Practical and Theoretical Geoarchaeology

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Dedicated by RIM to the late Peter Reynolds (Butser Ancient Farm, United Kingdom) and Roger Engelmark (University of Umeå, Sweden): pioneers of experimental farms (see Chapter 12)

From RIM: to Mum, Jill, and Flora
From PG: to my folks for sending me away to summer camp

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Preface

Geoarchaeology within the past two decades has become a fundamental discipline whose value is recognized by everyone interested in past human history. First, archaeologists have become increasingly sensitive to the fact that sediments and stratigraphy provide the ultimate context for the artifacts and features that they excavate. Understanding this sedimentary context and its implications is a requisite for carrying out modern archaeology and for interpreting the archaeological record fully and accurately. Environmentalists (e.g. paleoecologists, soil scientists, sedimentologists, geologists, biologists, and climatologists) on the other hand, have turned to archaeology, because it provides a long-term view of human–environment interactions that have shaped both Quaternary and Holocene landscapes. Such knowledge can have a critical bearing on the future, for example, through identifying areas of sustainable landuse. Interpretation of such ecological information depends upon detailed understanding of the pedosedimentary and geomorphological context, as in archaeology. Geoarchaeology is an important discipline, because as shown recently, it increases our understanding of human impacts on the landscape through the study of ancient soils and occupation deposits. These investigations can provide detailed histories of human endeavors up to the present.

Although geoarchaeology – though not defined as such – had its roots at least in the eighteenth century (Rapp and Hill, 1998) it never came together as a subdiscipline until the appearance of the edited volume "*Geoarchaeology: Earth Science and the Past*" by Davidson and Shackley (1976). At this time Renfrew (1976) coined the term "geoarchaeology" in his Preface. Since then, a number of texts have appeared, the earliest ones (e.g. Rapp and Gifford, 1985) again were collections of papers, which were followed by single authored volumes (e.g. Waters, 1992; Rapp and Hill, 1998). In most cases however, the archaeological and human element as geoarchaeology was often underexplored in favor of landscape studies. This present volume, *Practical and Theoretical Geoarchaeology*, attempts to address this deficiency by providing what we feel is a more balanced view of the discipline by including detailed investigations of human activities as revealed by geoarchaeology. Potentially fruitful avenues of expansion of the discipline are highlighted, for example, in chapters on caves, experiments, occupation deposits, and forensic applications.

This book aims to be both an educational and practical tool, describing how geoarchaeology is carried out across a wide range of environments and periods, employing examples from many countries. It endeavors to teach readers both how to approach geoarchaeological problems theoretically and how to deal with them in practice. The topics covered range from regional-scale studies down to smaller, open area excavations and strata in past and present urban areas, such as Roman and Medieval London. The book presents numerous field and laboratory techniques, exposing readers to approaches suitable to a variety of site situations. Instructive guidelines and protocols are given to show the reader how to create integrated reports that include field evaluations, laboratory assessments, and archive and publication reports.

The book is designed primarily for undergraduate students in Archaeology and those Environmental and Geoscientists, who wish either to train in geoarchaeology or gain a background in this applied science. It is intended to serve as a basic text and an intermediary course in geoarchaeology. It also serves as a necessary text for advanced undergraduates and postgraduate students requiring access to geoarchaeological skills. In addition, it should act as a valuable resource for professionals in order to help develop their awareness of both field and laboratory methods and to identify the full potential of geoarchaeological investigations either for research or mitigation archaeology. Beginners in the subject may benefit from reading Chapters 1 to 3 first, which provide introductions to stratigraphy, sediments, and soils.

Acknowledgments

Those who know us are keenly aware how long it has taken us to get this book together. We thank them here at the outset for their patience and any grief we might have inflicted. There are too many people to thank individually, but a number of folks helped us considerably in writing the book.

Early discussions with Wendy Matthews were very stimulating and helped frame the focus of the book. Similarly, before we were too far along, David Sanger provided some fundamental insights about geoarchaeology and its practitioners. He reminded us that most geoarchaeology books are not written by archaeologists. Again, we hope that this helped us steer a more equitable course on the subject. Along the way we benefited from extensive and intensive collaboration and picked up valuable insights from Ofer Bar-Yosef, Steve Weiner, Takis Karkanas, Trina Arpin, Sarah Sherwood, Carolina Mallol, Arlene Rosen, Harold Dibble, Shannon McPherron, Steve Kuhn, Mary Stiner, Susan Mentzer, Lauren Sullivan, as well as Mike Allen, John Crowther, Gill Cruise, Johan Linderholm, the late Peter Reynolds, and Pat Wiltshire.

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Students at Hebrew University, Boston University, the University of Tours, and the Institute of Archaeology, and members of the Archaeological Soil Micromorphology Working Group served as test subjects for various parts of this book over the years. Colleagues at HU (Na'ama Goren-Inbar, Nigel Goring-Morris, Anna Belfer-Cohen, and Erella Hovers) offered immense opportunities to observe exciting real-time geoarchaeology. Nigel Goring-Morris, simply one of the best field archaeologists around, furnished several examples of key sites that really helped build a geoarchaeological story. Colleagues at Texas (Mike Collins, Tom Hester, Britt Bousman, Lee Nordt, Charles Frederick) provided a different outlook and a growing experience, in spite of the accent. The years of field work at Dust Cave with Boyce Driskell revealed that anthropogenic deposits exist even for hunters and gatherers in the New World.

