THE ANALYSIS OF ARCHAEOLOGICAL MATERIALS

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Summary

The scientific investigation of archaeological materials adds a further, and often independent, dimension to the description and interpretation of artifacts, in addition to traditional stylistic, typological, and art historical approaches. Within an overall pattern of "typical" questions and research agendas, individual materials lend themselves to different degrees for specific inquiries. Due to the nature and general diversity of archaeological materials, as well as the relatively recent development of archaeological sciences, most of the methods employed in it are adopted from more widely used disciplines of the earth and material sciences. The main questions asked in archaeological science, however, are related to archaeological research, despite the dominance of scientists actively doing the laboratory work. This inevitably results in some modifications of the techniques used in order to match specific methodological constraints or intellectual approaches in archaeological science work. A number of well-established approaches to the main inorganic archaeological materials are briefly characterized, and future development towards more integrated studies is drafted.

1. Introduction

The scientific analysis of archaeological sites and finds is an indispensable part of archaeological research. It developed over more than 200 years in line with contemporary progress in thought and instrumentation in a number of fields, particularly chemistry, metallurgy, and the geosciences. Only relatively recently has it been recognized as a field in its own right, still largely drawing its methods from its parental sources. Archaeological science or archaeometry, to introduce two terms frequently used to label this field, cover the application of scientific methods to archaeological inquiry. This includes the major sub-disciplines of geophysics and remote sensing for prospecting and mapping, physical or absolute dating, geoarchaeology, bio-molecular and biological archaeology, and the analysis of inorganic archaeological materials. This article focuses on the latter, in particular on objects made of stone, ceramics, metal, glass, and other artificial materials, and the debris from making and working them. The approach followed centers around these materials and some typical questions to be asked, rather than the methods used, and analytical methods are explained only briefly in the glossary.

2. Historical Aspects, Foundations, Policy, and Professional Practice

The earliest scientific analyses of archaeological finds date back to the late eighteenth century. For 150 years afterwards, they were linked to a few individual pioneers and remained mostly isolated incidents until after the First World War. Only then did an increasing number of scientists start to devote themselves primarily to science-based archaeological research, culminating in the establishment of specialized laboratories, periodicals, and conferences. This professionalization, together with an increased awareness of cultural heritage and conservation issues, eventually led to a theoretical discussion, and underpinning, of practices and policies.

2.1 The Analysis of Archaeological Finds until the Mid-Twentieth Century

The origins of scientific methods applied to archaeological finds lie firmly within the development of analytical chemistry and the wide-ranging curiosity and interest of individual scholars. The emphasis of their work typically was to establish the composition of a find, and hence the early work dealt primarily with metal and glass finds: artificial materials whose composition was not immediately obvious. Towards the end of the nineteenth century, some scholars became interested in reconstructing production processes. Gowland was among the first to introduce ethnographic observations as a means to interpret archaeological evidence for metallurgy and also to analyze waste products and technological debris from the primary production of metals rather than finished objects alone. Similarly, Bordes undertook significant experimental work to understand the production of flint tools, resulting in a functional typology of flint artifacts.

2.2 The Professionalization of Archaeometry

The early stages of archaeological sciences were entirely borne out by the interest of individual scientists, and had very little in terms of planned research objectives beyond the characterization of an individual artifact. Archaeology in general only became interested in scientific methods with the rise of physical methods in prospecting and dating and the need to employ statistical methods to deal with large assemblages of artifacts, in particular ceramics. The threshold to professionalization was probably surpassed when the University of Oxford's Research Laboratory for Archaeology and the History of Art began to run a series of in-house conferences on physical prospecting and dating, and published a bulletin of its ongoing research. This soon developed into the journal *Archaeometry*, while the conference series became a regular biannual international venue. Even before that, conservation departments in several museums worldwide realized the importance of technical studies of artifacts for their subsequent conservation treatment and eventually developed into fully-fledged research laboratories. Since the 1970s, the number of scientists working full-time within archaeology, affiliated to dedicated laboratories, has increased dramatically. At the same time more archaeologists became interested in scientific work, resulting in truly interdisciplinary co-operation and increased theorization of aims and approaches. The professionalization of archaeometry was finally completed when archaeological sciences became a firmly established and regularly taught topic in major archaeology departments worldwide.

