# The Evolution of Stone Tool Traditions

by

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# ABSTRACT

This study focuses on two broad questions concerning how variability in lithic technology relates to the biological and cultural evolution of humans. First, when did cumulative culture evolve? To address this question, the complexity of lithic technologies spanning hominin evolution was compared to the complexity of non-human primate technologies, and complexity achievable through randomized flaking behaviors in order to identify when lithic technologies developed that were more complex than technologies that may not require cumulative culture. The results suggest that a modern-human like capacity for cumulative culture was likely shared with the last common ancestor between modern humans and Neanderthals, and likely was developing prior to 2 mya.

The second question focuses on whether one can reliably detect migrations and population expansions in the Pleistocene through lithic technology alone. To address this question, spatio-temporal variability in technology was compared to variability across cultural traits that do retain evidence of history: phonemes in human languages. Then, variability across technologies was measured in regions where population and migration histories are known *a priori*:  these data include carefully selected assemblages relating to the migrations of Ancestral Puebloan people from Northern Arizona into the river valleys of Central and Southern Arizona, as well as assemblages relating to the expansion of Austronesian speakers into Near, and Remote Oceania. While lithic technologies show similar spatio-temporal patterning to phonemes in languages, suggesting potential for strong historical signal in lithic technology, within Oceania and Arizona technologies either weakly, or do not reflect population history. This is likely in part because

prehistoric people tended to rapidly change their technologies to suit new circumstances. The above studies highlight the usefulness of broad, comparative studies of technological variation in addressing questions about the causes of variability in lithic technology and how lithic technology relates to the evolution of the genus *homo.*

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# CHAPTER 1: INTRODUCTION

Stone tools represent the most expansive record of hominin behavioral variation that anthropologists have access to. An ongoing issue in the study of stone tools and in our understanding of human evolution, is that there is widespread disagreement about how to interpret the very same patterns that we have observed in the archaeological record. The same record of technological change across the Pleistocene has been cited as evidence for contradictory models of when our cultural abilities evolved. Also, similarities in technology are often cited as evidence for cultural contact between hominins, or migrations and population expansions of hominins from one area to another. Others cite those same patterns as representing functional adaptations to local environments, or convergence. The goal of this dissertation is to provide the comparative data necessary to clarify both what stone tool technology can tell us about the evolution of culture in the hominin lineage, and whether lithic technologies retain strong evidence of history.

This dissertation includes four studies. One focused on when cumulative culture evolved in the hominin lineage, and three exploring whether lithic technologies are likely to retain strong evidence of history or are likely to be useful for detecting migrations in the Pleistocene. To address these issues I took a theoretically-informed, computational approach involving comparisons of over 1200 archaeological assemblages spanning the past 3 million years of human evolution. The comparative dataset built over the course of this project includes data on the presence or absence of technological modes using the recording system developed by John Shea (2016), and the procedural unit system, proposed by Perreault et al. (2012).

**Chapter 1:** Cumulative culture is the ability to accumulate, new, modified, or improved practices, technologies, and beliefs across generations, and is likely a key part of the behavioral diversity of our species, and ability to adapt to novel environments. The evolution of cumulative culture in the hominin lineage is proposed as a significant driver in the evolution of hominin brain size, life history, and body shape. However, the evolutionary history of cumulative culture is not well understood, and claims range from it being absent even among Neanderthals, to being a primitive feature of the genus homo.

In this chapter, I identify when hominins began relying on tool production sequences so long, and technological repertoires so rich that it is unlikely that hominins could maintain those technologies without some form of cumulative culture. I compared degrees of technological complexity, and richness found in stone tool assemblages over time, to degrees of technological complexity achieved by primates without cumulative culture, and to the degree of technological complexity, and variability that can be achieved through randomized flaking behaviors alone. In total 1197 archaeological assemblages were compared. I then assessed whether modern humans and Neanderthals differed in their technological complexity, and developed a paired Bayesian and simulation model to assess whether there was strong evidence for a rapid increase in technological accumulation at any point in the past 3 million years.

Hominins began relying on technologies unlikely to be discovered through randomized flaking behaviors by ~2 million years ago, and Modern humans and

Neanderthals in the Pleistocene show no qualitative difference in technological complexity, or technological variability. However, there was greater uncertainty about when there may have been a shift towards more rapid technological accumulation, while the best supported dates of an increase are in the past million years, the results are likely sensitive to uncertainty about the true ages of sites, error in measuring technological variation, and over-representation of sites in the past million years. Taken altogether, the findings suggest that hominins relied on cumulative culture by ~2mya, and a modern human-like capacity for cumulative culture may have been shared with the Modern Human/Neanderthal last common ancestor.

**Chapter 2**. Human culture varies across space and time because of interactions between groups, the passing on of cultural traditions to next generations, and adaptation. Disentangling the relative contributions of each has been a longstanding goal in anthropology (Beheim & Bell, 2011; Boas, 1896; Shennan et al., 2015; Steward, 1972). This is an especially important problem in stone tool studies, because archaeologists often use tool forms and production techniques to infer historical dynamics across the Pleistocene, including cultural transmission between Neanderthals and *Homo sapiens* in Eurasia, cultural transmission among Homo sapiens populations in Africa, and the movements of hominins into new areas (Kolobova et al., 2020; Mellars, 2006; Rose et al., 2011; Scerri et al., 2014; Tostevin, 2013). Nonetheless, it is often unclear if similarities in lithic technology are due to common history, independent invention through adaptation to similar circumstances, or other unknown processes (O’Brien et al., 2018). In this chapter, I propose that if lithic technologies do retain reliable evidence for history, we should expect them to show similar kinds of spatio-temporal patterning to cultural traits that do retain history, like languages. There should be substantial between-assemblage variation, relatively low frequency of convergence, and they should show strong patterns of spatio-temporal variability. Nearby assemblages should be more similar than very distant assemblages, and these patterns should be comparable to other cultural systems that do retain evidence of history. To assess the strength of those patterns in lithic technology, I use the global record of phonemic variation in language as a point of reference.

I first assess the amount of between-assemblage variability in lithic technology relative to between language variability in phonemes, I then explore 1. how many instances of convergence there are in linguistic and technological datasets, and 2. how strong spatio-temporal patterning is in lithic technology relative to language. Both approaches help us to build a stronger theoretical foundation for making assessments about historical signal within lithic technologies. The technological datasets and the linguistic dataset, show similar frequencies of convergence, and similar strength of isolation-by-distance, which highlights at least the potential for historical signal in lithic technology: there is sufficient between group variability for historical signal to be retained, and spatio-temporal patterning consistent with historical signal being present. However, in order to more directly measure the persistence of historical signal in lithic data, we need to focus on archaeological records where the population history and history of cultural exchange is well understood *a priori*. That is performed in the third and fourth chapters.

**Chapters 3 and 4.** The final two studies focus on measuring variability in archaeological records where we have relatively strong evidence for the cultural relatedness of groups *a priori*: the record relating to Austronesian expansions into Oceania, between 2000 B.C. and 1400 A.D., and the record relating to the migration of Ancestral Puebloan groups from Northern to Central Arizona ~1200-1300 A.D.. Historical connections in both cases have been reconstructed through multiple independent lines of evidence (other forms of material culture, linguistics, osteology, and DNA). These records, and their comparison to patterns in the global record allow us to assess whether closely related groups tend to be more similar in their lithic technology than distantly related groups. In both records, the relationships between technological variation, and population history are weakly supported. In the Southwest, for examples, Ancestral Puebloan migrants tend to be at least as similar to their new, slightly more distantly related neighbors, than they are to their ancestors above the Mogollon rim. Furthermore, there is only subtle between group variability within the Southwest, suggesting that the kinds of distinctions between archaeological cultures in terms of ceramics and architecture are not represented in lithic technology. In the case of the Austronesian expansion, there also was a weak relationship between technology and population history. In contrast to the American Southwest, there was more substantial within and between group variability. However, the structure of that variability was more consistent with rapid changes among Polynesians, leading to them being often more similar to outgroups than they are to other Austronesian groups. These results highlight that lithic technologies evolve in ways that are unlikely to make them useful for detecting prehistoric migrations.

The above studies highlight the usefulness of broad, comparative studies of technological variation in addressing questions about the causes of variability in lithic technology, and how variation should best be interpreted.

# CHAPTER 2: THE EVOLUTION OF CUMULATIVE CULTURE

Cumulative culture is the ability to accumulate, new, modified, or improved practices, technologies, and beliefs across generations. It is a key part of the behavioral diversity of our species, and ability to adapt to novel environments (R. Boyd et al., 2011; Kim Hill et al., 2009; Mesoudi & Thornton, 2018; Tomasello, 1999). Yet, the evolutionary history of cumulative culture is not well understood. Is cumulative culture unique to modern humans, shared with Neanderthals, or common to all hominins? This is important for understanding how cumulative culture evolved, the role it played in shaping hominin evolution and our role in shaping past ecosystems.

In this chapter, I assess the timing of the development of cumulative culture by measuring both the number of steps in stone tool reduction sequences and the number of distinct kinds of tools, and core types reported in assemblages spanning 3.3 million years of hominin evolution. Both measurements serve as proxies of technological complexity. This comparative sample addresses three questions to help triangulate the timing of the evolution of cumulative culture in the Hominin lineage. First, when did hominins begin relying on technologies with production sequences so long, and technological repertoires so rich that it is unlikely that hominins could maintain those technologies without some form of cumulative culture? To assess this, I compare degrees of technological complexity, and diversity found in stone tool assemblages over time, to degrees of technological complexity achieved by primates without cumulative culture, and to complexity that can be achieved through randomized flaking behaviors alone (Perston and Moore 2016), and also to the complexity of Chimpanzee technologies, like nutcracking (Visalberghi et al., 2015), and brush tipped termite production (Sanz et al., 2009). These baselines serve as reference points for what we might expect hominins to be able to achieve without cumulative culture.

Second, do modern humans and Neanderthals differ in their technological complexity? Directly comparing the technologies of late Pleistocene hominids will help to outline whether modern humans are more technologically complex than Neanderthals, which could lend support to cumulative culture that modern humans wield being a derived trait that evolved after the split between modern humans and Neanderthals. Otherwise, if there are no or subtle differences between both hominins, it could suggest that both species share an ancestral capacity to accumulate and maintain increasingly complex technological practices. To address this question, I focus in on Late Pleistocene records of technological change within Africa and Eurasia.

Thirdly, when do we observe a shift from slow technological accumulation, both in terms of the number of steps in reduction sequences, and in terms of the number of tools, and core reduction practices, to rapid accumulation? Estimating when such a transition may have occurred will help us further triangulate the evolution of cumulative culture. To address this question, I perform a paired simulation and Bayesian analysis approach to both assess when such a transition may have occurred, and to also explore whether different sources of error, such as error in measuring technological complexity, uncertainty in the dates of sites, and over-representation of recent sites relative to older sites, could cause us to infer the wrong timing of the evolution of cumulative culture.

By answering these three questions, I provide an overview of the development of cumulative culture within the hominin lineage.

## Background

### ***What processes are involved in the kind of cumulative culture that modern humans wield?***

Since there are varying definitions of cumulative culture, and varying assumptions about what processes enable those different definitions of cumulative culture, defining terms is important. Mesoudi and Thornton proposed a core definition of cumulative culture whose elements are shared across all definitions researchers tend to use. At its core, cumulative culture involves accumulation of improvements and subsequent transmission through social learning of those improved behaviors (Mesoudi and Thornton 2018). The core definition of cumulative culture says little about the precise mechanism that must be involved in transmitting information. In fact, derived learning mechanisms, like imitation and teaching, are likely not strictly necessary for the accumulation of improvements, and subsequent transmission of those improvements (Pradhan et al., 2012). In experimental contexts with human participants, imitation and teaching is not necessary for improvements across generations especially for relatively transparent as opposed to difficult to learn, opaque behaviors (Caldwell & Millen, 2009). Modeling work also suggests that through simple grouping behaviors, and in absence of any derived mechanism like enhanced cognition or imitation, there can be cumulative improvement in behavior within groups (van der Post & Hogeweg, 2008). In the core definition, behaviors need not become increasingly complex and difficult to learn over generations, they only need to be improved. That improvement may result in decreased complexity, or a reduced number of steps to perform the behavior (Mesoudi Thornton 2018). Some animal behaviors do meet this core definition. The refining of migration routes over time are the most straightforward examples (Jesmer et al., 2018; Sasaki & Biro, 2017). Refining of migration routes result in gradual reduction of uncertainty, and in the difficulty in learning the solution, as the solution is the simplest, shortest option of many potentially convoluted routes (Jesmer et al., 2018; Mesoudi & Thornton, 2018; Miu, 2017; Sasaki & Biro, 2017).

Behaviors that meet the core definition of cumulative culture often are not what anthropologists and archaeologists specifically are interested in explaining. Cumulative culture in the core definition can occur without teaching or imitation, and might involve only the improvement in one behavior over generations. This kind of cumulative culture can be modeled as a walk on a simple landscape, or improvement in a single dimension (like length of a migration route). Humans, on the other hand, pass on increasingly complex and increasingly difficult to learn behaviors across generations, and rely on derived learning mechanisms like teaching mediated with language. It is these more complex cultural traits that are characteristic of modern humans that I want to explain (Enquist et al., 2011). Such traits can have many steps, like making a seaworthy canoe. Without any kind of social learning, inventing, and mastering these complex technological traits is impossible for our species. Even with our large brains, capacity for cooperation, language, and teaching, that all make learning and passing on difficult to learn technological information much easier, it is still very costly for modern humans to learn complex technologies. Unlike the core case of cumulative culture, this kind of cumulative culture is more accurately modeled as a walk on a more complex, branching landscape of possible behaviors (Derex et al., 2018; Enquist et al., 2011; Pradhan et al., 2012).

Modern human cumulative culture meets what Mesoudi and Thornton described as the “extended definition” of cumulative culture (2018). Cumulative culture in the extended definition involves three phenomena, and is best thought of as an exploration of a technological “tree”. First, cumulative culture involves groups learning, modifying, and passing on behaviors with multiple functionally dependent steps, like recipes. Imagine a branching landscape with nodes, representing particular behaviors or steps in a recipe. Each behavior or node can be joined by branches which represent the functional linkages between traits, or the recipe instructions. The base of this behavioral tree, or its trunk, represents a behavior upon which all further behaviors are built. For example, think of baking recipes. There is some unknown number of recipes that involve one fundamental process, dry heat applied to ingredients in some sort of oven. A large portion of this tree is made up of branches that stem from use of flour, and use of water. Some branches/recipes in this tree terminate close to the ground, like unleavened bread, which can be made by applying dry heat to a dough whose only ingredients are flour and water. Further up in the tree are relatively complex recipes, with longer branches joined by many nodes. These might include variations of soufflè recipes, which are not just more complex because they have more ingredients, but also because the ingredients need to be treated and prepared in particular ways. Yolks need to be separated from egg-whites, and these whites need to have air incorporated into them until they reach a very particular structure. This process needs to take place independent of making of the soufflè base, and both the base and the whites need to be incorporated in a way that does not allow the air within the egg-whites to be released. With each of these steps, there is opportunity to make a mistake (or to modify the recipe to produce a variation on the original). As groups explore and pass on recipes, and accumulate new modifications, learning, remembering, and performing the "correct" sequence of actions in the right way becomes more costly (Derex et al., 2018; Mesoudi, 2011; Mesoudi & Thornton, 2018). Lithic technologies, similarly, are made up of different kinds of recipes, some with few steps, some with many, and the differences in how these steps are chained together can lead to diverse kinds of tools, and core technologies (Figure 2.1).

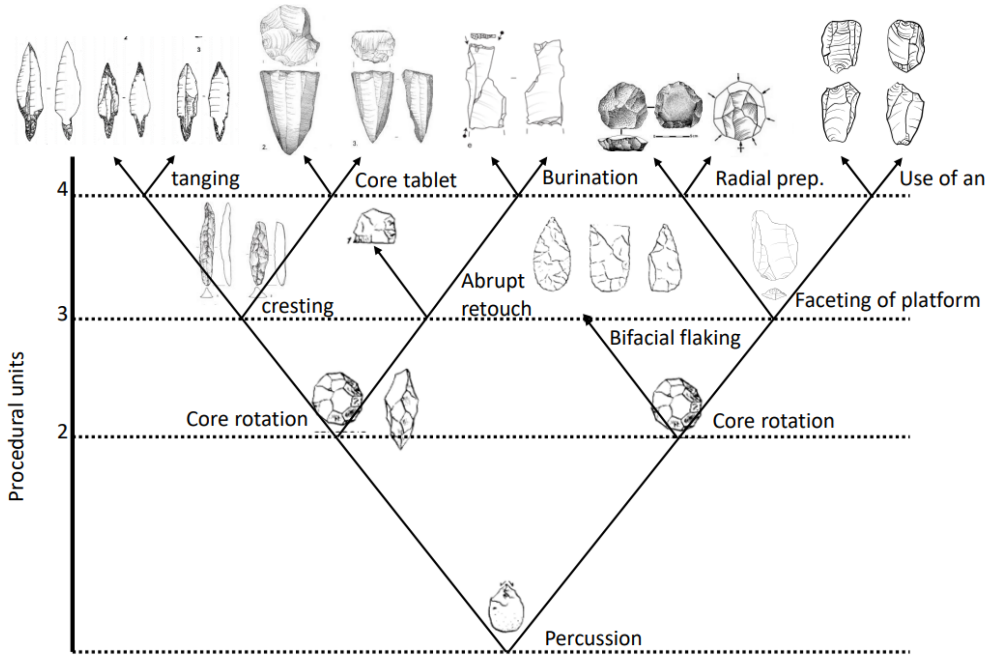


**Figure 2.1:** Example of how accumulating new procedural units/flintknapping techniques can lead to exploration of new portions of the technological morphospace, including distinct kinds of retouched pieces, tools, and core morphologies.

As groups transmit and modify complex behaviors, this leads to the second phenomena of the extended definition of cumulative culture: diversification of cultural lineages (Mesoudi & Thornton, 2018). As cultural behaviors accumulate more and more steps, and as more and more recipes are developed within groups, there is greater and greater potential for cultural differences between groups. One group might become entrenched in a particular region of the technological tree (producing blades as blanks for projectile points), while another might become entrenched in a separate region of that tree (producing projectile points through bifacial reduction)

Cultural diversification allows for the third phenomena underlying the extended definition of cumulative culture: recombination of cultural practices between lineages (Csibra & Gergely, 2011; Derex et al., 2013; Enquist et al., 2008; Enquist et al., 2011; Miu, 2017; Muthukrishna et al., 2014). Having more cultural behaviors to learn, either from others in your group, or from other groups in your metapopulation, means there is a great deal of fuel for creating new cultural behaviors through recombination (Robert Boyd & Richerson, 1996). Modern humans are unusual in their ability to recombine multiple unrelated behaviors into new, more complex recipes (Subiaul et al., 2015). Recombination of cultural traits from multiple distinct learning traditions through horizontal or oblique transmission allows us to more rapidly accumulate recipe steps, and develop different kinds of recipes more rapidly than would be the case if behaviors evolved only through accumulation of innovations within one group or learning tradition (Derex et al., 2018; Enquist et al., 2011; Kline & Boyd, 2010; Miu et al., 2018). For example, recombination is the main force by which new technologies have been produced in the United States. Since the 19th century, new patents increasingly are based on multiple pre-existing patents, as opposed to novel technologies based on no, or a single previous patent. Recombination is part of why there has been such an explosion of new patents over the past two hundred years (Youn et al., 2015). The branching nature of cumulative culture, in addition to recombination between cultural lineages means that culture can be modified at exponential rates, and rates faster than exponential growth (Enquist et al. 2008, 2011).

Cumulative culture that unambiguously features the three phenomena above, transmission of behaviors with many functionally dependent steps, cultural diversification, and recombination between lineages, is only found in modern humans. However, Chimpanzee groups in the Goulongo Triangle do appear to accumulate technological behaviors with many functionally dependent steps. There, Chimpanzees groups make brush tipped termite probes from sticks. This technology requires a relatively long manufacturing sequence involving up to 6 steps (Sanz et al., 2009): separating and fraying the fibers of the tip, splitting the stick lengthways, trimming the ends to modify the length of the probe, removal of extraneous vegetation, straightening of the brush, and repair of the brush. For further context, this group manufactures two kinds of tools in preparation for some termite fishing bouts: the brush tipped tool, and a perforating tool to punch into termite nests. Behaviors required for successful termite fishing using these methods are acquired piecemeal over the course of an individual’s lifetime. Actions involving the rejuvenation and maintenance of the brush tip are typically mastered at ~2-3 years. Manufacture of the tool itself is not mastered until ~4 years. The successful performance of all steps (making a perforating tool, making a brush tipped tool, perforating a nest, and fishing using the tool) is not seen in individuals until anywhere between 4-10 years, and few master them (Musgrave et al., 2020). Importantly, despite being a potential case of a form of cumulative culture that meets part of the extended definition, the precise learning mechanisms underlying the transmission of this technology are not well understood, and chimpanzees do not exhibit the kinds of rapid changes in technological behaviors that humans are capable of. So, what makes modern human like capacities for cumulative culture possible, and when might these traits have evolved?

### ***What enables the extreme form of cumulative culture in Modern Humans, and when did cumulative culture evolve?***

The best models for the evolution of cumulative culture explain it in terms of co-evolutionary feedback between traits that enable cumulative culture and the increasingly difficult to learn cultural information that hominins relied on over time. The unusual capacity for cumulative culture that modern humans exhibit is likely enabled by several derived characteristics. Our life spans are long. This gives humans more time to master difficult to learn skills. For example, among the Ache and, mastery of hunting, and the many skills needed to be a successful hunter, require decades of practice, and observation of other more skilled hunters (Walker et al., 2002). Among rural Fijian populations, difficult to learn and highly valued skills tended to be learned and taught later in life with the aid of older more knowledgeable individuals who have that specialized knowledge (Kline et al., 2013). A larger brain supplies the variation in behavior, and innovation that serves as raw material for cumulative cultural evolution, and helps to store complex cultural information, and may be better able to perform social learning tasks (Muthukrishna et al., 2018).

Recombination requires access to new behavioral variants, either within the group, or from another group. This means the inter-connectedness of groups is an important consideration in culture-evolutionary dynamics. Without access to diverse cultural models, the benefits of investing so heavily in larger brains, longer life history, and reliance on culture might not outweigh the costs. Among modern foragers, most people live with, and interact with unrelated people. This results in massive interaction networks where people are exposed to many cultural models from an early age onwards (Hill et al., 2011). These broad networks, with high inter-camp mobility and interaction within and between kin groups, can accelerate the pace of cultural accumulation (Migliano et al., 2020), though the antiquity of this kind of sociality is unknown.

Our prosocial nature, complex social structures, unusual capacity for cooperation between non-kin, and norms that enforce these behaviors also further enable cumulative culture (Tomasello, 2009). Individuals will benefit less from teaching if those who are distantly related do not engage in costly cooperation, and take on the cost of teaching them (Kline et al. 2013). Cumulative culture of technologies also likely requires manual dexterity, and an ability to effectively make and manipulate tools. Modern humans have an unusual ability to maintain both strong grips, and also delicate manipulation that aid in both tool manufacture and use (Key & Dunmore, 2018; Tocheri et al., 2008).

The current best operationalized and supported model explaining how cumulative culture evolved in our lineage argues that a long life span, and long childhoods, large brain relative to our body size, extreme prosociality and capacity for cooperation, a reliance on social learning, teaching and language evolved through gene-culture-coevolutionary cycles (Muthukrishna & Henrich, 2016). Over the course of this process, Hominins at some point shift away from a condition where social learning was an important part of how skills were learned as it is in many other animals, to one where adaptive behaviors accumulated over generations, creating selection pressures towards being more effective at social learning, storing information, and innovating, leading eventually to the pattern seen in modern humans (Henrich, 2017; Muthukrishna et al., 2018).

In summary, modern human cultural traditions are complex enough that they cannot be learned or maintained in a group without cumulative culture (Gergely & Csibra, 2006). Furthermore, modern human cultural traditions can rapidly accumulate cultural traits, through forces like recombination, and through our ability to transmit modify, and maintain complex cultural information in populations. Despite the importance of cumulative culture to the evolution of human behavior and biology, we understand very little about the timeline of its development. We do not know if the tasks early hominins performed would have required cumulative culture that meet an extended definition. It is also not clear if the closest relatives of modern humans shared a similar capacity for cumulative culture. Thus, to identify the timing of the evolution of cumulative culture in the hominin lineage, we should identify when 1: hominins began to rely on technologies that are unlikely to have been discovered through individual learning, or without some form of cumulative culture, 2: whether Pleistocene hominins differ in their capacity to transmit and maintain complex and rich technological traditions, and 3: when we see evidence for shifts from relatively slow accumulation, to rapid accumulation of cultural traits more consistent with the extended definition of cumulative culture. Answering the above questions requires studying carefully changes in technology across hominin evolution. However the lack of clarity about the timeline of the evolution of cumulative culture boils down in large part to disagreement about how we should interpret variation in the stone tool record (Tennie et al., 2017), and more fundamental obstacles to accurately measuring technological change across hominin evolution relating to the nature of the archaeological record, and how it is studied (Perreault, 2019).

### ***Cumulative culture and stone tool technology***

In the tree metaphor described above, species with cumulative culture are able to explore technological practices with increasing numbers of steps (i.e. travel further towards the tips of branches in the tree). As a result of that ability to move higher in elevation, groups are also able to explore different branches and nodes of the technological tree. Despite intensive research into the relationships between cumulative culture, and stone tool variation, there remains a lack of clarity about when cumulative culture that meets either the core or the extended definition evolved. We should expect hominins with cumulative culture that meets the extended definition to be capable of the maintenance of very rich technological repertoires and/or technologies with long production sequences, and capable of rapid technological accumulation. However, there are few studies that have systematically measured technological variation across many archaeological sequences. Hence, the linkage between the patterns described, and a cause in terms of cumulative culture, is sometimes not well supported theoretically. This is often because the units of analysis are inappropriate. Nonetheless, there have been recent advances in our understanding of how variable Pleistocene assemblages were, and how difficult it is to learn to produce these technologies with or without traits we associated with cumulative culture.

Chipped stone tools are the only source of information about technological change spanning the entirety of hominin evolution (Braun et al., 2019; Harmand et al., 2015). This is because chipped stone artifacts have been essential components of the human niche and preserve very well, making them the most ubiquitous artifacts in the archaeological record (Reynolds, 2018). Stone tools are also useful for systematically measuring technological change because all stone tool production occurs under the same basic set of physical constraints (Dibble, 1997; Režek et al., 2018). The diversity of chipped stone technologies found in the past 3.3 million years are based, in large part, on iterations of the same operation, flake removal, chained together in different ways (Mark Moore, 2010; Sellet, 1993; Shott, 2003). The decisions made while reducing cores and making tools leave diagnostic evidence (Moore, 2007). By studying the waste products from flaking events, and through comparison to experimentally produced artifacts, archaeologists reconstruct the kinds of actions that were taken by tool-makers in the past, how flakes were removed, and how the convexities of the core were managed across tool-making sequences. Reconstructions of tool making sequences are one of our primary sources for understanding prehistoric behavioral variation (Boëda, 1992; Boëda et al., 1990; Conard & Adler, 1997). Stone tools also tend to serve the same set of functions that were in demand across hominin evolution: cutting, scraping, and perforating (Shea, 2016). Thus, by focusing on lithic technology we may also hold constant many of the basic functions, and physical constraints in a way not possible if we had to track changes across different classes of technologies, such as stone tools, metals, basketry and household architecture. In order to relate technological change, to evolution of cumulative culture archaeologists have compared the patterns we see in the archaeological record to theoretically derived expectations for patterns we might expect to see if cumulative culture were absent as opposed to present, or to patterns we might expect to be associated with the evolutionary pressures favoring the evolution of cumulative culture. Those expectations center on technological complexity, richness, and rates of change in early assemblages.

However, some units of analysis are not well suited for measuring technological change. Patterns of technological change across hominin evolution are typically characterized in terms of the development of technological industries and technocomplexes. For example, the earliest stone tool industries, the Oldowan (2.8-1.8mya) and the Acheulean (1.8-~.5 mya) span over a million years, which suggests long periods of no, or very slow technological accumulation. The slow pace of accumulation in much of the Paleolithic, and weak evidence for between group differences in technology in the Oldowan, through Acheulean, appears inconsistent with what we would expect from cumulative culture (Boyd & Richerson, 2005). However, the low richness within assemblages, the low diversity between assemblages, and slow rates of accumulation argued to characterize the early archaeological record is partly due to analytical units masking variability between assemblages, and lack of standardization in how analytic units are defined. Because the outer boundaries of industries are not defined in a systematic way, they collapse very different amounts of variation within them. This is like attempting to measure biological variability within and between species, where there were many different schools of biology operating on different, largely implicit definitions of what a species is. This is not to say that systematic, and epistemologically sound units of analysis cannot be developed (Riede et al., 2019). Rather, until sounder systems become widely used, industries and technocomplexes as they are currently defined are likely not useful units of analysis for formally testing hypotheses about technological change, and evolutionary patterns (Riede et al., 2019; Shea, 2014; Wilkins, 2020).

However, even if industries as they are defined currently, were appropriate units of analysis, slow rates of change, and periods of technological stasis are also expected to occur over the course of the evolution of cumulative culture. For example, long periods of little change could represent technological accumulation reaching a plateau in difficulty (Mesoudi 2011). As hominins explore upper regions of the technological tree, transmitting and maintaining these technological traditions becomes more and more difficult without other developments that make further elaborations easier, or more worthwhile to learn and pass on, be they a larger brain, higher fidelity transmission mechanisms, shifts in life history, ecology, subsistence, or biomechanics (Greenbaum et al., 2019; Hopkinson et al., 2013; Kolodny et al., 2015; Lieberman, 2018; Morgan et al., 2015; Nowell & White, 2010). For example, early hominins likely did not have the same capacity for both delicate and forceful manual manipulation that would have made some of the tool-making actions seen in the later record, like facetting a platform, or abrading a platform, easier to perform (Key & Dunmore, 2018). Short juvenile periods may also have meant it would have been far too costly to invest in and learn more complex technologies (Hopkinson et al., 2013). Also, rapidly accumulating new technologies is unlikely to happen if there is a shallow pool of cultural traits to begin with. These kinds of pressures and restrictions might explain why hominins who may have relied on cumulative culture, and engaged in cultural accumulation in other domains, did not overhaul their chipped stone technologies for many generations (Morgan, 2016).

While periods of stasis, and low amounts of variation may theoretically occur during the evolution of cumulative culture, detailed technological comparisons of assemblages have highlighted variation argued by some to be consistent with incipient forms of cumulative culture (Kempe et al., 2014; Shipton & Nielsen, 2015; Stout et al., 2019). For example, the between-assemblage variation in assemblages at Gona ~2.6 mya, may be best explained by the presence of cultural traditions passed on through copying of tool-making methods (Stout et al., 2019). Later, the greater variability in technology between 1.8 and .7 mya was driven largely by development of bifacially flaked core-tools, large flake cleavers and prepared core technologies. These may also represent hominin populations fully relying on cumulative culture (Hopkinson et al., 2013).

Despite the variability in the early record, early technologies tend to have few steps in their production and in some cases can be reproduced by chance through randomized flaking behaviors (Moore & Perston, 2016). Even bifacially flaked core-tools, and some forms of what appear to be prepared cores can be produced as a byproduct of the simple action of striking a flake from a core over and over, where there is no overarching design goal aside from the removal of large flakes (Perston and Moore 2016). This suggests that, while there may be inter-assemblage differences, those differences may exist within a relatively narrow space of possibilities that could be discovered relatively easily, compared to technologies that cannot be replicated through randomized flaking algorithms (described in section 4.3). Thus, it may be that hominins relied only on chipped stone technologies whose discovery is essentially inevitable assuming hominins made many flakes across their lifetimes. In this case, it may be that technologies did not need to be transmitted and maintained through anything like cumulative culture (Tennie et al., 2017). The technologies are too simple to necessarily require derived learning mechanisms, like detailed copying of tool-making. Technologies may instead have been reinvented and passed on through social learning mechanisms common throughout the animal kingdom (Corbey et al., 2016; Tennie et al., 2017).

While the tools dating between 2.6-.7 mya appear simple, feature less variation compared to the later record, and oftentimes can be "discovered" through randomized flaking, making them, and passing on knowledge about how to make them is challenging without cultural transmission. Morgan et al. (2015) found successfully making even relatively simple flakes, like those produced by hominins at Gona, is a difficult process for modern humans without access to a cultural model to learn from. The more subjects could take advantage of derived learning mechanisms, like verbal and gestural teaching, the more effective they were at producing sharp flakes efficiently. This suggests that reliance on tools from the earliest archaeological record would have placed selection pressures on early hominins towards higher fidelity means of social learning. Becoming proficient in making Oldowan tools is more quickly achieved, and less costly than achieving similar mastery of later Acheulean biface technology (Stout & Khreisheh, 2015).

Most studies focused on relating the evolution of cumulative culture to data collected from stone tool assemblages tend to focus on particular case studies, or comparisons of small numbers of sites. But the evolution of cumulative culture could have been a process that occurred at the scale of millions of years. Measuring the development of cumulative culture requires systematic comparison of many lithic assemblages spanning the Plio-Pleistocene through the Holocene. Such large scale studies are rare and tend to focus on traits that do not directly relate to accumulation of steps in technological sequences, or the accumulation of more and more kinds of technologies. For example, Rezek et al. found that across hominin evolution, groups developed increasingly efficient methods of reducing cores, in terms of amount of cutting edge per unit of volume (2018). Efficiency is likely related to, but does not directly measure accumulation of technological innovations.

The above review gives us some signposts with which to potentially trace development of modern human like capacities for cumulative culture. Below, I perform three broad analyses to investigate the development of cumulative culture in the hominin lineage. First, when do we see levels of complexity and richness unlikely to be developed and maintained in hominin populations without cumulative culture that meets the extended definition? To address this question, I compare degrees of technological complexity, and diversity found in stone tool assemblages over time, to degrees of technological complexity achieved by primates without cumulative culture, and to the degree of technological complexity, and variability that can be achieved through randomized flaking behaviors alone. Second, do modern humans in the Pleistocene, and

Neanderthals differ in technological complexity and diversity? If Homo sapiens developed greater diversity and complexity, this would be consistent with that species having derived traits (whether related to cognition, life history, or sociality) that would have made them more adept accumulators of technological knowledge. Conversely, it could be there are few differences between both species, which would suggest they share a similar capacity for accumulation, and that capacity may be shared with their common ancestor. To address this, I focus only on technologies of *Homo sapiens*, and *Homo neanderthalensis* assemblages within the Pleistocene. Finally, with the extended definition of cumulative culture, we would expect populations to be able to rapidly accumulate new technological innovations. I assess when in hominin evolution there may have been a shift to rapid accumulation, and whether that date estimate pre or post-dates the evolution of modern humans.