Over the years, the interaction with many geoarchaeologists similarly shaped our thinking. At the outset, the late Henri Laville served as an inspiration for cave sediments, along with Prof. F. Bordes.

Marie-Agnès Courty has carried on this tradition of scholarship and friendship and has set the bar for geoarchaeological standards. Our first collaboration with her was invigorating and subsequent geoarchaeological interactions have helped us all develop and profit. We continue to be indebted to her.

Reid Ferring and PG were graduate students working in the Negev in the early 1970s and the latter has gained lots of insights into New World and Old World, geology, archaeology, and geoarchaeology, particularly in the field, waiting for things to happen. Rolfe Mandel and Vance Holliday, are among the foremost geoarchaeology practitioners, and they were instrumental in providing support, knowledge, and insights over the years. Much of this was sharpened by sharing the editorial helm with Rolfe at *Geoarchaeology*. Many hours were spent talking about the state of the discipline and the people who practice it. Vance Holliday in particular, devoted a lot of his time to furnish us with timely, constructive comments that significantly improved our message and how we should get it across. Not only are all these folks helpful, but they are simply nice people and made collaboration a pleasure. We also specifically would like to thank our other reviewer (from the United Kingdom), and Gill Cruise who played the devil's advocate with parts of the text. Duncan FitzGerald provided valuable advice on several chapters.

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Introduction

Geoarchaeology has become highly prominent these days, and geoarchaeological themes appear in journal articles, monographs, and reports, either within a specific section of an article or as a stand-alone publication. Journals embrace not only mainstream "geoarchaeological" type of publications, such as *Geoarchaeology* or the *Journal of Archaeological Science*, but also other journals that touch on more mainstream archaeological, anthropological, or geological subjects: *Journal of Human Evolution*, *American Antiquity*, *Journal of Sedimentary Research*, and *Antiquity*. In the United States, annual meetings of both the Geological Society of America (GSA) and the Society for American Archaeology (SAA), generally have at least one session or poster session, in addition to society-sponsored symposia on the subject. The GSA has an Archaeological Geology Division, and the SAA has the Geoarchaeology Interest Group. The Association of American Geographers (AAG) commonly has geoarchaeology sessions at their annual meetings.

Moreover, the most exciting archaeological sites that one reads about today – either in the popular press or professional literature – commonly have a substantial geoarchaeological component. The reader has only to be reminded about the significance of the geoarchaeological aspect of sites that are concerned with major issues relating to human development and culture. Some high profile issues and sites include: the use and evidence of the controlled use of fire (Zhoukoudian, China); the sedimentary context and the origin of early hominins (Dmanisi, Republic of Georgia; Boxgrove, United Kingdom; Mediterranean and South African caves – Gorham's Cave, Gibraltar; Kebara Cave, Israel; Blombos Cave, South Africa); peopling of the New World (Meadowcroft Rockshelter United States; Monte Verde, Chile); Near Eastern urban cultures (Çatal Höyük, Turkey; Abu Salabikh and Tel Leilan, Syria), and early management of domestic animals (Arene Candide, Italy). Even previously excavated localities, such as the Folsom site, are being reinvestigated from a more sophisticated geoarchaeological perspective.

These well-known landmark sites have really drawn attention to the contribution that geoarchaeology can make to, and its necessity in, modern archaeological studies. This situation was not the case a few decades ago when only a handful of archaeological projects utilized the skills of the geoarchaeologist; one of the authors (PG) could enumerate the sparse number of geoarchaeological studies at the time he was a graduate student in the late 1960s. Still, the best results have come from highly focused geoarchaeological investigations that have employed the appropriate techniques, and that have been intimately linked to multidisciplinary studies that provide consensus interpretations.

This book is about how to approach geoarchaeology and use it effectively in the study of archaeological sites and contexts. We shall not enter into any detailed discussion of the origins and etymology of "Geoarchaeology" versus "Archaeological Geology." (Full discussions of this irrelevant debate can be found in Butzer, 1982; Courty *et al*., 1989; Rapp, 1975; Rapp and Hill, 1998; Waters, 1992.) In a prescient, no-frills view of the subject Renfrew (1976: 2) summed it up concisely and provided these insights into the nature of geoarchaeology:

> *This discipline employs the skills of the geological scientist, using his concern for soils, sediments and landforms to focus these upon the archaeological "site," and to investigate the circumstances which governed its location, its formation as a deposit and its subsequent preservation and life history. This new discipline of geoarchaeology is primarily concerned with the context in which archaeological remains are found. And since archaeology, or at least prehistoric archaeology, recovers almost all its basic data by excavation, every archaeological problem starts as a problem in geoarchaeology.*

These issues of context, and what today would be called "Site Formation Processes" in its broadest sense, can and should be integrated regionally to assess concerns of site locations and distributions, and geomorphic filters that might have controlled them.

In this book – as will be seen throughout the volume – we take a decidedly pragmatic and functional approach. We do not see any need to differentiate between the two and consider geoarchaeology, archaeological geology, and geological archaeology to fall under the same rubric: any issue or subject that straddles the interface between archaeology and the earth sciences. Classifications – and in this case the distinctions between geoarchaeology and archaeological geology – are of value only if they are ultimately useful. Does it *really* matter how we categorize research that is aimed at studying postdepositional dissolution of bones at a site? According to the above this research would fall into both camps, but does it help us to know if we are doing geoarchaeology or geological archaeology or archaeological geology? For the sake of brevity, we employ the simple term, *Geoarchaeology*.

