Chapter 2
Intended Function: Inferring Manufacturing Performance

> *Early studies of ceramic function tended to dwell in this realm (intended function), and were based on fast and loose reasoning drawn from intuitive expectations …. (Rice 1996a, p. 140)*

In the last two decades "fast and loose" reasoning, as Rice notes above, have given way to stronger inferences based on principles derived from materials science, ethnoarchaeology and experimentation. This chapter reviews this growing body of research, which has gradually transformed pottery analysis in archaeology from poorly supported reasoning to much stronger inferences regarding intended vessel functions. Although the focus of this book is actual pottery function, a complete pottery analysis should consider both sides of the functional equation.

An analysis of intended function starts with this simple premise—all pots are designed to be used. That is, the potter made technical choices related to performance in manufacture and use in accord with the vessel's intended function(s), whether techno-, socio-, ideo- or emotive-functions. Although all aspects of function can be important in the design of a vessel, the overwhelming primary function of ceramic vessels, both prehistorically and ethnographically, is in processing, storing, and transporting food and liquids (Rice 1987, pp. 207–208). When Braun (1983) famously stated that we should consider "pots as tools" he was referring to the fact that ceramic vessels, like their chipped stone counterparts, have uses. We now take this perspective for granted, but it is worth noting that the focus for ceramic analysis was once primarily on stylistic factors through time and across space. Although chipped stone analysis also focused on stylistic variability, no one questioned that lithics were tools used to cut, scrape, drill, pierce, etc. Below I review the relationship between technical choices at the disposal of the potter and the relevant performance characteristics keyed to the vessel's intended function.

Potters can control the formal dimension of ceramic variability, which includes the metric properties of form (morphology), paste characteristics, firing conditions, and surface treatments (Bronitsky 1986; DeBoer 1984; Reid 1990; Steponaitis 1983, 1984; Tite 2008; van As 1984). Inferring intended function of vessels is a two step

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process. The first step is to understand technological variability. For example, one must first determine the temper type, size, and surface treatments, etc. as these are the technical choices made by the potter. An entire suite of analytical procedures that range from simple observation to molecular chemistry are at the disposal of archaeologists wanting to understand the technological variability of their sherds and vessels. The second step is to link the potter's technical choices, like a resin interior coating or large orifice diameter, to intended performance. These two steps are discussed below for each of the major technical choices related to pottery manufacture and use: shape, size, and form (morphology); temper type, size, quantity, clay chemistry and mineralogy (paste composition); firing temperature, atmosphere, and conditions (firing); and interior and exterior surface additions such as slips or resins, or modifications, as in texturing or corrugation (surface treatments). This review is followed by a discussion of how these technical choices and performance characteristics can be used to infer intended vessel function. Several types of pots in three of the major techno-functional categories, cooking, storage, and transport, are used as examples to demonstrate these points. Finally, using examples from around the globe, this chapter closes with a discussion of how archaeologists can use sherd collections to make inferences of intended function.

Understanding Technical Choices and Performance

As Rice (1987, pp. 208–210) notes, the techno-function of domestic pottery takes place in three realms: storage, processing (or transformation), and transfer (or transport) (see also Buko 2003; Smith 1988). Potters make design choices in form, temper type, surface treatments, etc., to create vessels to perform these roles. Thus, a liquid storage pot might be large with a restricted orifice on which a cover can be affixed, and a cooking (processing) pot might have a round base, for strength, and an open orifice to permit easy access. Because of its fragility, pottery is often not the first choice for transfer of goods, but sometimes a vessel's other performance characteristics outweigh its tendency to suffer breakage. This is especially true in the transfer of liquids like wine or olive oil, which moved about in pottery vessels for millennia with the help of ships or wheeled transport. But within each basic category, vessels can be designed specifically to store, transport, or process specific foods or liquids—thus, the shape, temper type, surface treatments, etc. could reflect whether a vessel's contents were hot or cold, wet or dry, transferred a short or long distance, among other features of specific activities (see Rice 1987, p. 208). There are myriad activities or characteristics of an activity along the behavioral chain of a vessel that can affect its form.

Morphology

Anna Shepard was one of the first to note the importance of recording shape-related metrical properties. She states that the "study of vessel shape can be approached from the standpoint of function" and that "the purposes of the vessels tell something of the activities and customs of the people who used them" (Shepard 1956, p. 224). Although Shepard notes the importance of linking form to function, her emphasis was really on documenting shape for classification and taxonomy, which dominated all artifact analysis at the time. It is in this context that Linton published the important article "North American Cooking Pots." He states that "there is a tendency to underrate the importance of simple utilitarian artifacts [like cooking pots] of types which are widely distributed in time and space" (Linton 1944, p. 369). Although most ceramic archaeologists were concerned with time-space systematics and not vessel use, he clearly points the way for more sophisticated functional inferences (Reid 1990). Linton goes on to note that an "effective cooking pot must have a mouth large enough to prevent explosive boiling over and to permit of stirring its contents, but at the same time small enough, relative to the pot's capacity and heating surface, to prevent it from boiling dry every few minutes" (Linton 1944, p. 370). He clearly was on the right track in linking what I would call technical choices to performance characteristics important for cooking vessels. Despite this effort by Linton to draw pottery analysts to a more functional approach, his article seems to have had little impact at the time. Even Shepard (1956, p. 224), who was sympathetic to functional analysis, noted that linking form to function was complicated and there were still too many unknowns in this line of research. Nonetheless, it was these early attempts at documenting shape and form for the purposes of classification that set the stage for stronger functional inferences about pottery (Ericson et al. 1972).

Rice (1987, p. 207) notes that "morphological characteristics—their attributes of shape and technology—are closely related to their suitability for a particular activity." There are plenty of good resources at the disposal of the ceramic analyst for linking form and function (e.g., Buko 2008; Orton et al. 1993; Rice 1987; Riemer 1997; Smith 1985, 1988; van As 1984). Sometimes these correlations are regionally specific, but there are also many cross-cultural correlations that are important (Roux 2007). The methods to illustrate, record, quantify, and classify vessel form are well illustrated by Rice (1987), whose examples are primarily from the American continent, and Orton et al. (1993) whose focus is mainly European. Their work is quite thorough and I cannot do more than summarize their findings.

Recording Morphological Variability

Orton et al. (1993, pp. 152–165) divide classification systems for vessel shapes into three categories: type series, measurement-based systems, and manufacturing stages. The type series is the system of classifications found in every part of the world and was devised primarily in the late nineteenth and early twentieth centuries. In North America, each regional sequence of types has a long history, usually tied to a few influential archaeologists who were first to work in an area and were most responsible for defining the culture history, which was based, in many cases, on pottery types that they too defined (e.g., Colton 1939; Ford 1938; Gladwin and Gladwin 1930; Kidder 1924; McKern 1939; for a review of this period see Lyman and O'Brien 2003; Lyman et al. 1997; O'Brien and Lyman 1998, 2003; O'Brien et al. 2005). Most pottery classification in North America can be traced to these early scholars who created the types, for the most part, to recognize prehistoric cultures that they could trace through time and across space.

Although, most archaeologists today do not believe that a collection of traits, including pottery types, equals a prehistoric culture, we are still left with the legacy of these types. An archaeologist must be able to identify Snowflake Black-on-White in the American Southwest, Laurel Incised in the Upper Great Lakes, Deptford Stamped in the Southeast, Plumbate from the Maya Lowlands, and Beaker Ware in England. What these types "mean" is open to debate, but that does not keep us from training each new generation of archaeologists to have at least a passing knowledge of these types. This is helpful because the types are not only minimally tied to specific times and places but anyone attempting to learn the archaeology of a region must be able to master the local jargon including the major pottery types. However, when I teach ceramic analysis or the archaeology of the Midwest, the classes are not devoted to memorizing pottery types and sequences, as might have been the case in James Griffin's classes at the University of Michigan in the 1960s. Today's archaeologist, nonetheless, still must have a familiarity with the major ceramic types, particularly those that have been linked to well-dated contexts. At a local professional archaeology meeting such as the Midwest Archaeological Conference, pottery types like Heinz Creek, Black Duck Banded, or Ramey Incised roll off the tongues of the speakers and all in attendance can visualize the design, shape, and other formal properties of these vessels. Speakers at the Pecos Conference in the American Southwest would hear pottery types like Tanque Verde Red-on-Brown or Salado Polychrome and those in attendance would know exactly what they are referring to. In modern archaeology, such classifications are not an end in themselves as these categories have little relevance in a performance-based investigation that seeks to infer the range of vessel functions. These "blunderbuss categories," as we have referred to "style" and "function" previously (Schiffer and Skibo 1997, p. 43), even when given new names like "technological style," can get in the way of understanding the performance of the vessels. Nonetheless, students still need to have a working familiarity with the pottery types and sequences in their areas of interest as long as there is an awareness of the limitations that these categories bring.

Formal and measurement-based classification (Orton et al. 1993) came about as a means to create more universal systems to describe and classify pottery assemblages. Smith (1988), in a cross-cultural analysis of whole vessels, found three metrical properties that are particularly relevant when correlating form to function: (1) the relative openness of the vessels profile, which is the ratio of the circumference of the lip to the total external surface area; (2) diameter of the vessel rim; and (3) the total volume. Using a series of statistical measures he found these properties to be particularly useful for determining if a pot was used for processing, storage, or transfer. Using a Southwestern United States ethnographic and archaeological collection, Smith (1985, p. 305) also came up with five "morphological correlates of use." They include:

1. Orifice size is proportional to the amount the contents are changed.
2. Serving of liquids or solids correlates with rim forms that do not curve inward.

3. Orifice size is inversely proportional to the duration of storage time.
4. Vessels that require access to the contents during use will have an orifice big enough for hand access.
5. Vessels used to transport liquids have a small orifice diameter.

These types of correlates can serve as a baseline for making more specific inferences about function from form.

The final classification category noted by Orton et al. (1993, pp. 163–165) is that of manufacturing stages. By this they mean classifying pottery based on manufacturing methods, such as the fast wheel, mold making, or hand modeling (Balfet 1984). Using traces on the vessels themselves, they infer the manufacturing life history, or *chaîne opératoire*. The Laboratory for Ceramic Studies at the University of Leiden has been especially active in increasing our understanding, through experimentation, ethnoarchaeological research, and the analysis of archaeological materials, manufacturing processes and stages, and how they may be inferred from traces on the vessels themselves (van As et al. 2008; see also Stilborg 1997). The focus is "on the translation of the phenomena observed on a pot or fragments of a pot, into the reconstruction of aspects of the potter's craft" (van As 1984, p. 131). I do not see this as a classification system so much as a critical component of any pottery analysis. Such holistic ceramic research has been going on in Leiden, mostly focusing on pottery from the Near East, for several decades with great success (e.g., Annis 1985; Franken 1975; London 1991; van As and Jacobs 1995), and much of the relevant research is published in the *Leiden Journal of Pottery Studies*. Students of ceramic research would be well served to become acquainted with their holistic system of analysis.

Performance Characteristics and Morphology

Morphology can be described and classified in many ways, and so the analyst needs to choose a strategy appropriate for the assemblage under investigation. When one's goal is to infer intended techno-function, these technical choices related to vessel morphology are grouped in relation to the performance characteristics they affect. Rice (1987, pp. 224–226) identified four performance characteristics related to vessel morphology, but she referred to them as "use-related properties." They are capacity, stability, accessibility, and transportability. Although other technical choices may affect these performance characteristics, they are impacted most directly by morphological characteristics. When the discussion is moved to performance characteristics, or the attributes the vessels must have to perform its functions, the analyst is in a much better position to infer intended function. A profitable way to access these performance characteristics is through a performance matrix, as illustrated in Table 2.1.

Capacity is the one performance characteristic related to morphology that can be easily assessed quantitatively as in liters or gallons. One must be aware, however, that vessels will have a maximum capacity and an actual capacity. In many use-contexts a vessel is not filled to its maximum capacity (but see Kooiman 2012);

Table 2.1 Performance matrix for Kalinga pottery vessels

Performance Characteristics	Vessel type *Rice*	*Vegetable/meat*	*Water*
Accessibility	Low/medium	High	Low
Stability	Medium	Medium	Low
Transportability	Medium	Medium	Low
Capacity	Variable	Variable	Variable
Heating effectiveness	High	Medium	N/A
Thermal shock	High	High	N/A

cooking pots are often just filled to half or three-quarters overall capacity. Differences between maximum capacity and actual capacity can be determined by other use-alteration traces such as internal carbonization (see Chap. 3).

