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Major Fallacies Surrounding Stone Artifacts and Assemblages

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Abstract
While lithic objects can potentially inform us about past adaptations and behaviors, it is important to develop a comprehensive understanding of all of the various processes that influence what we recover from the archaeological record. We argue here that many assumptions used by archaeologists to derive behavioral inferences through the definition, conceptualization, and interpretation of both individual stone artifact forms and groups of artifacts identified as assemblages do not fit squarely with what we have learned from both ethnographic sources and analyses of archaeological

materials. We discuss this in terms of two fallacies. The first is the fallacy of the "desired end product" in stone artifact manufacture, which also includes our ability to recognize such end products. The second fallacy has to do with the notions that lithic assemblages represent simple accumulations of contemporary behaviors and the degree to which the composition of the depositional units we study reliably match the kinds of activities that took place. Although it is beyond the scope of this paper to offer a comprehensive set of new methodologies and theoretical perspectives to solve these problems, our goal here is to stress the importance of rethinking some of our most basic assumptions regarding the nature of lithic objects and how they become part of the archaeological record. Such a revision is needed if we want to be able to develop research questions that can be addressed with the data we have available to us.

Keywords: Lithic studies, Lithic technology, Typology, Replicative experiments, Ethnoarchaeology, Site formation

Introduction

It is likely that the vast majority of archaeologists agree that one of our main goals is to use lithic objects, in addition to other sources of information, to inform on and ultimately explain the bio-cultural evolution of our hominin ancestors. In other words, we want to interpret variability observable in the archaeological record—both through time and across space—as a reflection of the trajectory of human evolution. To do this, archaeologists create units of analysis, which can be anything from different types of stone objects to the definition of assemblages composed of them, and, at a higher level, they combine these into new analytical units that are called industries, technocomplexes, cultures, or any number of other terms. All of these various analytical units are then used to investigate relationships among them and various contextual variables, including environment, mobility, subsistence strategies, *etc.*, and through the application of various evolutionary models, archaeologists develop hypotheses to explain the behavioral evolution of our hominin ancestors. The authors of this paper agree completely with this goal. However, we also see certain problems that are at the heart of this analytical process. These problems have to do with the definition, conceptualization and interpretation of two of our most basic units: the lithic objects themselves and their association in archaeological assemblages.

Considering individual objects, part of the problem that we will discuss here is the continued reliance on outmoded understandings of the processes that underlie variation in artifact form, regardless of whether or not the definition of our analytical units is based on characteristics of morphology or techniques of manufacture. It is often assumed, for example, that different forms found archaeologically have direct relationships to modes of past use. Of course, archaeologists are interested in how hominins acted in the past, and it is a fundamental aspect of archaeology to seek out proxies for past actions in the form of the stone artifacts recovered from archaeological sites. However, as we will discuss later in depth, research has repeatedly shown that lithic artifact forms do not have simple one-to-one functional referents, and even when past uses of a tool are reconstructed through wear traces or residues, it should not be assumed that the tool in question was made with the purpose of being used in

that way. Ethnographic studies demonstrate that a diversity of shapes may be selected for a given task, that individual forms may be used for a variety of purposes, and that the criteria for selecting particular objects for use were focused on such things as edge characteristics or size as much as, or even more so, than any consideration of overall shape. Furthermore, archaeological observations show that lithic objects are subjected to processes, such as resharpening and remodification, that continually alter their form. Finally, a single lithic object can be repeatedly picked up and reused for a variety of different purposes, without ever changing its form. This means that the morphology of a lithic object is virtually never a "finished form" with a particular intended or singular purpose since their forms and the uses to which they are put can vary throughout their use-lives. This is what Davidson and Noble (1989) call the "finished artifact fallacy," which means that the form of a lithic object when recovered by the archaeologist represents only one point in a continuum of repeated modifications.

Likewise, archaeological assemblages are often treated as though they accumulated through repeated occupations, with each occupation represented by the objects discarded at a more or less restricted moment of time in the past. This assumption leads to the goal of isolating the contents of each successive occupation separately to recover discrete slices of time in which behaviors took place (Binford 1981a). Like the search for the purpose of a particular artifact, occupations are often thought to have a purpose, as illustrated in categorizations of site types into kill sites, habitation sites, base camps, and the like according to the types of activities that we imagine took place there. To a large extent, this has led some to consider prehistoric archaeology as a kind of paleo-ethnography, whereby the actions of a particular group of individuals or even a single individual can be reconstructed (Bodu 1994; Gamble and Poor 2005). However, assemblages are also the result of many different processes and are thus not necessarily, or even likely, the result of a simple discard at particular points in time or as part of the performance of particular activities. As they are forming, assemblages are continuously altered as objects are added or removed, and those objects that remain in an assemblage—even those discarded much earlier in time—may be continuously subjected to further use and re-modification. In addition, natural processes—from erosion that removes objects to a diverse spectrum of geological processes that can physically modify lithic objects and alter their spatial associations—have an effect on both the composition and nature of an aggregate of archaeological materials.

As we will argue in this paper, the common perceptions among many archaeologists regarding the nature of variability in lithic object forms and among lithic assemblages represent two major fallacies in lithic studies. We are not claiming to be the first to identify these problems—some of these topics have been brought up many years ago. But we do feel that it is an opportune time to review some of these discussions, to attempt to synthesize them, and to bring in fresh perspectives. Although this review may be perceived as being somewhat negative, we believe that our arguments go to the very heart of how we do lithic analysis and how we interpret archaeological lithic assemblages. Moreover, we feel strongly that it is time to confront these fallacies explicitly and, in so doing, begin to develop analytical methods that take advantage of the full range of processes that were responsible for the lithic archaeological record with which we all deal. And although much of our discussion is illustrated

with examples from the Paleolithic, there are clear implications relevant to lithic industries from all over the world and from virtually all time periods.

Part I: The Fallacy of the "Desired End Product" in Stone Artifact Manufacture

When discussing the issue of desired end products, there are actually two different questions. One of these is: to what extent do "desired end products" represent the goals of past flintknapping? In other words, was the making of a particular kind of object, with a variety of special characteristics, the norm for traditional knappers in the past? The second question is: how can archaeologists recognize such products in the stone artifact record? We will begin the discussion by addressing the second question first.

The Problem of Identifying End Products in the Archaeological Record

Most current interpretations of stone artifacts assume that stone artifacts reflect past behaviors that are meaningful in terms of hominin evolution (e.g. Foley and Lahr 2003; Shea 2011). Of course, stone artifacts do reflect behavior to some extent, simply because much of their form and other attributes are the result of human action. Where it gets complicated, however, is that it is not always clear how many actions and/or individuals contributed to their production, and it is equally unclear whether a particular artifact was intended for a single or multiple uses. Even today, while there can be literally thousands of lithics in any given deposit, archaeologists are unable to determine efficiently and with certainty which ones were used and for what task, and it is often just as difficult to ascertain if a particular object is a by-product of the manufacturing process, a worn-out tool that had passed its usefulness, or a form that was naturally modified because of post-depositional processes.

Most typological and technological schemes used in lithics research assume that the identification of specific desired end products in the archaeological record can be made and that these can be differentiated from the by-products generated through the manufacturing process by mere inspection or cursory analysis. There are plenty of examples where this is seemingly relatively easy—elaborate lithic objects, such as Gerzean knives (Kelterborn 1984), Neolithic Danish daggers (Lomborg 1975), Folsom points (Sollberger 1985), or Solutrean Laurel Leaves (Smith 1966) are rarely, if ever, interpreted as waste or by-products. Other, more easily overlooked objects carry microscopic traces of their past use (Semenov 1964) which require more careful attention; in the case of microlithic inserts on sickles (Spurrell 1892; Curwen 1935) or many endscrapers (Takase 2010), on which wear traces are sufficiently clear that the direction of working and even the general class of worked materials can be reconstructed (Robertson et al. 2009). Again, however, these are exceptional cases. Vast portions of the Paleolithic record, for example, are populated with stone implements whose uses we do not understand even on the most basic level. For instance, demonstrating that Acheulean hand axes were tools in themselves, and not cores for producing flakes, is not simple (Jelinek 1977; Oakley 1972; see also papers in McPherron 2007). With less complicated objects, such as Oldowan choppers and chopping tools, the objects that were once considered to be functional tools are now largely thought to be by-products of flake production (Toth 1985, 1987; Potts 1991). Even Clactonian notches,

one of the main types behind Middle Paleolithic industrial variability (Dibble 1988) have the same issue. These are objects usually made on thick flakes and which exhibit one or more non-contiguous flake removals. Long thought to be tools in themselves, it seems just as likely that they should be interpreted as cores for the production of small flakes (Dibble and McPherron 2006). Central ("préferential") Levallois flakes provide a further example: while traditionally held to be the intentional product of Levallois reduction, they may also be interpreted as a product of the constraints inherent in the maintenance of single-surface core morphologies (Baumler 1988; Dibble 1995a; Sandgathe 2004).

What's the Point of Points?

Using the archaeologist's common sense to identify the function of a particular tool, much less that of an entire, morphologically defined class of tools, is dangerous. As an example, consider the problem of points, by which we mean objects that are thought to have been used as tips for projectiles or thrusting implements. Points occupy a privileged role in the archaeology of human evolution, in part because hunting technology allowed our ancestors access to a subsistence base that is much different from that seen in extant primates, but also because their resemblance to modern weapon analogues invites the identification of their function based solely on their formal characteristics. At the same time, in spite of some convergence of form given their purpose, variation in point morphology may reflect stylistic variation among different groups. Thus, from an archaeologist's perspective, points are quite useful for interpreting the past.

However, even though all pointed objects could conceivably have been used as weapon tips, and even though their shape may be highly suggestive of this, there is by no means a one-to-one correspondence between their form and their purpose (see Iovita 2011; Iovita and Sano 2016; Rots and Plisson 2014 for reviews). There are examples where preservation conditions are optimal and we recover not only the stone "point" itself but also its haft (Bröndsted 1957; d'Errico et al. 2012; Rust 1943). In a number of such cases, these "points" may have been hafted as knives (LaRue and Webster 2015; Marean and Assefa 1999; Schoville 2010), and thus did not function as an armature point. In contrast, many prehistoric arrowheads with preserved hafts have non-pointed or trapezoidal shapes (e.g. Madsen 1848; Troels-Smith 1960). Further, although arrowheads and spearthrower darts are often small and light, ethnographic examples of large and seemingly cumbersome dart "points", such as Australian leilira blades, demonstrate the need to be cautious when inferring purpose from form (Newman and Moore 2013).