Geoarchaeology is practiced at different scales (Stein and Linse, 1993). Furthermore, its use and practice vary according to the training of the people involved and the goal of their study. For example, geologists and geographers may well emphasize the mapping of large-scale geological and geomorphological features – such as where a site may be situated within a drainage system – or other regional landscape features. This is a regional perspective scale that exists in three dimensions, with relative relief possibly being measured in thousands of meters, especially if working in the Alps and Andes. Much of the geoarchaeological research carried out in North America is focused at this landscape scale. Geologists would also be interested in the overall *stratigraphy* of site deposits and how these might interrelate to major landforms, such as stream terraces, glacial landforms, and loess plateaus. Pedologists, on the other hand, would be more concentrated on the parent materials, the surfaces upon which soils were formed, and how both have evolved in conjunction with the landscape; such materials can be buried by subsequent deposition or can be found on the present-day surface. In either case, pedologists' focus tends to be on the scale of the soil pit, that is, on the order of meters. Archaeologists themselves may want to focus geoarchaeological attention upon microscale, centimeter-thick occupation deposits: what they are, and how they reflect specific or generalized past human activities. In the case of rescue/mitigation archaeology – commonly termed Cultural Resource Management (CRM) in the United States – geoarchaeology is tailored to the nature of the "job specifications" proscribed by the developer under the guidelines of salvage operations. Finally, the geoarchaeologist may well be just one member of an environmental team whose task is to reconstruct the full biotic/geomorphic/pedologic character of a site and its setting, and how these environments interacted with past human occupations. All these approaches can be relevant depending on the research questions involved, and holistically they could be subsumed under the term, "site formation processes" (Schiffer, 1987).

Archaeologists come from a variety of backgrounds. As stated above, in North America, archaeology is taught predominantly in anthropology programs, although some universities (e.g. Boston University, United States, and Simon Fraser University in Canada) actually have archaeology departments; Classical and Near Eastern Archaeology programs are not rare, and these tend to emphasize written sources over excavation. In Europe, archaeology is included within programs, or in departments and institutes, and not necessarily as an extension of anthropology.

Although in the United Kingdom, geoarchaeology is taught in a number of archaeological departments, this is not always the case in Europe as a whole. In France, for example, this subject may only be taught to prehistorians and not to classical or medieval archaeologists. Commonly, even in the United Kingdom and elsewhere in the world, geoarchaeology is more likely to be seen as an *ad hoc* offshoot of geology and geography. In North America, it is not anchored in any particular department and may be cross-listed among Anthropology, Archaeology, Geology, and Geography. In spite of good intentions and good training, many geoscientists tend to be naïve in their approach to solving archaeological problems, and as a consequence they effectively reduce their potential in advancing this application of their science. This often diminishes or even negates their contributions to interdisciplinary projects. The opposite situation can be found, where an archaeologist does not even know what questions to ask (Goldberg, 1988; Thorson, 1990).

Thus, as Renfrew (1976) so cogently demonstrated, geoarchaeology provides the ultimate context for all aspects of archaeology from understanding the position of a site in a landscape setting to a comprehension of the context of individual finds and features. Without such knowledge, even the most sophisticated isotope study has limited meaning and interpretability. As banal as it might sound, the adage, "garbage-in, garbage-out" is wholly pertinent if the geoarchaeological aspects of a site are ignored.

In the past, geoarchaeology was carried out very much by individual innovators. In North America, the names Claude Albritton Jr., Kirk Bryan, E. Antevs, E.H. Sellards, and C. Vance Haynes immediately come to mind as the early and prominent leaders in incorporating the geosciences into the framework of archaeology (see Holliday, 1997 and Mandel, 2000a for details). In fact, Mandel aptly points out that for the Great Plains, geoarchaeology – or at least geological collaboration – locally constituted an active part of archaeological survey for several areas, although it was patchy in space and time. Much of the emphasis was focused on evaluating the context of Paleoindian sites and how these occurrences figured into the peopling of the New World (Mandel, 2000).

In Europe, during the period from the 1930s to the 1950s, Zeuner (1946, 1953, 1959) at the Institute of Archaeology (now part of University College London), developed worldwide expertise in the study of the geological settings of numerous Quaternary and Holocene sites that ranged from India to Gibraltar. After Kubiëna (1938, 1953, 1970) called the world's attention to soil micromorphology, Cornwall (1958) also at the Institute of Archaeology, applied this technique to archaeology for the first time (see below). At the same time, Dimbleby (1962) developed the link between archaeology and environmental studies, and produced one of the first detailed investigations of past vegetation and monument-buried soils for Bronze Age England Dimbleby (1962). Duchaufour (1982) in France also systematically studied environmental change and pedogenesis. In mainland Europe, the legendary French prehistorian François Bordes (1954) – whose doctorate in geology dealt with the study of loess, paleosols, and archaeological sites, principally in Northern

France – placed the French Palaeolithic within its geomorphologic setting. Vita-Finzi (1969), working in the Mediterranean Basin, used archaeological sites to suggest the chronology of Mediterranean valley fills, which he related to both climatic and anthropogenic factors. Cremaschi (1987) investigated paleosols and prehistoric archaeology in Italy.

