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Surface Stone Artifact Scatters, Settlement Patterns, and New Methods for Stone Artifact Analysis

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Abstract

Movement and mobility are key properties in understanding what makes us human and so have been foci for archeological studies. Stone artifacts survive in many contexts, providing the potential for understanding landscape use in the past through studies of mobility and settlement pattern. We review the inferential basis for these studies based on archeological practice and anthropological understanding of hunter-gatherer bands. Rather than structured relationships among band size, composition, and mobility, anthropological studies suggest variability in how hunter-gatherer groups were organized. We consider how stone artifact studies may be used to investigate this variability by outlining a geometric approach to stone artifact analysis based on the Cortex Ratio. An archeological case study from Holocene semi-arid Australia allows consideration of the potential of this approach for understanding past landscape use from stone artifact assemblage composition more generally.

Keywords Lithics · Cortex Ratio · Landscape · Settlement pattern

Stone artifacts survive in contexts where other material forms may not, leading to a spatially abundant stone artifact record in many parts of the world dating from the earliest periods of hominin ancestry through to the recent Holocene. It is tempting, therefore, to relate distributions of stone artifacts across landscapes to the way people in the past used space. Movement and mobility are key properties in understanding what makes us human (Kuhn et al. 2016) and have long provided topics of study for archeologists (e.g., Binford 1979; Kelly 1983; Bamforth 1986; Geneste 1989; Kuhn 1995). The distribution of stone artifacts with different forms associated together, in

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differing densities, and in varied locations provides the bases for inferring mobility and from these settlement patterns. When combined with paleoenvironmental details including resource availability and topography, they provide key data for the creation of models of hominin behavior (e.g., Kuhn 1995; Blumenshine & Peters 1998). However, before thinking about the particular forms of mobility or settlement pattern that existed in the past, it is important to develop theoretical understandings of both the way hunter-gatherers organized themselves and the formation of the archeological material culture patterns that derived from this organization. Here, we consider both sides of this theoretical division. First, we consider how hunter-gatherer settlement pattern studies developed since the late twentieth century particularly in relation to understanding how groups of hunter-gatherers moved as inferred from settlement pattern studies. We contrast this with the way cultural anthropologists consider band membership and mobility. Second, we consider how archeologists have sought material culture correlates for hunter-gatherer band mobility highlighting the issues that structured models of this mobility raise when used to explain seemingly incomplete groupings of stone artifacts found in archeological deposits. Third, we consider geometric approaches to stone artifact analysis where patterns related to mobility considered at a landscape scale emerge through varied activities occurring across space and through time, yet are not reducible to the cumulative outcome of any particular set of activities as structured settlement pattern models require. We consider the implications of emergent pattern for constructing alternative approaches to studying stone artifacts.

The case studies on which we draw derive from Holocene arid and semi-arid landscapes where sedimentation rates are low and where rates of erosion may be relatively high, but where the mechanical robustness of stone artifacts means that they are frequently both preserved and visible. While later in time than Paleolithic studies, these case studies provide comparative data sets with which to assess stone artifact assemblages from earlier times. In environments where exposing forces act over large areas, archeologists have the opportunity to see the accumulated record of stone artifact use and consider how this might appear in places where visibility is otherwise restricted by sediment accumulation and vegetation (Davies and Holdaway 2018a, b). Exposures of this form allow analyses that an earlier generation of archeologists termed off-site (Foley 1981), siteless (Dunnell & Dancey 1983), distributional (Ebert 1992), or landscape (Isaac 1981) archaeology. More recent analyses consider the geomorphic contexts of these artifacts as a means from which to determine the formation of surface deposits (e.g., in Australia, Foley et al. 2017; Holdaway & Fanning 2014; Stern 2015).

Thought of in behavioral terms, the accumulation of different kinds and numbers of artifacts may show landscape use by groups of people in the past. However, the surface archeological record is a palimpsest, mixing materials from multiple activities and occupations. It is not usually a “true” palimpsest, to use Bailey’s (2007) definition, where previous depositional events are erased and overprinted but exist somewhere between this extreme and Lucas’ (2012) “true” stratigraphy, where discarded materials are buried immediately, preserving their precise order of deposition (see also Stern 2015). Given this, and its visibility, the surface record provides opportunities to investigate the outcomes from processes that took time to unfold (Isaac 1972; Binford 1981; Foley 1981; Bailey 2007; Davies and Holdaway 2018b); time that, in many cases, will well exceed the duration of occupation of places by singularly definable groups (Stern 1994).

Following the theme of the UISPP session "Old Stones, New Eyes? Charting future directions in lithic analysis," we use insights gained by studying surface stone artifact assemblages from mid to late Holocene contexts in semi-arid New South Wales, Australia, to rethink how stone artifacts enable investigation of mobility and landscape use. Studying extensive surface exposures of stone artifacts distributed across multiple surfaces leads to a consideration of how local stone artifact assemblage interpretation informs on past settlement patterns. Here, we consider the inferential basis for settlement pattern reconstructions looking at the influence of both archeological practice and anthropological studies. We outline a geometric approach to stone artifact analysis that allows consideration of emergent patterning in stone artifact assemblage composition before considering the potential of this approach for understanding past landscape use.

Settlement Pattern Studies and Hunter-gatherers

Archeology since the late twentieth century has seen an increase in the application of settlement pattern approaches, where sites reflect places where people lived, and artifacts manifest their cultural and sometimes biological identities. Studies' intent on learning about aspects of the lifeways of past peoples since the mid-twentieth century (Clark 1954; Leroi-Gourhan & Brézillon 1966, 1972) as reviewed by Malinsky-Buller et al. (2011) emphasizes the importance of single activities: hearth-making, artifact refits, and the intended manufacture of things. These different activities produce artifacts with a spatial and therefore functional coherence representing the structured behavior of groups who ranged across landscapes. The intra-site structure seen in the organization of artifacts surrounding hearths, specialist activity areas, and refuse dumps links in turn to the presence of specialized site types at a wider spatial scale (e.g., Henry 2012). If artifacts are spatially associated together, they must have functioned together and therefore their interpretation involves behaviors that allowed past peoples to interact successfully with their local environment. Following this line of reasoning, the assumed spatial and temporal structural coherence become the literal material manifestation of an adaptation by a social group.