### ***When do we see levels of complexity and richness unlikely to be discovered without cumulative culture?***

Humans can explore upper branches of high technological trees that cannot be reached without cumulative culture. Hominins with more primitive cultural capacities may have been able to explore only lower regions of the tree, where fewer behaviors need to be chained together to make and use a tools. If hominins were only able to explore lower boughs, we should not expect them to transmit and maintain many different kinds of technologies. These lower boughs include behaviors that are perhaps more straightforward for individuals to discover on their own, without cumulative culture, or perhaps they are achievable through some incipient form of cumulative culture closer to the core definition proposed by Mesoudi and Thornton (2018). We operationalize this lower region of the technological tree in two ways, first by referencing randomized flaking experiments that simulate what kinds of forms would be discovered through individual learning, and second by referencing the degrees of complexity observed in primates that likely rely on social learning, but do not possess cumulative culture that meets the extended definition.

The first way to operationalize these low regions of the technological tree is to use the results of randomized tool-making experiments to highlight technological modes, and tool making sequences one could discover through individual learning. Some stone tool-making behaviors, like distinct procedural units and flintknapping techniques or technological modes, are easier to discover than others, and do not require tool-making bio-mechanics beyond what hominins were capable of ~2.6 mya. For example, using a second class lever to remove blades from a prepared core is likely extremely unlikely to be discovered by chance, without several complex technologies already mastered (prepared cores, lever technology). Others are not so difficult. The forms of early Acheulean handaxes, and some of the geometries, and sequences of flake removals associated with prepared core technology can be produced “accidentally” by reiterating the same simple flaking algorithm over and over: removal of a large flake from an appropriate but randomly selected platform. The procedural units, and modes discoverable through randomized flaking can then serve to outline regions of the tree that hominins could relatively easily discover, and learn through randomized flaking strategies (Moore & Perston, 2016).

The second way to operationalize these regions is to use technologies of other primates as points of reference. Primates make and use tools, but these tools require fewer steps to make and use than technologies of modern humans, and do not require the kind of cumulative culture that meets the extended definition of cumulative culture. While the precise social learning mechanisms underlying primate behavioral variation are not well understood, some chimpanzee technologies appear to involve learning several functionally dependent steps (Pradhan et al., 2012). Comparing the number of steps in tool-making sequences between hominins and other non-human primates will help us further triangulate when hominins were relying on relatively difficult to learn tool-making sequences even compared to primates who do learn socially.

## Materials and methods

### *Measuring technological complexity*

The unit of measurement for measuring technological complexity we use here is the procedural unit. Procedural units are discrete, mutually exclusive manufacturing steps that can be chained together in the production of technologies (Table 2.1). Here, we measure the presence or absence of procedural units in stone tool making sequences (Perreault et al., 2013) reported in the literature. As hominins groups explore higher boughs of the technological tree, closer to the tips of branches, they are relying on longer tool-making sequences involving more procedural units that have a greater cost to learn compared to hominins happy enough to remain closer to the ground with easier to learn sequences.

**Table 2.1**: Procedural units and their short definitions. In this study, all procedural units reported, or observable based on illustrations and tables of artifact types were described as present. This included procedural units belonging to separate reduction sequences.

| Procedural units | Short description |
|---|---|
| 1. Heat treatment | Heat treatment used to improve flake-ability |
| 2. Platform facetting | Platform morphology modified by striking flakes across platform |
| 3. Centripetal shaping | Convexities maintained through centripetal removals |
| 4. Lateral shaping | Flakes struck from lateral margins of core to maintain convexities |
| 5. Distal shaping | Convexities maintained through flakes struck from distal edge of core |
| 6. Back shaping | Back of the core is shaped. |
| 7. Cresting | Cresting to shape core face during initial steps of core preparation. |
| 8. Debordante shaping | Convexities maintained through flakes along lateral margins of core face |
| 9. Overshot flaking | Invasive flake removals that clip or remove the distal margin of the core |
| 10. Kombewa flaking | Removal of flake from ventral surface of a flake |
| 11. Core tablet | Removal of core platform by striking flake into face |
| 12. Abrasion | Abrasion or grinding performed at any point in reduction sequence. |
| 13. Trimming platform overhang | Removal of chips to modify area below platform. |
| 14. Hard hammer percussion | Use of hard hammer |
| 15. Support core with hand | Support of core by hand |
| 16. Use of an anvil | Use of an anvil |

| Procedural units | Short description |
|---|---|
| 17. Core rotation | Rotation of core |
| 18. Soft hammer percussion | use of a soft hammer |
| 19. Indirect percussion | Use of a punch to remove flakes |
| 20. Flaking through pressure | Removal of flakes through application of pressure on core platform |
| 21. Hammer dressing | Modification of a piece through pecking |
| 22. Invasive flaking | Removal of non-cortical flakes that extend beyond the midpoint of the piece |
| 23. Ochre use | Use of ochre |
| 24. Asphalt use | Use of asphalt |
| 25. Retouch | Retouch of flake or core tool (unifacial only) |
| 26. Backing | Retouch forms an abrupt, scraper-like margin |
| 27. Notching | Retouch forms round concavity |
| 28. Burination | Removal of spalls along the margins of flakes |
| 29. Tanging | Retouching base of piece to form a tang |
| 30. Tranchet | Rejuvenation of core tool by striking a flake across the edge |
| 31. Bifacial retouch | Retouch on both faces of a flake or core-tool |
| 32. Invasive retouch | Retouch that extends to the midline of a tool |
| 33. Pressure flaked retouch | Pressure flaking retouch |

I analyzed data on tool-making sequence length based on descriptions of lithic technology in the literature. A codebook outlining the standards by which I count any given procedural unit as present or absent was develop to ensure reproducibility. This codebook follows the structure of those developed at the Center for Disease Control for processing interview transcripts, and serves to prevent coders from applying their own heuristics to the coding process (MacQueen et al., 1998). The structure of the codebook include definitions of the code (for example, the definition of *debordante* I employ), but also explicit inclusion and exclusion criteria, as well as written phrases, terms, and example illustrations that would be typical and atypical evidence sufficient to code the procedural unit as present. The codebook also has examples of evidence close, but not sufficient to code the technique as present.

I gathered technological data with wide temporal and spatial coverage, from passive hammer cores at Lomekwi, Kenya ~3.3 mya (Harmand et al., 2015) to quadrangular adzes, at Ka’eo quarry, Hawaii in the ~18-19th century A.D. (Clarkson et al., 2015). Tool-making sequence lengths (n = 56) were estimated based on the presence or absence of any one of 33 procedural units (Perreault et al. 2013). I surveyed descriptions of lithic technology reported in the literature from dated archaeological contexts in Africa, Eurasia, Greenland, Sahul, Oceania and the Americas, from the earliest archaeological record through the late Holocene. The sample includes only sites with detailed descriptions of the lithic technology, including discussions about how cores were managed, and illustrations of debitage, cores, and retouched elements. For each tool-making sequence identified, I coded as present or absent any one of 33 possible procedural units based on the standards outlined in the procedural unit codebook (Appendix I). The 33 possible procedural units include steps involved in core preparation (cresting, centripetal preparation, platform rejuvenation), the tools used to produce flakes (pressure flakers, anvils, hard hammers), and the nature of retouch (abrupt retouch, burination).

### ***Measuring technological richness***

Technological richness represents what different regions of the technological tree were explored by particular hominin groups. Unlike complexity, hominins could have relied on many distinct technologies, all of which were relatively simple to learn. Nonetheless, technological options are limited if a flintknapper does not chain together several procedural units. So, the total size of a technological repertoire should give some insight into how much technological variability particular groups were able to transmit, modify and maintain over time. Here, technological richness is measured using the mode A-I system of describing what technologies are present in assemblages (Shea, 2020, 2016). Technological modes that might be present in an assemblage could include the kinds of cores present (variations of unifacial hierarchical cores, variations of bifacial hierarchical cores, bipolar, and non-hierarchical pebble cores), types of retouched pieces in the assemblage (microliths, burins, points), types of core tools, and other modes. Some modes, like F1-F3, which broadly correspond to bifacial hierarchical cores, including Levallois cores, typically include facetted platforms, and core faces whose convexities are managed through *debordante* removals, or radial preparation (Table 2.2). Modes F1-F3 then, can be thought of as the clusters of branches in this technological tree that can become accessed when the requisite techniques are invented. As hominins discover more and more nodes, the new potential tool-making sequences and modes that stem from those nodes should rapidly increase.

**Table 2.2**: Technological modes analyzed in this study and their short descriptions based on Shea (2013, 2016, and 2020). Modes D encompasses different retouched tool types,

Modes E encompass bifacial core tools, Modes F encompass bifacial hierarchical cores, such as Levallois, Modes G encompass hierarchical cores with one dominant platform.

| Technological modes | Short description |
|---|---|
| B. Bipolar cores | Use of hammer and anvil to produce flakes |
| C. Pebble cores | non-hierarchical flake removal |
| D1. Retouched pieces with acute edges | |
| D2. Backed pieces | Includes pieces with retouch approaching 90 degrees |
| D3. Microliths | Backed pieces < 3cm |
| D4. Burins | Burins, burin spalls, tranchet flakes' |
| D5. Points | Awls, convergent scrapers, points |
| D6. Tanged piece | Basal retouch/notching forms a tang |
| D7. Core-on-flake | Detaching of flakes from other flakes |
| E1. Large cutting tool | Handaxes, cleavers, and picks |
| E2. Thinned biface | Thinned bifaces: follate and laurel leaf type artifacts |
| E3. Tanged biface | Retouch forms a tang on proximal margin of core tool |
| E4. Celt | Core tools flaked to produce sharp distal edge |
| F1. Preferential bifacial hierarchical core | Preferential Levallois |
| F2. Recurrent laminar bifacial hierarchical core | Recurrent Levallois |
| F3. Radial centripetal bifacial hierarchical core | Centripetal Levallois |
| G1. Platform unidirectional hierarchical core | Single platform flake cores |

| Technological modes | Short description |
|---|---|
| G2. Blade core | Single platform blade cores |
| G3. Microblade core | Single platform microblade cores |
| H. Edge abraded tool | Edges sharpened through abrasion |
| I. Groundstone | Tools produced through pecking and grinding |

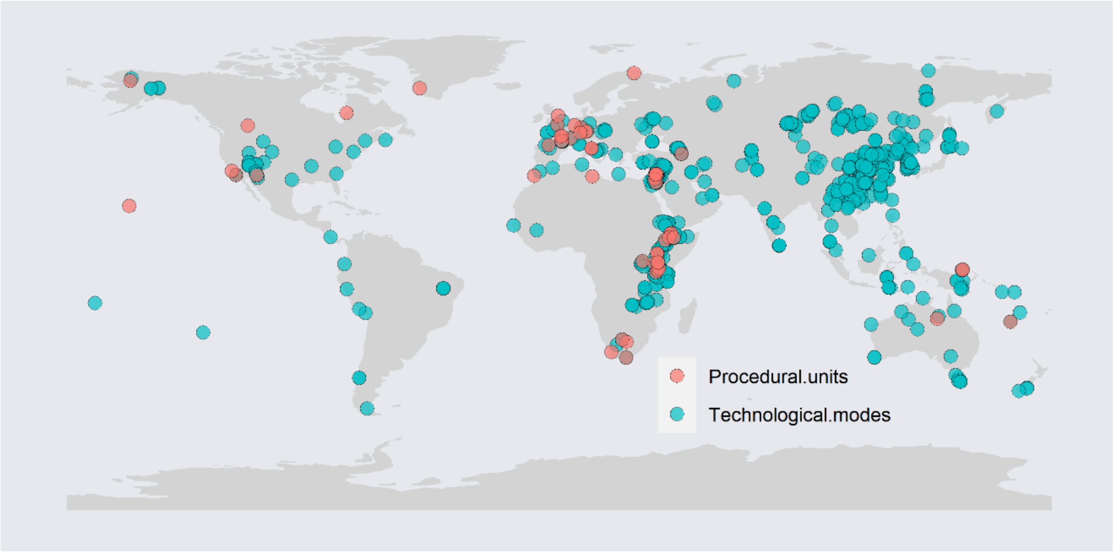


**Figure 2.2:** Map of all 1251 procedural unit, and technological mode inventories sampled for this study.

Technological richness is measured in terms of presence or absence of any one of 21 technological modes across 1195 assemblages (Shea, 2016, 2020). Of those, 461 were collected by John Shea (2016, 2020), and 668 assemblages in Asia were reported by Nishiaki et al. (2021) as part of the *PaleoAsiaDB* project. I collected further data on 65 assemblages. To prepare these data for analysis, I counted all modes coded as questionable “?” by the original author as absent. Overarching modes D, E, and F, were excluded and their sub-modes were included, to avoid double counting. I did not develop a codebook for the mode dataset, as the standards and definitions of those modes are clearly defined in the literature (Shea 2016, 2020).

### ***Measuring complexity and technological richness that can be achieved from simple flaking algorithms***

Through random flaking behaviors, several kinds of procedural units, and technological modes can be reproduced. To operationalize the lower branches of the technologies tree that hominins may be able to discover through individual learning, these easy-to-replicate technologies serve as reference points. Moore and Perston performed experiments designed to explore which kinds of early stone tool technologies were the result of a higher order plan or design, as opposed to the emergent outcome of moment to moment decisions about removing flakes from a core, with no other end goal in terms of the forms of tools, or the forms of cores (Moore & Perston, 2016). The experiment simulates behavior where there is the ability to select platforms, appropriate raw materials, hammer stones, and ability to effectively strike the platform. However, core platforms appropriate for flake removals are selected randomly, the core was struck removing a flake, after which a platform was randomly selected again. Despite the lack of higher-order planning, certain procedural units and technological modes are replicated. These include preparation of a core face for a preferential removal, or removal of burin spalls from the lateral margins of flakes. Others are not replicated during random removals, like tranchet blows, or core tablet removals on single platform hierarchical cores. While this random flaking algorithm presupposes an ability to repeatedly flake a core skillfully, which may have been a socially learned skill, The number of procedural units, and modes that are "discoverable" through randomized flaking algorithms is a useful proxy for technological strategies discoverable without the kind of cumulative culture that meets the extended definition.

In this case, the randomized flaking experiment produced several kinds of ostensibly complex artifacts, including handaxes, and prepared cores. Of these, the longest reduction sequence is five procedural units long, and involved the reduction of a core that is hard hammer percussed (1), rotated (2), supported by hand (3), with arguable centripetal shaping of one face (4), and an invasive removal mirroring what are often termed “predetermined” flakes in prepared core sequences (5). This sequence Moore and Perston present as evidence for proto-Levallois technology being reproducible through randomized flaking (Moore & Perston, 2016). Randomized flaking also produces 5 different technological modes. Of those, pebble cores (1), burins (2), core-on-flakes (3), bifacial core-tools (4), and preferential bifacial hierarchical cores like the sequence described in the previous paragraph (5) are replicated.

### ***Measuring the complexity of non-human primate technologies***

Non-human extant primate technologies are maintained across generations among animals with a relatively short life history, smaller brains, no prosociality, relatively primitive cultural capacities, and without the kind of cumulative culture that modern humans wield (Koops et al., 2022; Whiten et al., 2009). We measured the number of steps in primate tool-making sequences as reported in the literature. These include the production of brush tipped termite probes by chimpanzee (P. troglodytes) in the

Gualougo Triangle, Republic of Congo (Sanz et al., 2009) and (2) nutcracking behavior by *P. troglodytes* at Taï National Park in Côte d’Ivoire (Visalberghi et al., 2015).

Chimpanzees in the Goulongo Triangle produce both brush tipped termite fishing probes, as well as sharpened sticks used to perforate termite mounds. Of both tool types, the brush tipped probes had the longer production and maintenance sequence. Sanz et al. identified 5 steps involved in producing probes (fraying the end by pulling through teeth, splitting the probe lengthwise, separating fibers by biting, clipping probe length, and removing extraneous vegetation), and an additional step involved in rejuvenating the probe tip (pulling brush fibers through a closed fist) (Sanz et al., 2009). Here, I treat the termite probe technology as having 6 procedural units (5 methods of manufacture, and 1 rejuvenation technique). While it is unclear if a single probe underwent all of the above modifications, archaeologist when they reconstruct a single prehistoric reduction sequences often do so with artifacts, each of which may only retain some evidence of that sequence. Thus, there is always the possibility that some prehistoric individuals skipped or added certain steps, or had no knowledge of others. Defining a single prototypical reduction sequence ignores that between individual variability within a group. So, in a similar way, I ignore potential individual variability between chimpanzees in the Goulongo example and conflate all the steps identified in the group into one tool making sequence. The Tai chimpanzee nutcracking technology is simpler than the termite probe practice in the Goulongo Triangle, at least in terms of the number of steps involved. In this case, strictly speaking, there is no tool production involved, and the relevant procedural units reflect use of two tools used as found. There are only two procedural units involved, use of a hard hammer, and use of an anvil (Visalberghi et al., 2015).

I did not characterize technological richness of primate groups and compare it to hominin stone tool assemblages, because the measure of richness, the number of technological modes in an archaeological assemblage, is based on a mixture of morphological and technological criteria specific to lithic technology, and is not readily comparable to the number of distinct primate technologies.

## Analysis

### ***When did hominins develop unusually complex technologies?***

The 56 tool-making sequences vary widely in their length. Their number of steps range between 2 and 19 procedural units, with the median technology requiring 10 procedural units (Figure 2.4). The earliest assemblages (3.3-.8 mya) have the fewest number of procedural units (min = 2, max = 7, median = 5, N = 12) . Bipolar percussion identified at Lomewki (3.3 mya) includes 2 procedural units: use of an anvil, and hard hammer percussion. There is slight variability between ~3.3 and 1.8mya with the addition of two procedural units: free hand percussion, and core rotation at Oldowan sites Gona, Bokol Dora 1, Kanjera, and Lokalalei 2c (Braun et al., 2019; Delagnes & Roche, 2005; Plummer & Bishop, 2016; Stout et al., 2010). The next increases in recipe length are found at Nyabusosi 18 ~1.8 mya, which includes 7 procedural units: hard hammer percussion, support of the core by hand, core rotation, centripetal preparation of a core face, facetted platforms, maintenance of lateral convexities through debordante flakes, and invasive flaking (Texier, 1995). Other examples between 1.8 and the Brunhes-Mutuyama reversal ~.77 mya include large cleaver production on hierarchical cores, and other bifacial core-tools. New recipes with longer sequences, however, did not develop until after ~.77 mya.

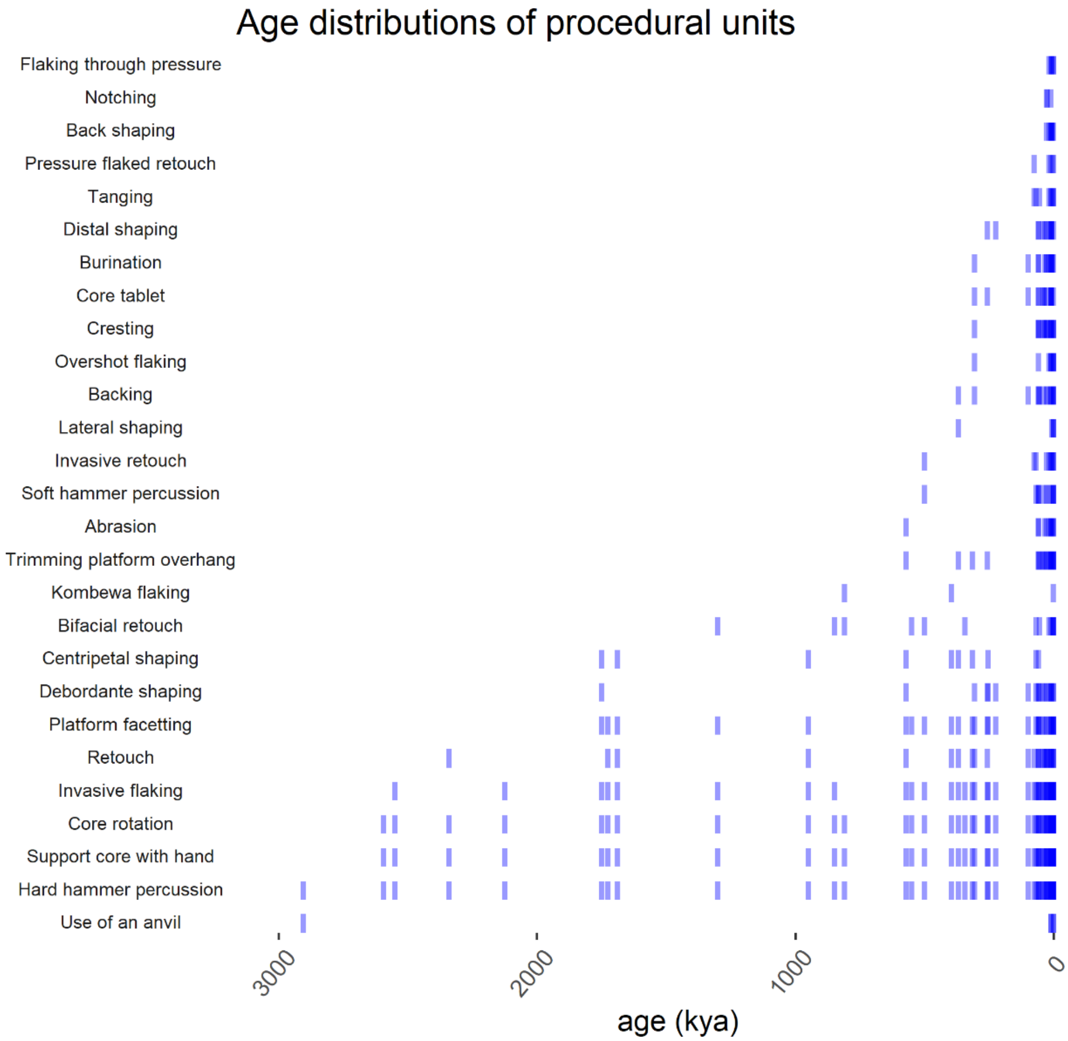


**Figure 2.3:** Temporal ranges of each procedural unit. The age of each assemblage with evidence for a particular technological mode is illustrated with a vertical blue line. Each blue line represents the median of the date range for that particular assemblage.

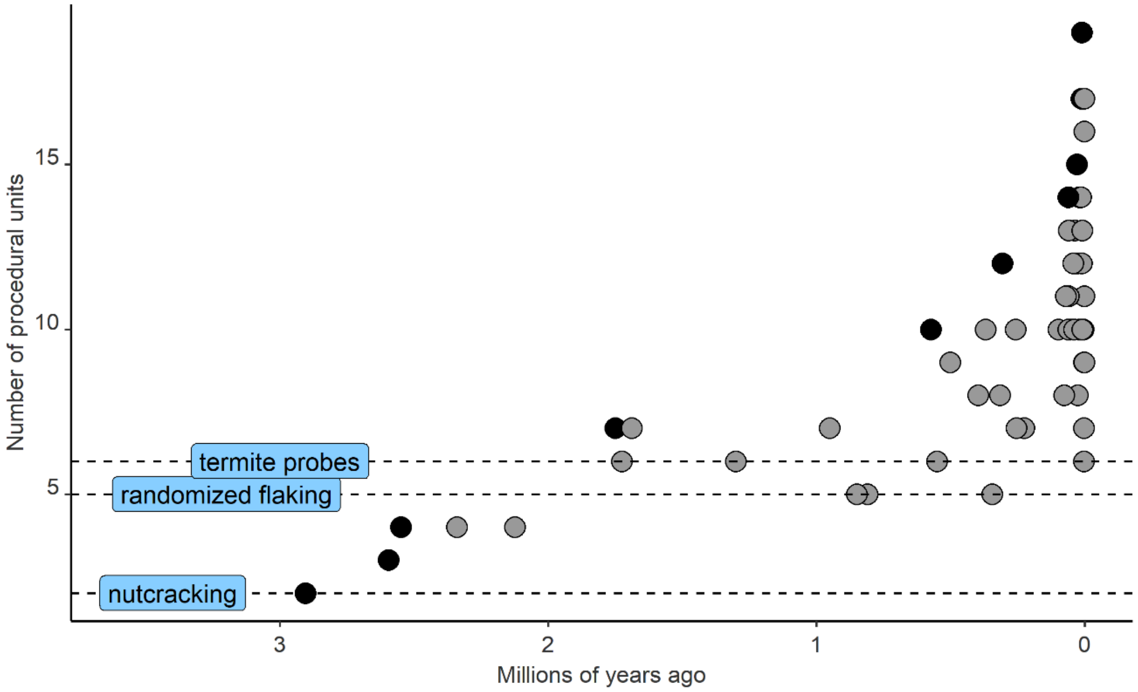


**Figure 2.4:** Relationships between age of assemblages, and degree of complexity in terms of procedural units. Total number of procedural units present in 56 tool-making sequences described in the literature. Samples marked in black represent the cumulative maxima, or the longest sequences up to that point in time. Dates are reported as the median of the date range reported for that site. The tool-making sequence length is compared to three reference lines: production of brush tipped termite probes by Chimpanzee groups in the Goualougo Triangle (Sanz et al., 2009), the length bifacial hierarchical core sequences that can be replicated by randomized flaking algorithms (Perston and Moore, 2016), and nutcracking technologies among *P. Troglodytes* at Tai, Côte d'Ivoire and *S. libidinosus* at Fazenda Boa Vista, Brazil (Mercader et al., 2007; Visalberghi et al. 2015).

Between the Brunhes-Mutuyama boundary (.77 mya), and the Holocene (.012 mya), there are far more technologies than the early record, and the median number of procedural units grew to twice that of the early record, marking comparatively rapid exploration of increasingly complex technologies compared to the early record (min = 5, max = 15, median = 10, N = 28). New levels of complexity were reached ~500 kya, with the development of thinned bifaces with tranchet resharpening at Boxgrove (9 procedural units), and the earliest evidence of blade production on bifacial hierarchical cores at Kathu Pan 1 (Wilkins and Chazan 2012). Between 500-12 kya, new blade making technologies, and ways of preparing cores, are found at Qesem ~200-400 kya (Shimelmitz et al. 2011), and in Howiesons Poort deposits at Klasies River Mouth ~53-68 kya (Villa et al. 2010), and Geißenklösterle cave ~29 kya (Hahn and Owen 2010).

The longest sequences in the dataset all were made during the Holocene (min = 6, max = 19, median = 11.5). The tool-making sequence of the most extreme length in this sample is found at the site Sujula in Finland dating to ~10kya. At Sujula, blades were struck from cores where one main platform was struck to produce blades and several other platforms struck to establish ridges along the core face, maintain convexities of the core face, and rejuvenate the main platform. Cores also had bifacially flaked posterior surfaces that could be used to anchor the core into a device to prepare it for blade removals. Across this process, a mix of hard hammer percussion, soft hammer percussion, pressure flaking, and indirect percussion were likely employed (Rankama & Kankaanpää, 2011). Some of the blades were retouched to form an abrupt margin and burin spalls were removed along the lateral, and proximal margins of those blades (Rankama & Kankaanpää, 2011) (Rankama & Kankaanpää, 2011). This blade technology, similar blade technologies in the Levant dating to ~11.6 kya (Barzilai & Goring-Morris, 2010), microblade technologies in Alaska ~1.8 kya (Desrosiers & Gendron, 2004), and quadrangular adze production in Hawaii about 200 years ago (Clarkson et al., 2015) all mark some of the longest tool-making sequences sampled.

The long sequences of the Holocene are found in the context of pastoral and food production economies, where groups could help to maintain unusually complex technologies through institutions, like craft specialization and apprenticeship. Pre-Pottery Neolithic villages in the Levant had an economic system based on agro-pastoralism, and cultivation. That subsistence system supported large villages with two story architecture. In that context, a complex method of making blades developed based on bidirectional removals of elongated blades from two opposed platforms, established through the cresting of a large core, and removal of initial crested spalls to establish both platform surfaces, and the core face. These technologies were likely very difficult to master, and are argued as evidence for craft specialization in the PPNB (Quintero & Wilke, 1995). According to the ethnohistoric record in Hawai'i, adze production was the domain of a privileged class of craft specialists, and some of the steps involved in making adzes are likely invisible to archaeologists such as soaking of adze blanks in medicinal water to improve flake-ability (Malo, 1903). Few modern day flintknappers possess the skill to produce many of the types of adzes seen across Polynesia (Clarkson et al. 2015).

To summarize, hominins were likely relying on unusually complex technological sequences difficult to discover and learn individually, and unlikely to be found among other primates by ~1.8 mya. By this time, Hominins could develop tool-making sequences longer than those found among chimpanzees, and technologies unlikely to be discovered through randomized flaking behaviors. The technologies of primates outside the hominin lineage fall at the lower end of the distribution of complexity. Tool-assisted nutcracking behaviors among chimpanzee groups at Tai, Côte d'Ivoire and S. libidinosus at Fazenda Boa Vista, Brazil (Mercader et al., 2007; Visalberghi et al., 2015) require two steps: use of a hammer, and use of an anvil. By ~2.6 mya, hominins were exploring tool-making sequences longer than the sequences involved in hammer and anvil use. It is not until ~1.8 mya, with the development of bifacial core tools, different forms of retouch, and some potential use of prepared cores, that hominins begin to explore chipped stone tool-making sequence lengths longer than the brush tipped termite probe manufacture steps in the Goualougo triangle chimpanzee groups. Of the tool-making sequences replicated through Moore and Perston's randomized algorithm, the longest is production of bifacial hierarchical preferential flake cores. Using the standards of measuring the number of procedural units employed in this study, this sequence would include 5 procedural units (Moore and Perston 2016). That hominins were relying on relatively complex technologies by 1.8 mya would suggest that they either had a form of cumulative culture that meets the extended definition, or had behaviors that would have strongly favored the evolution of that capacity.

### ***When did hominins develop unusually rich technological practices?***

Just as there is wide variation in the number of procedural units present across tool-making sequences. There is also wide variation in the number of technological modes identified across the 1195 sites (Figure 2.6). They range between 1 and 17 modes with the median assemblage having 5 modes. Similar to the pattern found in tool-making sequence lengths, hominin groups have explored more and more technological practices over time. The earliest assemblages (3.3-.8 mya) have the fewest number of technological modes (min = 1, max = 8, median = 3). Lomekwi 3 has evidence for modes: bipolar percussion and pebble core reduction. The first increases in the number of technological modes after 3.3 mya are associated with development of retouched tools, and platform cores at Gona, then with the addition of abrupt retouch at Lokalalei 2c (Delagnes & Roche, 2005). Further increases occurred with the development of bifacial core-tools, burination, and retouch to form points ~1.8-1.4 mya throughout Bed II of Olduvai Gorge (7 modes) (Leakey, 1971). on to the addition of platform cores again, along with other retouched forms and bifacial core tools at ’Ubeidiya ~1.25 mya (8 modes) (Bar-Yosef & Goren-Inbar, 1993). This was followed by a long period in which no new levels of diversity were reached until well after the Brunhes-Mutuyama boundary ~.77mya.

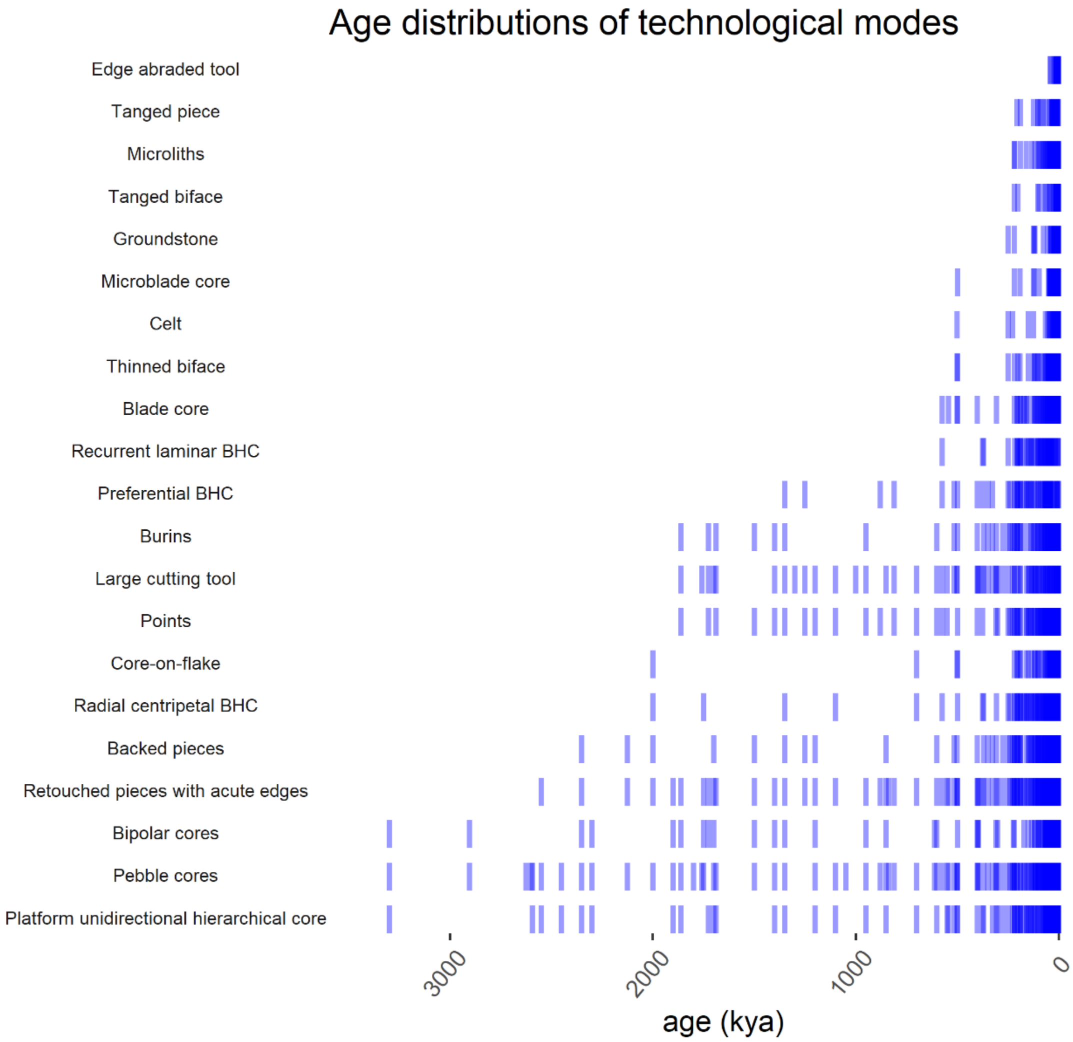


**Figure 2.5:** Temporal ranges of each technological mode. The age of each assemblage with evidence for a particular technological mode is illustrated with a vertical blue line.