It is worthwhile to examine this question in more detail in reference to the typology of the European Lower and Middle Paleolithic developed by Bordes (1961; see also Debénath and Dibble 1994). In his typology, Bordes distinguishes several different kinds of points: unretouched Levallois points, retouched Levallois points, Mousterian points, elongated Mousterian points, Tayac points, and stemmed points (Fig. 1). What all of these types have in common is their plan view morphology—they are basically pointed at one end. Retouched and unretouched Levallois points are basically the same thing—triangular Levallois flakes, with the former exhibiting light retouch on the two converging edges. If the retouch is heavy—that is, enough to have changed the shape of the original flake – then the piece is classified as a Mousterian point

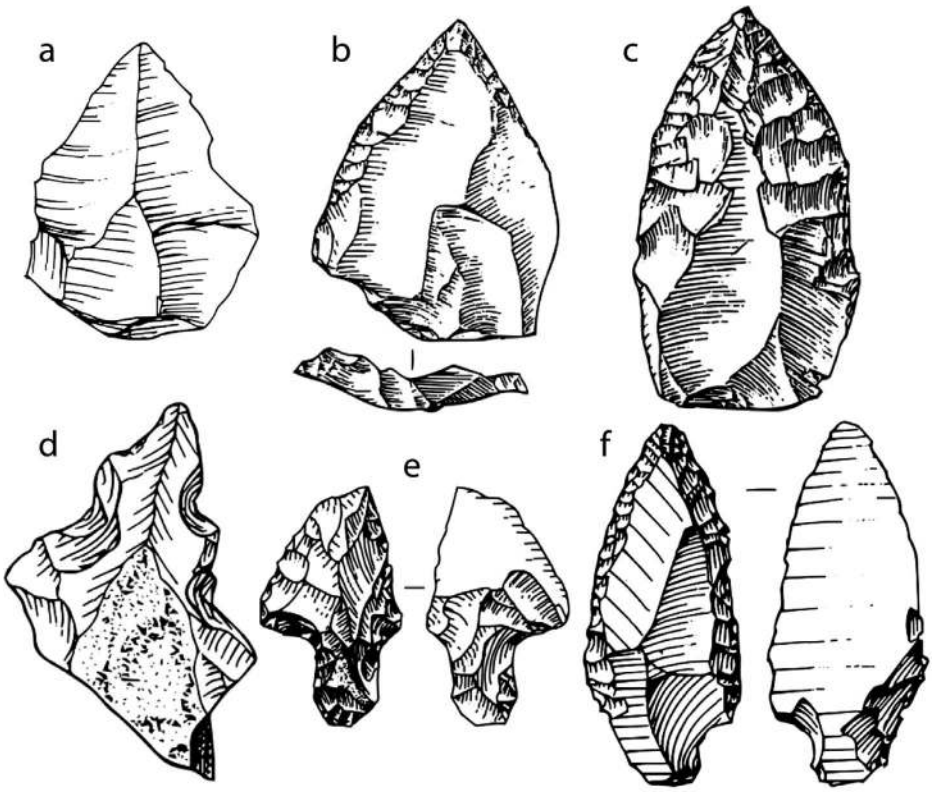

Figure 1. Different point forms defined in Bordes' typology. **a** Levallois point; **b** retouched Levallois point; **c** Mousterian point; **d** Tayac point; and **e**, **f** stemmed points. Redrawn from Debénath and Dibble (1994) and Dibble et al. (2012).

(Bordes actually defined two types of Mousterian points, elongated or not, depending on the ratio of length to width). This is because Mousterian points can be made on a flake of any shape, and that flake can be a product of any technology, as long as the two lateral retouched edges come together to produce a pointed end. A stemmed point, which is diagnostic of the so-called Aterian of North Africa (Dibble et al. 2013), must be pointed, but not necessarily because of retouch (though the proximal stem must be retouched). A Tayac point is essentially a convergent denticulate, that is, the two convergent edges exhibit contiguous notches.

If we accept that all of these points were weapon tips, then it makes sense to assume that the variation in form has something to do with either technical improvements or cultural tradition. However, some of these so-called points were clearly not weapon tips. Tayac points, for example, are diagnostic of the Tayacian, an "industry" now known to be largely the result of post-depositional processes (Chase et al. 2009). It is now clear that such processes (in this case mass movement of sediments) can, in themselves, result in pseudo-retouch such as notching and denticulation (the latter defined as two or more adjacent notches). For Mousterian points, the main problemis that they closely resemble convergent scrapers, with the principal difference between them—in the words of Bordes (1961) who defined them as a type—being that

someone "could kill a bear" with the former. Obviously, this is not a criterion that one could employ on a piece by piece basis, so given its subjectivity, the distinction is essentially meaningless. Moreover, there is a strong correlation between convergent scrapers and Mousterian points— those assemblages that have many of the former also have many of the latter, and vice versa (Dibble 1995b). This would not be expected if they served two distinct purposes. There is also a lack of consensus about whether or not Levallois points as a general technological category can be said to represent weapon tips. Although some evidence has been put forward for these being used as weapon tips exists (e.g. Shea 1988; Rots et al. 2011), it is often those specimens whose plan form is least pointed that exhibit these patterns, and it is undeniable that retouched Levallois points are just as likely to be lightly-retouched scrapers or knives than points (e.g. Shea 1988, 1990; Holdaway 1989; Solecki 1992; Solecki and Solecki 1993; Beyries 1988, Plisson and Beyries 1998). Finally, the stemmed pieces from the Aterian of North Africa are often considered to be projectile points (McBrearty and Brooks 2000), but it has been suggested that the operative part of these implements is the notch in the stem itself rather than the pointed end (Massussi and Lemorini 2004). Moreover, it has been shown quantitatively that Aterian pieces grade continuously into the more general type of Aterian "stemmed tool", which is not pointed in the least (Dibble et al. 2013; Iovita 2011).

In some African Middle Stone Age (MSA) industries, many tools that have a pointed plan form are considered to be points—a naturally pointed flake (produced by any technology), or a piece retouched on only one edge or on two (e.g. Clark 1999; Thompson et al. 2010; Wilkins et al. 2012; Fig. 2 gives examples). Many of these objects would be classified differently in Bordian systematics, either as scrapers, backed knives, or simply unretouched flakes. Is one typology a more accurate reflection of which tools were used as armatures for projectiles? The only way to tell would be to compare them with respect to their wear traces (see, for example, Wilkins et al. 2012). But because use-wear studies are so labor-intensive, pieces are usually pre-selected for microscopic analysis, and in the case of putative weapon tips, most are selected because they are pointed.

Complicating the picture even more is the fact that it has been repeatedly shown that actual prehistoric weapon tips underwent successive modification through resharpening or repair to the extent that their forms are completely different at different times in their use-lives (Ahler 1971; Clarkson 2006; Hiscock 2006; Hoffman 1985; Thomas 1981). They can even be transformed into completely different tools (Goodyear 1974), a process coined by Jelinek (1976) the "Frison effect" after the pioneering studies of Frison (1968). Again, such changes may reflect deliberate modification for a particular use, but within a continuum of variation it is impossible to identify any one particular form as being the one intended. In one poignant case, an artifact from the late Aurignacian, called a *burin des Vachons* that originally was thought to be an engraving tool, then later universally accepted as a bladelet core, was probably systematically recycled as a weapon tip (Dinnis et al. 2009) (Fig. 3a, b). Which of these forms was the desired end-product; the core, or the point? Because it appears that both were actually put to use in some way, the correct answer is "both". More importantly, it may easily be the case that between the original production of the core and the eventual use as a weapon tip, the tool changed hands at least once. For these reasons, we will never know if the intention of the *burin des Vachons* technique was to

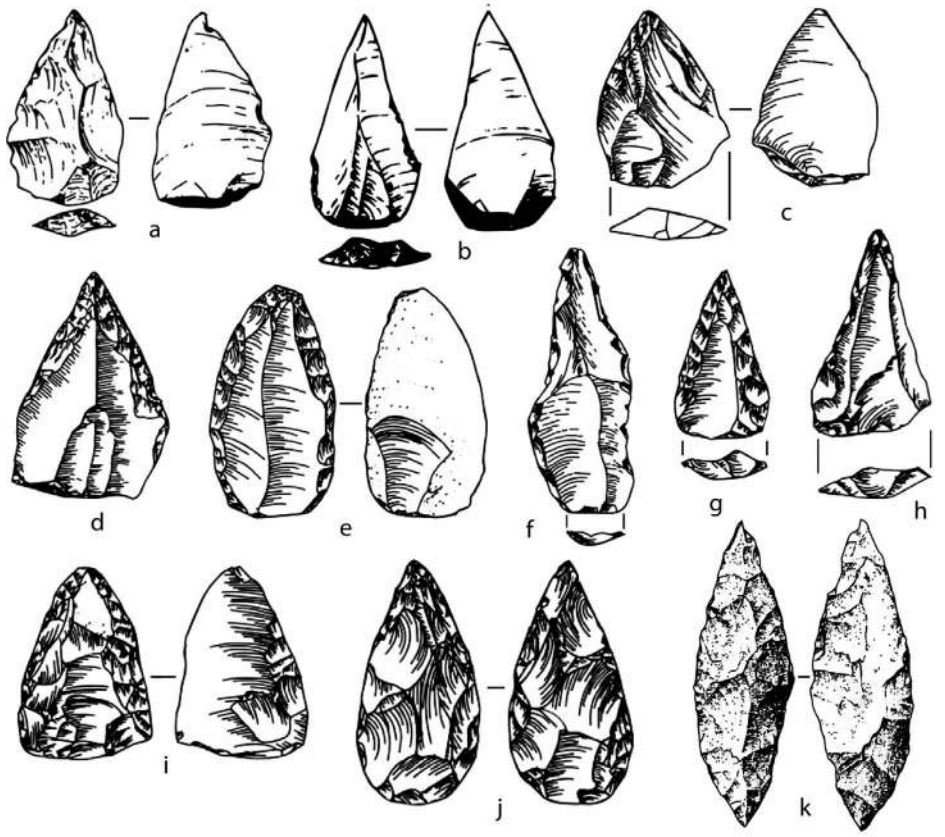

Figure 2. Various (un)retouched MSA points. **a**, **b** Unretouched/utilized point; **c**, **f**, **g**, **h**, **i** unifacial point; **d** Mousterian point on a Levallois flake; **e** unifacial point with basal thinning; and **j**, **k** bifacial point. Redrawn from Deacon (1995), Mohapi (2007), Villa and Lenior (2006) and Villa et al. (2009).