The basis for settlement pattern studies often involves the search for a set of isolatable resources to which people responded through movement (Kelly 1995). People occupied specific places and moved resources to the locations where they lived to a greater or lesser degree, based on the distribution and reliability of these resources, falling between the extremes of Binford's (1983) model of collectors and foragers (Sauvet 2017; cf. Turq et al. 2013). Things, mostly food resources but not exclusively so, found in specific locations were transported back to occupation sites in a form of vector-like movements between nodes of occupation and activity. Settlement patterns therefore depend on the identification of at least two site types: basecamps and extraction sites.

In the simplicity of this description, two issues arise, one distributional and the other anthropological. The distributional issue concerns the need to explain the background scatter of stone artifacts that exists between the sites or nodes of a settlement pattern. In places with visible surface records where such background scatters are apparent, including our case study below from semi-arid Australia, their attribution to either a scatter or a patch (to use Isaac's 1981 terminology) is frequently problematic. Depending on their definition, scatters dispersed among the vectors of a logistical settlement pattern can be numerous and compositionally similar to the node-like patches of occupation that the vectors are thought to link (Foley 1981; Ebert 1992). Boundaries between patches and the scatters are nearly always arbitrary leading to the application of techniques to study artifact distributions (e.g., Wandsnider 1996; Banning 2002). Unsurprisingly, when such criteria are applied, the composition of the patches versus the scatters fails to be discrete and artifact scatters attract a lesser status (e.g., papers in Rieth 2008; Bryant 2013; Dortch and Sapienza 2016). If the archeological record really relates to isolatable locations where people lived, why does this record not manifest itself more clearly in spatially discrete packages separable from the background scatters? In other words, why are arbitrary standards for site definition needed?

The anthropological issue relates to the long-standing debate in cultural anthropology concerning the definition of the hunter-gatherer band. In an earlier generation of studies of hunter-gatherer peoples, material aspects of land relationships were the focus, with emphasis placed on bands, their foraging patterns, and their territory (Kelly 1995). This began to change with the "Man the Hunter" conference that showed how hunter-gatherers did not always live in closed territories, replacing this notion with the idea that land was openly accessible (Jordan 2008). In Australia, for example, scholars like Radcliffe-Brown initially proposed that descent-based categories like tribes and clans were composed of people who occupied defined land areas, identifiable as their territories (Radcliffe-Brown's horde). However, ethnographic work notably by Thomson indicated that membership of hordes involved men from multiple clans (Peterson 2006). Peterson (1976) later argued that Radcliffe-Brown's combination conflated populations and language groups when in fact these were not equivalent. Anthropological treatments of Aboriginal social organization subsequently became concerned with the relationship between land ownership and land use, and the relationship between groups which exist on the ground and groups which exist in the head (Morphy 1999); in other words, actual group membership versus the explanations that people articulated for group membership. By the 1970s, there was little support for the band as a self-sufficient, patrilineal, patrilocal, landowning group resident uniquely in one region. Exogamy precluded the existence of bands without the presence of people belonging to different clans who were available as marriage partners and therefore some exchange of individuals between bands was essential. Band composition was thus by definition somewhat fluid. There was also an environmental necessity for shifting band composition based on the uneven distribution of resources within the landscape, necessitating the ability to vary band size depending on conditions, a pattern recognized among hunter-gatherers more generally (Kelly 1995, 203). With some resources localized and others available only seasonally, variation in band size allowed a match of group size and resource availability. Summarizing this shift in understanding, Peterson and Long (1986) proposed a scheme for what they termed territorial organization, incorporating four different ways of thinking about social organization, land access, and therefore band composition.

- The band—the land-using group of people
- The clan or estate group—landholding group of people
- The estate—an area held by a clan or estate group
- The range—the area used by a band

Morphy (1999) described the Aboriginal regional organization as manifest in the system of names Aboriginal people used for groups constructed in different ways. He described names applied to groups based on patrilineal descent, others where mothers, or mothers' mothers, belong to a particular group, and still others that grouped together people linked by ceremonial ties with groups that came together at a certain time of year to utilize a particular resource. Other types of groups formed at specific times to defend themselves against outsiders. Different divisions of the same population of Aboriginal people into a number of entities might occur with varying relationships to land (Sutton 1995, 42). These included small landholding units based on unilineal descent, groups based on local totemic or ritual connections, language groups, named sets of distinct languages, peoples in an environmentally similar country, and people grouped together because they traveled from the same direction. The different bases upon which these groups formed allowed for, at times, overlapping relationships between people and the land. However, group membership was not arbitrary or determined by individual negotiation because despite the apparent variability in the bases for group formation, there were still patterns in the structures of group membership (Morphy 1999). Anthropological studies thus demonstrated the need to consider the complexity and variability in the range of land tenure and territoriality that hunter-gatherer groups practiced leading to the abandonment of models where regional patterns in hunter-gatherer settlement pattern related to band membership (Jordan 2008).

