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Introduction to Practical and Theoretical Geoarchaeology

1.1 Introduction

People were doing geoarchaeology long before this term was invented for earth sciences applied to archaeology. One of the authors (PG) can remember a lecture in his first year at the University (1961) by Sheldon Judson on stream erosion in Italy (Judson, 1961, 1963). Shortly after that, he discovered others in the Old World who had carried out or summarized what would be considered "modern" geoarchaeology. These were published as major books that include, for example, works by Cornwall (1953), Zeuner (1946, 1958, 1959), and Butzer (1960, 1964; Butzer and Cuerda, 1962). It gained proper name recognition with the publication of an edited volume: *Geoarchaeology: Earth Science and the Past* (Davidson and Shackley, 1976).

Since that time, geoarchaeology has become highly prominent and almost common parlance on archaeological sites. Geoarchaeological investigations, either as independent research or tied to archaeological projects, appear in reports, monographs, books, and journal articles, and they may be either within a specific section of an article or as a stand-alone publication. The namesake geoarchaeological journal is simply *Geoarchaeology* (Wiley), but the discipline receives some attention in other, more broadly science-focused publications, such as *Journal of Archaeological Science* and *Archaeological and Anthropological Science, Quaternary International*, *Quaternary Science Reviews*, *Quaternary Research*, and others. Finally, geoarchaeological subjects make it into other publications that touch on more mainstream archaeological, anthropological, or geological subjects: *Journal of Human Evolution*, *American Antiquity*, *Journal of Sedimentary Research*, *Antiquity*, and *Sedimentary Geology*. There have also been inclusions in high-end science journals, *Nature* and *Science*.

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. It can be noted here that two of the authors are recipients of the GSA's *Rip Rapp Award for Archaeological Geology*. The Association of American Geographers (AAG) commonly has geoarchaeology sessions at their annual meetings. In Europe, more and more scientific meetings (e.g. Association for Environmental Archaeology, European Association of Archaeologists, European Geosciences Union, UISPP, and International Union of Soil Science (IUSS), Paleopedology Commission) include some aspect of geoarchaeology, including paleopedology, past agricultural practices and other human influences on the landscape, stratigraphy/microstratigraphy, and micromorphology of archaeological soil-sedimentary sequences and living floors.

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Likewise, 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; Wonderwerk, South Africa; Schöningen, Germany); the sedimentary context and the origin of various hominins (Dmanisi, Republic of Georgia; Denisova, Russia; Liang Bua, Indonesia; Boxgrove, UK; Atapuerca, Spain; Mediterranean and South African caves – Gorham's Cave, Gibraltar; Hayonim Cave, Israel, Blombos Cave, South Africa; Olduvai Gorge, Tanzania); peopling of the New World (Gault/Buttermilk Creek sites, Texas); Asian rice cultivation (Huizui, China); large Eastern European and Near Eastern settlements (Borduşani-Popină, Romania; Çatal Höyük, and Aşıklı Höyük, Turkey; Tel Dor, Israel); early management of domestic animals (L'abri Pendimoun à Castellar, France; Arene Candide, Italy; Negev Desert, Israel); tropical and European Dark Earth (Marco Gonzalez, Belize; London Guildhall, UK); and worldwide settlement morphology and funerary practices (Heimdalsjordet and Gokstad Mound, Norway).

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 only a few decades ago when only a handful of archaeological projects utilized the skills of the geoarchaeologist. Still, the best results have come from highly focused geoarchaeological investigations, which have employed the appropriate techniques, and which have been intimately linked to multidisciplinary studies that provide consensus interpretations.

This totally revised book is about how to approach geoarchaeology and use it effectively in the study of archaeological sites and contexts (see Preface). We shall not enter into any detailed discussion of the origins and etymology of "Geoarchaeology" vs. "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 their visibility on the landscape.

Geoarchaeology exists and is performed at different scales (Stein and Linse, 1993). Its usage 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 the location of a site within a drainage system or other regional landscape feature, and some may call this the geotechnical approach. This perspective is at a regional scale that exists in three dimensions, with relative relief possibly being measured in 1,000s 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, while it is more of a preliminary study approach in Europe. Geologists would also be interested in the overall *stratigraphy* of a site (including sediments, soils, features, etc.) and how these aspects might interrelate with major landforms, such as stream terraces, glacial features, and loess plateaus.

Pedologists, on the other hand, would be more concentrated on the parent materials, the surfaces upon which soils formed, and how both have evolved in conjunction with the landscape; these materials can be buried by subsequent deposition or occur on the present-day surface. In either case, pedologists' focus tends to be on the scale of the soil pit, i.e., on the order of meters.

