Manuals in Archaeological Method, Theory and Technique

Michael Brian Schiffer

The Archaeology of Science

Studying the Creation of Useful Knowledge

Springer

MANUALS IN ARCHAEOLOGICAL METHOD, THEORY AND TECHNIQUE

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Author's Sculpture, *Time Dilation*, Inspired by Einstein's Special Theory of Relativity (author photograph)

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Studying the Creation of Useful Knowledge

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Preface

For many years I had contemplated writing a book about science, having spent much time immersed in the science and technologies of early electricity. I had also done desultory reading in the history and philosophy of science and even wrote during the summer of 2002 a manuscript of poor quality. But not until October of 2011 did inspiration strike, allowing me to revisit and reconceive the book project. To pass the time during an all-day train trip from northern Virginia to Boston, I read Harrison and Schofield's (2010) *After Modernity: Archaeological Approaches to the Contemporary Past*. From this engrossing work I learned that a few archaeologists had been documenting the remains of twentieth-century scientific activities, including the testing of nuclear weapons in the Nevada desert.

Discovering that other archaeologists had already begun the study of modern science was the impetus I needed to envision *The Archaeology of Science*, which would showcase traditional strategies as well as new case studies. By the time the train reached Boston, I had written on a yellow pad many pages of notes and a provisional outline. This book would explore the diverse research activities that archaeologists use to study science—ancient and modern. Upon returning to Tucson in January, I began work on this project in earnest; the research was exciting and the writing most pleasurable.

Behavioralists have long maintained that archaeologists investigate the science embodied in traditional technologies (e.g., McGuire and Schiffer 1983; Schiffer and Skibo 1987, 1997). Toward this end we employ—singly and in combination—experiments, ethnoarchaeology, and archaeometry to tease out the generalizations that people had discovered about, for example, the properties of materials and processes of artifact manufacture and use. However, as Harrison and Schofield show, our efforts need not be confined to studying the science of ancient technologies and of traditional peoples. Indeed, my earlier forays into electrical science and technology demonstrated that the science of early modern and modern technologies implicates a host of new research questions whose answers may be sought in diverse lines of historical and archaeological evidence. The archaeology of science, then, embraces the old and new, the exotic and familiar—in short, scientific activities of all times and all places.

To give some coherence to this expansive vision, I have rethought from a behavioral perspective the general concepts of scientific knowledge and reconsidered the relationships between science and technology. My notions on these topics, presented in chapters "Science: A Behavioral Perspective" and "Varieties of Scientific Knowledge," promote a holistic view of science and of the archaeology of science. The remaining chapters explore what the archaeology of science has been (Part II) and what it is becoming (Part III).

Instead of trying to survey all previous work, a patent impossibility that would result only in strings of "drive-by" citations, I present extended examples and lengthy case studies that, in light of the discussions in chapters "Science: A Behavioral Perspective" and "Varieties of Scientific Knowledge," illustrate archaeological strategies for researching science. I hope that the case studies will interest the reader as much as they have the writer, for they handle intriguing subjects such as the first machine that generated electricity, the Polynesian colonization of New Zealand, and a nuclear-thermal engine for rockets.

Throughout the chapters, especially in Part III, I offer suggestions about research potential, often in the form of substantive questions, which perhaps the next generation of archaeologists will design projects to answer.

This book's main target audience is advanced undergraduates and graduate students. Indeed, *The Archaeology of Science* could serve well as a text in a seminar-style course whose discussions focus on the several stages of student-initiated projects undertaken in the spirit of this book.

Although this book is aimed at other archaeologists and their students, I believe that the provocative arguments in Part I, especially, could potentially interest scholars in every discipline that studies science: history, philosophy, sociology, and cultural anthropology. Among the many features that may give the work some traction in other disciplines are the following.