Although some geoarchaeological research is funded by granting agencies (NSF, NGS, NERC, CNRS), much, if not most, of modern geoarchaeological work – in both the New and Old Worlds – is fostered and sponsored by CRM projects, ultimately related to human development throughout the world. Approaches and job specifications vary according to whether investigations are at one end of the spectrum, short-term one-off studies, or long-term research projects at the other. Geoarchaeological work can be done by single private contractors or by huge international teams, which may well include specialists who also act as private contractors. Nowadays, local authorities, government agencies (e.g. State Departments of Transportation in the United States) and national research funding agencies (e.g. NSF in the United States, AHRB and English Heritage in the United Kingdom, AFAN and the CNRS in France, and Nara National Institute in Japan) may all be involved in commissioning geoarchaeological investigations. It is currently a very flexible field. It is also one where there is an increasing need for formal training, but where relatively few practitioners have been in receipt of one.

Geoarchaeological work is now often broken up into several phases, with desktop investigations, fieldwork survey, excavation, sample assessment, and laboratory study, all being likely precursors to full analysis and final publication. This is all part of modern funding and operational procedures.

Single-job or site-specific studies may be as straightforward as finding out "What is this fill?" whereas problem-based research could involve the gathering of geoarchaeological data on the possible first controlled use of fire, as at Zhoukoudian, China (Goldberg *et al.*, 2001; Weiner, 1998). Sites are investigated at different scales and sometimes, for very different reasons. At one time "dark earth" – the dark colored Roman-medieval urban deposits found in urban sites across northern Europe – engaged the particular interest of geoarchaeologists because these enigmatic deposits commonly span the "Dark Ages," and human activities at this time were poorly understood (Macphail, 1994; Macphail *et al.*, 2003). Analysis of "dark earth" therefore, became a research-funded topic for urban development sites (CRM projects in urban areas) across Belgium, France, and the United Kingdom, for example. On the other hand, attention can be focused on individual middens and midden formation because they provide a wealth of material remains, particularly organic, that are normally poorly preserved and complex to understand and interpret (Stein, 1992). Regional studies of the intertidal zone, for example, may include the investigation of middens as one single component. The recent study of the intertidal deposits of the River Severn around Goldcliff, Wales, for example, involved analysis of sediment and drowned soils in order to investigate sea level changes and their effects on the populations living in the coastal zone during the Mesolithic through Iron Age periods (Bell *et al.*, 2000). Equally, studies of alluvial deposits and associated floodplains (Brown, 1997; French, 2003) have involved the search for buried sites, within the overall realm of evaluating the distribution of archaeological sites. The Po plain of Italy (Cremaschi, 1987) and the Yellow River of China (Jing *et al.*, 1995) both feature a series of late prehistoric settlements. Many of the most significant Paleoindian and Archaic sites in the United States are situated within alluvial sequences (Ferring, 1992, 1995; Mandel, 1995, 2000a).

Modern geoarchaeological research makes use of a vast number of techniques that either have been used in geology and pedology or have been developed or refined for geoarchaeological purposes. Early geoarchaeological research until the latter part of the last century, at least in North America, was predominantly field-based and made use of both natural exposures and excavated areas. More recently, field techniques have become more improved and technologically sophisticated (Hester *et al.*, 1997). Natural exposures can be supplemented with surface satellite remote sensing data (Scollar, 1990), as well as subsurface data derived from machine-cut backhoe trenches, augering, coring, and advanced geophysical techniques (e.g. magnetometry, electrical resistivity, and ground penetrating radar-Kvamme, 2001). Moreover, such data can be assembled and interrogated using Geographic Information Systems (GIS; Wheatley and Gillings, 2002) that can be used to generate and test hypotheses.

Laboratory techniques have similarly become more varied and sophisticated. At the outset, many geoarchaeological studies adopted techniques from geology and pedology that were aimed at sediment/soil characterization. Thus traditional techniques characteristically consisted of grain-size analysis (granulometry), coupled with other physical attributes (e.g. particle shape, bulk density, bulk mineralogy), as well as basic chemical analyses of organic matter, calcium carbonate content, extractable iron, and so on. The analysis of phosphate to elucidate activity areas or demarcate site limits has a longer history spanning over 70 years (Arrhenius, 1931, 1934; Parnell *et al.*, 2001). Conventional techniques with long historical pedigrees, such as x-ray diffraction (XRD), electron microprobe, x-ray fluorescence (XRF), instrumental neutron activation analysis (INAA), and atomic absorption (AA) have been enhanced by rapid chemical, elemental, and mineralogical analyses of samples through the use of Fourier transform infrared spectrometry (FTIR), Raman spectrometry, and inductively coupled plasma atomic emission spectrometry (ICP-AES) (Pollard and Heron, 1996).

In addition, a notable advance in geoarchaeology has been the application of soil micromorphology to illuminate a wide variety of geoarchaeological issues (Courty *et al.*, 1989; French, 2003). These issues range from the development of soil and landscape use (e.g. Ayala and French, 2005; French and Whitelaw, 1999; Romans and Robertson, 1983) and the formation of anthropogenic deposits (Macphail *et al.*, 1994; Matthews, 1995; Matthews *et al.*, 1997) to the evaluation of the first uses of fire (Goldberg *et al.*, 2001).

Finally, geoarchaeological research has been facilitated by the development of numerous dating techniques just within the past two to three decades. Now, sites within the span beyond the widely accessible limits of radiocarbon are potentially datable with techniques, such as thermoluminescence (TL), optically stimulated luminescence (OSL), and electron spin resonance (ESR) (Rink, 2001).