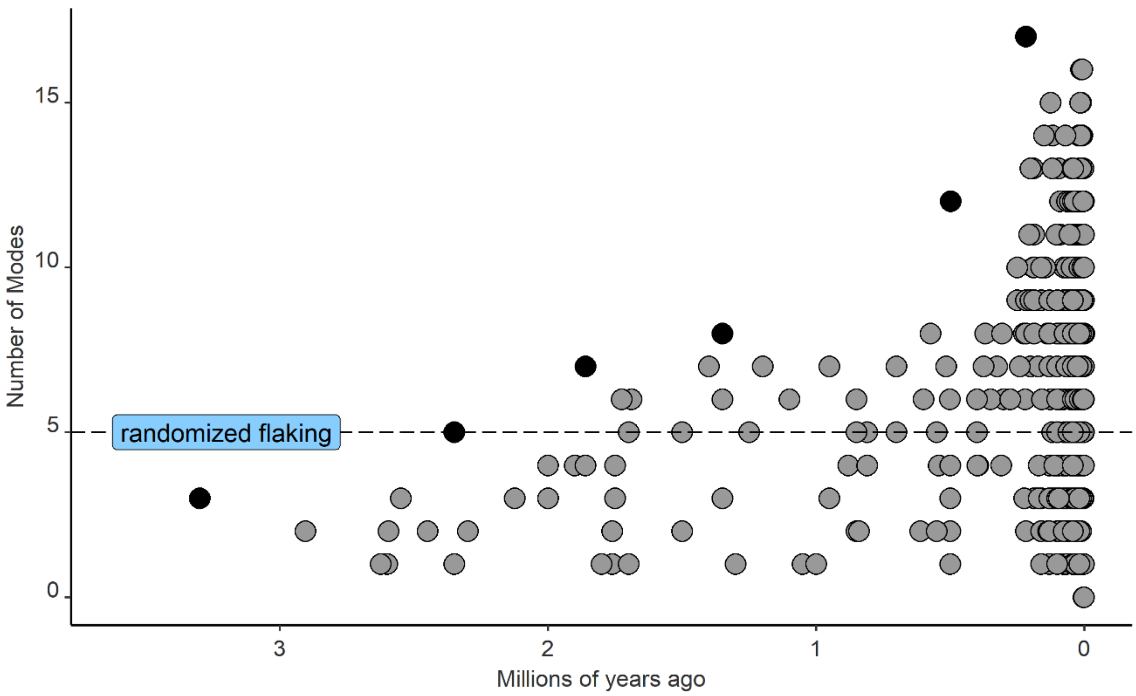


**Figure 2.6:** Total number of technological modes present across 1195 assemblages compared to the number of modes that can be achieved through randomized flake removal algorithms in experiments reported by Perston and Moore (2016) marked by the horizontal line. Dates are reported as the median of the date range reported for that site. Samples marked in black represent the cumulative maxima, or the most diverse sequences up to that point in time.

The period between the Brunhes-Mutuyama boundary (.77 mya), and the Holocene (.012 mya) marks a period where we both have more sites relative to the previous time period, and also assemblages with more modes than either the previous period, or any assemblage sampled in the Holocene (min = 1, max = 17, median = 5, N = 910). The median number of sites in this later period is twice that seen in the record prior to .77 mya. The first sites with a greater number of technological modes after the

Brunhes-Mutuyama boundary are found with the development of cores-on-flakes, thinned bifacial core-tools, bifacial hierarchical cores, single platform blade cores at Cartwright's site ~500 kya (12 modes) (Waweru, 2007), and microliths at Twin Rivers (17 modes) ~200 kya (Barham, 2000). While the most diverse assemblages are found between the Holocene and the Brunhes-Mutuyama boundary, the Holocene is very similar in terms of the degree of diversity (min = 1, max = 16, median = 8, N = 225).

In Moore and Perston's randomized flaking experiment, distinct technological modes can be replicated through only randomized flaking behaviors. These include 5 modes: Modes C (pebble cores), D4 (burins), D7 (core on flake), E1 (large cutting tool), F1 (preferential bifacial hierarchical cores). By ~1.8 mya, hominins beginning to transmit and maintain more technological modes than are likely to be reproduced through randomized flaking behaviors. This suggests that hominins were developing, and transmitting technologies that may have been relatively difficult to discover, and learn. Relying on these difficult to discover and learn technologies, if it did not require cumulative culture meeting the extended definition, would have placed selection pressures on things like life history, brain size and structure, and communication, that all could help hominins more easily learn these practices.

### ***Were Pleistocene Modern Humans more technologically complex than Neanderthals?***

In the above sections I assessed when hominins began relying on technologies more complex than three baselines. In this section I further triangulate the timing of the evolution of cumulative culture in the Hominin lineage by directly comparing the technological complexity of Modern Humans and Neanderthals. If there are differences, like if modern humans tended to have more complex cultural practices than Neanderthals, it could mean that modern humans have a more derived, and improved ability to transmit complex cultural traditions, whatever the underlying mechanism (cognition, differences in sociality, differences in life history). Arguments about differences, or lack thereof, between modern humans and Neanderthals in terms of cognition and technological complexity have played a big part in arguments about the reasons for Neanderthal extinction (Breyl, 2021). For example, it could be that *Homo sapiens*, due to their ability to transmit and maintain richer, and more complex technological traditions, outcompeted Neanderthals (Shea, 2003; Timmermann, 2020). If this were the case, then it could mean that traits that facilitate the kind of cumulative culture that modern humans wield developed late in hominin evolution, possibly after the last common ancestor between our species and Neanderthals. However, as we should expect for a species so closely related to modern humans, Neanderthals also had long childhoods, evidence for symbolic thought, language, and other traits tied to modern human ability to transmit and maintain complex cultural traditions (Galway-Witham et al., 2019). Furthermore, it is not clear whether the extinction of Neanderthals was due to competition with modern humans, . Modelling work has illustrated that Neanderthal extinction could have occurred without any differences in cognition, language ability, or sociality between them and *Homo sapiens* (Barton et al. 2011).

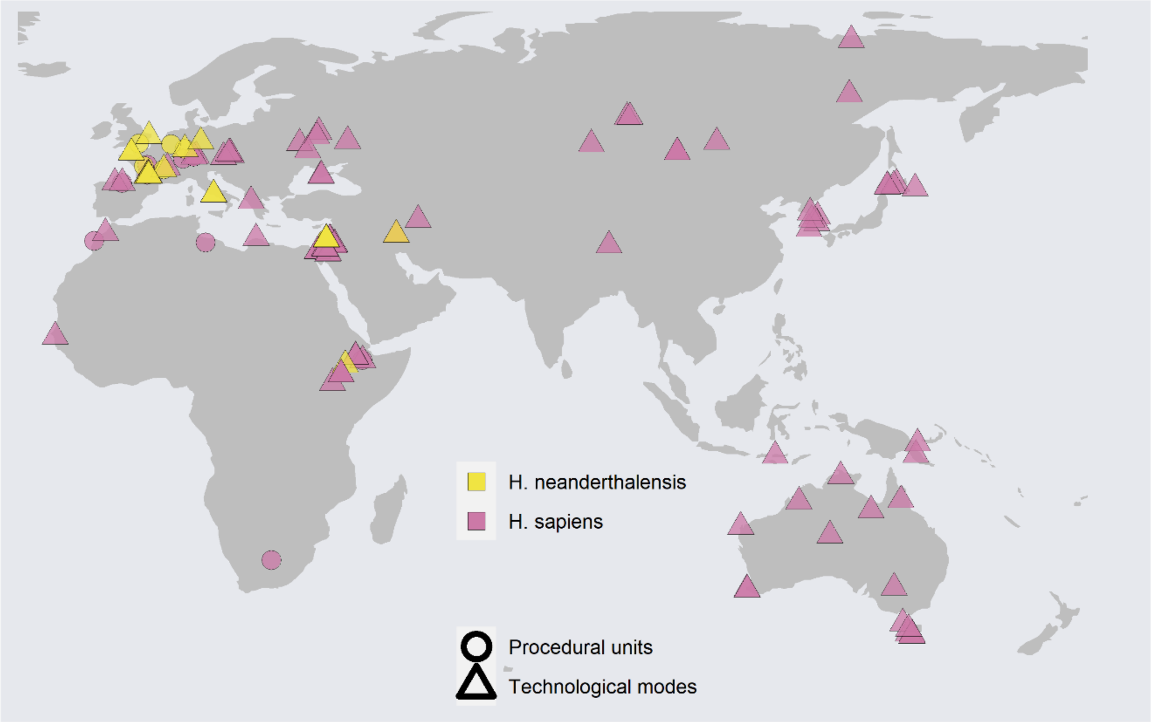


**Figure 2.7:** Map of Neanderthal/H. heidelbergensis and Modern Human assemblages compared in this study.

Here, I measure whether late Pleistocene hominins differ in their technological complexity. I focused in on assemblages produced by modern humans in Eurasia and Africa, as well as assemblages associated with *H. heidelbergensis* and *H. neanderthalensis* all prior to the Holocene among both the procedural unit and technological mode datasets (Figure 2.7). When we focus in on this subset of the dataset, we are studying 17 procedural unit inventories, and 122 technological mode inventories.

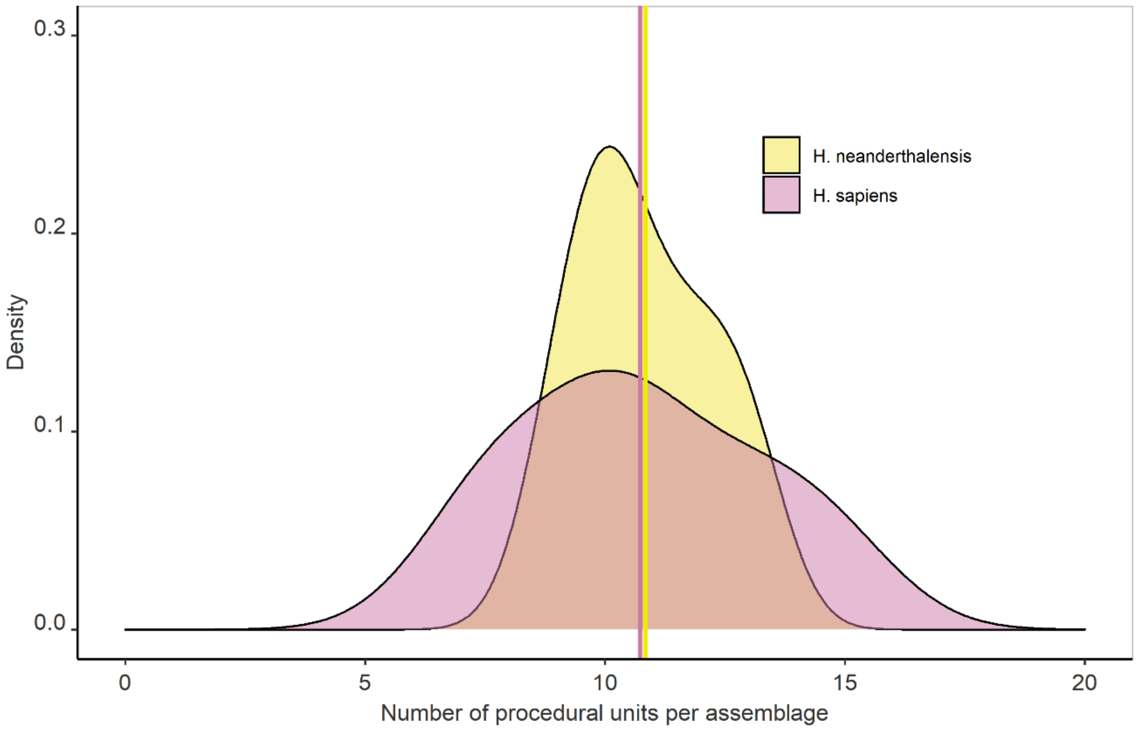


**Figure 2.8:** Procedural unit totals among assemblages separated by species: *H. neanderthalensis/heidelbergensis*, and *H. sapiens*. N = 17.

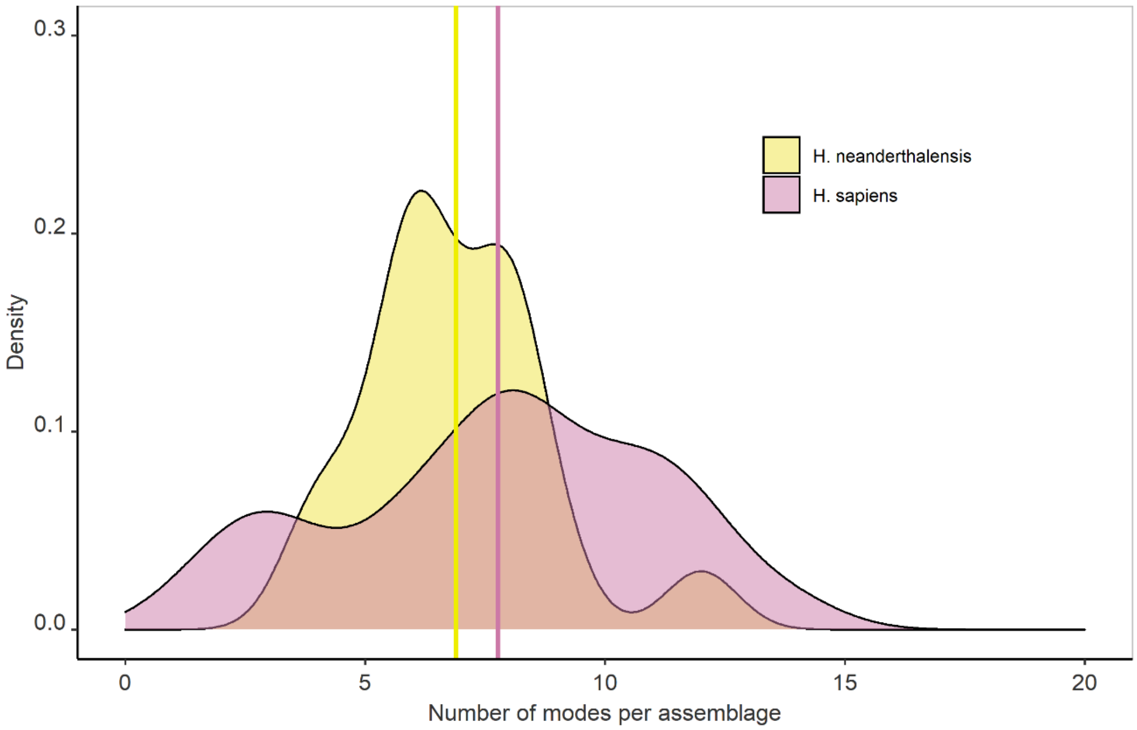


**Figure 2.9:** Technological mode totals across assemblages divided by species. N = 122.

There is little evidence for a strong difference in complexity between Neanderthal and modern Human sequences in the Pleistocene (Figures 2.8 and 2.9). Neanderthal sequences range between 9 and 13 procedural units, with a median of 10.5 (N = 6), which is well within the range of modern human sequences predating 12 kya (7 - 15 procedural units, median = 10, N = 11). The differences between the distribution of procedural units between both species' technologies are not significant (bootstrap Kolmogorov-Smirnov test p-value: 0.557). The main difference between both species is the greater variability of modern humans, which does include assemblages with more procedural units than in the Neanderthal assemblages.

Like in the procedural unit dataset, there is little evidence of strong differences between modern humans in the Pleistocene, and closely related hominins, though the richest modern human assemblages fall just outside the range of other hominins. In the case of modes, the technological repertoires of Neandethals and *H. Heidelbergensis* (4-12 modes, median = 6.5, N = 18) fall well within the range of modern human cases predating 12 kya (1-14 modes, median = 8, N = 104). The differences between both datasets are not significant (bootstrap kolmogorov-Smirnov test p-value: 0.02). Here, again, there is greater variability in modern human modes than in the Neanderthal assemblages.

The mixed evidence for differences between modern humans and Neanderthals suggests that if there were intrinsic differences in the capacity for cumulative culture between those species, it may have been subtle, or it was strong and not reflected in either procedural units or technological modes. This relates well to prior studies focused on evaluating underlying causes of Neanderthal extinction which have found that stochastic processes could be the cause, rather than differences in cognition and adaptability of either species (Barton et al., 2011). Furthermore, other studies focused on evaluating the hierarchical complexity of stone tool reduction sequences have found that Levallois technologies, not later appearing blade technologies, have the greatest degree of hierarchical complexity (Muller et al., 2017). The development of Levallois prior to the evolution of *Homo sapiens* is further evidence for the development of cumulative culture that meets the extended definition perhaps prior to the evolution of the Neanderthal and *Homo sapiens* last common ancestor.

## When did a shift to rapid technological accumulation occur?

In the above sections, I assessed when hominins began relying on technologies more complex than three baselines for what we might expect hominins to achieve without cumulative culture. I then assessed whether modern humans and Neanderthals differ in their technological complexity. The results suggest that hominins were relying on technologies that would have required, or favored the evolution of, cumulative culture that meets the extended definition, and that there is on striking difference between Modern humans and Neanderthals in terms of technological complexity. Here, I further explore the timing of the evolution of cumulative culture by assessing when in hominin evolution there may have been a shift from relatively slow to rapid technological accumulation.

Modern humans accumulate new technological behaviors across generations much more quickly than other primates. When the shift from relatively slow accumulation, to rapid accumulation occurred within our lineage is important for understanding how our species evolved, and the cultural development of our species. The development of cumulative culture may have been slow and gradual, rapid, or punctuated, and may have involved multiple major transitions in cultural abilities. However, in the extended definition of cumulative culture, very rapid technological accumulation like what modern humans are capable of should be possible through things like recombination, which allows for qualitatively higher rates of accumulation compared to other methods of accumulation (Magnus Enquist et al., 2011). I try to identify a most likely range of dates for a shift towards more rapid increases relative to the prior record. So, while recognizing that there may have been multiple changes in accumulation over time, I assume the presence of a single shift in technological accumulation as a first point of exploration. Future studies will try to more formally exclude different models of the tempo of cultural accumulation.

### ***Materials and methods***

I take a mixed Bayesian and simulation approach to assessing when there may have been a transition to rapid accumulation of technological modes and procedural units. First, I focus on how rapidly hominins reached new degrees of technological complexity across the record. I generated a time series describing how many new procedural units, or new modes accumulated over time. Across both the procedural unit and technological mode datasets, I measured the cumulative maxima of each dataset, or the most complex or rich archaeological assemblages up to that point in time. For each new cumulative maxima, I measured the total increase relative to the previous cumulative maxima. Then, I divided the archaeological record into 100,000 year time intervals. In each interval, I added the total number of new traits accumulated for each jump in the cumulative maxima within that interval. The result was a sequence of 100,000 year bins, and the total number of traits added across all increases in the cumulative maxima within each bin.

This time series was analyzed with a Gibbs sampling algorithm to generate a posterior distribution describing in which 100,000 year intervals there may have been an increase in the rate of accumulation. I treat the accumulation of new technological traits as a *Poisson* process, that follows some rate. I expect that the lambda value for the early record tends to be low, and in the very late record, this tends to be higher, and that at some point hominins shift from relatively slow, to relatively rapid accumulation. This time series was analyzed with a Gibbs sampling algorithm, to estimate the posterior distribution of three parameters: a breakpoint marking when there was a shift to higher rates (k), the rate of accumulation prior to the breakpoint (lambda), and the rates after that breakpoint (alpha). For each parameter, 5,000 posterior estimates were produced, and the highest density intervals at 90% levels were measured using the R package "HDInterval" (Kruschke, 2020).

### ***Results***

The most likely shifts towards higher rates of accumulation likely fall in the past 1 million years. Among procedural units, the 90% highest density interval for the date of an increase accumulation rates falls between 0.04 and 0.74 mya. This date range falls squarely within the late middle Pleistocene and includes estimates that predate the evolution of modern humans. There is more uncertainty about when such a shift in rates happened within the technological mode dataset, thought he best supported estimates still fall in the past 1 million years. Among modes, the 90% highest density interval falls between 0 and 3.51 mya. While a shift in the past 1 million years is the most probable, I cannot confidently reject that there were relatively stable rates of accumulation of modes from the earlier record onward (Figure 2.10).

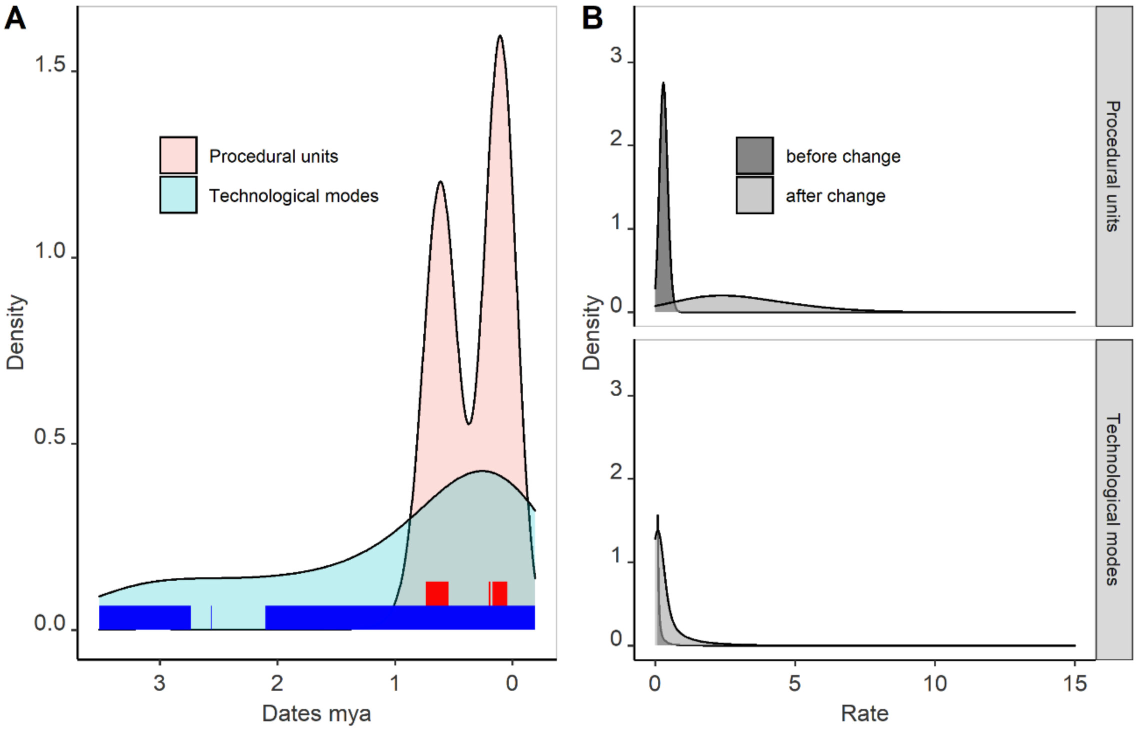


**Figure 2.10:** Left panel: Posterior distribution for the estimated date (k) of shift from slow, to rapid accumulation of procedural units (red) and modes (blue). Solid lines indicate the margin of the 90% discontinuous highest density intervals for the estimate of k. Right panel: estimated rates of accumulation before (dark gray) and after (light gray) the estimated shift towards higher rates.

### *How sensitive are date estimates of technological transitions to error?*

Various random and systematic sources of error may influence our perception of changes in technological complexity, rates of accumulation of cultural traits, as well as our ability to make inferences about the cultural abilities of extinct hominins. Sources of error can stem from the nature of the archaeological record, how sites and assemblages are studied and reported, error in measuring technological variation, and uncertainty in the true ages of sites. In this and the following section, I explore whether our estimate of a transition to rapid accumulation in the past 1 million years might be robust to those various sources of error and bias.

For example, lumping together technological behaviors of unrelated groups into the same analytical unit may result in overestimates of complexity. In most archaeological sites, debitage and tools represent accumulations of many behaviors that likely occurred across generations. These include the creation, modification, recycle, re-use, and transportation of artifacts. During excavation and analysis, these chaotic accumulations of many behaviors are lumped together into discrete assemblages, typically by stratigraphic unit. These assemblages are then studied, characterized and compared to others (Rezek et al., 2020). During this process, Archaeologists are may lump together artifacts that belong to distinct behavioral trajectories of different groups into discrete assemblages (Barton & Riel-Salvatore, 2014; Coco et al., 2020; Rezek et al., 2020; Vaquero, 2008). The degree to which lumping of unrelated technologies is likely to occur relates to the depositional environment of artifacts. For example, the products of unrelated behaviors are more likely to become lumped together if sedimentation rates are low (Barton & Clark, 1993; Tryon, 2019).

Even if archaeological sites represented evidence for the cultural repertoire of single groups, and if all time periods in hominin evolution were equally well represented, generating interpretations about what technologies were or were not present is still prone to error. Researchers are prone could misreport, or disagree in their interpretations about the presence or absence of manufacturing steps, types of tools, or technological strategies (Beck & Jones, 1989; Fish, 1978; Gnaden & Holdaway, 2000; Hodson et al., 1966; Perreault, 2018; Prentiss, 1998; Whittaker et al., 1998). When sites are excavated, there are often size thresholds below which artifacts are not collected, or not analyzed, which can obscure the presence of some kinds of core management techniques, and methods of producing tools (Towner & Warburton, 1990). Other natural processes, like patination, rolling, and battering may erase evidence of some kinds of behaviors, such as the abrasion of platforms. Likewise, trampling, and battering may also create features that mimic various kinds of retouch (Adler et al., 2014; de la Peña & Witelson, 2018; Harold Dibble et al., 1997).

Furthermore, after assemblages are analyzed, the information extracted needs to be further compressed into a paper. These include prose descriptions, tables of artifact counts, and illustrations of individual artifacts and schematics of the analyst's interpretation of how tools were made. In addition to the above sources of error, the analysis for this study involved condensing published reports, or an analyst's description into my interpretation of the presence or absence of particular technological features, and my own errors may contribute to skewing our perception of technological change.

In the previous section, I detected a shift towards more rapid accumulation likely in the past 1 million years, though this interval is more ambiguous for the technological mode data. Shifts in rates may be sensitive to uncertainty in the true dates of assemblages, and error in measuring tool-making sequence length, and technological diversity.

In this section, I investigate the extent to which uncertainty in the ages of assemblages, uncertainty in the true level of technological complexity, and the over-representation of recent sites in the archaeological record are likely to cause us to come to wrong conclusions about when a shift to more rapid accumulation may have occurred. To accomplish this, I took a simulation approach. I simulated 2000 new datasets, where new levels of complexity and new ages were drawn from random distributions parameterized by our original estimates. These simulated assemblages were then analyzed using the same Gibbs sampling algorithm described above.

For each of the procedural unit assemblages, and each technological mode assemblage, I drew new estimates of the total number of technological traits from a *Poisson* distribution, with an expected value given by the original total estimate. So, in the original dataset, if I counted the number of procedural units at Gona, and found three, when I resampled new estimates for Gona, I would draw from a *Poisson* distribution with an expected value of 3. That distribution would be narrow compared to the *Poisson* distributions for some of the later sites, with more procedural units. This way of modeling error is meant to represent how error in measuring complexity, or technological diversity, likely scales with the number of steps reported, or number of technologies reported. Archaeologists who study Oldowan tools probably will not differ immensely in their descriptions of how many steps are involved in making something like a chopper. Whereas in later assemblages, with many more kinds of things, there is likely greater room for misinterpretation and error. Some behaviors might erroneously become lumped together into one long tool-making sequence, or maybe in a long tool-making sequence, the researcher only focuses on the last few steps of the sequence. Drawing from a *Poisson* results in substantial deviation from our original estimate, and so represents a kind of worst case scenario.

To incorporate uncertainty in the true ages of assemblages, I also drew 5,000 new date estimates for each sample from a uniform distribution given by the reported date range for that assemblage. The result was 5,000 new datasets for both the procedural unit and technological diversity data, with varying estimates for technology, and age. Within each of the 5,000 simulated datasets, I identified the 1st through *n*th new level of complexity reached (the cumulative maxima across the dataset), measured the magnitude of each increase in the cumulative maxima to produce a time series. Across each of the 5,000 time series, I performed the same Gibbs sampling algorithm as described in section 4.3. For each of the 5,000 time series, 1,000 posterior estimates were produced for each of the three parameters: estimate date at which rates of accumulation increased, the estimated rate before that date, and the estimated rate after that date. The result was 5,000 chains, which I concatenated, and thinned by intervals of 20.

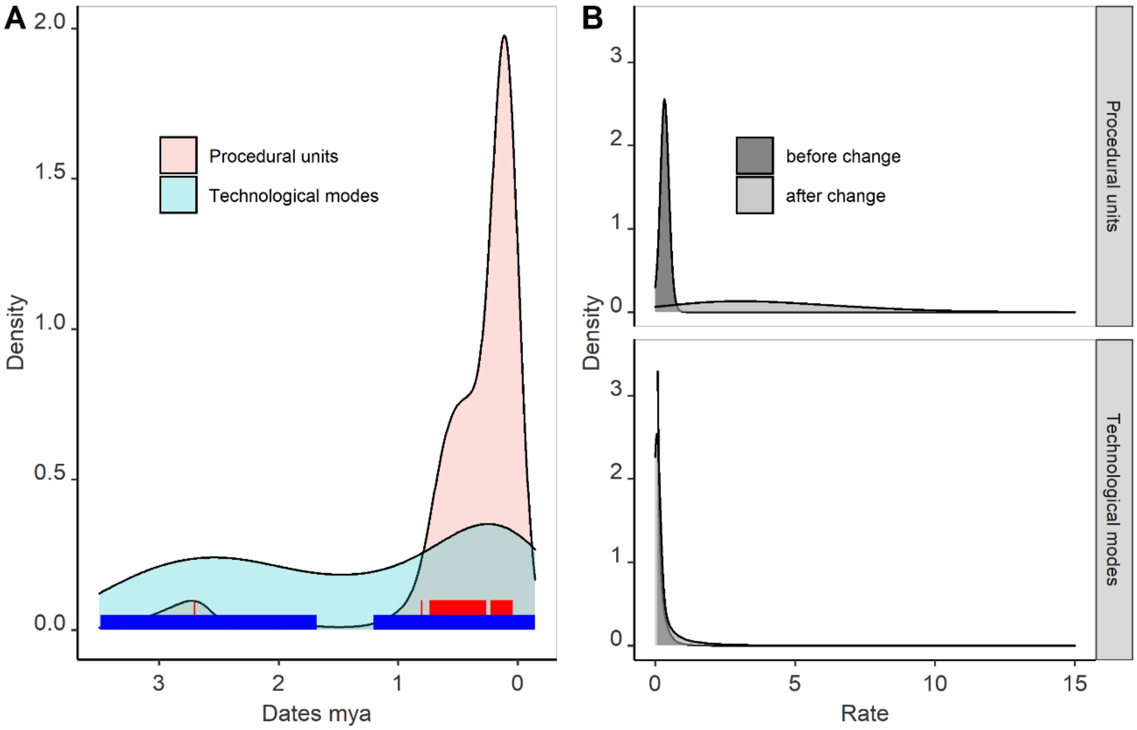


Figure 2.11: Left panel: Posterior distribution for the estimated date (k) of shift from slow, to rapid accumulation of procedural units (red) and modes (blue) based on 5,000 simulated datasets, where error in measuring time, and technology are incorporated. Solid lines indicate the margin of the 90% discontinuous highest density intervals for the estimate of k. Right panel: estimated rates of accumulation before (dark gray) and after (light gray) the estimated shift towards higher rates.

When I incorporate those sources of measurement error, the findings are very similar to the raw dataset. Among procedural units, the 90% highest density interval for the date of the shift is discontinuous and ranges between 0.04 and 2.71 mya. Before shifts to higher rates, new levels of complexity were reached slowly (0.13 to 0.57 procedural units per 100,000 years, 90% HDI). Rates after the shift can be an order of magnitude greater (0.40 to 7.72 procedural units per 100,000 years). The highest density interval for the estimate of *k* is discontinuous for the procedural units. There is a relatively high probability of the shift both at the start of the Oldowan ~2.7 mya, and within the past million years. Among modes there is far greater uncertainty about the timing of a shift towards more rapid accumulation. The 90% highest density interval spans the present, to 3.49 mya. Only the period There is also less evidence for a strong shift in accumulation (Figure 2.11, B). Rates of technological accumulation before and after proposed shifts are very similar, compared to the differences in rates before and after proposed shifts in the procedural unit data.

The similarity in findings between the raw and simulated data suggest that a shift towards rapid accumulation after ~800 thousand years ago is still likely in the procedural unit data, though again it would be inappropriate to reject the possibility that there has been little change in accumulation of technological modes from the earliest archaeological record onwards.

### ***Measuring the effect of taphonomic bias, in addition to measurement error on detecting shift in rates.***

Finally, in addition to error in measurement, and uncertainty about the true ages of sites, there is a strong over-representation of recent sites relative to older sites which could drive our perception of recent, rapid accumulation.

In the case of procedural units, there are 12 sites in the record prior to ~770 kya, and 44 sites more recent than 770 kya. In the case of modes, there are 58 prior, and 1137 after 770 kya. The overrepresentation of recent sites, and dearth of old sites may also produce misleading patterns of cultural change at a million year scale. The geological opportunities for sites to enter the archaeological record are uncommon, and geological processes tend to erode sites soon after their deposition (Surovell et al., 2009). As a consequence, there are more opportunities to sample a greater range of behavior, including short lived complex traditions, in the recent record. Conversely, if early hominins developed short lived experiments in rich technological practices or long tool-making sequences tailored to unusual circumstances, I may not have the sampling density to detect that evidence. This taphonomic bias could in part explain how the recent record includes more cases of complex reduction sequences, technologically rich assemblages, and more evidence for rapid change compared to the earliest record (Perreault, 2012).

To investigate whether the dates of shifts in rates are driven by over-representation of recent sites, I performed the same simulation and Gibbs sampling routine described above, but for each of the 5000 simulated datasets I sampled fewer assemblages post-dating 770 kya. The number of sites sampled from the past 770 ky is the number of assemblages dating between 770 kya and 3.3 mya, divided by that span of time. So, for each simulated dataset, I only selected ~3 assemblages for procedural units, and ~17 sites for technological modes from contexts more recent than 770. The 770 boundary was selected here as an arbitrary year needed to be selected for this analysis, and it marks the Brunhes-Mutuyama boundary after which point there tends to be greater number of sites reported compared to before, though this is not a sharp transition.

