Earth Science and Archaeology

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Over the past few decades there has been a considerable increase in attempts at and interest in the integration of the earth sciences and archaeology. Specifically, this integration is oriented toward applying the principles and techniques of the earth sciences in solving archaeological problems. These approaches to archaeology range from employment of a full-time field geologist on the staff of large research projects to the petrographic analysis of pot sherds or remote sensing studies of archaeological sites. Several anthropology departments in North America also now include geologists and physical geographers on their faculty. These developments are to be applauded, for all of the individuals and disciplines involved have much to gain from one another. Many archaeologists have long recognized the importance of at least certain kinds of geologic data, but now there is increasing recognition of the significance of archaeological data in the earth sciences, especially in the areas of chronology and human impact on the biosphere. Unfortunately, we will probably never witness the extinction of archaeological books, monographs, or reports that relegate such investigations as soils or sediments to appendices.

The emerging discipline involving the interface of archaeology and earth science has been given a number of names and there is a considerable body of literature on the terminological subtleties involved. At the risk of semantic overkill this reviewer would like to take the opportunity to add a few more observations. “Geoarchaeology,” “archaeological geology,” and “archeogeology” have been applied to the topic under consideration. Some writers such as Butzer (1980, 1982), who coined the term “geoarchaeology” (Butzer 1973) and Rapp and Gifford (1982; 1985, in the volume under review) detect subtle but significant differences between the terms.

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Others, such as Gladfelter (1977, 1981), Hassan (1979), and Farrand (1985) appear to be less particular and use the terms more or less interchangeably. To this reviewer there is no significant distinction between archaeology done by means of geological methods, techniques, or concepts, as Butzer (1980) defined geoaarchaeology, and the applications of geological techniques to the solution of archaeological problems, given as the definition of archaeological geology (Rapp and Gifford 1982). The preferred term in this paper is geoaarchaeology. Geoarchaeology is here defined as the application of the earth sciences to archaeological problems or, as Gladfelter (1981) defined it, the geoscience tradition within archaeology. Geoarchaeology is the preferable term in part because of its simplicity; it is easier to write and speak. Moreover, geoarchaeology accommodates all of the earth or “geo” sciences, such as geography and soil science in addition to geology; it does not restrict earth sciences to geology.

With the growing interest in geoarchaeology is a demand for more literature on the topic. Until recently attempts at reviews of the subject or discussion of applications were rare. Butzer (1971, 1982), one of the leading theoreticians and practitioners of geoarchaeology, presents the only single-author volumes dealing with the method and theory of the subject. \textit{Geoarchaeology: Earth Science and the Past} (Davidson and Shackley 1976) is one of the only other volumes available and it is primarily a diverse collection of papers dealing with sediments and stratigraphy at archaeological sites. Several journals which often have geoarchaeological papers have also appeared, including \textit{Archaeometry} and \textit{Journal of Archaeological Science}, and several informative newsletters are now available with the founding of such organizations as the Archaeological Geology Division of the Geological Society of America and the Society for Archaeological Sciences. It was, therefore, of considerable interest to the geoarchaeological community when the volumes under review here, \textit{Archaeological Geology} and \textit{Archaeological Sediments in Contexts} appeared in the spring of 1985, followed, incidentally, within a year by the \textit{International Journal of Geoarchaeology}.

The two new volumes are welcome additions to the geoarchaeological literature. The authors of the combined total of 23 papers include individuals well-known in the field as well as newer practitioners and established specialists from other disciplines. The writers share a considerable amount of information on a wide variety of topics. It is unfortunate that the papers are not as up-to-date as one might wish. In the Stein and Farrand volume most of the contributions have citations as recent as 1983. There are few references from 1983 in the Rapp and Gifford work, however. Both publications apparently suffered from long turn-around times.