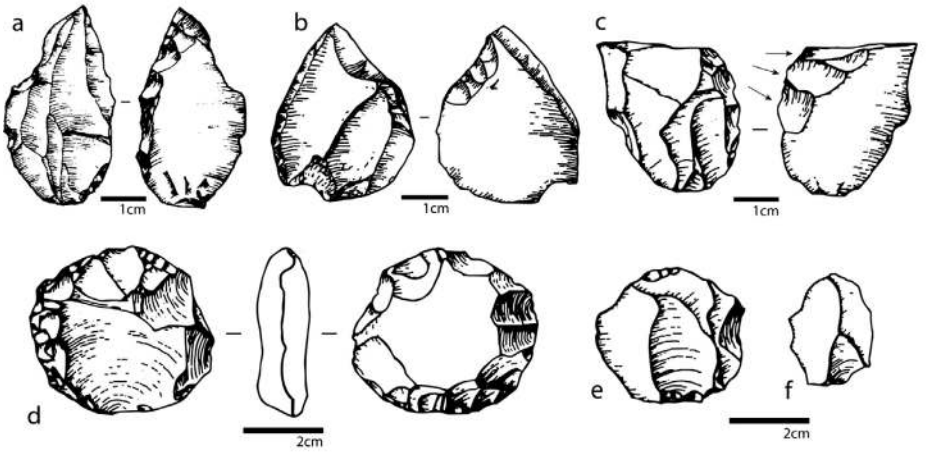

Figure 3. Miscellaneous types discussed in text. **a**, **b** Burins des Vachons (redrawn after Dinnis et al. 2009, Figs. 2, 6, and 7); **c** truncated-faceted piece, with arrows depicting flake removals from the interior surface of the flake core; **d** very small Levallois core; and **e**, **f** Levallois flake from Middle Paleolithic site of Pech de l'Azé IV (**c–f** redrawn from Dibble and McPherron 2006, Fig. 1).

produce bladelets via a core or to produce cores that could later be used as weapon tips, or that both or neither of these were intended.

All of these so-called points illustrate that numerous processes contribute to the variability we see in lithic artifacts, even if we examine just one major class of objects. In fact, other examples of these kinds of problems are numerous. So, for example, are truncated-faceted pieces tools or are they cores to produce small flakes (Dibble and McPherron 2006, 2007) (Fig. 3c)? Are Aurignacian carinate endscrapers and burins functional objects in themselves or are they to be interpreted as bladelet cores (Hays and Lucas 2000, Olszewski 2007a, Olszewski et al. 2011; for other such examples see McPherron 2007)? Beyond considerations of tool types that do not reflect the uses they are purported to have, there is the case of tool types that are the result of natural processes, either mass movement of sediments as mentioned above, or trampling, that create damage that can mimic retouch (Behrensmeyer et al. 1986; McBrearty et al. 1998; McPherron et al. 2014; Douglass and Wandsnider 2012; Pargeter 2011; Rots and Plisson 2014).

There is no question that some lithic objects underwent relatively few changes, and ended up in the archaeological record still reflecting their original intended, or desired, nature. However, other lithic artifacts can be reflective of tools at their final stages of use and remodification or at some earlier point in their use-lives. And many others are clearly the result of natural processes or combinations of natural and behavioral mechanisms. While this has been recognized by some archaeologists for some time, it is enough to warrant a deep skepticism about our abilities to identify desired end products in the archaeological lithic record, even when it would seem to appear obvious. The problem is that archaeologists can use any criterion for establishing a type—in the case of points, it is often just the presence of a pointed end—and it can be tempting to assume that for the individual who used that tool the tip was of paramount importance. But the one point we are making here (and this one is intentional) is that interpreting a particular type as a desired end project is not a given—rather, it must be demonstrated, and this demonstration has to be made by a consistent concurrence of evidence of its actual use independently correlated with at least one feature linked with intentionality. Moreover, the entire life-history of the artifact must be considered.

Unretouched Flakes

If the identification of desired end products is difficult for retouched objects, the difficulty is even greater for identifying those unretouched flakes that were used as tools and those that were not. That simple, unretouched flakes were used is without question: there are numerous examples in the literature showing that they were transported (for a recent example, see Turq et al. 2013—why would they be moved from one location to another if they were not intended to be used for something?)—and numerous other examples where they retain microscopic evidence of use (reviewed in Holdaway et al. 2014). It is also true that many major industries—from the Early Paleolithic of China (Gao 1999, 2013; Gao and Norton 2002), to the Middle Stone Age of Africa (Dibble et al. 2012; Olszewski et al. 2010a, b; Volman 1981), and Holocene Australia (Douglass 2010; Holdaway and Douglass 2012) – are overwhelmingly comprised of unretouched pieces. Just as an example, among the nearly 22,000 MSA lithic objects studied during a recent survey near the historic town of Abydos, Egypt

(Olszewski et al. 2010a, b), there were only 22 scrapers of various sorts, the same number of notched pieces (which may have been the result of trampling), and approximately the same number of other various Bordian types. In other words, only 0.3 % of the lithics exhibited any signs of retouch. Stone artifact assemblages from Holocene contexts in Australia show similar low proportions of retouched tools, usually less than 5 % of the total number of artifacts, and the majority of those that are retouched consist of notches and denticulates or tools with very light scraper retouch (Douglass et al. 2015; Holdaway et al. 2014). What are sometimes described as "formal" tools, that is, pieces where the morphology represents deliberate shaping or repeated use and resharpening in the same manner, account for less than 1 % of the total number of artifacts (e.g. Holdaway and Fanning 2014).

There are other data that show that extremely small flakes—even less than 1 cm in maximum dimension—were deliberately manufactured (and therefore presumably used) and left in their unretouched state (Fig. 3d, e) (Agam et al. 2015; Barrera and Kirch 1973; Dibble and McPherron 2006; Olszewski 2004; Rios-Garaizar et al. 2015; Schousboe et al. 1983). Such pieces are so small that for many archaeologists they fall below the size cut-off for point provenience (i.e. direct coordinate information during excavation procedures). But the fact that these small pieces were produced from identifiable small cores means that they were not by-products but intended removals. In the case of pre-Contact Hawaiian volcanic glass small flakes, these items often are found in high quantities surrounding imu (underground ovens) or scattered in agricultural fields (Olszewski 2004).

So, it would be inconceivable to believe that so many—sometimes as much as 99 % of the objects produced and discarded—were not the result of manufacture with specific intended uses. The only other conclusion is that many flakes were used in their unmodified state. But the problem is, which ones? Not all activities leave use-wear traces, especially those that involve ephemeral contact with soft materials—so even a 100 % accurate use-wear analysis would not identify all tools that had once served some purpose. This means that, except in relatively rare situations, it is not at all straightforward to distinguish desired end products from waste. And as we saw earlier, even when an artifact has been modified, it is not at all clear that the form that it has when recovered from the archaeological record represents a desired end product.

To What Extent Do Stone Artifacts Represent End Products?

It is one thing to point out the difficulties in recognizing desired end products in the archaeological record. However, there are many reasons to think that most lithic artifacts were not deliberately manufactured with such a goal, and many only became tools through a process of selection that occurred after their initial discard. But before presenting the evidence for this, we would like first to review the two major sources that are responsible for the very strongly held view that lithic objects often represent end products: ethnographic accounts of traditional flintknappers, and modern archaeologists who perform replications of archaeological objects.

Although hampered by the paucity of peoples who continued to use stone, ethnographic observations have provided some insight into the highly controlled production of specific forms through traditional techniques. For instance, there are accounts

where informants demonstrate the production of pressure flaked points (e.g. Nelson 1916), adze manufacture (e.g. Stout 2002), Australian Kimberly points (Harrison 2006 and references therein), and blade cores (e.g. Spencer and Gillen 1912; Binford and O'Connell 1984; see Akerman 2007 for a review). Specifically, these observations illustrated structured production sequences of certain artifact forms that demanded skill and experience in the knapper, and this is why traditional knappers are referred to as "craftsmen" (e.g. Stout 2002; Mourre et al. 2010), "specialists" (e.g. Torrence 2011), or "artisans" (Sackett 1982) by some archaeologists.

The opportunities for ethnographic observation of stone artifact use were never extensive simply because, as many contact era studies indicate (e.g. Bamforth 1993; Cobb 2003 and studies therein), once metals became available to aboriginal peoples, the use of stone declined rapidly. So, by the time archaeologists became interested in traditional flintknappers, the number of extant cultures still using stone tools were limited to just a few groups, primarily in Africa, New Guinea, and Australia (e.g. Brandt et al. 1996; Gould 1980; Gould and Saggers 1985; Gould et al. 1971; Hayden 1979; White 1967; White and Thomas 1972; White and Dibble 1986; although see additional interesting observations made on gun flint and sickle blade manufacture in Witthoft 1966 and Skertchly 1879). Of course, only a few specific technologies were represented among those groups, and they were not always typical of those seen in prehistoric contexts. Moreover, the stone technologies utilized by these groups usually represented only minor components within their larger technological systems, which at times encompassed many modern material elements including metals, modern weapons, and modern means of transport (Weedman 2006). Ethnographic studies provided only limited windows into variability in behavior in how artifacts were made and used, and were generally interpreted to show the same pattern of intentional production followed in replicative experiments (compare for instance, the accounts discussed in McCall 2012 with Holdaway and Douglass 2012).

