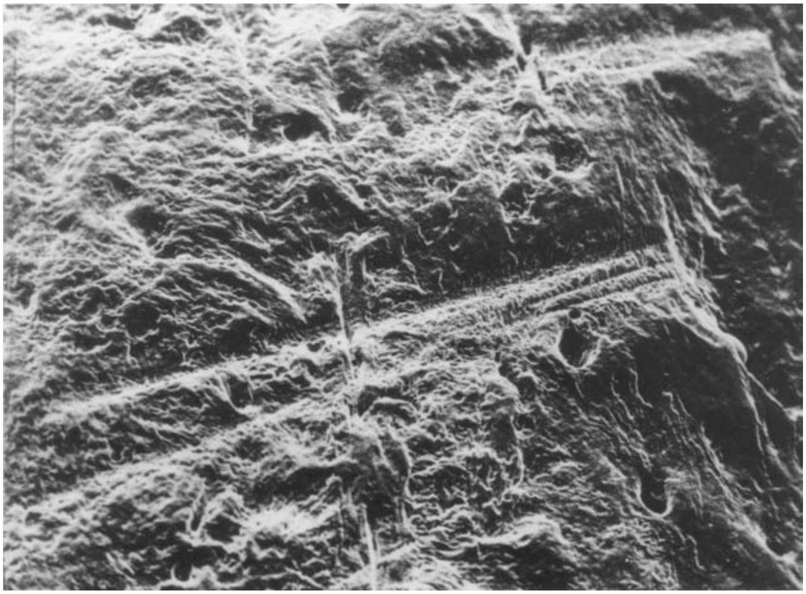

FIGURE 2.15 This animal bone from the FxJj; 50 site in Koobi Fora, Kenya, shows evidence of cut marks made by stone tools.

FIGURE 2.16 Crew members use a flotation machine to recover ancient carbonized plant remains.

fragments rise to the surface, where they can be skimmed off and identified (Figure 2.16).

The importance of such analyses lies in the fact that these plants indicate much about the climates and vegetation of the periods in which these animals lived. We shall see, for example, that there are debates about when and where various animals were domesticated (chapter 6).

Human bodies are treasure troves of information for archaeologists, particularly if they are mummified. For example, 11 naturally mummified bodies found in beach sand in northern Chile that date to about 1000 B.C. indicated when analyzed that, among other things, one of them is the earliest known coca leaf chewer, while other bodies showed the changes of the bones of the inner ear that are typical of people who spend a lot of time diving in cold water. In addition, they had the kinds of dental caries and missing teeth associated with the sticky starches of an agricultural diet—although about 40 percent of their diet came from marine resources.[31]

Studies of human *paleopathology*, in general, can tell us much about the demography and health of ancient peoples.[32]

A rapidly growing technical specialty within archaeology is *geoarchaeology*, the combination of archaeological and geological analyses.[33] Geology and archaeology form a "natural" marriage in many obvious ways, for both disciplines are concerned with the alterations of natural landscapes. Glaciers, changing rainfall patterns, and many other natural forces alter landscapes, and so, of course, do people. Geologists are broadly concerned with ancient physical environments, and archaeologists require knowledge of these environments to interpret their finds.

Geoarchaeological analyses involve many different kinds of questions and techniques. In the Egyptian Delta, for example, many of the earliest communities were built on large sand-gravel mounds created by the Nile as it deposited the sediments it carried. But many of these communities have been buried under many meters of sediments from all of the annual floods since that time, and by other factors as well. Moreover, the Nile tributaries in the Delta have changed course many times, leaving a maze of criss-crossed buried river channels. To find these buried sand-gravel mounds and the archaeological sites on them thus often requires complex geological analyses involving augering, satellite image analysis, and many other techniques.

Geoarchaeological analyses are sometimes required simply to determine if some alteration to the landscape or objects are of natural or human origin. Other geoarchaeologists deal with dating strata, reconstructing ancient temperature and rainfall patterns, and related problems.

Reconstructing the physical environment and cultural ecology of any particular site usually involves the coordinated efforts of many specialists. In some ancient sites, for example, such as the floors of caves, the archaeological record is principally one in which repeated seasonal occupations of an area have left strata containing small particles of bones, burned seeds and other plant remains, debris from making stone tools, and other remnants. Spilled food, human wastes, the manure of domestic animals—all these and many other factors associated with human life change the chemistry, texture, and contents of the surfaces on which people live. A geoarchaeologist might, for example, measure the chemical composition of a large sample of sediments taken from different areas of such a site and look for areas relatively high in nitrogen and the other by-products of organic decay. Other specialists would identify the plants and animals that lived or were consumed in the adjacent areas.

Artifact Analyses

Aside from ancient buildings, in sheer bulk the largest part of the archaeological record is made up of stone tools and pottery fragments (sherds). Stone tools are the earliest known artifacts, having been first used more than two million years ago, and they have remained in use to the present day. When a chunk of fine-grain stone is struck with sufficient force at the proper angle with another rock or with a wood or bone baton, a shock wave will pass through the stone and detach a flake of the desired size and shape. Classrooms all over the world are bloodied each year as instructors attempt to demonstrate this process, but with a little experience most become quite skilled. In analyzing ancient stone tools, many archaeologists have mastered the skills needed to make stone tools themselves. Few things are sharper than a fragment struck from fine-grain flint or from obsidian (volcanic glass). Obsidian is so fine-grained that flakes of it can have edges only about 20 molecules thick—hundreds of times thinner than steel tools. One archaeologist (the late Richard Daughtery, of Washington State University) convinced his doctor to use obsidian tools as well as standard surgical scalpels during his own heart surgery and claimed that the incisions made with obsidian healed faster.

FIGURE 2.17 This "Susa A" style jar, from early fourth millennium B.C. Iran, exemplifies the hand-painted, highly decorated pottery styles that were widely distributed in Southwest Asia just before initial cultural complexity.

Through experimentation, some archaeologists are able to produce copies of almost every stone tool type used in antiquity. A common research strategy is to make flint tools, use them to cut up animals, saw wood, clean hides, bore holes, and so on, and then compare the resulting wear traces with the marks found on ancient artifacts. Sometimes electron-scanning microscopes are used to study minute variations in these use marks. Some rough correspondence can be found between the types of lithic uses and the characteristics of wear marks, but there are many ambiguities. Archaeologists have shown that the marks produced on stone tools by different uses can be subtle and often ambiguous.[34]

Ethnographic data from people who still use lithics, like Brian Hayden's study of stone use in the Mexican highlands and Polly Weissner's study of how the !Kung hunter-gatherers use styles of stone spear-points to identify their social groupings,[35] indicate that even crude-looking stone tools may reflect a great amount of social life and economic forces.[36]

Ceramics were in use much later than the first stone tools (appearing in quantity in many places about 10,000 years ago), but they were used in such massive quantities in antiquity that, for many archaeologists, life consists mainly of the slow sorting and analyzing of potsherds. Ceramic pots were first made by hand and dried in the sun or low-temperature kilns, but in many areas of the Old World, the invention of the potter's wheel and high-temperature kilns produced pottery that is nearly a form of glass and therefore all but indestructible (Figure 2.17).

