# The Archaeological Field Staff: The Geologist

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*This article is the first in a series devoted to discussions of the responsibilities, activities, and techniques of the various specialists who might make up a modern archaeological field staff. The articles are all written by scholars with extensive field experience. It is hoped that the series will be beneficial to scholars in framing the design of their research projects, in planning their budgets, and in determining the number and types of specialists best suited for the projects envisioned. Readers are urged to comment on the series in the light of their own experiences in the field: letters will be published in* Perspectives.

*Authors of a few of the forthcoming articles in this series include Vaughn M. Bryant, palaeobotany; Frederick R. Matson, ceramics analysis; and Al B. Wesolowsky, physical anthropology.*

THE EDITOR

*Few major excavations are now mounted without staff representation from the natural sciences. The classical concern of the geologist with stratigraphy and chronology coupled with his/her broad training in the natural sciences makes the geologist a particularly necessary component of the field staff. Responsibilities of the staff geologist are likely to include regional geologic studies, lithology and identification, on-site stratigraphy and sedimentology, other technical assistance (e.g., surveying), and post-excavation laboratory analyses. The staff geologist should play a major role in the final synthesis of all environmental data.*

**Introduction**

The work of a field geologist is in many ways analogous to that of the field archaeologist.

1. Each is a stratigrapher with a sedimentary sequence to interpret.
2. Each deals with problems of chronology: potsherds in archaeological strata are analogous to index fossils in geologic strata. Each uses radiometric dating techniques.
3. Each must deal with an incomplete record: part of any initial depositional sequence is subject to later erosion, intrusion, and alteration.
4. Each is faced with a wide variety of lithological materials, many of which contain information on the origin and subsequent change in the depositional matrix.
5. Each needs accurate maps for a base on which to plot field data.
6. Each has found geophysical prospecting a useful tool when appropriate field conditions prevail.

Since the days of Heinrich Schliemann, natural scientists have worked with archaeologists in the painstaking task of archaeological excavation. In a large-scale modern excavation, the methods and the knowledge of many natural sciences must be applied to extract as fully as possible the information contained in the natural materials and their spatial relationships as found at any excavation site.

Few if any excavations are as well staffed as the situation may merit. It may be contended that if a field staff can have only one natural scientist, this individual should be a geologist. The ordering of the "hard" sciences from the basic or zero order through the dependent orders is:

mathematics — physics — chemistry — biology — geology.

That is, a mathematician can function without a knowledge of any of the others; a physicist must know mathematics in order to do physics; a chemist must know both mathematics and physics to do chemistry; a biologist must know mathematics, physics, and chemistry to do biology, and a geologist must have a basic understanding of each of the other sciences to do a broad range of geology.

Because of his breadth of knowledge, he may assume a broad range of responsibilities on an excavation. For example, most geologists receive training in surveying, lithology, paleontology, chemistry, petrography (microscopy), geomorphology, sedimentology, and stratigraphy. In addition, many geologists have training in one or more of the following related disciplines: geophysical prospecting, air photo interpretation, materials science (metals, slags, cements, ceramics, plasters), botany, ecology, soil science, and computer science.

If both Old World and New World archaeology are taken into consideration perhaps one hundred American geologists have participated on a field expedition. In Old World areas the following archaeological geologists come immediately to mind: Herbert E. Wright, Jr., Sheldon Judson, Claude Albritton, Reuben Bullard, Robert L. Folk, Jr., and William Farrand; in the New World Vance Haynes, John Albanese, Larry Agenbroad, and of course the fathers of New World archaeological geology, E.H. Sellards and Kirk Bryan. Many earth scientists, particularly those involved in Quaternary studies, tephrochronology, paleontology and paleoecology, have made contributions of great significance to archaeology, but this paper deals only with the archaeological field geologist.

**Responsibilities of the Staff Geologist**

The potential responsibilities of the archaeological staff geologist can be discussed under five broad headings.

1. regional geologic studies;
2. lithology and identification;
3. on-site studies;
4. other technical assistance;
5. post-excavation laboratory analyses.