Due to the relative lack of ethnographic accounts, archaeologists came to rely on their own resources to reconstruct how lithic artifacts are made and used. Of these, flintknapping, using what are, or what are considered to be, techniques and methods used in the past, has traditionally been an important technique to understand lithic technology (Flenniken 1984; Flenniken and Raymond 1986). Because most flintknapping experiments are undertaken to try to reproduce or replicate particular prehistoric technologies and end products, they are termed replicative experiments. By replicating certain forms, it is thought possible to understand more of the technical processes that are required in their manufacture (Inizan et al. 1999).

Replicative flintknapping has a long history in archaeology. In the 19th century, when the debate began on whether the Paleolithic flint implements found in association with the remains of extinct animals were of natural or human origin, replicative experiments, such as by Evans (1897), were carried out to resolve this problem. If it could be demonstrated that a sequence of flake removals from a nodule led to the manufacture of a particular shaped product, and this sequence could be shown to occur repeatedly, then human involvement was indicated. It was thus through replication that the anthropogenic origin of stone tools was demonstrated, along with the initial development of criteria that could be used to differentiate real artifacts from naturally-produced Becofacts^ (Johnson 1978; also see Van Riper 1993).

In the 1960s, replicative experiments started to gain widespread popularity due mostly to the work of Crabtree (e.g. 1966, 1967, 1970, 1972) in North America and Bordes (e.g. 1953, 1971) in France, and each of them influenced a large number of later flintknappers. Although the goals have changed considerably since the earliest experiments, replicative experiments are one of the major approaches in lithic analysis (e.g. Boëda 1986, 1988a, b, 1993, 1995; Boëda et al. 1990; Eren et al. 2008, 2011a, b; Eren and Lycett 2012; Pelegrin 1990; Tryon et al. 2005;Wilke et al. 1991) and it has directly led to a growing emphasis on production and manufacture in understanding past technologies (see Odell 2000; Andrefsky 2009; Haidel 2007 for discussion) and other related behavioral phenomena, including skill, learning, and cultural transmission (e.g. Bamforth and Finlay 2008; Eren et al. 2011a, b; Ferguson 2003; Geribàs et al. 2010; Kempe et al. 2012; Mesoudi and O'Brien 2008; Morgan et al. 2015; Nonaka et al. 2010). Clearly, such experiments have provided important insights into largely extinct technologies, and without them our approach to lithics would probably be very different from what it is today.

Both ethnographic observations and replicative studies have led to a very strong assumption that most lithic objects found in the archaeological record are desired end products, just like ceramic vessels, metal objects, and a myriad of other artifacts found in the archaeological record or being manufactured today. This leads to a very common conceptualization for the production of lithic objects that the manufacturing process is essentially linear in nature, with various steps ultimately leading to the desired end product (for one example, see Fig. 4; for other similar conceptualizations see Bleed 2001, 2002a, b; Inizan et al. 1999; Jelinek 1991; Shott 1996). The reconstruction of these processes—from raw material selection, through core preparation and flake removal, and ultimately to the fashioning of tools, is at the base of much of current lithic research (e.g. Inizan et al. 1999; Pigeot 1990; Schlanger 1996), including approaches that focus directly on sequences of production (Bleed 2002a; Marks and Volkman 1983; Van Peer 1992).

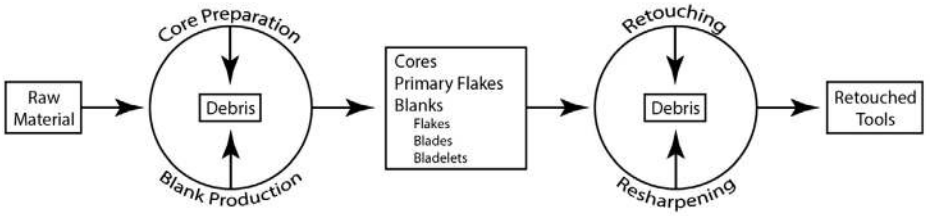

Figure 4. A conceptual model for the production of flaked stone artifacts that characterizes much of the current Paleolithic literature. In this figure, raw material refers most often (but not exclusively) to unworked rocks, which are selected on the basis of various characteristics, such as size, shape, quality of material for flaking or use, etc. The selected nodule then becomes a "core" as it goes through a phase of preparation and blank production. In the preparation phase, striking platforms may be set up and particular kinds of flakes removed in order to modify the core surface morphology (e.g., "predeterming flakes" or éclats prédéterminants in the jargon of chaîne opératoire; see Boëda 1988a, b, 1993, 1995; Boëda et al. 1990). This then sets up the core for the removal of those flakes whose shape has been "predetermined" by the core surface morphology (éclats prédéterminés). The degree of such preparation may vary. While some of these flakes may be fully functional in their natural state, others may go through a further series of modifications (through retouch) that transform them into useful objects and objects may be resharpened or remodified after cycles of use. All of these phases result in various by-products (debris), including shatter, broken flakes, small preparation or retouch flakes, and the like. Once the final objects have served their purpose, they are discarded. Figure was redrawn from Debénath and Dibble (1994)

While such a linear—or goal directed—process was undoubtedly sometimes followed in the production of some lithic artifacts, it is just as true that it is incorrect to put too much emphasis on this form of production. One major reason for this caution is due to the difficulty of identifying desired end products, as discussed above. Acheulean bifaces may have been primarily cores and convergent scrapers may reflect only the last stage in a cycle of use and remodification. If either of these scenarios is true, then trying to understand their form as the result of purposeful manufacture will more likely result in interpretations that are largely incorrect since they will not be based on the actual processes that led to the form as it is found in the archaeological record. In other words, if artifacts found in the archaeological record are largely a result of having been discarded because they outlived their usefulness, then we may find ourselves mistakenly replicating the objects that early hominins decided they did not want rather those they did.

The Disconnect Between Manufacture and Selection

While understanding how stone tools were made is one of the primary goals of replicative experiments, their emphasis on manufacture has led to the notion that most stone tools that were used were deliberately manufactured for that purpose. As we said earlier, this is analogous to similar assumptions regarding most other technologies, both prehistoric and through to modern times. However, it is important to emphasize that stone artifacts differ from almost every other kind of human technology in terms of their durability. Many other common technologies, such as ceramics, woodworking, basketry, metallurgy, and hide-working, are all either susceptible to breakage, become unusable over time, or lose their original qualities completely through recycling (such as through the melting and recasting of metals). Although some kinds of stone can suffer from diagenesis in particular contexts, for the most part the materials used for chipped stone manufacture are virtually indestructible. One of the implications of this fact is that products originally manufactured by one person can be picked up later and put to further use. For example, a nodule reduced to a certain point by one knapper can, many decades, centuries, or millennia later, be further reduced by another knapper (McDonald 1991). Likewise, individual products, such as flakes or tools, that were made and used by one person may be picked up and subjected to further use and remodification by someone else (Turq et al. 2013). Even pieces from a broken lithic object can be repurposed. This is what we mean by selection: selecting previously made lithic objects and using them for some task.

It is not clear that the potential for reuse of stone artifacts is fully appreciated by many lithic archaeologists, particularly in recognizing the relatively small role that manufacture plays in comparison with the selection of already existing artifacts. In fact, several ethnoarchaeological accounts clearly show that the selection is much more common than the deliberate production of specific forms. For instance, Hayden (1979:168), Gould et al. (1971), and Sillitoe and Hardy (2003: 654, 660) provide examples where the raw material for flaking comes from previously worked nodules abandoned by whoever used the location previously. There are other accounts (e.g. Hayden 1979: 85; MacCalman and Grobbelaar 1965: 25; McDonald 1991; Weedman 2006:217) of how products from core reduction were selected for use by different individuals, often on the basis of different sets of criteria for determining what is considered a suitable end product.

In the ethnographic case of Slippery and Billy in Central Australia (Hiscock 2004: 73–74; see also Sillitoe and Hardy 2003: 558), the knapping process was further complicated by the presence of two individuals:

> The typical knapping posture for Billy was kneeling on the ground ... The core rested on the ground to the left and in front of Billy's left knee, between 0.3 and 0.8 m from his body. This core was positioned and manipulated by Billy's left hand. The hammerstone was held in his right hand. In the act of knapping Billy would bring the right hand round in an arc and down toward his left kidney, hitting the uppermost part of the core by his left knee. Successfully detached flakes would fly to the left and behind the knapper.... [and thus] landed out of Billy's sight and anywhere from centimetres to twelve metres from his back. The highest density of material was found up to four metres behind the knapper, and could not be viewed by him. Because Billy was unable to observe flakes he struck off, it was his habit to have an aide, in this case his friend Slippery. Slippery looked at the flakes that had been detached behind Billy's back and retrieved some for closer inspection. Slippery sat to the right of the knapper and parallel to, or slightly behind him. In that way Slippery was protected from any airborne flakes, but he remained some distance from the landing flakes; and on occasions where he was not far behind the knapper he also had to twist his torso to examine the knapping results. This created the intriguing circumstance in which a knapper was often unaware of the flakes that were produced, and the identification of flakes suitable for use was made by someone other than the knapper.

Another example comes from the work of White and Thomas (1972; see also White and Dibble 1986) on the ethnographic study of the Duna-speaking people in New Guinea Highlands. White and Thomas (1972: 278) observed that: "[f]lakes and cores—the distinction is irrelevant to highlanders—are selected for tasks if they have features suitable for the work at hand." In other words, any single piece of stone can be used for different tasks as long as it possesses a usable edge and is of a suitable size for the task. They continue by noting that "[m]odern highlanders, then, do not regard their flaked stone tools as a series of formal or single-functional types, but as pieces of stone, parts of which may be used to perform certain activities." This lack of concern on the shape of stone artifacts was also discussed by Gould et al. (1971: 154), who stated the Australian Aborigines of the Western Desert similarly showed little interest "in the shape of the tool—except for the angle of the working edge relative to the particular task involved". In this case, the emphasis on flake edge and overall size in relation to the given tasks at hand means there is no essential link between particular flake's form and the specific function or use to which it is put (Holdaway and Douglass 2012).

