CHAPTER 2

HOW WE KNOW WHAT WE THINK WE KNOW ABOUT STONE TOOLS

> Of each thing, ask what is it in itself, in its own constitution? What is its substance and material, and how did it come to be? What does it do in the world, and how long does it persist?
>
> Marcus Aurelius Antonius (AD 167 *Meditations* 8.11)

This chapter explores the sources of our current knowledge about stone tools, namely ethnographic and ethological observations, experimental archaeology, and contextual clues from the archaeological record. These sources allow us to develop a "Pre-Industrial Model" of human/hominin stone tool use. Contrasts between this Pre-Industrial Model and observations of non-human primate tool use allow testable predictions (hypotheses) about changes and variability in hominin stone tool production and use.

SOURCES OF INFORMATION ABOUT LITHIC TECHNOLOGY

Most of what archaeologists think we know about prehistoric stone tool technology is based on either actualistic or contextual information. Actualistic information comes from ethnoarchaeology, experimental archaeology, and any circumstances in which stone tool production, use, and discard have actually been observed. Contextual information is archaeological evidence interpreted according to generally accepted principles of geology, biology, chemistry, and other scientific disciplines.

Actualistic Information

Ethnoarchaeology: Ethnoarchaeology observes how living humans create an archaeological record. Most systematic ethnoarchaeological studies of stone tool technology involve people who otherwise use metal tools, or people who are lithic craft specialists, producing stone knives, axes, and grinding stones (Binford 1986, Toth, Clark, and Ligabue 1992, Searcy 2011). There are

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relatively few ethnoarchaeological studies of people who habitually make and use stone tools as routine parts of their daily lives. Ethnoarchaeological accounts of stone tool production and use are unevenly distributed around the world. The most detailed accounts of stone tool use by hunter-gatherers are from Australia (Hayden 1979, Gould 1971, 1980; for recent overviews, see Holdaway and Douglas 2012, McCall 2012). Stone tool use by horticulturalists, pastoralists, and former hunter-gatherers is more widely documented in Africa, Southeast Asia, and the Americas (Nelson 1916, White 1968, Gallagher 1977, Miller 1979, Clark and Kurashina 1981, Brandt and Weedman 1997, Weedman 2006).

Experimental Archaeology: "Experimental archaeology" describes a wide range of activities from contrived mechanical experiments to more holistic "experiential" activities. Experiments can often demonstrate *probable* sources of variability (Eren et al. 2016), while experiential activities more typically suggest *possible* sources of variation (Shea 2015a). Many rocks used to make knapped stone tools fracture conchoidally, and mechanical experiments have investigated this property (for a review, see Dibble and Rezek 2009, Lin et al. 2013). The mechanics of groundstone technology have been less extensively researched, possibly due to the wide range of rocks shaped by abrasion (Dubreuil and Savage 2014). Hobby/craft knappers have documented experiential approaches to investigating rock fracture (Johnson 1978, Whittaker 1994) to such an extent that archaeologists use their terms for stone tool production rather than terms from fracture mechanics (Crabtree 1972, Inizan et al. 1999). Other experiential activities include teaching stone tool production and use to others and using stone tools for various purposes (Shea 2015b). Some of these tool use experiments focus on identifying microwear patterns diagnostic of certain activities (Keeley 1980, Odell 1981). Others aim for subjective assessments of how well stone tools with different qualities perform in one or another task (e.g., Jones 1981, Schick and Toth 1993: 147–186, Shea, Davis, and Brown 2001, Shea, Brown, and Davis 2002). Still other experiments simulate trampling and geological sources of damage in order to develop criteria for recognizing their effects in the archaeological record (e.g., McBrearty et al. 1998, Pargeter and Bradfield 2012).

Contextual Information

Contextual information is inferred from the archaeological record. Such information includes stratigraphic associations, artifact-refitting patterns, stone tool cut-marks, microwear, and residues. Because contextual information is based on inferences rather than direct observations, it has to be used cautiously.