Stability is the ability of the vessel to stand upright. Shepard (1956, p. 237) notes that stability is determined by a vessels "shape, the distribution of its weight, and the breath of its base." Some vessels are flat bottomed or have legs and thus have high stability. Some round bottom pots have moderate stability in that they will stay in the upright position while on a flat surface but they will rock easily when nudged. Kalinga cooking pots are in this category, as are many Southwestern and Midwestern United States cooking pots that have round bottoms. A curved base increases strength but decreases stability, which is mitigated by having a tripod-like hearth design so that vessels rest securely on three points, sometimes referred to as "firedogs." When not on the fire, unstable pots could be placed on pot rests or concavities in the hearth or floor, as is done by the Kalinga. Some vessels have zero stability and cannot stand upright on their own. The Gamo of Ethiopia create cooking vessels that need support to stand upright (Arthur 2006), and many of the pottery types from the Eastern United States have conical bases as do Middle Eastern amphorae. In cases when pots have zero stability they must depend on other technologies to hold them upright.

Accessibility is a performance characteristic that relates to how easily the contents of the vessel can be accessed. The orifice diameter and the attributes of the vessel's neck have the greatest impact on accessibility. Many storage jars have a restricted orifice diameter and limited accessibility, so that neither hand nor an implement ever enters the vessel. In these cases, as is in liquid or seed storage, the contents are designed to be removed by pouring. The other extreme is complete accessibility, which is seen in many cooking pots whose contents have to be stirred and then removed by hand or with a utensil. Kalinga cooking pots provide a clear example of slight differences in accessibility: vegetable/meat cooking requires frequent stirring and a higher overall accessibility, but rice cooking pots are only accessed once when the rice is removed. Rice cooking pots thus have a narrower orifice diameter to limit accessibility (and also increase heating effectiveness).

Transportability relates to how easily the vessels can be moved short or long distances. Ceramic vessels in general are not known for great transportability as vessels are fragile and heavy, relative to other containers. But ceramic vessels are

Fig. 2.1 Kalinga vessel types. From left to right, *immosso* (water vessel), *ittoyom* (rice cooking vessel) and *oppaya* (vegetable/meat cooking vessel) (From Skibo (1992), p. 60)

well suited to holding liquids, and if the fragility issue can be countered by other technical choices to increase strength and with other technologies to avoid impacts (supports, wheeled carts, etc.), then such vessels will have increased transportability. Most vessels, however, have relatively low transportability and are designed to move relatively short distances, if at all. Kalinga water vessels have very low transportability when full, as they are heavy and awkward to carry. Consequently, many pots spend their entire life history on a shelf where they are refilled with water transported in other vessels. Most cooking pots have some limited transportability as they must travel on and off the fire. Such movement puts a limit on capacity because it becomes very difficult for one person to move a large vessel on and off a fire. Short-distance transport can be aided by implements, which can be used to grasp pots, an especially important consideration if they are removed hot.

Let's examine an ethnoarchaeological example from the Kalinga to illustrate the relationship between morphology and performance. The Kalinga have a water vessel (*immosso*) and, as noted earlier, two basic cooking pot forms; one to cook rice (*ittoyom*) and the other to cook vegetables and meat (*oppaya*) (Fig. 2.1). Each of the cooking vessels is made the same way in terms of paste, surface treatment, and design. The only design difference relates to accessibility and heating effectiveness; the latter is the ability of the vessel to heat its contents. Heating effectiveness, like most performance characteristics, is influenced by a variety of technical choices like thickness, temper type, and especially surface treatment. In this case, heating effectiveness is a secondary performance characteristic related to morphology (a more complete discussion of cooking pot performance involving all relevant technical choices is presented below).

An archaeologist who discovered Kalinga pottery in archaeological context would be able to correctly discriminate these two types of cooking vessels based upon measurements of the orifice diameters and the height-to-width ratio (except in the cases of the intermediate forms discussed in Chap. 1). The vegetable meat pots have a more open orifice diameter and are more squat in profile while the rice cooking pots

Fig. 2.2 Kalinga vessels in use. Rice cooking pots (L) is in the simmer position while the vegetable/meat pot is on the fire (From Skibo (1992), p. 137)

have a narrower mouth and are taller in profile. The metrics speak clearly to accessibility. Rice cooking pots are accessed only when the rice is added to the pot and then again when it is removed with a spatula-like wooden tool. Rice pots are put on the fire until the water boils, then the vessel is removed and placed next to the fire. Rice cooking pots stay on the fire for 20 min or so and are not accessed during this time (Fig. 2.2). Vegetable meat pots, on the other hand, can stay on the fire for over an hour (in the case of boiling beans) and are accessed many times to stir, add other ingredients, and then to ladle out the contents for serving. Accessibility, a primary performance characteristic, is clearly reflected in vessel morphology.

Transportability of the cooking vessels is rated as "medium" because both are carried when full and empty. Hot pots are taken off the fire with the help of a rattan tool that looks much like a belt, which is slid over the top of the rim and fits nicely around the neck (Fig. 2.3). Hot pots can then be moved off the fire without touching the hot ceramic surface. Kalinga vessels are also made so that they can be nested and stacked. Potters transport the vessels in this way, as do women returning from the water source, where the vessels are washed and then filled with water (Fig. 2.4). Two or three nested cooking pots filled with water are carried back to the house on a woman's head, and the water from these vessels then fills the water pots.

The water vessel (*immosso*), with low accessibility, stability, and transportability is clearly a vessel designed for liquid storage. Stability is the only performance characteristics that could be higher in these types of vessels, but the Kalinga compensate for low stability by placing the vessels on rattan rings (Fig. 2.5). Once in place on the shelf, the water vessels are rarely moved.

Fig. 2.3 A pot being placed on the fire with the use of a rattan pot carrier (From Skibo (1992), p. 66)

Fig. 2.4 Carrying nested pots, filled with water, back from the water source (From Skibo (1992), p. 77)

Fig. 2.5 Pots in use resting on rattan rings (From Skibo (1992), p. 66)

Heating effectiveness is a secondary performance characteristic but is still important to the overall performance of these two cooking vessels. The objective in rice cooking is to bring the contents to a boil as fast as possible, and heating effectiveness of the rice cooking pots is increased by the smaller orifice. Rice cooking pots are also covered while on the fire, which also increases heating effectiveness. Because heating effectiveness is such an important performance characteristic for rice-cooking vessels, it is no surprise that aluminum pots had almost completely replaced their ceramic counterparts (Skibo 1994). Vegetable meat pots, in contrast, with their wider mouth have poorer heating effectiveness and are also left uncovered while on the fire. The goal for vegetable meat cooking is to bring the contents to a simmering temperature but without boiling and boil over. Consequently, poorer heating effectiveness is preferred because it permits the pot to stay on the fire for a long period without boil-over, which leads to the inconvenience of a doused fire.

Paste Composition: Temper (Type, Size, Shape, Quantity) and Clay (Type, Chemistry)

Owen Rye is a potter who, much like some of the early flintknappers like Don Crabtree pointed the way for functionally based lithic analysis, contributed significantly to the functional study of pottery and our ability to link technical choices to performance (Rye 1976, 1977, 1981; Rye and Evans 1976). His 1976 article, “Keeping your temper under control,” is not only one of my favorite titles but also important for understanding the clay-temper dynamic in traditional pottery. Rye spent a great deal of time replicating various types of ceramics and, much like Crabtree, believed that replication is an important means to understand a traditional technology. The importance of the early flintknappers, like Crabtree and Bordes, is that they played a big role in understanding a technology that was no longer in use—a dead technology. Ceramic technology, of course, never died, and one can visit a local pottery studio where people might be performing tasks similar to those of early Neolithic potters of Europe or Woodland potters of the Eastern United States. Because pottery technology never “died,” there is a tendency to take it for granted. After all, most of us made functional vessels in grade school and coerced our mothers to display these works of “art.” But just because a 10-year-old child can make a pot does not mean that it is a simple technology. Pottery technology is much like playing a harmonica, where anyone can play a recognizable tune with just a little instruction, but it takes years of practice to bend notes and master the Blues’ riffs of James Cotton or Howlin’ Wolf. It is researchers like Rye, and Shepard (1956) before him, who paved the way for archaeologists to better understand the complexities of making pottery. One of the wonderful legacies of the earliest flintknappers is that there is the unwritten rule that anyone who studies lithics should be able to perform at least rudimentary flintknapping so that they can learn firsthand the skill involved in this craft. Unfortunately, a parallel does not exist among many ceramic analysts (with some notable exceptions such as the Lieden or Scandinavian Schools discussed above). I would think that Owen Rye would agree with the statement that anyone who studies ceramics should also have experience with making and or replicating pottery. Although there are many books on pottery, as there are now many books on flintknapping, the knowledge and appreciation for the craft that one acquires with hands-on experience is invaluable. I said at the outset that ethnoarchaeology changed forever the way I view pottery and its relationship to people. The same can be said about replicative experiments with clay. It is one thing to read about how, for example, temper affects workability, firing temperature impacts thermal shock, or how a smudge is applied, but it is another thing to feel the workability of wet clay change as organic temper is added or to feel the heat of a kiln as a red hot vessel is removed for smudging.

The relationship between morphology and techno-function has a long history because, in part, it is much easier to perceive the relationship between a vessel’s orifice diameter or shape and likely use. The relationship between temper and techno-function took a bit more convincing and is still a work in progress. As Bronitsky and Hamer (1986, pp. 89–90) note, temper type has long been considered an attribute most tied to cultural factors instead of techno-function. Although temper selection in some instances may be related to socio-, ideo, or emotive function, archaeologists have started to explore how the choice of a particular temper might have an impact on how the vessel performs during manufacture and use (Braun 1978, 1983; Bronitsky 1986; DeBoer 1984; Reid 1984; Steponaitis 1983, 1984).

In the mid-1980s while I was still a graduate student at the University of Arizona, I walked into the newly formed Laboratory of Traditional Technology and saw

Gordon Bronitsky kneading a lump of clay on top of a wooden crate. Michael Schiffer created the lab and acquired space in the Haury Building with a mix of creativity and bravado (see Schiffer 1995, pp. 22–24). I was the first graduate assistant and was given the honorary title of Assistant Director of the laboratory, which had no space. But Schiffer and I acquired several truck loads of donated scientific equipment, some of them packed in wooden crates. We stacked the wooden crates and odd assortments of equipment in the hallway of the building until some of the department's faculty started to complain about the mess and congestion. The Department Chair asked us to move the equipment into a recently vacated room on the first floor of the building. We were instructed that this was only a temporary move, as the Department had other plans for the space. But we moved in, quickly put a sign on the door, and a quarter century later and counting the Laboratory of Traditional Technology still resides in that same room. The equipment, however, was donated to surplus property at the University, who sold it at auction, with the Lab getting a portion of the proceeds. A good mentor like Mike Schiffer teaches many important lessons, but none was more practical than how to acquire space and funds in a university system.

It was in the midst of this move that Gordon Bronitsky appeared, fresh from a Fulbright in Holland at the University of Leiden's Laboratory of Ceramic Studies. There he studied with van As and others who had a long-standing interest in the relationship between ceramic technology and use. Bronitsky advocated a materials science approach to archaeological ceramics (Bronitsky 1986; Bronitsky and Hamer 1986). Schiffer was, and still is, a studio potter, but Bronitsky introduced a new way to look at ceramics. I had a long-standing interest in prehistoric ceramics and also a growing interest in experimentation and ethnoarchaeology. In 1987 I took a sojourn from the lab to join Longacre in the Philippines to conduct the research that would become *Pottery Function* (1992). Thus, the initial direction of the Laboratory of Traditional Technology was created by this convergence of people and ideas. There was a flurry of replicative experiments in the next several years that contributed greatly to our understanding of the relationships between temper, firing temperature, and surface treatment and ceramic performance in manufacture and use.