Accounts of Australian Aboriginal stone tool use by Horne and Aiston (1924: 101) also illustrate the creation of wide range of flake products from which tools suitable for different tasks were selected out after production: "When chipping flakes from the main stone or core, called kutna by the Wonkonguru, all flakes that are likely to be of use are saved, some for use as knives, yutchawutas, some for graving tools, pirries, and others as chisels, tuhlas." Likewise, in his study of flake tool production by Alyawara speaking Australian Aborigines, Binford (1986: 553) "repeatedly observed

the situation in which another worker would take up the core reduction, remove his blank, etc., while his debris accumulated over that of the previous workers", and between knapping episodes individuals other than the knappers would retrieve artifacts from the debris pile to take to other family camps. In these ethnographically observed instances, core reduction was in fact rapid and causal, but nonetheless produced a wealth of varied but useful "end products" (Holdaway and Douglass 2012). All of this suggests that the identification of useful characteristics or attributes of unretouched flakes is an area that needs much more attention (see, for example, Braun et al. 2009b; Douglass et al. 2015; Holdaway et al. 2014; Holdaway and Douglass 2015; Lin et al. 2013). But in the meantime, two important points should be emphasized. The first is that nearly all the products of reduction will be used for something (e.g. Binford 1986: 553), and that individual users may at times select from the "debris" created in a previous task for subsequent use (Hayden 1979: 29–37). The second point is that in many cases the manufacturing process is quite distinct and often separated in time from the independent process of selecting particular objects for particular tasks. Archaeologically, we also see such second-hand selection of lithic artifacts, as indicated by the presence of double patina, polish, or fire damage, indicating that at least some time passed between the original manufacture of the object and its subsequent reworking (e.g. McDonald 1991; Olszewski 2007b; Peresani et al. 2014, 2015; Vaquero et al. 2012, 2015; Barkai et al. 2015 and papers therein). There are also numerous archaeological examples of reuse. One can be seen in the pre-Contact Hawaiian archaeological record (Olszewski 2007b). In this instance, basalt was chipped to form an adze preform (usually at the basalt source); this preform was then transported back to a site where it was further knapped to achieve the adze form and then ground and polished. Some of these adzes were damaged through use. However, rather than return to the basalt source and start a new preform, the damaged adze was recycled by selecting it for further modification (additional knapping, and then grinding and polishing) to create another (smaller) adze (see also Turner and Bonica 1994). Another example has been described by Dibble (1984; 1987; 1995b) for the Middle Paleolithic of Western Europe and elsewhere. Early in the use-life of a scraper it may be worked on only one lateral edge. Through the course of the use life of this retouched tool it may be resharpened and can pass through several different typological categories—as a double scraper, a convergent scraper, or a transverse scraper. Similar processes have been demonstrated for Oldowan "tools" (Braun et al. 2009a; Potts 1991), Acheulian bifaces (Iovita and McPherron 2011; McPherron 1999, 2000), Epipaleolithic microlith shaping (Olszewski 1993, 2016), various kinds of projectile points (Goodyear 1974), notches and denticulates (Hiscock and Clarkson 2007; Holdaway et al. 1996) and Australian tula adzes (Cooper 1954: 92–4). The retouched artifact excavated from the archaeological record is not always—and perhaps, only rarely—reflective of some end product that was imagined at the time a nodule was originally struck. Rather, what we see in the archaeological record are objects that may have been used for a wide variety of tasks and remodified/resharpened over time as necessary. Again, this is the "finished artifact fallacy" of Davidson and Noble (1993).

All of these studies, both ethnographic and archaeological, call into question the assumption that all stages of stone artifact manufacture occurred at one time or that flaking was necessarily undertaken by a single individual as a conscious and deliberate act to produce of a particular form. At the same time, they show a much more

fluid and flexible approach to making use of all sorts of different products that result from the knapping process. Instead of focusing on the manufacture of a limited number of desired end products, ethnographic accounts of knappers often relate how the knapping of cores produces a large variety of products. Any of these products were then selected by other individuals for specific tasks, and thus the relationship between production and selection may temporally be quite distinct. At the same time, it is not often the case that a single object is simply made, used, and then discarded.

While Aboriginal people may not be a perfect model for the prehistoric past, it is clear that the ways in which even modern people knap is highly variable and does not always match the simplified, and linearized, abstractions such as the one shown in Fig. 4. It also clear that categories such as end products, by-products, and waste reflect the archaeologists' perspective more than past reality. A modern flintknapper replicating an Acheulian biface may produce hundreds or even thousands of lithic objects, and after the fact may be content to consider all of them as waste. It seems much less likely that someone who makes a living off of stone objects, and who has to transport them on foot, would feel the same way.

All of this is the result of the durability of lithic objects, which enables processes of selection and multiple generations of modification to continue long after their original manufacture. Thus, cores can be reused, and original flake blanks can also serve as cores for the removal of smaller flakes. Flakes that were originally intended to shape a core surface—éclats prédeterminants—may later have utility for various uses. A once finished tool that was used and discarded can later be picked up and remodified into an altogether different type. Moreover, these processes can continue long after an object was produced. Without any doubt, the way that lithics can be used and reused many times over makes it clear that Bone person's trash is another's treasure^. And as soon as someone selects an object for use—regardless of whether it was considered by the original knapper as by-product or waste, that object becomes, by definition, a desired object. Thus, the intention of the maker is not always the same as that of the user.

It should be clear enough, therefore, that the process depicted in Fig. 4 is, at best insufficient, and at worst, largely incorrect. It is simply unrealistic—and contrary to both ethnographic and archaeological evidence—to assume that every time someone needed a stone object for a particular task they would begin the whole process shown in the Fig. 4, from acquisition of the raw material, through core preparation, blank removal, and the final fashioning of a new object. For the most part, it seems much more likely that people selected appropriate objects from what was at hand, whether or not those pieces had already been made, used, and discarded by someone else.

A New Conceptualization of the Production of the Archaeological Record

This then leads to a somewhat different conceptualization of the accumulation of stone artifacts in the archaeological record. For archaeologists today, the archaeological record, at least the portion that can be recovered and analyzed, represents the sum total of what was made and used in the past and. To a person living in the past, however, that same "record" is simply a source of raw material; pieces discarded long previously that can be picked up and used again and again. Each time they are discarded, those same pieces re-enter the record and remain there until they are picked up again. At times they may be used in their current state, or they can be further modified. Much

of this depends on processes of selection of existing objects, not repeated manufacture. Natural taphonomic processes can modify them still further. This kind of process is shown in Fig. 5, which captures the types of potential changes that occur through selection and repeated use and remodification, among other processes. It is intended to capture the durability and history of use of stone artifacts by emphasizing how the act of discard does not remove the object from the possibility of future use, but instead puts it back into a context that, in effect, facilitates future use. The process illustrated here recognizes that some objects were deliberately set aside, or cached (e.g. Hiscock 1988) and at the same time it can model how some artifacts were simply lost (e.g. Binford 1977; Ebert 1979; Yellen 1977). Not every artifact necessarily had a complex use-life history but every artifact had the potential for such a history.

For the reasons outlined above, sites themselves can be seen as more than just spots where certain activities were carried out – because they contain artifacts from previous site visits, they were also sources of stone raw materials (Schick 1987). Just as sites are visible in the landscape today, so would many of them have been visible to prehistoric groups who may or may not have had a connection to the groups who earlier used that locale. The potential to reuse artifacts many times after they were manufactured means that a site that was previously occupied represents, in itself, a primary source of lithic material. Why, therefore, would anyone bother to get new raw material and go through the trouble of producing new blanks when there are thousands of perfectly usable flakes all around – even if they were made by someone else many years earlier? This fact may also explain, at least in part, why some locales appear to have been persistently visited or occupied more than others – as discarded lithics accumulated, these locales would have served as a magnet that attracted subsequent visits or occupations (Douglass et al. 2015; Holdaway and Fanning 2014; Holdaway et al. 2014). In effect this sets up a feedback loop: regardless of any other amenities

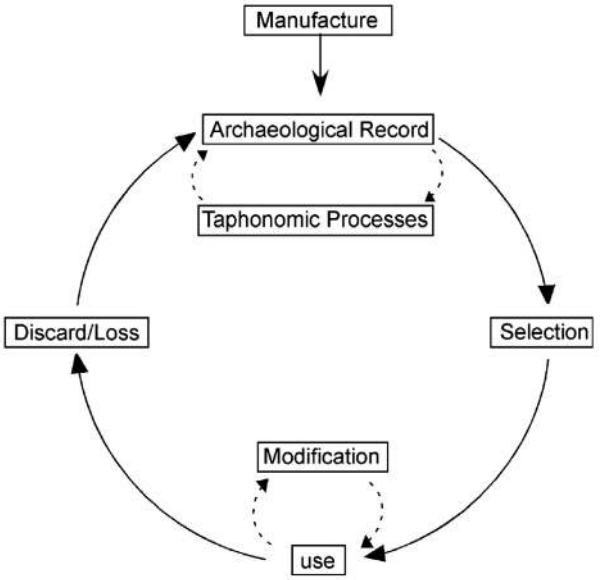

Figure 5. The interaction of stone artifacts with the archaeological record modeled as a dynamic process. In this view, manufacture is only a small component, producing objects that can be selected, modified, and used repeatedly for different tasks.

that a particular location might offer, the discarded artifacts from one occupation encourage further use of that same spot. In fact, subsistence-related or other activities need not have taken place there – only pickup and discard. Lithic material is, after all, an essential resource, whether or not it had been manufactured and used previously. So, while a great deal is written about raw material sources in Paleolithic archaeology, with the source of the raw material most often defined in geological terms (e.g. Andrefsky 1994; Braun et al. 2009a; Féblot- Augustins 1990), past peoples were also active in creating their own raw material sources by leaving artifacts that could be reused in the future.

Thus, to a very significant degree, the anthropogenic influences on the formation of the record can be conceptualized as an ongoing process of human transformation of lithic materials through selection, use, and discard, with a realization that this process, or set of processes, repeats itself many times. Manufacture, of course, plays a role in this process, but again—because of the durability of lithic objects—that role may be much less than often imagined simply because objects made much earlier in time continue to be useful. From the archaeologist's view, what we find is not just what they made, but what they continued to select, modify, and reuse. By overly emphasizing the role of manufacture, we tend to underestimate or even miss these other processes as major contributors to the nature of the assemblages that we excavate.