Stratigraphic Associations: Stone tools occur together with other artifacts and ecofacts (natural objects), and these associations can inspire hypotheses about the motivations of prehistoric tool makers. Yet, such spatial and stratigraphic associations can also be misleading, or at least interpretively complex (Schiffer 1987). The geological "principle of association" holds that artifacts enclosed in the same sediment were buried at the same time in a broad sense, but this does not mean they were buried simultaneously or as the result of the same activity. Tools in the same archaeological assemblage may have been deposited days, weeks, months, years, even centuries apart from one another. The most common targets of archaeological excavations – caves/rockshelters and landforms near water sources – are perennial magnets for human occupation. If humans are in the vicinity, they reside there. Assemblages from such sites likely combine the traces of multiple occupations near to one another in time. More valuable sources of insights come from small sites where sediments were deposited quickly, and in which the possibility of multiple separate human/hominin occupations is low. Because such "mini-sites" lack the archaeological visibility of larger lithic accumulations, they form a tiny fraction of the global record for hominin stone tool use.

Artifact Refitting: Matching fracture surfaces on stone tools can allow one to reconstruct how artifacts were shaped and detached from one another, but not all such matches provide the same information. Fractures caused during core reduction and artifact shaping (refits) and edge resharpening (modifications) shed light on tool production and maintenance. Fragments separated by other causes (breaks) may reflect trampling, soil compaction, and other depositional processes, even excavation-related damage. Spatial analysis of artifact refitting patterns can provide insights into toolmaking strategies as well as about site formation processes (for overviews, see Cziesla 1990, Laughlin and Kelly 2010). Refitting studies frequently assume that all flakes struck from a particular rock were detached near to one another in time, by the same person, or at least by members of the same co-residential community. This is not necessarily true. The ethnographic record offers up numerous accounts of stone tools being made from artifacts found eroding from abandoned habitations and archaeological sites.

Stone-tool Cut-marks and Percussion Damage: After stone tools, vertebrate fossils are the second most common things found at prehistoric archaeological sites. Some of these fossils preserve cut-marks and fractures caused by stone tool use (Shipman 1981, Blumenschine and Pobiner 2007). Sites with exceptional preservation can also preserve wood with wear traces from stone tool use. Such discoveries are revolutionizing archaeologists' views about earlier hominin technological strategies (e.g., Conard et al. 2015). Needless to say, however, such evidence suffers from the problem of "false negative" findings. The absence of preserved bone, wood, cordage, and other organic artifacts does not necessarily indicate hominins overlooked these materials' potential value as tools.

Microwear: Microwear (fractures, abrasion, and polish) on stone tool edges and surfaces furnishes clues about the use of particular stone tools, about the parts of the tools that were used, the motions employed, and the nature of the worked materials (for reviews, see Semenov 1964, Shea 1992, Odell 2004: 152). Activities involving high loading forces, prolonged use, and work on relatively hard materials leave more distinctive wear traces than tasks involving low loading forces, brief use, and cutting softer materials. Microwear traces are relatively small-scale phenomena that can be altered by post-depositional mechanical wear, such as flowing water, soil movement, trampling, and other factors (Shea and Klenck 1993, Levi-Sala 1996).

Residues: Organic residues, including blood, hair, starch particles, and inorganic substances, such as red ochre (iron oxide), can sometimes be detected on stone tool edges and surfaces. The principal challenge in interpreting this evidence lies in differentiating between residues bonded to the tool surface as the result of cutting; residues from handles, fibers, and mastic use to attach tools to handles; and residues from sediments enclosing the tools. Though archaeologists have gained considerable expertise in visual identifications of residues, many such residues are ambiguous, and interpreting them can require physical or chemical analysis (for a recent review, see Monnier, Ladwig, and Porter 2012).