These anthropological explanations for variation in band composition and relationships to land bring to a head questions regarding the relationship between group organization and the material manifestation of residence, and therefore mobility particularly in its archeological expression (Zvelebil 2003). Following the variable conceptualizations of group organization discussed above, the material expression of the moment, for example, the archeological living floor, may vary since the structure and identity of a group who occupied a particular location will itself vary dependent on the particular context. That is, how a group might be composed at one point in time might be different from the composition of that group at a different point in time. Not only must band composition vary to maintain clan exogamy but also the manifestation of action in the deposited material record will likely change depending on the ideas used as the basis for group formation and in response to resource availability (Wengrow & Graeber 2015). This is not to suggest that band composition was stochastic. Ethnographic accounts indicate people's attachments to the lands in which they lived and as noted above, group membership was not open to individual negotiation. But it does emphasize that group composition varied for a wide range of reasons. Given the potential for multiple levels of group organization created for such reasons, what group structure might the archeological record manifest? How can archeologists' model movement among occupational nodes if the people doing the movement vary in the way they come together? Archeological sites might reflect sets of occupations with these orientated in a variety of ways, the immediate function of which reflecting complex historical contingencies. The outcome of anthropological studies of hunter-gatherers led to a reassessment of the basic assumptions for hunting and gathering as a distinct form of society (Zvelebil 2003; Jordan 2008; Wengrow & Graeber 2015), seen most clearly in models that emphasize the lack of a clear distinction between foragers and food producers (e.g., Smith 2001).

Seasonality, Environment, and Band Structure

Of all the potential ways in which people might relate to the land which would leave a structured material record, the ecological explanation appears as the most likely and it is this that archeologists including Binford (1983) focused upon (Tyron et al. 2014). Archeologists have used ethnoarchaeological observations to help understand variability in archeological phenomena from the artifact ranging on up in scale to the site and on to the landscape. Summarizing these studies, Lane (2014) lists studies of butchery practices and carcass disposal (e.g., Gifford-Gonzalez 1989), discard around hearths (e.g., Binford 1983), differences between basecamps and special activity sites (e.g., Binford 1980), the season of site occupation (e.g., O'Connell 1987), and the degrees of mobility as key research areas (e.g., Binford 1979; Kelly 1983; Bamforth 1986). Group organization and therefore residence form vary in relation to resource availability, and resources vary seasonally. For example, in Australia, Allen (1971) understood the need to incorporate variation in band composition with groups seen to travel out from the Darling River into areas that were "seasonally" resource rich. Here, seasonality related not so much to an annual seasonal cycle but to the availability of moisture linked in turn to longer environmental cycles like those driven by the El Niño-Southern Oscillation (Holdaway et al. 2013). His vision of a settlement pattern based on seasonality was very influential in Australian archeological studies and continued to form the reference point for a body of subsequent work; however, in the work after Allen's study, the implications of anthropological consideration of band structure is apparent.

Anthropological recognition of variation in hunter-gatherer group composition and its relationship to landholding has not always translated well beyond the bounds of the discipline. In 1998, for example, the Australian Government released the controversial Reeves Report, which was intended to reconcile Aboriginal traditional land ownership with federal and state administration of economic activity. Based on selective accounts from older anthropological research, its recommendations included the amalgamation of Local Aboriginal Land Councils into regional bodies, effectively requiring Aboriginal people to collocate as though all of their ideas and activities related to one geographical area. Anthropologists were quick to point out how the legislative report reflected an out of date understanding that misunderstood the separation of different aspects of land utilization by Aboriginal people in different parts of the continent (e.g., papers in Altman et al. 1999).

Archeologists have emphasized the size of the landscape over which some Aboriginal groups would range, particularly in regions with low and variable rainfall (Allen 1971; Veth 1995; Holdaway et al. 2013). In these places, the notion of a single landholding group with economic and ideological ties to a particular parcel of permanently occupied land had little ethnographic or archeological reality. Veth (2003, 3), commenting on an Australian High Court decision regarding the demonstration of connection to country in Native Title cases, states unequivocally that "[a]ny test for connection that requires physical occupation at the local level... essentially misunderstands the structure of land use for Aboriginal Australia." This is because even though the local environment might induce absences of a group for periods of a decade or more, it does not necessarily remove their connection to it in the long term, a notion with significant ramifications for the identification of discrete groups through the material record and their association with particular places.

Material Culture Correlations to Settlement Patterns

Whereas anthropological reactions to the Reeves Report and other indigenous land rights legislation have emphasized processes leading to variability in relation to land tenure and land occupancy, interest in using ethnographic analogies in archeology to inform on structured relationships from intra-site artifact distributions through site types to settlement patterns has oftentimes retained an adherence to a more rigid structure. Material culture concentrations in sites enable functional associations with a dichotomy in site definition between specific extractive activities and more general occupation in the form of base camps.

Despite the variation in group composition and land use known from anthropological studies of near contemporary hunter-gatherers, archeological manifestations of settlement are frequently defined using documented cases of structured group behavior applied cross-culturally. For example, Yellen's (1977, 85–125) ring model and the Drop-Toss Model developed by Binford (1978, 1983) relate the distribution of portable material culture remains to the presence of intra-site structure. This structure, or at times its lack, in turn relates to the identification of basecamps or special purpose sites (Henry 2012). Using Binford's (1983) forager and collector modes, functional site types link settlement pattern to mobility. Torrence (1983, 2001) for example, linked technology to mobility through the concept of risk, while Bleed (1986), using Binford's modes, suggested that foragers used generalized but maintainable tool-kits, while collectors used specialized but reliable tools (Lane 2014). These studies led to others that sought to interpret material culture through a structured set of relationships that linked artifact presence and proportions to mobility, settlement patterns, and resource procurement (e.g., Wallace & Shea 2006; Henry et al. 2017).