*Regional Geologic Studies*

Prerequisite information for a reasonable understanding of the physiographic setting of a site includes geomorphic studies on two scales. On the larger scale,

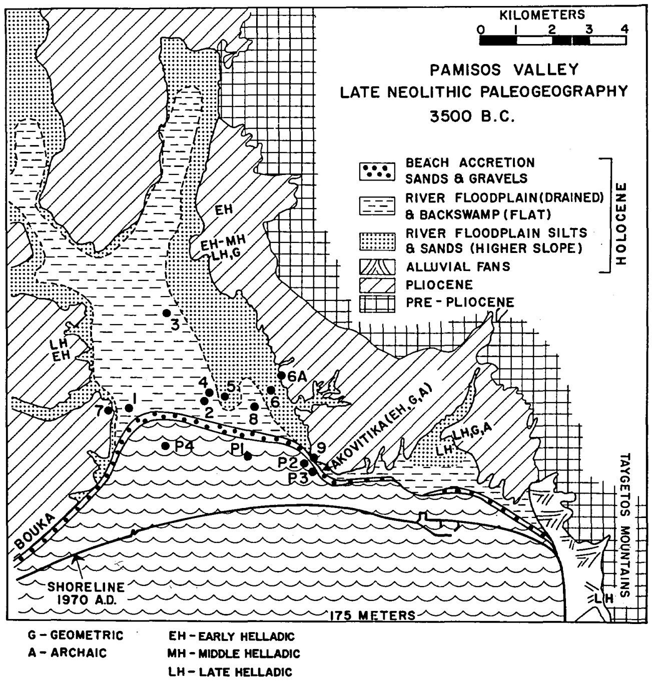


Figure 1. A paleogeographic reconstruction of the Pamisos Valley area, at the head of the Gulf of Messenia, in late Neolithic time. The solid circles indicate the location of drill holes (from Kraft, Rapp, and Aschenbrenner[5]).

studies to determine the paleogeography of areas hundreds or even thousands of square kilometers in extent, such as those of Loy,[1] Butzer and Hansen,[2] or even Vita-Finzi,[3] are of undoubted importance in providing a regional basis for environmental interpretations. The nature and extent of the commitment to large-scale regional studies will vary with the site and with excavation priorities.

The geologist must undertake a systematic study of the geology and geomorphology of the local area containing the excavation site. Such a study has many components. An accurate description of the present regional physiography should be presented on maps. If adequate topographic base maps are not available, they should be constructed for the site and its immediate environs.[4] Regional maps can be made from aerial photographs or satellite photos. These maps provide the base for

1. William G. Loy, *The Land of Nestor: A Physical Geography of the Southwest Peloponnese,* National Acad. of Sciences, Office of Naval Res. Rpt. No. 34 (Washington, D.C. 1970).

2. Karl W. Butzer and Carl L. Hansen, *Desert and River in Nubia* (Madison 1968).

3. Claudio Vita-Finzi, *The Mediterranean Valleys: Geological Changes in Historical Times* (New York 1969).

4. For example, see Jesse E. Fant and William G. Loy, Chapter 2, "Surveying and Mapping," in *The Minnesota Messenia Expedition:*

delineation of agricultural land, roadways, waterways, water supplies, and so forth.

A description of the modern situation must be supplemented by a study of the recent geomorphic changes affecting the area. Geologic processes on the surface are dynamic. River valleys, coastal plains, and hill crests (all prime possibilities for habitation sites) are particularly subject to rapid physiographic change. Erosion, deposition, eustatic sea level change, crustal movements, and climatic change all contribute to altering many regions to the point where modern maps cannot be used to plot features present in antiquity. Rivers such as the lower Mississippi, migrating laterally in broad valleys, can move across the landscape at a rate of kilometers per century. Where major physiographic features have undergone significant change paleogeographic maps should be constructed for plotting the archaeological data relating to the ancient environment of the site.

Using some geomorphic analysis, but primarily drill-core data, three of us from the Nichoria excavation have reconstructed the sequence of coastal environments and shorelines at the head of the Messenian Gulf and provided paleogeographic maps for selected archaeologically important periods in the late Holocene. Figure 1 is one of the paleogeographic maps from this investigation.[5] Note that the shoreline has migrated seaward four kilometers in the last 5,500 years. From the reconstruction it can be shown that the Early Helladic site at Akovitika was constructed along a shoreline. It now lies in a backswamp over a kilometer from the coast. It is also interesting to note that the chronological sequence of habitation sites in this area migrated seaward along with the shoreline. Thus, modern physiographic maps often do not provide an adequate representation of physical features for the periods of archaeological interest.

The staff geologist should be responsible for providing the best paleogeographic maps consistent with available time and funding. Figure 1 is based on data from many drill cores and is but one of many such maps covering many coastal areas included in our investigations. Obviously most excavations have neither the funds[6] nor, perhaps, the need for such intensive studies of physiographic change. Yet the archaeological geologist must at least be prepared to indicate the areas where significant change has occurred and also provide an approximation of the magnitude of such change.