A PRE-INDUSTRIAL MODEL OF LITHIC TECHNOLOGY

Insights from actualistic and contextual sources allow one to construct a model for lithic technology, one that differs from early archaeologists' Industrial Model. This "Pre-Industrial Model" contrasts with its Industrial counterpart in recognizing a greater range of variability in stone tool production, use, and discard (Table 2.1). Inasmuch as this model pulls together evidence from both historical and present-day (ethnographic) sources, it is discussed below using the "ethnographic present" tense.

Pre-industrial Stone Tool Production

Pre-industrial humans' choices of lithic raw material are governed by a combination of practical mechanical considerations such as ease of access, fracture properties, hardness, and silica content (Binford 1980, Gould 1980). Nevertheless, subjective qualities, such as aesthetics or perceived symbolic associations, play roles as well. Lithic raw material procurement is frequently "embedded" in daily foraging tasks carried out within a few kilometers of habitation sites. The most common lithic raw materials at any archaeological site are usually those available in the immediate geological substrate or within a 10–30 km radius of the site. Quarrying operations ("direct procurement") occur, too, but these usually involve small work parties or individuals visiting

TABLE 2.1. *Industrial, pre-industrial, and non-human primate models of stone tool use*

Activity	Industrial Model	Pre-industrial Model	Non-human Primate Model
Raw material procurement	Quarried and transported in-bulk to production sites	Mixed strategies of quarrying, embedded procurement, recycling	Aggregates of individually transported objects
Agency	Adults	Adults (males >females), children (?)	Mainly females and children
Transmission	Formal apprenticeship	Imitation and directed learning	Imitation
Production methods	Standardized	Some stereotyped production, but little standardization, much variability	Tools used without modification
Artifact designs	Size varies, but form and function are strongly correlated	Size varies, and form–function correlations are variable	Large tools, whose form and function are strongly correlated
Context of production	At special-purpose workshops at or near habitation sites	Not necessarily correlated with habitation sites	Not applicable
Artifact repair	Yes, typically by specialists	Yes, but variable, context-dependent	No
Artifact discard	Distant from production sites	Variable, both near and far from production sites, habitation sites, resource extraction sites	At location where used to extract food resources
Change through time	Substitution	Addition	Little/no change? (Inadequate evidence)

a geological source. At such sources, people replace worn-out tools on the spot and reduce raw rock into small, efficiently transportable packages. Sedentary groups supplying long-term residential sites sometimes undertake in-bulk quarrying operations. Abandoned habitation sites and archaeological sites are also used as sources of tool materials. Lithic materials are also procured socially, through exchanges among individuals. Such exchanges range from straightforward commercial transactions involving producers, consumers, and middlemen to more complex ones guided by symbolic/supernatural motivations. Many individuals deploy more than one such raw material procurement strategy simultaneously.

Unlike Industrial Era factory work, ethnographic flintknapping occurs on an irregular schedule, either as tools are needed or during "down-time" between other activities. Most ethnographic tool makers use more than one distinct way of obtaining cutting edges. Indeed, stone tools continued to be made and used thousands of years after the appearance of metallurgy in the Near East and in Africa (Rosen 1997, Mitchell 2002). To this day, some indigenous populations in Africa, Asia, and Australia continue to use stone tools alongside metal ones.

While there are instances of craft specialization in the ethnographic record, much stone tool production involves non-specialists. In ethnographic literature, adult males do most of the tool making, but this may reflect reporting bias by adult male ethnographers (but see Gould 1980). There is no reason to assume prehistoric stone tool production or use was invariably organized along gender lines (Gero 1991, Arthur 2010). For evidence of prehistoric stone tool use by women, one need look no further than Exodus 4: 25–26,

> Now it came about at the lodging place on the way that the Lord met (Moses) and sought to put him to death. Then Zipporah took a flint and cut off her son's foreskin and threw it at Moses' feet, and she said, "You are indeed a bridegroom of blood to me." So He let him alone.