In one influential Australian settlement pattern example, grinding stones become markers of occupation permanence. An increase in the frequency of grinding stones in the late Holocene indicates an increase in sedentism and therefore increased population levels since more grinding stones indicate more sites and therefore more occupation (Smith 2013, 202). However, the evidential relationship between grinding stones, occupation, and people is not a direct one but depends instead on a preconceived notion of the kinds of behaviors associated with sedentism. Grinding stones left at a site remain in place despite the absence of people who intended to reuse them upon their return (Cane 1989). In such cases, the permanence of the "site furniture" (Binford 1979) of which grinding stones form an example, should not be equated with the permanence of residence. Edwards (1989) makes this argument in his discussion of stone foundations for house structures in Epipaleolithic southwest Asia. In this example, the longevity of the material record does not correlate directly with the longevity of the behavior with which it was involved since the house foundations continued to exist well after people had abandoned the site. Edwards contrasts the long-term temporality of the house foundations with the short-term temporality implied by the large numbers of portable artifacts abandoned in and around the house foundations as trash. As this example shows, one cannot use the permanency of materials in a direct way to describe the permanency of occupation. If it is mobility that is of interest including its lack, then material items that have the greatest potential to move need to be studied in order to provide tests of conceptual models of movement. In this sense, grinding stones are of little use for studying mobility if indeed they formed site furniture, left in place when people moved elsewhere (Davies 2016, 131).

The difficulties associating grinding stones and other components of archeological assemblages within an ethnographically defined timeframe are partly due to time averaging, a concept borrowed by archeologists from paleontology (Bailey 1983; Stern 1993). In many instances, the periods represented by geological deposits will greatly exceed the periods during which fossil species existed. Unless understood, this mismatch may lead to incorrect assumptions about the evolution and extinction of species if these species are incorrectly associated only with the temporality of geological deposits. If material culture items are produced and used at different rates, and if the people responsible for their creation use them in different places, then sets of artifacts may accumulate together in different ways and with different temporalities. Like the geological example of time averaging, the temporality of deposit creation will often mean that things found together were never used together (Dibble et al. 2017). At issue therefore is how to interpret patterns that become apparent within both time and space that result from the accumulation of potentially unrelated activities.

Following a conventional settlement pattern approach, categories of function expressed as site types explain groups of artifacts found together. However, site type designations often involve the quantification of the frequency of artifact types, based on the assumption that artifacts accumulated in the record with the same temporality. For example, the flakes and cores found together with a grinding stone acted in concert and entered the record together at the termination of their use. If, however, grinding stones are site furniture then by definition they have longevity different to some other forms of material culture, most obviously flakes and cores manufactured quickly and moved easily. In many instances, a single archeological deposit effectively sums together items that may in fact have very different artifact life histories. Artifact proportions therefore require a different form of behavioral interpretation compared with “moment in time” functional explanations like those that link intra-site distributional patterns to different site types (Isaac 1972).

The patterns in stone artifact assemblages emerge as time passes in much the same way that the anthropological regularities in hunter-gatherer land use emerge. These kinds of patterns may be generated by individual instances of activity but are connected by relationships that may or may not be linear, or may be connected to elements that do not bear directly on the formation of individual signatures but influence other components of the larger pattern (Kohler 2012). The resultant phenomena exhibit qualities that are not captured by a study of the proximal causal mechanics alone (e.g., flake manufacture or grindstone use) but are only discernable from spatiotemporal scales larger than those at which the individual entities within the system are interacting.

Stone artifacts survive, whereas artifacts made from organics, for example, bone and wood, do not. Durability leads to the cumulative retention of the outcomes of human manufacture on each artifact. This sometimes results in an emphasis on manufacture and the intention involved in the way a block of stone was worked to produce end-products (e.g., Faivre et al. 2017; Turq et al. 2013 provide numerous additional examples). Intention is assumed to correlate with the intensity of manufacture seen for example in the much-discussed dichotomy between expedient, and therefore less intended, and over designed, and therefore more intended, tools (Bleed 1986). Like the reliance on defining structured settlement patterns, the emphasis on intention through manufacture leads to the search for assemblages that closely match highly structured stone artifact manufacturing sequences.

As Turq et al. (2013) remark, assemblage completeness is an elusive thing. They suggest that a focus on end-products and intention leads to what they term the "complete reduction sequence fallacy" that is where the presence of the range of elements from a reduction sequence from cortical flakes to a core is interpreted as though the knapping sequence was carried out on the site. What they show instead, based on data collected in a series of studies from the 1980s onward, is that for Middle Paleolithic sites from Aquitaine, transport leads to the fragmentation of reduction sequences. Transport involved multiple elements including complete flakes, flake fragments, and chunks. In other words, many more elements than those thought to be the intended products were valued sufficiently for transport. In addition, they suggest that recycling of artifacts was probably much more common than acknowledged by archeologists also leading to reduction sequence fragmentation.

Putting these elements together, anthropological studies of hunter-gatherer settlement and land use suggest a varied constitution of people on the land through a time where regularities emerge only when spatial and therefore temporal scales are increased. Increasing attention to the distribution of artifacts, beyond the patches to include the scatters, suggests an alternative to sites as spatially and temporally distinct locations of occupation. The interplay between the life histories of different artifacts suggests that patterns in assemblages may emerge from time averaging. The "New Eyes" approaches called for must therefore engage with the ways in which sets of artifacts accumulate through time and across space. It is necessary to question epistemologies based on sequences flowing from the conception of an end-product, its manufacture, use and abandonment, and the outlay of such a structure across the landscape. Ethnography of hunter-gatherers shows that explaining pattern by expanding from such moments of behavior to wider spatial and therefore temporal scales is unlikely to succeed. The reactions to the Reeves Report in Australia indicate that the simple relationships among group composition, land use, and mobility may not exist. What is needed instead are techniques that seek to explain the patterns that emerge from the time-averaged archeological record, where the accumulative nature of materials that distorts the ability to distinguish individual events becomes an asset rather than a liability.