Ceramics form such a large part of archaeologists' lives because ceramics express so much about the people who made them.[37] Pots are direct indicators of function, in that they show how diets and economies changed over time. David Braun, for example, has documented how pottery in the American Southeast changed in prehistoric times as a form of agriculture developed in which people boiled seeds of various native plants, and pottery was developed to withstand the heat and mechanical stresses of this kind of food preparation.[38]

Ceramics are almost always analyzed on the basis of their *style*. This idea of style is hard to define, but—as discussed later—changing styles are the basis on which archaeologists date much of the archaeological record. But for many archaeologists, ceramics styles are more than just convenient devices for dating—stylistic decoration of artifacts is the primary means by which one can enter the cognitive world of the ancients. Societies throughout history have invested their objects with styles that have profound and complex meanings and effects. As we will see in the case of the Maya (chapter 13) and every other early civilization, rulers used particular symbols and styles, such as in styles of dress, personal ornamentation, and inscriptions, as mechanisms through which they portrayed, communicated, and implemented their power. In all societies, styles fix social meaning and are powerful ways in which these groups define and construct their culture. Styles of objects, language, and personal behavior identify people in terms of gender, age group, ethnic group, socioeconomic class, and many other important ways.[39]

Although stone tools and ceramics make up much of the archaeological record, artifacts of wood, animal hides, metals, minerals, and almost everything else have been in use for thousands, and in some cases even millions, of years (Figure 2.18).[40]

ARRANGING ARTIFACTS

The novelist Luis Borges imagined an ancient Chinese classification of animals that included the following categories:

> (a) those that belong to the Emperor, (b) embalmed ones, (c) those that are trained, (d) suckling pigs, (e) mermaids, (f) fabulous ones, (g) stray dogs, (h) those that are included in this classification, (i) those that tremble as if they were mad, (j) innumerable ones, (k) those drawn with a very fine camel's hair brush, (l) others, (m) those that have just broken a flower vase, and (n) those that resemble flies from a distance.[41]

A zoologist working with this classification of animals might develop exquisite sensibilities, but he or she would have a difficult time using this system to study animal remains of archaeological interest. A fundamental procedure of science, or any form of analysis, is to construct classifications, or *typologies*, that facilitate certain kinds of research objectives. To understand how the world operates, we have to categorize it into groups of similar things and then discover the relationships among these groups. Modern chemistry or physics, for example, would be inconceivable were it not for classes such as electrons, atoms, and molecules, and the laws of thermodynamics. In the same way, evolutionary biology is possible only because of concepts of chromosomes, cells, and species, and the principles of population genetics. These notions about classification and analysis are quite straightforward and simple, but when we consider the kinds of data archaeologists work with, we find that archaeological classifications and analyses have differed somewhat from those of other disciplines.[42] The archaeologists' broken pottery, house foundations, and stone tools have not been organized in classifications in the same ways as the atom and the cell. A potassium atom is exactly the same thing to a Japanese chemist and an American chemist, but when a French archaeologist describes stone tools from southern France as "scrapers," those artifacts differ in many respects from North American "scrapers" as described by an American archaeologist. Archaeological classifications generally have been constructed with much more limited purposes than the units of the natural sciences. It is theory, whether biological, quantum, or Marxian, that tells the researcher how to break up the world for analysis, and in archaeology the only theories are relatively weak behavioral generalizations.

One of the most common classifications in archaeology has been in terms of *functional* types. Archaeologists, for example, frequently categorize the 1.75-million-year-old tools from Olduvai Gorge as "cleavers," "scrapers," and "choppers" (Figure 2.19). Such a classificatory system is based in part on ideas about how our earliest ancestors actually used these tools. Obviously, imagination plays a role in creating functional types, particularly when archaeologists are dealing with extremely old remains left by people very unlike known or

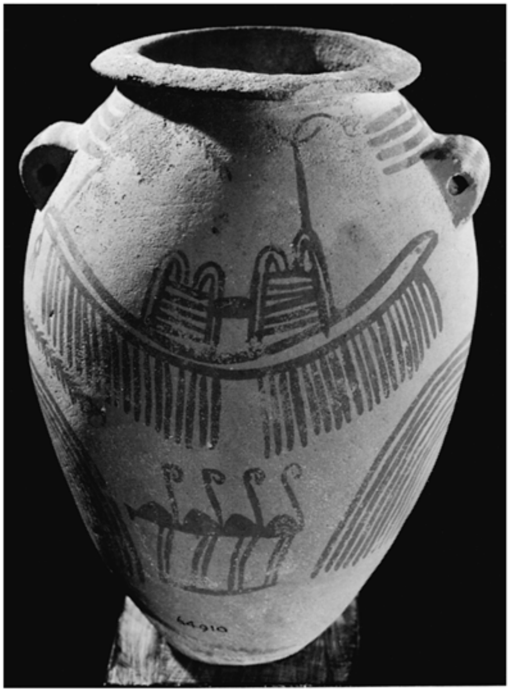

FIGURE 2.18 A great part of the world's archaeological record is composed of stone, wood, and clay artifacts. The flint knife depicted here dates from about 4000 B.C., from Egypt. Its ivory handle is carved with scores of delicate animal figures. The ceramic pot and figurine are also from Egypt, from about 3100 B.C.

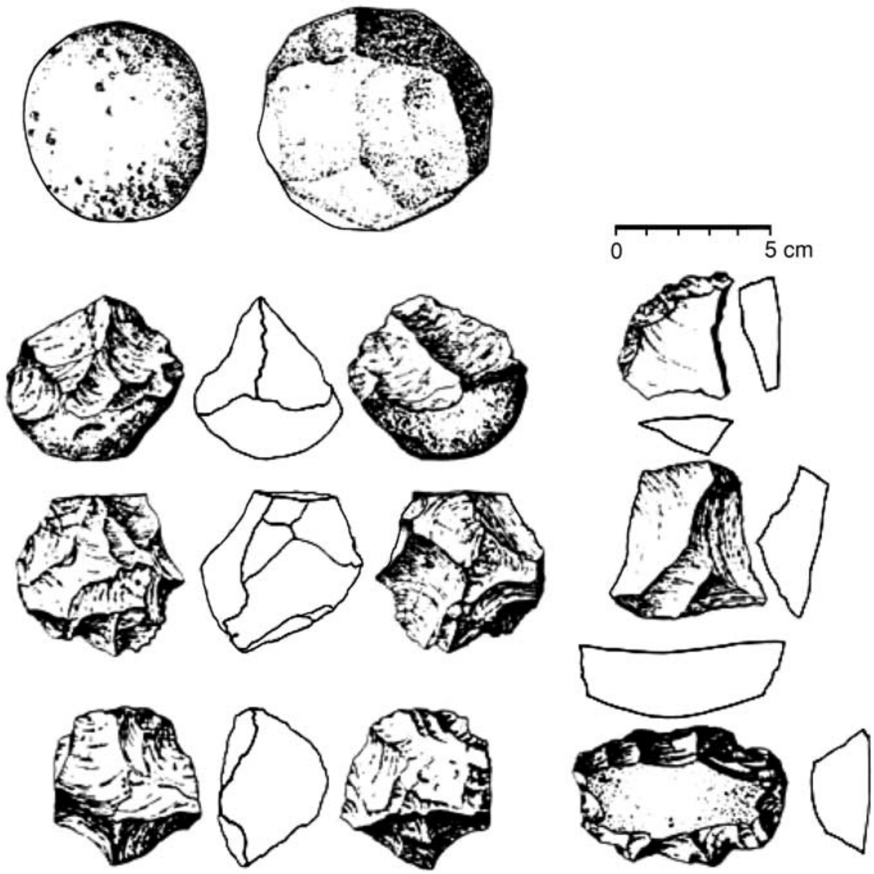

FIGURE 2.19 Some examples of 1.75-million-year-old Oldowan stone tools.

existing cultures. The use of high-powered microscopes to study wear patterns on stone tools and other technical advances has given archaeologists more confidence in their ability to infer the functions of artifacts, but there will always be an element of speculation, inference, and error in these typologies.