The first of the experiments had to do with the effect of temper on vessel performance. I participated in an American Anthropological Association symposium, organized by Bronitsky, where I met Kenneth Reid, who had excavated the site of Nebo Hill in Kansas. Through careful recovery methods he found small sherds (crumbs) of Late Archaic fiber-tempered pottery. This was one of the northernmost locations for Late Archaic pottery, which led Reid (1984) to suggest that perhaps the distribution of the pottery type, which was confined primarily to the southeastern United States, was created in part by noncultural formation processes—freeze thaw cycles. In fact he found a correlation in the distribution of pottery and the number of below freezing days. Though just a second year graduate student, I approached Ken Reid after the session and stated that we could test this hypothesis in the newly formed Laboratory of Traditional Technology. When I told Mike Schiffer of the plan he got to work and somehow acquired a heavily used but still functional freeze-thaw chamber. That led to a series of experiments that looked at the relationship between temper-type and firing temperature and vulnerability to breakdown in freeze thaw cycles (Skibo et al. 1989). Reid was right: low-fired fiber-tempered pottery was indeed very vulnerable to breakdown. But we also used this opportunity to look at the performance advantages that fiber-tempered pottery might have. The results of these tests are discussed below.

Recording Paste (Clay and Temper) Variability

Chemical and mineralogical characterization of pottery has a long history in archaeology, for we are interested in learning where pottery was made (e.g., Abbott 2000; Carter et al. 2011; Neff 1992; Neff and Bishop 1988; Stoltman 1989, 1991, 2011; see Rice 1987, 1996b; Velde and Druc 1998; for a review of the various techniques). This area of study is, of course, of critical importance as it provides basic information on which to build inferences about the organization of production, exchange systems, and political economy. There have been many studies throughout the pottery making world that have used a variety of characterization techniques to speak to these important issues (Abbott 2000; Rice 1996b; Bishop et al. 1982; Fargher 2007; Middleton and Freestone 1991; Neff 1992; Stoltman 1989, 1991). Sourcing clay and temper will always be the primary concern in this type of analysis, but these same characterization techniques can also be applied to understanding intended function. The underlying assumption is that potters select clay and temper usually within a short distance from the point of manufacture. There are a lot of ethoarchaeological data to support this generalization (Arnold 1985; Arthur 2006, p. 31; Longacre 1985; Neupert 2000). Clay and temper are difficult to transport, so there is a strong correlation between clay and temper sources and the location of manufacture. Arnold (1985, pp. 31–57) has done the most extensive examination of this relationship and has found that most clay and temper are found within 7 km of the potters workshop. Although potters choose nearby clay and temper, they still do have choices among the nearby sources. It is these choices that are of interest here (see Neupert 2000).

Performance Characteristics and Paste Composition

Paste composition (clay and temper) affect performance both in manufacture and use. Manufacturing performance characteristics include workability, and ease of manufacture.

Workability is a potter's assessment of the clay in relation to specific forming techniques (for present purposes, hand-building). As Bronitsky (1986, pp. 212–218) notes, three clay properties are of interest to the potter: controllability, formability, and plasticity. Potters usually collapse these properties by feel into a general category of workability (Rice 1987, pp. 60–63; Rye 1981, p. 21). Potters assess workability by testing the clay's ability to bend, as in a coil, without cracking, and to hold the form under pressure. Clay can be "soft," which means the paste deforms easily but does not hold up under pressure, to "stiff," in which the clay is hard to form yet holds up well under pressure. Workability is based on the relationship between clay mineralogy, water content, presence of organics, and temper. For example, generally speaking clay because less workable—more stiff—as more mineral temper is added. Some large vessels, however, may require a stiffer paste, and adding more temper would create that effect. Dry organic temper, such as chopped grass, can make a very soft, plastic, sticky clay workable because it absorbs some of the moisture (Skibo et al. 1989).

Ease of Manufacture is a component of workability in that it is an assessment of how much time and effort is necessary in the construction of a vessel. Some pots are manufactured in stages sometimes over several days and require various tools and skills to produce, while other pots are made in one sitting and a potter can go from wet clay to finished fired vessel in one day. Temper and paste properties play a significant role in ease of manufacture. For example, a pot with 40% mineral temper, which is common in cooking pots, can be very difficult to manufacture. The clay is excessively stiff, prone to cracking when bent, and the surfaces are not easily smoothed. Less temper, let's say 20%, would increase the ease of manufacture but reduce its effectiveness as a cooking pot. We demonstrated (Skibo et al. 1989) that ease of manufacture was a primary performance characteristic for Late Archaic fiber-tempered pots in the eastern United States. If potters were interested in making a vessel in one sitting, they could collect surface clay, which is often excessively plastic and too sticky to be workable, but add organic temper to absorb the moisture and increase workability. Such a vessel would then be dried next to the fire and then placed into the fire where the clay could sinter, making a serviceable cooking pot. Expediency is important in these contexts.

Some of the performance characteristics important in use include thermal shock resistance, cooling effectiveness, portability, impact resistance, and abrasion resistance.

Thermal shock resistance is the ability of a vessel to withstand repeated exposure to heat without cracking. If a pot is used for boiling, then the interior would not exceed 100 °C, while the exterior could be 500 °C to 600 °C. The outer surface expands, creating tensile stresses that form micro cracks. Unless impeded, these micro cracks will pass through the entire vessel and result in catastrophic failure. A vessel with low or no thermal shock resistance would break with the first exposure to heat. Anything that interrupts these micro cracks, like temper or pore spaces, increases thermal shock resistance. It is no coincidence, therefore, that cooking vessels around the world often have a heavily tempered paste.

Cooling effectiveness refers specifically to water storage vessels. Pots having some permeability will permit the passage of water to the exterior surface where it evaporates, removing heat and thus cooling the vessel's contents (Schiffer 1988). Although permeability is influenced also by firing temperature and surface treatments, paste characteristics can also alter cooling effectiveness. Thus pots with much more mineral temper have greater permeability.

Portability simply refers to how easy it is to transport the vessel over short or long distances. Certainly size, shape, strength, and the availability of other technologies affect portability considerably, but so can paste. For example, organic tempered pottery can be up to 30% lighter than similar sand tempered pottery, which could be a factor in vessel portability (Skibo et al. 1989)

Impact resistance is the ability of a pot to resist impacts, which is the most common way vessels ultimately break. Pottery, compared to other containers such as baskets or skin bags, has very low impact resistance, but because of other important performance characteristics ceramics are used regardless of the high probability that they will break one day from an impact. It has been shown that there is a significant relationship between temper type, amount and size and impact resistance (Bronitsky and Hamer 1986; Mabry et al. 1988; Neupert 1994).

Finally, *abrasion resistance* is the ability of the vessel to resist the loss of surface material through various types of cultural or noncultural processes such as trampling or fluvial transport. Temper type and amount can alter the abrasion resistance of pottery significantly (Skibo and Schiffer 1987; Vaz Pinto et al. 1987). For example, organic tempered pottery is more prone to abrasion under a variety of conditions than similarly made mineral tempered pottery.

To illustrate the relationship between paste composition and performance, let's turn to a series of experiments focused on understanding the use of organic temper in the Late Archaic of the Southeastern United States. This case study illustrates how temper and clay selection affect workability and ease of manufacture, portability, heating effectiveness, thermal shock resistance, and abrasion resistance.

Case Study: Late Archaic Pottery

The Early Woodland in the Eastern United States was initially defined by the appearance of pottery but better dated sites and more careful excavation revealed that Late Archaic hunter-gatherers were actually the first potters in North America (Reid 1984). This is a story that is repeated in many parts of the world as no longer can archaeologists simply equate the appearance of pottery with the "Neolithic Revolution" and the transition to more settled life and plant cultivation. Pre-agricultural hunter-gatherers are often the first potters in a region (Harry and Frink 2009; Harry et al. 2009; Frink and Harry 2008; Jordan and Zvelebil 2009; Sassaman 1993; Skibo et al. 2009). Many of these hunter-gatherer potters tempered their vessels with organic matter of some sort, usually a kind of dried grass.

Prior to our work the choice of organic temper was often given some form of "cultural" explanation, such as the people were making a transition from baskets to pottery and grass temper was a bridge between these two technologies. Such explanations did not consider how a temper selection might influence the performance of the vessel in manufacture or use (see also Sassaman 1993). Our experiments considered two general questions; Why did Late Archaic potters use organic temper, and why do all potters across the Eastern United States switch to sand temper during the Early Woodland?

The results of the experiments can be summarized in a performance matrix (Table 2.2).

Table 2.2 A performance matrix for late Archaic and Woodland pottery technology (Adapted from Schiffer and Skibo 1987, p. 607)

Performance characteristic	Late archaic	Woodland
Ease of manufacture (expediency of manufacture)	+	−
Portability	+	−
Heating effectiveness	−	+
Impact resistance	−	+
Thermal shock resistance	−	+
Abrasion resistance	−	+

Based on this series of experiments, organic tempered pottery scores better than comparable sand tempered pottery in two important performance characteristics—ease of manufacture and portability. In terms of portability, I noted above that organic tempered pottery is lighter than sand tempered pottery of equivalent form. Although overall weight is not the only issue in portability it could certainly play a significant role under some conditions. We concluded, however, that ease of manufacture was the most important and thus primary performance characteristic for the Late Archaic potters of the Southeastern United States.

Recall that ease of manufacture is a suite of performance characteristics that includes plasticity, green strength, and drying rate, among others. The aspect of ease of manufacture that we think explains the presence of organic temper in this 2,000 B.C. pottery relates to expediency of manufacture. If one wants to make a pot quickly, perhaps even in one sitting, the fastest way to do that would be to collect wet clay, which is abundant in the Southeast United States. Such alluvial clay, however, is excessively plastic, sticking to the potter's hands and to surfaces to such an extent that forming a vessel is virtually impossible. Our experiments have shown that adding mineral temper does not ameliorate this excessive plasticity, but that adding chopped dry organic matter, as in Late Archaic pottery, dries the paste and increases workability to the point where a vessel can be formed. Simple open forms, as was common in this technology, can be made using the slab technique. Such a vessel could then be dried quickly next to the fire and then placed directly in the fire. Late Archaic pottery was fired to a very low temperature that could be reached in a simple open fire.

In order to better visualize the appearance of pottery in the Southeast and then the transition to mineral tempered pottery, imagine that you are part of a band of hunter-gatherers in what is today Georgia arriving at a Fall campsite. Your group has been coming to this same campsite for generations to harvest shellfish and to collect the local nuts and other autumn resources. At this campsite there is a need for cooking vessels to process food (The story is a little blank here because it is still unknown what was processed in these pots—an analysis of absorbed residues is needed on these collections). Your group arrived at the campsite by mid-morning, dug up some wet clay, added chopped dry grass, and made simple vessels very quickly. In the early evening the vessels were placed in the fire and then pulled out the next morning. After just a few hours of work the small group had a serviceable cooking pot that could have been placed directly over the fire.

The transition to mineral tempered pottery that occurred in the Eastern Woodlands and in many other parts of the world can also be explored by examining the performance matrix. Mineral tempered pottery score higher on all other performance characteristics related to cooking pots and vessel durability: thermal shock resistance, heating effectiveness, impact resistance, and abrasion resistance. Once the Woodland potters became more committed to ceramic technology, they made choices better suited to their lifeway and cooking vessels. If expediency was no longer a concern, potters likely collected dry clay, ground it up, added temper and water, and perhaps let the clay sit for a time (aging it) before making vessels. Such a process would take several days instead of just 12 h or so for the Late Archaic vessels.

Some have suggested that the poor heating effectiveness of organic tempered vessels might be because the containers were used for indirect heating with hot rocks instead of placing them directly over a fire (Reid 1989; Sassaman 1993). If such were the case, then you would actually want a vessel with poor heating effectiveness to retain the heat instead of conducting it through the wall (Reid 1984). In the case of the Late Archaic vessels, however, Beck et al. (2002) found evidence of exterior soot on a significant number of sherds from a sample. Sassaman (1993) also found evidence of sooting on the collection he analyzed, thus it is certain that a good portion of the early pottery was used over a fire. In many cooking and hearth situations, exterior sooting may be absent on the base and the upper half of the vessel. Such a vessel, when broken into sherds, would have evidence of sooting on less than half (and likely closer to a third) of the sherds even though the vessel was used exclusively over a fire. Sassaman (1993), however, found that sites on the coast had sherds with more evidence of sooting than those on the interior. Consequently, he suggests that fiber-tempered pottery in the Savannah River Basin was more likely used in indirect heating. This is an interesting case study that involves the social performance of both soapstone objects (used in indirect heating) and ceramic vessels and I revisit it in Chap. 3. I cannot rule out hot-rock boiling in ceramic containers, as thick, open-mouthed fiber-tempered vessels could serve that role nicely, but it does not surprise me that there is also significant evidence that many of these vessels were used over a fire. Indeed, the primary performance advantage of ceramic vessels over wood, bark, or skin containers is that they can be placed over a fire.