An Alternative Approach: Lithic Geometry and Its Contextualization in the Landscape

Settlement pattern approaches use sites as central nodes and in a sense work outwards from these nodes to determine the operation of a settlement system across the landscape. For example, people occupy sites as preferred locations and, following a logistic model, move materials from elsewhere in the landscape back to places of residence (e.g., Binford 1979; Kelly 1983; Lourdeau 2011, 183). The composition of artifact assemblages at nodes therefore reflects the activities centered on those locations. Thought of in this way, artifact assemblages may change in composition because the movement of items from one location provides for their use at another. These assemblages may be *depleted* because items are removed or they are *augmented* through the addition of artifacts from elsewhere. But depleted or augmented from what, exactly? Such concepts assume a pristine *moment in time* existence for an assemblage, modifiable by other, subsequent, human action and/or taphonomic process. Artifact manufacturing sequences may be incomplete because parts of the sequence are missing. *Foreign* items reflect new or different groups visiting the site disturbing the remains from previous occupations. Such disturbance may, for example, involve the scavenging of artifacts left because of previous activities.

Imagine, however, that the node or site is not the center of analysis. Assemblage-generating activities occur across the landscape with greater or lesser frequency, not only at specific locations, and with greater or lesser material consequences. If no one place is central, removal always leads to deposition at another location. The artifacts found at one location are a consequence of the operation of activities across the landscape, not the activities that occurred at that point in space. The material left at specific locations does not solely determine the activities that occurred there; rather, activities that occurred at places elsewhere determine artifacts left at the specific points identified by archeologists. Interest in manufacturing sequences does not involve determining intention through reconstructing a sequence of actions to obtain a desired product but involves understanding what is missing through the flow of lithics across the land. The fragmentation of the outcome of production, as Turq et al. (2013) term it, is of primary interest, not the complete reduction sequence visible at a single location. Groups with a single identity do not create patterned material records that persist, but a pattern emerges instead from the multiple forms of social interaction with the land that occurred over time through the actions of groups constituted in a number of ways.

From this perspective, a site is an observation of part of an emergent phenomenon in time, one that only takes its meaning in the wider context of the landscape. This approach shares conceptual similarities with physical field theories, wherein the strength of fields varies across space and time, and particles are an emergent product of the interactions of different fields and their strengths at any given point (Zee 2010; see also Barad 2007). Looking at the archeological record in this way has implications for interpretations of settlement pattern from scatters and patches of stone. Dyson (1953, 61), for example, in a discussion of fluid models of electric fields, argues that “it is meaningless to speak about the velocity of liquid at any one point… fluctuations in the neighborhood of the point become infinitely large as the neighborhood becomes smaller... The only quantities that have meaning are velocities averaged over regions of space and over intervals of time.” If the same logic was applied to the archeological record, intra-site assemblage and single artifact qualities recorded in isolation will vary, but that variance only takes meaning when values are taken together over time and space.

This alternative approach involves turning the conventional way of studying settlement pattern archeology through the analysis of portable artifacts inside out. Remains left behind at one place allow inferences about the activities occurring everywhere else, enabling testable hypotheses about the condition of the record in other places. Patches inform on the activities represented by the scatters. The attributes retained on stone artifacts continue to inform on what went on at earlier times in the artifact life history, but these allow inferences about a distributed landscape use through the process of fragmentation. From this perspective, reuse and recycling are behaviors no different in their potential significance from a manufacturing sequence beginning with an unworked block of stone taken from a wider realm of raw material.

The surface archeological record lacks sites in the sense of geographic or geomorphic forms that bound accumulations of artifacts as occurs for example in some rock shelter deposits. It is therefore a record easier to think about in different ways than many buried deposits. In the following, we outline a method applied to surface deposits in Australia using the Cortex Ratio, a geometric measure of artifact surface area as an indicator of artifact movement to help interpret spatially extensive artifact distributions. Because it involves a geometric measure, the method does not rely on artifact typologies, or on *chaîne opératoire* or attribute approaches to understand artifact reduction sequences. In this sense, it provides an alternative to the debates between Monnier and Missil (2014) and Faivre et al. (2017) about the importance of quantitative attribute analyses versus those based on observation and refitting.

The Cortex Ratio measures the proportional relationship between the cortical surface area observed on artifacts in an assemblage and the cortical surface area expected for that assemblage based on geometric solid models for the raw materials that produced them (Dibble et al. 2005; Douglass et al. 2008). Using an apple as an analogy, the peel of the apple is the cortical surface. No matter how the apple is sliced, a measure of the amount of peel on each piece gives the original surface area of the apple (Davies & Holdaway 2018b). Estimating the average dimensions of an apple provides an indication of the surface area of the peel that should be present from a single apple. A ratio of one occurs if the observed area is equal to the amount expected. However, the addition of apple slices with peel increases the ratio while removing slices with peel decreases it.

Moving back to lithics, the Cortex Ratio provides a proxy for mobility by indicating the movement of cortical material in or out of an assemblage given the difference from the amount of cortex expected. A number of studies describe the specific methods for calculating the Cortex Ratio (e.g., Dibble et al. 2005; Douglass et al. 2008; Lin et al. 2016; Phillipps & Holdaway 2016), while others have been used to assess the influence of raw material variability (e.g., Douglass and Holdaway 2011). While it is true that variability exists in the sizes of cobbles selected for flaking at different times and places in the past, in many cases estimates of this variability are possible (Lin et al. 2015). As Douglass and Holdaway (2011) show, the technique is relatively insensitive to raw material size differences. However, the interpretation of the values for the ratio depends on "various facets of occupation and mobility, such as the regularity and duration of (re)occupation or the frequency, velocity, and linearity of movement need to be assessed" (Lin et al. 2015, 102). In other words, values measured at the level of individual assemblages need to be contextualized within wider systems of movement and discard. If we imagine a movable observation window delineating an archeological assemblage, some lithic reduction products might enter the assemblage with others transported away. Increasing or decreasing the discard or manufacture events within the window plus the addition of objects from outside the window or removal of flaked objects from it creates the archeological artifact assemblages. Obviously, movement in this case refers to activities related to the transfer of artifacts to, from, and within the window of observation, and movement unrelated to lithics is not visible.