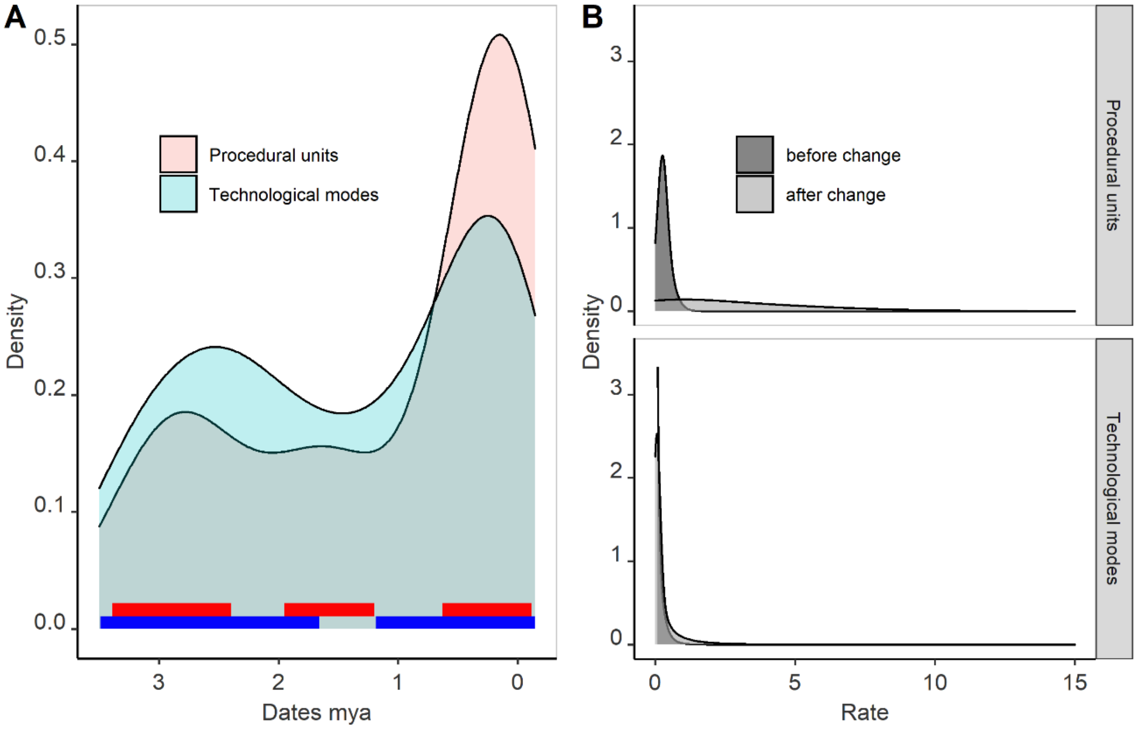


Figure 2.12: Left panel: Posterior distribution for the estimated date (k) of shift from slow, to rapid accumulation of procedural units (red) and modes (blue), among simulations where only a small number of sites from the past 770 ky were included. These simulations also incorporate error in measuring time, and technology. Solid lines indicate the margin of the discontinuous 90% highest density interval for the estimate of k. Right panel: estimated rates of accumulation before (dark gray) and after (light gray) the estimated shift towards higher rates.

When the simulated datasets compensate for the over-representation of recent sites, the result was much greater uncertainty about when in hominin evolution there was a shift towards rapid accumulation. The best supported breakpoints still are found in the past 1 million years for both tool-making sequence, and technological diversity data (Figure 2.12). However, estimates reach between 0 and 3.39 (90% HDI) for the procedural unit data, and 0 and 3.49 mya for the technological mode data (Figure 2.12). I suggest the recent shift in accumulation of complexity is robust to measurement error, but could be driven, in part, by over-representation of recent sites.

This result highlights the care with which we must assess technological change across hominin evolution. Taphonomic biases could in part be driving our perception of increases in technological complexity over time. A more obvious case of this would be the lack of preservation of wood artifacts in many kinds of environments. It is unclear, for example, when hominins first began manufacturing things like wood spears. The earliest examples of wood spears are in temperate environments of Northern Europe, ~500 kya at sites like Shoningen and Clacton-on-sea, both of which were waterlogged, anerobic sites (Allington-Jones, 2015; Milks, 2020). Such contexts dating to the Pleistocene likely do not exist outside of higher latitude environments. meaning that we can say very little about whether similar complex wood technologies were produced even earlier within Africa.

## Discussion

Through a comparative meta-analysis of previously published datasets (Nishiaki et al., 2021; Shea, 2013, 2020) and descriptions of assemblages, I found technological complexity increased from the earliest record through the Late Pleistocene and Holocene. Hominins, by ~1.8 mya relied on likely difficult-to-learn technologies compared to randomized flaking sequences, and chimpanzee technologies. Between the early record, ~3.3-.7 mya and the end of the late Pleistocene ~700-12 kya, the median number of procedural units and modes had doubled compared to that achieved between ~3.3 and .7

mya. Furthermore, in the late Pleistocene, there is little evidence for differences in technological complexity between modern humans, and their closest relatives. High levels of complexity and diversity shared between these species suggests a similar cultural ability to modern humans was shared with the common ancestor of *H. sapiens* and *H. neanderthalensis*. Based on the raw data, a shift towards rapid accumulation of technological variation and complexity likely occurred in the past million years, and could predate the earliest evidence of modern humans. This further suggests a shared cultural capacity between the LCA of modern humans and Neanderthals. A shift towards higher rates in the past million years appears robust to measurement error, but taphonomic bias may in part influence the perception of recent, rapid changes in technology, and slow rates of change in the earlier record. Nonetheless, when this bias is taken into account, the probability distribution describing when a shift to rapid accumulation occurred is neither uniform, nor skewed towards the early record. The best supported time periods still fall within the past 1 million years.

These findings, taken together with the fossil record, and other studies of Pleistocene material culture suggest hominins were relying on culture to transmit and maintain stone tool technologies ~1.8 million years ago, while modern-human like capacities for cumulative culture developed in the past million years, and were likely present in the LCA of *Homo neanderthalensis* and *Homo sapiens*. Fossil evidence for changes in life history, brain size, biomechanics of the hand, and archaeological evidence for complex behaviors, and previous studies measuring stone tool complexity are consistent with this time frame (Muller et al., 2017).

Modern human reliance on cumulative culture may stem in part from the way humans make their living. Early hominins entered foraging-technological niche that favored the evolution of traits that make cumulative culture possible: a longer life history, larger brain, biomechanical modifications to facilitate our reliance on tools, and mechanisms to make learning tool use easier (Antón et al., 2014). Across the primate guild, a greater reliance on difficult to learn foraging tasks predicts life-history and brain size variation (DeCasien et al., 2017; Schuppli et al., 2016). Modern humans rely on complex foraging tasks to make their living, and have specialized in these tasks across many kinds of habitats (Roberts & Stewart, 2018). A reliance on such complex, difficult to learn foraging tasks, especially applied to such diverse ecologies, is one context in which I expect a greater benefit to be gained from teaching (Gurven et al., 2020), and the evolution of a longer juvenille and post-reproductive period (Hawkes, 2020; Richerson & Boyd, 2020). The earliest potential evidence for these extractive, tool-assisted behaviors in the hominin lineage are represented in the tool-marks at Dikkika ~3.4 mya (McPherron et al., 2010). The earliest percussive stone tools, and flaked stone tools date to ~3.3 million years ago at Lomekwi 3, predating later Oldowan flaked tools ~2.8 mya likely associated with the earliest members of the genus Homo (Braun et al. 2019). Australopithicenes, and early hominins, may have relied on percussive tools to access marrow (Thompson et al., 2019), and chipped stone tools to scavenge meat (Blumenschine & Selvaggio, 1988; Dominguezrodrigo et al., 2005; Semaw et al., 2003). After ~2 mya the evidence for a reliance on hunting as a method of obtaining protein and fat becomes more clear (Diez-Martín et al., 2015; Ferraro et al., 2013). An increase in access to meat would have helped provided the energy for the increases in brain and body size observed across hominin evolution (Braun et al., 2010), and driven further changes in life history and biomechanics. From 3.3 mya through the earliest cases of modern humans, we see a tripling in brain size from ~450 $cm^3$ to ~1400 $cm^3$ (Antón et al., 2014; Du et al., 2018).

The first technologies above the primate technology and randomized flaking baselines date to ~1.8 mya and are associated with the evolution of *Homo erectus*. *Homo erectus* had a post-cranial anatomy very similar to modern humans. Relative to early hominins, they had a larger brain size, longer life history, and derived hand morphology (Antón et al., 2014; Tocheri et al., 2008; Ward et al., 2013). These changes are tied to an increasing reliance on meat, and other nutritious foods now made accessible through difficult-to-learn foraging techniques and habitual tool use (Antón et al., 2014; Thompson et al., 2019). These adaptations would likely have favored traits that made mastering technologies less costly. Nonetheless, Homo erectus did not share modern-human like life history This means life spans, and juvenile periods would have been comparatively short leaving less time for difficult-to-learn behaviors to be mastered (Kline et al., 2013; Nowell & White, 2010; Walker et al., 2002).

Many of the traits that we associate modern human capacities for cumulative culture are found after erectus, and likely were present in some form in the last common ancestor of Neanderthals and Modern Humans. The traits in common likely include a modern human-like life history (Ponce de Leon et al., 2008; Xing et al., 2019), large brain size (Galway-Witham et al., 2019; Hublin et al., 2015), and similar hand morphologies that would have supported delicate and forceful actions that help to support tool production and use (Key & Dunmore, 2018; Tocheri et al., 2008). However, the evidence is less clear about whether *Homo sapiens* and *Homo neanderthalensis* shared similar social structure, size of social networks, a pattern of residing with mostly unrelated individuals, and a reliance on cooperation.

A shift to rapid technological accumulation in the last 1 million years may predate the earliest evidence of modern humans. This timeline is consistent with previous work arguing that the most complex lithic technologies, and other difficult to discover and master behaviors are found soon after the Brunhes-Matuyama magnetic reversal ~770 kya, and in contexts not necessarily associated with modern humans. Previous studies argued that the most complex chipped stone technologies include Levallois methods of core preparation (Muller et al., 2017; Perreault et al., 2013; Stout, 2011). Hominins also began developing the most efficient methods of making flakes reported in the archaeological record ~300-100kya (Režek et al., 2018). Similarly, the bifacially flaked core-tools dating to ~500 kya at Boxgrove England likely require over a hundred hours of practice in addition to teaching with verbal instruction for modern humans to master (Pargeter et al., 2019). These were likely produced by *Homo heidelbergensis*. Other behavioral changes visible in the archaeological record indicate hominins like *Homo heidelbergensis*, and *Homo neanderthalensis* were likely relying on difficult to learn technologies with many steps involved in their production. Hominins at Gesher Benot-Yaaqov likely used fire to detoxify plants ~780,000 years ago. After 600 kya we begin to see the first evidence of clothing, art and symbolism, the manufacture of wood spears, and ochre use well before the earliest evidence of modern humans (Galway-Witham et al. 2019).

While other primates can do without it, modern humans cannot survive without cumulative culture. I suggest cumulative culture as modern humans practice it, evolved gradually from the earliest record onwards, with a form that meets the extended definition being reached prior to the evolution of the last common ancestor of Neanderthals and Modern Humans.

# CHAPTER 3: EVALUATING THE RELIABILITY OF LITHIC TECHNOLOGY FOR RECONSTRUCTING CULTURAL RELATIONSHIPS

Human culture varies across space and time because of interactions between groups, the passing on of cultural traditions to next generations, and local adaptations. Disentangling the relative contributions of each has been a longstanding goal in anthropology (Beheim & Bell, 2011; Boas, 1896; Mathew & Perreault, 2015; Shennan et al., 2015; Steward, 1972). Lithic technology in particular, represents the longest and most geographically widespread product of hominin culture, and interpreting its variability across space and time has been challenging. More specifically, there remains widespread disagreement about the extent to which lithic technologies are useful for inferring interaction, and shared history between groups in the archaeological record. Archaeologists often use tool forms and production techniques to infer historical dynamics across the Pleistocene, including cultural transmission between Neanderthals and *Homo sapiens* in Eurasia, cultural transmission among Homo sapiens populations in Africa, and the movements of hominins into new areas (Kolobova et al., 2020; Mellars, 2006; Rose et al., 2011; Scerri et al., 2014; Tostevin, 2013). Unfortunately, it is often unclear if similarities in lithic technology are due to common history, independent invention through adaptation to similar circumstances, or other unknown processes (O’Brien et al., 2018). In this chapter, I propose that if lithic technologies do retain reliable evidence for history, there should be substantial between-assemblage variation, relatively low frequency of convergence, and they should show strong patterns of spatio-temporal variability. Nearby assemblages should be more similar than very distant assemblages, and these patterns should be comparable to other cultural systems that do retain evidence of history.

One reason it is unclear if similarity in lithics is reliable evidence of cultural relatedness is that we have a poor understanding of how variable stone tool assemblages are in general. Any similarity (or lack thereof) between individual assemblages needs to be contrasted to the expected level similarity in the lithic record. Are assemblages more similar than the expected level of similarity in lithic technology in general? Answering this question requires a better understanding of the size of the morphospace of lithic technology, both the theoretical (what can be) and the realized one (what portion of the theoretical morphospace has been explored by hominins). The breadth, and depth of the realized morphospace of lithic technology, in itself, provides us clues on the general usefulness of lithics in reconstructing historical relationships. For instance, if the realized morphospace is small, this would suggest that hominins, experiencing a myriad of ecological circumstances over the last 3 million years, were drawn to a relatively small number of technological behaviors. This would imply, in turn that we should not expect lithics to reflect well underlying historical relationships of their makers, much in the same way that highly convergent traits in biology are unreliable indicator of phylogenetic distance. The reverse, i.e., a vast realized morphospace, would suggest that there is more likely to be the kind of between group variability that could allow a historical signal to be retained.

But there is another reason why we have a poor understanding of the potential for detecting historical signals in lithic technology. Above, I explained that similarities must have some reference to an expected level of similarity we would expect between randomly selected assemblages. This is a direct function of the size of the effective morphospace. But, this morphospace itself needs to be compared to other morphospaces. Why? Imagine that we find that the volume of the lithic morphospace is some quantity X. But what does X mean? Is this large? What is the minimum size if can be for technology to reliably contain historical signal? Thus, the question that needs to be answered is not merely "how large is the morphospace for lithic technology" but rather "how does the size of that morphospace compare to that of other morphospaces for things that we know, *a priori*, retain evidence of history? If other evolutionary traits, like language, have similar degrees of between group variability to lithic technologies, then this tells us something very different about the likelihood of convergence, and the potential for historical signal in lithic technology than if technology were far more constrained in its variability than language.

Finally, other kinds of traits, like languages, and genes have strong evidence of spatio-temporal patterning at multiple scales, from particular regions, to the global scale (Creanza et al. 2015). That spatio-temporal patterning is consistent with these evolutionary traits retaining evidence of history: nearby groups are more likely to share traits either through common history, or interaction, than spatio-temporally distant groups (Creanza et al., 2015; Shennan et al., 2015; Shennan, 2020). While this isolation-by-distance can also be caused be adaptation to local environments that themselves have spatio-temporal patterning, a lack of isolation by distance or weak isolation by distance would highlight very low potential for strong historical signal. Determining if technological variation has similar spatio-temporal patterning to these other systems, which we know do retain evidence of history, will help us to further assess the capacity for historical signal in stone tool technology. By studying variability across space and time in technologies, and other cultural systems, like language, we can further assess whether statistical signals we know relate to usefulness of traits for reconstructing histories, are stronger, or weaker in technology than in language.

In this study, I set out to answer two broad questions both involving measuring statistics that should relate closely to the potential strength of historical signal in lithic technology. First, is convergence more likely in lithic technology than in language? If so, this would suggest lithic technologies should have weaker capacity to retain evidence of history. Second, is isolation-by-distance weaker in lithic technology than in language? Again, if so, this would suggest a lesser capacity for historical signal in lithic technology. Answering both questions will help us develop a stronger theoretical foundation for making assessments about historical signal in lithic technology.

## Theoretical background:

Archaeological research focused on reconstructing migrations, connections between populations, or ancestor-descendant relationships through stone tool variability tend to follow two broad approaches: the diagnostic approach, and the phylogenetic approach. Both approaches assume that similarity in technology reflect underlying historical relationships. In the diagnostic approach, the focus is on attributing material to particular analytical units. These units are considered to represent shared technological practices of some group, whether it be a community of practice, a lithic industry, or even species (Maher & Macdonald, 2020; Masojć et al., 2021; Rose et al., 2011). In this approach, assemblages or individual tools are fit into one of many possible categories, or they are used to define new categories. Often these categories represent types, industries, or technocomplexes, or a subdivision of one of those entities (i.e. the Kou Point, Proto-Aurignacian, Acheulean, Sultanian, Khiamian) (Reynolds, 2020). Here, some kinds of traits, when they are shared between two assemblages, are described as resulting from some kind of historical connection. In the case of the Acheulean, it could be that all hominins who made Acheulean technologies are part of one coherent learning tradition that spanned Africa and Eurasia, for over a million years. In the case of the Khiamian, it is argued to represent a cultural tradition that existed for a few hundred years localized to the Southern Levant (Smith et al., 2016). Assemblages are tied into one of these categories often based on the presence, or relative frequencies of various "Fossil Directeurs" (Reynolds, 2020). These can be particular tool forms, or particular methods of reducing cores. For example, there are many kinds of technologies present in the Pre-Pottery Neolithic of the Southern Levant. However, only a few are diagnostic to particular techno-complexes. The Khiamian is defined by the presence of el-Khiam points, small truncated blades fashioned into points with bilateral notching above the base. In contrast, the "Sultanian" industry is marked by an absence or small frequency of el-Khiam points, and the presence of large backed blades called Beit-Tamir knives, and a higher frequency of burins (Smith et al., 2016).

One goal of the diagnostic process is to identify distinct kinds of social relationships based on technological variation. These include attempts to identify social boundaries and groups with shared identities, or learning traditions that might cross-cut group boundaries. To distinguish between these different processes, several different approaches to studying and interpreting stylistic variation have accumulated (Carr, 1995; Jeffery J. Clark, 2001; Conkey & Hastorf, 1990; Gosselain, 2000; Hegmon, 1992; Hodder et al., 1982; Lemonnier, 1986; Wiessner, 1983, 1984; Wobst, 1977a). Broadly speaking, style is proposed as variation in material culture that bears information useful for reconstructing social relationships, and while there are many proposed types of style (see Hegmon 1992, Conkey 1990, Wiessner 1984) it is useful to discuss them as belonging to two broad categories: active and passive (Barton 1997). Active styles, are those intended to communicate or signal some kind of information to others, like status, political, family or group affiliation (Bowser, 2000; Hart & Engelbrecht, 2012; Hegmon, 1992; Lycett, 2017). Alternatively, the forms of artifacts and techniques involved in their production, may be produced and reproduced without the intent of signaling identity. These cases would be encompassed by passive style (Barton, 1997; Conkey & Hastorf, 1990; Neiman, 1995; Plog, 1995; Sackett, 1982) In such cases, similarities in material culture, or in the technological decisions that produced different kinds of material culture, may reflect the proximity of social ties between makers. Here, similarity or dissimilarity in these cases could entail membership in the same, or distinct communities of practice or learning traditions (Lemmonier 1986, Gosselain 1998, Gosselain 1992:572. Dietler and Herbich 1989).

For example, communities of pot-makers differ in the kinds of idiosyncratic choices they make during the production process. While pots were traded widely, the know how of those production sequences are not as likely to be transmitted readily between learning communities (Dietler & Herbich, 1989; Gosselain, 1992, 1998; Lemonnier, 1986). So, when we find idiosyncratic methods of producing things common in one region, later practiced in another, this may represent strong evidence of migration (Jeffery J. Clark, 2001; Jeffery J. Clark & Lyons, 2012; Hegmon et al., 2000; Neuzil, 2005). Tying technological variability to particular groups is used to answer questions about historical relationships at a spatio-temporally narrow scale, between different groups in the ethnographic present, or among archaeological sites separated by only a few generations (Dietler & Herbich, 1989; Matthew A Peeples, 2018; Mills et al., 2013; Neuzil, 2005; Wiessner, 1984, 1984; Wobst, 1977b).

The success of the diagnostic approach at spatio-temporally narrow scales is used as part of the argument for a middle-range theory linking technological variability to history in the archaeological record, where assemblages may be separated by thousands of years and kilometers (Hutchence & Scott, 2021; Kolobova et al., 2020; Mellars, 2006; Rose et al., 2011; Tostevin, 2013; White et al., 1982; Wobst, 1974). In the Paleolithic, the recipes for making tools, for example, are proposed as more reliable markers of shared history, and migration than similarities in the forms of final products (Sackett, 1982; Tostevin, 2013). Nonetheless, as the spatio-temporal scales of comparison increase, convergence becomes an increasingly likely explanation for similarity between assemblages. Exactly how far apart assemblages must be for convergence to be a more likely explanation for similarity than shared history is not clear, and this threshold differs substantially between researchers (Kuhn & Zwyns, 2018; Will & Mackay, 2020).

In the phylogenetic approach, the goal is often to infer the evolutionary histories of material culture using tools and models borrowed from paleobiology, such as the generation of phylogenetic models based on stone tool variation. In evolutionary systems, phylogenetic or historical signals represent tendencies of related groups to be more alike than unrelated groups. When historical signals are strong, similarity is a reliable proxy for relatedness. When signals are weak, similarity is an unreliable proxy (Kamilar & Cooper, 2013). Historical signals may emerge between any two contexts, be they individuals or groups, adjacent to one another or thousands of kilometers apart, contemporaneous or separated by many generations. In all cases they are caused by inheritance from the same or related pools of cultural information through social network ties that link individuals across time and space. This results in statistical dependence between the form of that information, and historical relationships (Creanza et al., 2015; Levinson & Gray, 2012; Lycett & von Cramon-Taubadel, 2016). Phylogenetic models are often used to evaluate proposals about the histories of particular technologies, like whether or not particular kind of technologies were independently invented, or were historically related to other technologies (Lycett, 2009, 2007). For example, the attributes of Levallois cores, and other prepared core technologies in the Victoria West tradition, fit best a phylogenetic model in which the Victoria West tradition developed independently of Levallois technology (Lycett, 2009). Many of the phylogenetic approaches have been applied to bifacially flaked points in North America. Here, the phylogenetic distance between artifacts is argued to reflect underlying population dynamics and interaction networks (O’Brien et al. (2016)).

Importantly, both approaches infer the history based variation in lithic technology, whether researchers are interested in phylogenetic reconstructions, or in tying assemblages to the same or related cultures. As such, both approaches must face the same issues that can complicate historical inference. I discuss below in an evolutionary framework three factors that are likely to influence between-assemblage variability, the frequency of convergence: 1) the size of the lithic morphospace, 2) the topography of fitness landscapes, and 3) developmental biases.

### ***Morphospace size and historical signal***

Strong historical signals in evolutionary traits require some potential for between group variability. However, the options available for life to explore are not limitless. Morphospaces describe the range of possible forms a trait may take (McGhee, 2015; Raup, 1967). The traits in question can be simple (the length of a bat’s wing), to complex (a multidimensional representation of hominin cranial shape), and could represent more abstract concepts (the kinds of possible marriage norms a society could follow) (Passmore & Jordan, 2020). Morphospaces are hierarchically organized. First there is the theoretical morphospace. This theoretical morphospace encompasses all forms that are theoretically possible, whether or not they have been explored, and whether or not these are associated with lesser or greater fitness. For example, the production of flakes that are meters as opposed to centimeters long is theoretically possible, but likely has not been achieved by humans given the immense amount of energy needed to achieve such a fracture, as well as access to an appropriate raw material. More interesting for the purposes of this study is the realized morphospace. This is the subset of the theoretical morphospace that has been explored.

The breadth of the realized morphospace influences the strength of historical signals. This is because historical inference relies on a healthy amount of between group variability. If there is little room for between group variability, then between group similarities and differences are unlikely to be reliable sources of evidence for relatedness. This is because restricted morphospaces have less potential for inter-group variation, and fewer possible solutions to problems (Donoghue & Ree, 2000; Revell et al., 2008). In contrast, systems with broad morphospaces have more potential for between group differences, and distinct historical trajectories. The wide potential for between group variability is part of why linguists are able to reconstruct the histories of languages using phylogenetic approaches and the comparative method (Gray et al., 2010; Greenhill et al., 2020), and why genetic data are useful for reconstructing population histories (Degnan & Rosenberg, 2009).

Stone tool technologies are thought to have relatively restricted theoretical, and realized morphospaces. For example, the morphospace of chipped stone technology is likely determined in largely by constraints on flake forms (McGhee, 2018; Moore, 2011; O’Brien et al., 2018). During reduction, variables like the depth and angle of a core platform, the convexity of the core face, the orientation of dorsal scars, the percussor used, the angle and strength of the blow, and the characteristics of the raw material all influence the morphology of a flake and the core from which it was struck. Some of these variables do not vary independently and their relationships may differ by raw material type (Dibble & Rezek, 2009; Lin et al., 2013; Moore, 2011). All of these factors limit the number of possible artifact forms (Cotterell & Kamminga, 1987; Dibble & Whittaker, 1981a; McPherron et al., 2020; Moore, 2011; Pelcin, 1997; Speth, 1972).

While the form of individual flakes may be relatively restricted, flake removals and other flintknapping actions can be chained together in very distinctive ways. Thus, there is likely more potential variability in how technologies can be organized, than in the forms of flakes. As outlined in Chapter 1, human cumulative culture involves groups learning, modifying, and passing on behaviors with multiple functionally dependent steps, like recipes (Mesoudi & Thornton, 2018). Imagine a branching landscape with nodes, representing particular behaviors or steps in a recipe. Each behavior or node can be joined by branches which represent the functional linkages between traits, or the recipe instructions. The base of this behavioral tree, or its trunk, represents a behavior upon which all further behaviors are built. Stone tool *Chaînes opératoires* similarly are made up of several steps, some of which may be functionally dependent on the others (Audouze & Karlin, 2017). Those steps can be added, or lost, and different regions of the technological tree may be explored. That such a diverse tree could be explored through removal of flakes from a core, is part of why archaeologists following either diagnostic or phylogenetic approaches are often interested not just in the metric properties of particular artifacts, but the chains of actions that were performed to produce artifacts. Studying variability in technological decision making is a core Anthropological approach to identifying shared learning contexts, and historical connections (Jeffery J. Clark, 2001; Sackett, 1982; Tostevin, 2013). In particular, technological sequences are often proposed to be particularly effective at identifying shared learning traditions, and have been measured to detect small scale population movements at the scale of hundreds of kilometers, and a few generations (Jeffery J. Clark, 2001; Cochrane, 2018; Neuzil, 2005). The same underlying reasoning has been applied to much larger spatio-temporal scales of analysis, thousands of years, and kilometers in the case of studies of Paleolithic stone tools (Sackett, 1982; Scerri et al., 2014; Tostevin, 2013).

Nonetheless, some regions of the technological tree are difficult, or impossible to reach given the constraints of flake forms. For example, producing flakes from platforms that are near 90 degrees is difficult to perform consistently with control over the shape of the resulting flake and core (Cotterell & Kamminga, 1987; Dibble & Whittaker, 1981b). As a consequence, it is difficult, to flake a stone adze with a square cross section, though several tricks make it possible (Clarkson et al., 2015). These include treating the inside of pronounced bulb of percussion negatives as platforms, indirect percussion, and manipulating the termination of flakes using an anvil (Clarkson et al., 2015). There are similar problems with knapping long thin and narrow blades by freehand percussion that are overcome through use of indirect percussion, and application of pressure to punch flakes from cores. Nonetheless, there are no recorded instances of adzes flaked with five sides, though they may be theoretically possible. Maintaining each of the five sides would mean having to maintain, and strike flakes from platforms that are more obtuse than 90 degrees while maintaining control over the shape and size of the flake. Without such control, the adze would split, or one of the other four carefully maintained platforms could be accidentally removed by an overshot flake.

In sum, while the morphospaces of individual artifacts are relatively well understood, the realized morphospace of technologies, and how close together prehistoric groups were in that space is not clear. Since technological decision making plays a strong role in diagnostic, and phylogenetic approaches to studying prehistoric lithic technologies, this is a big problem. Through measuring variability systematically across the archaeological record, we can develop a stronger idea of how much between group variation has evolved over the past 3 million years, and if that amount of variability is more or less consistent with a broad realized morphospace, and higher potential for reliable historical inference.

### ***Fitness landscapes, developmental constraints and historical signal***

What influences which areas of the theoretical morphospace are likely to be explored by groups in the past? The theoretical morphospace for technology could be vast, but within that morphospace many forms may not be practical, or may incur too high a cost for them to be maintained across generations, or might have developmental requirements that are not yet met. There may also be higher fitness forms that theoretically could be adopted by a group, but those forms could be separated from the group’s current practices by a deep and wide fitness valley. These factors will influence whether the realized morphospace is relatively large, or narrow. For example, Raup (1967) developed a mathematical formula that described the various kinds of shell morphologies that should be possible among mollusks. However, only a very narrow subset of those forms have actually been explored either by extant, or fossil mollusk species (McGhee, 2018; Raup, 1967). There may be only a few viable strategies for evolution to explore, leading to only a narrow subset of the morphospace being explored (Losos, 2011). If those viable strategies are adaptive across many kinds of environments this would mean that groups will converge on a narrow range of forms without ever interacting with one another (Losos, 2011).

As outlined in chapter 1, the technological tree metaphor assumes a dizzying number of potential combinations of traits and the potential for stark inter-assemblage differences in technology. However, it is unclear if human groups explored trees like this for lithics, or if groups tended instead to be drawn to a relatively small number of branches in the lithic technological tree (McGhee, 2018). The constraints on flake forms provide limits to the theoretical lithic morphospace, but they also lead to limitations on what kinds of technological strategies are more or less efficient, or which are likely to have lesser, or greater payoffs. For example, Brantingham and Kuhn (2014) proposed a theoretical morphospace for prepared bifacial hierarchical cores, including Levallois cores. Such cores must operate within constraints on flake and core forms, while still supplying pieces worth the time of the knapper. They found that while there are many potential ways to orient flaking surfaces and platforms of a prepared core, deviations from a tight range of core geometries rapidly decreases the efficiency of flaking. As we might expect, wherever cases of prepared bifacial cores are found their morphologies tend to fall within that narrow range of morphological variation they identified as being the most efficient (Adler et al., 2014; Brantingham & Kuhn, 2001). Thus, if we assume that hominins tended to maximize the payoffs associated with making tools (Herzog & Goodale, 2019), we should expect different human groups to occasionally reach the same peak in the fitness landscape, and we should expect this to happen more frequently if the realized morphospace is narrow.

Some regions of morphospaces might not be explored because of developmental biases (Uller et al., 2018). The growth of organisms is often controlled by strict, phylogenetically conserved programs including gene regulatory networks (Davidson & Levine, 2008; Verd et al., 2019). Developmental biases, like regulatory networks, influence how independently individual traits can vary, which can negatively influence historical reconstructions. Phylogenetic analyses often assume that the traits being compared vary independently of one another (Brocklehurst & Benevento, 2020). For example, dental traits are often used to infer the phylogenetic relationships between fossil taxa due to their durability, and diversity of morphologies. However, dental traits strongly covary with one another, in large part due to how traits are linked through development (Kangas et al., 2004). Many traits are so tightly integrated that they can be considered as discrete modules with their own histories (Brocklehurst & Benevento, 2020; Goswami & Polly, 2010). These developmental biases may result in path dependence within lineages, such that the kinds of traits present among the ancestors of a population will in part determine what kinds of traits are likely to evolve in the future.

Developmental biases are not as well understood in technologies, though they likely influence the historical trajectories of technological traditions. The physical constraints of flintknapping itself, as described above, can be thought of as developmental constraints, as can the kinds of technological practices a group has, and the norms, attitudes and worldviews that relate to technology. These all could influence what other technologies are likely to develop or become accepted, and how tightly integrated different cultural and technological practices might be (Knappett & van der Leeuw, 2014). For example, Levallois reduction incorporates and builds upon many elements of bifacial core reduction. The earliest Levallois core technologies are also in close association with bifacial core tools (Tryon et al., 2006). In contrast to proposals that link expansion of Levallois technology to particular hominin expansions (Armitage et al., 2011; Lahr & Foley, 1997; Valladas et al., 2013), it may be that reliance on bifacial core technology across Africa and Eurasia provided hominins with the technical knowledge to more easily develop Levallois methods of core reduction in multiple areas independently (Adler et al., 2014; Tryon et al., 2006).

Similar developmental biases may have spurred rapid change in technology. For example, in New Zealand, formal blade production on large silcrete cores began within a generation or two of the first human settlements (Leach, 1969). Blade production is argued to be an adaptation to butchering the *Moa* which were the only terrestrial megafauna in Polynesia. How blade technology developed so quickly, when there is little evidence for blade production elsewhere in Oceania at the time has long been a puzzle (Wilson, 1999). However, many of the techniques involved in making silcrete blades are also practiced in the production of quadrangular adzes, which are common across Polynesia, and New Zealand. The debitage from both reduction processes as practiced in New Zealand are also very similar, and blades are sometimes produced as byproducts of adze manufacture. Based on these findings, Leach (1969) suggested that despite leading to very different final products, developing blade production was enabled by the existing reliance on adze production. Both the Levallois and New Zealand blade technology examples highlight how developmental biases may channel groups into specific parts of the technological morphospace, an example of path dependence.

### ***Problems with measuring the realized morphospace.***

While the size and shape of the realized technological morphospace is very important for understanding the potential for historical signal, there have been few attempts to measure it. This is in large part because of a lack of systematic comparisons between assemblages at a global scale. Such large scale analyses are necessary to explore both the realized morphospace for lithic technology, and how selection and developmental biases could structures variability across space and time. So, why are systematic comparisons of lithic variability at a global scale rare? Much of the research on technological change at broader scales has relied on technocomplexes, and lithic industries as units of analysis (Geoffrey Clark & Riel-Salvatore, 2006; Shea, 2014a; Wilkins, 2020). While suited for answering some questions, industries and technocomplexes mask how much variability they contain, and it is often difficult to formalize how much any two technocomplexes differ. This makes these analytical units unreliable for comparative research, and weak fuel for statistical and computational analyses (Barton & Clark, 2021; Reynolds, 2020; Shea, 2014b; Wilkins, 2020).

Alternative approaches to characterizing variability in terms of industries, and technocomplexes are fast developing, though quantification of lithic variability at a million year scale is not common, and tends to be limited to particular artifact classes, like flakes (Režek et al., 2018). In the case of flakes, there are broad evolutionary trajectories over the past 2 million years such that later hominins have been more successful at exploring more efficient methods of producing flakes (Rezek et al. 2018). Similarly, Hayden (1987) explored evolution of different methods of sharpening, from retouch, to the production of sharpened, abraded edges during the Holocene. As we might expect given the physical constraints on flake forms, there is broad overlap in flaking efficiency between populations separated by thousands of kilometers and hundreds of thousands of years. In contrast, systematic methods of measuring variability in technology in terms of the presence or absence of different kinds technological practices have highlighted substantial within-region similarity, and between region dissimilarity spanning the MP-UP transition in Asia (Nishiaki et al., 2021). This study builds on these comparative approaches.

However, measurements of the realized morphospace are not enough to draw strong conclusions about the potential for historical signal. It is useful to also have another frame of reference, or yardstick to compare lithic technology. In this study, phonemes in languages serve this purpose.

### ***Languages as a comparison system to global patterns in lithic technology***

Linguistic segments, or phonemes, are useful cultural traits to compare to procedural units and technological modes for several reasons. Linguistic segments are discrete sounds that can be identified in speech. Each segment itself has a suite of features, or some element of speech that can be independently controlled, like whether or not the sound is made through labial action, or by circulating air through the nose, or whether or not a particular feature is aspirated. Segments are identified in a language by encoding spoken speech, and identifying which of the many possible segments are present. Because any language's sounds can be coded as segments, and because of their irreducible nature, they are frequently studied as evolutionary traits in comparative studies of linguistic variation (Kirby & Sonderegger, 2013), and while they are not ideal for reconstructing relationships between languages, phonological inventories and phonotactics have been shown to have historical signals (Dockum, 2018; Macklin-Cordes et al., 2020), as well as strong evidence for spatial isolation by distance. In the context of this study, linguistic segments can be characterized as presence absence data, and so can be studied using the same statistical tools as the technological mode and procedural unit data.