There are few detailed ethnographic accounts of children making or using stone tools, but it is reasonable to suppose prehistoric children did so, either for their own tool needs or in learning by imitating adult activities (Shea 2006a). Only recent post-Industrial parents systemically keep children away from sharp implements "for their own good."

Ethnographic flintknapping can be either highly stereotyped or widely variable, but there is little standardization. Even when ethnographic knappers work toward the production of similar artifacts, complex patterns of similarities and differences emerge (Binford 1986, Toth et al. 1992). The same variability can be seen in the work of craft/hobby flintknappers, some of whom can identify one another's work by simple visual inspection of the artifacts (Whittaker 2004).

Pre-industrial Stone Tool Use

Ethnographic humans use stone tools as projectile armatures, as tools for butchery, pulverizing seeds and nuts, carpentry, hide-working, flintknapping, carving stone, bone, and other hard materials, and for symbolic/ritual purposes (e.g., scarification, bloodletting). Though ethnographic documentation for stone tool use in some of these activities is actually rather sparse, many tasks performed today with metal tools were undoubtedly done in earlier times using stone tools. This being said, there are at least three activities for which ethnographic humans use metal tools for which there is little ethnographic or archaeological evidence of stone tool use. These activities include immediate pre-oral food processing (cutting food into small pieces immediately prior to eating them), digging in soil, and as weapon armatures for fishing. Inuit and other Arctic peoples used abraded-edge cutting knives (*ulus*) to cut up food

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prior to ingesting it, but other than this, the ethnographic record offers few other examples of stone tools (or indeed metal ones either) specifically dedicated to this activity. Wear traces and plant and animal tissues preserved on archaeological stone tools suggest simple flakes may have been used for these tasks, but it is also possible that much pre-oral food processing with stone tools was so brief that it left little detectable archaeological evidence. A few stone tools from North American contexts preserve "hoe polish" from tilling silty sediments (Witthoft 1967), but such wear traces are otherwise rare. That so few stone tools are used to dig in soil or as tips for fishing spears probably reflects the fact that these tasks involve high risks of tool breakage due to collisions with rocks in the geological substrate.

Nearly every major category of stone tool that has either been subjected to microwear and/or residue analysis or whose use has been observed ethnographically exhibits functional variability (Odell 2004). Mobility also affects form–function relationships (Binford 1979, Parry and Kelly 1987). Transported stone implements are often design compromises, tools that perform adequately in the wide range of tasks their owners might encounter while on the move. Sedentary populations maintained larger and more functionally specialized toolkits.

Some findings from ethnoarchaeology contradict common archaeological assumptions about retouch and stone tool use. For example, archaeologists often equate retouch (small fractures along tool edges) with evidence of use. Ethnographic humans routinely use tools without putting such edge damage on them. They also retouch tools that they do not end up using. Predictably, many retouched archaeological stone tools preserve no traces of microwear or residues. Most archaeologists assume that unretouched flakes/flake fragments shorter than 2–3 cm in any dimension were too small to have been used as cutting implements, but ethnographic stone cutting tools include many such small unretouched artifacts.

Pre-industrial Stone Tool Discard

Stone tools are sharp. Understandably, much ethnographic stone tool production takes place away from high-foot-traffic areas in habitation sites. When lithic production happens at residential sites it can be accompanied by in-bulk removal and re-deposition of lithic artifacts away from living spaces (Gallagher 1977). Thus, archaeological sites where residues of stone tool production occur in great quantities may not have been habitation sites at all, but rather workshops or dumping areas located some distance from where people were actually living at the time. Juxtaposed concentrations of flintknapping debris and habitation traces (hearths, architecture) may reflect reuse of former habitation sites as impromptu stone tool procurement/production sites.