Archaeologists themselves may want to focus geoarchaeological attention upon microscale, cm-thick occupation deposits: what they are, and how they reflect specific or generalized past human activities, and how they may fit into larger behavioral patterns. In the case of rescue/mitigation archaeology, in the USA commonly termed Cultural Resource Management (CRM), geoarchaeology is tailored to the nature of the "job specifications" proscribed by the developer under the guidelines of salvage operations. In Europe, the whole funding remit is to extract as much geoarchaeological and associated paleoenvironmental information as possible, and specialists have urged the importance of site visits, and advising and training of site staff even before machining and excavation commences. Thus, 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 were interrelated with past human occupations. All the above approaches can be relevant depending on the research questions involved; 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 very rarely, some universities (e.g. Simon Fraser University in Canada) actually have archaeology departments; Classical and Near Eastern Archaeology programs are not rare, but 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. Many archaeologists there have no science background, and come from History or Art History.

Although in the UK geoarchaeology is taught in a number of archaeological departments, it is not taught in all archaeology degrees and this is the same across 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 UK and elsewhere in the world, geoarchaeology is often an "optional module" or is found 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. Despite good intentions and good training, many geoscientists tend to be naïve in their approach to solving archaeological problems, and therefore they effectively reduce their potential in advancing this application of their science. This situation often diminishes or even negates their contributions to interdisciplinary projects. The opposite situation can be found, where an archaeologist does not know what questions to ask of a deposit sequence or feature (Goldberg, 1988; Thorson, 1990). Recognition of these educational constraints to what geoarchaeology can achieve for both the site and the researcher is the main *raison d'être* for this 2nd edition.

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. As such, it serves as the lowest common denominator to all archaeological sites worldwide. 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 concisely 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, 2000b).

In Europe during the 1930s to the 1950s, Zeuner 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 (Zeuner, 1946; Zeuner, 1953; Zeuner, 1959). After Kubiëna called the world's attention to soil micromorphology (Kubiëna, 1938, 1953; Kubiëna, 1970; Zeuner, 1946, 1953, 1959), Cornwall, also at the Institute of Archaeology, applied this technique to archaeology for the first time (Cornwall, 1953) (see below). At the same time, Dimbleby (and later, J. G. Evans) 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; Evans, 1972). Duchaufour in France also systematically studied environmental change and pedogenesis (Duchaufour, 1982), and some of the earliest paleo-pastoralism rock shelter studies were developed in France (Binder et al., 1993; Brochier, 1983). In mainland Europe, the legendary French prehistorian François Bordes, whose doctorate in geology was concerned with the study of loess, paleosols, and archaeological sites, principally in Northern France (Bordes, 1954), placed the French Paleolithic within its geomorphologic setting. Vita-Finzi, 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 (Vita-Finzi, 1969). Cremaschi (1987) investigated paleosols and prehistoric archaeology in Italy.

Although some geoarchaeological research is funded by granting agencies (NSF, NGS, NERC, CNRS, DFG, ARC), 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 USA; National Cultural Heritage Administration, China) and national research funding agencies (e.g. NSF in the USA, AHRC and Historic England in the UK, and AFAN and the CNRS in France; Nara National Institute, Japan; Cultural History Museum, University of Oslo, NiKU and NTNU, Norway) 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?" On the other hand, problem-based research could involve the gathering of geoarchaeological data on the possible controlled use of fire, as at Zhoukoudian, China (Goldberg et al., 2001a; Weiner, 1998) or origin of salt working coastal "redhills" in England (Biddulph et al., 2012). 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 have been poorly understood (Macphail et al., 2003a; Nicosia et al., 2017), while South and meso-American tropical Dark Earth (*terra preta*) recorded pre-conquest settlements in some cases (Arroyo-Kalin, 2017). Analysis of "Dark Earth" therefore, became a research-funded topic for urban development sites (CRM projects in urban areas) across Belgium, France, and the UK, for example, Brussels being a particularly well-studied urban area (Devos et al., 2020a).

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, an early interdisciplinary study being Mesolithic Westward Ho! (UK) (Balaam et al., 1987); more recently, South American middens and an Antarctic seal-hunting site have come under scrutiny (Villagran et al., 2009; Villagran et al., 2013). Submerged sites (Grøn et al., 2021) and deeply stratified deposits can be found, and in some cases accessed through cofferdams or coring (Linderholm et al., Submitted) (Macphail and Goldberg, 2018a: 15–20). 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 and history of archaeological sites and past land uses such as herding (Macphail, 2011a); in Norway there can be the added complication of landslides (Macphail et al., 2016). The Po plain of Italy (Cremaschi, 1987; Cremaschi and Nicosia, 2012) and the Yellow River of China (Kidder and Liu, 2017) both feature a series of late prehistoric settlements; water management and wet rice paddy fields are also phenomena of prehistoric east Asia (Lee et al., 2014; Zhuang, 2018). Many of the most significant Paleoindian and Archaic sites in the USA are situated within alluvial sequences (Ferring, 1992; Mandel, 2000a; Mandel, 2008; Mandel et al., 2018).