In this book, we aim to present a fundamental, broad-based perspective of the essentials of modern geoarchaeology in order to demonstrate the breadth of the approaches and the depth of problems that can be tackled. As such, it is also aimed to promote a basic line of communication and understanding among all multidisciplinarians. We cover a variety of topics that discuss thematic issues, as well as practical skills. The former encompasses such broad concepts as stratigraphy, Quaternary and environmental studies, sediments, and soils. We then provide a survey of some of the most common geological terrains that provide the natural settings for almost all archaeological sites. These are established geoarchaeological topics into which we have incorporated some new findings. Unlike previous books on geoarchaeology, we have dedicated a second major portion of the volume to new topics that are normally not entertained by previous geoarchaeological texts, such as "human impact," "experiments," and occupation deposits including Roman and medieval archaeology, and forensic applications. It is important also to obtain some insights into practical aspects of geoarchaeology, including how specifically geoarchaeologists should fit in to a project. Similarly, two chapters are devoted to a presentation of the methods – pragmatic and theoretical – currently used in geoarchaeology. These include not only field techniques (e.g. the use of aerial photos, how to describe a profile, and collect samples), but also those techniques that are used in the laboratory. Although we summarize the "what," and "how," we also try to emphasize the "why," and provide a number of example-based caveats for important techniques. A final facet deals with the practical aspects of reporting geoarchaeological results, keeping in mind that material presented in reports differs from that in articles. Reports essentially present the full database and arguments, whereas articles are commonly more thematic and focused, and by necessity are constrained to present results more concisely. Reports, which are seldom published in full, constitute the "gray literature" and make up an important part of the scientific database. They are too commonly overlooked, ignored, or simply are not readily accessible.

As a final point, we maintain that geoarchaeology in its broadest sense, must be made understandable to all players involved, be they archaeologists with strong training in anthropology, or the geophysicist, with minimal exposure to archaeological issues. All participants should have enough of a background to understand what each participant is doing, why they are doing it, and most importantly, what the implications of the geoarchaeological results are for all team members. Too often we hear about the geospecialist simply turning over results to the archaeologist, essentially being unaware of the archaeological problem(s), both during the planning stages and later during execution of the project. Hence they cannot correctly put their results to use. On the other hand, many archaeologists tacitly accept results produced by specialists with few notions on how to evaluate them. This book attempts to level the playing field by providing a cross-disciplinary background to both ends of the spectrum. Such basic material is needed to establish a dialogue among the participants so that problems can be mutually defined and mutually understood, regardless of whether you call yourself an archaeological geologist or geoarchaeologist.

Part I

Regional scale geoarchaeology

Introduction to Part I

Geoarchaeological endeavors operate at a variety of scales. These undertakings range from regional views of archaeological sites – their distributions and associated activities (e.g. cultivation, hunting ranges, trading routes, and networks) – to microscopic study of the deposits, artifacts, and features found within them. In the following chapters we examine the issues linked to landscape scale geoarchaeology, and describe the most salient aspects of some of the principal geological environments and processes that geoarchaeologists are likely to encounter. Although archaeological sites and associated remains can be found in most geological environments (including what is now marine; Faught and Donoghue, 1997), most human occupations, or at least their traces, are not evenly spread throughout these environments. Sites associated with temperate *fluvial* (stream) environments, for example, are considerably more abundant than those from desertic or glacial terrains. Thus, although we try to touch on all these situations, we may provide more detail for those with greater representation in the geoarchaeological record. Detailed treatises on geological environments can be found in many geomorphology and sedimentology texts, such as Boggs, 2001; Easterbrook, 1993; Reading, 1996; and Ritter *et al.*, 2002.

1

Sediments

1.1 Introduction

Sediments – those materials deposited at the earth's surface under low temperatures and pressures (Pettijohn, 1975) – constitute the backbone of geoarchaeology. The overwhelming majority of archaeological sites is found in sedimentary contexts, and the material that is excavated – whether geogenic or anthropogenic – is sedimentary in character. In this section we examine some of the basic characteristics of sediments, many of which can also be applied to soils (Chapter 3). We have two principal goals in mind. Since sediments are so ubiquitous in archaeological sites, it is necessary to have at least a working knowledge of some of these characteristics so as to be able to share this descriptive information with others. Essentially, these descriptive characteristics constitute a *lingua franca*: the term "sand" (Table 1.1), for example, corresponds to a defined range of sizes of grains, irrespective of composition. Second, and perhaps more important, is that many of the descriptive parameters that we observe in sediments commonly reflect – either individually or collectively – the history of the deposit, including its (1) origin, (2) transport, and (3) the nature of the locale where it was deposited, that is, its environment of deposition. Figuring out these three aspects of a sediment's history constitutes a subliminal mindset of sedimentologists, whether they are studying a 100 m thick sequence of Carboniferous sandstones in Pennsylvania or a 10 cm thick sandy layer within a Late Pleistocene cave in the Mediterranean. In sum, by observing and recording the lithological attributes of a sediment we not only provide an objective set of criteria to describe it, but also a means to get some insights into its history.

1.2 Types of sediments

Sediments can be classified into three basic types, clastic, chemical, and organic, of which the first two are generally the most pertinent to geoarchaeology. Clastic sediments are the most abundant type. They are composed of fragments of rock, other sediment, or soil material that reflect a history of erosion, transport, and deposition. Most clastic sediments are terrigenous and deposited by agents such as wind (e.g. sand dunes), running water (e.g. streams, beaches), and gravity (e.g. landslides, slumps, colluvium). Typical examples of clastic sediment (as based on decreasing sizes of the components) are sand, silt, and clay (Table 1.1). In the geological record, when such materials become lithified, the resulting rock types are sandstone, siltstone, and shale, respectively.