Another widely used archaeological classificatory approach employs *chronological* types. Chronological (or "historical") types are artifacts whose combination of attributes is known to be limited to particular time periods. We have already noted that stylistic elements such as pottery decorations and house architecture have limited distribution in time, and by sorting artifacts into groups based on their similarity of stylistic elements we can often devise relative chronologies of archaeological remains.

While depending on chronological and functional types in most analyses, archaeologists continue to search for more powerful systems of arrangement. In contemporary archaeology, debates about the logic and mechanics of arranging and classifying artifacts into analytical units continue, with some stressing a statistical approach, others more formal methods, and yet others completely new ways of linking tool forms and tool types.[43]

Quantitative Methods and Computers in Archaeology

Once archaeologists have grouped the artifacts of the archaeological record into classes or types, they analyze the distribution of these classes and types through time and space. In a film scene, W. C. Fields, while dealing cards, was asked by a prospective player, “Is this a game of chance?” Fields—felonious eyes agleam—replied, “Not the way I play it!” Modern archaeology, on the other hand, is in many crucial ways a game of chance in the sense that we must use probability theory and statistics to interpret what we find. Chance in this sense enters directly into the formation of what archaeologists have to work with—the archaeological record. Some 1.7 million years ago, for example, an individual who from the neck down looked very much like ourselves made a light lunch of a cow-like animal (possibly killed and partially eaten by some other animal) and tossed some of its bones into some lakeside sediments, where the bones were preserved—cut marks intact—until Louis Leakey dug them out in the 1950s. Doubtless this same individual of 1.7 million years ago munched on other bones that were thrown away in areas where they rotted or were totally fragmented by hyenas, and have thus disappeared. And chance enters into not only the preservation of objects but also their discovery. Many major archaeological sites in European countries, for example, are within a short distance of major roads—a sign that there are probably many other sites that have not yet been discovered because no one has happened on them. Chance—or, more precisely, probability statistics—is also part of the analytical methods of modern archaeology. The costs in time and money of archaeology are such that even well-known sites, like the ancient Iranian city of Susa, where the biblical Esther lived 3,000 years after the city’s founding, are so large that even a century of excavation has removed only a small fraction of the site. Even in Egypt, where centuries of excavations and reoccupation have destroyed many sites, hundreds of huge sites have been only partly excavated.

The only reasonable archaeological strategy in the face of such a massive archaeological record is to *sample*: to excavate some parts of some sites in the hope that these samples will accurately reflect the whole.

The essentials of statistical sampling are familiar to most people. Polling organizations regularly ask a few thousand people how they are going to vote in an election and use this information to make very reliable predictions about the voting behavior of the larger population (all the people who actually vote). Defining the target population—that is, what it is one is trying to estimate—is the key to valid statistical analyses. Introductory statistics professors are fond of citing the fact that the average adult human has one testicle and one breast. One of the reasons sampling works in elections is that pollsters *stratify* samples: They know from previous elections that people in the North vote differently from those in the South and that certain occupational groups are far more likely to vote than others. Thus, they break up, or stratify, their samples so that these and other subpopulations are proportionately represented. Then, by using procedures of statistical inference, they are often able to estimate election results quite precisely.

Archaeologists also use sampling theory and procedures. If they wish to know relatively straightforward information, such as the number and kinds of sites in a large region, they can divide the area up into subareas—perhaps stratifying it according to ecological zones—and then go out and record the number of sites in perhaps 10 percent of all the subareas. Excellent results are usually obtained from such procedures, if the objective is simply an estimate of site densities. One critical sampling problem derives from the great size and complexity of the archaeological record. Suppose, for example, that you have the idea that trade in items such as flint and obsidian was a key element in the rise of the first states of ancient Mexico. The only way to test your idea would be to determine if there had been a significant increase in the amount or kinds of these commodities at sites occupied just prior to or during the period when the first states appeared. To do this with statistical precision, you would have to excavate at least portions of a statistically valid sample of at least 30 or 40 sites—something just not feasible in today's archaeology. The result is that archaeologists are not purists when it comes to using statistics and probability models. Because so much of the residue of the past has decayed, and because of the high cost of gathering and analyzing archaeological data, archaeologists tend to misuse statistics and probability theory by making sweeping inferences on the basis of inadequate data. No Wall Street trader (or even drunk riverboat gambler) would bet on the odds that archaeologists do when testing their hypotheses; but archaeologists deal only in history and science, whereas gamblers and stockbrokers deal in money.

Archaeologists have opted for the only realistic compromise: They use statistical sampling techniques, knowing that they often don't meet the theoretical requirements of optimal statistical inference, but believing that useful—if not perfect—results can be obtained. Fortunately, most statistical sampling techniques are very "robust" in that one can strain their assumptions badly and still get quite reasonable results.

To a large extent, archaeological interest in sampling and many other aspects of modern archaeology are side effects of the invention and improvement of the modern computer. Applying even the simplest statistical description and inference to archaeology would be impossibly time-consuming without computers. Quantification in archaeology is not just a matter of sampling: It underlies most other methodological advances. The archaeological record is so complex that in most cases the archaeologist cannot see patterns in the welter of data without the aid of numerical summaries or quantitative presentation.

One example of new methodologies that help identify complex archaeological patterning is the Geographic Information System (GIS), which has been used by both processual and post-processual archaeologists. With this technique, spatial data, such as the location across the landscape of certain types of stone artifacts or the distribution of house sites and temples, are combined with nonspatial information, such as images or database records.[44] GIS is designed so that questions about the data can be asked and analyzed with statistics. In my (Olszewski) ASPS project in Egypt, for example, I might want to know where a certain type of stone artifact, such as a Levallois core, has been found. By setting up a query, I can generate a map showing the distribution of Levallois cores, along with descriptive database information about each of them. One advantage of GIS is that once I've generated this map, I can ask questions about it to generate other maps. For example, perhaps I want to know where the Nubian Levallois cores are in relationship to radial Levallois cores (Figure 2.20). If a pattern is present, then I can run additional queries and statistical analyses that will facilitate interpreting the pattern.

DATING THE PAST

Computers are useless. They can only give you answers.

Pablo Picasso (1881–1973)

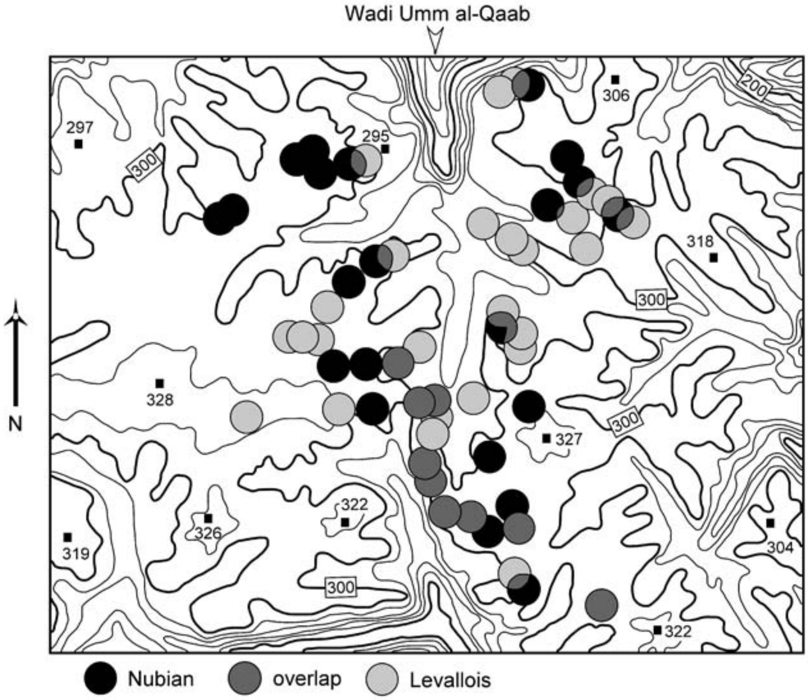

FIGURE 2.20 The distribution of Middle Paleolithic Levallois and Nubian cores in surface samples near the Wadi Umm al-Qaab, Egypt; collected by the Abydos Survey for Paleolithic Sites project.