2.3 Policy and Professional Practice

Archaeological sites and artifacts are basically a non-renewable resource and are a significant part of our cultural heritage. In addition, they can be of considerable spiritual, aesthetic, and monetary value. Recognition of this led to a number of restrictions and specific approaches in the methods used in the scientific study of sites and artifacts. Major issues are the degree of invasiveness and destructiveness of such studies and the documentation and publication of methods used, and results obtained. In the terminology followed here, invasiveness refers to the sampling method, while destructiveness refers to the actual analysis of that sample.

Scientific analysis and curatorial interests can conflict. The desire to understand an object's past as preserved in its material present often contradicts the desire to spare that object for the future from invasive sampling and destructive analysis. There are a number of methods that allow characterizing an object as a whole without being invasive or destructive. Such methods are, for instance, the determination of physical properties such as size and mass, specific weight, magnetism, or X-ray and related imaging techniques. In contrast, most chemical and textural analytical methods are restricted to the sample that is available to them. In non-invasive analysis this is typically the outer, visible, surface of an object, while sampling the interior typically removes some material from it, and is thus invasive. The surface of archaeological finds, however, is often different in appearance and composition from the body and may not be representative for the whole object. This can be due to several reasons, but intentional surface treatment and post-depositional corrosion or patination are among the most important ones. The information obtained from a sample taken can often be vital in developing the best possible conservation treatment for the object—or group of objects—concerned. The identification of the best possible sample size and location again requires discussion among the various professions involved. Thus, a balance has to be found between the desire to obtain certain information and the damage done to an object by sampling. Once a sample has been taken, it can be analyzed either destructively, as, for instance, by dissolving it in acids or fluxes in order to feed the solution into an instrument or partly destructively, as in the preparation of polished sections for microscopic investigation or powders for X-ray diffraction analysis. The sample also can be analyzed non-destructively as in neutron activation or certain procedures in X-ray fluorescence analysis.

The wide range of analytical methods generally available today, and often useful for the investigation of archaeological finds, means that no single laboratory can have all the facilities on hand. The development and spread of specialized archaeometry laboratories has been mentioned, but there is still a significant amount of work that has to be done elsewhere. It is therefore crucial that the archaeological questions be defined before an appropriate laboratory is chosen for the work to be done. The analysis of archaeological objects only for the sake of analysis, or with inappropriate methods chosen solely for their availability, cannot be considered professional.

Archaeological sites and objects are part of humankind's heritage regardless of individual ownership. The vast majority of archaeological research is publicly funded, as is the scientific analysis of archaeological material. Good practice, therefore, requires that any such research be fully documented, and the results be published in a suitable way. The full publication of the original data is particularly important, clearly separate from the interpretation that builds on the data.

3. Aims and Approaches of Materials Analysis in Archaeology

The most basic question to be answered by scientific analysis of an archaeological object is its chemical or textural composition. The two terms are used here, respectively, to address the overall presence in an object of chemical elements at specific concentrations, and the textural patterns of individual phases or particles which together make up the whole object. In this, the term "textural" analysis includes mineralogical, metallographic, and ceramographic approaches as well as physical and chemical methods that aim to characterize individual compounds or phases (rather than elements) and their setting within a larger, and often multiphase, object. The results of such analysis can then be used to discuss, among other things, the origin and possibly the age of an object and its relation to others of its kind. In addition, the results can shed light on the function, role, and meaning of this object within society; the techniques used in its production, use, and deposition; and, finally, the identification of corrosion phenomena and possible conservation treatments. The diversity of these aims, coupled with the wide range of materials found in an archaeological context, require an educated decision as to which methods are to be used. It is the central aim of this article to help in making this decision. It should be mentioned here that the article does not cover the wide range of technical information that can be gained by studying the visible morphology of items such as stone tools or pottery, which often contain significant evidence of production techniques.