\textit{Archaeological Geology} contains 14 papers plus a bibliography of archaeological geology. Editors John Gifford and George Rapp present the first chapter in the book, “History, Philosophy, and Perspectives.” This is an interesting and informative history of the relationship between archaeology and geology, which began in the first half of the last century in Europe as a natural outgrowth of the debate over the antiquity of humankind. The authors persuasively argue that this close collaboration waned, particularly in this country, early in the 20th century as each discipline became more rigorously defined and especially as archaeology transformed “from a natural to a more social science” (p.10). Throughout much of this century geoarchaeology in this country was confined largely to the question of
human antiquity, involving such notable geologists as Ernst Antevs and Claude Albritton. The work of John Hack and Kirk Bryan in the west are principal exceptions to this trend. Only in the last few decades has geoarchaeology emerged as a recognized discipline in North America as part of the general trend toward more interdisciplinary, environmentally oriented, archaeological studies. One significant omission in this historical survey is mention of the "eolith" debate in Europe in the later 19th and early 20th centuries. The various studies of rock-breakage carried out at the time provided the foundation for much of modern experimental lithic technology. Also, in historical treatments of geoarchaeology there should be some mention of the important work of E. H. Sellards, Glen Evans and Grayson Meade for the Texas Memorial Museum in Texas and New Mexico from the 1930s through 1950s (e.g., Evans 1951; Sellards 1952).

Chapter 2 is a discussion of "Geomorphology and Archaeology" by Donald Davidson. The focus is on the Old World with, unfortunately, little mention of such work in North America and the paper primarily presents some applications of geomorphic principles and techniques to archaeology. These applications include geomorphic mapping for site-distribution analyses and as a framework for studying environmental change, followed by a discussion of the use of evidence for geomorphological changes along rivers and coasts and in deserts and caves for paleoenvironmental reconstructions. The emphasis throughout the paper is on human-land relationships with enlightening discussions of how earth surface processes can affect site location and distributions and the nature of the archaeological record itself both during and following occupation. There is also a brief, but important discussion of the use of geomorphic analysis in site conservation, a topic all too seldom considered. Although examples from North America would be useful, this paper is an excellent review of some of the many ways in which geomorphology can contribute to archaeology.

In Chapter 3 John Kraft and his associates review "Geological Studies of Coastal Change Applied to Archaeological Settings". The paper is largely a discussion of their own previously published, though nevertheless significant, research in the eastern Mediterranean and along the Atlantic coast in Delaware. The emphasis is on paleogeography and site preservation. They demonstrate how drastically the relationship between a site and the ocean can change as a result of sea level change, of particular concern to those looking for or working with late Pleistocene and early Holocene sites on the Atlantic and Gulf coasts. The work of these individuals makes for valuable case histories, though it is already widely available (including a chapter in the Stein and Farrand volume, discussed below), and the paper could have been strengthened with the inclusion of the work of others, such as Snow (1972) in New England, DePratter and Howard (1977) along the Texas coast, or some of the papers in Masters and Flemming (1983).

Chapter 4, "Paleoenvironments and Contemporary Archaeology: A Geoarchaeological Approach," by Fekri Hassan, is a fine companion paper to that of Davidson in Chapter 2. Hassan argues for the use of the earth sciences far beyond the standard applications such as stratigraphy, site-specific depositional environments, and dating and discusses how geomorphic and sedimentological data can be used to evaluate site-formation processes (including post-occupation changes), subsistence activities, settlement location, and regional paleoenvironments. The
case histories discussed are from Egypt, but a wide variety of applications and techniques from many areas is cited.

Reuben Bullard's Chapter 5, "Sedimentary Environments and Lithologic Materials at Two Archaeological Sites," is one of the weakest in the volume. The chapter covers the author's work at sites in Israel and Tunisia and appears to serve as an example of the kinds of information geologists can provide archaeologists, but the purpose of the paper is never made clear. A number of important geoarchaeological topics are discussed or raised including the significance of the physiographic setting of an archaeological site and the difficulties of applying standard sedimentological terms to various sorts of cultural deposits (such as wheat). However, there is no overall pattern or cohesion to these discussions, and the paper ends rather abruptly with a discussion of harbour sediments. There are also a number of terms introduced without explanation, including, from soil science, "C-Ca [sic] calichified zone" (p. 105), "rendzina" and "rendzinate" (p. 107), and "caliche" (p. 120), along with the curious term "soil-sediment" (p. 130). Many readers will probably be lost in this review.