Case Study: Shell Tempered Pottery

In North American archaeology perhaps the most infamous temper is shell, which was added to pottery throughout much of Eastern North America during the Late Woodland/Early Mississippian Period (AD 700–1100) (Boszhardt 2008; Dunnel and Feathers 1991; Feathers 2006, 2009; Feathers and Peacock 2008; Lafferty and Roberts 2008; Pauketat and Emerson 1991; Rafferty and Peacock 2008; Roper et al. 2010; Sabo and Hilliard 2008). It has generated so much interest because its appearance coincides with the introduction of maize and then its subsequent dominance in the diets of many groups during this period. Shell tempered pottery also appears during the rise of Cahokia, one of North America's greatest prehistoric cities with perhaps as many as 15,000 residents but whose influence is seen over tens of thousands of square miles (see Pauketat 2004).

Did the shell tempered cooking pot play a role in this most interesting political and economic transition? Vincent Steponaitis (1983, 1984) was one of the first to suggest that it might. Based on an analysis of pottery from the site of Moundville, in Alabama, he concluded that shell temper was added to the pots to enhance techno-functional performance. He noted that the non-cooking vessels were tempered with finely ground shell whereas the cooking vessels had coarse shell. He conducted tests on the pottery itself and concluded that the coarsely tempered cooking ware would have greater resistance to thermal shock and mechanical stress. Although these results were preliminary, in part because the tests were performed on pottery recovered from archaeological context, and thus had reduced strength (1984, p. 114), Steponaitis transformed the way that archaeologists look at shell-tempered pottery. “If there is a general lesson to be learned from the results obtained so far, it is that archaeologists should be much more circumspect about regarding all the variability they see in ceramics as being purely stylistic” (Steponaitis 1984, p. 115).

Bronitsky and Hamer (1986) did a series of replicative experiments that tested the performance of various tempers, including shell, under conditions of impact and thermal shock. Instead of using archaeological specimens, as was done by Steponaitis, they produced ceramic test briquettes and found that burned shell temper produced samples that were considerably more durable. The most thorough examination of shell temper in the Eastern United States, however, has been conducted by James Feathers (Dunnel and Feathers 1991; Feathers 1989, 1990, 2006, 2009; Feathers and Peacock 2008; Feathers and Scott 1989). Focusing on pottery produced in southeastern Missouri, Feathers concluded that shell tempered pottery had significantly higher strength (toughness and thermal shock resistance) than comparable sand tempered pottery, which is in basic agreement with the results first reported by Steponaitis (1984). He argues that potters made the transition to shell temper in southeastern Missouri because of this improved techno-functional performance. But Feathers (2006, p. 116) goes on to note that we cannot simply use this explanation for the “pan-Eastern spatial and temporal distribution” of shell-tempered pottery. In fact the timing of the spread of shell-tempered pottery, its relationship to the appearance of corn, changes in the socio-political landscape and other historical factors must be considered and Feathers argues, and I agree, that it is unlikely that this simple functional explanation can account for the appearance and spread of shell-tempered pottery throughout this vast region.

We have noted elsewhere that “technologies are context dependent, their form and prevalence contingent upon local, historically constituted conditions” (Skibo and Schiffer 2008, p. 67; Schiffer 2005, 2011). In terms of the adoption and use of shell temper across the Eastern United States, the devil is certainly in the details as it is up to the archaeologist to construct empirically grounded narratives for this change that take into account the techno-functional advantages of shell temper but also relevant contextual factors. As a technology, such as shell tempered pottery, gets transferred from community to community, the vessels get redesigned as new sources of clay and shell are used, and potters make changes to the recipe that are in line with their own technological traditions. Moreover, new performance characteristics might be important in these new communities that account for changes to the pottery. These types of textured historical narratives can be built upon a behavioral foundation for the adoption, use, and transfer of technology from one community to the next (Schiffer 2002, 2005, 2011; Schiffer and Skibo 1987, 1997; Skibo and Schiffer 2001, 2008).

Another fundamental issue in explaining the invention, and widespread adoption of shell-tempered pottery (using experimental data) is that of behavioral significance (Schiffer and Skibo 1987). Feathers (2006) also notes the importance of behavioral significance but uses different terminology. Behavioral significance means that just because shell temper increases thermal shock resistance, it does not necessarily follow that prehistoric potters were aware of this strength difference and, even if they were aware of it, that they assigned it important in the adoption of shell temper. We maintain that behavioral significance differs from statistical significance. When we conduct strength tests we are apt to find that a change in temper creates a change in strength that is statistically significant. But statistical significance does not correlate necessarily with behavioral significance, which is the ability of the potter or pot user to actually notice and assign importance to the difference in strength. It is up to the archaeologist to argue for behavioral significance of a particular performance characteristic on the basis of other lines of evidence (what the vessel was used for, how was it made, societal factors, etc.). This is the reason for constructing the performance matrix, which helps the researcher to discern patterns in the performance characteristics of each technology.

Firing Temperature

Pottery is human-made stone, and what creates this transformation from clay to ceramic is heat. Traditional handmade earthenware pottery is fired either in an open-fire, usually for a short period of time, or in closed kilns of various types, which usually involves longer firing times and higher temperatures (see Rice 1987, pp. 153–163 for a review). Gosselain (1992) has shown that firing temperatures in open and kiln fires are extremely variable and, in fact, firing temperatures overlap considerably in the two regimes. Thus, potters have little control of the temperature within the kiln once the fire is lit. What potters can control, however, is the firing time. Open-fires usually reach temperature quickly, and overall firing times are usually between 20 and 30 min. Kiln fires, however, reach a maximum temperature slowly and hold that temperature considerably longer (Gosselain 1992). Because actual firing temperature is a function of time, temperature, and atmosphere, potters do have some control over this important technical property through choosing fuels, method of stacking, etc. (Rice 1987; Tite 1995). Tite (1995, 1999) finds that open firing temperatures are between 500°C and 900°C but most are between 600°C and 800°C. Temperatures in kilns range from 600°C to 1,000°C but most are between 750°C and 950°C. Actual firing temperature of pottery, which is based on changes in the mineralogy or microstructure, are estimates of total heat input (time, temperature, atmosphere). Tite (1999, p. 189) suggests that actual firing temperature of open fires is between 550°C and 750°C and 750°C to 950°C for kiln fires.

How Firing Temperature Is Estimated

"Mineralogical changes dependent on firing temperature include the breakdown of clay minerals, the decomposition of calcite, and the formation of high temperature phases such as spinel, gehlenite, wollastonite and mullite" (Tite 1995, p. 37). A variety of techniques from the simple to the complex have been used to estimate firing temperature. These range from hardness tests and color comparison to examination of the extent of vitrification of the clay minerals using a scanning electron microscope (Orton et al. 1993, pp. 133–135; Rice 1987, pp. 426–435).

These techniques all work to varying degrees of accuracy and one's choice of technique depends on how accurate a measurement of firing temperature is needed. Anyone can do simple refiring tests or scratch tests to get an impression of relative hardness and, presumably, firing temperature, but not everyone has the skills and funds for scanning electron microscopy. But because firing temperature is very important for understanding vessel performance in use (see below) and can be used to infer the type of firing regime, many analysts find it necessary to get highly accurate estimates. One of my favorite and relatively underutilized methods is thermal expansion measurement, which can be determined with a relatively simple device referred to as a "dilatometer."

One reason I have such a warm feeling for this device is because Michael Schiffer got an ancient dilatometer donated to the Laboratory of Traditional Technology shortly after it was founded. Steven Falconer was the first to use this device, which looked like it came directly from Dr. Frankenstein's laboratory. Steve got the machine going and used it to estimate firing temperatures for his research on ceramics from the Jordon Valley (Falconer 1987, 1995). Estimating firing temperature through thermal expansion analysis is based on the simple idea that reheated ceramics expand up to the point at which they were originally fired, after which the ceramic resumes sintering and begins to shrink. A dilatometer has a furnace that heats the ceramic, and a push rod measures the linear expansion of the sample, which is plotted against temperature. Because rate of heating and other factors can affect firing temperature estimates, analysts usually employ a method of reheating the sample and applying a correction formula first proposed by Tite (1969).

Performance Characteristics and Firing Temperature

The performance characteristics influenced by firing temperature include, strength (e.g., impact and abrasion resistance), thermal shock resistance, and permeability. These performance characteristics were described earlier but let me review how firing temperature can affect them. Mabry et al. (1988) demonstrate that there is an incremental increase in *strength*, measured in impact resistance, as firing temperature increases. Strength can be measured in other ways such as a using a ball-on-three-ball technique (Neupert 1994) or by assessing abrasion resistance (Schiffer and Skibo 1989). As Shepard (1956, p. 130) notes, ceramic strength would be an effective way to classify pottery if it could be "measured satisfactorily." To that end, a good deal of effort has been put into designing behaviorally relevant measures of pottery strength including impact resistance (Mabry et al. 1988) and biaxial flexure (Neupert 1994; see Pierce 2005 for a comparison of various techniques). The advantage of the impact tester is that it measures a behaviorally relevant performance characteristic as impacts are one of the most common reasons for ceramic breakage. The disadvantage of the impact tester is that it is best suited to assess impact resistance on flat, experimentally made samples. This type of testing is only relevant when attempting to determine the effect of a particular technical choice (such as temper type, surface treatment, or firing temperature) in a very controlled environment. Neupert's (1994) method of testing tensile strength with the ball-on-three-ball device has the advantage of being able to test strength on curved specimens that can include archaeological samples. For example, Beck (2002) demonstrates that Hohokam Red-on-buff pottery from southwestern Arizona increase in strength over time, which she suggests might have resulted from higher firing temperatures.

Thermal Shock Resistance generally decreases as firing temperature goes up as sintering reduces pore space, which impedes micro crack propagation. Low fired pottery has more pore space and thus higher thermal shock resistance (see Harry et al. 2009). Similarly, as firing temperature increases pore space and water *permeability* goes down. Completely vitrified pottery, such as porcelains, are impermeable.

Surface Treatments

Archaeologists have a long tradition of recording various surface treatments as they are essential for creating and describing various stylistic traditions (see Shepard 1956, pp. 65–72). For example, in the American Southwest vessels that are polished would be distinguished typologically from a vessel that was slipped and then polished. Likewise, the direction of cord-markings on the exterior of pottery from the Midwestern United States is enough to distinguish one type from another. Painting, in some ways the most infamous of the surface treatments because of its ability to inform on socio-functions as well as serve important chronological and special markers, has long been recorded in minute detail. Experiments have shown that, like temper, and firing temperature, surface treatments play an important role in vessel performance from reducing permeability to increase heating effectiveness, to evoking powerful religious emotions.

How are Surface Treatments are Recorded

Archaeologists have become quite adept at recording surface treatments, as many can be properly identified with the naked eye or with low power magnification (see

Rice 1987). In archaeological laboratories across the globe analysts record surface treatments, from finger-smoothed and textured to slipped and glazed.

Pottery surface treatments are unique in that some are applied before and others after firing. Pre-firing surface treatments applied while the clay is still workable include: finger-smoothed, tool smoothed, textured, and corrugated. Pre-firing treatments applied when the clay is bone-dry include but are not limited to, slipped, polished, and painted. Post-firing surface treatments include smudging, painting, and various forms of organic surface treatments such as resins or fats. The latter surface treatment is likely one that is routinely missed by analysts as they often do not survive in the post-depositional environment (Skibo et al. 1997). For example, the Kalinga apply a pine resin to their vessels, but sherds in the local midden show no evidence of it. Indeed, ethnographically post-firing organic surface treatments are routinely applied as a means to reduce permeability of low-fired wares. One can infer that similarly low-fired pottery recovered from archaeological context would also have been excessively permeable when in use and that prehistoric potters likely applied some form of post-firing organic surface treatment that is no longer visible on the surface of excavated sherds.