In summary, while the morphospace of lithic technology could be very broad, shapes of fitness landscapes and the nature of developmental biases may channel hominins into exploring a much narrower subset of that space. By measuring how much variability there is between lithic assemblages we can begin to narrow down what kinds of technological spaces hominins explored. It may be that the morphospace is broad, and has many fitness peaks. Also, developmental biases may not tend to cause unrelated groups to develop similar technologies. In this case, we should expect broad between group differences. In contrast, narrow morphospaces, fitness landscapes with few peaks, and strong developmental biases may tend to channel hominins to the same sets of technological practices independently of one another. In this case, we would expect to find relatively little between-assemblage variability, and higher frequency of convergent evolution.

## Convergence in lithic technology and language

What are the chances that two groups develop the same technology, independently of one another? In order to investigate whether the expansion of the realized morphospace over the past 3 million years led to distinct historical trajectories, or to hominins tending to repeatedly move into the same or nearby regions of the morphospace, I focus here on measuring how often similarities in technological inventories are found in widely separated contexts. A multi-million year, multi-continent sample is a great dataset within which to identify cases of convergence as very similar assemblages separated by thousands of kilometers and hundreds of thousands of years are unlikely to be caused by any process aside from convergence. In the following section, I focus first on measuring how much between-assemblage variability there is relative to between language variability at a global scale, and then on assessing how often we find instances of convergence in both the language, and technological datasets.

The challenge here is to detect cases of probable convergence without a fully resolved phylogenetic tree or network describing the true historical relationships between groups. In this study, we only have the similarity in trait inventories, as well as their distance in space and time. I compiled two kinds of data to explore how variable lithic technologies tend to be: data about the broad artifact types and technological practices present in assemblages using Shea's technological mode system (Shea, 2013) and information about the discrete steps involved in making stone tools using the procedural unit system (Maloney, 2019; Perreault et al., 2013). Both technological modes and procedural units measure variation in technological decision making, and so are congruent with anthropological approaches to identifying shared learning contexts, and historical connections (Jeffery J. Clark, 2001; Sackett, 1982; Tostevin, 2013). I then measured technological distances between each pair of assemblages, as well as their separation in time and space as summarized below.

### ***Mode data***

The Mode system proposed by John Shea (2013) characterizes assemblages through the presence or absence of distinct kinds of artifact classes. Technological modes that might be present in an assemblage might include core types (variations of unifacial hierarchical cores, variations of bifacial hierarchical cores, bipolar, and non-hierarchical pebble cores), types of retouched pieces in the assemblage (microliths, burins, points), types of core tools, and other modes (Table 3.1).

**Table 3.1**: Technological modes analyzed in this study and their short descriptions based on Shea (2013, 2016, and 2020). Modes D encompasses different retouched tool types, Modes E encompass bifacial core tools, Modes F encompass bifacial hierarchical cores, such as Levallois, Modes G encompass hierarchical cores with one dominant platform.

| Technological modes | Short description |
|---|---|
| B. Bipolar cores | Use of hammer and anvil to produce flakes |
| C. Pebble cores | non-hierarchical flake removal |
| D1. Retouched pieces with acute edges | |
| D2. Backed pieces | Includes pieces with retouch approaching 90\degree |
| D3. Microliths | Backed pieces < 3cm |
| D4. Burins | Burins, burin spalls, tranchet flakes' |
| D5. Points | Awls, convergent scrapers, points |
| D6. Tanged piece | Basal retouch/notching forms a tang |
| D7. Core-on-flake | Detaching of flakes from other flakes |
| E1. Large cutting tool | Handaxes, cleavers, and picks |
| E2. Thinned biface | Thinned bifaces: follate and laurel leaf type artifacts |
| E3. Tanged biface | Retouch forms a tang on proximal margin of core tool |
| E4. Celt | Core tools flaked to produce sharp distal edge |
| F1. Preferential bifacial hierarchical core | Preferential Levallois |
| F2. Recurrent laminar bifacial hierarchical core | Recurrent Levallois |
| F3. Radial centripetal bifacial hierarchical core | Centripetal Levallois |
| G1. Platform unidirectional hierarchical core | Single platform flake cores |
| G2. Blade core | Single platform blade cores |

| Technological modes | Short description |
|---|---|
| G3. Microblade core | Single platform microblade cores |
| H. Edge abraded tool | Edges sharpened through abrasion |
| I. Groundstone | Tools produced through pecking and grinding |

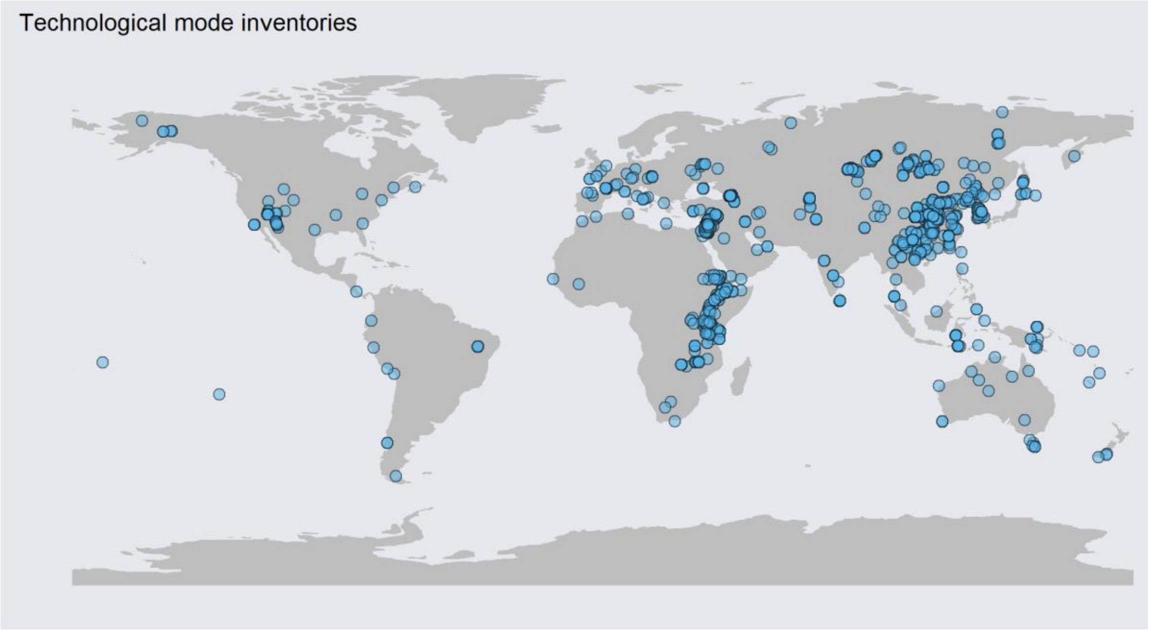


**Figure 3.1:** Map of all 1125 technological mode inventories.

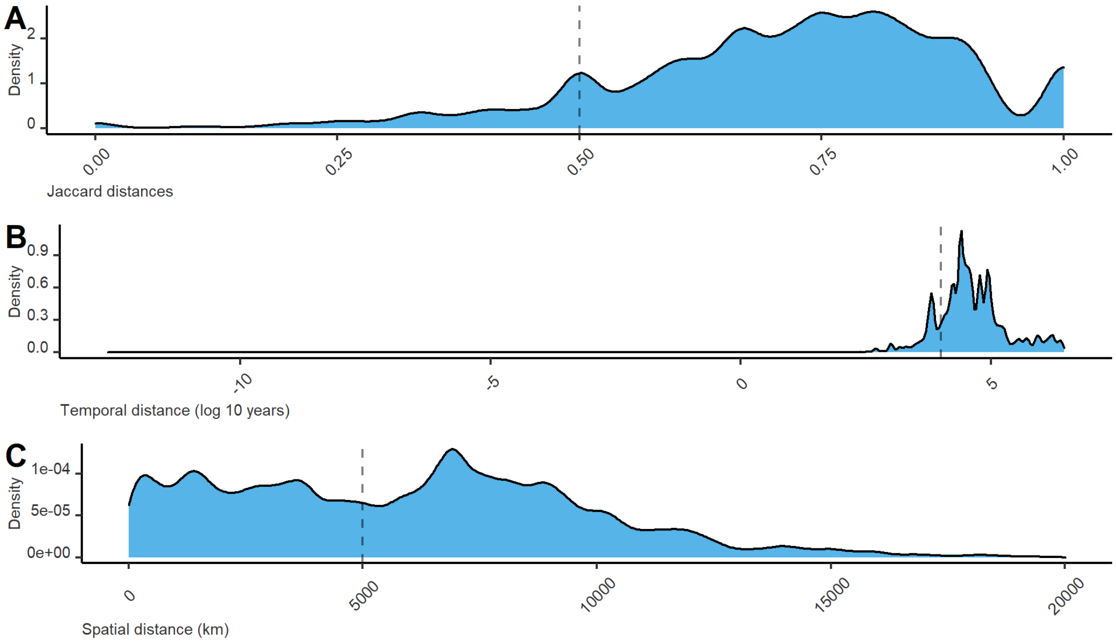


**Figure 3.2:** Summary of pairwise Jaccard (A), temporal (B), and the haversine/spatial distance between each pair (C). Vertical dashed lines indicate the thresholds used to define convergence: the 10th percentile of Jaccard distance, temporal distances of 10,000 years, and spatial distances of 5,000 km

The mode dataset includes the presence or absence of any one of 21 technological modes across 1125 assemblages (Shea, 2016, 2020). Of those, 393 were collected by John Shea (2016, 2020), and 667 assemblages in Asia were reported by Nishiaki et al. (2021) as part of the *PaleoAsiaDB* project. I collected further data on 64 assemblages. To prepare these data for analysis, I counted all modes coded as questionable "?" by the original author as absent. Overarching modes D, E, and F, were excluded and their sub-modes were included, to avoid double counting. I did not develop a codebook for the mode dataset, as the standards and definitions of those modes are clearly defined in the literature (Shea 2016, 2020).

### ***Procedural unit data***

Procedural units are discrete, mutually exclusive manufacturing steps involved in the production of tools (Maloney, 2019; Perreault et al., 2013). The procedural unit system was originally developed to characterize the complexity of stone tool making systems. However, they are also a means of characterizing within and between group technological variability. For example, one assemblage might have evidence for bipolar percussion using both a hard hammer and an anvil, and the production of flakes from single platform cores with their platforms prepared and rejuvenated, while another assemblage may not have bipolar percussion, single platform cores that might have their platforms prepared, but never rejuvenated. With the procedural unit system, both assemblages are broken down into two directly comparable presence/absence vectors. The first assemblage would have both procedural units associated with bipolar percussion, and the units associated with prepared and rejuvenated single platform cores counted as present (like use of a hard hammer, use of an anvil, platform preparation by abrasion, platform preparation by microchipping, and platform rejuvenation through core tablets), while the second assemblage would only have units associated with prepared single platform cores (use of a hard hammer, platform preparation by abrasion and microchipping) counted as present. One strength of this system is that it can capture relatively subtle differences between assemblages, such as differences in how core platforms are prepared between sites. However, the system does not capture differences in how procedural units might be bundled together, or the order in which procedural units were employed. For example, it may be that two assemblages have the same sets of procedural units (invasive flaking, flaking with a soft hammer, platform abrasion) that are applied in different orders to produce very different kinds of core technologies like blade cores at one assemblage, and bifacial cores in another.

**Table 3.2**: Procedural units and their short definitions. In this study, all procedural units reported, or observable based on illustrations and tables of artifact types were described as present. This included procedural units belonging to separate reduction sequences.

| Procedural units | Short description |
|---|---|
| Heat treatment | Heat treatment used to improve flake-ability |
| Platform facetting | Platform morphology modified by striking flakes across platform |
| Centripetal shaping | Convexities maintained through centripetal removals |
| Lateral shaping | Flakes struck from lateral margins of core to maintain convexities |
| Distal shaping | Convexities maintained through flakes struck from distal edge of core |
| Back shaping | Back of the core is shaped. |
| Cresting | Cresting to shape core face during initial steps of core preparation. |
| Debordante shaping | Convexities maintained through flakes along lateral margins of core face |
| Overshot flaking | Invasive flake removals that clip or remove the distal margin of the core |
| Kombewa flaking | Removal of flake from ventral surface of a flake |
| Core tablet | Removal of core platform by striking flake into face |
| Abrasion | Abrasion or grinding performed at any point in reduction sequence. |

| Procedural units | Short description |
|---|---|
| Trimming platform overhang | Removal of chips to modify area below platform. |
| Use of an anvil | Use of an anvil |
| Soft hammer percussion | use of a soft hammer |
| Indirect percussion | Use of a punch to remove flakes |
| Flaking through pressure | Removal of flakes through application of pressure on core platform |
| Hammer dressing | Modification of a piece through pecking |
| Invasive flaking | Removal of non-cortical flakes that extend beyond the midpoint of the piece |
| Retouch | Retouch of flake or core tool (unifacial only) |
| Backing | Retouch forms an abrupt, scraper-like margin |
| Notching | Retouch forms round concavity |
| Burination | Removal of spalls along the margins of flakes |
| Tanging | Retouching base of piece to form a tang |
| Tranchet | rejuvenation of core tool by striking a flake across the edge |
| Bifacial retouch | Retouch on both faces of a flake or core-tool |
| Invasive retouch | Retouch that extends to the midline of a tool |
| Pressure flaked retouch | Pressure flaking retouch |

The procedural unit dataset includes the presence or absence of any one of 28 procedural units across 81 assemblages (table 3.2). These data were collected from the literature. In order to make the coding process replicable, I produced a codebook outlining the standards by which I would count any given procedural unit as present or absent. This codebook follows the structure of those developed at the Center for Disease Control for processing interview transcripts, and serves to prevent coders from applying their own heuristics to the coding process (MacQueen et al., 1998). The structure of the codebook include definitions of the code (for example, the definition of *debordante*), but also explicit inclusion and exclusion criteria, as well as written phrases, terms, and example illustrations that would be typical and atypical evidence sufficient to code the procedural unit as present. The codebook also includes examples that are close, but not sufficient to code the technique as present. The dataset has wide temporal and spatial coverage, from passive hammer technology at Lomekwi, Kenya ~3.3 mya (Harmand et al., 2015) to quadrangular adzes, at Ka'eo quarry, Hawaii in the ~18-19th century A.D. (Clarkson et al., 2015). I sampled descriptions of lithic technology reported in the literature from dated archaeological contexts in Africa, Eurasia, Greenland, Sahul, Oceania and the Americas, from the earliest archaeological record through the late Holocene. I sampled only sites with very detailed descriptions of the lithic technology, including discussions about how cores were managed, and detailed illustrations of debitage, cores, and retouched elements.

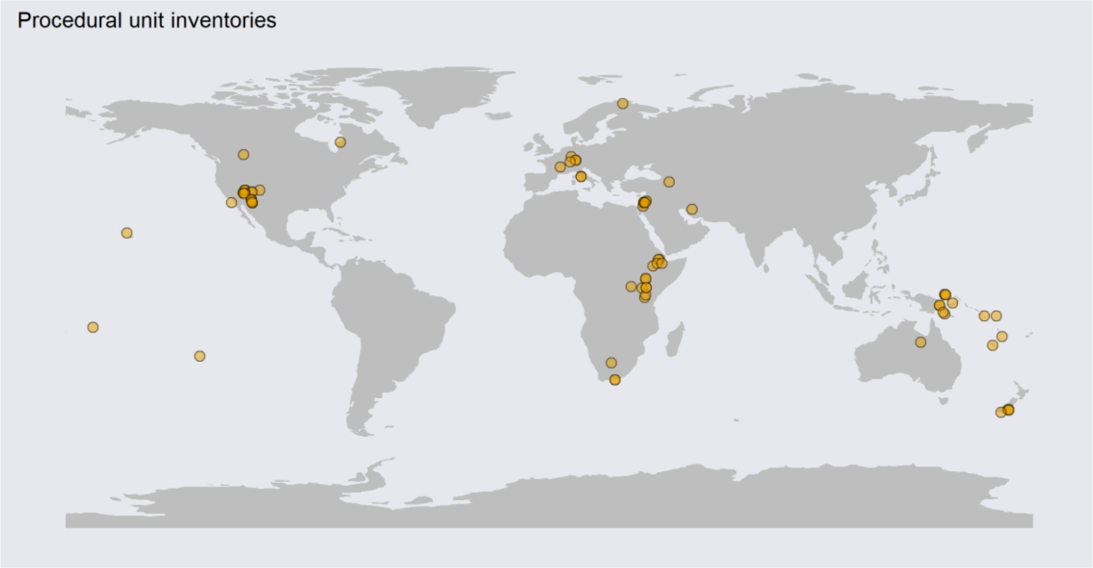


**Figure 3.3:** Map of all 81 procedural unit inventories

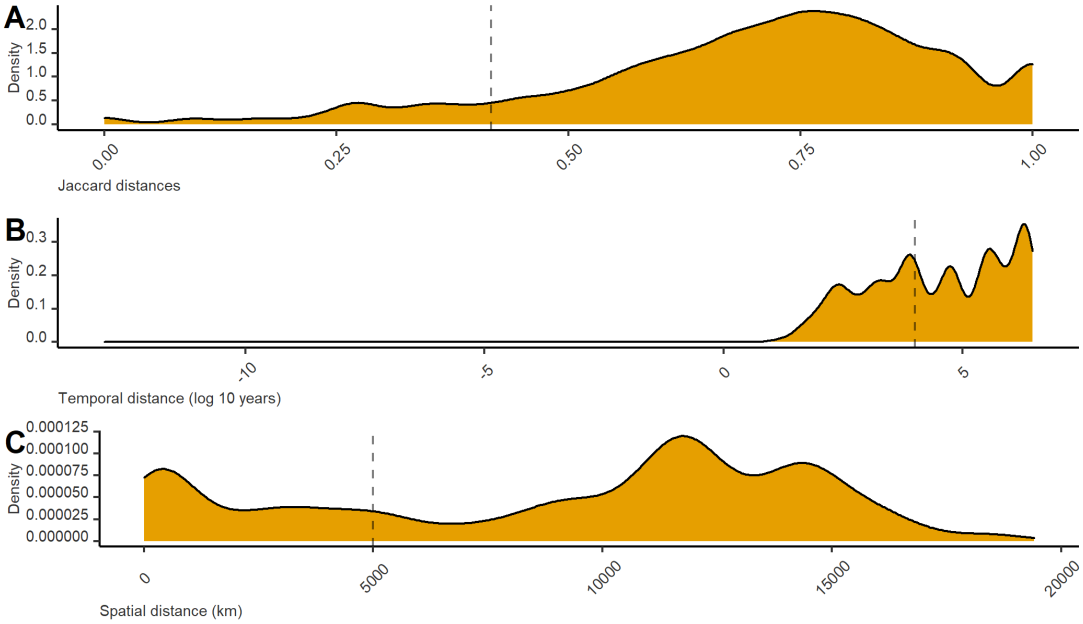


**Figure 3.4:** Summary of pairwise distances between all procedural unit inventories. Three distances between each pair are summarized here. (A): The technological distance between procedural unit inventories reported as Jaccard distances. (B): the log transformed temporal distances between each pair. (C): the haversine/spatial distance between each pair (C). Vertical dashed lines indicate the thresholds used to define convergence: the 10th percentile of Jaccard distance, temporal distances of 10,000 years, and spatial distances of 5,000 km

### *Language data*

I collected data on the presence or absence of any one of 3,183 linguistic segments across 2,059 doculects from the PHOIBLE 2.0 database (Moran & McCloy, 2019). To avoid longstanding problems in how languages are defined (i.e. the lack of any agreement about how to define a language, and distinguish it from a dialect) PHOIBLE 2.0 follows the resource based definition of linguistic varieties (Cysouw, 2013). Here, each phonological inventory corresponds in most cases to one study of linguistic variation in a particular place and time, among one or some number of a group of speakers. Each of these studies is a “doculect”. In the database, each phonological inventory represents a coded doculect, or the synthesis of a several doculects for a particular group of speakers in unusual cases (Moran & McCloy, 2019).

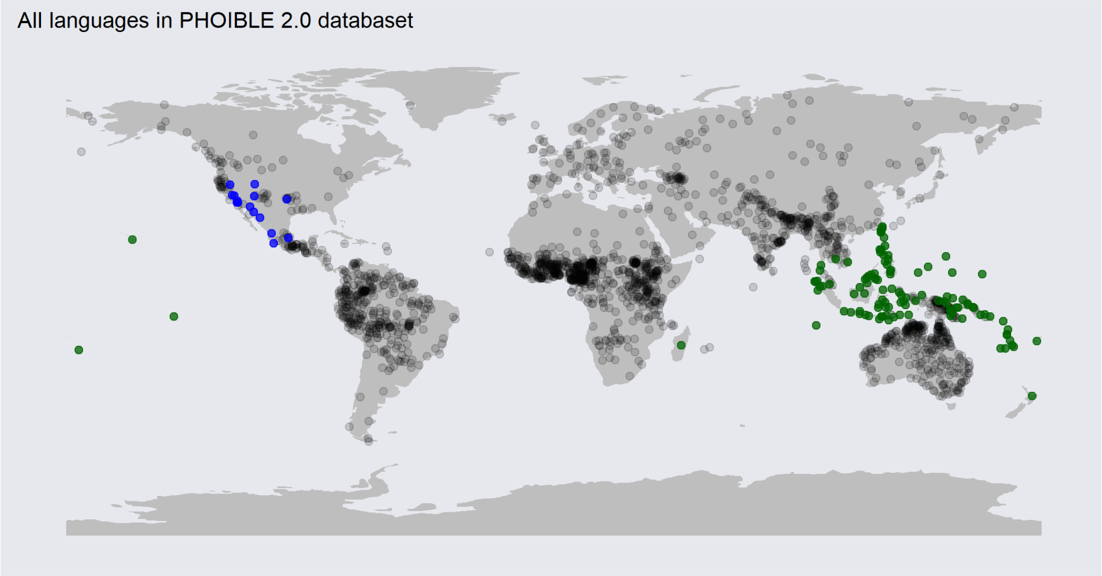


**Figure 3.5:** Map of 2186 languages in the PHOIBLE 2.0 dataset. Uto-Aztecan languages are highlighted in blue, and Austronesian languages are highlighted in green.

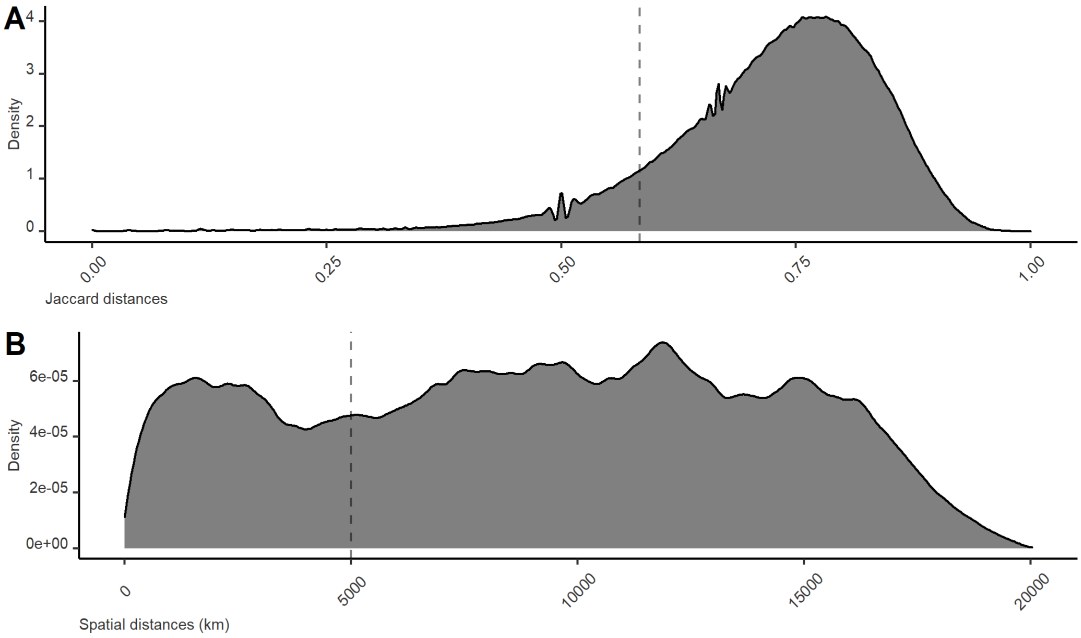


**Figure 3.6:** Summary of 2,118,711 pairwise Jaccard (A) and Haversine (B) distances between all linguistic segment inventories. Vertical dashed lines indicate the thresholds used to define convergence: the 10th percentile of Jaccard distance, and spatial distances of 5,000 km.

To study variability at narrower time scales, I focused also on two language groupings with particularly well resolved historical relationships: Austronesian (N = 6216 doculects) and Uto-Aztecan (N = 105 doculects) (Figure 3.5). By focusing on two hierarchical levels of variation: global linguistic variability, and variability within the Austronesian and Uto-Aztecan groupings I investigate: 1. how much extant diversity is there in general? and 2. how much variability has developed across Oceania and SE Asia, or across North and Central America since the middle Holocene? Differences between languages, and spatial distances between languages were measured in the same way as in the technological data. Similarities between languages were calculated as Jaccard distances: the number of observations shared in between two groups divided by the total number of observations, aside from shared absences, in either set. Spatial distances were measured using the Haversine distance, or great-circle distances between doculects given their latitude and longitude as recorded in the PHOIBLE 2.0 database.

### ***Defining convergence***

I focus here on measuring how often similarities in technological inventories are found in widely separated contexts. How widely separated is enough for us to interpret the similarity as a case of convergence? To operationalize similarity in technology and language, I measured Jaccard distances between each unique pair of assemblages, and each pair of doculects. Jaccard distance is measured as the number of observations shared divided by the total number of observations, aside from shared absences, in either set. Between each inventory, I measured spatial distance using the Haversine distance, or great-circle distances between points given their latitude and longitude. I measured temporal distances between archaeological assemblages as the absolute difference between the midpoints of their date ranges.

Similar assemblages that are separated by both 5,000km and 10,000 years, and similar languages separated by more than 5,000 km are defined here as instances of convergence. These distances were selected after considering the later results in this chapter, which finds weak evidence for isolation-by-distance among sets of cultural traits this far apart in space and time.

In order to more closely investigate cases of convergence, I defined “similar” in two ways. First, I focused on assemblages that had identical sets of traits to one another, then I focused on inventories whose Jaccard distances to one another are in the 10th percentile, or pairs more similar than 90% of other pairs. Within those two groups, pairs that are identical, and pairs within the 10th percentile of Jaccard distances, I measured how many pairs had both assemblages separated by more than 5,000km and 10,000 years. In the linguistic dataset, which has no temporal dimension, I define convergence as instances of identical, or similar sets of phonemes separated by more than 10,000 km.

### ***Results: Frequency of convergence is similar between phonemes, procedural units and technological modes***

The process of language evolution has led to very distinct kinds of phoneme inventories, which still cover only a small part of the theoretical morphospace. The number of possible inventories for the linguistic segments data can be calculated with the formula $N^r$, where N is the number of possible states each trait can take. In this case, there are only two possible trait states (present or absent) so N = 2. N is raised to the power of r, which is the number of traits in the recording system. The PHOIBLE dataset has summarized languages by the presence or absence of any one of 3,183 linguistic segments. If we raise 2 to the power of the number of possible phonemes ($2^{3183}$), the result is a theoretical morphospace that is practically infinite (~$1.50825 \times 10^{958}$ possible inventories). Despite the vast morphospace, of the 2059 sampled doculects, there are still 391 doculects with identical phoneme inventories.

Stone tools, in contrast, represent 3 millions of years of technological experimentation by not just different human groups, but also distinct hominin species. Between the earliest cases of hominin chipped stone technology, and the kinds of technologies modern humans relied upon in the Holocene, groups invented many new technological modes and procedural units, and explored new regions of the technological morphospace as outlined in chapter 1. Nonetheless, the number of possible technological mode inventories is only 2,097,152. This includes inventories of all sizes, from instances where only one is present, to the instances with the most technological modes are present. The smaller theoretical morphospace for technological modes is in part due to modes as analytical units encompassing more variability than individual phonemes, which are intended to be irreducible in a way modes are not intended to be. Still, despite there being millions of possible inventories, there are only 606 of the two million or so unique combinations represented in the dataset. This means that just over half (53.9%) of the 1125 technological mode inventories are unique.

Procedural units, unlike technological modes and more like phonemes, are intended to be irreducible, minimally identifiable traits. There are 268,435,456 possible procedural unit inventories, still far fewer than the phoneme morphospace, but far more vast than the technological mode theoretical morphospace. Nonetheless, there are still many instances of identical procedural unit inventories. There are only 68 cases of unique inventories in the 81 sampled assemblages (84.0% of all assemblages).

Despite having a narrower theoretical morphospace, the median Jaccard distance of lithic assemblages is comparable to each of the language samples. All technological groupings, and language groupings are skewed closer to one, suggesting substantial between sample variability, as opposed to 0, which would suggest low variability. Across all 2,058 languages in the PHOIBLE 2.0 database, the median Jaccard distance between languages is 0.75. As we should expect for sets of languages that are closely related to one another, the linguistic distances within the Austronesian and Uto-Aztecan families is lower than the global record. The median Jaccard distance between Uto-Aztecan languages is 0.69, and for Austronesian languages it is 0.63. Austronesian languages, despite spanning from Rapa Nui in the Southeastern Pacific, to Madagascar, tend to be more similar to each other than either all the languages in the dataset, or all the languages in the Uto-Aztecan family. This is likely because many of the languages in the Austronesian family diversified very recently, especially languages in Eastern Polynesia. For example, differences between Eastern Polynesian languages like Marquesan, Hawaiian, and Māori, likely developed only since the expansion of humans into Eastern Polynesia from Western Polynesia starting in the 13th century A.D.(Cochrane, 2018), which was followed by generations of continued contact between distant island chains within Polynesia. There is not a similarly recent well-defined episode of linguistic diversification in the Uto-Aztecan family (Hill, 2001). The technological data is more similar in the degree of between-assemblage variability found across all doculects in the PHOIBLE 2.0 dataset than what is found within language families that diversified in the past few thousand years (Figure 3.7). This is consistent with the much greater time depth of the technological sample (millions of years), and greater spatial scale (global) allowing for more potential diversification of technology, relative to the narrow spatio-temporal scope of both language families.

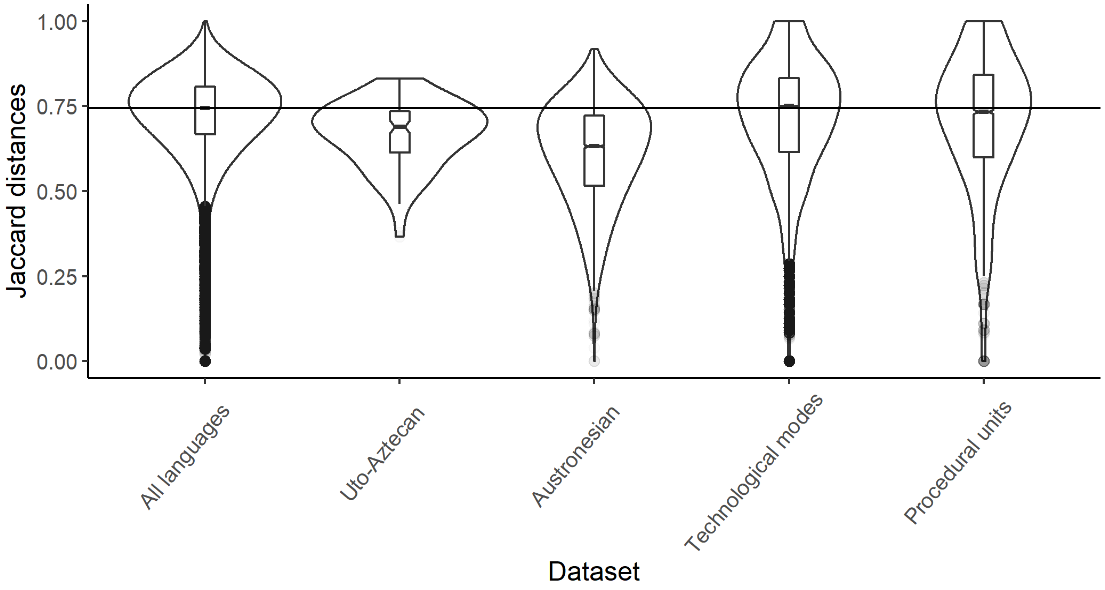


**Figure 3.7:** Violin plots outlining the distribution of pairwise Jaccard distances across the language datasets, compared to pairwise Jaccard distances between technological datasets. The datasets here include 2,118,711 pairwise distances between all languages in the PHOIBLE 2.0 dataset, 105 distances between all languages in the Uto-Aztecan language family, 6,216 distances between all languages in the Austronesian language family, 632,250 distances between technological mode inventories, and 3,240 distances between procedural unit inventories. The horizontal line marks the median pairwise distance among all languages in the PHOIBLE 2.0 database.

Convergence in procedural unit and mode inventories is comparable in frequency to convergence in phoneme inventories. Among technological mode inventories, there are only a few examples of identical assemblages separated widely in space and time, and just under 8% of spatio-temporally distant pairs fall within the 10th percentile of Jaccard distances to one another. Convergence is less common in the procedural unit dataset. Of the assemblages separated by 10,000 years, and 5,000 kilometers, there are no examples of pairs with identical sets of procedural units to one another, and only about 1-2% of cases within the 10th percentile of technological distances (Table 3). Finally, instances of convergence within the language dataset fall between both procedural units, and technological modes in their relative frequency. There is one instance of two doculects sharing the same phoneme inventories separated by 10,000 km, and 5% of distant doculects fall within the 10th percentile of Jaccard distances (Table 3.3).

**Table 3.3**: Summary of the frequency of convergence among technological mode, procedural unit, and linguistic segment inventories.

| | Technological Modes | | Procedural Units | | Linguistic Segments | |
|---|---|---|---|---|---|---|
| | N | % | N | % | N | % |
| Cases of convergence (identical) | 591 | 0.16 | 0 | 0.00 | 1 | 0.00 |
| Cases of convergence (10th percentile) | 27,553 | 7.69 | 37 | 1.59 | 79,495 | 5.03 |
| Total distant comparisons | 358,421 | | 2,321 | | 1,581,280 | |

In sum, technologies, and languages show similar patterns of variability, and of convergence. This despite the theoretical morphospaces for these traits being radically different. This suggests that some processes are reducing between group variability, whether that is selection, developmental constraints, or other processes, such that distant groups relatively often explore similar regions of the morphospace. This finding suggests that in linguistic segments, technological modes, and procedural units, striking similarities could be misleading evidence of common history. In the next section, I take a closer look at the spatio-temporal dimensions of technological variability, and compare those patterns to spatial patterns within languages. This will give us further insight as to whether the global stone tool record has statistical properties we would associate with strong potential for historical signal.