Chapter 6, "Palynological Applications to Archaeology: An Overview" by James E. King, is a fine summary of this important topic. Besides the better known applications of palynology to regional environmental reconstructions, King also reviews the role of pollen in microenvironmental reconstruction, dietary analyses, and investigations of agricultural practices. The author also draws from his own extensive research in the American Midwest to illustrate how methods of investigation should be designed according to the questions being asked.

Soil science in archaeology is addressed by Robert C. Eids in "Theoretical and Practical Considerations in the Analysis of Anthrosols" (Chapter 7). The paper focuses on soil chemistry rather than on pedology (soil morphology, classification, and genesis) and is composed principally of a twenty-one page introduction to soil chemistry, a five page summary of soil horizon nomenclature, four pages on analysis of anthrosols (soils significantly modified by human activity) focusing on phosphates, the author's specialty, and closing with an appendix on laboratory determination of phosphates, organic carbon, Eh, and pH. Most of the information in the paper is useful and well presented, but rather out of balance. The introductory material could have been shortened and the discussion of anthrosols expanded. As it is, the reader will probably gain a better understanding of anthrosols by referring to Eidt's (1984) monograph on the topic. The soil horizon nomenclature could be eliminated because most of the chapter has little to do with soil morphology. Moreover, the horizon and classification terminology used in the chapter is based on European systems, which is fine as far as it goes, but there is no correlation with the U.S. Soil Taxonomy, which will cause difficulties for most American workers. Finally, there was no discussion of alternate chemical analyses. Many archaeologists, including geoarchaeologists as well as other earth scientists, are not aware that there are different ways of analyzing some chemical characteristics and the results are not always comparable. For example, it would be useful to know how Eidit's various phosphate fractions compare with the forms of phosphorous used in soil-geomorphic studies (e.g., Birkeland 1984; Walker and Syers 1976).

In Chapter 8 John Weymouth and Robert Huggins provide a nice summary of "Geophysical Surveying of Archaeological Sites". The emphasis is on magnetic and
resistivity surveying. For each method the history, theory, methods and instrumentation, and applications are described along with a number of examples of the employment of each technique. A useful addition to the discussion would be the limitations of each technique. One final point—the term "soil sediment" (p. 222) crops up again, defined as sediment in which a soil profile has formed. Other "types" of sediment listed include sand, till, and mud. The presence of a soil profile in no way determines a type of sediment, and the other "types" mix classifications based on texture and genesis.

The next three chapters deal with various dating techniques. "Archaeomagnetism", Chapter 9, by D. H. Tarling, is a well done overview of the topic. There is a good discussion of the theory behind the method and its potential as an absolute dating technique which, unfortunately, has yet to be fully realized. Other applications of the technique include provenance studies and artifact reconstruction. Virginia Steen-McIntyre also presents a good review of "Tephrochronology and its Application to Archaeology" in Chapter 10, which covers the theory of the technique, practical field methods for taking ones own samples, and a good choice of case histories. The uses of tephrochronology in stratigraphy, dating, and preservation of buried surfaces and artifacts are well outlined. The paper also includes an exceptional bibliography. In Chapter 11 Robert Folk and Salvatore Valastro present an excellent, short discussion of "A Successful Technique for the Radiocarbon Dating of Lime Mortar." This is an important, though for many a highly specialized, approach.

Ceramic analysis is dealt with by Diana Kamilli and Arthur Steinberg in Chapter 12, "New Approaches to Mineral Analysis of Ancient Ceramics." They discuss methods useful in the analysis of ceramic materials and firing histories of pottery, including transmitted and reflected, unpolarized, and polarized light, the scanning electron microscope and electron microprobe, element density scanning, and photomicrograph analysis. They make a valuable point that many or all of these analyses may be necessary to answer the questions at hand. As an example, all of these methods are applied to a single sherd in order to determine the provenance of the raw materials used and the firing technology employed. This chapter will be most useful to those ceramicists with some geological training, because no glossary or other attempts at explaining the technical terms are used.