Glazes, which are glasses, can be applied to bone dry vessels in a one-stage process, as in some traditional Japanese potteries. Often, however, glazes are applied after the first ("bisque") firing and then refiring at a higher temperature (requiring a kiln) to achieve complete sintering (Rice 1987, pp. 98–102). Glazing, especially on a vessel's interior, also has the effect of making a vessel largely impermeable to water.

Performance Characteristics and Surface Treatments

Surface treatments influence a number of techno-functional performance characteristics including thermal shock resistance, permeability, abrasion resistance, and heating effectiveness. Surface treatments such as painting also may perform socio-, ideo-, and emotive functions. For example, Ramos Polychrome, or Salado Polychrome in the American Southwest, or Ramey Incised in the Midwest performed functions related to ritual and religious/political identity. These types of inferences, however, are context dependent, and thus I will leave that aside for now and discuss how various surface treatments can affect techno-functional performance regardless of time or space.

A series of experiments, combined with ethnographic and archaeological observations as well as materials science principles, have laid a strong foundation for understanding the relationship between various surface treatments and vessel performance during manufacture and use. One of the most important performance characteristics for cooking vessels is thermal shock resistance, which is influenced by a number of surface treatments. Schiffer et al. (1994) demonstrate that interior and exterior surface treatments significantly influence a pottery vessel's resistance to both thermal shock cracking and thermal spalling. Interior surface treatments that have some permeability increased a vessel's thermal shock resistance. That is because water in vessel's wall reduces the temperature differences between the interior and exterior of the vessels, and so lowers thermal stress. Thus, impermeable vessels tend to be more susceptible to thermal shock. However, highly permeable vessels were prone to thermal spalling, as water turned to steam as it exited the exterior surface and caused spalling. Any type of exterior textured surface (e.g., simulated cord-marked, corrugated, and stuccoed), however, improved a vessel's thermal shock resistance. Texturing of many varieties is found on cooking pots around the globe, suggesting that thermal shock resistance is a primary performance characteristic that was improved in many cases by having a roughened exterior surface.

Focusing just on corrugation, common on ancient Puebloan vessels of the American Southwest, Pierce (2005) evaluated the cost and performance characteristics of corrugation found on the base, upper body, and neck of the vessel. He found that simulated Puebloan vessels with corrugated exteriors improved the thermal shock resistance and thus extended vessel use-life. Interestingly, creating Puebloan-style vessels with exposed coils increases production time considerably (see also Young and Stone 1990). It takes far longer to make corrugated vessels with narrow, even, overlapping coils than it does to make a vessel with a smooth surface. Although the potter must take time to smooth the exterior of a uncorrugated vessel, a great deal of time is saved if a potter can add large coils and be less concerned with keeping the coil overlaps even. As Pierce's study shows, ancient Puebloan potters chose a surface treatment that was more time-consuming to make but greatly increased the vessel's thermal shock resistance and thus use-life. But given the many interactions among technical choices and performance characteristics, one cannot merely claim that exterior surfaces were always corrugated to improve thermal shock resistance.

Heating effectiveness and evaporative cooling effectiveness are also influenced considerably by surface treatments (Harry et al. 2009; Schiffer 1988, 1990). Young and Stone (1990) tested how corrugation might influence heating effectiveness. One of the long held functional explanations for corrugation is that it increases the exterior surface area of the vessel thus exposing a greater area to heat and, presumably, increasing heating effectiveness. This is an intuitively satisfying correlation because one can easily imagine that it would be important in many cooking situations to increase heating effectiveness especially if fire wood was scarce. Young and Stone (1990) made replicas of Southwestern plainware and corrugated pottery and performed some experimental cooking. They found that the corrugated vessels did not heat up the contents of the vessel faster than the plainware vessels. Nor did they find that the corrugated vessels cooled faster than the plainware vessels. But as the experiments described above demonstrate (Pierce 2005; Schiffer et al. 1994), corrugation does enhance thermal shock resistance. The Young and Stone (1990) study provides an important lesson in archaeological inference—assumptions about the techno-functional performance of any technology need to be tested, even those that seem to have strong intuitive backing.

Potters often use surface treatments to control permeability, which affects heating effectiveness and evaporative cooling effectiveness. In several experiments Mike Schiffer explored these effects. Mike had a serious hip injury and surgery in the late 1980s that significantly reduced his mobility. During his long recovery he hobbled down to the Laboratory of Traditional Technology and made test vessels with various surface treatments, put them through a battery of heating and cooling experiments and obtained important results (Schiffer 1988, 1990). In low-fired, earthenware cooking pots potters must contend with a serious issue—such pots are excessively water permeable. Not only can the liquid contents simply seep out of a permeable vessel, but even small amounts of water on the exterior of the pot significantly reduce heating effectiveness. As mentioned earlier, the evaporating water on the exterior actually removes heat from the surface and can keep water in a vessel from ever boiling. The deleterious impact of water permeability is illustrated by Kalinga cooking vessels, which are removed hot from the firing and a pine resin is melted onto the interior surface. During use and washing the pine resin gradually wears wears off and after about 3 months Kalinga women will no longer use them for cooking because water in the pots will not boil. This is especially a problem for rice cooking pots, which the cooks try to bring to a boil as quickly as possible. This ethnoarchaeological observation is backed up by Schiffer's (1990) experiments where he found that the greater the water loss the longer it took to heat water in the vessel. Testing surface treatments such as slip and polish, smudged, finger smoothed, and resin coated, he found that the vessels with the least permeable interior surfaces had the greatest heating effectiveness.

In a related series of experiments he examined the relationship between various surface treatments and evaporative cooling effectiveness (Schiffer 1988). This test was initiated by the observation that people living in arid lands often prefer ceramic water storage containers because the water stays cooler. It is based on the principle that evaporating water on the exterior of vessels takes away heat and thus keeps the vessel and its contents noticeably cooler. His experiments showed that in low-fired vessels evaporative cooling effectiveness for low-fired vessels is indeed controlled by the permeability of surface treatments.

Surface treatments can also influence a vessel's overall strength, which has been assessed through flexural strength or tensile strength (Harry et al. 2009) and abrasion resistance (Schiffer and Skibo 1989). Experiments have shown that surface treatments greatly affect abrasion resistance (Skibo et al. 1997). Smudging and resin coatings provided the greatest abrasion resistance, whereas slipped and polished and textured performed worst. Understanding abrasion resistance of surface treatments has implications for use-alteration analysis (Chap. 4), vessel performance in use and maintenance, as well as in responses of pottery to noncultural formation processes.

Case Study: Thule Pottery

A fascinating ceramic technology is found among Arctic potters of the Thule Culture from about AD 500 to the nineteenth century. Using archaeological, ethnographic, and experimental data, Karen Harry and Liam Frink have explored how these hunter-gatherer vessels were manufactured and used in a unique social and environmental context (Frink and Harry 2008; Harry and Frink 2009; Harry et al. 2009). To call these vessels "ceramics" may be a stretch as they were extremely low-fired—often

Table 2.3 A performance matrix for Thule pottery (Adapted from Harry et al. (2009))

Performance characteristic	No surface treatment	Seal blood and oil
Heating effectiveness	–	+
Tensile strength	–	+

little more than fired hardened because little sintering has taken place. Nonetheless, the investigators argue that these vessels were used directly over a fire to parboil meat. However, such low-fired pottery, being extremely permeable, has poor heating effectiveness. To compensate for the low-strength and high permeability of their low-fired ceramics, Thule potters coated the interior surfaces with seal blood and seal oil. The experiments of Harry et al. (2009) demonstrated that low-fired ceramics coated with seal blood were much stronger than similar vessels lacking a surface treatment. Experimentally created vessels coated with seal blood and oil were also able to bring water to a boil about 10 min faster than untreated vessels, if they survived at all, as untreated vessels tended to disintegrate. Although the performance matrix (Table 2.3) is over simplified, it illustrates the stark contrasts in performance of the replicated Thule pottery. Heating effectiveness is a primary performance characteristic in this case, the investigators argue, because of the lack of firewood in Arctic regions.

Karen Harry and Liam Frink demonstrated that by combining archaeological evidence, ethnography, ethnohistoric reports, and experiments they could put these puzzling, under-fired, Artic ceramics into proper context. Such a multifaceted approach helps to tease out the factors involved in the manufacture and use of this or any pottery. Their studies provide important new insights not only into Thule pottery but also into hunter-gatherer pottery studies in general (e.g., Eerkens 2003, 2004; Eerkens et al. 2002; Reid 1989, 1990; Sassaman 1995; Simms and Bright 1997).

Inferring Intended Function: Primary and Secondary Performance Characteristics, and Derivative Choices

Understanding the performance of any pottery requires that we understand primary and secondary performance characteristics as well as the derivative technical choices that go into a design (Frink and Harry 2008; Harry et al. 2009). A primary performance characteristic is one that is weighted highly in the performance matrix, whereas a secondary performance characteristic is important but not the driving force behind the potter's technical choices. If a technical choice deleteriously affects another performance characteristic, a derivative choice is often made as compensation. Let us return to the humble cooking pot, one of my favorite technologies, which is often the most common type of vessel made and used in a region, and about whose design I have discussed on many occasions (Skibo 1994, 2009; Skibo and Schiffer 1987, 1995; Skibo et al. 1989). The cooking pot provides an instructive example of the complexities involved in the making even the most mundane of technologies and the derivative technical choices that may be required.

A primary performance characteristic of pottery is thermal shock resistance. It is relatively easy to make a vessel but it is much more difficult to make one that can survive the repeated thermal stresses of a cooking fire for more than a few heating-cooling cycles. As discussed earlier, several technical choices enhance thermal shock resistance, including keeping the firing temperature low, adding large amounts of temper, texturing or corrugating the exterior surface, and creating a vessel with a globular shape. These are choices routinely seen in cooking vessels around the world (Skibo and Schiffer 1995). The assumption has long been that these heavily tempered, low-fired, rough textured ("crudware") vessels are made this way because potters care little about appearance of this everyday cookware (Frink and Harry 2008). I have long contended, however, that this characterization is inappropriate. Cooking pots are often "ugly," as Frink and Harry (2008) refer to them, because of the imperative to increase thermal shock resistance—not because the potters do not care. In fact cooking pots often require more skill and time to construct than vessels that are more aesthetically pleasing. Our experiments have shown that creating a vessel with up to 40% temper (which is common in cooking vessels) is somewhat difficult and texturing or corrugation can add considerably to construction time (Pierce 2005). So instead of thinking of these vessels as simple constructions thrown together without care, we need to consider them as significant technological achievements (Harry et al. 2009, p. 35).

Technical choices that improve thermal shock resistance, however, can adversely affect other performance characteristics, thus the need for derivative choices to "correct" for these problems. As the Harry and Frink (2009) experiments demonstrated, a low firing temperature also creates a vessel with high water permeability. If the vessel is used for moist cooking (i.e., boiling), then this permeability will significantly decrease heating effectiveness to the point where the vessel's contents never reach a boil. But derivative choices, particularly an interior surface treatment, can reduce or eliminate water permeability. Thus it is no surprise that cooking pots around the globe often have an interior surface treatment, which can reduce permeability but also in some cases increase impact or tensile strength of the vessel. Low firing temperatures also create vessels with reduced strength, which can also be improved by selecting certain surface treatments (such as resin) that both reduces permeability but also increases strength.

Cooking pots made at the household level are also an important technology because it is most often made and used by women (Skibo and Schiffer 1995). Many technologies studied by archaeologists are presumed to have been male-related. Thus studying pottery gives us the opportunity to understand how women solved functional problems in the design of a life-sustaining technology. Although men may be involved in various steps of household pottery manufacture (such as collecting firewood, digging and transporting clay, or carrying finished vessels), the ethnographic record clearly demonstrates that this technology is dominated by women throughout its behavioral chain. Thus, when we point out that potters at the household level made technical choices to increase thermal shock resistance or reduce permeability we are talking about women making these choices. This is significant because all early pottery manufacture was done at the household level, and in many parts of the world (such as much of North America) it is presumed that all vessels in prehistory were made at the household level and thus by women.

Is It Just About Techno-function?