The basics of excavating artifacts and features, classifying them, and counting them are relatively straightforward problems common to many sciences. But like other disciplines, archaeology involves many specialized forms of *measuring* artifacts and the rest of the archaeological record. This field is generically referred to as *archaeometry*.

Dating Methods in Archaeology

The primary importance of dating methods in archaeology is in analyzing cultural changes. To take an example, some have argued (chapter 6) that people first domesticated sheep and goats and began farming wheat and barley in the Middle East because human population densities had risen to the point that people could no longer survive on hunting and gathering alone. Other people suggest that rising population densities had little to do directly with the origins of agriculture in this area.

Our only hope of resolving such disputes—of testing hypotheses—about the mechanics of major cultural transformations is to look at the archaeological record. If we conduct archaeological surveys in the area of the Middle East where agriculture first appeared and determine what sites were occupied during what periods and how large they were, we can estimate population densities before, during, and after the period when agriculture first appeared—about 10,000 years ago. If we discover that there is no significant rise in population densities just before and during the period when we find the first domesticated plants and animals and agricultural implements, we might reject the idea that rising population densities were the important direct cause of this change. In short, our only hope of determining cause and effect in ancient cultures is to show correlations in time and space.

But how are we to date artifacts in order to show such correlations?

Archaeologists rely on two different kinds of dating methods. In some situations the objective is to obtain a *chronometric* date: that is, an age expressed in years, such as "that house was built 7,200 years ago." In many situations, chronometric dates may be difficult to obtain or simply unnecessary for the problem at issue, and for these situations archaeologists have devised several methods of *relative* dating, in which the objective is to arrange sites or artifacts in a sequence that reflects the order in which they were created—even though we may not know for certain the actual age of any of them.

CHRONOMETRIC DATING

Many archaeologists dream of a small pocket-sized device, stuffed with microchips and Star Trekian "dilithium oxide" crystals, which, when pointed at an artifact, will read out the object's exact date of manufacture. Fanciful as this may sound, modern physiochemical dating methods have been greatly improved in the last decade, and age estimates are becoming increasingly reliable.[45]

Perhaps the most precise and yet technologically simple form of chronometric dating is *dendrochronology*—the use of sequences of tree rings to infer time.[46] Most trees add a single "ring" each year to their circumference; thus, if we count the number of rings, the age of a tree can be precisely established. Normally the tree grows faster in wet years than in dry ones; therefore, over the centuries there is a unique series of changes in ring widths, and precise dates can be inferred by comparing cross sections of trees that overlapped in time (Figure 2.21). By comparing beams, posts, and other artifacts to cross sections taken from trees that live for long periods, it is often possible to determine the exact year in which the tree used to make the artifact was cut. But here's the rub: In dry climates tree trunks cut as lumber tend to be used and reused for very long times, so that the date that the tree actually was cut may be centuries earlier than the period it was used as a beam in some house. Also, since local climates vary, dendrochronological records must be built up for each region, and at present detailed records are available for the North American West, Europe, and the Near East.

The most widely used chronometric technique is ^{14}C (carbon-14 or radiocarbon dating), a method first outlined in the 1940s by Nobel laureate Willard Libby.[47] When solar radiation strikes the upper atmosphere, it converts a small amount of atmospheric nitrogen into the radioactive isotope ^{14}C. Wind and other factors spread this ^{14}C throughout the atmosphere, and because all living organisms exchange gases with the atmosphere, the ratio of ^{14}C in their cells is equal to that in the atmosphere. When the organism dies, the ^{14}C trapped in its cells begins to revert to nitrogen. This disintegration occurs because ^{14}C is unstable. Because we know that approximately half of any given quantity of ^{14}C will disintegrate in about 5,730 years, we can estimate the time an

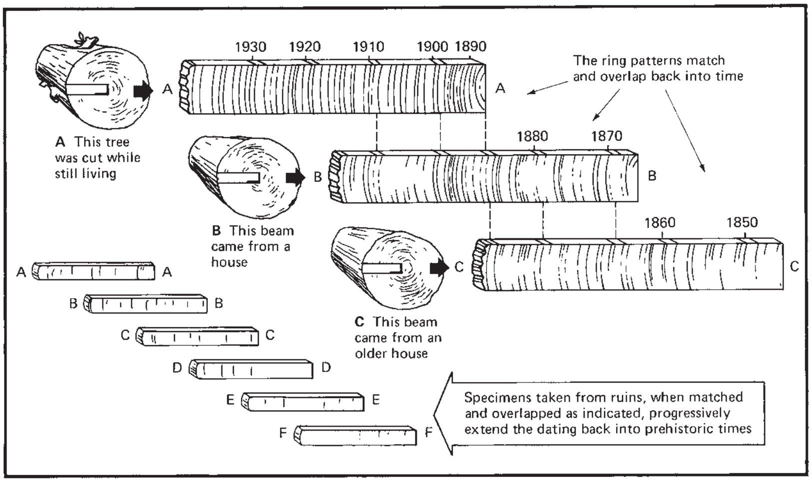

FIGURE 2.21 The most precise dates in archaeology are derived through dendrochronology. In many important areas of the world, however, a dendrochronological sequence has not been established, and in other areas, such as Mesopotamia, there are no native, long-lived species of trees.

organism has been dead by measuring the amount of ^{14}C against the stable isotopes ^{12}C and ^{13}C remaining in its cells. After about 50,000 years, too little persists to be measurable with standard laboratory methods, although with large samples and the most powerful equipment, reliable dates up to 100,000 years ago are theoretically possible.

Radiocarbon dating works best on wood and charcoal, but paper, leather, bone, skin, peat, and many other organic materials can also be dated by this method. Grains and grasses make excellent archaeological samples when charred by fire because they preserve well and are short-lived compared to trees.

The ratio of ^{14}C in the atmosphere has not been constant over the last 50,000 years, and thus ^{14}C dates have had to be "corrected" by measuring the ratio of ^{14}C in tree rings dated through dendrochronology. Fortunately, some trees, such as the bristlecone pine of northern California, live thousands of years; cores from their trunks can be dated through dendrochronology, and then each ring can be radiocarbon-dated to construct a "correction curve."[48] Logs found submerged in northern European bogs, where they have been preserved for thousands of years, have recently allowed the calculation of a radiocarbon correction curve extending back more than 7,000 years for that area. But samples dated by the ^{14}C method can still be contaminated with younger or older carbon sources, such as ground water or petroleum deposits.

Additionally, we also know that the amount of ^{14}C is not the same for all environments. The northern and southern hemispheres, for example, have different proportions of ^{14}C. These types of factors must be considered or accounted for by the laboratories that process samples for ^{14}C dating.