Evaluating variability introduced through the changes in mobility and activities undertaken beyond a window on the assemblage requires not only a means of observing how a set of processes might contribute to the formation of archeological patterning but also understanding how variation in relevant parameters (e.g., frequency and linearity of movement) influences the character of that patterning. As mentioned above, ethnoarchaeological studies are often a source of inspiration in settlement pattern studies, but these are constrained by the inability to observe how those systems operate under controlled variation (cf. Binford 2001). Experimental studies, on the other hand, let the researcher vary parameters (e.g., Dibble and Rezek 2009) but are limited to mainly mechanical processes operating in the short term. Both of these are useful means for contextualizing variability in archeological assemblages but are limited in the scope of phenomena they may be reasonably expected to represent.

Computer simulation provides another means to experimentation, particularly where systems of interest operate at spatiotemporal or organizational scales unobservable in a laboratory or in the field (Kohler 2000; Perry et al. 2016). In a simulation, variables that hold supposed, speculated, or otherwise unknown influence in the past may be incorporated as fully controllable components of an analogous modeled system. However, focus on particular cases rather than general processes has historically inhibited the usefulness of simulation for making inferences useful across archeological contexts (Costopoulos 2010). An alternative, exploratory approach to simulation enables the historical scientist to experiment with a range of conditions that may (or, perhaps more tellingly, may not) produce similar patterning to that observed or expected (Premo 2010). This aligns with a need to contextualize the archeological record within a range of historical potentials that account for variation in the arrangement of behavior across landscapes.

Davies et al. (2018) use an exploratory agent-based simulation to compare patterns in Cortex Ratios ranging between highly constrained and highly linear movements. The simulation generates artifacts through a process that controls the degree of reduction, and therefore removal of the cortex, as well as the proportion of artifacts selected for transport. Movements undertaken by an agent within a window of observation are modeled as linear displacements between discard events that are either more or less tortuous (Fig. 1), simulated using a Lévy walk (Brantingham 2006). At one end of this spectrum, movements between discard events might be as short and tortuous as to mimic no movement occurring at all; at the other end, they might carry on in a single direction forever. Like the "true" palimpsest and stratigraphy, neither of these extremes is particularly realistic, but they provide theoretical bookends for exploring different configurations of movement in between. The outcomes of individual simulation runs allow the researcher to see how Cortex Ratios emerge through different combinations of manufacturing, transport, and discard; in aggregate, these recombined outcomes show what might be expected from assemblages recorded by archeologists across an entire landscape.

Exploring the parameter space of the simulation shows that the nature of movement does not itself specify whether the value of the Cortex Ratio is above or below one, but rather controls the magnitude of variability around a mean value. Considering movements occurring between discards, low tortuosity (i.e., high linearity of movement) limits time spent in an observational window and therefore provides fewer opportunities for discard and/or manufacture. Flakes carried in or out with a low tortuosity of movement therefore have an outsized influence on local Cortex Ratio values. High tortuosity movements (i.e., low linearity), in contrast, reduces variability in Cortex Ratio values through more frequent local reduction and discard within the same observation window.

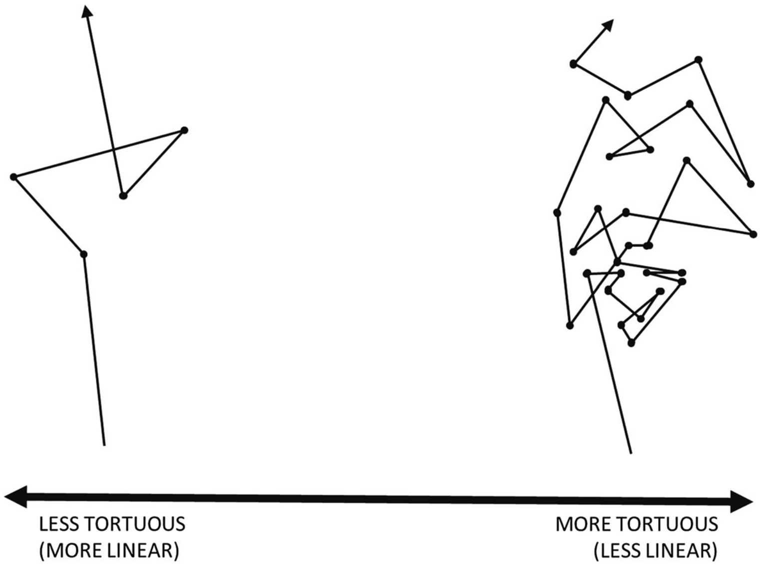

Fig. 1 Variation in the tortuosity of movement (lines) between discard events (dots)

Shifting the mean value of Cortex Ratios away from one requires repetitive addition or subtraction of artifacts, which means that individuals moving in or out of a window of observation must be consistently carrying artifacts with them. Localized depletion of the cortex, for example, requires that the amount of flaked material transported into an observational window be less than the amount of material taken away. This is harder to achieve if cortical flakes and/or cores arrive from outside the observation window in any frequency. On the other hand, if an individual arrives in the window of observation with few or no artifacts on hand, then it becomes more likely that they will leave with more artifacts than they came with, shifting the balance of material flow and therefore the Cortex Ratio. As stated above, that magnitude will be limited if there is substantial cycling (i.e., progressing from manufacture to discard) of lithic objects within the window of observation.