From the discussion above one might get the impression that I give great favor to techno-functional performance. From a theoretical perspective, this is not the case as the model used here includes socio-, ideo, and emotive performance in the design and use of technology. In a number of case studies we have argued that various non techno-functional performance characteristics are of primary importance (Schiffer 2011; Skibo 1994; Skibo and Schiffer 2008; Skibo and Walker 2002; Walker and Schiffer 2006). Although some scholars emphasize what we would call socio-function over techno-function (e.g., Gosselain 1998; Lemonnier 1986, 1992), I would argue that this approach is an incomplete examination of the manufacture and use of a technology. Our focus on pottery, and in particular utilitarian wares, was a purposeful investigation of technical choices, like temper type and surface treatment, which had previously been given various cultural and social explanations. Our goal was to fill this lacuna, not suggest that techno-functional performance explains all aspects of all technologies. But in terms of cooking pots, which has been our focus in experiments, we do argue that techno-functional performance characteristics like thermal shock resistance are primary. However, there are many ceramic types, like Salado and Ramos Polychrome in the American Southwest, and Ramey Incised in the Midwest, whose socio- and ideo-functional performance characteristics are primary. Crown (1994), for example, argues that ideo-functional performance best explains why Salado Polychrome appears across a wide area. Although these vessels were made locally with different clays, the potters took great care in replicating the distinctive Salado designs, so much so that without chemical sourcing techniques one might easily conclude that the pots were made in a central location and then distributed. This cult-like emulation speaks to important ideo-functional performance.

Case Study: Metal Pots and Symbolic Performance

During the Kalinga ethnoarchaeological research, I discovered that nearly all Guina-ang households had enough metal pots for everyday cooking, yet ceramic vessels were still being made and used. That is because Guina-ang cooks used metal pots only for rice cooking (91% of the recorded cases) but ceramic vessels were still used for 98% of the vegetable and meat cooking. This differential replacement of pottery vessels by metal pots can be easily explained by considering the performance advantages of each vessel (Skibo 1994). As noted above, the objective of rice cooking is to bring water to boil as quickly as possible, and so the Guina-ang cooks preferred metal pots because of their much greater heating effectiveness. Vegetable-meat cooking, however, often required long-term simmering, thus ceramic vessels, with their lower heating effectiveness, were better suited for this task. In fact, vessels with a higher heating effectiveness that come rapidly to a boil are avoided for such cooking because boil-over is not only a time-consuming nuisance but may also douse the fire. Ceramic pots, with their lower heating effectiveness, can sit on the fire at simmering temperatures without much tending and fear of boil-over.

The use of metal pots by the women of Guina-ang in the late 1980s also involved an important symbolic performance characteristic. The women insisted on scrubbing metal pots with sand after each use to restore their original shine. The time spent washing metal pots was significantly greater than that devoted to ceramic pots. Because soot impregnates the exterior surface of the vessels, Kalinga women exert a great deal of effort, by hand or foot and a rag and sand slurry, to make them shiny again. Such behavior has no techno-functional advantage and, in fact, it shortens the metal vessel's use-life because the vigorous scrubbing thins the vessel wall and eventually renders them easy to puncture. So what explains this extreme cleaning behavior? The answer is that the metal vessel's socio- and ideo-functions are enhanced by their visual appearance—shininess—when being stored in the home.

Everyday Kalinga ceramic pots are usually stored and stacked on shelves that line the wall or are placed directly on the floor near the wall. Larger pots used for gatherings such as funerals or weddings are placed in the rafters out of sight. Metal pots, however, whether large or small are all hung above the hearth from the rafters for all to see. In fact, these shiny vessels are one of the first things that catch one's eye when entering a home and indicate a household's wealth or modernity for all to see. Kalinga women could hang sooted metal pots but they would not have the same visual performance. Clearly, symbolic performance, even in everyday cooking pots, can play a significant role during use.

From Sherds to Intended Function

When I was a graduate student in the mid-1980s I looked forward to getting each issue of *American Antiquity*, opening the package with great enthusiasm (online accessibility of journals has taken away this simple pleasure). Cracking open the April, 1986 issue I immediately spotted in the table of contents David Hally's article, "The Identification of Vessel Function: A Case Study from Northwest Georgia." His analysis of sixteenth century pottery was a practical application of the approach that we were advocating primarily from an experimental and ethnoarchaeological point of view. I was so impressed with Hally's work that I contacted him immediately and invited him to be an outside reader of my dissertation, and he accepted. I reread the article in preparation for this book and I am still impressed (see also Box in Chap. 3). If one seeks a good model to follow for a ceramic analysis, this timeless paper should be consulted. Kenneth Sassaman's (1993, 1995, 2002) work in the

Southeastern United States also provides an excellent example of how to integrate social performance of vessels with utilitarian performance to elucidate the complexities of technological change. He notes that "a social perspective on technological innovation does not preclude the need for detailed technofunctional analyses" (Sassaman 1993, p. 4).

In the 1990s I became aware of the work of Eric Blinman and Dean Wilson (Wilson and Blinman 1993, 1995; Wilson et al. 1996) that focused on ceramics from northern New Mexico, and the work of Michael Whalen (1994) on Jornada Mogollon pottery in the southern part of that state. These works in the American Southwest provide sound examples of bringing sherd data to bear on behavioral inference. More recent examples of forward-looking functional analysis are provided by Karen Harry and Liam Frink (Frink and Harry 2008; Harry and Frink 2009; Harry et al. 2009) in their work from the extreme northern part of the American continent. Izumi Shimada's (Shimada 2007; Shimada and Wagner 2007) holistic approach to pottery production and other technologies from Peru is also noteworthy for its integration of many lines of evidence, including experimentation and archeometric analyses. Other examples of innovative ceramic studies include Margaret Beck's (Beck 2006, 2009) analysis from the American Southwest and Valentine Roux's (2003, 2010) work in the southern Levant. Roux's work is especially important because she too combines technical analyses, with ethnoarchaeology and experimentation to infer how vessels were made and used.

The above examples are just a fraction of the fine functional studies going on now (see also Arthur 2001; Falconer 1995; Feathers 2006; López Varela et al. 2002; K. Nelson 2010; Silva 2008; Sullivan 1989), many of which are done in cultural resource management contexts (e.g., Hays-Gilpin and van Hartesveld 1998; Heidke 1999; Stark and Heidke 1998). My examples are also biased toward North America (for European examples, see van As 2004; Buko and Pela 1997; Pavlů 1996; Roux 2003; Stilborg 1997; Vieugué et al. 2008). But these are the types of analysis that I aspire to, and from which I borrowed heavily in the discussion that follows.

These analyses are able to use sherd data, which dominates the archaeological record, and make inferences about vessel function because they share some or all of following analytical steps. First, think in terms of whole vessels. Archaeologists find sherds, but to make inferences about function we must use whole vessels as our unit of analysis. One way to accomplish this is to implement an intensive refitting or at least a vessel grouping program that estimates the minimum number of vessels that could have created the sherd assemblage. As Sullivan (2008; Sullivan et al. 1991) notes, studies that conduct intensive refitting and conjoining obtain important clues about cultural and noncultural formation processes and lead to stronger inferences about vessel use-life and site function (see also Chapman and Gaydarska 2007).

Second, employ appropriate ethnographic information. Hally (1986) and Frink and Harry (2008; See also Harry and Frink 2009; Harry et al. 2009; Sassaman 1993) integrated ethnographic observations on pottery manufacture and use into their analyses. There are, of course, important things to consider when using ethnographic data, but these researchers demonstrate how such data can be used profitably in the study of ceramic assemblages.

Third, record the physical properties but think in terms of technical choices and relevant performance characteristics. Whalen (1994), in an analysis of a large ceramic assemblage from the southwestern United States, demonstrates how a researcher can move from a discussion of technical choices such as surface treatments, firing temperature, and morphology to inferences about intended functions (see also Falconer 1995; Harry et al. 2009; Sassaman 1993; Skibo et al. 2009).

Fourth, infer the relationship between technical choices and intended functions in the assemblage's social and environmental context. Ideally, correlations between technical choices and performance should be made initially in a controlled experimental setting (e.g., Bronitsky and Hamer 1986); this is then followed by more field-based experiments that take into account local contextual factors. Pierce (2005) and Harry et al. (2009) employ generalized knowledge about the relationship between technical choices and performance characteristics and then perform more specialized experiments that take into consideration the local contexts. Others, such as Shimada and Wagner (2007), Shimada (2007), see also Sassman (1993), may not focus on conducting their own experiments (though they have done some) but their analyses use principles derived through experimentation, ethnoarchaeology, and materials science, which are integrated with a detailed understanding of the ceramic technology and other important contextual information. This enables them to conduct with great success what they call a "holistic" approach to pottery production.

Fifth and finally, augment inferences about intended function with an analysis of use-alteration traces (residue, abrasion, and carbonization). As I illustrated in Chaps. 3, 4, and 5, a number of researchers now routinely incorporate use-alteration traces into their ceramic analyses, which help them to better understand the overall function of their ceramics.

The rest of this book is dedicated to describing how these use-alterations form, how they can be recorded, and how then can inform on the actual functions of vessels.

References

Abbott, D. R. (2000). *Ceramics and community organization among the Hohokam*. Tucson: University of Arizona Press.

Annis, M. B. (1985). Resistance and change: Pottery manufacture in Sardinia. *World Archaeology, 17*(2), 240–255.

Arnold, D. E. (1985). *Ceramic theory and social process*. Cambridge: Cambridge University Press.

Arthur, J. W. (2001). A functional analysis of early pithouse ceramics. In M. Diehl & S. A. LeBlanc (Eds.), *Early pithouse villages of the Mimbres Mogollon and their regional context* (pp. 69–76). Cambridge: Peabody Museum, Harvard University.

Arthur, J. W. (2006). *Living with pottery: Ethnoarchaeology among the Gamo of southwest Ethiopia*. Salt Lake City: University of Utah Press.

As, A. van (1984). Reconstructing the potter's craft. In S. E. van der Leeuw & A. C. Pritchard (Eds.), *The many dimensions of pottery: Ceramics in archaeology and anthropology* (pp. 129–164). Amsterdam: University of Amsterdam.

As, A. van, & Jacobs, L. (1995). An examination of the clays probably used by the ancient potters of Lehun (Jordan). *Newsletter: Department of Pottery Technology, 13*, 14–25.

As, A. van (2004). Leiden studies in pottery technology. *Leiden Journal of Pottery Studies, 20*, 7–22.

As, A. van, Jacobs, L., & Hofman, C. L. (2008). In search of potential clay sources used for the manufacture of the pre-Columbian pottery of El Cabo, Eastern Dominican Republic. *Leiden Journal of Pottery Studies, 24*, 55–74.

Balfet, H. (1984). Methods for formation and the shape of pottery. In S. E. van der Leeuw & A. C. Pritchard (Eds.), *The many dimensions of pottery: Ceramics in archaeology and anthropology* (pp. 171–202). Amsterdam: University of Amsterdam.

Beck, M. E. (2002). The ball-on-three-ball test for tensile strength: Refined methodology and results for three Hohokam ceramic types. *American Antiquity, 67*(3), 558–569.

Beck, M. E. (2006). Linking finished ceramics to raw materials: Oxidized color groups for lowland desert clays. *Kiva, 72*(1), 93–118.

Beck, M. E. (2009). Residential mobility and ceramic exchange: Ethnography and archaeological implications. *Journal of Archaeological Method and Theory, 16*, 320–356.

Beck, M. E., Skibo, J. M., Hally, D. J., & Yang, P. (2002). Sample selection for ceramic use-alteration analysis: The effects of abrasion on soot. *Journal of Archaeological Science, 29*, 1–15.

Bishop, R. L., Rands, R. L., & Holley, G. R. (1982). Ceramic compositional analysis in archaeological perspective. In M. B. Schiffer (Ed.), *Advances in archaeological method and theory* (Vol. 5, pp. 275–330). New York: Academic.

Boszhardt, R. F. (2008). Shell-tempered pottery from the upper Mississippi River Valley. *Southeastern Archaeology, 27*(2), 193–201.

Braun, D. (1978). *Woodland ceramic technology and chronological implications, Western Illinois*. Paper presented at the Midwest Archaeological Conference, Bloomington, Indiana.

Braun, D. P. (1983). Pots as tools. In A. Keene & J. Moore (Eds.), *Archaeological hammers and theories* (pp. 107–134). New York: Academic.