Concomitant with the physiographic study the staff geologist has the responsibility of delineating the bedrock geology of the region. Early man retrieved most of his materials from the locality he inhabited. The bulk of these are rock products (the others are primarily forest and animal products). Thus, a careful study of the lithology of local rock strata can indicate the sources of ceramic and building clays, chert and other lithic materials, temper for pottery,[7] and structural building blocks. A careful survey should also uncover quarry sites and the locations of actual or potential springs, seeps, or other potable water supplies. It normally requires special laboratory studies to authenticate the specific sources for clays, lithic materials, etc. It is imperative to be able to identify which excavated substances were available locally and which were exotic.

Some geologically rarer items such as metals, steatite, obsidian, and so forth are not commonly available near most habitation sites. The geographic origins of these materials are nevertheless important to the understanding of any site because such information often provides some of the best evidence for prehistoric trade and cultural connections. Therefore, related investigations into the provenience of these geologic raw materials are warranted. Examples of such a study are given below in the section on post-excavation laboratory investigations.

In the tectonically active eastern Mediterranean and Near East, earthquakes are frequent in certain seismic zones. It has become popular to ascribe destruction of masonry walls to violent earthquakes, particularly where no evidence of associated fighting and pillaging might point to intruders. I suggest caution in such interpretations. However, the staff geologist should be aware of the abundant seismic literature that exists for these regions. Seismic zones and frequency of quakes of a given Richter magnitude are well-delineated. The major drawback of available data is that Mercalli intensity maps have only rarely been made. These would provide the best data on the local effect of earthquakes on man and structures.

Finally, although the staff geologist may not consider himself a climatologist, he is often the one most qualified to see that paleoclimatologic data are incorporated into the regional environment synthesis. This is especially important for prehistoric sites. For most regions of the world the Holocene period (following the

*Reconstructing a Bronze Age Regional Environment*, eds., Wm. A. McDonald and George Rapp, Jr. (Minneapolis 1972).

5. John C. Kraft, George Rapp, Jr., and Stanley E. Aschenbrenner, "Late Holocene Paleogeography of the Coastal Plain of the Gulf of Messenia, Greece, and its Relationships to Archaeological Settings and to Coastal Change," *Bull. Geol. Soc. Amer.* (1975 in press).

6. Most of the funds for our coastal change project came from sources not connected with the Nichoria excavation.

7. For example, see Reuben G. Bullard "Geological Studies in Field Archaeology: Tell Gezer, Israel," *BiblArch* 33 (1970) 97-132.

retreat of continental glaciers from North America and Europe) has been one of shifting climatic patterns.

*Lithology and Identification*

During excavation there is a daily need for a staff member to identify natural geologic materials, particularly to distinguish between man-made and natural objects. Concretions, for example, can resemble artifacts or fossils.

Bits of metallurgical slag and related evidence of pyrotechnology often go unrecognized. The same may be said for small, non-descript pieces of rock such as pumice. At the Nichoria excavation the identification of pumice led to the recognition of the first evidence from a Greek mainland site for the mid-second millenium eruption of Thera.[8] Other substances that might come to the attention of the staff geologist are exotic bits of clay (such as pure white kaolin), shell, plaster, cement, pozzolanic material, and a variety of oxidized metals. In the case of bronze, malachite is more likely to be found as the oxidation produce than cuprite. In each case the correct identification is likely to be important to interpretation.

Small finds include many objects made from rocks or single minerals (e.g., from steatite, quartz, chert, gypsum, obsidian). Many published objects identified as steatite or soapstone are most likely serpentine. Serpentine has also been misidentified as malachite. The staff geologist should be familiar with the common varieties of these rocks and minerals.

Fine-grained, very black material in a coarser, lighter matrix was often submitted for identification at Nichoria. Such material turned out to be manganese oxide stain, humus, or finely divided charcoal. With the aid of a microscope and simple chemical tests these substances can readily be distinguished. Another common question is whether a given piece of coherent clay earth is the remains of mud brick or other clay building material. This is not always an easy question to answer. At Nichoria, Eiler Henrickson and I were able to determine, through a series of experiments with local clays, that only through accidental firing could any of the Bronze Age mud bricks remain in coherent form. This brief discussion is not intended as a comprehensive guide but rather as an indication of the range of materials found in most excavations.

To assist with the identification of excavated materials it is advisable, where funds and conditions permit, to set up a small laboratory or work area for lithologic analyses. The minimum equipment includes a good binocular microscope; normal mineralogical aids such as streak plates, magnets, steel needles, and the like; dilute hydrochloric acid; a sieve or two, a few simple chemicals, and pH paper. At Nichoria we had in addition a polarizing microscope, a variety of chemical reagents, and a sieve shaker with a complete set of sieves for size analysis of unconsolidated materials.