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Ethnographic stone tool discard behavior varies widely and in response to several circumstances. Where raw materials are abundant, the threshold for discarding them is often relatively low. That is, tools are discarded with minimal effort to retouch or resharpen them. Where raw materials are scarce, tools are often heavily resharpened, but this can vary widely, too. Because of the considerable amount of time and energy needed to remove and replace tools attached to handles, these artifacts are often heavily retouched and resharpened (Binford 1979, Keeley 1982). Hand-held tools are often discarded as soon as their cutting edges become perceptibly dull.

NON-HUMAN PRIMATE STONE TOOL USE

Chimpanzees, bonobos, gorillas, orangutans, and macaques (*Macaca*), as well as more phylogenetically distant monkeys (e.g., capuchin monkeys *Cebus* spp.) use tools in the wild (Panger et al. 2003, Haslam et al. 2009, Toth and Schick 2009). For research on the stone tool evidence, however, chimpanzees and bonobos are most directly relevant due to their morphological similarity to humans. Table 2.1 summarizes some of the ways in which stone tool use by these non-human primates differs from both Industrial and Pre-Industrial models of human stone tool use.

Non-human Primate Raw Material Procurement and Stone Tool Production

Non-human primate raw material procurement involves transporting rocks from localities where they are available on the surface to places where they are used. Tool materials are neither excavated from bedrock deposits nor pre-shaped for transportation.

Wild-living non-human primates use stone in its natural form. They select stones for use as tools based on size, shape, and compositional criteria, but raw material choice is largely governed by the local geological substrate. Chimpanzees have been observed transporting stones several kilometers (Boesch and Boesch 1984a), but these are extreme examples for that species. They rarely carry stones more than a few hundred meters.

Two captive bonobos have been taught to make and use stone cutting tools in laboratory settings (Toth et al. 1993), but spontaneous and systematic flaked stone cutting tool production has not been observed among apes living outside captivity.

Non-human Primate Stone Tool Use

The overwhelming majority of observations of non-human primate stone tool use report hand-held stone percussors being used to crack open nuts (Haslam et al. 2009) (Figure 2.1). These artifacts are relatively larger in comparison to their users' body size than the stone tools humans use for similar tasks. Monkeys

Figure 2.1 Chimpanzee stone tool use. (Photograph provided by Tetsuro Matsuzawa of the Kyoto University Primate Research Center, used with permission.)

also use stone tools to fracture the shells of crabs and molluscs as well as to dig in sediment. Neither edges nor abrasive stone surfaces are used to modify other materials. Non-human primates may bring stone tools into juxtaposition with one another, but they do not attach them to other non-lithic materials as multi-component tools. Nut-cracking stones are rarely repurposed for other tasks.

Adult females chimpanzees and their dependent offspring use stone tools more often than adult males (Boesch and Boesch 1984b). Juveniles learn techniques for cracking nuts with stone tools mainly by observing and imitating adults over prolonged periods (i.e., years).

Non-human Primate Stone Tool Discard

In those cases where stone tools have broken during use, non-human primates may continue to use them, but they do not attempt to restore their functionality by further physical modification. Non-human primates usually abandon stone tools where they are used. Consequently, after many individual episodes of stone transport, use, and deposition large accretional accumulations of stones can appear at non-human primate tool use locations (Mercader, Panger, and Boesch 2002).

Why Compare Human vs. Non-human Primate Lithic Technology?

Anthropologists have long viewed non-human primate behavior as a model for the behavior of human ancestors (Kinzey 1986), but doing this risks ignoring significant evolutionary differences between extant primates and extinct hominins as well as differences in their habitats (Potts 1987). Just as comparing human vs. non-human primate anatomy inspires hypotheses about sources of morphological variation among hominin fossils, comparing differences in human vs. non-human stone tool use can help us develop hypotheses about how evolutionarily derived human behaviors influenced variation in the stone tool record. Before we can make these comparisons and generate the hypotheses that can be tested with prehistoric lithic evidence, we need to change some of the ways archaeologists describe that evidence. These changes are outlined in the next chapter.