Archeological discussions of mobility focus on whether populations were residentially or logistically mobile thought of in simple terms as the frequency with which individuals return to basecamp (Kelly 1983, 1995). In their model Davies et al. (2018) imagine a residential basecamp as involving short, redundant moves where tortuosity is high, while more linear, less tortuous movements to and from an outlying periphery occur in order to transport resources back to the base (Fig. 2a). Moving toward the more residential end of the foraging spectrum involves less of a distinction between the base and peripheral areas with most areas used in similar ways movement-wise (Fig. 2b). Simulation results illustrate how Cortex Ratios vary spatially following different residential and logistical movement scenarios. Foraging with flake use concentrated within a single catchment produces assemblages with different Cortex Ratios, collectively distributed around a value of one with variability determined by the tortuosity of movements between discard events, itself a consequence of more base-like or periphery-like movement. If carry-in and carry-out behaviors were not significantly

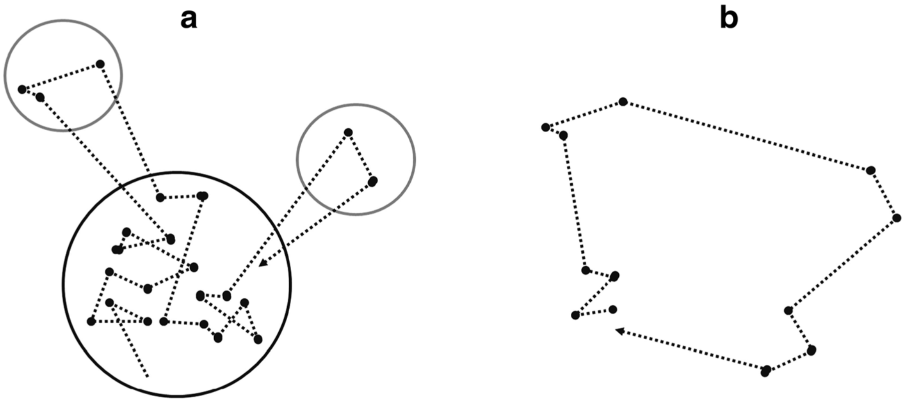

Fig. 2 Tortuosity of moves around (**a**) a basecamp involving short, redundant moves where tortuosity is high, with more linear, less tortuous movements to and from an outlying periphery transporting resources back to the base and tortuosity at the more residential end of the foraging spectrum (**b**) involving less of a distinction between the base and peripheral areas with most areas used in similar ways movement-wise

different between the base and periphery locations, the distributions of Cortex Ratios in both areas should still fall around one although less variably so at residential basecamps.

From this, it follows that differences in the transport and discard of stone between these places explain the distribution of Cortex Ratio values around one in a base versus a peripheral area. If lithic resources were located at a distance from the base and were transported in from the periphery, as in a quarrying scenario, the Cortex Ratios would fall below one in peripheral assemblages and above one in base assemblages. In contrast, if the manufacture of flakes occurred within the base areas for use in the periphery, then the periphery would have an inflated ratio and with lower values at the base. Finally, if there were no substantial differences in the redundancy of place use, but the amount of stone carried in versus carried out differed between places, then this would generate imbalances in Cortex Ratios as well; however, as long as redundancy in movement patterns between discards are similar across the landscape, variability should be more or less consistent between locations.

These scenarios, played out in a simulated world, suggest that the distribution of raw material in the landscape could strongly influence patterning in Cortex Ratios, since the availability of raw material influences whether stone can be carried out of a location and into another or vice versa. With stone spread evenly through the landscape, foragers will generate assemblage level Cortex Ratios distributed around a value of one. However, foragers carrying a stone from material rich places to places with reduced raw material availability will discard more imported material into local assemblages as artifacts become worn or broken. Over time, imported flaked objects will build up without comparable export of locally sourced material. Faced with a reduced lithic toolkit in a place with limited stone resources, return visits to a more readily accessible stone source would allow tool replenishment, producing a low carry-in/high carry-out situation. Any disparity between stone rich and stone poor areas is exaggerated as the difference in tortuosity of movement between them becomes greater. Moreover, in areas where abundant raw material and similarly abundant subsistence resources overlap, local cycling of manufacture and discard can outweigh the overall loss of material to areas with poor economic and raw material resources resulting in Cortex Ratios only marginally depressed at the base but inflated and highly variable at the periphery.

The expectations derived from the simulation allow comparisons with empirical studies. In the Australian case study from Rutherfords Creek discussed by Davies et al. (2018), a broad distribution of Cortex Ratios occurs around a mean value of 0.53 ± 0.22. This is consistent with simulations featuring an overall low tortuosity movement pattern with more cortical flakes leaving assemblages than added to them. This similarity is interesting, but not simply because it proves that this suite of behaviors occurred at Rutherfords Creek; instead, it is useful for making predictions about what the record might look like elsewhere. If the formation of the lithic record operated in a way that was similar to that in the simulation, the wide distribution around a relatively low average suggests that human activity was probably not centered on Rutherfords Creek, but that it may have been part of a wider residential round or peripheral to some other location. Furthermore, given that the creek area is rich in stone resources, the low average Cortex Ratio value suggests that other places may have been absorbing flaked material from Rutherfords Creek without equivalent exports. The record in these other places should show distinctive differences from that at Rutherfords Creek, but these differences might be expected to be most pronounced in places where raw material availability is more limited.

Discussion

The foregoing is not meant to claim that logical inferences about the ethnographic past are necessarily, or even probably, wrong. Groups of people of course made and used stone artifacts. They also used multiple places in the landscape for specific purposes. In many cases, they very likely followed some form of transhumant settlement pattern and transported resources between places. However, the archeological materials that we deal with are not literal recordings of these varied actions. They instead combine the incomplete residues from many of these events and others, the outcome of the actions of multiple individuals incorporated into the myriad forms of groups that the ethnographic record informs us hunter-gatherers created.