When contemplating equipment for an excavation, the staff should consider the advisability of incorporating some system to disaggregate and separate the fine fraction of the soil matrix.[9] During the five seasons of excavation at Nichoria we employed several different techniques to recover small archaeological remains. These ranged from various forms of traditional dry screening to froth flotation, wet sieving, and gravity classification. The materials recovered from such processing can be divided into the following categories: shells, bone and teeth, botanical remains (including charcoal and seeds), small finds, pottery, metal, slag, and miscellaneous rock fragments, as well as the size fractions of the mineral sediments.

At Nichoria[10] the recovery of bones and teeth of microfauna through normal excavation procedures was virtually nil. However, 47 of 206 earth samples processed by gravity concentration contained such material. Recovery of these materials can lead to a much more detailed statement of the natural environment of a site. Of 401 composite samples of botanical materials 84 (21%) were recovered by processing the fine sediment of the earth matrix. Of the 401 samples 73 contained seeds; 40 of these were from the gravity concentration processing, i.e., over half of the seeds came from samples recovered by processing the fine fraction of the matrix.

It was in the matter of recovery of metal and metallurgical materials that such processing at Nichoria made one of its major contributions. The results of the excavation of one part of the site (designated Area V) indicated the presence of a copper-working industry. This was established from materials recovered through normal excavation and sieving at the trench. However, very few originally metallic artifacts were found and none of them contained metallic copper; all were com-

8. George Rapp, Jr., Strathmore R. B. Cooke, and Eiler Henrickson "Pumice from Thera (Santorini) Identified from a Greek Mainland Archaeological Excavation," *Science* 179 (1973) 471-473.

9. For example, see David French, "An Experiment in Water-Sieving," *AnatSt* 21 (1971) 58-64; T. W. Jacobsen, "New Radiocarbon Dates from Franchthi Cave: A Preliminary Note Regarding Collection of Samples by Means of Flotation," *JFA* 1 (1974) 303-304; W. Fredrick Limp, "Water Separation and Flotation Processes," *JFA* 1 (1974) 337-342.

10. Data are from the manuscript for the chapter "Screening and Gravity Concentration," by Stanley E. Aschenbrenner and S. R. B. Cooke for *The Nichoria Excavation*, vol. I, edited by George Rapp, Jr. and Stanley E. Aschenbrenner to be published by the University of Minnesota Press in 1976.

pletely oxidized. Without the specimens of metallic copper recovered for analysis by gravity concentration the reconstruction of Middle Helladic I metallurgy could not have proceeded very far. Fortunately, the processing of the fine-grained earth matrix from this area provided a large number of small pieces of metallic copper prills, spatters, and droplets. In addition, the processing recovered many small pieces of slag which has aided the study of the level of metal technology during the early period. Thus, without physically separating and analyzing the fine grained fractions from archaeological deposits, many important data actually present in the deposits may be lost.

*On-Site Studies*

Prior to regular excavation, many large sites located by surface potsherds but with no other remains in evidence require a rationale for selecting the location of trial trenches. Geophysical prospecting methods using primarily the magnetometer and the electrical resistivity meter have proven immensely valuable in certain geologic settings.[11] Relatively flat-lying sedimentary bedrock provides the best terrane. Volcanic rocks preclude the use of the magnetometer because the much larger geologic anomalies will swamp out the smaller archaeological ones.

At Nichoria we used an LSEC proton magnetometer and a Bison electrical resistivity meter in 1969 to identify promising locations.[12] We ran more than 100 magnetomer grids and 40 electrical resistivity surveys. Of the 66 trial trenches dug, 40 were laid out over geophysical anomalies. Of these, 30 revealed significant archaeological features including walls, pits, and burials. Eight anomalies were caused by geologic features (particularly sand lenses picked up by the resistivity meter), one anomaly remains unexplained, and one located a sardine can. The flat-lying Pliocene sediments at Nichoria provide an excellent background for detecting the magnetic contrast between the iron-free limestone building blocks and the surrounding iron-rich settlement debris. The permeable bedrock and fill also provided strong electrical resistivity contrasts to the impermeable limestone of buried walls and foundations.

Figure 2 is a plotted magnetometer anomaly and

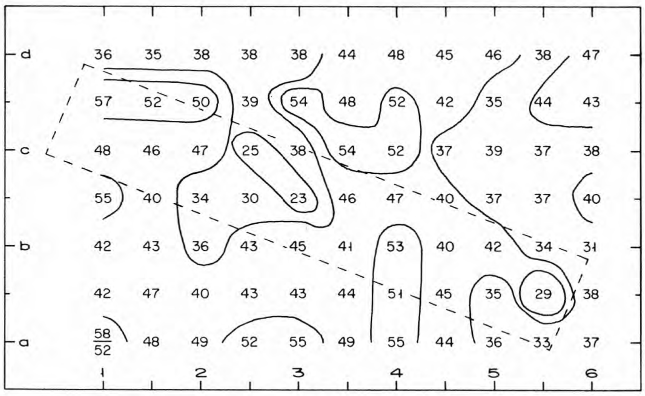


Figure 2. Contoured raw magnetometer data from one 6 m. x 10 m. grid. The rectangle outlined by the dashed lines indicates where the trial trench was to be dug.