Volcaniclastic debris, consisting of volcanic ash, blocks, bombs, and pyroclastic flow debris are also considered as clastic sediments (Fisher

TABLE 1.1 Common grain size scales used in geology and pedology

Wentworth class (geology)[1]	Size range	Phi (Φ) units[2]	UK soil science class equivalent[3]	Size range	USA soil science class equivalent[4]
Boulder	>256 mm	−8	Boulders Very large stones	>600 mm 200–600 mm	
Cobble	64–256 mm	−6 to −8	Large stones	60–200 mm	
Pebble	4–64 mm	−2 to −6	Medium stones Small stones	20–60 mm 6–20 mm	
Granule	2–4 mm	−1 to −2	Very small stones	2–6 mm	
Very coarse sand	1–2 mm	0 – 1			1–2 mm
Coarse sand	0.5–1 mm	1–0	Coarse sand	0.6–2 mm	0.5–1 mm
Medium sand	250–500 μm	2–1	Medium sand	212–600 μm	250–500 μm
Fine sand	125–250 μm	3–2	Fine sand	63–212 μm	100–250 μm
Very fine sand	63–125 μm	4–3			50–100 μm
Coarse silt	31–63 μm	5–4	Coarse silt	20–63 μm	Silt = 2–50 μm
Medium silt	16–31 μm	6–5	Medium silt	6–20 μm	
Fine silt	8–16 μm	7–6	Fine silt	2–6 μm	
Very fine silt	4–8 μm	8–7			
Clay	<4 μm	>8	Clay	<2 μm	<2 μm

1. Modified from Nichols, 1999
2. $\Phi = -\log_2 d$ (d = grain diameter)
3. Avery, 1990; Hodgson, 1997
4. Soil Survey Staff, 1999

and Schmincke, 1984), Overall, they are relatively uncommon in geoarchaeological contexts as they are restricted to volcanic areas. Nevertheless, they constitute an important aspect in the stratigraphy and formation of some key archaeological sites. Pompeii, considered the type site for depicting instances in archaeological time (Binford, 1981), is covered by about 4 m of volcaniclastic debris (tephra), consisting of pumice, volcanic sand, lapilli (2–64 mm), and ash (<2 mm) (Giuntoli, 1994). The site of Ceren, in San Salvador, represents a similar type of setting, where structures and agricultural fields were buried under several meters of tephra (Conyers, 1995; Sheets, 1992). Volcaniclastic deposits in rift valleys play critical roles in the dating and stratigraphy of Pliocene and Pleistocene deposits from sites in East Africa, the Jordan Rift, Turkey, and Georgia. Sites such as Olduvai Gorge, Koobi Fora, Gesher Benot Ya'akov, and Dmanisi, are just a few of the sites where archaeological and hominin remains are intercalated with volcanic rocks and tephra (Ashley and Driese, 2000; Deocampo *et al.*, 2002; Gabunia *et al.*, 2000; Goren-Inbar *et al.*, 2000; Stern *et al.*, 2002).

Marine organisms such as mollusks and corals, for example, produce shells of calcium carbonate. In cases where these hard body parts are subjected to wave action, they can be broken into small centimeter to millimeter size fragments, resulting in the formation of a bioclastic limestone, for example (Table 1.2). Coquina is an example of a coarse bioclastic

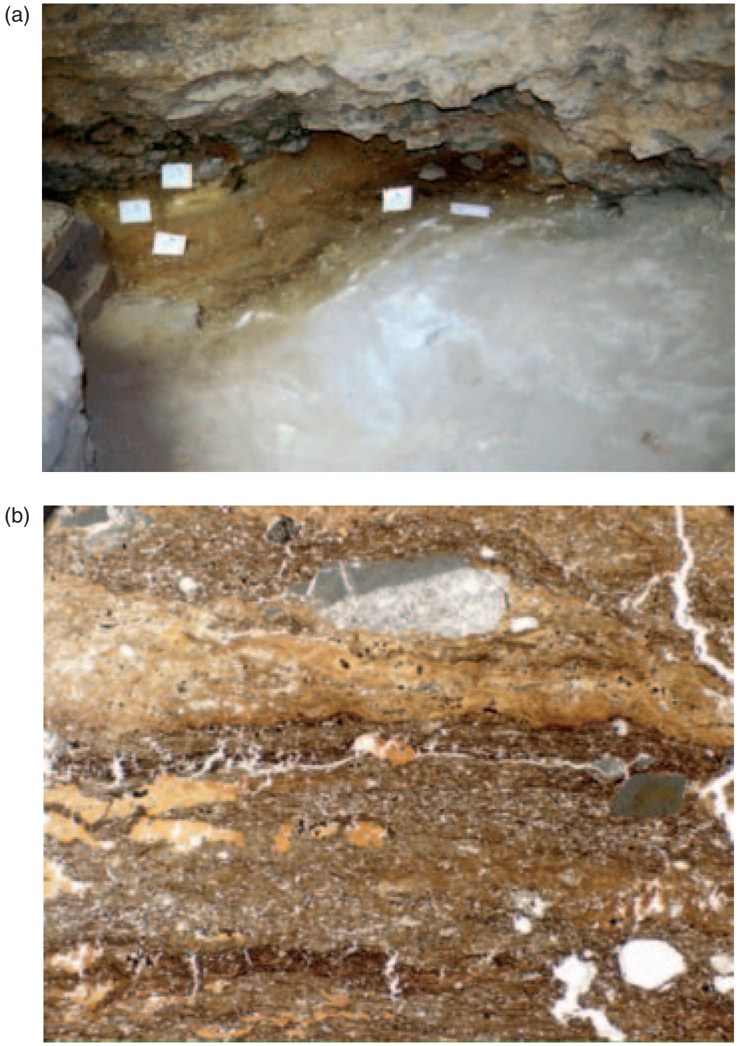

Plate 8.2 (a) Putative hearth from Layer 10 in Zhoukoudian, Locality 1. The structured appearance was long thought to be a result of in situ burning activity associated with the controlled use of fire.
(b) Photomicrograph of thin section from middle of the deposit showing finely laminated mineral and organic material, only some of which is charred. These laminated sediments accumulated in standing water depressions within the cave (see Goldberg *et al.*, 2001 for details.). Plane-polarized light; width of field is ca. 6.4 mm.