The challenge to develop a "New Eyes" approach is to avert the threat of "theory-induced blindness" (Kahneman 2011), where the fundamental assumptions that support our theories go unexamined. To do this, we must take seriously the implications of the "complete reduction sequence fallacy," whereby complete reduction sets are assumed to be the only ideal for interpretation. It is not that complete reduction sequences are always absent. Refitting studies indicate that sometimes blocks of stone were worked and then discarded at one place, possibly by one person, and maybe at one time (e.g., Stern 2015; Faivre et al. 2017). But their existence does not mean that such sequences can be generalized to explain the composition of all or even most artifact assemblages across space and time. If we think that landscape use through mobility will allow the construction of models that help explain human evolution then we need to analyze our most prolific proxy, stone artifacts, in ways that allow assessments of variations in artifact manufacture, transport, and discard related to this mobility.

Insisting on a highly structured understanding of assemblage composition, site types, group membership, and settlement pattern, one that does not exist in ethnographic studies of near contemporary hunter-gatherers and may never have existed in the past, can only serve to limit our vision of the past. Groups may not occupy places or territories continuously, nor are they necessarily composed of a uniform set of people, nor did they necessarily always undertake the same activities repeatedly at the same locations for the same reasons. As long as our definition of a group is imagined in such ways, reconstructing settlement patterns of a singular "group" in the past is unlikely to succeed in most cases. At a minimum, we should not be basing our settlement pattern models a priori on something that has a readily identifiable ethnographic counterexample.

We can learn about the manufacture of stone artifacts individually, but this may not tell us much about the composition of lithic assemblages. If we want to learn about mobility, we need to understand what was taken away not just what was left behind. We need to understand what drove variability in the composition of assemblages at particular locations, but also what drove variability in the patterns that emerge across a region. As the ethnographic example above illustrates, we cannot begin with the assumption that regional differences relate to different cultural groups in simple terms. In at least one part of the world, what constitutes a group is too fluid and situational to allow such an inference. Equally, as the simulation example shows, we need to assess how much of the variability in artifact assemblage composition is driven by broad landscape differences in raw material availability and resource distribution. This means analyzing assemblage comparisons across multiple areas, not only across regions and continents but also within landscapes. We need to understand the significance of the size of the observation windows that we are using, remembering always that what is missing is always as important to the histories of those places as is what is present. We need to be aware that the transportation of material in some cases effectively created sources of stone available for others to reuse (Douglass et al. 2015).

The Cortex Ratio is based on geometry; therefore, how artifacts were made is irrelevant when it is calculated; indeed, as the apple analogy shows, it need not even be concerned with stones at all. The technique uses cortex because cortex surface area together with other size measurements provides the data needed to calculate geometric properties of stone artifacts although other geometric measures use volume rather than the surface area (Ditchfield et al. 2014; Phillipps & Holdaway 2016). It might therefore be better named the geometric approach although the cortex ratio as a name has precedence in the literature (Dibble et al. 2005). Of significance here is that the cortex ratio is a different type of measure to those currently employed, because it breaks down the interpretive process to a more fundamental level than that used traditionally in lithic analyses and settlement pattern archeology. Rather than begin the search for material correlates from a presumed settlement pattern, the model instead becomes a more basic one considering *parts of stones that have moved more or less*. We can understand how it varies through simulation and then we can contextualize its archeological manifestations against these simulated outcomes at a variety of spatial and temporal scales.

From this perspective, the immediate aim becomes less about confirming that a particular form of settlement was in effect than about using a theoretical understanding of the formation of an archeological pattern from a variety of settlement arrangements to ask questions about the condition of the archeological record in other places. While the immediate inferential returns are limited to more basic information (e.g., place *x* saw more importation, place *y* saw more depletion), the opportunities to ask questions with ramifications for behavior beyond the immediate vicinity improve (e.g., if most places surveyed feature depletion, what *kinds* of places might feature importation?).

To some degree, discussions like those between Monnier and Missil (2014), and Faivre et al. (2017) miss the point. It is not about measurement versus refitting as a preferred technique, one more scientific and the other more humanist. Rather, the focus needs to be on developing methods that make use of the accumulative and distributional properties of archeological materials and that clearly articulate what types of inferences are possible from such a record and how these inferences are of evolutionary significance. This remains a challenge for stone artifact studies generally.

Conclusion

"New Eyes" approaches to lithic analysis must engage with the ways in which sets of artifacts accumulate through time and across space. Anthropological studies of hunter-gatherer settlement and land use suggest regularities emerge only when spatial scales are increased. Similarly, studies of the distribution of artifacts suggest the need for an alternative to sites as spatially and temporally distinct locations of occupation. There is a need for techniques that seek to explain the patterns that emerge from a time-averaged archeological record, where the accumulative nature of materials that distorts the ability to distinguish complete sets of events becomes an asset rather than a liability. The Cortex Ratio is one such technique. Application allows remains left behind at one place to provide inferences about the activities occurring everywhere else, enabling testable hypotheses about the condition of the record in other places. Because the use of the ratio breaks down the interpretive process to a more fundamental level than that used traditionally in lithic analyses, we can understand how it varies through simulation and then we can contextualize its archeological manifestations against these simulated outcomes at a variety of spatial and temporal scales. It therefore provides an alternative to both so-called scientific and humanist approaches to stone artifact analysis and a technique more compatible with studying the variability in hunter-gatherer social organization that the ethnographic record indicates likely existed in the past.

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Compliance with Ethical Standards

Conflict of Interest The authors declare that they have no conflict of interest.

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