A major advance in radiocarbon dating was made in the 1970s when various researchers used particle accelerators (the AMS method, or accelerator mass spectrometry) to date samples. This method allows reliable dates to be obtained from samples the size of a match-head, whereas older methods require about a handful of carbon. Accelerator dating has other advantages: Samples can be more easily purified of contaminants, individual samples can be subdivided into very small amounts and tested for internal consistency, and older samples can be dated because problems involving background radiation have been obviated. Because accelerator dating can be done on such small samples, reliable dates can be obtained from the cooking soot on pots, dung, and other organic temper in pottery, slag, textiles, and many other materials.

In February 1989 an international team of 21 scientists reported the results of radiometric dating of the Shroud of Turin, a cloth that appears to bear the image of a man who has been whipped and crucified. For centuries, many people have believed that the Shroud was used to wrap the body of Jesus Christ. The scientists took three samples of cloth, each about 50 mg (about the size of a postage stamp), and sent them to three different laboratories, in England, Switzerland, and the United States. Using accelerator mass spectrometers, scientists at the three laboratories all concluded independently that the linen used for the Shroud was made about A.D. 1260–1390.

Interpretations of radiocarbon dates are rarely simple. The radiocarbon method was first applied by Libby to wood from the Pyramid of Djoser in Egypt, and over the years thousands of radiocarbon analyses of Egyptian materials have been made. In a recent attempt to refine the radiocarbon chronology of Egypt, I (Wenke) was part of a group of scholars[49] that retrieved hundreds of samples from the 22 major Egyptian pyramids and scores of temples and tombs. Because we were engaged in a decade-long project to try to define the basic mechanics of ancient Egyptian cultural change, one of the aims of this study was to determine when the Egyptian pyramids were built. Construction of the enormous pyramids and other monuments in the Nile Valley was obviously a critical part of this cultural change, since they must have required astounding investments of time and energy. But how do we know when they were built and what their relation in time was to fluctuations in the Nile floods, political developments in neighboring areas, and other important events?

Not a single ancient text from the age when the pyramids were built has ever been found that describes their construction, or even refers to them. Egyptologists have dated the pyramids primarily on the basis of names on inscriptions in temples and tombs in areas near the pyramids. Ancient king-lists have been found, and the length of reigns of specific kings are often given in inscriptions, so Egyptologists have been able to estimate the sequence of pharaohs and how long each ruled. Occasionally, a text would record a specific astronomical event in the reign of a specific king, such as the rising of the star Sirius at a particular time and place on the horizon. Such events can be precisely dated, so we know the dates of some rulers with great accuracy. Unfortunately, such astronomical observations have not been found for the period when the pyramids appear to have been built.

Most of the mortar used to bind the blocks of stone making up the pyramids appears to have been produced by burning gypsum to create a powder that was combined with water and other materials. Thus pieces of carbon from the fires can be found throughout this mortar. We thought that if these charcoal fragments could be dated, then we could estimate when the brush, trees, and so on, had been cut to get the fuel to burn the gypsum, and from this we could estimate the age of the pyramids. We also hoped that if we took a lot of samples in sequence, from the base to the top of each pyramid, we might arrive at some estimate of how long it took to construct them and the sequence in which they were constructed.

After having obtained the necessary research funds and permissions, we started at the first course of the Great Pyramid of Khufu and began extracting bits of carbon out of the mortar. Six months later we had just over a hundred samples from 17 of the largest pyramids. Some samples were about the size of a pea; others constituted roughly a handful of carbon. We sent the larger samples to the Radiocarbon Laboratory at Southern Methodist University for conventional radiocarbon dating, and we sent the smaller samples to a laboratory in Switzerland, to be dated with the recently developed AMS methods. The majority of our dates came out almost 400 years older than most Egyptologists would estimate as the ages for these various pyramids. We presented a paper on our results at a scientific conference and were informed by most Egyptologists and virtually everyone else that our radiocarbon dates had little or nothing to do with the ages of the pyramids. It was suggested that our dates came out too old because (1) the ancient Egyptians used old wood in the fires to produce the mortar, or (2) the carbon came from plants that naturally absorb relatively large amounts of radioactive carbon, or (3) the mortar itself had contaminated the carbon, or (4) the correlation curves we used were wrong. Because of "wiggles" in the correction curve, for example, for any particular sample one might be able to read three or more different dates from the graph, none of which is more likely than the other dates.

All these factors may, in fact, have played a role in producing our dates, and even though we tried to control for as many of them as we could, we still were in no position to conclude that the traditional Old Kingdom chronology is wrong. In 1994–1995 we returned to Egypt and collected hundreds of additional samples. This time, with botanical identifications of the materials analyzed and a more comprehensive sampling design, our initial results were confirmed in the sense that the radiocarbon chronology for the construction of the pyramids shows that most of the monuments we dated were built earlier than the historical chronology would suggest.[50]

In any case, as the preceding indicates, radiocarbon dating can be very useful, but interpretations of radiocarbon dates are usually difficult: Dates that agree with one's suppositions tend to find a ready audience, while dates that do not are often labeled "intrusive."

Another important form of archaeological dating is the potassium-argon method. Potassium-argon dating is based on the fact that a radioactive isotope of potassium (^{40}K), present in minute quantities in rocks and volcanic ash, decays into the gas argon (^{40}Ar) at a known rate (half of a given amount of ^{40}K will change into ^{40}Ar in about 1.3 billion years). Because ^{40}Ar is a gas, it escapes when rock is molten (as in lava), but when the rock cools, the ^{40}AR is trapped inside. By using sensitive instruments to measure the ratio of ^{40}K to ^{40}Ar, it is possible to estimate the time since the rock or ash cooled and solidified.

Because of the long half-life of ^{40}K (1.3 billion years), potassium-argon dating can be used to estimate dates of materials many millions of years old. The remains of our ancestors at Olduvai Gorge and other sites more than a million years old have been dated with the potassium-argon method.

Carbon-14 and potassium-argon dating remain the mainstays of chronometric dating, but archaeologists can now use many other techniques involving chemical changes, although most of these are subject to considerable error and many qualifications.[51]

Paleomagnetic dating is based on the fact that the north and south pole have "reversed" their magnetism many times. Today the north pole is positive and the south pole is negative, but these were reversed in some periods, such as for most of the period between about 700,000 and 1.6 million years ago. Magnetic rocks preserve a record of these changes in polarity. As a result, finds that are, for example, between two layers of magnetic rock can often be roughly dated.

Luminescence dating[52] has become increasingly important in archaeological research. The technique is based on the fact that commonly occurring crystalline minerals such as quartz and feldspars "soak up," in a sense the radioactivity of the naturally occurring radioactive elements in the sediments in which they are found. In this sense they *record* how long they have been exposed to these radioactive elements. When these minerals are heated to a high enough temperature (e.g., by firing pottery or using earthen ovens) or are "bleached" by sunlight the record of exposure to natural radiation is erased, setting their radiological "clocks" at zero. Once these materials cool, or in the case of sediments are removed from sunlight through burial, the minerals again begin to record their time in contact with their radioactive environment. Even sun-baked surfaces such as agricultural fields and natural soils will record the time of their own burial. In a dark laboratory the accumulated energy can be released as light and measured with a device called a photomultiplier. The earliest technique, thermoluminescence (TL, developed in the 1970s for pottery), uses heat to release the light. Optically stimulated luminescence (OSL), developed for application to sediments, uses one wavelength of light to release light of another wavelength. In both TL and OSL the researcher uses the luminescence record from the sample together with the rate of radioactivity decay in its environment to calculate the age of the sample. Recent technical advances have made possible OSL age determinations for single grains of sand. Age determinations from zero to one million years are possible with TL and OSL. Luminescence techniques can be used to date the last heating of an artifact or the burial of a surface. This has the great advantage of dating the actual construction of the artifact, or the burial of a site. The radiocarbon method, in contrast, dates the death of the organism—an event that may be very far removed from the creation of an artifact or its burial.