Bronitsky, G. (1986). The use of materials science techniques in the study of pottery construction and use. In M. B. Schiffer (Ed.), *Advances in archaeological method and theory* (Vol. 9, pp. 209–276). Orlando: Academic.

Bronitsky, G., & Hamer, R. (1986). Experiments in ceramic technology: The effect of various tempering materials on impact and thermal-shock resistance. *American Antiquity, 51*, 89–101.

Buko, A. (2003). Invisible in archaeological ceramics: Research problems. In G. Tsoucaris, & J. Lipkowski (Eds.), *Molecular and structural archaeology* (pp. 249–261). Proceedings of the NATO advanced research series, Sicily.

Buko, A. (2008). Ceramology: What is it and why? *Archaeologia Polona, 46*, 15–27.

Buko, A., & Pela, W. (1997). *Imported and locally produced pottery: Methods of identification and analysis*. Warsaw: Scientific Society of Polish Archaeology.

Carter, S. W., Wiegand, B., Mahood, G. A., Dudas, F. O., Wooden, J. L., Sullivan, A. P., & Bowring, S. A. (2011). Strontium isotopic evidence for prehistoric transport of gray-ware ceramic materials in the eastern Grand Canyon region, USA. *Geoarchaeology, 26*(2), 189–218.

Chapman, J., & Gaydarska, B. (2007). *Parts and wholes: Fragmentation in prehistoric context*. Oxford: Oxbow Books.

Colton, H. S. (1939). *Prehistoric culture units and their relationships in Northern Arizona* (Vol. 17). Flagstaff: Museum of Northern Arizona.

Crown, P. L. (1994). *Ceramics and ideology: Salado polychrome pottery*. Albuquerque: University of New Mexico Press.

DeBoer, W. (1984). The last pottery show: System and sense in ceramic studies. In S. E. van der Leeuw & A. C. Pritchard (Eds.), *The many dimensions of pottery*. Amsterdam: University of Amsterdam.

Dunnel, R. C., & Feathers, J. K. (1991). Late Woodland manifestations of the Malden Plain, Southeast Missouri. In M. S. Nassaney & C. R. Cobb (Eds.), *Stability, transformation, and variation: The late Woodland Southeast* (pp. 21–45). New York: Plenum.

Eerkens, J. W. (2003). Residential mobility and pottery use in the Western Great Basin. *Current Anthropology, 44*(5), 728–738.

Eerkens, J. W. (2004). Privatization, small-seed intensification, and the origins of pottery in the Western Great Basin. *American Antiquity, 69*(4), 653–670.

Eerkens, J. W., Neff, H., & Glascock, M. D. (2002). Ceramic production among small-scale and mobile hunters and gatherers: A case study from the Southwestern Great Basin. *Journal of Anthropological Archaeology, 21*(2), 200–229.

Ericson, J. E., Read, D., & Burk, C. (1972). Research design: The relationships between primary functions and the physical properties of ceramic vessels and their implications for ceramic distributions on an archaeological site. *Anthropology UCLA, 3*, 84–95.

Falconer, S. (1987). Heartland of villages: Reconsidering early urbanism in the southern Levant. Unpublished Ph.D. dissertation, University of Arizona, Tucson.

Falconer, S. (1995). Rural responses to early urbanism: Bronze Age household and village economy at Tell el-Hayyat, Jordan. *Journal of Field Archaeology, 22*(4), 399–419.

Fargher, L. F. (2007). A microscopic view of ceramic production: An analysis of thin-sections from Monte Albán. *Latin American Antiquity, 18*(3), 313–332.

Feathers, J. K. (1989). Effects of temper on strength of ceramics: Response to Bronitsky and Hamer. *American Antiquity, 54*(3), 579–588.

Feathers, J. K. (1990). Explaining the evolution of prehistoric ceramics in Southeastern Missouri. Unpublished Ph.D. dissertation, University of Washington, Seattle.

Feathers, J. K. (2006). Explaining shell-tempered pottery in prehistoric Eastern North America. *Journal of Archaeological Method and Theory, 13*(2), 89–133.

Feathers, J. K. (2009). Problems of ceramic chronology in the Southeast: Does shell-tempered pottery appear earlier than we think? *American Antiquity, 74*(1), 113–142.

Feathers, J. K., & Peacock, E. (2008). Origins and spread of shell-tempered ceramics in the Eastern Woodlands: Conceptual and methodological frameworks for analysis. *Southeastern Archaeology, 27*(2), 286–293.

Feathers, J. K., & Scott, W. D. (1989). Prehistoric ceramic composite from Mississippi Valley. *American Ceramic Society Bulletin, 68*(3), 554–557.

Ford, J. A. (1938). A chronological method applicable to the Southeast. *American Antiquity, 3*(3), 260–264.

Franken, H. J. (1975). *Potters of a Medieval village in the Jordan Valley: Excavations at Tell Deir All –a Medieval Tell, Tell Abu Gourdan, Jordan*. Amsterdam: North-Holland Publishing.

Frink, L., & Harry, K. G. (2008). The beauty of "ugly" Eskimo cooking pots. *American Antiquity, 73*(1), 103–120.

Gladwin, W., & Gladwin, H. S. (1930). *A method for the designation of Southwestern pottery types* (Medallion papers, no. 7). Arizona: Globe.

Gosselain, O. P. (1992). Bonfire of the enquiries. Pottery firing temperatures in archaeology: What for? *Journal of Archaeological Science, 19*(3), 243–259.

Gosselain, O. P. (1998). Social and technical identity in a clay crystal ball. In M. T. Stark (Ed.), *The archaeology of social boundaries* (pp. 78–106). Washington, DC: Smithsonian Institution Press.

Hally, D. J. (1986). The identification of vessel function: A case study from Northwest Georgia. *American Antiquity, 51*(2), 267–295.

Harry, K., & Frink, L. (2009). The Arctic cooking pot: Why was it adopted? *American Anthropologist, 111*(3), 330–343.

Harry, K. G., Frink, L., O'Toole, B., & Charest, A. (2009). How to make an unfired clay cooking pot: Understanding the technological choices made by Arctic potters. *Journal of Archaeological Method and Theory, 16*, 33–50.

Hays-Gilpin, K. A., & van Hartesveld, E. (1998). *Prehistoric ceramics of the Middle Rio Puerco Valley, an overview*. Flagstaff: Museum of Northern Arizona.

Heidke, J. M. (1999). Cienega phase incipient Plainware from Southeastern Arizona. *Kiva, 64*(3), 311–338.

Jordan, P., & Zvelebil, M. (Eds.). (2009). *Ceramics before farming: The dispersal of pottery among prehistoric hunter-gatherers*. Walnut Creek: Left Coast.

Kidder, A. V. (1924). *An introduction to the study of the Southwestern archaeology*. New Haven: Yale University Press.

Kooiman, S. (2012). *Old pots, new approaches: A functional analysis of pottery and decoration along lake superior's south shore.* Master's thesis. Illinois State University, Normal, IL.

Lafferty, I. I. I., & Robert, H. (2008). The diffusion of shell-tempered pottery into the Baytown area of the Northern Lower Mississippi Valley. *Southeaster Archaeology, 27*(2), 172–192.

Lemonnier, P. (1986). The study of material culture today: Toward an anthropology of technical systems. *Journal of Anthropological Archaeology, 5*(2), 147–186.

Lemonnier, P. (1992). *Elements for an anthropology of technology* (Anthropological papers no. 88). Ann Arbor: Museum of Anthropology, University of Michigan.

Linton, R. (1944). North American cooking pots. *American Antiquity, 9*(4), 369–380.

London, G. A. (1991). Standardization and variation in the work of craft specialists. In W. A. Longacre (Ed.), *Ceramic ethnoarchaeology* (pp. 182–204). Tucson: University of Arizona Press.

Longacre, W. A. (1985). Pottery use-life among the Kalinga, Northern Luzon, the Philippines. In B. Nelson (Ed.), *Decoding prehistoric ceramics* (pp. 334–346). Carbondale: Southern Illinois University Press.

López Varela, S. L., Van Gijn, A., & Jacobs, L. (2002). De-mystifying pottery production in the Maya lowlands: Detection of traces of use-wear on pottery sherds through microscopic analysis and experimental replication. *Journal of Archaeological Science, 29*, 1133–1147.

Lyman, R. L., & O'Brien, M. J. (2003). Cultural traits: Units of analysis in early twentieth-century anthropology. *Journal of Anthropological Research, 59*(2), 225–250.

Lyman, R., O'Brien, M. J., & Dunnell, R. C. (1997). *The rise and fall of culture history*. New York: Plenum.

Mabry, J., Skibo, J. M., Schiffer, M. B., & Kvamme, K. (1988). Use of a falling-weight tester for assessing ceramic impact strength. *American Antiquity, 53*(4), 829–839.

McKern, W. C. (1939). The Midwestern taxonomic method as an aid to archaeological culture study. *American Antiquity, 4*(4), 301–313.

Middleton, A. P., & Freestone, I. C. (1991). *Recent developments in ceramic petrology*. London: British Museum Publications.

Neff, H. (1992). *Chemical characterization of ceramic pastes in archaeology*. Madison: Prehistory Press.

Neff, H., & Bishop, R. L. (1988). Plumbate origins and development. *American Antiquity, 53*(3), 505–522.

Nelson, K. (2010). Environment, cooking strategies and containers. *Journal of Anthropological Archaeology, 29*(2), 238–247.

Neupert, M. A. (1994). Strength testing archaeological ceramics: A new perspective. *American Antiquity, 59*(4), 709–723.

Neupert, M. A. (2000). Clays of contention: An ethnoarchaeological study of factionalism and clay composition. *Journal of Archaeological Method and Theory, 7*(3), 249–272.

O'Brien, M. J., & Lyman, R. L. (1998). *James A. Ford and the growth of Americanist archaeology*. Columbia: University of Missouri Press.

O'Brien, M. J., & Lyman, R. L. (2003). *Cladistics and archaeology*. Salt Lake City: University of Utah Press.

O'Brien, M. J., Lyman, R. L., & Schiffer, M. B. (2005). *Archaeology as a process: Processualism and its progeny*. Salt Lake City: University of Utah Press.

Orton, C., Vince, A. G., & Tyers, P. (1993). *Pottery in archaeology*. Cambridge: Cambridge University Press.

Pauketat, T. R. (2004). *Cahokia mounds*. New York: Oxford University Press.

Pauketat, T. R., & Emerson, T. E. (1991). The ideology of authority and the power of the pot. *American Anthropologist, 93*(4), 919–941.

Pavlů, I. (1996). *Pottery origins. Initial forms, cultural behavior and decorative styles*. Prague: Vydavatelstvi Univerzity Karlovy.

Pierce, C. (2005). Reverse engineering the ceramic cooking pot: Cost and performance properties of plain and textured vessels. *Journal of Archaeological Method and Theory, 12*(2), 117–157.

Rafferty, J., & Peacock, E. (2008). The spread of shell tempering in the Mississippi Black Prairie. *Southeastern Archaeology, 27*(2), 253–264.

Reid, K. C. (1984). Fire and ice: New evidence for the production and preservation of Late Archaic fiber-tempered pottery in the middle-latitude lowlands. *American Antiquity, 49*(1), 55–76.

Reid, K. C. (1989). A materials science perspective on hunter-gatherer pottery. In G. Bronitsky (Ed.), *Pottery technology: Ideas and approaches* (pp. 167–180). Boulder: Westview.

Reid, K. C. (1990). Simmering down: A second look at Ralph Linton's 'North American cooking pots'. In J. M. Mack (Ed.), *Hunter-gatherer pottery from the Far West* (Nevada State Museum anthropological papers no. 23, pp. 8–17). Carson City: Nevada State Museum.

Rice, P. M. (1987). *Pottery analysis: A sourcebook*. Chicago: University of Chicago Press.

Rice, P.M. (1996a). Recent ceramic analysis: 1. Function, style and origins. *Journal of Archaeological Research, 4*(2), 133–163.

Rice, P. M. (1996b). Recent ceramic analysis: 2. Composition, production and theory. *Journal of Archaeological Research, 4*(3), 165–202.

Riemer, H. (1997). Form und Funktion. Zur systematischen Aufnahme und vergleichenden Analyse prähistorischer Gefäßkeramik. *Archäologische Informationen, 20*, 117–131.