The last two chapters in the volume deal with provenance studies of the raw materials used in manufacturing artifacts. Both papers are very well done and nicely illustrate how geologic techniques can be used to identify raw material sources. Chapter 13, by Norman Herz, is on "Isotopic Analysis of Marble." The marble in question is for Greek artifacts. Petrographic techniques, trace element analysis, and electron spin resonance have been used in provenance studies with varying degrees of success, but using the stable isotope signatures of carbon and oxygen now appears to be the most promising method. The paper describes the method, how it has been applied to specific artifacts and quarry sites, and also for use in reconstructing broken artifacts. George Rapp, in Chapter 14, provides a survey of "The Provenance of Artifactual Raw Materials". This brief but comprehensive paper reviews such geochemical and geological techniques as trace element, stable isotopes, neutron activation, and mass spectrometry used for "fingerprinting" and determining the sources of lithics, ceramics, and metals. Rapp also
emphasizes the use of powerful statistical techniques in sorting through the tremendous quantities of data generated by the analyses.

At the end of the book is a 52-page "selective bibliography" of geoarchaeology. It is organized by topic including 19th century studies, ceramic petrography, environmental geoarchaeology, geochronology and dating, geomorphic studies, geophysical prospecting, hominid studies, lithic materials, metals and mining, paleoclimatology, paleontology, provenance studies, archaeological sediments, site geology, and a miscellaneous category. This bibliography, combined with the references from the other chapters should prove an invaluable source for researchers. The volume ends with a very short and incomplete index.

The purpose and audience of this volume are not made explicit. Apparently the book is intended to be a broadly based introduction to the topic. As is the case with many anthologies, however, the coverage is very uneven. The papers range from general surveys of particular fields to specific techniques or site specific studies. Moreover, a number of important topics are left out or only marginally touched upon. Sediment studies were not included although they are covered in some detail in the Stein and Farrand volume (see below). Pedology, other than Eidt's discussion of anthropods, is also conspicuous by its absence. Soils are mentioned by a number of authors, but their nature and significance apparently misunderstood. Beyond soil chemistry there have been few successful attempts at outlining a "useable methodology" (Butzer 1977) for the archaeological interpretation of soils. However, credit must be given the editors for bringing together the first broad coverage of geoarchaeology under a single cover.

Archaeological Sediments in Context consists of nine papers resulting from a symposium on the topic held at the 1982 meetings of the Society for American Archaeology. Following the introduction there are four general papers dealing with sediments in various settings, then four more papers that essentially cover additional sedimentary environments but are more geographically restricted than the preceding contributions. In the brief introduction to the volume Stein and Farrand identify the goal of the symposium which resulted in the volume as the examination of the "various roles of sediment analysis in the study of: a. the sedimentary matrix containing the artifacts; b. the history of sediment accumulation within a site; and c. the prediction of site location" (p. 1). There follows a discussion of the history of the field and the author's own theoretical approach to geoarchaeology and sediment analysis. The approach is a holistic one, with sediment analysis viewed as an integral part of the study of the social, physical, and biological world of prehistoric peoples. The holistic approach is also an important part of sediment analysis as seen in the writer's emphasis on context. As stated "If one examines archaeological sediments, not just for the purpose of environmental reconstruction, but also in reference to the content of archaeological remains and site-formation processes, it can be readily appreciated that sediment studies are an essential component in prehistoric research" (p. 2). Their short discussion is enlightening and the approach admirable.

Stein's chapter, "Interpreting Sediments in Cultural Settings," is an excellent introduction to sediment analysis and various approaches that can be taken to sorting out human versus natural impact on sediments in a site. There are several particularly noteworthy aspects of the paper. Soils and sediments, terms often and
inappropriately used interchangeably, are explicitly defined and differentiated (p. 6). Following a nice summary of approaches to collection, analysis, and interpretation of sediments, three case histories of archaeological sediment analysis are presented, including a shell midden in Kentucky, a village in Greece, and a rockshelter in Missouri. This is an important discussion illustrating the different kinds of approaches that can or must be taken as the situation varies. The paper also has a good collection of references. In reading the paper two points come to mind which are not discussed. First, researchers must be aware of and able to identify textural variation resulting from soil-forming processes (such as eluviation and illuviation of clay). Also, as mentioned earlier, there are a number of ways of performing certain analytical techniques and presenting the resulting data, but these may be difficult if not impossible to compare.