Electron spin resonance (ESR) dating is similar to luminescence dating in that the scientist measures the record of exposure to radiation. In ESR, samples of ancient teeth and some other materials are placed in a variable magnetic field and the energy interactions between the object and the magnetic field are measured. ESR is less destructive than other dating techniques, but like TL and OSL it can be applied to very tiny samples (less than 1 g).

Other methods of physical dating have been developed and applied to archaeological problems, and refinements of these methods continue. All of these techniques have inherent expected margins of error and all are still somewhat experimental. Thus, archaeologists tend, where possible, to use as many different techniques on as many samples as possible, in hopes that a clear pattern will be observed with all of the methods converging on approximately the same age estimates. In a recent analysis of Egypt in the period between about 170,000 and 70,000 years ago, scientists on a project directed by Fred Wendorf, Romuald Schild, and Angela Close applied an impressive array of different dating techniques, including uranium series dating of carbonates and tooth enamel; thermoluminescence dating of deposits, both with traditional techniques and the newer optical methods; electron spin resonance dating of tooth enamel and other materials; and amino-acid analyses of eggshells.[53]

RELATIVE DATING

To the novice, perhaps one of the most impressive things archaeologists can do is to be able to tell the approximate date, place of manufacture, and place of origin of a tiny sherd of pottery simply by looking at it.

This kind of relative dating involves the concept of "style." Artisans throughout history have invested their artifacts with characteristics that vary predictably over time and space, and the distribution of these stylistic elements tends to follow certain patterns, whether the objects involved are skirt lengths, musical forms, or stone tools. Styles originate in some small area, spread to adjacent ones, reach a peak in popularity, and then die out (Figure 2.22). To some extent, styles reflect rates of interaction and shared aesthetic preferences, and these are not always exact functions of time and distance. Dress styles in midtown Manhattan, for example, may be more similar to those on Rome's Via Veneto than to those in a small town in rural New Jersey, even though this pattern of stylistic similarity "reverses" their relative distances. And often a style dies out at its point of origin long before it reaches its ultimate dispersal.

Seriation, a type of relative dating, is often used where many surface collections of artifacts have been made. Several generations of archaeologists,[54] for example, have surveyed most of the area around Mexico City, identifying thousands of settlements dating from 12,000 years ago up to the Spanish Conquest. Most of these sites are small mounds whose surfaces were littered with pottery sherds and obsidian tools. The differences in style between a Late Aztec Black-on-Orange dish (c. A.D. 900) and Middle Formative plainware

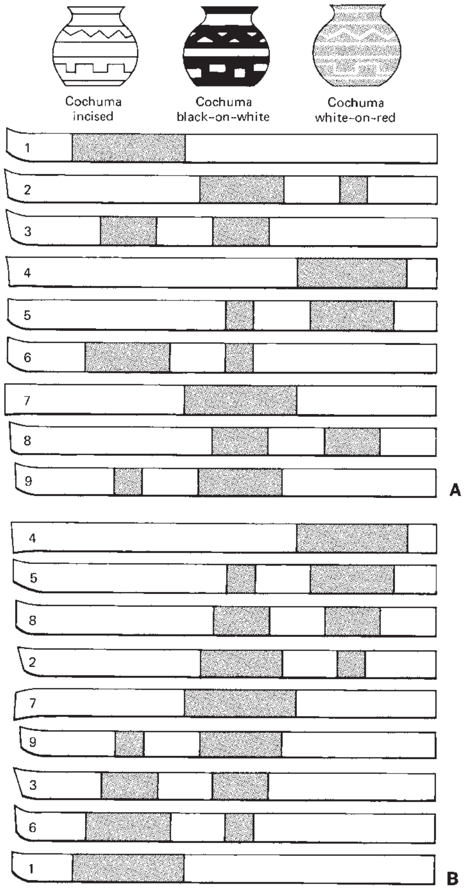

FIGURE 2.22 Relative seriation of nine archaeological sites on the basis of three pottery styles from the American Southwest. The percentage that each pottery style represents of the total pottery found at each site is represented by the width of the colored area on the strip of paper (**A**). Since most styles tend gradually to grow in popularity and then slowly die out, a seriation can be produced by arranging the paper strips in such a way that the three pottery styles have this "battleship shape" distribution through time. The inferred order of the nine sites is shown in **B.** Mathematical models and computer programs have been developed to sort scores of sites and pottery styles into these kinds of graphs. Such mathematical aids are often needed because the number of possible unique orderings of 9 sites is 9!, or 362,880.

jar (c. 550 B.C.) are so obvious that anyone can learn to date sites of these periods in a few days of study. On this basis, archaeologists have dated thousands of sites without excavating them, simply by grouping them into a relative seriation of four or five major periods. Carbon-14 dating can be used to provide a few absolute dates to anchor this sequence, and most chronologies based on changes in artifact styles are derived from excavations, in which the archaeologist can order the found pottery in time on the basis of stratigraphy. But pottery styles alone are all that is necessary to construct a seriation. Accurate relative seriations usually require massive quantities of data from artifacts of a highly decorated nature (like pottery) from a relatively small area, and they tend to be least precise when extended to largely undecorated objects such as early stone tools (Figure 2.23).

SUMMARY AND CONCLUSIONS

Having considered various elements of modern archaeological methods and theory, it is, perhaps, useful to consider an example of a specific archaeological project. As one such example, I (Wenke) offer the Fayyum Archaeological Project, which I codirected in Egypt in the 1980s. I offer this example not as a model of its kind, but simply as an illustration of the kind of archaeology that remains in some ways typical of contemporary archaeology.

The proximate cause of the Fayyum Archaeological Project, which was wholly conducted in Egypt, was in fact the Iranian Revolution. I had done archaeological research in Iran on several occasions in the early 1970s and was due to resume work there in 1979, on a day almost exactly between the shah's departure from Iran and the first seizure of the American Embassy by Islamic militants. I had received my first National Science Foundation grant and would probably have gone to Teheran despite the revolution, had the Iranians permitted—which they emphatically did not. Through a series of events too baroque to recount here, I had the good fortune to be able to work instead in Egypt.

I was hardly the first archaeologist forced to change geographical focus by political events. Political situations in many countries, from Peru to China, from Russia to Tanzania, have often rerouted archaeologists.

In 1980 I codirected excavations at el-Hibeh, a site on the Nile that was a major town during most of the first millennium B.C.[55] But I had long been interested in the origins of agricultural economies, and I was much impressed by some new ideas about agricultural origins in Egypt. Simply put, I was curious why wheat and barley farming appeared in Egypt so long—about 2,000 years—after it did in Southwest Asia. So while in Egypt I started searching for an area in which to investigate the origins of Egyptian agriculture.