Figure 3. Results of the preliminary excavation of the trench outlined in Figure 2.

Figure 3 shows structures unearthed in the trial trench.

A major role for the archaeological staff geologist lies in studies of the archaeological sedimentary matrix on the site. The methods of sedimentology and microstratigraphy are just beginning to be applied to archaeological strata. The primary criterion used by digging archaeologists to delineate levels or strata is color. Texture and structure usually remain secondary criteria. Yet the geologist knows that texture (primarily grain size for clastic materials) and lithology are most likely to provide the evidence for establishing the depositional environment and the depositional processes.

Geologists have long used peels for the study of unconsolidated sediments. Peels are impregnated surface samples that show sedimentary structures as well as objects such as bone, charcoal, ash, and sherds. Peels are, therefore, both outcrop samples and replicas that can be brought into the laboratory for study. Some measurements and observations not easily made in trench

11. For example, see F. Rainey and E. K. Ralph, "Archaeology and Its New Technology," *Science* 153 (1966) 1481-91.

12. George Rapp, Jr., "Geology in Aid of Archaeology: Investigations in Greece," *JourGeolEd* 18 (1970) 59-65; George Rapp, Jr. and Eiler Henrickson, "Geophysical Exploration," *The Minnesota Messenia Expedition: Reconstructing a Bronze Age Regional Environment*, eds., Wm. A. McDonald and George Rapp, Jr. (Minneapolis 1972) 234-239.

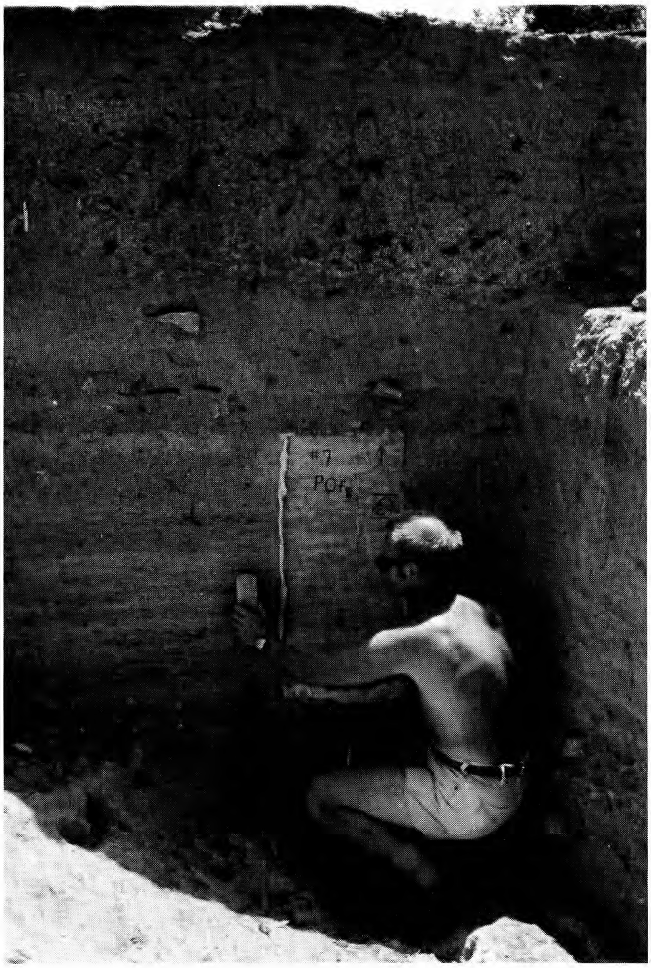

Figure 4. A peel in place on a trench wall at Nichoria.

walls thus can be deferred to the laboratory, where they can be studied and restudied at the convenience of the investigator. Peels can be X-rayed and photographed under controlled conditions.

The principle of making relief peels depends upon differential penetration by a binding compound into the unconsolidated sedimentary strata. Many binding compounds have proved satisfactory. Figure 4 shows a peel in place and Figures 5 and 6 exhibit two examples of peels taken by the author at Nichoria. Goldberg[13] has recently published a brief field guide to taking peels.