Farrand’s chapter on “Rockshelter and Cave Sediments” is a good overview of the subject. In the introductory statements he emphasizes the necessity for full interaction among the archaeologists, earth scientists, and other specialists on an archaeological project, making the important point that in the absence of an on-site geoarchaeologist a sediment sample put in a bag becomes simply a “sack of dirt” (p. 22). There follows a good general statement on the rockshelter/cave-mouth environment. Most of the rest of the paper deals with rockshelter sedimentology, including a particularly useful discussion of presentation and interpretation of data. It is unfortunate that this otherwise fine chapter has such a short list of references cited. There is some overlap between this chapter and Stein’s review of sediment studies in a rockshelter. This is not a significant problem, however, because Stein’s rockshelter discussion complements Farrand’s chapter.

The following chapter, “On the Interpretation of Archaeological Sites in Alluvial Settings,” is by Bruce G. Gladfelter. Archaeologists have always been aware of the significance of streams and rivers and associated environments in the archaeological record, but seem to be generally unaware of the great strides made in studies of fluvial geomorphology over the last 30 years. This paper, the best in the volume, brings together archaeology and contemporary fluvial geomorphology emphasizing the humid mid-latitudes. Among other significant points raised are the effects of pedogenesis on sediment texture and the uses and abuses of particle-size data in archaeological reconstructions (p. 42–43), that archaeological materials in alluvial settings are part of the sedimentary record (p. 43–44), the difficulties of interpreting radiocarbon dates from alluvial settings (p. 44–46), and the many complexities and pitfalls inherent in reconstructing climate from alluvial records (p. 46). A number of case histories are cited, primarily from the American Midwest, where so much fluvial geomorphology has been done, and the paper ends with a very good list of references.

Fekri Hassan’s paper “Fluvial Systems and Geoarchaeology in Arid Lands: with Examples from North Africa, the Near East, and the American Southwest” is a companion paper to Gladfelter’s. The paper has a nice, though brief introduction to arid environments. The rest of the paper deals with weathering and pedogenesis, erosion and transportation, fluvial processes, geomorphic settings of alluvial sites, lithologic associations, alluvial aggradation, and allogenic streams. The discussion of allogenic streams (those that receive their water from outside the arid area) is particularly significant. The other discussions are fine as far as they go, but much
more could have been included and there are significant omissions. Contrary to the title there is very little discussion of the important geomorphological work done in the American Southwest. There is no discussion of arroyos and their environmental and stratigraphic implications (e.g., Cooke and Reeves 1976; Hall 1977). This could have broadened the statements on aggradation (p. 65–66) which are too general considering the enormous complexities of fluvial systems in deserts. There is no mention of the landmark soil-geomorphic studies in the Rio Grande Valley of New Mexico (summarized in Gile et al. 1981) and there is little discussion of the significance of dust, especially in soil-forming processes. In an introductory statement on erosion and transport there is the unusual statement that in arid-land streams “clay-sized material is virtually lacking” (p. 55). This ignores systems such as the Rio Puerco of New Mexico, with a sediment load as high as 680,000 parts per million including a significant silt and clay fraction (Hawley et al. 1983); a stream often described as “too thin to plow and too thick to drink”! Finally, the list of references is simply too short given the vast amount of literature available. Indeed, under the discussion of lithologic associations, including the very important topics of alluvial fans and ephemeral lakes there are no references.

The rest of the chapters in the volume deal with more region-specific studies. This section begins with a paper by George D. Gardner and Jack Donahue on “The Little Platte Drainage, Missouri: A Model for Locating Temporal Surfaces in a Fluvial Environment”. This deals with an attempt to understand surface-site distribution and to assess the potential for buried sites using remote sensing, data from drill holes and test pits, laboratory analyses of sediments, and paleohydrologic reconstructions. The results are interesting and instructive—the sediments and surfaces of the region are very old or very young, thus sites are either on old surfaces and could represent any age, are mixed with thin loess deposits, or, if buried, are very young. A number of the methods and assumptions used in the study are, however, unclear. For example, in testing the model for locating buried archaeological sites only two of the nine potential sites yielded cultural remains, yet these results were considered significant (p. 71). Most of the results of the lab data were published elsewhere, but some sort of summary or representative sets of data would have been helpful, particularly in helping the reader to unravel the rather complex discussion of terrace development (p. 77). A “temporal surface” or the “temporal surface approach” is never fully explained. Finally, the rather out-of-date assumption is made that terraces are formed during periods of glacial advance with a 1955 work the only reference to terrace development and the archaic four-fold sequence of midcontinent glacial stratigraphy is used with passing reference to “recent work” showing “a more complex Pleistocene stratigraphy” (p. 73). Although glacial stratigraphy is not the point of the paper, assumptions of terrace age based on glacial stratigraphy are used to predict archaeological site locations and it would seem wise to use the most up-to-date information and ideas on glaciation and terrace development.