## Isolation by distance in technology compared to language

Is isolation by distance similarly strong in lithic technology, as it is in phoneme inventories? If so, this would suggest that there is similar potential for historical signal in lithic technology. How strongly traits are correlated in space and time is likely closely related to the potential strength of historical signal (Creanza et al., 2015; Diniz-Filho et al., 2013; Shennan et al., 2015; Shennan, 2020). People close to one another in space and time are more likely to exchange cultural ideas directly, or indirectly, than distant people. If traits retain evidence of history, then those traits should also show signs of isolation-by-distance as is the case in language, and genes (Creanza et al., 2015). For example, linguistic variability among Japanese speakers shows a linear isolation by distance pattern, consistent with nearby speakers sharing similarities in language as a result people tending to interact mostly with others who live nearby as opposed to those on the other end of the archipelago (Huisman et al., 2019). Lithic technologies do also show evidence of spatio-temporal autocorrelation. For example, Nishiaki et al. (2021) found that within Asia, technological modes show some evidence for spatial autocorrelation within marine isotope stages. Those assemblages that are closer to one another in space within a time bin, tend to have greater overlap in the technological morphospace than assemblages that are further apart (Nishiaki et al., 2021). Similar patterns have been found in the MSA of East Africa, and in the record of Marine Isotope Stage 5 in the Sahara (Scerri et al., 2018, 2014; Tryon & Faith, 2013).

While isolation-by-distance is documented in lithic technology, it is not clear if the pattern is weaker than we might expect to find in cultural systems that do retain evidence of history, like language. The same factors discussed above that influence the frequency of convergence: morphospace volumes, fitness landscapes, and developmental constraints, should also influence the strength of isolation-by-distance. It could be that the morphospace is narrow, or the fitness landscape has few peaks. In this instance, we should expect similarities to occur in widely separated contexts, which would weaken any association between space, and technology. It could also be that rates of technological change are rapid, such that closely related groups who live nearby, may quickly modify their technologies to suit their local circumstances. In this case, both groups may become technologically dissimilar, despite their proximity. By directly comparing isolation-by-distance relationships between language, and technology, we can assess whether those relationships differ. If both systems show similarities in how and how well time and/or space explain similarity, this may tell us that technology shows a similar capacity to retain historical signal to linguistic segments.

### *Methods*

In this section I illustrate how technological distance is structured relative to spatial and temporal distance, and how linguistic distance is structured relative to spatial distance using linear models. To investigate the strength of the effects of spatial and temporal distance on the Jaccard distances between inventories, I assessed whether intercept only models, models with only space, or only time as a predictors best fit the data using Aikake Information Criteria scores. 95% prediction intervals for the effects of space and time were calculated while holding the other effect constant to set values. Prediction intervals were calculated using both the GGpredict() package (Lüdecke, 2022).\

### *Results: comparable patterns of isolation by distance in technology and language*

Phonemes, technological modes, and procedural units each show evidence for isolation-by-distance: nearby groups either in space or time or both tend to have more overlap in cultural traits. In the linguistic segment dataset, which has no temporal dimension, doculects within 100 kilometers of one another tend to be the most similar. The distribution of pairwise Jaccard distances between these nearby doculects is well below the range of the 25th and 75th quantile of all pairwise comparisons in the phoneme dataset (Figure 3.8). Simply put, doculects nearby in space are unusually similar relative to the global distribution of pairwise Jaccard distances. As increasingly distant doculects are compared, the distributions of pairwise distances reach closer to what we might expect to be drawn randomly from the global distribution. At scales of comparison between 1,000 and 10,000 km, for example, the median pairwise Jaccard distance falls very close to the median of the global distribution, .75.

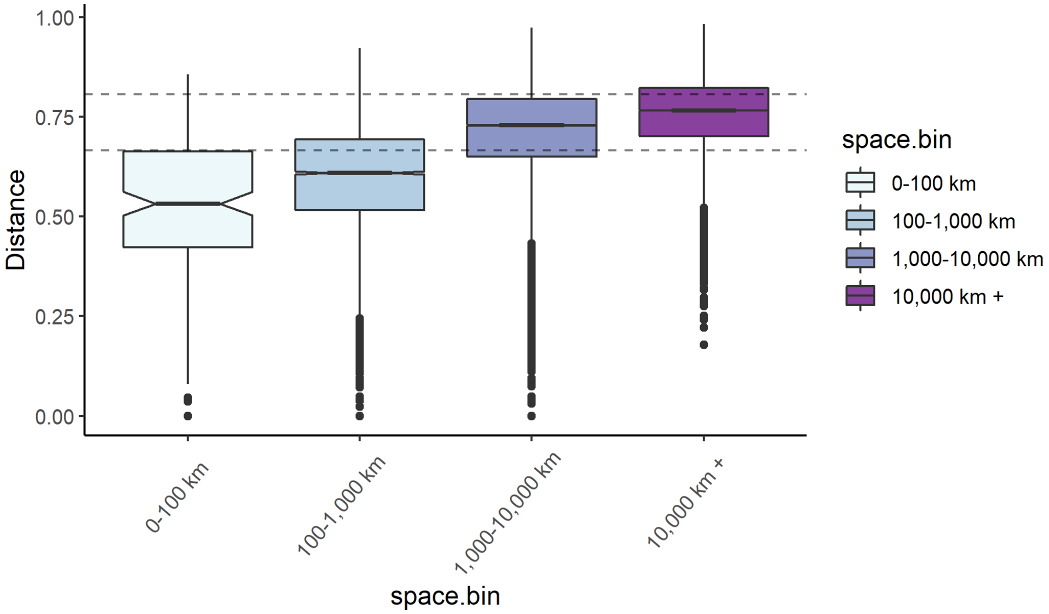


**Figure 3.8:** Relationship between spatial distance, and Jaccard distance between linguistic segment inventories in the PHOIBLE 2.0 dataset. The horizontal dashed lines represent the 25-75% interquartile range of the whole dataset.

The technological data show similar patterns, though in this case we have the additional temporal dimension. Technological mode and procedural unit inventories show evidence of both spatial, and temporal isolation by distance (Figure 3.8). Technological mode inventories that are both close in space, within 100 km of one another, and date to within 1,000 km of one another tend to be the most similar out of all the spatio-temporal groupings, while assemblages that are more than a million years apart, and separated by more than 1,000 km tend to have the greatest between-assemblage Jaccard distances (Figure 3.9 top). This pattern is broadly similar within the Procedural unit dataset (Figure

3.9 bottom). Similarly, in both technological datasets, assemblages that are greater than either 100,000 years apart, or more than 1,000 km apart tend to have similarities between one another that fall well within the global distribution of pairwise distances. At these greater spatio-temporal scales of comparison, assemblages tend to be no more similar than we might expect if we were drawing assemblages randomly from the record.

Finally, the isolation-by-distance relationship between technology, and space, for example, is stronger when comparing assemblages within 1,000 years of one another than it is when comparing assemblages greater than 1,000 years from one another. In these narrow spatio-temporal scopes, the closest assemblages tend to be very similar, and the most distant assemblages in space are very dissimilar. This is also the case if we focus on the isolation-by-distance pattern between technology and time. If we focus on only the pale blue boxplots (representing pairwise distances within 100 km of one another), as we compare spatially nearby assemblages that are increasingly temporally distant, there remains consistent evidence for greater dissimilarity at greater temporal scales of comparison (Figure 3.9).

The above patterns are all consistent with isolation by distance in both the linguistic, and technological systems. However, it is important that we explore more specifically whether the strength of isolation-by-distance is similar in technology to language. If not, it could suggest that despite there being evidence of isolation by distance, it may be more subdued in technology. A weaker relationship in technology could mean less potential for historical signal in that system.

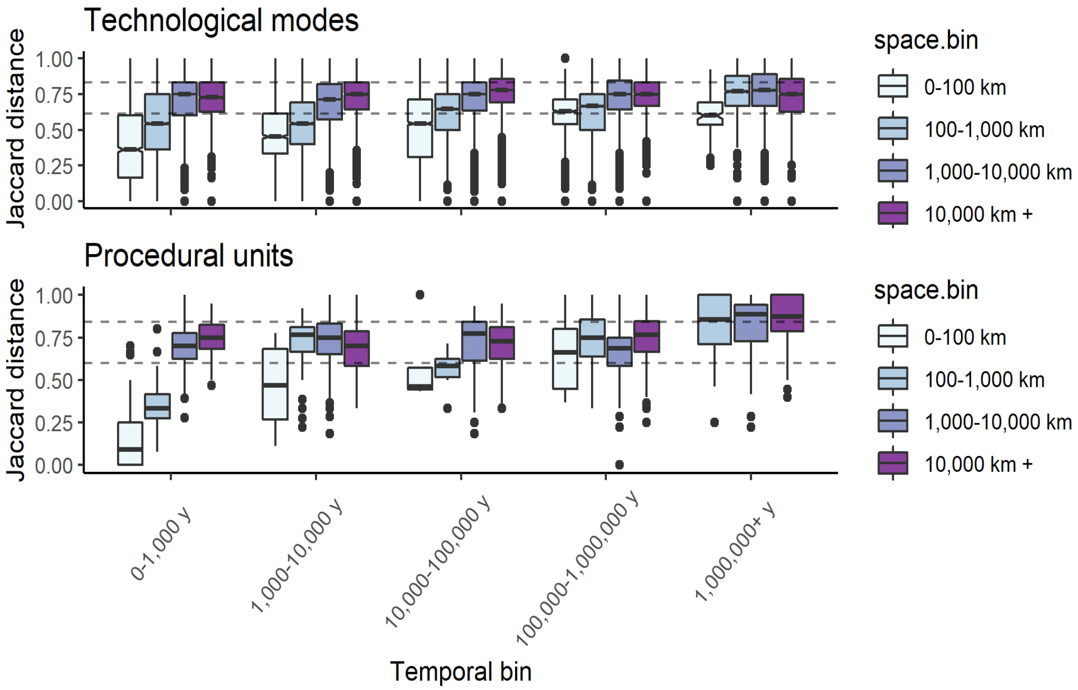


**Figure 3.9:** Relationship between spatial distance, and Jaccard distance between linguistic segment inventories in the PHOIBLE 2.0 dataset. The horizontal dashed lines represent the 25-75% interquartile range of the whole dataset. The mean global values are .75 in both datasets.

In the language data, the relationship between spatial distance, and linguistic distance is strong, as has been documented elsewhere: doculects that are closer in space, tend to share more segments in common than doculects that are further apart (Figure 3.10, Table 3.4, Table 3.5). The slope associated with each 1% increase in space is a 0.08% increase in the Jaccard distance between doculects, and the confidence interval for the slope falls well above 0.

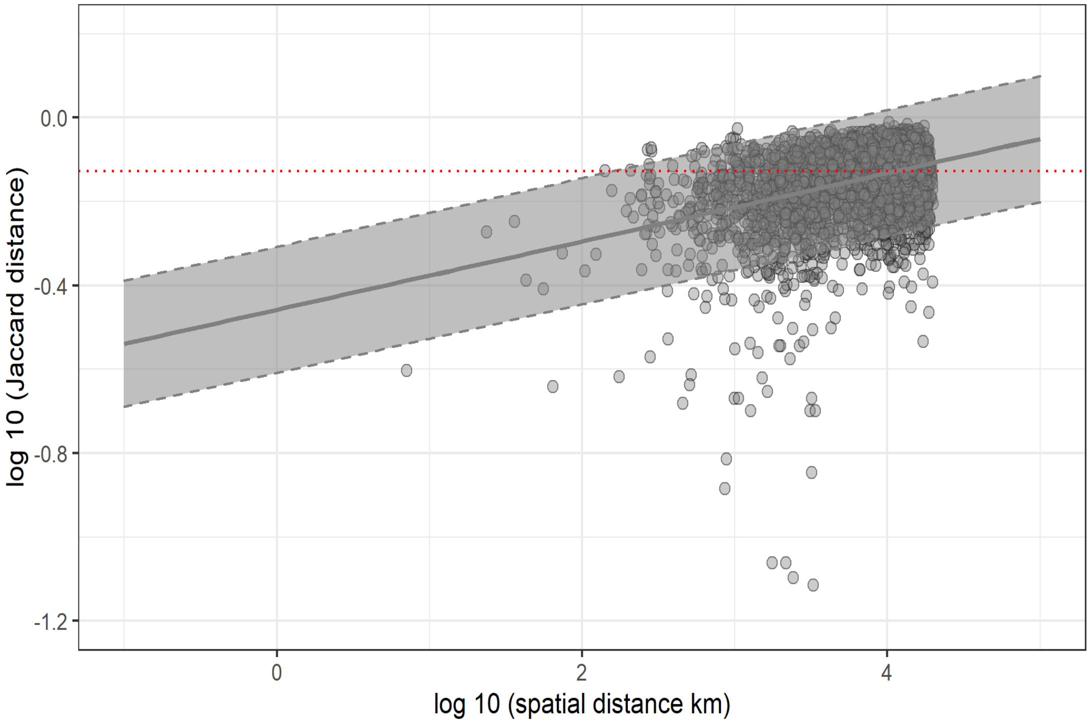


**Figure 3.10:** summary of linear model describing the relationship between spatial distance, and Jaccard distance across each pair of doculects in the PHOIBLE 2.0 database. The median Jaccard distance is plotted as a horizontal dotted red line. All units have been log transformed.

**Table 3.4**: Summary model fits between intercept only, and model with a slope for spatial distance in the PHOIBLE 2.0 dataset.

| | Linguistic Segments | |
|---|---|---|
| Model | Adjusted $R^2$ | Aikake Information Criterion |
| (Intercept) | 0.00 | -4533620.66 |
| Log10 (space) | 0.15 | -4866113.00 |

**Table 3.5:** Summary of parameter estimates for linear models explaining relationships between spatial distance, and Jaccard distance among linguistic segment inventories.

| Linguistic Segments | | |
|---|---|---|
| Predictors | Estimates | CI |
| Intercept | -0.458 | -0.459 to -0.457 |
| log10 (Space) | 0.082 | 0.081 to 0.082 |
| Adjusted R-Squared | 0.15 | |

Both the procedural unit, and technological mode data also show strong evidence for isolation-by-distance: sites that are further apart in space and time are more dissimilar than sites that are close together, and the effect is greatest at narrow spatio-temporal scales. Among technological modes, for each 1% increase in space, there is a proportional 0.13% increase in the Jaccard distance between assemblages, and there is a 0.13% increase in Jaccard distance for each percent increase in time (Table 6, Table 7, Figure 11). The pattern is similar among procedural units, though the slope is much sharper at narrow spatio-temporal scales. For each 1% increase in space, there is a proportional 0.16% increase in the Jaccard distance between assemblages, and there is a 0.22% increase in Jaccard distance for each percent increase in time (Table 6, Table 7, Figure 12).

Both technological models also highlight the spatio-temporal scales at which we are likelier to lose any robust evidence for common history. At the broader spatio-temporal scale, the effects of either space or time on technological distance tends to be very weak. In both technology models, if we assume a temporal distance of 100 thousand years, the model intercept for the effect of space on technology is near the median Jaccard distance, and the slope is very subtle (Figures 3.11 and 3.12 panel C). There are similar patterns of the effect of time on technological distance if we assume a spatial distance of 10,000km (Figures 3.11 and 3.12, panel D). At broader scales, the relationship is weak, and the expected values of technological distance remain close to the median of the global distribution.

Both technological models suggest that, while there may be robust isolation-by-distance at narrower spatio-temporal scales, as we compare increasingly distant archaeological sites in one dimension, then their distance in the other dimension explains less of the technological distance. At broader spatio-temporal scales of comparison, something closer to an intercept only model could explain the data: space or time might not do much of a better job at explaining variability than just the average technological distance alone. This is all consistent with what we should expect if lithic technologies did retain evidence of history: nearby assemblages may be more similar than distant assemblages, but we should not expect this pattern to hold at all spatio-temporal scales.

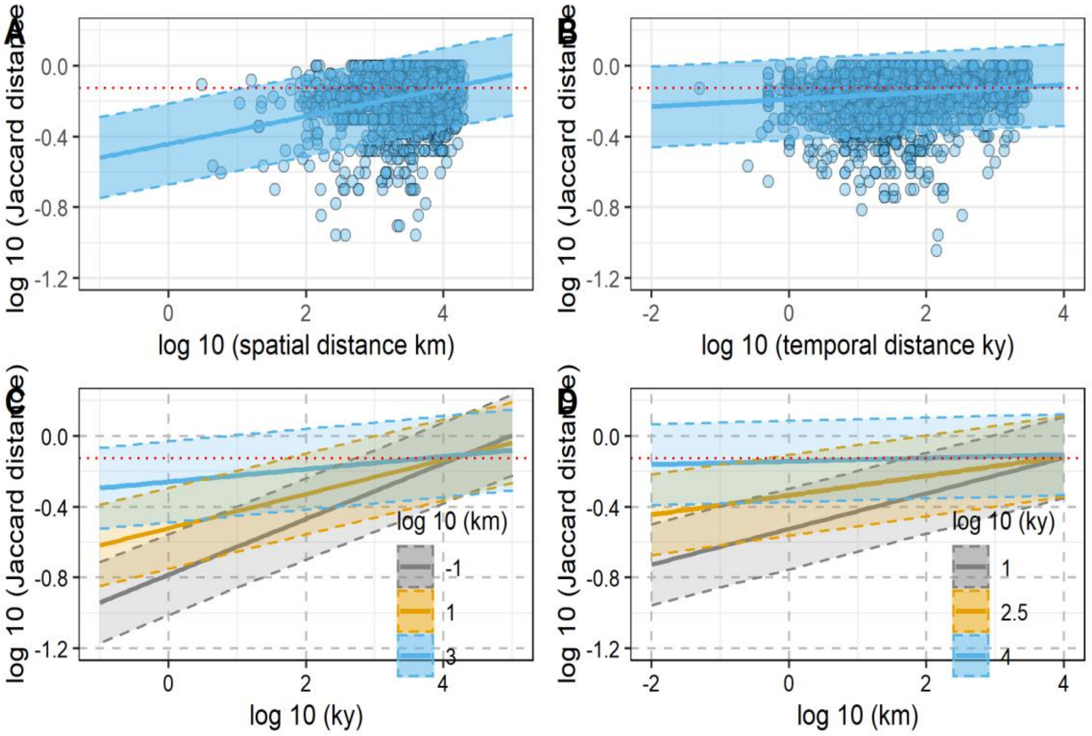


**Figure 3.11**: Summary of linear model describing the relationship between spatial distance, temporal distance, and technological distance across each pair of assemblages in the technological mode dataset. A: Relationship between spatial distance and technological distance on the log scale. B: Relationship between temporal distance and technological distance on the log scale. C: Relationship between temporal distance, holding different spatial distances constant. D: Relationship between spatial distance and technological distance holding different values of temporal distance constant. In plots A and B, the line represents the predicted values of technological distance for all spatial (A) and temporal (B) distances conditional on the mean value of the other predictor. The envelope surrounding the prediction line represents the 95% prediction interval. The median Jaccard distance is plotted as a horizontal dotted red line.

**Table 3.6**: Summary of model fits between intercept only, slope for space, slope for time, and model with both slopes and an interaction in the technological mode dataset.

| Technological modes | | |
|---|---|---|
| Model | Adjusted $R^2$ | Aikake Information Criterion |
| (Intercept) | 0.00 | -778870.32 |
| Log10 (space) | 0.09 | -835219.86 |
| Log10 (time) | 0.01 | -786999.65 |
| Log10 (space) : Log10 (time) | 0.11 | -848297.03 |

**Table 3.7**: Summary of parameter estimates for linear mixed models explaining relationships between spatial distance, temporal distance, and technological distance among technological mode inventories.

| Technological modes | | |
|---|---|---|
| Predictors | Estimates | CI |
| (Intercept) | -0.652 | -0.657 to -0.646 |
| Log10 (space) | 0.127 | 0.125 to 0.129 |
| Log10 (time) | 0.131 | 0.128 to 0.134 |
| Log10 (space) : Log10 (time) | -0.030 | -0.031 to -0.030 |
| Adjusted R-Squared | 0.113 | |

**Table 3.8**: Summary of model fits between intercept only, slope for space, slope for time, and model with both slopes and an interaction in the procedural unit dataset.

| Procedural units | | |
|---|---|---|
| Model | Adjusted $R^2$ | Aikake Information Criterion |
| (Intercept) | 0.00 | -2758.86 |
| Log10 (space) | 0.39 | -4336.02 |
| Log10 (time) | 0.22 | -3552.53 |
| Log10 (space) : Log10 (time) | 0.53 | -5172.86 |

**Table 3.9**: Summary of model fits between intercept only, slope for space, slope for time, and model with both slopes and an interaction in the procedural unit dataset.

| Procedural units | | |
|---|---|---|
| Predictors | Estimates | CI |
| (Intercept) | -0.778 | -0.802 to -0.754 |
| Log10 (space) | 0.155 | 0.148 to 0.162 |
| Log10 (time) | 0.216 | 0.200 to 0.232 |
| Log10 (space) : Log10 (time) | -0.050 | -0.054 to -0.046 |
| Adjusted R-Squared | 0.531 | |

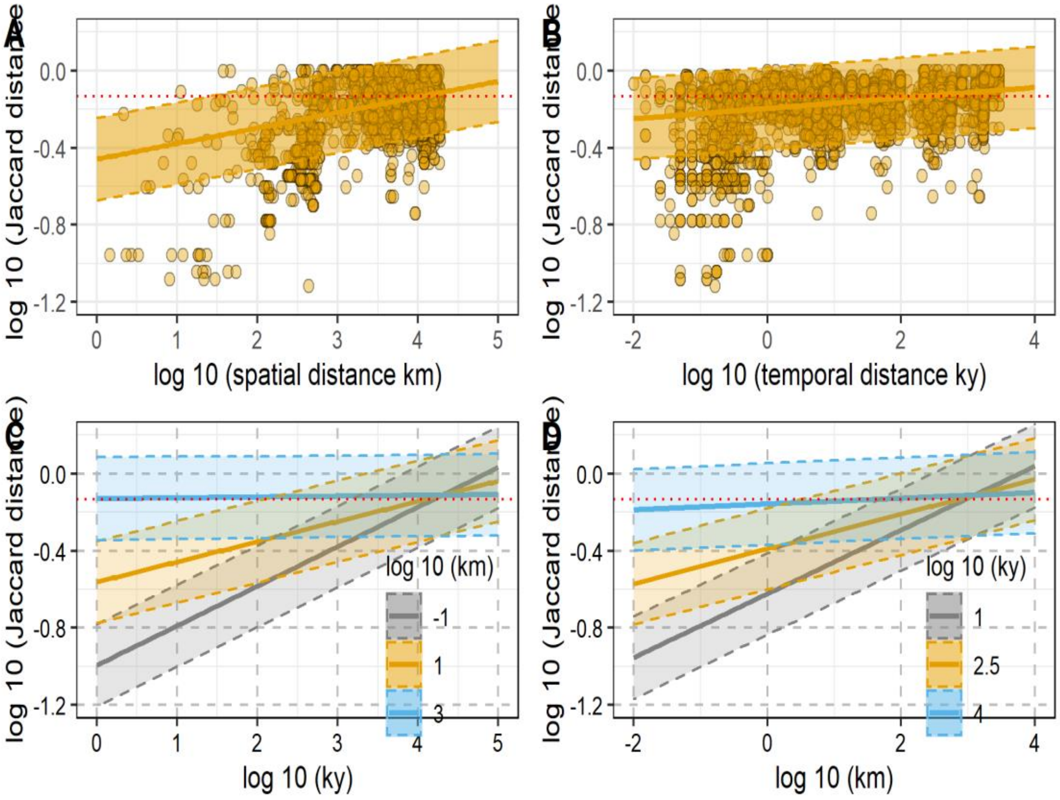


**Figure 3.12**: Summary of linear model describing the relationship between spatial distance, temporal distance, and technological distance across each pair of assemblages in the procedural unit dataset. A: Relationship between spatial distance and technological distance on the log scale. B: Relationship between temporal distance and technological distance on the log scale. C: Relationship between temporal distance, holding different spatial distances constant. D: Relationship between spatial distance and technological distance holding different values of temporal distance constant. In plots A and B, the line represents the predicted values of technological distance for all spatial (A) and temporal (B) distances conditional on the mean value of the other predictor. The envelope surrounding the prediction line represents the 95% prediction interval. The median Jaccard distance is plotted as a horizontal dotted red line.

Finally, the goal of this section is to directly compare the strength of the association between space, and technology compared to space and language. If we hold temporal distance for technology constant at 100 years, then the relationship between space and technology appears similar to the relationship between space and phonemes. There is wide overlap in the prediction intervals between all three models, and while there may be a sharper slope in the procedural unit model (Figure 3.13). The similarity between all three models suggests similar strength isolation by distance in both global technological datasets and the global linguistic dataset. As such, it may be that there is a comparable capacity for historical signal between technological datasets, and linguistic datasets.

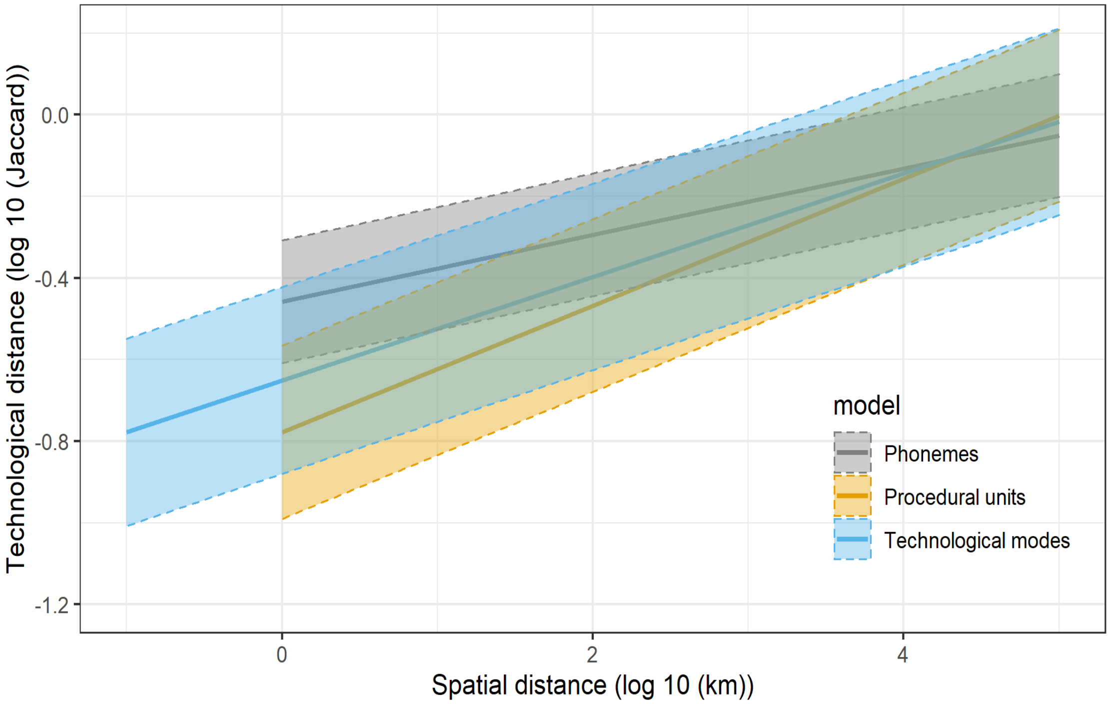


**Figure 3.13**: Summary of linear model describing the relationship between spatial distance, and technological distance across each pair of doculects in the PHOIBLE 2.0 database (gray), each pair of procedural unit inventories (orange), and each pair of technological modes (blue). Here, for the technological models, the slope plotted represents the slope assuming a fixed temporal distance of 100 years. The colored envelope, and dashed lines outline the 90% prediction interval for each model.

## Conclusion and discussion

The degree to which lithic technologies retain reliable evidence of culture history is not well understood in large part because broad, comparative studies of technological variation are rare, making it difficult to measure the kinds of patterns we might expect in an evolutionary system that has the capacity to retain evidence of history. In this chapter, I contributed by measuring how often convergence happened, and the strength of isolation-by-distance in lithic technology relative to phonemes in languages. The frequency of convergence, and strength of isolation-by-distance appears similar among all three kinds of data, which suggests lithic technology could have a similar capacity for historical signal.

The results of this study supports previous proposals that convergence should always be treated as a possible explanation for similarity in lithic technology (O'Brien et al., 2018; Will & Mackay, 2020), and show additional evidence for isolation by distance in lithic technology previous identified in the East African MSA, the Sahara during Marine Isotope Stage 5, and Paleolithic of East Asia (Nishiaki et al., 2021). However, the important contributions here are the global scope of the study, and the inclusion of another cultural system, language, as a point of reference. By treating linguistic variability as a model to compare to technological variability, we are able to place technological variability in a much clearer context. These findings exclude the idea that lithic technology is so constrained in its variation that we cannot use it for historical inference.

This study also helps to address the scales of comparison at which similarities in assemblages are more likely the result of convergence than shared history, or the spatio-temporal scale at which we are unlikely to detect shared history. Archaeologists who study high quality records, with many different sources of information about technology, and well refined chronologies, can more confidently explain similarities in technology as resulting from shared history. This is especially the case with ceramics technologies in the American Southwest. Communities of pot-makers differ in the kinds of idiosyncratic choices they make during the production process. While pots were traded widely, the know-how of those production sequences are not as likely to be transmitted readily between learning communities (Dietler & Herbich, 1989; Gosselain, 1992, 1998; Lemonnier, 1986). So, when we find idiosyncratic methods of producing things common in one region, later practiced in another, this is often proposed as strong evidence for migration (Jeffery J. Clark, 2001; Jeffery J. Clark & Lyons, 2012; Hegmon et al., 2000; Neuzil, 2005). This same reasoning is extended to lithic technology. The recipes for making tools are proposed as more reliable markers of shared history, and migration than similarities in the forms of final products (Sackett, 1982; Tostevin, 2013). Researchers interested in using stone tools as cultural markers often focus on the Pleistocene, whose temporal scale and resolution are far coarser (Perreault, 2019). Similarities in lithic technologies separated by thousands of Kilometers and tens of thousands of years are argued to result from shared history (Kolobova et al., 2020; Mellars, 2006; Rose et al., 2011; Tostevin, 2013). Exactly how far apart assemblages must be for convergence to be a more likely explanation of similarity is not clear, and this threshold differs substantially between researchers (Kuhn & Zwyns, 2018; Will & Mackay, 2020). Among procedural unit inventories that scale should be considered much narrower than the technological mode inventories. At scales of analysis beyond 10,000 years, or beyond 1,000km assemblages are about as dissimilar as assemblages drawn from the entire record.

As a caveat, spatio-temporal autocorrelation is not necessarily evidence for the presence of historical signals. Human groups could instead be adapting to ecological conditions that themselves have spatio-temporal autocorrelation. In this case, groups who are nearby one another may tend to rely on similar technologies, not because they shared common history or interacted with one another, but because they have adapted their technologies to similar pressures. People who are far away from one another will tend to face different pressures and tend to have different technologies adapted to those circumstances regardless of how closely related they are. Spatio-temporal autocorrelation only tells us about the potential for historical signals and should not be interpreted as a direct measure of historical signal. That analysis is performed in chapters 3 and 4 of this dissertation. Whatever the underlying mechanisms are, if there is no or weak relationship between time, space and similarity compared to language, then we should not expect strong historical signals to be maintained in these traits.

Overall, this study helped highlight what can be learned about technological evolution, and the usefulness of chipped stone technology as cultural markers, by quantifying variability in technology at a global, and million year scale compared to other evolutionary systems. The next steps are to more directly measure historical signals in lithic technology by studying technological variability in contexts where the population histories of groups and their interactions with one another are well understood. In the following two chapters, I measure lithic variability relating to well documented instances of people moving into new areas, and bringing other aspects of their culture with them: the Ancestral Puebloan migrations into Central Arizona, and the expansion of

Austronesian speakers into Oceania. Both cases allow us to assess whether lithic technology, which as demonstrated here has the capacity for historical signal, actually does retain evidence of shared history, and whether that evidence reflects the population histories of Oceania, and Arizona.

# CHAPTER 4: MIGRATION AND TECHNOLOGY IN THE AMERICAN SOUTHWEST

Archaeologists have long been interested in reconstructing particular population histories based on variability in lithic technology. For example, among pre to post Aksumite lithic assemblages in the Highlands of Ethiopia, similarity in lithic manufacturing techniques across time is argued as evidence not just for historical continuity in technology (the same stone tool tradition persisting across time), but also population continuity (the same group of people persisting in that area over time), and ethnic continuity (a people with a shared identity persisting across that span of time), and serves as part of a broader argument for modern Aksumites having a deep history in that region (Phillipson, 2009). In much the same way, similarities in technology in two separate geographical areas are often interpreted as resulting from specific mechanisms, like migrations and population expansions. Technological similarity may indicate that similarities between two areas are caused by the movement of people practicing a particular technology from the first area to the second. The presence of Nubian Levallois techniques in the Arabian Peninsula, for example, is argued evidence for a Red Sea route of modern human expansion out of East Africa and into Asia (Rose et al., 2011).

However, technological variability may not reflect ethnic continuity, population continuity, or migrations of peoples. This would be the case if technologies are readily transmitted across group boundaries. For example, bow and arrow technology spread very rapidly throughout California, across ethno-linguistic boundaries, and became established technological practice among groups with very distant historical relationships to one another (Kennett et al., 2013).

The following two chapters address the reliability of lithic technologies in reconstructing population histories. In order to meet this goal, I focus here specifically on migration events and population expansions. Migrations and population expansions have long been a focus of stone tool studies, and are useful natural experiments. Natural experiments, especially those involving migrations, have been very useful means of teasing apart cause and effect, in Biology (Jesmer et al., 2018; Rogers et al., 2012), Anthropology (Hamilton & Tallavaara, 2021; Mascie-Taylor & Little, 2004; Richerson & Boyd, 2008), History and Economics (Algan et al., 2016; Diamond & Robinson, 2010; Nunn, 2010; Powell et al., 2017).

There are two questions that the following chapters will answer. First, does technological variability reflect population history? Are groups who we know had either culturally interacted, or were descended from the same source population, more similar to one another technologically than groups that are more distantly related, or groups who are distantly related, but shared similar ecologies, and socio-technological adaptations? If lithic technologies are reliable means of reconstructing population histories, and migrations, then we should expect the most closely related groups to have the most similar technologies, and vice versa. This should depend in part on whether migrants maintain technologies reminiscent of their ancestors, or rapidly modify their technologies to suit new ecological circumstances, such that evidence of shared history is lost.

Second, at what spatio-temporal scales are lithic technologies reliable evidence of migration? Are we more likely to find reliable evidence of migrations when we are tracing technological patterning over a relatively small spatial area, over the course of a few generations? Alternatively, it may be that such a narrow spatio-temporal scale of study will not have the between-group variability necessary to detect migrations.

To understand the reliability of lithic technology in reconstructing migrations, and population expansions, I studied lithic technologies of well-studied archaeological records in the late Holocene, among unusual cases where anthropologists have come to precise estimates of cultural distances between prehistoric groups. The variability within these records are then compared to outgroups that are unrelated culturally, some with similar subsistence strategies, and others having very different ways of life in very different ecologies. This chapter focuses on the migrations of agriculturalist Ancestral Puebloan groups from the Colorado Plateau into the Sonoran Desert ~800 BP. The sites included in this study cover a relatively narrow temporal scope of ~1000 years, a spatial scope of ~500 km, and two distinct ecological zones, the Sonoran Desert, and high desert of the Colorado Plateau. Technological variability within and between archaeological groups in the Southwest are then compared to outgroups, including Pre-Pottery Neolithic groups in the Levant, and assemblages drawn randomly from the archaeological record.