A small-bore auger or core drill can be used to assist the trench master in deciding whether or not to continue excavating in a given area. With this technique one can determine the remaining depth of the archaeological strata and often determine if new or different archaeological horizons lie below. This is particularly important for large sites that cannot be completely excavated and for any site where there is hesitation about removing a wall or an important horizon to investigate stratigraphically lower levels. We have used this technique sparingly but successfully at Nichoria. Coring was used successfully in Illinois to provide guidelines for future excavation of Monks Mound at the Cahokia site.[14]

A variety of useful chemical tests can be made at the site. Chief among these are pH determinations. They can serve as a guide to conservation practices at the site. The state of preservation of the recovered bone material, metals, and ceramics will be greatly influenced by soil pH. pH data can also supplement other data in reconstructing likely past depositional conditions in the archaeological matrix. Systematic analyses for phosphorus can be used to outline habitation or burial areas where other evidence is lacking. Bone is composed of calcium phosphate. In acid environments bone decomposes fairly rapidly, but much of the bone phosphate remains nearby in some form of colloidal collophane.

Dilute hydrochloric acid is used by the soil scientist to detect soil horizons. A detailed study of present and buried soil horizons can aid in the interpretation of land use patterns through time.[15] If the region has been carefully studied by soil scientists it may be possible to get rough dates on erosion and deposition by the stage of soil development. Conversely, a site with good pottery dates for successive levels is an excellent place to study rates of soil formation. For any but the simplest site, detailed soil and bedrock profiles should be drawn by the staff geologist.[16]

On many sites a distinct reddening of certain horizons or sections of a profile has been cited as evidence of an intense fire. Such interpretations should be approached with caution. The chief coloring agent in all soils is the element iron in some combined state. Goethite, $HFeO_2$, lends a brown color to the soil; hematite, $Fe_2O_3$, is more reddish. Goethite will transform to hematite when heated to between 250-400°C but other geochemical reactions can cause red/brown discoloration in the soils. One way to test a fire hypothesis is to heat some adjacent non-red earth matrix to determine the amount of reddening produced by fire.

13. Paul S. Goldberg, "Sediment Peels from Prehistoric Sites," *JFA* 1 (1974) 323-328.

14. Nelson A. Reed, John W. Bennett, and James Warren Porter, "Solid Core Drilling of Monks Mound: Technique and Findings," *AmAnt* 33 (1968) 137-148.

15. For example, see N. J. Yassoglou and Catherine Nobeli, "Soil Studies," Chapter 10, in McDonald and Rapp, op.cit. (in note 4) 171-176.

16. For example, see Marija Gimbutas "Anza, ca. 6500-5000 B.C.: A Cultural Yardstick for the Study of Neolithic Southeast Europe," *JFA* 1 (1974), especially p. 37.

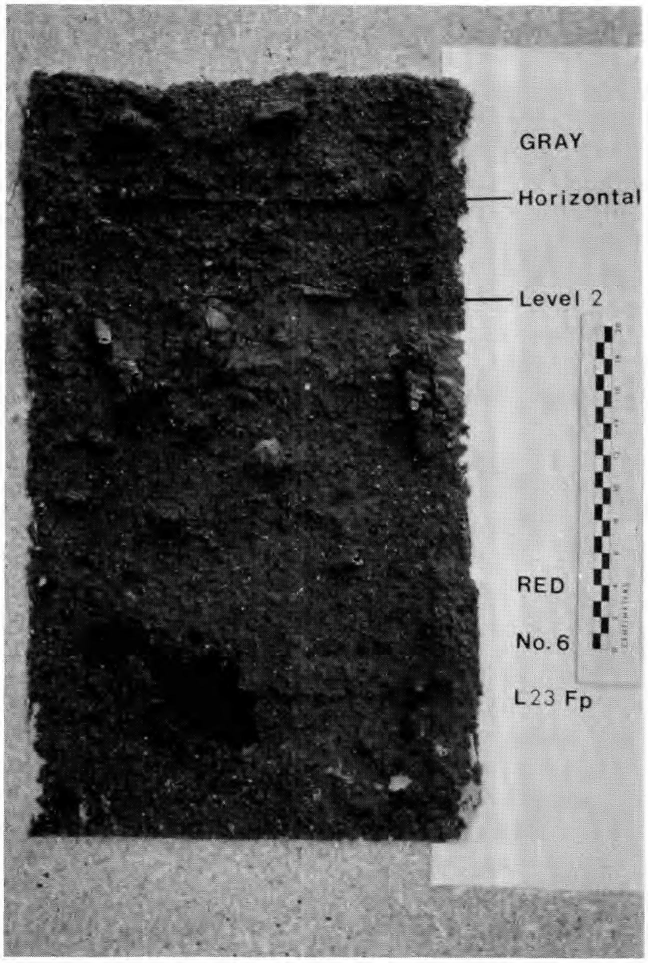


Figure 5. A peel removed for study. Surface layers of bones, sherds, and charcoal, as well as matrix material, are retained on the peel.