3.1 Stones

Scientific analysis of natural stones is very much restricted to provenancing artifacts such as obsidian, precious or semi-precious stones and jewellery, stone vessels and tools, and stones used as building materials. The geological origin of such artifacts, which are chemically and structurally unchanged natural materials, implies that much of the methodology applied to them is closely linked to, and develops with, mainstream geological research. The provenancing of obsidian, both in the Americas and in the eastern Mediterranean and Western Asia, is based primarily on trace element analysis, mostly using XRF, ICP or NAA. Major and minor element concentrations allow allocating obsidian to specific volcanic regions, while trace elements often allow the identification of individual obsidian flows as likely sources for given artifacts. The analysis of various stable isotope ratios contributes increasingly to this field. Similarly, other volcanic rocks such as lava, used for vessel production, grinding tools and millstones and often traded over long distances, were successfully provenanced using geological methods, resulting in the identification of past trade and distribution pattern.

The analysis of minerals used for jewellery, for instance, lapis lazuli, garnet, emerald, and the many variants of quartz and agate, more often than not has to be done without sampling and using non-destructive methods. Here, physical methods that were developed for the gem industry and modern jewellery are often useful, such as determining optical properties of the mineral, type and amount of inclusions, density, etc. Due to the inherent properties of the various minerals involved, and the range of compositional and optical characteristics within each, analysis of the chemically more complex minerals is often more likely to result in success than that of quartz and related minerals. Flint, agate, rock crystal, etc. offer little in terms of diagnostic trace elements or optical properties and are rather difficult to provenance. Characteristic colors and textures, however, can sometimes be diagnostic.

Building stones from archaeological contexts are often studied petrographically by combining optical microscopy of thin sections with geochemical analysis. The usually large quantities of material involved typically allow complete sampling for various methods, enabling a sufficient characterization for provenancing. The limiting factor here can be the necessary background information of the possible source regions, requiring extensive fieldwork and knowledge of the regional geology, as well as historical aspects of land use and transport organization. Provided that this information is available, very detailed information can be gained from archaeological material. A major example here is the close identification of source regions and quarries for polished stone axes in the British Isles. A special case is the provenancing of marble, which is often petrographically too homogenous to offer an easy approach. Here, much research has been done using stable isotope ratios, such as oxygen, to discriminate sources. The morphological study of microwear on flint surfaces eventually gives information about the type of material that was cut or otherwise manipulated using these tools. Hide, bone, grass, etc. leave a characteristic surface polish on the flint, allowing the identification of its primary use.

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Biographical Sketch

Thilo Rehren was appointed Professor of Archaeological Materials and Technologies at the Institute of Archaeology, University College London, in September 1999. Before that, he worked for almost 10 years as a research scientist at the Deutsches Bergbau-Museum in Bochum, Germany, studying a wide range of metallurgical remains, from iron smithing slags to Early Bronze Age copper casting crucibles from Jordan, pre-Columbian gold processing in Ecuador to Greek and Roman silver refining, and mid-nineteenth century platinum coins from Russia, and Late Bronze Age Egyptian glass and pigment production to Roman and Medieval brass making remains. His formal training was as a geoscientist, with a first degree in Mineralogy and Economic Geology from the former mining academy TU Clausthal, and a PhD from Freiburg University in petrology, specializing on island arc volcanic geochemistry and magma development. His current research interest focuses on the reconstruction of high-temperature technological processes used in antiquity, with special emphasis on the integration of various analytical techniques a well as in taking an integrated approach to the analysis of remains of complex workshop settings. Current fieldwork for this includes projects in Uzbekistan, Egypt, and Central Europe.