“Geoarchaeological Interpretations of Great Lakes Coastal Environments” is discussed by Curtis E. Larsen. This valuable contribution deals with certain characteristics of lake environments not always appreciated or recognized by archaeologists. The paper includes a good background discussion of geoarchaeologically significant aspects of Great Lakes environments and a history of regional
shoreline studies and previous geoarchaeological investigations. The rest of the paper deals with the now more apparent complexities of Great Lakes shore environments, the implications of this on site location, preservation, and prediction, and the author's own lake-level history. The most significant aspect of this is Larsen's case for the presence of buried and possibly well stratified Early and Middle Archaic sites in some locations, contrary to earlier ideas which held that there were no sites dating to the period 10,000 to 5,000 B.P.

John Kraft's paper on "Marine Environments: Paleogeographic Reconstructions in the Littoral Region" is, again, based mostly on his previously published material (Kraft wrote or coauthored 15 of the 19 references cited). The paper has some interesting case histories, but much of the data was presented in the other volume under review here. Given the theme of the volume the value of the presentation could have been enhanced with an expanded discussion of processes of coastal sedimentation and erosion, particularly as related to archaeology, with examples from other regions besides the coasts of Delaware and Greece.

The last chapter in the volume is by Charles Schweger on "Geoarchaeology of Northern Regions: Lessons from Cryoturbation at Onion Portage, Alaska." This interesting paper deals with a process of considerable significance to archaeologists working in the high latitudes. The paper has a brief but informative introduction to the topic of seasonally and permanently frozen ground. There follows background information on the site, then a summary of the buried soils apparent in the stratigraphic sections. Most of the rest of the paper is a discussion of the cryoturbation features at the site and the paleoecological interpretations derived therefrom. There is no question that freezing and thawing can affect context in archaeological sites, but otherwise this paper is out of place in this volume. Little of the discussion pertains to disturbance of the archaeological contexts; the focus is more on the paleoecological aspects of cryoturbation features. Moreover, the paper has little to do with sediments per se and would be more appropriate in a volume on post-depositional processes.

Overall, this volume presents a number of very useful and generally well-done papers built around the topic of archaeological sediments and contexts. Beyond the questionable appropriateness of the paper on cryoturbation, the biggest problem is one of omission. Two very important topics were left out: eolian environments, especially sand dunes and loess, and lake basins. This is quite unfortunate considering the number of archaeological sites found in these settings.

It is difficult to compare Archaeological Geology with Archaeological Sediments in Context. The former covers a wide range of topics and the latter is focused on a specific theme. For that reason the Stein and Farrand volume is more successful in fulfilling its goals, being considerably more cohesive. This reviewer would like to suggest to future editors of geoarchaeology volumes to either build around a collection of papers on various general topics or to focus on a theme as done by Stein and Farrand. Geoarchaeology is simply not a topic that can be covered in any detail in a single volume; the earth sciences cover too broad a group of disciplines.

In closing it should be emphasized that a book or collection of books will not turn anyone into a geoarchaeologist; adequate training in archaeology and the earth sciences is mandatory. This is not to say that all archaeologists should be geoarchaeologists. What is important is that both earth scientists and archaeologists
interested in geoarchaeology or required to deal with it be able to communicate with one another, to be able to ask the proper questions and understand the answers. Toward these ends Archaeological Geology and Archaeological Sediments in Context, in spite of some shortcomings, are valuable contributions to geoarchaeology and should help to foster communication among and between earth scientists and archaeologists.

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