Part II: The Fallacy of Assemblages as Representing Simple Accumulations of Contemporary Behaviors

Because anthropological archaeology is not usually focused on individual artifacts, we more typically deal with groups of artifacts, or assemblages, that represent the totality of stone artifacts recovered from a distinct context. Usually this context is defined geologically (e.g. a stratigraphic level), although anthropogenic features and certain techniques of excavation (such as spits or the exposure of artifacts on a single horizon) may also be used to define it. There are many reasons why this is so fundamental to archaeological method. First, given the relatively high degree of variability among individual stone artifacts, we need larger samples to understand the range and central tendencies of the material. Second, by taking finer slices of a site's stratigraphic sequence, we hope to limit the chronological span represented by the artifacts, thus establishing some degree of contemporaneity among the objects. And finally, when coupled with spatial data, we use the presence of different kinds of artifacts and their distribution across space to help inform about the range of activities that took place during that time. Essentially, then, an assemblage becomes a unit of analysis on a higher order than individual artifacts, and similar assemblages (whether defined temporally or in other terms) are then combined into even higher order units such as industries, techno-complexes, and the like.

While such an approach is crucial for archaeological interpretations, it is important to understand its limits, and probably the single biggest issue is the degree of contemporaneity of the objects within an assemblage. As we will discuss in this section, this issue is actually quite complex, and it is not just a question of how much time elapsed between the deposition of one object and another. Rather, a large number of processes are involved in the formation of an assemblage and all of these not

only affect the contemporaneity of the objects within it but also the overall assemblage composition.

We will begin by presenting, in Fig. 6, a simplified version of how assemblages are formed that sees it as a result of a repeated series of succeeding occupations. Each occupation introduces new materials to the site, and lithic objects are manufactured, used and discarded, essentially following a pattern similar to that shown earlier in Fig. 4. Because it is often assumed that an assemblage represents a number of discrete occupations, we can represent it as a summation (from one to some number of events or occupations) of the products created during cycles of manufacture, use, reuse and remodification, up to their eventual discard. Thus, the final result, the assemblage as it is recovered archaeologically, is an accumulation of various kinds of objects.

Underlying this view of assemblage formation are a number of important assumptions that are necessary if we want to use the assemblage to inform us of past activities that took place at a specific point of time and at a specific locale.

1) The first assumption is that there is a certain level of contemporaneity among the objects recovered from the assemblage. Obviously this assumption is necessary to understand synchronic spatial variability, but it is just as important for recreating technological strategies that were used at any one time
2) The second assumption concerns the integrity of the assemblage from a behavioral perspective—that is, that the objects found together are those that were originally manufactured, used, and deposited there. If a significant number of objects were brought in or taken away, our ability to recreate the activities that took place there, including lithic production, will be compromised.
3) The third assumption relates to the integrity of the assemblage with respect to natural agencies. That is, we assume that, barring major taphonomic changes such as slope or water transport and redeposition, the spatial associations among artifacts and their character reflect ancient discard.

Each of these assumptions will be discussed in turn.

The Contemporaneity of Objects within an Assemblage

While the contemporaneity of assemblages from different sites is a major problem in archaeology, the contemporaneity of the artifacts from a single assemblage from one site is also not always certain. This is especially true for Paleolithic assemblages, which are most often defined by their incorporation in a distinct geological sedimentary horizon. Partly as a result of the application of radiometric chronologies, and partly because of a better appreciation of geological deposition, we know that the stratigraphic units from which archaeological assemblages are created can represent incredibly long

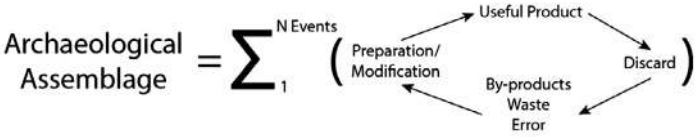

Figure 6. A conceptual model for the creation of stone artifact assemblages based on successive iterations of the processes of manufacture, use, reuse, and discard.

periods of time. In many cases this means hundreds, or even thousands of years of sedimentary deposition in association with the artifacts from a distinct stratigraphic horizon. To put it quite simply, geologically-defined layers are geological units that reflect geological time scales (Stern 2008). On the other hand, archaeological behaviors take place over human time scales, which are orders of magnitude shorter. The deposition of the artifacts within a single geological unit may easily represent many distinct occupations by different groups who performed many different activities at significantly different times. When we aggregate an assemblage defined on geological criteria and treat it as a single analytical unit, the effect is to homogenize the internal behavioral variability that represented those separate occupations and/or activities (Binford 1982; Bordes et al. 1972; Stern 1994).

Even if an assemblage were to be shown to lie on a stable geological surface, there is no guarantee that the artifacts reflect a single episode of occupation or even that various occupations can be distinguished and analyzed independently. By definition, a stable surface is one that exists for a significant period of time and thus, again, is able to represent an aggregation of distinct occupations (see, for example, Barton and Riel- Salvatore 2014; Davies et al. 2015; Olszewski et al. 2010a, b).

While objects within a geological layer cannot be assumed to be contemporaneous in a human-behavioral sense, archaeologists do rely on a number of methods to argue that certain objects within such a layer can be more precisely related temporally. One of these is the excavation technique known as décapage, whereby a thin layer of sediments is removed, thus exposing a "surface" of supposedly contemporaneous objects. Unfortunately, décapage, as an excavation technique, can be quite misleading, especially given that the level being followed is often somewhat arbitrary, and it actually exposes a "surface" of artifacts that is essentially based on their vertical position. Thus, distinctions between such surfaces are, in fact, not real, since they are essentially an artifact of the technique of excavation. Moreover, geoarchaeological studies have demonstrated that in cases where features that reflect extremely short-term events are discovered, such as fire features or floor bedding, they can, in fact, have resulted from multiple repeated activities involving the reuse and movement of existing materials (Aldeias et al. 2012; Dibble et al. 2009; Goldberg et al. 2012). The presence of such features will always be of considerable interest, but the complexity of the formation processes associated with sites makes inferences about the spatial association of activities problematic. This certainly applies to lithics that we might find in proximity to features. For example, there are often marked differences in the likely longevity of hearth use and the time period over which the sediment that buried the hearth was deposited. This means that artifacts found on the same surface into which the hearth was cut may have been deposited at a quite different time than the hearth construction event.

Lithic refits are another means to try to demonstrate contemporaneity. One of the earliest and most famous examples of this technique was done by Worthington Smith (1894) at the English site of Caddington, and since then numerous such studies have been performed (e.g. Bodu 1996; Close 2000; Villa 1982, 1983; Volkman 1983). However, while refits tell us the order in which objects were removed from a block of stone, they cannot tell us who removed them (a single or multiple knappers) or the duration of time over which the nodule was reduced (Bar-Yosef and Van Peer 2009). While it may be tempting to assume that a block of stone was knapped by a single individual, we previously discussed instances where multiple individuals knapped the same block

of stone (e.g. Binford and O'Connell 1984) and where different people may retrieve a variety of objects removed through the reduction of a single block of stone (Holdaway and Douglass 2012). Thus, the removal of individual flakes may or may not reflect a single event concerned with the production of particular products based on a single strategy of reduction.

The notion that artifacts found in spatial proximity share a similar context of use also lacks theoretical justification given the potential for features to be repeatedly reused and artifacts to be reused and moved. Yellen (1977: 134), for example, remarked on his ethnographic experiment with the Bushmen that "[m]ost tasks [at a camp site] may be carried out in more than one place and in more than one social context and conversely in any single area one can find the remains of many activities all jumbled together."

Time-averaging

As noted by Lucas (2012: 106–109), the application of time-averaging to archaeology by Stern (1994) used a concept borrowed from paleontology. Time-averaging in paleontology is based on the idea that the association of fossils with deposits is essentially arbitrary, as the life-cycles of the organisms that were eventually encased in those deposits has no relationship to the length of formation time of the sediments. This is understandable because fossils are deposited through natural processes, and the animals present represent faunal communities that can reflect relatively stable climactic conditions over quite long periods of time. For the earlier ranges of prehistory, for example the Paleolithic in the Old World or even the Paleoamerican and Archaic in the New World, the temporal scale of deposits in which cultural materials are found is often extensive and thus mirrors this paleontological situation. Nonetheless, the life-cycles of the individual artifacts cannot be assigned to specific moments in time within those deposits.

This is not to say that temporally-constrained, specific uses of place (e.g. as hunting camps or kill sites) did not take place in the past. However, since many archaeological assemblages are formed over geological time scales, an excavated assemblage, in effect, collapses all of this time and treats it more or less as a single temporal event. Time-averaging, then, represents the difference in the temporalities of stone artifact manufacture and use, hearth creation and use, and the temporality of burial by sediment. There is no reason to believe that the activities that took place at a site were in any way consistent during the course of the formation of the assemblage (see Binford 1978a; Dunnell 1992; Hayden 1979 for examples). This, in turn, means that, at best, assemblages derived from geological strata can, and almost certainly do, reflect a kind of homogenization of unrelated and varying activities. This is true regardless of the rate of sedimentation or artifact deposition (cf. Malinsky-Buller et al. 2011). At worst, time averaged assemblages could show patterns that are drastically different from the actual processes underlying their formation (e.g. Davies et al. 2015; Premo 2014).

While much of archaeology treats sites as places where activities occurred, it does not often consider other aspects of long-term site use that impact time-averaged deposits. The overall effects of time-averaging mean that archaeologists are dealing with assemblages that reflect the site's position in the landscape (such as a place that acts as a natural trap for the deposition of cultural and natural materials), the topographic setting of that locale (e.g. good visibility, access to water, good shelter in inclement

weather, etc.), and the rate at which artifacts are eventually buried and sometimes re-exposed. As mentioned earlier, the very fact that lithics may be exposed on the surface may attract later populations to the same locale. As a result of these factors, the assumption of contemporaneity among the artifacts from a particular assemblage is problematic at best, and more often than not it is simply incorrect.