1. A fully general definition of science is provided that applies to all human societies (see chapter "Science: A Behavioral Perspective").
2. I bring into the scope of science studies the activities of ordinary people, apparatus consisting of mundane objects, and the kinds of scientific knowledge that render predictable people's interactions with the material world (see chapter "Science: A Behavioral Perspective").
3. New insights are offered into the relationship of science and technology by focusing on projects (see chapter "Science: A Behavioral Perspective").
4. I treat at length the several kinds of scientific knowledge that enable predictions, including recipes (see chapter "Varieties of Scientific Knowledge").
5. A bridge is built between the "unobservables" invoked by traditional (folk) theories and the theories of modern science by means of the concept of "quasi-natural entity" (see chapter "Varieties of Scientific Knowledge").

Finally, in explaining this project to friends and family, I realized that this book may have an audience beyond the academy because the case studies in Parts II and III are so fascinating and eminently accessible to the general reader.

Alexandria, VA, USA Michael Brian Schiffer

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Acknowledgments

During the fall of 2001, I was a Senior Fellow in the Dibner Institute at MIT where I was able to interact with more than two dozen junior and senior fellows who represented a variety of disciplines studying science and technology. On the basis of lunchtime presentations and discussions it became clear to me that an archaeological perspective might make useful contributions. However, the draft I wrote during the following summer was, as Jennifer L. Croissant kindly pointed out, a polemic that would inflame rather than inform. She also supplied constructive suggestions that have helped me in crafting the present work. I am greatly indebted to Jen for sparing me the embarrassment of trying to get that horrid manuscript published.

In January of 2012, I put out a call to historical archaeologists, asking for information about projects that had studied scientific activities. I received dozens of replies containing many citations, pfds, and other information. From these I selected some examples and case studies that appear in Parts II and III. A mere thank you cannot express my delight in the collegiality of historical archaeologists, including Lyle Browning, Henry Cary, Craig Cessford, Sarah E. Cowie, Melissa Diamanti, C. J. Evans, Denis Gojak, Christina J. Hodge, Silas Hurry, Nicholas M. Lucchetti, Natascha Mehler, Robin O. Mills, Michael R. Polk, James Symonds, and Steven Walton.

In writing *The Archaeology of Science* I have been fortunate to obtain from various colleagues insightful critiques of several chapters. I thank them one and all for giving generously of their time and expertise in support of this project (see individual chapters for specific acknowledgments). I single out for special thanks Deborah J. Warner who provided instructive comments on the entire manuscript, helping me to express ideas with greater clarity and brevity.

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As always, Annette, my wife and best friend, gives me love and encouragement, provides feedback on ideas, endures graciously my random bouts of exuberance and despair, and makes our lives a magical journey.

Alexandria, VA
December 2012

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Part I

Introduction

Renowned for theories and equations that helped make modern physics, Newton and Einstein are icons of Western science, their Herculean achievements celebrated in the academy and in popular culture. Regrettably, the high visibility and veneration of stars like Newton and Einstein foster several misunderstandings about the nature of science.

First is the impression that science-making is an activity fit only for geniuses. As Kuhn (1970) reminds us, most scientific activity is actually routine problem-solving, presumably done by people less gifted than Newton and Einstein. Second is the belief that the products of scientific activity must be expressed mathematically. In fact, much scientific knowledge is neither quantitative nor quantifiable. Moreover, significant *qualitative* knowledge is present in natural history, much biology and geology, most science in ancient states, and all science in traditional societies. Third is the notion that the major goal of scientific activity is to create theories. Theories are of course important, even in traditional societies, but scientific activity generates knowledge of many kinds. In countering these and other misunderstandings, this book presents a general conception of science, *applicable to all societies*, that includes the contributions of ordinary people, recognizes the importance of qualitative findings, and handles many varieties of scientific knowledge.