Roper, D. C., Josephs, R. L., & Beck, M. E. (2010). Determining provenance of shell-tempered pottery from the central Plains using petrography and oxidation analysis. *American Antiquity, 75*(1), 134–156.

Roux, V. (2003). Ceramic standardization and intensity of production: Quantifying degrees of specialization. *American Antiquity, 68*(4), 768–782.

Roux, V. (2007). Ethnoarchaeology: A non historical science of reference necessary for interpreting the past. *Journal of Archaeological Method and Theory, 14*(2), 153–178.

Roux, V. (2010). Technological innovations and developmental trajectories: Social factors as evolutionary forces. In M. J. O'Brien & S. J. Shennan (Eds.), *Innovations in cultural systems: Contributions from evolutionary anthropology* (pp. 217–233). Cambridge: MIT Press.

Rye, O. S. (1976). Keeping your temper under control: Materials and the manufacture of Papuan pottery. *Archaeology and Physical Anthropology in Oceania, 11*(2), 106–137.

Rye, O. S. (1977). Pottery manufacturing techniques: X-ray studies. *Archaeometry, 19*(2), 205–211.

Rye, O. S. (1981). *Pottery technology: Principles and reconstruction*. Washington, DC: Taraxacum.

Rye, O. S., & Evans, C. (1976). *Traditional pottery techniques of Pakistan: Field and laboratory studies*. City Of Washington: Smithsonian Institution Press.

Sabo, G., & Hilliard, J. E. (2008). Woodland period shell-tempered pottery in the Central Arkansas Ozarks. *Southeastern Archaeology, 27*(2), 164–171.

Sassaman, K. E. (1993). *Early pottery in the Southeast: Tradition and innovation in cooking technology*. Tuscaloosa: University of Alabama Press.

Sassaman, K. E. (1995). The social contradictions of traditional and innovative cooking technologies in the prehistoric American Southeast. In W. K. Barnett & J. W. Hoopes (Eds.), *The emergence of pottery: Technology and innovation in ancient societies* (pp. 223–240). Washington, DC: Smithsonian Institution Press.

Sassaman, K. E. (2002). Woodland ceramic beginnings. In D. G. Anderson & R. C. Mainfort (Eds.), *The Woodland Southeast* (pp. 398–420). Tuscaloosa: University of Alabama Press.

Sassaman, K. E., & Rudolphi, V. (2001). Communities of practice in the early pottery traditions of the American Southeast. *Journal of Anthropological Research, 57*, 407–425.

Schiffer, M. B. (1988). The effects of surface treatment on permeability and evaporative cooling effectiveness of pottery. In R. Farquhar, R. Hancock, & L. Pavlish (Eds.), *Proceedings of the 26th international archaeometry symposium* (pp. 23–29). Toronto: University of Toronto press.

Schiffer, M. B. (1990). The influence of surface treatment on heating effectiveness of ceramic vessels. *Journal of Archaeological Science, 17*, 373–381.

Schiffer, M. B. (1995). *Behavioral archaeology: First principles*. Salt Lake City: University of Utah Press.

Schiffer, M. B. (2002). Studying technological differentiation: The case of 18th-century electrical technology. *American Anthropologist, 104*(4), 1148–1161.

Schiffer, M. B. (2005). The devil is in the details: The Cascade model of invention processes. *American Antiquity, 70*(3), 485–502.

Schiffer, M. B. (2011). *Studying technological change: A behavioral approach*. Salt Lake City: University of Utah Press.
Schiffer, M. B., & Skibo, J. M. (1987). Theory and experiment in the study of technological change. *Current Anthropology, 28*(5), 595–622.
Schiffer, M. B., & Skibo, J. M. (1989). A provisional theory of ceramic abrasion. *American Anthropologist, 91*(1), 101–115.
Schiffer, M. B., & Skibo, J. M. (1997). The explanation of artifact variability. *American Antiquity, 62*(1), 27–50.
Schiffer, M. B., Skibo, J. M., Boelke, T. C., Neupert, M. A., & Aronson, M. (1994). New perspectives on experimental archaeology: Surface treatments and thermal response of the clay cooking pot. *American Antiquity, 59*(2), 197–217.
Shepard, A. O. (1956). *Ceramics for the archaeologist*. Washington, DC: Carnegie Institution of Washington.
Shimada, I. (Ed.). (2007). *Craft production in complex societies: Multicraft and producer perspectives*. Salt Lake City: University of Utah Press.
Shimada, I., & Wagner, U. (2007). A holistic approach to pre-histpanic craft production. In J. M. Skibo, M. W. Graves, & M. T. Stark (Eds.), *Archaeological anthropology: Perspectives on method and theory* (pp. 163–197). Tucson: University of Arizona Press.
Silva, F. (2008). Ceramic technology of the Asurini do Xingu, Brazil: An ethnoarchaeological study of artifact variability. *Journal of Archaeological Method and Theory, 15*(3), 217–265.
Simms, R. G., & Bright, J. R. (1997). Plain-ware ceramics and residential mobility: A case study from the Great Basin. *Journal of Archaeological Science, 24*, 779–792.
Skibo, J. M. (1992). *Pottery function: A use-alteration perspective*. New York: Plenum.
Skibo, J. M. (1994). The Kalinga cooking pot: An ethnoarchaeological and experimental study of technological change. In W. A. Longacre & J. M. Skibo (Eds.), *Kalinga ethnoarchaeology: Expanding archaeological method and theory* (pp. 113–126). Washington, DC: Smithsonian Institution Press.
Skibo, J. M. (2009). Archaeological theory and snake-oil peddling: The role of ethnoarchaeology in archaeology. *Ethnoarchaeology, 1*(1), 27–56.
Skibo, J. M., & Schiffer, M. B. (1987). The effects of water on processes of ceramic abrasion. *Journal of Archaeological Science, 14*(1), 83.
Skibo, J. M., & Schiffer, M. B. (1995). The clay cooking pot: An exploration of women's technology. In J. M. Skibo, W. H. Walker, & A. E. Nielsen (Eds.), *Expanding archaeology* (pp. 80–91). Salt Lake City: University of Utah Press.
Skibo, J. M., & Schiffer, M. B. (2001). Understanding artifact variability and change: A behavioral framework. In M. B. Schiffer (Ed.), *Anthropological perspectives on technology* (pp. 139–149). Albuquerque: University of New Mexico Press.
Skibo, J. M., & Schiffer, M. B. (2008). *People and things: A behavioral approach to material culture*. New York: Springer.
Skibo, J. M., & Walker, W. H. (2002). Ball courts and ritual performance. In J. M. Skibo, E. McCluney, & W. H. Walker (Eds.), *The Joyce Well Site: On the frontier of the Casas Grandes world* (pp. 107–128). Salt Lake City: University of Utah Press.
Skibo, J. M., Schiffer, M. B., & Reid, K. C. (1989). Organic-tempered pottery: An experimental study. *American Antiquity, 54*(1), 122–146.
Skibo, J. M., Butts, T. C., & Schiffer, M. B. (1997). Ceramic surface treatment and abrasion resistance: An experimental study. *Journal of Archaeological Science, 24*(4), 311.
Skibo, J. M., Malainey, M. E., & Drake, E. C. (2009). Stone boiling, fire-cracked rock and nut oil: Exploring the origins of pottery making on Grand Island. *Wisconsin Archeologist, 90*(1–2), 47–64.
Smith, M. F. (1985). Toward an economic interpretation of ceramics: Relating vessel size and shape to use. In B. A. Nelson (Ed.), *Decoding prehistoric ceramics* (pp. 254–309). Carbondale: Southern Illinois University Press.
Smith, M. F. (1988). Function from whole vessel shape: A method and an application to Anasazi Black Mesa, Arizona. *American Anthropologist, 90*(4), 912–923.

Stark, M. T., & Heidke, J. M. (1998). Ceramic manufacture, productive specialization, and the early classic period in Arizona's Tonto Basin. *Journal of Anthropological Research, 54*, 497–517.

Steponaitis, V. P. (1983). *Ceramics, chronology, and community patterns: A methodological study at Moundville*. New York: Academic.

Steponaitis, V. P. (1984). Technological studies of prehistoric pottery from Alabama: Physical properties and vessel function. In S. E. van der Leeuw & A. C. Pritchard (Eds.), *The many dimensions of pottery: Ceramics in archaeology and anthropology* (pp. 79–128). Amsterdam: University of Amsterdam.

Stilborg, O. (1997). Shards of Iron Age communications: A ceramological study of internal structures and external contacts in the Gudme-Lundeborg Area, Funen, during the Late Roman Iron Age. Unpublished Ph.D. dissertation, Lunds Universitet, Lund.

Stoltman, J. B. (1989). A quantitative approach to the petrographic analysis of ceramic thin sections. *American Antiquity, 54*(1), 147–160.

Stoltman, J. B. (1991). Ceramic petrography as a technique for documenting cultural interaction: An example from the Upper Mississippi Valley. *American Antiquity, 56*(1), 103–120.

Stoltman, J. B. (2011). New petrographic evidence pertaining to ceramic production and importation at the Olmec site of San Lorenzo. *Archaeometry, 53*, 510–527.

Sullivan, A. P. (1989). The technology of ceramic reuse: Formation processes and archaeological evidence. *World Archaeology, 21*, 101–114.

Sullivan, A. P. (2008). Ethnoarchaeological and archaeological perspectives on ceramic vessels and annual accumulation rates of sherds. *American Antiquity, 73*, 121–135.

Sullivan, A. P., Skibo, J. M., & VanBuren, M. (1991). Sherds as tools: The roles of vessel fragments in prehistoric succulent plant processing. *North American Archaeologist, 12*(3), 243–255.

Tite, M. S. (1969). Determination of the firing temperature of ancient ceramics by measurement of thermal expansion: A reassessment. *Archaeometry, 11*(1), 131–143.

Tite, M. S. (1995). Firing temperature determinations – how and why? In A. Lindahl & O. Stilborg (Eds.), *The aim of laboratory analyses of ceramics in archaeology, April 7–9, 1995 in Lund Sweden*. Stockholm: Kungl. Vitterhets historie och antikvitets akademien.

Tite, M. S. (1999). Pottery production, distribution, and consumption – the contribution of the physical sciences. *Journal of Archaeological Method and Theory, 6*(3), 181–233.

Tite, M. S. (2008). Ceramic production, provenance and use – a review. *Archaeometry, 50*(2), 216–231.

Vaz Pinto, I., Schiffer, M. B., Smith, S., & Skibo, J. M. (1987). Effects of temper on ceramic abrasion resistance: A preliminary investigation. *Archaeomaterials, 1*, 119–134.

Velde, B., & Druc, I. C. (1998). *Archaeological ceramic materials*. New York: Springer.

Vieugué, J., Mirabaud, S., & Regert, M. (2008). Contribution méthodologique à l'analyse fonctionnelle des céramiques d'un habitat néolithique: l'exemple de Kovačevo (6 200-5 500 av. J.-C., Bulgarie). *ArchéoSciences, 32*, 99–113.

Walker, W. H., & Schiffer, M. B. (2006). The materiality of social power: The artifact-acquisition perspective. *Journal of Archaeological Method and Theory, 13*(2), 67–88.

Whalen, M. E. (1994). *Turquoise ridge and late prehistoric residential mobility in the desert Mogollon Region* (Vol. 118). Salt Lake City: University of Utah Press.

Wilson, C. D., & Blinman, E. (1993). *Upper San Juan Region pottery technology.* Office of Archaeological Studies, Archaeology Notes 80, Museum of New Mexico, Santa Fe.

Wilson, C. D., & Blinman, E. (1995). Changing specialization of white ware manufacture in the Northern San Juan Region. In B. J. Mills & P. L. Crown (Eds.), *Ceramic production in the American Southwest* (pp. 63–87). Tucson: University of Arizona Press.

Wilson, C. D., Blinman, E., Skibo, J. M., & Schiffer, M. B. (1996). The designing of Southwestern pottery: A technological and experimental approach. In P. R. Fish & J. J. Reid (Eds.), *Interpreting Southwestern diversity: Underlying principles and overarching patterns* (pp. 249–256). Tempe: Arizona State University.

Young, L. C., & Stone, T. (1990). The thermal properties of textured ceramics: An experimental study. *Journal of Field Archaeology, 17*(2), 195–203.

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