The Integrity of an Archaeological Lithic Assemblage

Transport

The other common assumption concerning assemblages is that the objects represent a continuous deposition of what was made and used during the formation of the assemblage. Turq et al. (2013) call this assumption the "complete reduction sequence fallacy", where the range of lithic products found in an assemblage is thought to represent the entirety of past reduction sequences for the production of certain desired end-products. Contrary to this assumption is the demonstrable fact that lithic objects are continuously brought into sites and are also continuously removed. This can be due to taphonomic processes (see below) but also due to human transport.

No one would deny that, like modern hunter-gatherers (e.g. Binford 1978b; Yellen 1977), prehistoric human populations did not inhabit a site but rather a landscape, and their movement around that landscape was an essential part of their various adaptations to the surrounding conditions. But as people move, so do artifacts, and the transport of objects across a landscape can potentially mix materials derived from independent behaviors that occurred at different places and at different points in time. If artifacts were used more than once, then there is a good chance that at least some of these uses occurred in places other than in the location where they were finally discarded. The behaviors that lead to the types of assemblages conceived of in Fig. 6 are in many cases likely to span several locations, as shown in Fig. 7. This means that to address and compare the behavioral dynamics throughout the course of hominin evolution in a comprehensive manner, it is necessary to situate and interpret the record of hominin behavior formed under distinct contexts at a landscape scale (Blumenschine 1991; Isaac 1986;

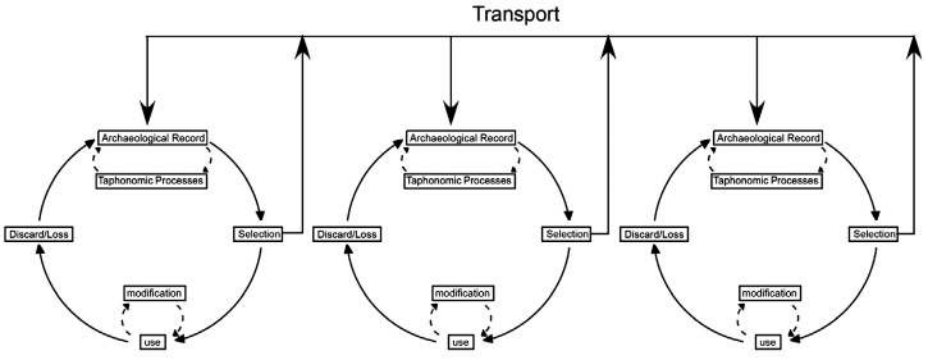

Figure 7. An expansion of Fig. 5 to represent landscape scale movement. Artifacts are brought in from one locale to another, and subsequently, used, remodified, and discarded repeatedly. They can then be picked up and transported to another locale, where these cyclical patterns can be repeated once again. It is important to note that this process does not have to reflect the actions of a single person or group, since artifacts brought into a place at one time can be selected for transport many years later.

Potts 1991). It is also important to emphasize that such movement of objects across a landscape also depends on selection, and it is not clear exactly why certain objects are selected for transport and others not. One might think that it is only so-called finished tools, or desired end products that would be selected for transport, but as Turq et al. (2013) show, a wide variety of forms were transported by Neandertals, sometimes over significant distances (see also Geneste 1985; Roebroeks et al. 1988). The removal and introduction of transported items, while certainly under the control of behavioral factors, nonetheless will affect the character and composition of an assemblage in terms of both technology and typology (Schick 1986, 1987). Thus, the record that we as archaeologists find in an assemblage only represents the last point at which those artifacts were deposited. Again, as described above, the behavioral process at the heart of such transport is the selection, not manufacture, of the items to be carried away.

This discussion should also touch on the concept of fragmentation (Dunnell and Dancey 1983; Foley 1981a, b; Gould 1980; Schlanger 1994; Turq et al. 2013), which deals with the nature of the spatial dimension with regard to behaviors over landscapes. The main point of fragmentation is that each place where archaeological materials are situated in a landscape records only a part (a "fragment") of the total behavioral pattern. When sites are excavated and/or recorded, archaeologists are essentially recovering fragments. Even when such fragments appear to be contemporary across a landscape, this is not necessarily true as such fragments may belong to different points in time (e.g. see Davies et al. 2015; Holdaway and Fanning 2014).

Site Formation Processes or Taphonomy

Today most archaeologists recognize that these accumulations may be altered by a variety of taphonomic processes (Lenoble and Bertran 2004; McPherron 2005; Schiffer 1972), which has led both to an emphasis on finding more or less "pristine" sites or layers (Binford 1981a; Malinsky-Buller et al. 2011) and to analytical methods to filter out such "distorting" effects (Schiffer 1983). The "Pompeii Premise" debate between Binford (1981b) and Schiffer (1985) concerned such efforts. The term was first used by Ascher (1961: 324) to describe the notion, often implicitly assumed, that the archaeological record of a particular site or layer reflects "remains of a once living community, stopped as it were, at a point in time". In a similar vein, the archaeological record could be viewed as the deposition of materials from multiple systemic episodes (sensu Schiffer 1972), further modified or transformed by post-depositional processes. By identifying and removing the effects of post-depositional transformations, it was argued that archaeologists have the ability to reconstruct the original human-scale behavioral events. The tendency to search for fine slices of time translates into the common assumption that ideal archaeological sites are those that preserve intact records of contemporary behavioral patterns—patterns that operate within an ethnographic or human time scale that is directly relatable to the archaeologist observer. In other words, archaeologists today still search for sites that resemble "Pompeii", where the locations of objects remain preserved exactly as they were during the last occupation. In terms of the process of site formation shown above in Fig. 6, this would be a site that preserves only a few, or ideally just one, iteration of manufacture, use, reuse, and discard of objects (e.g. as claimed for Nahal Mahanayeem in Israel, Sharon and Oron 2014 or Abric Romaní, e.g. Vaquero and Pasto 2001). Excavation strategies

such as *décapage* or other "ethnographic excavation" techniques centered on uncovering settlement floors in situ, are intended to help demonstrate the contemporaneity of artifacts (Audouze and Leroi-Gourhan 1981). Similar attempts include use of hearths to "anchor" floors as discrete behavioral episodes (Henry 2012) and again illustrate archaeologists' interest in identifying synchronic spatial organization of past activities. Sites that are thought to demonstrate contemporaneity are to be preferred because it is in these sites that the manufacture of certain artifact forms and their use are seen to be most clearly delineated both spatially and temporally. However, as discussed earlier, demonstrating the contemporaneity of a group of objects is extremely difficult and oftentimes problematic.

The history of archaeology is replete with examples of efforts to locate such sites. The Mesolithic site of Star Carr (Clark 1954, 1972) represents one of the earliest attempts to isolate a so-called living floor or occupation surface, but in the latter part of the twentieth century the practice became much more common. Among well-known examples are Upper Paleolithic and Mesolithic sites such as Etiolles (Olive and Pigeot 2006; Pigeot 1987), Pincevent (Leroi-Gourhan and Brezillon 1966), Gönnersdorf (Bosinski 1979), and Meer (Cahen et al. 1979). Claims of living floors are fairly common even in the Middle Paleolithic and Middle Stone Age, for example, Biache- Saint-Vaast (Tuffreau and Sommé 1988), Cagny-l'Epinette (Tuffreau et al. 1995; cf Dibble et al. 1997), Hortus (de Lumley et al. 1972), Ripiceni-Izvor (Paunescu 1965), Sibudu (Goldberg et al. 2009; Sievers and Muasya 2011), and Abric Romaní (Vallverdú et al. 2005, 2010, 2012). For the Lower Paleolithic, occurrences of claimed contemporaneity include Bilzingsleben (Mania and Weber 1986), Boxgrove (Bergman and Roberts 1988), Torralba (Freeman and Butzer 1966; Howell 1989), Terra Amata (de Lumley 1966, 1969), Latamne (Clark 1967, 1968), 'Ubeidiya (Bar-Yosef et al. 1993; Stekelis 1966), Koobi Fora (Bunn et al. 1980; Kroll and Isaac 1984), and Olduvai (Leakey 1971). In the New World, examples include Ushki Lake (Goebel et al. 2003) and the Sheaman Site (Frison and Stanford 1982). One of the goals of finding such sites is the potential to do a kind of paleo-ethnography (Leroi-Gourhan and Brezillon 1972). That is, to reconstruct the use of space by identifying discrete but contemporary activity areas used by a single group of people.

As studies show, however, even the eruption that engulfed Pompeii is not so easily seen as an instantaneous event (Murray 1999). What is reflected in the record of Pompeii is the outcome of human activities in response to events through time that unfolded up until some unfortunate individuals were killed by the eruption. In this sense, the archaeological record at Pompeii does not represent the activities at one catastrophic instant in time but rather the record created up until that moment (Lucas 2012: 13 also emphasizes the point that contexts remain dynamic). Furthermore, the archaeological record continued to accumulate and change at Pompeii after the eruption, as evidenced by the addition of graffiti among other things. The notion that the archaeological record continues to be impacted after the deposition of material remains was a point made by Schiffer (1972), but as Patrik (1985: 52) remarked, Schiffer's approach did not distinguish "between what distorts the record and what is recorded by the record."

Putting this particular debate aside, and thanks to a much greater appreciation of site formation process, archaeologists today have a sounder grasp of the various processes that underlie the accumulation of artifacts as well as their repositioning

within or between places. It is also clear that these same processes can create pseudo artifacts and aggregations of archaeological materials that mimic those that resulted from human activity. Between pristine living floors and completely mixed, derived, or altered deposits are those that are somewhat disturbed but which maintain a basic level of integrity. That this is by far the most typical pattern for Lower and Middle Paleolithic sites has been recognized for some time (Bordes et al. 1972: 15–18). There is also variability in the nature of disturbances and their impact on different aspects of the archaeological materials. The spatial arrangement of lithic artifacts may be affected by water action. The faunal assemblage may be subjected to the action of scavengers. The smaller lithic component may be removed by fluvial activity, leaving only the larger stone artifacts. In some cases, entire "sites" may be created simply by streams depositing their loads at bends in a drainage system (so - called "downstream sites") or by materials washing into a cave (Chase et al. 2009; Schick 1986; for a recent review concerning the deposition of hominin remains, see Huffman et al. 2010). Again, the fact is that natural taphonomic mechanisms likely played a role, to varying degrees, in the creation of virtually all prehistoric assemblages. In this sense, these processes perhaps should be conceptualized not as disturbances or distortions but rather as being fundamental parts of the formation of the archaeological record as it is observed today. We should, therefore, not be concerned with whether or not a particular site was disturbed, but rather we should focus on the degree and effects of these taphonomic mechanisms on particular classes of materials and how they shape the assemblage pattern (e.g. Davies et al. 2015; Dibble 1995c).