The second case study is the expansion of Austronesian speakers across Oceania ~3000-800bp. This study covers a much broader spatio-temporal scale: 4,000 years, and 8,000 km, a quarter of the earth’s circumference, and diverse ecologies spanning a wide latitudinal range, from the tropics of Melanesia, to temperate environments in New

Zealand. Here, cultural groups studied include Papuan groups in the Bismarck Archipelago, Lapita groups in near and remote Oceania, and Polynesian groups across the Polynesian triangle. The variability within these groups that are known to have either interacted, or have shared history, are compared to cultural outgroups: Australian/Tasmanian, Chumash, as well as pre-pottery Neolithic groups.

Below I outline the various processes that are likely to influence whether lithic variation is a reliable reflection of population histories in general, and how they might be applied to understanding the records in the Southwest, and Oceania.

## Theory

While researchers use lithic technologies to propose particular migration routes, and cases of population expansion, we do not understand how reliably lithic technology reflects those processes. Various other processes likely influence the strength of correlation between technological change, and population histories. In the previous chapter, I discussed how morphospace size, fitness landscapes, and developmental constraints of evolutionary traits, and lithic technologies influence the persistence of historical signal. Below, I discuss other factors that will influence our ability to detect population expansion and migration through lithic technology, like how often lineages exchange cultural information with one another, or how permeable social boundaries are, as well as rates of cultural change and social factors that influence between group variability. These all, in addition to the breadth of the technological morphospace, fitness landscapes, and developmental biases all will influence how technologies change as people move into new areas, and whether those technologies then retain evidence of common history. I then outline specifically how technologies may, or may not reflect migration histories in a region.

### *Rate of horizontal transmission and historical signal*

Horizontal transmission between groups likely influences the strength of historical signal in lithic technology, and the scale at which cultural traits retain evidence of history. It should also, then, influence the scale and strength of spatio-temporal autocorrelation. Horizontal transmission between groups could be very rare. This could be due to extrinsic mechanisms, like geographic isolation. Groups may be separated by geographic features that make frequent contact unlikely. Groups may have no opportunity to interact with one another, or contact is rare and brief, leaving little time substantial cultural borrowing. Lack of horizontal transmission could also be due to intrinsic mechanisms. Groups could be culturally isolated from one another through what Durham (1982, 1992) termed “ transmission isolating mechanisms” (TRIMS). TRIMS are intrinsic mechanisms within human societies that serve to maintain homogeneity within a group, and heterogeneity between groups including endogamous marriage practices, conformity, or xenophobia (Durham, 1992; Youngblood et al., 2020). These mechanisms might ensure that more interaction occurs with members of the same group (endogamous marriage, and xenophobia), or they might ensure that new cultural variants, perhaps from other groups, do not become adopted (conformity biases). If there are no extrinsic factors that prevent exchange of information across groups, cultural traits under the influence of

TRIMS are perhaps more likely to retain something like a phylogenetic structure more amenable to trying technological variation to population history. Tehrani and Collard argued that TRIMS, like some of those above, ensured that Turkmen textile weaving practices had a tree-like historical structure. Within each Turkmen tribe, mothers teach their daughters how to make textiles, and those daughters tend to only marry within their tribal group (Tehrani & Collard, 2002; Youngblood et al., 2020). These norms mean that there is little between-tribe transmission of craft knowledge. These circumstances allowed for phylogenetic reconstruction of the relationships between craft traditions. similar TRIMS may serve to dampen cultural sharing between electronic music scenes (Youngblood et al., 2020). In this case, the boundaries between electronic music subgenres, and associated music scenes are maintained through conformist mechanisms, like criticism from other practitioners if individuals deviate from musical norms within their group or for lack of perceived commitment to those norms by going mainstream. Strong TRIMS may be part of why variability in folk music traditions reflect population histories of their practitioners (Pamjav et al., 2012).

In contrast, cultural traits might not be constrained by TRIMS. There may be high degrees of horizontal transmission between groups, at multiple hierarchical scales, from local communities, to ethnolinguistic groups, to metapopulations. Much human interaction occurs between groups through institutional mechanisms like exogamous marriage practices, exchange and economic ties. For example, exogamy among Indigenous groups in Australia, and Amazonia has resulted in multilingual groups, or sets of languages that are very similar to one another despite being spoken by distant speakers

(Aikhenvald, 2002; Heath, 1981; Sorensen, 1967; Steele & Kandler, 2010). Where multiple groups with different languages rely on trade with one another, establishment of common languages is frequent (Croft, 2003). In other cases, trade relations might result adopting many of the components of one party's language, and incorporating it into ones own, as is likely the case among the now-Bantu speaking Akta in Central Africa (Duke, 2001).

The effectiveness of TRIMS at isolating cultural lineages also depends on time. While ethnic boundaries, and non-overlapping social networks might be maintained for some time, social norms evolve, and new lifeways develop that may re-arrange how people interact with one another (Barton & Riel-Salvatore, 2012; Boyd & Richerson, 1994). As a consequence, social boundaries are unlikely to be static, and certainly unlikely to be so if our window of observation is at the thousand-year scale. Lithic assemblages represent the accumulation of often many generations of debitage and discarded tools (Barton & Riel-Salvatore, 2014; Rezek et al., 2020). As the products of many generations of accumulation, it may be that they vary at scales well beyond shorter lived periods of cultural isolation.

However, weak TRIMS do not necessarily result in loss of historical signal. Instead, they may result in cultural entities that vary at hierarchical levels well above that of the ethnolinguistic group, or particular regions. The lack of TRIMS acting on some kinds of technological variation, are likely in part why culture-areas identified by Anthropologists can encompass extremely wide areas, especially relative to the scale at which people interact on a daily basis (Binford, 2019; Cashdan et al., 1983). For example, about half of potters across sub-Saharan Africa, decorated their pots through use of roulettes which are a class of objects rolled across the surfaces of unfired clay pots to produce repeating decorative patterns (Gosselain, 2000b). Roulettes can be fashioned in many ways, from carving wooden rods, to coiling and knotting woven fibers. Their use dates back as far as 5000 BP. Sub-Saharan potters do not appear to adhere to strict norms about what kinds of roulettes should, or should not be used. The same potter might experiment with using carved rods, or corn-cobs. Particular kinds of roulettes see use across wide areas. For example, groups that use both fiber and carved roulettes span from Nigeria, to South Sudan. While slightly to the south, groups who rely on carved roulettes are found from Cameroon to Uganda. Both technological distributions are more or less bounded by natural barriers, with the Sahara marking the northern boundary of the fiber-carved distribution which spans much of the Sahel. The carved technological distribution spans much of the transition zone between the Sahel and Rain forest systems to the South. The distributions of these tools are more or less continuous, and are found across linguistic groups with very distinct histories. This is suggestive of these technological practices not being shared across groups due to some deeper history, but instead due to transmission of technological practices across group boundaries, with the boundaries of technological practices not being determined so much by intrinsic factors like TRIMS, but instead by extrinsic factors like geographic barriers, and differences in environment (Gosselain, 2000a).

Disentangling what technological traits are more or less likely to be transmitted readily across group boundaries has a long history in Anthropology. Researchers have proposed that the visibility of traits, and the nature of learning contexts may influence how readily they may become adopted by others. Technological sequences are often proposed to be particularly effective at identifying shared learning traditions, and have been measured to detect small scale population movements at the scale of hundreds of kilometers, and a few generations Cochrane (2018). This is because the specific kinds of technological decisions made in producing a technology are argued to be less likely to be visible to more distantly related groups than the end product (Lemonnier, 1992; Tostevin, 2013). However, this assumes that technological systems are very open ended: there are have many different methods of producing similar end products such that distant observes are unlikely to reconstruct the same or similar sequence of technological actions. Furthermore, there are have been few attempts to explore how lithic technological decision making cross cuts, or does not cross cut, different kinds of group identities.

### ***Rate of change and historical signal***

The overall rate of evolutionary change over time will also influence the persistence of historical signal, and this is dependent on both the scale of observation (are the groups compared all closely, or distantly related?) and on the breadth of the morphospace (is it narrow or vast?) (Ackerly, 2009; Dornburg et al., 2019; Klopfstein et al., 2017; Revell et al., 2008; Townsend, 2007). Evolutionary change is necessary for there to be historical signal in evolutionary traits (Kamilar & Cooper, 2013). However, change can be rapid enough relative to the breadth of the possible morphospace that historical signal rapidly weakens. For example, among mammalian dental characteristics, increased rates of evolutionary change are associated with increased instances of homoplasy. This means taxa jump across the morphospace within relatively few generations to such a degree that independent lineages frequently either add, or lose the same characters (Brocklehurst & Benevento, 2020). Traits that evolve too rapidly relative to the size of their morphospace may show no sign of historical signal at all. For example, very closely related species of birds often have completely different song frequencies, and differences in whether harmonics or buzzes are present (Rheindt et al., 2004). Both the rapid leaps in evolution of birdsong, and the relatively narrow range of the realized morphospace for bird song frequencies, means that there is weak, if any, phylogenetic signal (Rheindt et al., 2004).

### ***Detecting migrations through technological variabiltiy***

As outlined in chapter 2, Morphospace size, fitness landscapes, developmental biases, and extrinsic and intrinsic factors that influence the degree of horizontal transmission between lineages, should all influence whether we are able to detect migrations using technology alone. Imagine a scenario in which we know the population history of three groups of people through linguistic studies, DNA research, and other lines of evidence. Let us make one of these groups, group A, our focal group. We know that at some point in the past, the group A linage split off from the ancestors of another group, group B. Following that split, members of the new A lineage migrated into a new region. Group A and Group B can thus be considered closely related culturally as they have a recent shared history.

Further back in the past, the common ancestors of both Group A and B underwent a similar splitting event, with some members moving into a new area, and becoming culturally isolated from the lineage that led to members of group A and B. This group, Group C, shares a more distant common ancestor with groups A and B, thus is more distantly related to those groups, than they are to one another.

Group D is an outgroup, a group of people very distantly related to groups A-C. In this case, they may either occupy similar, or very different environments, and have either very similar, or distinct subsistence systems. Nonetheless, if lithic technologies do retain strong evidence for population history, we should expect D to be technologically different from groups A-C. We also should expect A and B will have very small technological distances to one another, A should be moderately distant from C, and should be much further from D (Figure 4.1). Importantly, in this case, migrations and population expansions result in both extrinsic, and intrinsic cultural isolation mechanisms that result in phylogenetic, branching histories.

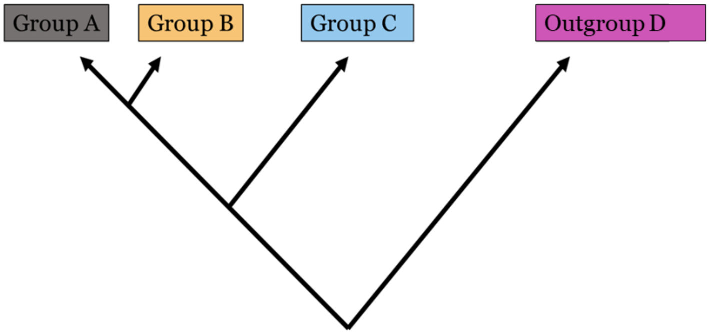


**Figure 4.1**: Simplified schematic outlining how divergent population histories are related to cultural relatedness. In this scenario, groups A and B both diverged from the same group/culture, and both are descendants of groups who are also ancestors of people who split from ancestors of group C deeper in time. If we focus on a single focal group (group A) these group fissioning events should lead to cultural diversification such that there is increasing cultural ‘distance’ between group A, and groups B, C, and the outgroup D (bottom).

With this model population history in mind we can evaluate how different patterns of technological change could result in lithic technologies either reflecting that population history or having only a weak or no relationship to population history. We can conceptualize technologies of each of the four groups as occupying some region in a possible technological morphospace. Such a morphospace would have more dimensions than what we could visualize, but here I show it along two dimensions (Figure 4.2). If technologies retain evidence of history, then both Group A and B, given their recent shared history, should be more similar to one another than they are to either group C, or the outgroup D. In this case technological similarity among groups reflects their historical relationships.

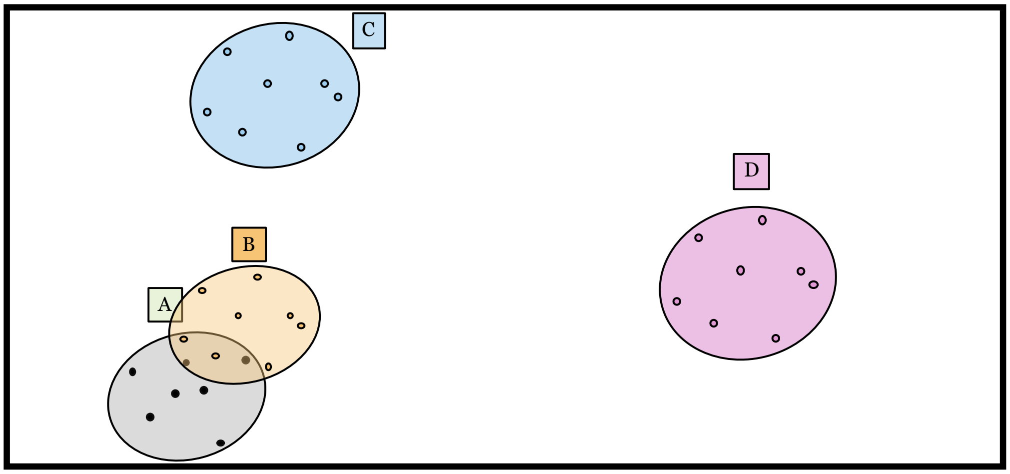


**Figure 4.2:** Example of how technological variation might be an accurate reflection of the history between groups A, B, C, and D. Each group occupies some portion of a possible technological morphospace.

However, variation in lithic technologies not reflect population histories. For example, there could have been relatively little technological change over time, such that the branching of populations was not associated with technological change. If, in our population scenario outlined above, there was little technological change, then we might expect groups A, B, and C, to overlap substantially in the technological morphospace (Figure 3). There are several ways this could happen. Migrants, and related groups, could all be part of a broader interaction network, exchanging technological information across group boundaries. That broader network may prevent the development of between group variability. It could also be that groups all are facing similar developmental constraints, or ecological pressures, that do not favor developing different technologies. Many other processes and prevent the development of between group variability. However, whatever the causes, the finer grained population history involving fissioning of groups from one another would not be reflected in the technological variability between the three groups.

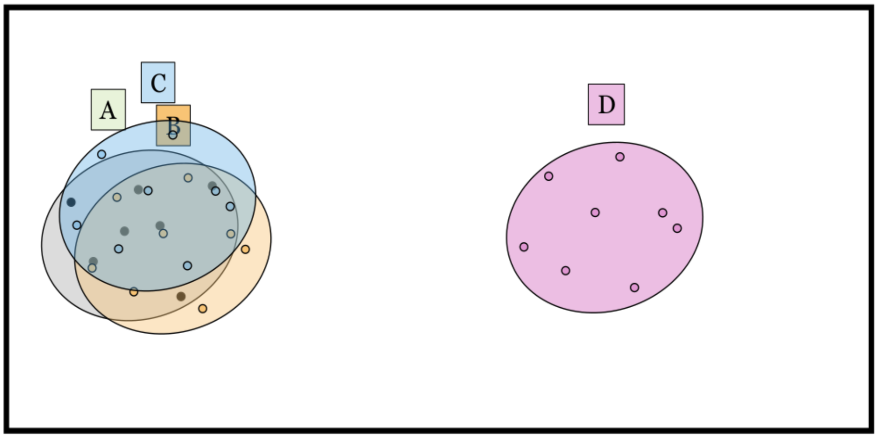


**Figure 4.3:** Example of how technological variation might be an inaccurate reflection of population histories of groups A, B, C, and D. Here, technological variation is collapsed into two dimensions, and each point represents a lithic assemblage, or technological repertoire of a particular group. Each group's assemblages occupy some portion of a possible technological morphospace. In this instance, either due to slow rates of technological change, or cultural exchange between groups A, B, and C, there is little inter-assemblage variation across those three groups. In this instance, the relative similarity and dissimilarity of assemblages is a poor reflection of the true population/migration histories of these groups.

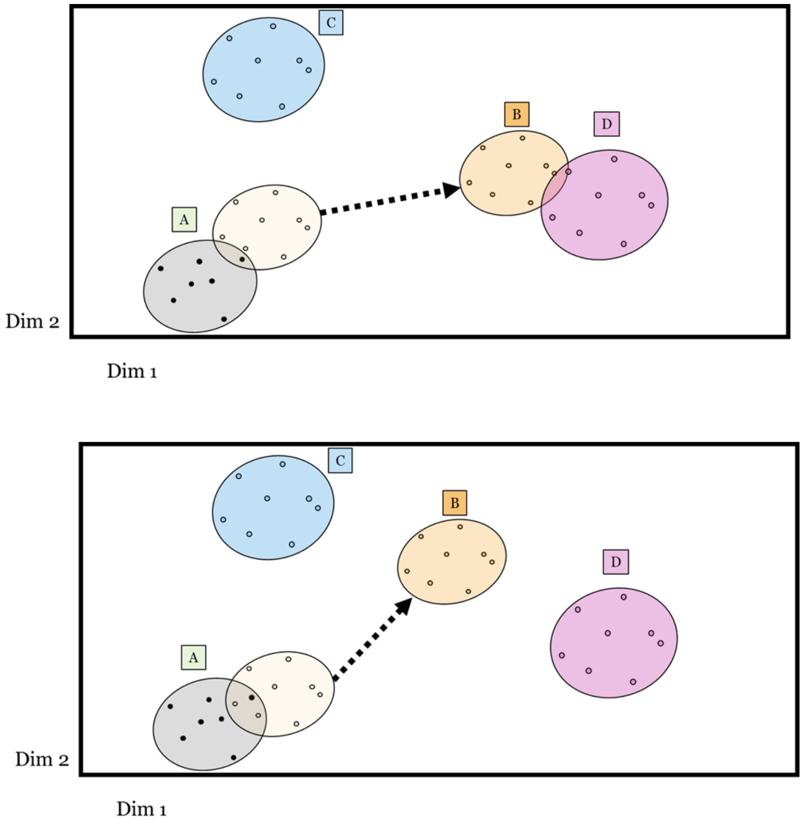


**Figure 4.4:** Example of how technological variation might be an inaccurate reflection of population histories. In this instance, rapid technological change in the B lineage has resulted in greater similarity to more distantly related groups, like C, and D, compared to group A with which they share a close history. Top: rapid change can result in cases of convergence, where completely unrelated assemblages are very similar to one another. Bottom: rapid change can also result in a more general lack of strong association between technology and history. The most closely related groups may not tend to have the most similar technologies, and vice versa, though there may be no cases of convergence.

Technologies could also change fast enough to erase evidence of continuity between migrants and their source population. Rather than occupying similar parts of the technological morphospace, group A, and group B could have very different technologies. Here, group B shares more in common technologically with an outgroup than with the technologies of group A. This could be the result of rapid technological change within the B lineage. Similarly, even without convergence, rapid technological change could erase evidence of common history (Figure 4.4. bottom). In this case, group B has rapidly modified technologies and occupies a separate region of the morphospace from A, C, and D. Again, multiple factors acting alone or together could cause relatively rapid change. It may be that group B has migrated into a region with distinct ecological pressures from those of group A, favoring rapid technological change. Or, following the migration there is true extrinsic and intrinsic isolation between B and related groups, allowing for more rapid cultural change. Whatever the cause, the result is that technological distances between groups do not reflect population histories.

In summary, various processes could strengthen or weaken the relationships between technological variation, and population histories. In most cases, including this study, we cannot know in great detail which combinations of mechanisms are driving the observed within and between group variability in technology (selection, strong or weak transmission isolating mechanisms, developmental constraints). This is in large part because it is difficult to perform formal comparative research of lithic technological variation (Reynolds, 2018; Will et al., 2019). This makes it harder to take advantage of the many benefits of the comparative method, including being able to test hypotheses about adaptation, causes of variation, and developing a stronger understanding of how evolutionary processes work (Harvey & Pagel, 1991). Below, and in the following study, I perform systematic comparative studies of technological variation in contexts where we know the population histories *a priori*, and where we also have information about the history of cultural exchange. This comparative approach should allow us to assess whether technological variability reflects population history. If variability does seem to reflect history, we may at least infer that historical signal is present, despite the many ways in which it could have been erased. If there is little strong evidence for technological variability relating to population history either in the Southwest, or in Oceania, this is an important step towards building a stronger theory for how to use lithic technology for inferring population dynamics.

### ***Ancestral Puebloan Migrations***

The first case of migration is the expansion of Ancestral Puebloan groups from the Colorado Plateau, into the river valleys of Central and Southern Arizona (Clark, 2001; Lyons, 2003) in the 13th century A.D.. In part due to historical accident, an arid climate that encourages preservation, abundant ceramics, and the relative youth of the record, the archaeological record of the American Southwest is both very well studied, and has a very well defined, high resolution model of cultural change, and migration (Glowacki & van Keuren, 2012; Barbara J. Mills et al., 2016b; Ortman & Cameron, 2011). In this case, the focal group will be migrant groups in Central and Southern Arizona, closely related to Ancestral Puebloan groups on the Colorado Plateau (Figure 5).

Ancestral Puebloans and other agricultural groups above and below the Mogollon rim share a common history in Archaic populations that lived throughout the Southwest. Most groups in the North American Southwest are part of the Uto-Aztecan language family, and that shared heritage extends at least as far back as the early Agricultural Period in the 2nd millennium (Hill 2001). Their shared history, and persistent networks of migration, trade, and cultural exchange (Glowacki & van Keuren, 2012; Mills et al., 2016b; Ortman & Cameron, 2011), have resulted in wide overlap in architecture, subsistence, settlement, ideology and material culture across the Southwest, on and below the Colorado Plateau (Cordell & Gumerman, 2006). Nonetheless, within that context, distinct cultural traditions did develop.

The earliest evidence of agriculture on the Colorado Plateau dates to around 1500 BC. However, after the arrival of new kinds of crops and new varieties of corn in the middle of the 1st millennium A.D., there was a trend towards rapid population growth, and increased sedentism (Cordell et al., 2007; Dean et al., 1985; Gumerman et al., 2003). During the Basketmaker III period between 500 and 750 A.D., settlements on the Colorado Plateau were small, and had few features: one or a handful of pithouses, storage pits and other features. By 700 A.D. groups built above ground masonry roomblocks, while over time pithouses increasingly took non-domestic roles in settlements, including evidence for use as ritual spaces. Settlements increased in size, with multiple households being clustered closer to one another. The roomblock style of organizing space and associated kiva, or unit pueblo, is a distinctive trait of Colorado Plateau Pueblo populations.

Puebloan groups also had distinctive material culture. Corrugated pottery is a distinctive element of Colorado Plateau ceramic technology not produced below the Mogollon Rim. Other kinds of material culture are diagnostic of sub-groups within the Ancestral Puebloan complex on the Colorado Plateau. For example, Kayenta and Tusayan are archaeological cultures on the Colorado Plateau defined by their distinctive material culture. People who took part in these cultures made very distinctive kinds of ceramics, both in their decoration, manners of manufacture, and form. The distinctive ceramic types that are connected to Kayenta/Tusayan groups include Tusayan white wares, Tsegi orange, Jeddito Orange, and Jeddito Yellow (Lyons, 2003, p. 27). Unusual and diagnostic ceramic forms include perforated plates likely used in the process of ceramic manufacture (Crotty, 1983; Lyons, 2003, pp. 18–19). The first examples of these are found in Basketmaker III contexts, and became common in the area by 1150 A.D. (Christenson, 1994; Lyons, 2003, p. 20). Other unusual forms include handles of ceramic spoons bearing effigies. While these are exceedingly rare among sites in Arizona, they are relatively common in the Kayenta area of Northern Arizona (Kidder & Guernsey, 1919, pp. 143–144). Techniques for manufacturing ceramics are also diagnostic. Such as the use of rivet attachments to bind a ladle to its handle Lyons (2003). Thin slab metates (Di Peso 1958, Lyons 2003: 34-35, and Manos with pecked finger grooves (Lyons 2003) are also likely diagnostic to Kayenta groups. Kayenta Kivas also often have distinctive entrybox complexes. Here, a slab lined hearth is placed in the interior of the kiva, in front of the entry opening. A larger vertical slab, or deflector, protects the hearth from gusts that might pass through the kiva (Dean, 2002). Groups on the Colorado plateau also had a distinctive way of organizing space in settlements that involved connecting multiple rooms to one another, in extended grids. These roomblock style settlements are not found below the Colorado Plateau until the 13th and 14th centuries A.D.. In summary, Kayenta groups on the Colorado Plateau have a set of material traits, visible in the archaeological record, which are very different other Ancestral Puebloan groups above the Mogollon rim, including Virgin branch groups at the Westernmost extent of the Ancestral Puebloan cultural complex.

The material culture of Ancestral Puebloans on the Colorado Plateau are distinct from groups below the Mogollon rim, like the Hohokam. The Hohokam cultural complex saw its own historical trajectory, and distinct subsistence patterns, and material culture develop, and can be considered as more distantly related to the Ancestral Puebloan cultural complexes than they are to one another. Hohokam site ranges include the Phoenix and Tucson basins, and surrounding river valleys throughout the Northern Sonoran Desert, like the Tonto basin, and San Pedro Valley. In these areas, in the 1200s-1300s A.D., settlements are dominated by Hohokam architectural styles, pithouses (semi-subterranean, circular structures), compounds (above ground structures build around a central courtyard), and platform mounds (Rice, 1998). Hohokam groups produced a distinctive red-on-buff pottery. They practiced cremation as well as specific forms of inhumation that differed from Ancestral Pueblo traditions. While engaged with trade with groups on the Colorado Plateau, evidence of local production of Ancestral Puebloan style material culture in the Hohokam area is very rare until the 13th century A.D..

By ~1250-1275 A.D. much of the four corners region was depopulated, and sites with both architectural styles and pottery diagnostic of ancestral Puebloan groups is found at sites in River Valleys below the Mogollon Rim. The question of whether these similarities between sites above and below the Mogollon rim was the result of migration, or other processes was a classic question among early Southwest Archaeologists, and there has been more than 60 years of research focused on tracking migrant groups in the Southern Southwest Haury (1958).

While the degree to which behavioral changes may be attributed to migration, horizontal transmission, or through local developments is disputed, there are a few archaeological identifications of migrant communities that are uncontroversial. There are two general types of settlements argued to relate to migrations within the Southwest. These include “Site Unit Intrusions”, which represent cases like at Point of Pines, Reeve Ranch Ruin, and Goat hill where Northern migrants established their own spatially separate and distinct communities, and produced material culture of non-local form (Haury, 1958; Mills et al., 2016b). Other sites show more subtle evidence of Northern migrants, often in cases where migrants were not spatially separate from neighboring groups, but intermingled. This pattern is well represented in the Salt River arm of Tonto Basin, where Hohokam, and migrant groups lived with one another (Clark, 2001). In both cases, migrants produced material culture typical of their ancestors on the Colorado Plateau, a short distance away from communities with very different kinds of architecture, and material culture. Both kinds of migrant contexts were sampled for this study: Site unit intrusions in San Pedro Valley, and less separated migrant communities in Tonto Basin.

These migrant communities, both site-unit intrusions, and integrated communities, developed right around the time when the Ancestral Puebloan area was depopulated (~1250-1300 A.D) and tend to be located in already populated river valleys, like the Phoenix Basin, Lower San Pedro Valley, Verde Valley, and Tonto Basin (Ciolek-Torrello & Welch, 1994; Clark, 2001; Geib et al., 1985; Haury, 1958; Lyons, 2003 ; Zier, 1976). Migrant communities produced ceramics similar to those made by Ancestral Puebloans above the Colorado Plateau but with modifications. These ceramics fall under the broader rubric of the “Maverick Mountain Series”.

For example, settlements in the San Pedro valley just prior to the arrival of migrants in the 13th century A.D. include pithouses, adobe compounds, and ballcourts typical of Tucson and Phoenix Basin Hohokam settlement. Ceramics recovered from sites across the San Pedro Valley also demonstrate strong ties to the Hohokam complex (Clark & Lyons, 2012). Once the Four Corners region began to be depopulated, migrants likely arrived in the San Pedro Valley. Two roomblock sites with strongest evidence for Kayenta migrants in San Pedro Valley are sampled in this study, Davis Ranch (AZ:BB:11:36), and Reeve Ruin (AZ:BB:11:26) (Clark & Lyons, 2012; Di Peso, 1958). Both are uncontroversial examples of “site-unit intrusions” which were established at the edge of the Hohokam range (Gerald & Lyons 2018). They have distinctive archaeological features, like Kivas, roomblock architecture with contiguous rooms distinct from Hohokam architectural style, and represent the earliest instances of the production of northern style pottery within the San Pedro Valley (Clark & Lyons, 2012).

Ancestral Puebloan migrants in the Tonto Basin were more closely integrated with Hohokam groups, which likely had roots in regular interactions between Ancestral Puebloan groups, and people within Tonto Basin prior to the depopulation of the plateau (Clark, 2001; Barbara J. Mills et al., 2016a). Within Tonto Basin, house-in-pit compounds and platform mounds were the standard sites, and were associated with material culture emblematic of the Hohokam complex. In 13th-14th century A.D., migrant communities were established at the eastern margin of Tonto basin, at Griffin Wash locus A, U:4:4, U:8:454/14c, and Meddler point (Clark, 2001; Elson et al., 1995, pp. 304–305; Lindauer, 1997; Rice, 1998). Roomblocks are both distinct from other Hohokam compounds in their organization of domestic space, and most are located away from access to the higher quality farmland in the Western margin of the basin (Elson et al., 1995, pp. 304–305).

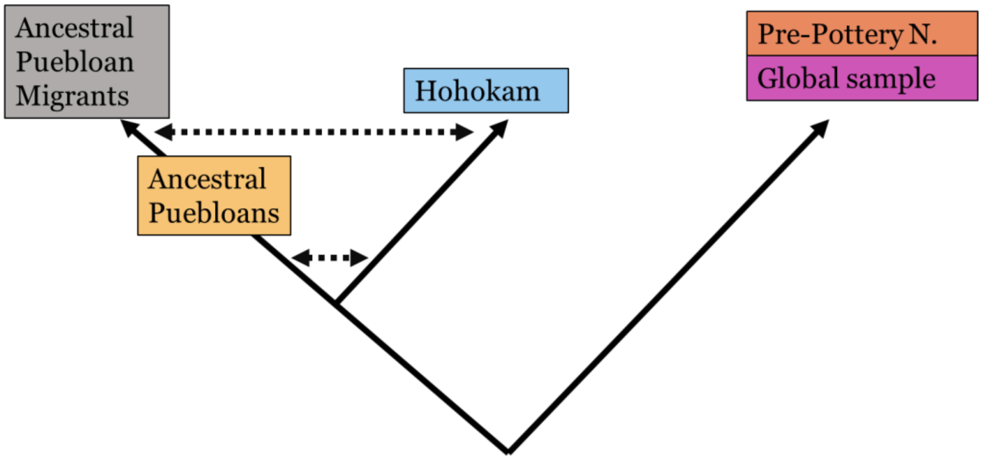


**Figure 4.5**: Simplified model of historical relationships among groups sampled in the American Southwest. The dotted lines highlight interaction between Ancestral Puebloan migrants groups and their ancestors on the Colorado Plateau, and groups below the Plateau. The outgroups in this instance are samples drawn from archaeological contexts

outside the Americas, as well as a sample of Pre-Pottery Neolithic assemblages in the Southern Levant.

The different histories of Ancestral Puebloan, Hohokam and other groups in the American Southwest, and the social relationships between groups reconstructed through lines of evidence independent of lithic technology, have made the region attractive for lithicists interested in testing whether lithic variability maps onto identity groupings (Ryan, 2017; Williams et al., 2013). However, previous attempts to assess whether lithic technological variation show evidence of the kinds of social boundaries inferred from other kinds of material culture in the Southwest have found few between group differences. Projectile points, bifacially flaked “knives”, drills, reliance on pressure flaking to retouch both bifaces, and in some cases drills were ubiquitous across many of the Agricultural period assemblages in the region. These practices occur along with a more general reliance on non-formal flake production Mathien (1997).

Most of what we know about lithic technological variation across the Southwest relates to projectile point forms (Ryan, 2017; Sliva, 2015). Archaeologists have proposed some projectile points as diagnostic of Fremont and Kayenta cultures being restricted to the Four Corners region between 900-750 bp. The main example is the Bull Creek point, which is a narrow isosceles triangle in plan view, without side notches, and only a concave base as a means for hafting (Holmer & Weder, 1980). The Bull Creek point is one of the few whose spatio-temporal distribution closely matches that of Kayenta ceramics (Holmer & Weder, 1980; Jennings et al., 1981; Woods, 2009). Furthermore, isolated Bull Creek points are also found in Kayenta Enclave sites in Central Arizona, like Reeve Ranch in the Lower San Pedro Valley (Wambach, 2014).

Other implements using similar methods of production to projectile point manufacture are also common across the Southwest from Basketmaker through Pueblo periods. These include larger bifacially flaked implements (“knives”). Their production involved bifacial flaking and thinning, often through soft hammer percussion (Whittaker, 1984). Pressure flaking was also implemented to shape the final edges through retouch (Bradley, 1997). Pressure flaking was also involved in the finishing of other tools. Drills were often made on recycled projectile points and bifaces, or on flake blanks and their tips often were retouched through pressure flaking, sometimes through trifacial flaking, to produce a stout bit with a diamond shaped cross section (Bradley, 1997; Gooding, 1980; Walling, 1988).

Other kinds of flaked tools that may not have involved pressure flaking were also produced in the Southwest. Flake production occurred through non-hierarchical core reduction strategies, often involving hard hammer percussion with no platform preparation, either through overhang removal, or through platform abrasion (Mathien, 1997; Walling, 1988; Wambach, 2014; Ward, 2004; Whittaker, 1984). Cores, and their products were often re-used as choppers. These include relatively large tools with bifacial edges, that have seen heavy damage. These are often made on either coarsely flaked cobbles, on large flakes, or on the kinds of non-hierarchical cores used to make flakes (Bradley, 1997; Whittaker, 1984).

There is little evidence of more formalized blade making, microblade manufacture, and prepared core technologies are absent, though there may be isolated examples of these practices among late prehistoric and protohistoric Sobaipuri assemblages (Bradley pers. comm.). In some cases, burin spalls from flakes may have been used as microdrills, but evidence for this technology is largely indirect, and diagnostic debitage are likely to have been passed through relatively large screens (Curcija, 2020).

Across the Southwest, axes were most often produced by pecking and grinding (Gosden, 1989; Phagan, 1986). To form a haft, these axes often had either two notches pecked into them to form a waisted profile, or they had a grooves of various kinds to serve as the haft (Phagan, 1986). These could be made on cobbles, or recycled manos, as is the case among Puebloan sites in the Westernmost extreme of their range, north of the Grand Canyon (Dalley & McFadden, 1988), and Hohokam sites in Central Arizona (Adams, 2002). However, there are also cases of fully flaked axes, formed through bifacial flaking of large nodules or flakes, which saw no pecking or grinding to shape them. Published examples at Basketmaker III sites in Durango (Love-dePeyer, 1980) and Dolores River Valleys in Colorado spanning basketmaker through Pueblo III periods had a haft formed by retouch of two large notches (Phagan, 1986).