Finally, the staff geologist will be responsible for taking samples for C-14 dating, for pollen analysis, and for special studies such as a systematic look for volcanic ash.

### *Other Technical Assistance*

In the absence of a regular surveyor the field staff geologist may be called upon to do the surveying, as he may be the only staff member with surveying experience. Surveying and leveling in the trenches can, in all but the smallest excavations, be a major undertaking. The staff geologist may also be responsible for undertaking or supervising photogrammetry at the site.

In the absence of a ceramicist the geologist, long familiar with thin sections and petrography, may be asked to try his hand at petrographic studies of recovered pottery. The results that can be gained from such studies will be covered in a future article in this series. Depending upon his particular specialty the staff geologist may also double as staff paleontologist or palynologist. The possibilities are as great as the varieties of specialized geologic knowledge.

One final comment must be made on "other" technical assistance. The number of technically trained staff members on an excavation is normally small. This small number of individuals is invariably called upon to provide the expedition with technical assistance ranging from equipment repair, through construction of a myriad of needed items that cannot be purchased locally, to even the rebuilding of a malfunctioning septic tank. The staff geologist may also bear major responsibility for site conservation after excavation and study are completed. Being a member of the technical staff of an excavation may require more than normal flexibility and ingenuity.

### *Post-Excavation Laboratory Analyses*

The increasing degree of interaction between natural scientists and archaeologists leads to more sophisticated programs of analyses of artifactual materials. Analyses are now being sought to answer specific questions concerning the technology of artifact manufacture or the provenience of the raw material from which an artifact was made. An immense variety of historical, cultural, archaeological, and technological questions can be asked about clay building materials, ceramics, glass, metals, fibers, and so forth. It is neither possible nor desirable in this paper to present a systematic look at the scope of post-excavation analyses. Rather I should like to present two types of studies as indicative of what is being done.

In recent years numerous successful studies have determined the provenience of archaeological materials.

Figure 6. Peel taken from a partially-excavated Middle Helladic hearth at Nichoria.

To cite a few: Cann et al.[17] and Gordus et al.[18] with obsidian, Perlman and Asaro with pottery, [19] Brill et al.[20] with lead-containing objects, Shackleton and Renfrew[21] with shell ornaments, and Craig and Craig[22] on marble objects.

Eiler Henrickson and I, assisted from time to time by many others, have been attempting to establish trace element fingerprints of the source deposits for copper and tin, particularly for the Bronze Age of the eastern Mediterranean and for Paleo-Indian cultures of North America. We have made nearly 2,000 analyses of native copper, copper minerals (primarily malachite, chalcopyrite, and cuprite), cassiterite, smelts from these minerals, and copper and bronze artifacts. Trace element concentrations are determined by neutron activation techniques for up to 30 separate elements. Two statistical discriminant functions have been developed to assign an analyzed unknown to one of the known populations (geographical source areas).

Extensive work on native copper indicates that we can identify with a high degree of confidence not only the region but actual mines. This work has also shown that single elements cannot be used satisfactorily as tracers to establish provenience. Ultimately, trace-element fingerprints should be available for most of the world's copper and tin deposits. Thus for archaeological sites rich in copper or bronze, unambiguous assignments of provenience should be possible for at least some of the artifact metals. The special techniques and results of this investigation will be published elsewhere.

Many geologic scientists have been involved with questions concerning the Minoan eruption of Santorini (Thera), its relationship to destruction on Crete, and its potential for being the source of the Atlantis legend. However, Charles and Dorothy Vitaliano[23] have now launched a systematic study of earthy materials from archaeological sites and soils on Crete to search for traces of Santorini tephra. Volcanic ash (tephra) from the Minoan eruption of Santorini can be used, in closed deposits, as an excellent chronological marker. If enough well-dated and closed deposits are discovered that contain Santorini tephra it should be possible to date the eruption more closely so that the occurrence of the tephra will be an even better chronological marker. Tephrochronology has been widely used in Quaternary geology. It should find increasing use in some archaeologically important regions in the Pacific, North America, and the Mediterranean.

Some analytical methods, such as those of organic biogeochemistry, have been little used in archaeological research. As more earth scientists become involved in archaeological investigations more methods will be utilized. The need is for more cooperation and more laboratories specially developed for archaeological materials, such as those at the Universities of London, Oxford, Pennsylvania, Arizona, Minnesota, and Michigan. The *Journal of Field Archaeology* is publishing an *Archaeometric Clearinghouse,* a list of American laboratories which deal with archaeological materials.