By now, many of the claims for the presence of living floors, such as those cited earlier, have been challenged with the reference to a large number of factors that potentially play significant roles in the formation of an archaeological assemblage. These factors include geological aspects of the surrounding matrix (aeolian, alluvial, or slope) and post-depositional processes that may have later affected them, primarily through mass movement and erosion (e.g. Bertran et al. 2012; Dibble et al. 1997; Schick 1992; Waters 1992). Other processes include bone accumulation by carnivores, bone weathering to indicate that occupation may have been extended or repetitious (Behrensmeyer 1978), natural explanations of what appear to be artificial patterns, and lack of demonstration that all material on a surface belongs to the same occupation (for example, see Aldeias et al. 2012; Binford 1981a, 1978a, b; Boeuf 1976; Bordes 1980, de la Torre and Benito-Calvo 2013; Klein 1987; Kluskens 1995; McPherron 2005; Potts 1986; Shipman 1986; Todd 1987; Villa 1983).

Thus, there are a number of processes, both natural and anthropogenic, that detract from the notion that—except in extraordinary circumstances—objects within our defined archaeological assemblages meet the assumptions of contemporaneity (i.e. the objects that are recovered were part of a single or even limited set of behavioral contexts) and integrity (i.e. the objects we find in an archaeological assemblage reflect and represent the totality of behaviors that took place).

Discussion and Conclusions

Our goal in this paper is to present and discuss what we consider to be two critical fallacies in how the analysis of stone artifacts is used by archaeologists to develop

interpretations of past human behavior. These fallacies affect our inferences at the scale of individual artifacts all the way up to complete lithic assemblages.

The first of these fallacies is the notion that lithic artifacts found in the archaeological record represent the intentions of ancient people to create specific objects (i.e. desired end products). When we use this term, we mean that they are objects that were first conceived of by a knapper before the knapping process begins and that s/he takes the necessary steps and employs the necessary materials and techniques to produce that particular product. This concept of intentionality is an underlying component in much of prehistoric archaeology today. The concept that the form of archaeological materials is directly reflective of the needs or desires of individuals in the past is fundamental to many approaches apparent in the archaeological literature. Even when archaeologists accept that emic realities are an unattainable goal of studying stone artefacts (e.g. Bar- Yosef and Van Peer 2009; Tostevin 2011, 2012), the premise of most analytical approaches from typology to chaîne opératoire, and from experimental replication to evolutionary models of artifact phylogenies, all assume that artifact form reflects a large degree of intention.

Of course, there is little doubt that some lithic objects were purposefully manufactured to have characteristics, both in terms of design and functionality, that are still identifiable post-excavation. Our point, however, is that it is highly unlikely that the overwhelming bulk of lithics should be viewed in these terms. Even when it is relatively clear that an object was deliberately modified to have certain characteristics, say in the case of a bifacially flaked and fluted projectile point, the final shape of the tool at the time of its last discard may have changed considerably over its use-life due to processes such as resharpening. This is truer for stone artifacts than it is for many other materials, primarily because of the durability of lithic tools. This fact alone leads to the increased potential for stone objects to be discarded and then picked up at a later time and further modified, and the process of discard/selection can be repeated many times. This is, in fact, what we see in ethnographic studies of stone tool producers and users, and as noted above, it is also demonstrable archaeologically by objects that exhibit double patina or in examples where objects produced by preceding industries are collected, remodified, and used many millennia later (McDonald 1991).

Even if certain objects represent preconceived forms and deliberate manufacture, we still must contend with the reality that an emic understanding of this conception is likely archaeologically invisible. Just because a lithic object resembles a contemporary tool (e.g. Coon's (1951) types such as "screwdrivers" from the Zagros Mousterian site of Bisitun), and even if they can be shown to be effective at certain tasks (e.g. Oldowan bola stones [Harrison 1947; Leakey 1948], or the use of Acheulian bifaces as thrown discuses [O'Brien 1981; Whittaker and McCall 2001]), such arguments are not sufficient in themselves to demonstrate that they were purposefully made to carry out those tasks. Even when use can be inferred through wear or residue analyses, the evidence on most artifacts betrays complex use-lives that invalidate simple associations between manufacture and utilization (van Gijn 2014).

Simply put, what is possible, especially when viewed from our twenty-first century perspective, does not necessarily, and probably only very rarely, translate to what is probable for the use of these items in the past. At the same time, while replicative experiments can suggest hypotheses as to how a particular object could have been made, such experiments logically begin with an assumption that the object to be replicated

was, in fact, an example of the kind of end product deliberately made in the past. As we have discussed, it is not sufficient to say that retouched pieces are "tools" (i.e. manufactured for a task) and that unretouched pieces are debris (i.e. the by-product of the manufacture of tools). And given the multitude of demonstrations that lithic objects can undergo repeated modifications through re-use, resharpening, and recycling, arbitrarily deciding that one kind of object is "what they wanted" and another as being essentially past its use-life and thus "what they discarded" is undoubtedly fraught with uncertainty. The fact is, almost all stone artifacts are subject to iterative cycles of selection, use, reuse, and transport and all of this can take place over very long periods of time—in fact, over geological time in many cases.

This same perspective carries over to lithic assemblages. The fallacy that we highlighted here is that these are simple accumulations of objects manufactured and/ or transported into a specific locale, where they were used and discarded. Again, this kind of behavior undoubtedly did occur, and perhaps some assemblages, including examples of discrete knapping events (e.g. Chiotti et al. 2007; Close 2000; Lindly et al. 2000) do reflect more or less discrete moments in time. However, most assemblages are defined in terms of geological strata, and therefore represent accumulations over geological time. They are not simple accumulations, and in some cases, the objects in those contexts were subject to processes that are more reflective of geological timescales (measured in thousands of years) rather than human ones (measured in decades). These processes include the same cycles of selection–modification–use– discard that operate on the level of individual artifacts, but they also can be significantly altered by anthropogenic processes, such as transport, as well as natural formation processes. Thus, it is unreasonable to assume that the objects recovered from a distinct context were made and used at the same time and in that particular context. Likewise, we rarely will encounter a "pristine" assemblage—it is much more likely that they will contain some objects made and used at one place, but at the same time they will be missing objects that were removed and include a number of objects that were brought in. And no matter how finely we excavate, it is very difficult to establish any meaningful degree of contemporaneity among the objects. The archaeological record is not a series of static events or isolated locations, but rather it is dynamic across both time and space.

Finally, an underlying theme of this discussion is that in current lithic studies there is too much emphasis on processes of manufacture, and not enough focus on processes of selection. To clarify, while there is a wealth of discussions for the selection criteria of artifacts as portable tool-kits, much of these discussions are couched within a manufacture-focused framework—that is, how to produce artifacts that possess these selected properties. It is undeniable that every lithic object was "made" at some time, so it is understandable that manufacture may play an essential role in creating the archaeological record. But it is highly unlikely, in fact it would be incredulous, to think that every time someone in the past needed a stone object to carry out some task, they started by collecting a particular kind of nodule, prepared it, removed a flake blank with desired characteristics, and then fashioned it into the exact tool that is found in the archaeological record. It would, after all, be simpler, more economical, and much more efficient simply to select appropriate pieces from those that had already been manufactured and discarded, and perhaps modifying them as needed. Thus, selection, as a behavioral process, is extremely important in contributing to the archaeological

record. The simple fact is that lithics can be selected and reused several times and previously discarded lithics essentially form a natural resource at both the site and landscape scale. At the same time, it is undeniable that other factors, especially natural processes that can remove or add materials to an archaeological site, also play a role. In many cases the extent of this is undervalued. Again, selection and taphonomy are processes that can and do operate on a geological timescale, and thus are more in accord with the time dimension that is a fundamental aspect of the archaeological record.

Lithic assemblages form part of the archaeological record, but formulating ways in which to interpret the prehistoric behaviors and patterns that they partially reflect requires due consideration of the dimensions of time and space vis-à-vis those lithic assemblages. These dimensions allow recognition of patterning over long periods of time and across the landscape; they represent not individual actions but the actions of many.

Moreover, the types of research questions that can be successfully pursued need to be asked within the framework of a time scale that is appropriate to the question. Given the inevitable loss of resolution over time, it may not be possible to address some types of research questions because the time scale needed is not available. The assumptions on which analyses of stone artifacts are based need to incorporate a better understanding of the scales of time represented by the archaeological record investigated. For stone artifact analysis, this means adopting more sophisticated models than those that rely on the linear process of artifact manufacture depicted in Fig. 4, and for assemblages, it means abandoning the notion that they reflect simply an accumulation of objects as shown in Fig. 6.

It is likely that some will read this article and conclude only that we are intent on trying to demolish much of the current practice in our field. It may also be that others will contend that we have said nothing new. Yes, we have tried to bring together as much evidence as possible to show that many of our most fundamental assumptions regarding lithic objects and assemblages are incorrect. Despite earlier critiques of many of these assumptions, we contend that they remain very important, perhaps subconsciously, to research design in Stone Age archaeology. Therefore, our goal has been to show that it is time to rethink those assumptions and to begin focusing on building perspectives and models that more realistically reflect what we have learned about the nature of lithics and how they came to be deposited. This is fundamentally important if we want to be able to develop research questions that can be addressed with the data we have available to us. This is a process that has happened in the history of scientific disciplines, from clarifying the nature of the paleontological record (Gould and Eldredge 1993) to an appreciation of gravitational lensing of light (Einstein 1936; Walsh et al. 1979). Although it will not be an easy or straight-forward process, the time has come for lithic archaeologists to do the same.

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