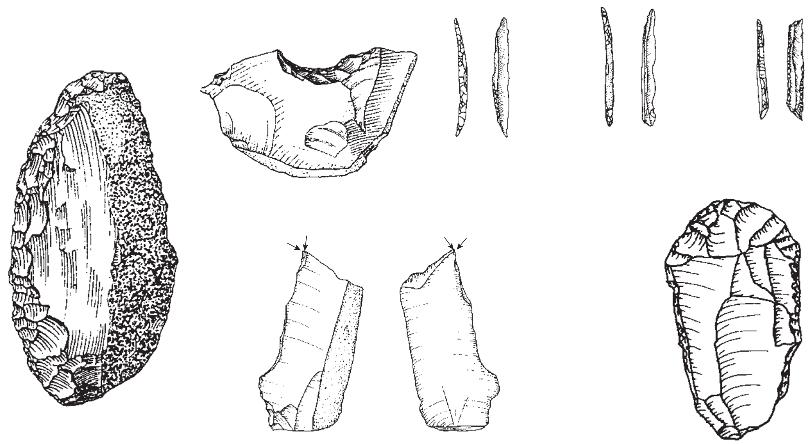

FIGURE 2.23 Many stone tool types are not good indicators of short time periods, and thus are not useful in seriation. On the left is a Middle Paleolithic sidescraper. The top row shows a Middle Paleolithic notch and Epipaleolithic microliths. The bottom row shows an Upper Paleolithic burin and an endscraper.

Many of the most important sites in Egypt have been excavated for decades and are already being studied by other archaeologists; one cannot just decide to excavate this or that site. The late Professor Michael Hoffman suggested that I look at unsurveyed parts of the Fayyum Oasis, in central Egypt. Years of work by other archaeologists had shown evidence of early agriculture at the site, but it was not being explored at that time.

Although my main interest was the origins of agriculture, I wanted to do a complete regional survey, to locate sites of all periods in this area. The remains of large towns of the last few centuries B.C., for example, can be found at many places in the research area. Archaeological projects in Egypt usually have on their staffs an Egyptologist—someone who reads ancient Egyptian writing—and I was fortunate enough to recruit a recent graduate from the Sorbonne (The University of Paris), Dr. Mary Ellen Lane, as codirector. With a representative of the Egyptian Antiquities Organization, we made several trips into the deserts of the southern Fayyum without finding much except a restaurant in the provincial capital, where I got deathly ill for only 90 piastres.

In the 1920s, the intrepid British archaeologist Gertrude Caton-Thompson had surveyed the southern edge of the Fayyum Lake, noting here and there scatters of Neolithic-style stone tools. One day, hiking through an area near where she had surveyed, we saw a large pile of bones. On inspection it proved to be the remains of a hippopotamus, and we were delighted to see that near it were stone projectile points (“arrowheads”) of a Neolithic type. Within a few hours of surveying, it was evident that we had found a dense scatter of hearths, pottery, stone tools, and animal bones, and that the styles of artifacts suggested two periods of occupation: an “Epipaleolithic” period of occupation by hunter-foragers at about 7000 B.C., followed by an occupation by some of Egypt’s earliest known farmers, at about 5500 B.C. Thus, we had the opportunity to study one of the most important cultural changes in Egypt, the transition from hunting-foraging to agriculture. Other archaeologists had worked in the Fayyum on this problem, but we had found a well-preserved part of the archaeological record there that we thought would give us new and important data to analyze this transition.

Back in Cairo, several weeks of library research convinced us that what we had was significant, and that we should try for our first field season in the summer of 1981—a year later. All we needed was $200,000, a staff of at least 20 trained archaeologists, and permission from the Egyptian government.

Famed felon Willie Sutton, when asked why he robbed banks, patiently explained, "That's where the money is." Archaeologists, too, must go where the money is, and in this era it is mainly in the hands of the government. After months of writing proposals, we received about $200,000 from the U.S. Agency for International Development and the U.S. National Science Foundation. We then recruited our staff of specialists in ancient plant remains, animal bones, and geology, and conscripted eight graduate students to assist with the demanding field work.

On June 4, 1981, we left Cairo in several jeeps and trucks to make the four-hour trip to the research area. We lived that summer and autumn in a large gray house that looked across a green palm grove and the blue of the Fayyum Lake to the white limestone cliffs on the northern edge of the Fayyum Oasis. Our villa—the country home of a wealthy Cairo family—was a lovely international-style building with every convenience except three: water, electricity, and a sewage system. But we bought a generator, the provincial governor graciously arranged for a water truck to visit us every three days, and we devised an entertaining method of periodically napalming our open cesspool.

"Tell me what you eat, and I will tell you what you are," said the French gastronome Brilliant-Savarin, but archaeological field projects usually do not usually offer much scope to express one's self in terms of the food one chooses to eat. Our budget and the remoteness of our field quarters meant that our diet was almost wholly composed of bread, canned tuna fish, a vile processed cheese by-product, rice, tomatoes, and several hundred chickens, who were executed on our kitchen steps and then converted into indescribable meals. "Fire-Cracked Veal" and "Dreaded Veal Cutlet" were occasional holiday treats. We bored each other constantly with food fantasies. The morbidity rates—physical and psychological—on archaeological projects are often high, especially when, as in our case, water for washing was scarce and the cook had nothing but contempt for the germ theory of disease. We totaled at least five different strains of parasitical and bacterial infections among our crew, and we lost many days to illness. There was also one emergency appendectomy (mine), performed in Cairo after a thought-provoking four-hour truck ride from the desert, greatly assisted by our geologist, Professor Fekri Hassan, now of the University of London, whose truck and driver got me to a Cairo hospital in record time. After the appendectomy it was determined that I had kidney stones, not appendicitis, but I was in no position to complain.

When we began our six months of field work, we geared most of our efforts to reconstructing as precisely as possible the ways of life of the people who had lived in the Fayyum in the Qarunian period (c. 6500 B.C.), just before the appearance of domesticated plants and animals in this region, and in the succeeding Neolithic Fayyum A period (c. 5000 B.C.), when the first agriculturalists appeared. We hoped to reconstruct the pattern of human settlement in the Fayyum between 7000 B.C. and A.D. 1500 and explain the changes in these settlement patterns over this long period.

We began by making a topographic map of the area in which we intended to work. We then devised a sampling program and collected every artifact in the sampling units defined, that is, in the hundreds of 5-by–5-m squares in our study area. The Fayyum is surrounded by the Sahara Desert, and the average temperature during most of this work was over 40°C

(104°F); by midday the stone tools were often so hot we would have to juggle them as we bagged them. Afternoons were spent back at the field camp, sorting, drawing, and photographing artifacts, drinking warm water, and drawing each other's attention to the heat. In some cases, "It's not the heat, it's the humidity" is not at all true. In September we began excavations, mainly of the hearths and pits that were the dominant feature of both the Qarunian and Fayyum A occupations. In most we found charred animal bones, some carbonized plant remains, and other debris.

To evaluate our "model" of how agriculture appeared in the Fayyum and why, we had to collect sufficient evidence to make statistical arguments about certain kinds of conditions and events in Fayyum prehistory. The details of these arguments are not relevant here, but it should be stressed that as in most archaeological projects, not all the information we had hoped would be there was actually found. But most of it was, and the preliminary analysis of this information was published in several journals and presented at various conferences.[56] We have since made occasional returns to the Fayyum to collect more information, in hopes that eventually we will produce a more complete analysis of this part of the world's archaeological record.

In Cairo, after the season was over, we delivered the artifacts to the Egyptian Museum and made preparations to leave. It is traditional, after the privations of the field, to treat oneself to some rest and relaxation, and some project members agonized between such choices as the Club Med's Red Sea beaches or the delights of Rome. Most of the crew just went home and enjoyed the luxury of sleeping past 4:00 A.M.