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. Natural exposures can be supplemented with surface satellite remote sensing data, 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; see references in Gilbert et al., 2017). Moreover, such data can be assembled and interrogated using Geographic Information Systems (GIS) (Landeschi, 2019; Wheatley and Gillings, 2002) that produce deposit models and which can be used to generate and test hypotheses (Carey et al., 2018).

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, etc. 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; now supplemented with micro-XRD), electron microprobe, x-ray fluorescence (XRF and micro-XRF), and instrumental neutron activation analysis (INAA), atomic absorption (AA) have been enhanced by rapid chemical, elemental, and mineralogical analyses of samples through the use of Fourier transform infrared spectrometry (FTIR and micro-FTIR), Raman spectrometry, and by inductively coupled plasma-atomic emission spectrometry (ICP-AES) or mass spectrometry (ICP-MS) (Artioli, 2010; Gilbert et al., 2017; Weiner, 2010).

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 earlier works have been enhanced with new books reflecting the evolution and maturity of the discipline (French, 2015; Karkanas and Goldberg, 2018; Macphail and Goldberg, 2018a; Nicosia and Stoops, 2017; Stoops et al., 2018a). Important topics range from the development of soil and landscape use (French, 2015; Gebhardt et al., 2014; Zhuang et al., 2013), the formation of anthropogenic deposits (Banerjea et al., 2015a; Cammas et al., 1996b; Macphail, 1994a; Macphail et al., 2007a; Matthews et al., 1997), to the evaluation of the first uses of fire (Berna et al., 2012; Goldberg et al., 2001, 2017b; Stahlschmidt et al., 2015b), and the use of experiments and ethnoarchaeology to produce such insights (Banerjea et al., 2015b; Cammas, 2018; Carey et al., 2014; Friesem et al., 2014a; Macphail et al., 2004). The science has also been strengthened by geoarchaeologists standing by their analyses (Goldberg et al., 2009a; Macphail, 1998; Macphail et al., 2006).

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) (Mercier et al., 2007), optically stimulated luminescence (OSL) (Jacobs et al., 2019; Jankowski et al., 2020), and electron spin resonance (ESR) (Duval et al., 2018; Rink and Schwarcz, 2005).

In this book we aim to present a fundamental, wide-ranging perspective of the essentials of modern geoarchaeology in order to demonstrate the breadth of the approaches and the depth of problems that can be proposed and tackled. Additionally, it is aimed to promote a basic and straightforward line of communication and understanding among all multi-disciplinarians. 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 present a survey of some of the most common geological terrains that provide the natural settings for most archaeological sites, and expanded into chapters on “slopes”, “rivers”, “lakes, “aeolian settings”, “marine coasts”, and “caves”. These are established geoarchaeological topics into which we have incorporated some new findings. Unlike many books on geoarchaeology, we have dedicated a major portion of the volume to topics that were normally not treated in many geoarchaeological texts. While the first edition (2006) pioneered chapters on “human impact”, “occupation deposits”, “human materials”, and “applications to forensic science”, for example, these have been revised into “clearance, cultivation and other soil modifications” (e.g. from mining), “human use of materials”, “anthropogenic deposits”, “experimental and ethnogeoarchaeology”, and “forensic and mortuary geoarchaeology”. The topics span the course of human history from early hominins in African caves, major food production developments across south-east Asia to settlement patterns and urban sites across Europe and south-west Asia.

Similarly, it is important also to obtain some insights into practical aspects of geoarchaeology, including how geoarchaeologists should specifically fit in to a project. Similarly, two chapters are devoted to a presentation of pragmatic and theoretical methods currently used in geoarchaeology. These include not only field techniques (e.g. from remote sensing, satellite and drone imagery, coring, to describing a profile and collecting samples), but also those techniques that are used in the laboratory (varying from bulk, microscope to instrumental approaches). Although we summarize the “what” and “how”, we also try to emphasize the “why” and provide several example-based caveats for important techniques. A final facet deals with the practical aspects of manipulating and reporting geoarchaeological results (e.g. with GIS) while 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. We suggest electronic archives can be best accessed online, but these websites need to have been built and be under continual maintenance.

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 geo-specialist simply turning over results to the archaeologist, essentially being unaware of the archaeological problem(s), both during the planning stages and later, after 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, mutually understood, and best interpreted.