Let us begin by considering science as both a process and a product. As a *process*, science consists of varied activities, or practices, for fashioning many kinds of useful—strictly speaking, *potentially* useful—knowledge.[1] In fact, science is not *a* process but many processes. There is no single scientific method because people create new knowledge in many ways for many uses in diverse societal contexts. A person may begin with an observation, puzzle, anomaly, problem, hunch, question, theory, dream, model, analogy, or new artifact, and can reach an outcome inductively,

[1] I considered using terms like "natural knowledge," which dates back to the late seventeenth century, and "practical knowledge," of more recent vintage, to denote the products of science. I rejected the former because it ignores the agency of humans in knowledge-creation activities and the latter because the term "practical" is highly problematic (Schiffer 2008, chapter 1).

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deductively, abductively, and even by nonlogical means. The processes of science-making are of archaeological interest because virtually all involve material phenomena, usually artifacts (cf. Hankins and Silverman 1995; Rothbart 2007).

The expected *product* of scientific activities is new knowledge: descriptions and generalizations—qualitative and quantitative—about the material world that permit predictions. This predictive capability makes scientific knowledge useful by enabling the forward motion of activities (cf. Atran and Medin 2008; Reichenbach 1966; Schiffer and Miller 1999). Thus, no human society has failed to create scientific knowledge, for it empowers people to conduct activities on the basis of their predicted outcomes. Through scientific knowledge, whether possessed implicitly or explicitly, people collect plants that can be eaten and select stones that can be chipped. Likewise, scientific knowledge allows engineers to design bridges that will survive strong winds and heavy loads and physicists to predict that ramping up the power in CERN's Large Hadron Collider will not generate a swarm of black holes and destroy Earth.

Scientific knowledge makes possible, though it does not guarantee in every instance, effective human interactions with artifacts and with living and nonliving phenomena of the natural environment. And it matters not whether ancient foragers were making digging sticks or hundreds of corporations are making a nuclear aircraft carrier because activities of every kind and complexity embody scientific knowledge. By facilitating activities—and thus activity change—the products of science are of archaeological interest.

With its high-tech research tools, complex organizational structures, and many specialized social roles, modern science merely elaborates processes established during the Paleolithic for creating useful knowledge.[2] In every society, ancient or modern, people playing different social roles create and use different kinds of scientific knowledge—as "situated knowledge" (Wylie 2003:31) or "socially distributed" knowledge (e.g., D'Andrade 1995:208; Hutchins 1995). In traditional societies, hunters employ their own activity-specific descriptions, generalizations, and artifacts—as do gatherers. In industrial societies, the differentiation of scientific knowledge is extreme because the conduct of virtually every activity requires specialized knowledge. It follows that societies having highly diverse activities also have highly differentiated science.

The Study of Science

The specialists in industrial societies include scholars in many disciplines who study the history, processes, and products of science. Indeed, science is probably studied in more disciplines than any other academic subject and is also a major focus of

[2] People obviously create many other kinds of knowledge having their own domains of use, from social science to theology, but they are not treated in this book.

interdisciplinary programs that go by the acronym STS (science-technology-society). The following list includes perspectives commonly found in science studies.

1. History of an idea or generalization such as the origins of field theory (Williams 1980).
2. A survey of science during a specific period in a particular country or region; e.g., the "scientific revolution" in Europe, 1500–1800 (Hall 1956).
3. The investigations performed in a given organization such as Leiden University (Ruestow 1973) or Bell Laboratories (Smits 1985).
4. The effects of society and culture on science, sometimes construed as the social construction of science (e.g., Barnes, Bloor, and Henry 1996; Golinski 1998).
5. History of a discovery, as in determining the structure of DNA (Watson 1968).
6. History of a discipline such as chemistry (Partington 1961–1970).
7. The organization of science, such as the history of eighteenth-century scientific societies (McClellan 1985) or the growth of "big science" (Galison and Hevly 1992).
8. Biography or autobiography of an investigator; e.g., Powers' (2012) biography of chemist Herman Boerhaave.
9. Study of a specific apparatus (or instrument) and classes of them, as in Hackmann's (1978) monograph on eighteenth-century electrical machines.
10. Researching a specific and usually large-scale undertaking, such as the Manhattan Project (McKay 1984).
11. Ethnography of a laboratory, as in Latour and Woolgar's (1979) fieldwork at the Salk Institute.
12. The cognitive structure of scientific knowledge, such as Nagel's (1961) philosophical treatment.
13. Cognitive processes of scientific research, as in the study of discovery by Klahr et al. (2000).
14. The scientist as a goal-seeking social being (Osbeck et al. 2011)
15. Science and politics; science and government (Hughes 2002).