**Discussion and Conclusions**

Geologists are obviously much more necessary on a prehistoric excavation site than one primarily dealing with reconstruction of classical temples. But the importance of their presence for the understanding and interpreting both of materials and deposition at historical sites has also been clearly demonstrated.[24] I would suggest that geologists *with sufficient archaeological training* would be better equipped than anyone to deal with the myriad of problems encountered in excavation stratigraphy.

Possibly the most pressing general problem is to make an excavation an interdisciplinary rather than a multidisciplinary effort. McDonald suggests[25] that it may be possible if younger people are given inter-

17. J. R. Cann, J. E. Dixon, and C. Renfrew, "Obsidian Analysis and the Obsidian Trade," *Science in Archaeology,* eds., D. Brothwell and E. S. Higgs (London 1969) 578-591.

18. A. A. Gordus, J. B. Griffin, and G. A. Wright, "Activation Analysis Identification of the Geological Origins of Prehistoric Obsidian Artifacts," *Science and Archaeology,* ed., R. H. Brill (Cambridge 1971) 222-234.

19. I. Perlman and F. Asaro, "Pottery Analysis by Neutron Activation," *Archaeometry* 7 (1969) 21-52; F. Asaro, M. Dothan, and I. Perlman, "An Introductory Study of Mycenaean III CI Ware from Tel Ashdod," *Archaeometry* 13 (1971) 169-175.

20. R. H. Brill and J. M. Wampler, "Isotope Studies of Ancient Lead," *AJA* 71 (1967) 63-77; R. H. Brill, W. R. Shields, and J. M. Wampler, "New Directions in Lead Isotope Research," *Application of Science in Examination of Works of Art,* ed., W. J. Young (Boston 1971).

21. N. Shackleton and Colin Renfrew, "Neolithic Trade Routes Re-Aligned by Oxygen Isotope Analyses," *Nature* 228 (1970) 1062-1065.

22. Harmon Craig and Valerie Craig, "Greek Marbles: Determination of Provenance by Isotopic Analysis," *Science* 176 (1972) 401-403.

23. Charles J. Vitaliano and Dorothy B. Vitaliano, "Volcanic Tephra on Crete," *AJA* 78 (1974) 19-24.

24. See especially Robert L. Folk, "The Geologic Framework of Stobi," *Studies in the Antiquities of Stobi I,* ed., James Wiseman (Beograd 1973) 37-57 and, also by Folk, "Geologic Urban Hindplanning: An Example from a Hellenistic-Byzantine City, Stobi, Yugoslavian Macedonia," *EnvGeog* 1 (1975) 5-22.

25. Personal communication; see also Wm. A. McDonald, "The Problems and the Program," Chapter 1, especially pp. 9-17, in McDonald and Rapp, op.cit. (in note 4).

disciplinary training. Butzer[26] argues that we have not yet achieved an integrated ecological approach to archaeology. I suggest that the integration of the archaeological staff geologist into a truly interdisciplinary excavation effort must take place at three key points: (1) the initial planning and definition of the scope of the excavation, (2) the daily work and decision-making during actual excavation, and (3) the ultimate ecological-cultural synthesis in the final publications. It should also be pointed out that the background geologic work related to excavation is basic to the cultural interpretations. Therefore, the geologic-ecological data should be published at the beginning of final site reports.

Another problem inherent in the system is the unresolved question of whether archaeology is a discipline or only a series of techniques, and the related question of which scholars/scientists are archaeologists. Are pottery typologists always archaeologists, whereas ceramicists sometimes are and sometimes are not, and metallurgists studying ancient technology from artifacts are not?

Archaeological geology is certainly on its way to becoming a subdiscipline. Academic departments and geologic surveys may take some time before they recognize it as such, but a group of over 100 archaeological geologists meet regularly at the annual meeting of the Geological Society of America and Associated Societies to present papers in regular sessions and symposia. Possibly the best way to locate an archaeological staff geologist for an upcoming excavation would be through this group. Because of the wide variety of specialties gathered together under the designation *geology*, or *earth science*, an archaeologist seeking geologic colleagues should first determine the appropriate type and then seek individuals with this expertise. Numerous journals now exist for the publication of archaeological geology, including *Journal of Field Archaeology*, *Archaeometry*, *Journal of Archaeological Science*, *Environmental Geology*, and *Science*.

Finally, it should be stressed that one individual would not likely have the time or expertise to perform all of the tasks described in this article as responsibilities of an excavation staff geologist.

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26. Karl W. Butzer, "The Ecological Approach to Archaeology: Are We Really Trying?" *AmAnt* 40 (1975) 106-111.