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NOTES

1. In recent years, the term *physical anthropology* has often been replaced by *biological anthropology*.
2. Urban anthropology is becoming an increasingly important area of study. See, for example, Fox, *Real Country: Music and Language in a Working-Class Culture*.
3. Including many scholars who teach at universities in Australia, New Zealand, and elsewhere.
4. Rathje, "A Manifesto for Modern Material Culture Studies."
5. The idea of "feature," although still common in archaeology, has been discarded by some archaeologists in favor of a terminology based on depositional stratigraphy; see, for example, Harris, *Principles of Archaeological Stratigraphy*, 2nd ed.
6. For example, Dunnell and Dancey, "The Siteless Survey: A Regional Scale Data Collection Strategy"; Thomas, "Nonsite Sampling in Archaeology: Up the Creek without a Paddle?"; Peters and Blumenschine, "Landscape Perspectives on Possible Land Use Patterns for Early Pleistocene Hominids in the Olduvai Basin, Tanzania."
7. *Wadi* is the local term for a canyon.
8. Schiffer, *Formation Processes of the Archaeological Record*.
9. The term *taphonomy* (see Reconstructing Ancient Environments and Cultural Ecologies) comes to archaeology from faunal analysis. Today this term is widely used in the context of reconstructing how archaeological sites are formed by both natural and cultural processes over time.
10. Schiffer, *Formation Processes of the Archaeological Record*.
11. See, for example, Relethford, *Genetics and the Search for Modern Human Origins*; McBrearty and Brooks, "The Revolution That Wasn't: A New Interpretation of the Origin of Modern Human Behavior."
12. Wolpoff et al., "Multiregional, Not Multiple Origins."
13. Blumenschine et al., "Blind Tests of Inter-Analyst Correspondence and Accurarcy in the Identification of Cut Marks, Percussion Marks, and Carnivore Tooth Marks on Bone Surfaces."
14. Dibble et al., "Testing the Reality of a 'Living Floor' with Archaeological Data."
15. Orientation of artifacts is obtained by measuring the X, Y, and Z coordinates of the ends of elongated artifacts and bones, along with the strike (horizontal) and dip (vertical).
16. Dunnell, "Science, Social Science, and Common Sense: The Agonizing Dilemma of Modern Archaeology."
17. "In Memory of Eva Gore Booth and Con Markiewics," 1923.
18. Brady and Ashmore, "Mountains, Caves, Water; Ideational Landscapes of the Ancient Maya."
19. Currently the archaeology programs of the U.S. National Science Foundation and the U.S. National Endowment for the Humanities often face funding cuts through congressional action.
20. See Enge, "Retooling the Global Positioning System"; McPherron and Dibble, *Using Computers in Archaeology: A Practical Guide*, pp. 54–63. UTM stands for universal transverse Mercator, a grid system that

is placed over the entire world. It measures each grid in meters, so that a UTM reading gives you an Easting and a Northing, such as $E^{36R7}75039$ $N^{34}24964$. This particular UTM corresponds to a location in west-central Jordan, just southeast of the Dead Sea.

21. See McPherron and Dibble, *Using Computers in Archaeology: A Practical Guide*, pp. 30–53.
22. This has been attributed to Mies van der Rohe and others.
23. Jefferson was once described as "a gentleman of 32 who could calculate an eclipse, survey an estate, tie an artery, plan an edifice, try a cause, dance a minuet, and play the violin." James Parton, *Life of Jefferson*.
24. Jelinek, "The Tabun Cave and Paleolithic Man in the Levant."
25. Wheeler, *Archaeology from the Earth*.
26. Sease, *A Conservation Manual for the Field Archaeologist*.
27. Lyman, *Vertebrate Taphonomy*.
28. Grayson, *Quantitative Zooarchaeology*.
29. Binford, "Human Ancestors: Changing Views of Their Behavior"; Bunn, "Archaeological Evidence for Meat-Eating by Plio-Pleistocene Hominids from Koobi Fora and Olduvai Gorge"; Shipman, "Early Hominid Lifestyle: Hunting and Gathering or Foraging and Scavenging?"
30. Moore et al., *Village on the Euphrates*; Piperno, *Phytolith Analysis*; Gilbert and Mielke, eds., *The Analysis of Prehistoric Diets*; Bodner and Rowlett, "Separation of Bone, Charcoal, and Seeds by Chemical Flotation."
31. Ortner and Aufderheide, eds., *Human Paleopathology: Current Syntheses and Future Options*.
32. Ibid.
33. See, for example, Holliday, ed., *Soils in Archaeology: Landscape Evolution and Human Occupation*.
34. Vaughn, *Use-Wear Analysis of Flaked Stone Tools*; Keeley, *Experimental Determination of Stone Tool Use: A Microwear Analysis*.
35. Hayden, *Lithic Studies Among the Contemporary Highland Maya*; Weissner, "Style and Social Information in Kalahari San Projectile Points."
36. See also, for example, Gould, *Recovering the Past*.
37. For an excellent review of the role of ceramics in archaeological analysis, see Rice, *Pottery Analysis*.
38. Braun, "Pots as Tools."
39. See, for example, papers by Hodder, Plog, Wiesner, and others in Conkey and Hasdorf, eds., *The Uses of Style in Archaeology*.
40. Information collected about artifacts is stored in databases. These can be relatively simple, such as records in software programs such as Access or Excel, or quite sophisticated, combining photographs of the artifacts, data on their location within a site, their measurements and other attributes, field notes describing them, and so on. One example of this type of database is at http://www.museum.upenn.edu/mis/index.html.
41. Jorge Luis Borges, *Other Inquisitions: 1937–1952*, quoted in Aldenderfer and Blashfield, *Cluster Analysis*, p. 7.
42. Adams and Adams, *Archaeological Typology and Practical Reality*.
43. See, for example, Whallon and Brown, *Essays on Archaeological Typology*; Read, "The Substance of Archaeological Analysis and the Mold of Statistical Method: Enlightenment Out of Discordance?" pp. 45–86; Dunnell, "Methodological Issues in Americanist Artifact Classification"; Adams and Adams, *Archaeological Typology and Practical Reality*; Dibble, "The Interpretation of Middle Paleolithic Scraper Morphology."
44. See McPherron and Dibble, *Using Computers in Archaeology: A Practical Guide*, pp. 188–215.
45. Beck, ed., *Dating in Exposed and Surface Contexts*.
46. Baillie, *Tree-Ring Dating*.
47. Libby, *Radiocarbon Dating*.
48. Taylor, *Radiocarbon Dating: An Archaeological Perspective*; Taylor, "Radiocarbon Dating: The Continuing Revolution." Until recently, radiocarbon dates were often published as a certain number of years before A.D. 1950, the benchmark year in which the method was first established. "BP" was often used for corrected radiocarbon dates, "bp" for uncorrected dates (the "bp" first referred to "before present" or even "before physics"; see Taylor, *Radiocarbon Dating: An Archaeological Perspective*, p. 5). These correction curves allow dates to be calibrated—adjusted to be more accurate—and they are often reported as cal BC or cal BP. Because not all dates can be calibrated, there is a wide range of how dates are reported in the archaeological literature.
49. Haas et al., "Radiocarbon Chronology and the Historical Calendar in Egypt."
50. Bonani et al., "Radiocarbon Dates of Old and Middle Kingdom Monuments in Egypt."
51. Mahaney, *Quaternary Dating Methods*; Taylor and Aitken, *Chronometric Dating in Archaeology*.
52. I (Wenke) am indebted to Dan Bush for the following discussion.
53. Wendorf, Schild, Close, et al., *The Middle Paleolithic of Bir Tarfawi and Bir Sahara East*.
54. Sanders et al., *The Basin of Mexico*.
55. I (Wenke) thank Maurice and Lois Schwartz, the National Science Foundation, and the U.S. Agency for International Development for their support of this research.
56. See, for example, Wenke et al., "Epipaleolithic and Neolithic Subsistence and Settlement in the Fayyum Oasis of Egypt."