Researchers in a specific discipline tend to emphasize particular perspectives. Philosophers study research processes and the structure of knowledge. Sociologists treat scientific research as collective action and illuminate the role of social processes and consensus building in the evaluation of knowledge claims. Thus, the sociology of science includes the ethnography of a laboratory, the organization and social construction of science, and science and politics. Employing an ethnographic perspective, sociocultural anthropologists delve into the nature, organization, and uses of scientific knowledge in traditional societies and also research the role of culture in the everyday practice of science in industrial societies. And psychologists conduct experiments on the cognitive processes of learning and discovery. In contrast to social and behavioral scientists, a physicist or chemist writing about her discipline may adopt a biographical or autobiographical perspective as well as histories of ideas, disciplines, and discoveries. The works of historians range widely over many perspectives. Despite the intellectual faddism endemic in the social sciences and humanities, rendering some perspectives more or less trendy at given times, all perspectives survive in the academy today.

Archaeologists occupy a large—and growing—niche in the study of science. Simply put, this book is primarily about defining and illustrating that niche, highlighting the contributions that we have made and may make. The archaeology of science consists of perspectives that *in their entirety* define a distinctive approach. Individually, the perspectives are not exclusive to archaeology, nor would they all be present in any one study, but together they distinguish a diversified research program that is illuminating some dark corners of science.

The Archaeology of Science

Robert T. Gunther used the phrase "archaeology of science" to label his efforts, in the early decades of the twentieth century, to build science museums at Oxford and Cambridge Universities (Bennett 1997). Archaeology was in some ways an apt term for digging into historical documents and for assembling the scattered and tattered apparatus of earlier British science. Anderson (2000), in a paper advocating the study of surviving chemical apparatus together with documents, titled his paper "The Archaeology of Chemistry." Although these scholars construe the archaeology of science somewhat narrowly, both fasten on the foundation of any archaeological investigation: a concern with people making and using artifacts.

Artifacts, also known as technologies, material culture, products, objects, devices, gadgets and gizmos, or just plain things, encompass everything that people make or modify. The artifacts of scientific activities, especially those participating in experiments, are often called *apparatus* (a term that is both singular and plural) or, in modern science, instruments (Baird 2004; Bud and Warner 1998).

Artifacts are central to archaeological research, but we do not consider them in isolation. Rather, our task is to situate artifacts, whether ancient or modern, in their behavioral, societal, and environmental contexts, making use of all relevant lines of evidence. Thus, depending on our questions, we may exploit the archaeological record, the historical record, the ethnographic and ethnohistorical records, and oral history. We might even conduct experiments, carry out an ethnoarchaeology project, make use of knowledge and technology from the physical and biological sciences (archaeometry), and scour the literatures of other disciplines. Archaeologists are eclectic and opportunistic, reaching across subject matters and respecting no disciplinary boundaries. And so it is, especially, in the archaeology of science.

In addition to placing artifacts into their contemporaneous contexts, we order them temporally and ask about the hows and whys of technological change (Schiffer 2011). Adopting a temporal perspective leads to new insights as we document and explain changes in apparatus and illuminate their roles in creating knowledge (e.g., Schiffer 2008; Schiffer, Hollenback, and Bell 2003). We also do comparative studies, seeking to explain variability among artifacts, even those in different technological traditions.

The proper archaeology of science has a long history that began by the early nineteenth century. The initial stirrings of interest appeared when researchers asked