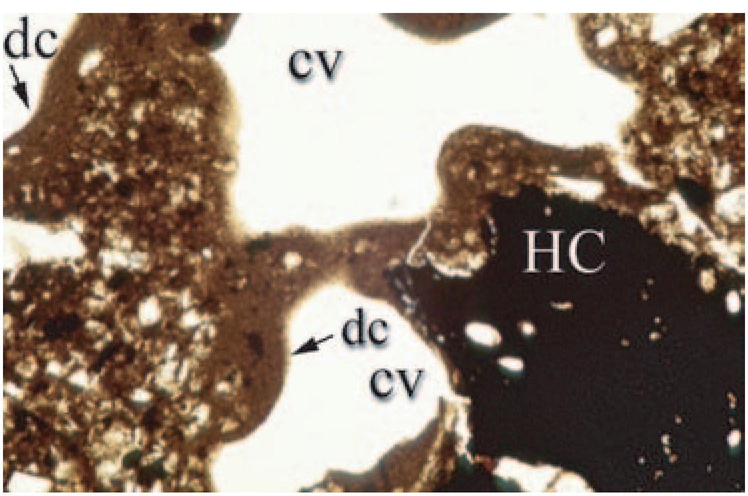

Plate 9.1 Photomicrograph of Neolithic old land surface (Fig. 9.4 OLS) at the "midden area" at Hazleton, showing: very dusty soil containing microscopic and coarse (HC; hazelnut shell) charcoal, the occupation (cultivation, trampled) disturbed soil characterized by closed vughs (CV) formed by very dusty clay (DC) void coatings. PPL, frame is 1.35 mm.

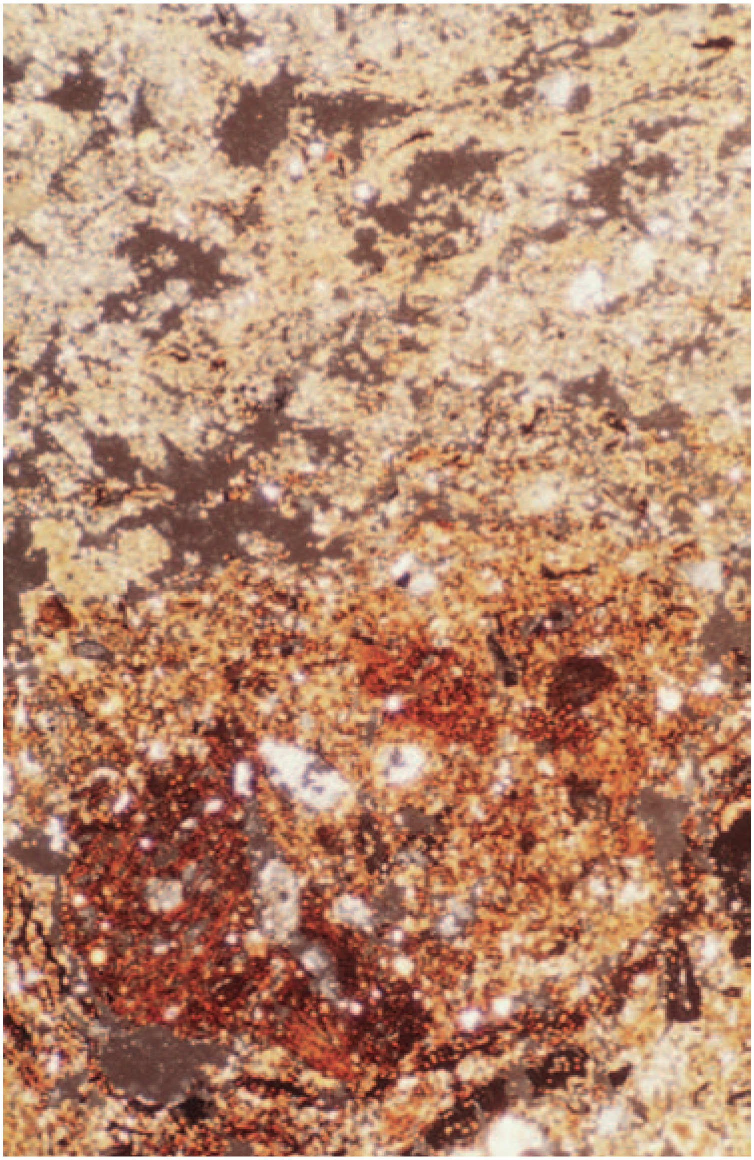

Plate 10.1 Neolithic pastoralism at Arene Candide cave, Liguria, Italy (see Fig. 10.1); *in situ* ashed stabling deposits; photomicrogragh of the junction between the phosphate- and dung-stained stabling floor 'crust', and the overlying ashed fodder and bedding layer; as Fig. 10.1c but under crossed polarized light (XPL), and showing birefringent ash that includes twig ash, faecal spherulites and calcium oxalate remains of tree leaves (Macphail *et al.*, 1997). Note rubefied stabling crust layer (frame width is ~5.5 mm).

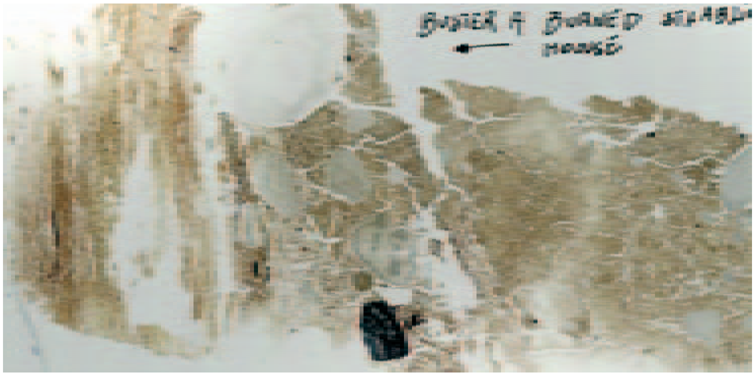

Plate 12.1 Butser Ancient Farm, Hampshire, United Kingdom, 1990; 13 cm long thin section scan of the stabling floor and buried soil, from center of Moel-y-gar stabling roundhouse. 0–30 mm: compact organic stabling floor crust composed of horizontally layered plant fragments embedded in phosphate; 41% LOI; 6,000 ppm P. 30–90 mm: phosphate-stained stable floor with phosphatised chalk clasts and chalk soil, and included coarse wood charcoal; 32% LOI; 2840 ppm P. 90–130 mm: weakly phosphate-stained chalk soil with relict features of earthworm working; 23% LOI; 1460 ppm P.

Plate 13.1 An example of plant-tempered burned daub from Ecsegfalva, Early Neolithic Hungary (Körös culture); daub contains alluvial clay clasts (C) and void pseudomorphs of plant (P) temper; note rubefied edge (RE). Length of thin section scan is ~55 mm.

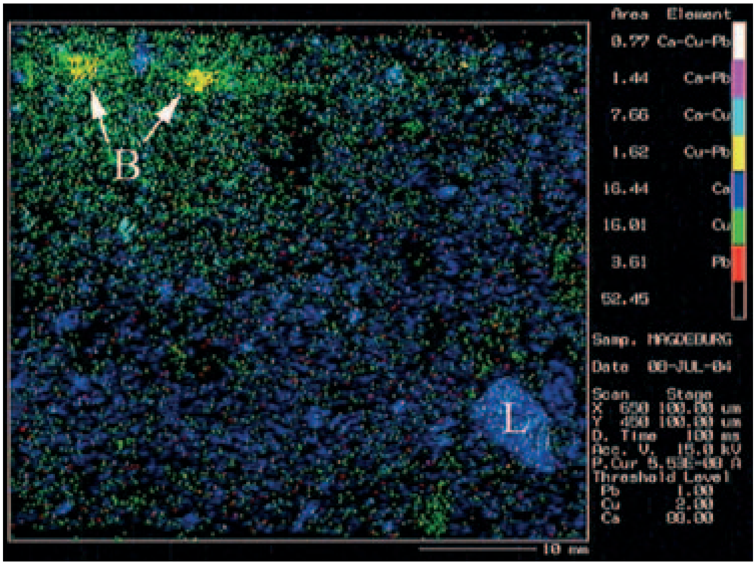

PLATE 13.2 Twelth Century Magdeburg, microprobe maps of Cu (copper) showing location of bronze casting fragments – bronze bell manufacturing evidence; Bronze casting droplets (B) are a focus for Cu-Pb with Cu staining emanating out as corrosion products; there is also a scatter of calcitic (Ca) ash and limestone fragments (L). Scale bar =10 mm

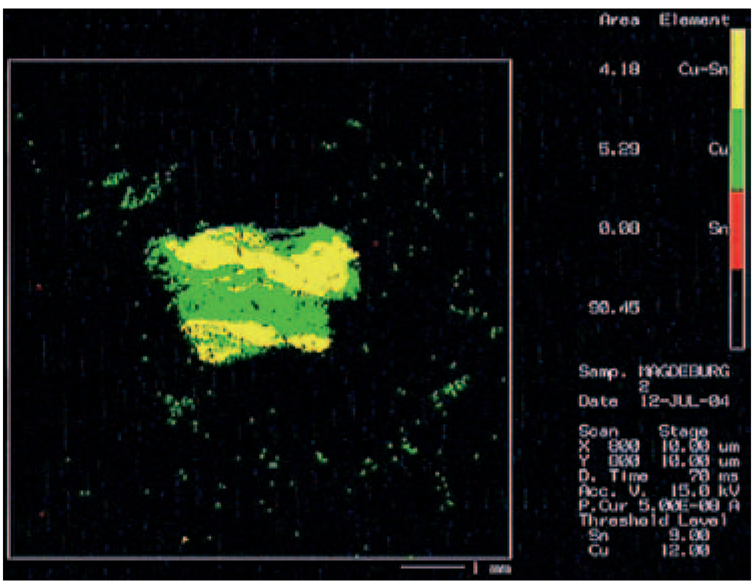

PLATE 13.3 Detail of bronze casting fragment – microprobe map of Cu and Sn (tin). Scale bar =1 mm.