Previous studies attempting to tie lithic variation to particular migrant groups in the Southwest have seen mixed success. Overall there is little evidence that particular point designs are diagnostic to particular cultural groups, like peoples associated with Hohokam and Ancestral Puebloan material culture. For example, Ryan studied material culture of Ancestral Puebloan Migrant groups in the Tucson and San Pedro River valleys, and found that projectile point designs made by groups at those sites were not strongly differentiated from other non-migrant groups in the same regions (Ryan, 2017). Furthermore, flake measurements proposed as useful for tracing cultural transmission (Tostevin, 2013), do not show significant between group differences in the Southwest consistent with their being able to diagnose the presence of particular culture-groups (Paige & Perreault, 2017). Nonetheless, some patters in flake attributes within sites argued to have mutlti-ethnic communities in the Southwest, like at Cox Ranch Pueblo, are argued to represent the presence of multiple technological styles consistent with a more diverse community (Williams et al., 2013). However, it is not clear whether the diversity in styles at Cox Ranch is within the range of what we would expect in any other community in the region.

The temporal window in which to study Ancestral Puebloan migrants as culturally discrete entities is narrow. By 1350-1400 A.D., soon after the diaspora from the Colorado Plateau starting ~1275 A.D., between group ceramic diversity was substantially reduced, as a similar range of wares, Salado Polychromes, were produces and became the target of consumption across the Southwest. The reduction of between-group differences in ceramics are argued to be symptoms of the spread of a new popular ideology, which more tightly integrated groups with previously distinct identities (Crown & Bishop, 1994; Mills et al., 2015). More generally, indigenous groups today trace their own origin as the amalgamation of distinct tribes and cultures within the Southwest, highlighting an ongoing process of ethnogenesis, as opposed to branching processes, in the development of group identities (Hays-Gilpin & Gilpin, 2018; Ortman, 2010)

In summary, while groups in the Southwest are related through trade, migration, and shared history, distinct historical trajectories are evident above and below the Mogollon rim, among Hohokam and Ancestral Puebloan groups. The migrations of Ancestral Puebloan groups below the Mogollon rim is a useful opportunity to investigate whether those migrants retain evidence of their origin.

## Measuring technological variability in the Southwest

The results of this chapter follow a sequential results format. There are three sections, each including the background, methods and results addressing one part of the broader problem. The first section involves a simple overview of what technologies are present across the sampled assemblages. Here, I explore in detail which cultural groups have what technologies, and note potential between group differences, and what technologies are associated with those differences. In this section, I evaluate whether there may be shared derived cultural traits that could be used to detect migrations.

In the second section I evaluate whether the within and between-group variability in technology reflects population history. To do so, I quantify similarity and dissimilarity between the sampled assemblages using Jaccard distances, and assesses the within and between group variability of assemblages through a multidimensional scaling analysis approach. I test whether there are significant between-group differences using a

PERMANOVA approach, and outline which pairs of groups are significantly different through post-hoc tests.

The third and final section addresses whether historical reconstructions based on technological data reflect the true population history. In this section, I produce hypotheses of historical relationships between assemblages based only on technology using a Neighbornet approach, and I assess whether those reconstructions reflect the population history of the American Southwest.

In this study, I treat Ancestral Puebloan migrants as a focal group, and assess how technological variability, reflects the historical relationships between those migrants, their ancestors, and more distantly related groups in the Southwest, as well as unrelated groups elsewhere in the world. Lithic variability among three Ancestral Puebloan migrant enclaves within the Hohokam culture area two in the Lower San Pedro Valley, and one in Tonto Basin are compared to variability among Ancestral Puebloan sites above the Mogollon Rim in the Kayenta area (Klethla Valley in Northern Arizona), and Virgin area (Shivwitz Plateau in NW Arizona, and Virgin River in Southwest Utah), and finally to variability among Hohokam assemblages made by their new neighbors in Tonto Basin and San Pedro Valley. For this study two kinds of data, procedural units and technological modes, were collected and analyzed across 25 archaeological sites in the American Southwest, compared to a global sample of outgroups. Here, I outline the basic units of the analysis: the traits and assemblages sampled.

### ***Procedural unit data***

Procedural units are discrete, mutually exclusive manufacturing steps involved in the production of tools (Maloney, 2019; Perreault et al., 2013). The procedural unit system was originally developed to characterize the complexity of stone tool making systems. However, they are also a means of characterizing within and between group technological variability. For example, one assemblage might have evidence for bipolar percussion using both a hard hammer and an anvil, and the production of flakes from single platform cores with their platforms prepared and rejuvenated, while another assemblage may not have bipolar percussion, single platform cores that might have their platforms prepared, but never rejuvenated. With the procedural unit system, both assemblages are broken down into two directly comparable presence/absence vectors. The first assemblage would have both procedural units associated with bipolar percussion, and the units associated with prepared and rejuvenated single platform cores counted as present (like use of a hard hammer, use of an anvil, platform preparation by abrasion, platform preparation by microchipping, and platform rejuvenation through core tablets), while the second assemblage would only have units associated with prepared single platform cores (use of a hard hammer, platform preparation by abrasion and microchipping) counted as present. One strength of this system is that it can capture relatively subtle differences between assemblages, such as differences in how core platforms are prepared between sites. However, the system does not capture differences in how procedural units might be bundled together, or the order in which procedural units were employed. For example, it may be that two assemblages have the same sets of procedural units (invasive flaking, flaking with a soft hammer, platform abrasion) that are applied in different orders to produce very different kinds of core technologies like blade cores at one assemblage, and bifacial cores in another.

The procedural units collected for this study include steps involved in core preparation (cresting, centripetal preparation, platform rejuvenation), the tools used to produce flakes (pressure flakers, anvils, hard hammers), and the nature of retouch (abrupt retouch, burination). The procedural unit dataset includes the presence or absence of any one of 28 procedural units (Table 4.1). These data were collected from the literature, as well as by studying assemblages in person.

**Table 4.1**: Procedural units and their short definitions. In this study, all procedural units reported, or observable based on illustrations and tables of artifact types were described as present. This included procedural units belonging to separate reduction sequences.

| Procedural units | Short description |
|---|---|
| 1. Heat treatment | Heat treatment used to improve flake-ability |
| 2. Platform facetting | Platform morphology modified by striking flakes across platform |
| 3. Centripetal shaping | Convexities maintained through centripetal removals |
| 4. Lateral shaping | Flakes struck from lateral margins of core to maintain convexities |
| 5. Distal shaping | Convexities maintained through flakes struck from distal edge of core |
| 6. Back shaping | Back of the core is shaped. |
| 7. Cresting | Cresting to shape core face during initial steps of core preparation. |
| 8. Debordante shaping | Convexities maintained through flakes along lateral margins of core face |

| Procedural units | Short description |
|---|---|
| 9. Overshot flaking | Invasive flake removals that clip or remove the distal margin of the core |
| 10. Kombewa flaking | Removal of flake from ventral surface of a flake |
| 11. Core tablet | Removal of core platform by striking flake into face |
| 12. Abrasion | Abrasion or grinding performed at any point in reduction sequence. |
| 13. Trimming platform overhang | Removal of chips to modify area below platform. |
| 14. Use of an anvil | Use of an anvil |
| 15. Soft hammer percussion | Use of a soft hammer |
| 16. Indirect percussion | Use of a punch to remove flakes |
| 17. Flaking through pressure | Removal of flakes through application of pressure on core platform |
| 18. Hammer dressing | Modification of a piece through pecking |
| 19. Invasive flaking | Removal of non-cortical flakes that extend beyond the midpoint of the piece |
| 21. Retouch | Retouch of flake or core tool (unifacial only) |
| 22. Backing | Retouch forms an abrupt, scraper-like margin |
| 23. Notching | Retouch forms round concavity |
| 24. Burination | Removal of spalls along the margins of flakes |
| 25. Tanging | Retouching base of piece to form a tang |
| 26. Tranchet | Rejuvenation of core tool by striking a flake across the edge |
| 27. Bifacial retouch | Retouch on both faces of a flake or core-tool |
| 28. Invasive retouch | Retouch that extends to the midline of a tool |
| 29. Pressure flaked retouch | Pressure flaking retouch |

In order to make the coding of procedural units from the literature replicable, I produced a codebook outlining the standards by which I would count any given procedural unit as present or absent. This codebook follows the structure of those developed at the Center for Disease Control for processing interview transcripts, and serves to prevent coders from applying their own heuristics to the coding process (MacQueen et al., 1998). The structure of the codebook include definitions of the code (for example, the definition of *debordante*), but also explicit inclusion and exclusion criteria, as well as written phrases, terms, and example illustrations that would be typical and atypical evidence sufficient to code the procedural unit as present. The codebook also includes examples that are close, but not sufficient to code the technique as present. I sampled only sites with detailed descriptions of the lithic technology, including discussions about how cores were managed, and detailed illustrations of debitage, cores, and retouched elements.

Assemblages that I studied in person were first analyzed through an attribute analysis approach. I gathered attribute data from flakes, cores, and retouched elements, including platform dimensions, and type, flake dimensions and dorsal scar orientations, presence or absence of different kinds of treatments, including platform abrasion, facetting, or evidence for core rejuvenation. All cores and retouched pieces were photographed, and I illustrated a subset of pieces that captured evidence for particular technological behaviors, like core rejuvenation, platform preparation, or different stages of tool manufacture. Based on the attribute analysis, as well as previously published studies of the same assemblages, I determined which procedural units were present, and which were absent. Finally, procedural units which were either ubiquitous, or absent across all assemblages were excluded from this study.

### ***Technological mode data***

The Technological Mode system (Shea, 2013) characterizes assemblages through the presence or absence of distinct kinds of artifact classes. In contrast to procedural units, that represent particular flintknapping behaviors, technological modes can be thought of as the result of a bundle of procedural units, performed in more specific orders to produce particular kinds of artifacts. For example, mode E2, thinned bifacial core tools, involves not just one flintknapping technique, but several, which lead to particular kinds of end products. Technological modes that might be present in an assemblage might include core types (variations of unifacial hierarchical cores, variations of bifacial hierarchical cores, bipolar, and non-hierarchical pebble cores), types of retouched pieces in the assemblage (microliths, burins, points), types of core tools, and other modes (Table 4.2).

**Table 4.2**: Technological modes analyzed in this study and their short descriptions based on Shea (2013, 2016, and 2020). Modes D encompasses different retouched tool types, Modes E encompass bifacial core tools, Modes F encompass bifacial hierarchical cores, such as Levallois, Modes G encompass hierarchical cores with one dominant platform.

| Technological modes | Short description |
|---|---|
| B. Bipolar cores | Use of hammer and anvil to produce flakes |
| C. Pebble cores | non-hierarchical flake removal |
| D1. Retouched pieces with acute edges | |
| D2. Backed pieces | Includes pieces with retouch approaching 90\degree |
| D3. Microliths | Backed pieces < 3cm |
| D4. Burins | Burins, burin spalls, tranchet flakes' |
| D5. Points | Awls, convergent scrapers, points |
| D6. Tanged piece | Basal retouch/notching forms a tang |
| D7. Core-on-flake | Detaching of flakes from other flakes |
| E1. Large cutting tool | Handaxes, cleavers, and picks |
| E2. Thinned biface | Thinned bifaces: follate and laurel leaf type artifacts |
| E3. Tanged biface | Retouch forms a tang on proximal margin of core tool |
| E4. Celt | Core tools flaked to produce sharp distal edge |

| Technological modes | Short description |
|---|---|
| F2. Recurrent laminar bifacial hierarchical core | Recurrent Levallois |
| F3. Radial centripetal bifacial hierarchical core | Centripetal Levallois |
| G1. Platform unidirectional hierarchical core | Single platform flake cores |
| G2. Blade core | Single platform blade cores |
| G3. Microblade core | Single platform microblade cores |
| H. Edge abraded tool | Edges sharpened through abrasion |
| I. Groundstone | Tools produced through pecking and grinding |

Mode data were collected from the literature, from existing datasets, and by assessing assemblages directly through the attribute analysis approach described in above. When collecting data from the literature, I read descriptions of chipped stone assemblages and based on illustrations of artifacts, prose descriptions of the assemblage, and data tables, determined whether there was sufficient evidence to infer the presence of each technological mode. Mode data were also collected from three existing datasets, one published by Nishiaki et al. and two published by Shea (2016). Across these dataset, duplicate entries were excluded, modes coded as questionable were counted as absent, and assemblages for which the source reference could not be found were excluded. As was the case with procedural units, Assemblages I studied in person were first analyzed through an attribute analysis approach, where flakes, cores, and retouched elements were sampled, analyzed, and illustrated or photographed. Based on that analysis, as well as previously published studies of the same assemblages, I determined which technological modes were present or absent.

### ***Sites Sampled***

Across the Southwest, I collected data on lithic variability across 25 archaeological sites. I compared lithic variability among three Ancestral Puebloan migrant enclaves within the Hohokam culture area: two in the Lower San Pedro Valley (Davis Ranch and Reeve Ruin), and one in Tonto Basin (Griffin Wash locus A) to variability among Ancestral Puebloan sites in the Kayenta area (Klethla Valley in Northern Arizona), and Virgin area (Shivwitz Plateau in NW Arizona, and Virgin River in Southwest Utah), and finally to variability among Hohokam assemblages in Tonto Basin and San Pedro Valley (Figure 4.6, Tables 4.3 and 4.4).

Both Davis Ranch and Reeve Ruin were excavated by Archaeology Southwest over the course of their lower San Pedro Project in the 2000s (Clark & Lyons, 2012). The Archaeology Southwest project excavated 6 test units in Davis Ranch, and 9 in Reeve ruin, making them some of the more intensively investigated sites of the 29 excavated over the course of the project. Both sites are located across the river from one another in the Cascabel district, had Kivas with the Kayenta entry box complex that is diagnostic of Kayenta groups from the four corners region, as well evidence for production of maverick mountain series pottery, and perforated plates (Clark & Lyons, 2012). The data gathered for this study is derived from the materials recovered over the course of these

Archaeology Southwest excavations. I collected data from these sites in person using the attribute analysis approach.

Griffin Wash locus A was excavated during the Roosevelt Community Development project, which focused on testing 27 sites in the Salt River arm of Tonto Basin prior to the construction of Roosevelt Dam. As was the case in the Lower San Pedro project, these sites include both platform mounds and compounds with a closer affinity to Hohokam groups, and a small number of roomblock settlements associated with Ancestral Puebloans (Elson et al., 1995:282). Griffin Wash locus A is one of those roomblock settlements and was the most intensively tested of its kind within the basin. Technological data from this site was collected from published studies of the chipped stone and groundstone assemblages (Adams, 1995; Lindeman, 1995).

The Ancestral Puebloan sites in Northern Arizona include sites in Klethla Valley, just West of Black Mesa. The Klethla Valley sites were investigated in 1971-1972 by the Museum of Northern Arizona who were contracted by the Salt River Project to study the area in advance of the construction of the Black Mesa Navajo Generating Station coal haul railroad (Swarthout et al., 1986). Of the 104 sites identified, 34 were excavated in their entirety, and two were sampled for this study: NA 11047, and 11057 both bore relatively rich lithic assemblages, date to between 1100 and 1250 A.D., and have architecture and ceramic assemblages that are emblematic of the Kayenta/Tusayan cultural complex. I analyzed the Klethla sites in person, and supplemented my analysis with prior descriptions of the assemblages by Stebbins and Swarthout (Stebbins et al., 1986; Swarthout et al., 1986).

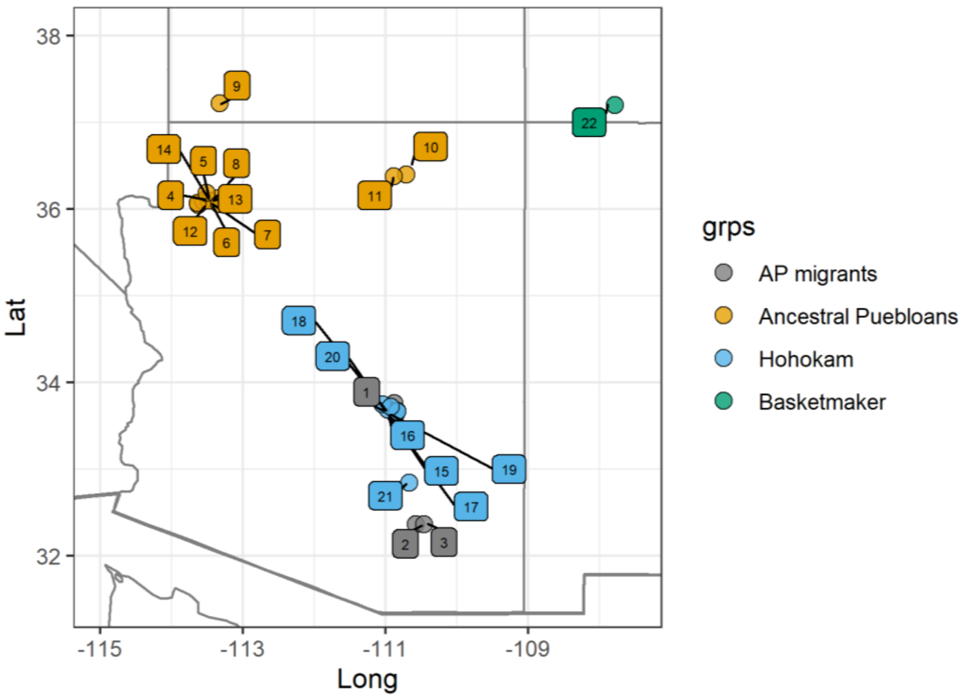


**Figure 4.6**: map of sampled assemblages in the American Southwest. Assemblage key: 1. Griffin Wash A V:5:90, 2. AZ BB:11:26, 3. AZ BB:11:36, 4. Granary House, 5. Site 232, 6. Peter's Pocket, 7. Lava Ridge Ruin, 8. Andrus Canyon, 9. Little man sites, 10. NA 11047, 11. NA 11057, 12. Corn Cob, 13. Coyote, 14. To'tsa, 15. Eagle Ridge B V:5:104, 16. Hedge Apple V:5:189, 17. Meddler Point V:5:4, 18. Eagle Ridge A V:5:104, 19. Porcupine Site V:5:106, 20. Pyramid Point V:5:1, 21. AZ BB:2:19 and 22. 5LP110 and 111 .

**Table 4.3**: Sites sampled: procedural units

| Context | Source | Cultural group |
|---|---|---|
| Griffin Wash A V:5:90 | Lindeman 1995 and Adams 1995 | AP migrants |
| AZ BB:11:26 | This study | AP migrants |
| AZ BB:11:36 | This study | AP migrants |

| Context | Source | Cultural group |
|---|---|---|
| Granary House | Wambach 2014 | Ancestral Puebloans |
| Site 232 | Wambach 2014 | Ancestral Puebloans |
| Peter's Pocket | Wambach 2014 | Ancestral Puebloans |
| Lava Ridge Ruin | Wambach 2014 | Ancestral Puebloans |
| Andrus Canyon | Wambach 2014 | Ancestral Puebloans |
| Little man sites | Walling 1988 | Ancestral Puebloans |
| NA 11047 | This study and Stebbins 1986 | Ancestral Puebloans |
| NA 11057 | This study and Stebbins 1986 | Ancestral Puebloans |
| Corn Cob | Wambach 2014 | Ancestral Puebloans |
| Coyote | Wambach 2014 | Ancestral Puebloans |
| To'tsa | Wambach 2014 | Ancestral Puebloans |
| Eagle Ridge B V:5:104 | Lindeman 1995 and Adams 1995 | Hohokam |
| Hedge Apple V:5:189 | Lindeman 1995 and Adams 1995 | Hohokam |
| Meddler Point V:5:4 | Lindeman 1995 and Adams 1995 | Hohokam |
| Eagle Ridge A V:5:104 | Lindeman 1995 and Adams 1995 | Hohokam |
| Porcupine Site V:5:106 | Lindeman 1995 and Adams 1995 | Hohokam |

| Context | Source | Cultural group |
|---|---|---|
| Pyramid Point V:5:1 | Lindeman 1995 and Adams 1995 | Hohokam |
| AZ BB:2:19 | This study | Hohokam |
| 5LP110 and 111 | Love-dePeyer 1980 | Basketmaker |
| Kfar HaHoresh | Barzilai and Goring-Morris 2010 | PPN |
| Tepe Rahmatabad | Nishiaki et al. 2013 | PPN |
| Sha'ar Hagolan | Ariel-Shatil 2006 | PPN |
| Lomekwi 3 | Harmand et. al. 2015 | Global sample |
| Lokalalei 2c | Delagnes and Roche 2005 | Global sample |
| Kanjera | Plummer and Bishop 2016 | Global sample |
| NY 18 Nyabusosi | Texier 1995 | Global sample |
| Hugub KK51 | Gilbert et al. 2016 | Global sample |
| Nor Geghi 1 | Adler et al. 2014 | Global sample |
| Torre in Pietra level M | Villa et al. 2016 | Global sample |
| Qesem Cave | Barkai et al. 2005 and Barzilai et al. 2011 | Global sample |
| Torre in Pietra level D | Villa et al. 2016 | Global sample |
| Koilomot locus 2 | Tryon et al. 2005 | Global sample |
| Wallertheim West Concentration | Conard and Adler 1997 | Global sample |
| Ein Qashish | Malinsky-Buller et al. 2014 | Global sample |
| Geissenklosterle Cave Gravettian | Hahn and Owen 1985 | Global sample |
| Sujula | Rankama and Kankaanpaa 2011 | Global sample |
| GFJ | Pavlides and Kennedy 2007 | Global sample |

Ancestral Puebloan sites in the Shivwits Plateau area in Northwest Arizona at were investigated by Karen Harry as part of the Shivwits Research Project from 2006 to 2012 (Harry et al., 2013; Wambach, 2014). These assemblages are outside the Kayenta region, at the Western margin of the extent of the Ancestral Puebloan cultures. This region was also depopulated in the 12th century A.D. (Benson et al. 2007, Pelletier 2022). Data gathered for this study is derived from Wamback's analysis of chipped stone material from eight sites, spanning the middle PII to early PIII periods (1000-700 BP) (Wambach, 2014). The three Ancestral Puebloan sites in Southwestern Utah, along the Virgin river, sampled here were excavated by Dalley and McFadden in 1982 (Walling, 1988). The sites fall within the PI to early PII periods (~1200-950 BP). The data gathered for this study is derived from Walling's analysis of the assemblages (Walling, 1988).

**Table 4.5**: Sites sampled: technological modes

| Context | Source | Cultural group |
|---|---|---|
| AZ BB:11:26 | This study | AP migrants |
| AZ BB:11:36 | This study | AP migrants |
| Griffin Wash A V:5:90 | Lindeman 1995 and Adams 1995 | AP migrants |
| NA 11047 | This study and Stebbins 1986 | Ancestral Puebloans |
| NA 11057 | This study and Stebbins 1986 | Ancestral Puebloans |
| Lava Ridge Ruin | Wambach 2014 | Ancestral Puebloans |
| Granary House | Wambach 2014 | Ancestral Puebloans |
| Andrus Canyon | Wambach 2014 | Ancestral Puebloans |
| Corn Cob | Wambach 2014 | Ancestral Puebloans |

| Context | Source | Cultural group |
|---|---|---|
| Coyote | Wambach 2014 | Ancestral Puebloans |
| Site 232 | Wambach 2014 | Ancestral Puebloans |
| Peter's Pocket | Wambach 2014 | Ancestral Puebloans |
| To'tsa | Wambach 2014 | Ancestral Puebloans |
| AZ BB:2:19 | This study | Hohokam |
| Pyramid Point V:5:1 | Lindeman 1995 and Adams 1995 | Hohokam |
| Meddler Point V:5:4 | Lindeman 1995 and Adams 1995 | Hohokam |
| Hedge Apple V:5:189 | Lindeman 1995 and Adams 1995 | Hohokam |
| Eagle Ridge A V:5:104 | Lindeman 1995 and Adams 1995 | Hohokam |
| Eagle Ridge B V:5:104 | Lindeman 1995 and Adams 1995 | Hohokam |
| Porcupine Site V:5:106 | Lindeman 1995 and Adams 1995 | Hohokam |
| 5LP110 and 111 | Love 1980 | Basketmaker |
| Catal Huyuk | Shea 2013 | PPN |
| Tepe Rahmatabad | Shea 2013 | PPN |
| Byblos | Shea 2013 | PPN |
| Ain Ghazal | Shea 2013 | PPN |
| Beidha I-VI | Shea 2013 | PPN |
| Kfar HaHoresh | Shea 2013 | PPN |
| Nahal Hemar | Shea 2013 | PPN |
| Nahal Issaron | Shea 2013 | PPN |
| Sha'ar Hagolan | Ariel-Shatil 2006 | PPN |

| Context | Source | Cultural group |
|---|---|---|
| Abu Ghosh | Shea 2013 | Global sample |
| Panga Ya Saidi Levels 1-4 | Shea 2020 | Global sample |
| Wadh Lang'o 1 | Shea 2020 | Global sample |
| Strashnaya Cave 4 | Nishiaki 2021 | Global sample |
| Arta 2  Layers 1-3 | Nishiaki 2021 | Global sample |
| Tyumechin 4 tempo 1 | Nishiaki 2021 | Global sample |
| Ogonki 5 Layer 3 | Nishiaki 2021 | Global sample |
| Tor Aeid | Nishiaki 2021 | Global sample |
| Sefunim Layer D.8 | Nishiaki 2021 | Global sample |
| Shibazhan C | Nishiaki 2021 | Global sample |
| Fanzenshanyan Layer 2 | Nishiaki 2021 | Global sample |
| Xinxiangzhuanchang Layer 4 | Nishiaki 2021 | Global sample |
| Shuidonggou Loc.8 Layer 2 | Nishiaki 2021 | Global sample |
| Meigou Lower | Nishiaki 2021 | Global sample |
| Haga Layer 2 | Nishiaki 2021 | Global sample |

The non-Ancestral Puebloan assemblages include sites in Tonto Basin, and the Lower San Pedro Valley. The single Hohokam site in San Pedro Valley, Ash Terrace, is in the Northern, Aravaipa district of the Lower San Pedro, in areas of the valley where there is little evidence for Ancestral Puebloan migration: a lack of northern architectural features and roomblocks, and little evidence for local production of diagnostic ceramics. The site dates to the Classic period (~750-550 BP) and is a platform mound site, typical of Phoenix Basin Hohokam settlement of the time (Clark & Lyons, 2012). I studied material from Ash Terrace collected over the course of the Archaeology Southwest Lower San Pedro Project. The five Hohokam assemblages sampled in the Tonto Basin are Eagle Ridge loci A and B, Hedge Apple, Meddler Point, Porcupine and Pyramid point All span a period of time between 1500 and 700 BP, and are also located within the Salt River arm of Tonto Basin. All materials from these sites were also collected over the course of the Roosevelt Community Development project. I collected data from these sites from prior studies of the assemblages (Adams, 1995; Lindeman, 1995).

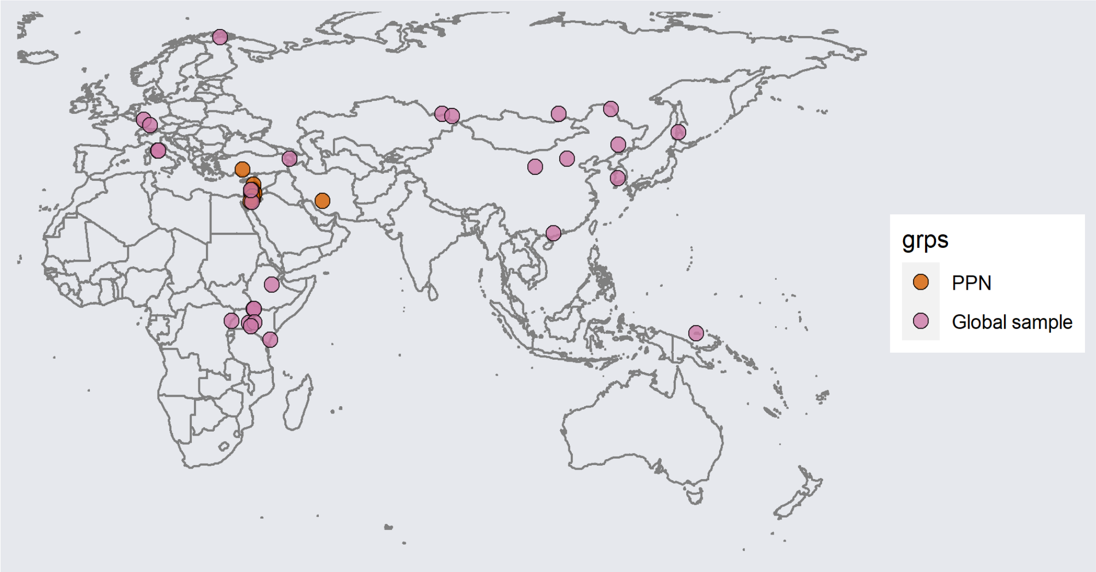


**Figure 4.7:** Spatial distribution of 40 assemblages sampled from global archaeological record, including outgroups with similar ecologies and subsistence practices to agricultural groups in the Southwest: Pre-Pottery Neolithic groups in Southwest Asia (PPN).

I also collected data from two outgroups meant to help provide context for variability within the Southwest. The first are outgroups produced by Pre-Pottery Neolithic (PPN) groups in the Southern Levant who, while historically unrelated, share similarities in ecology, subsistence and technology to agriculturalist groups in the American Southwest. 12 PPN assemblages in total were sampled, 3 of which were sampled for procedural unit data, and 9 of which were sampled for technological mode data. The second are 15 randomly selected assemblages from the global record. These were drawn without replacement from a global dataset of assemblages excluding the

Southwest, and Oceania (N= 37 procedural unit assemblages, and n = 1076 technological mode assemblages) (Figure 4.7, Tables 4.3 and 4.4).

### ***Results***

Ancestral Puebloans, Ancestral Puebloan migrant communities, Hohokam groups, and Basketmaker groups all explored similar regions of the procedural unit (Figure 4.8), and technological mode morphospaces (Figure 4.9), with some minor differences. All groups produced tanged or notched projectile points through pressure flaking, and in the process produced thinned bifacial core tools (mode E2), and tanged thinned bifacial core tools (mode E3). The associated procedural units for these practices include retouch through pressure (PU 30), invasive retouch (PU 29), bifacial retouch (PU 28), notching (PU 24), and forming a tang (PU 26) through retouch. Flake production occurred on non-hierarchical cores (mode C), except in the case of a few single platform cores (mode G1). Core platforms tended not to be facetted (PU 2), or rejuvenated through the removal of core tablets (PU 11). However, some platforms show signs of abrasion in the Shivwitz Plateau (Wambach, 2014), among Kayenta sites in Klethla Valley, and among Kayenta enclaves in the Lower San Pedro. Abraded platforms are the most common on biface thinning flakes (PU 29), that also tend to be on finer grained materials, like chert or jasper, and often also have lipped platforms, a sign of soft hammer percussion (PU 16). While biface thinning flakes with lipped platforms were recovered from the Hohokam assemblage at Ash Terrace, I did not find sufficient evidence for platform abrasion at that site.

Within this sample, flakes themselves were treated as cores among only the Ancestral Puebloan sites, and Ancestral Puebloan migrant communities. In the Klethla Valley and Lower San Pedro, this practice often involved bipolar percussion of obsidian flakes (Mode B, PU 15), which was part of a broader strategy of reducing small nodules or flakes of obsidian by bipolar percussion. Some of these bipolar obsidian flakes were then used to produce projectile points. At Shivwits plateau, flakes used as cores are not described as being reduced by bipolar percussion (Wambach, 2014). Bipolar percussion less common among Hohokam sites, though it is present in both Tonto Basin, and the San Pedro Valley. including cases similar to the Klethla valley and San Pedro Valley where bipolar flakes from obsidian nodules were used to produce projectile points (Bayman, 1995). Thus, the lack of that practice at Ash Terrace should not be taken as evidence for a lack of the practice across Hohokam sites. There are few kinds of retouched tools in the American Southwest aside from projectile points, these include flakes with marginal retouch (PU 22), scrapers, and notched flakes (mode D1/PU 23), all of which are found across each culture group sampled in the Southwest.

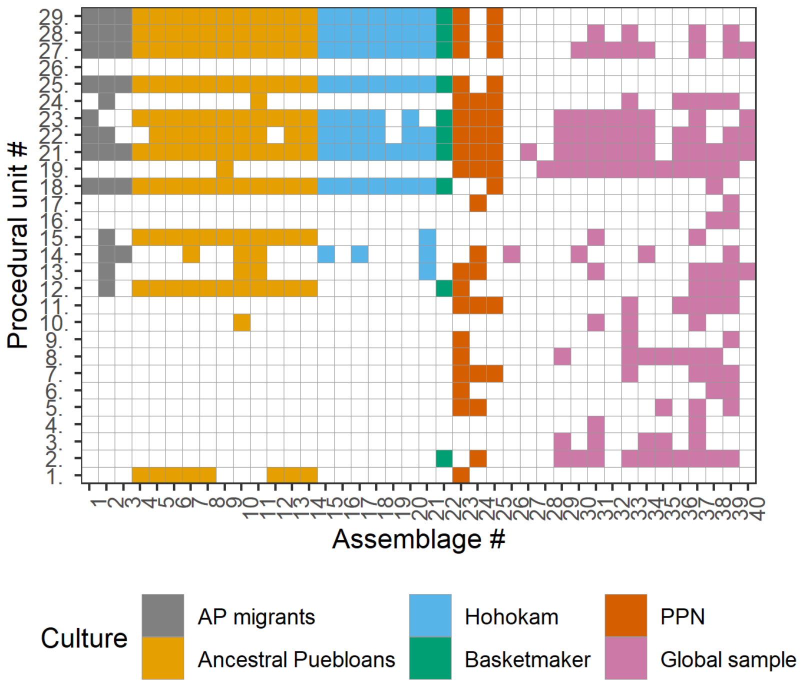


**Figure 4.8:** Procedural unit presence and absence for each assemblage. Presence or absence of 28 traits is recorded in each row. The traits included are listed in Table 1. Columns represent each assemblage in the study. Assemblage key: 1. Griffin Wash A V:5:90, 2. AZ BB:11:26, 3. AZ BB:11:36, 4. Granary House, 5. Site 232, 6. Peter's Pocket, 7. Lava Ridge Ruin, 8. Andrus Canyon, 9. Little man sites, 10. NA 11047, 11. NA 11057, 12. Corn Cob, 13. Coyote, 14. To'tsa, 15. Eagle Ridge B V:5:104, 16. Hedge Apple V:5:189, 17. Meddler Point V:5:4, 18. Eagle Ridge A V:5:104, 19. Porcupine Site V:5:106, 20. Pyramid Point V:5:1, 21. AZ BB:2:19, 22. 5LP110 and 111, 23. Kfar HaHoresh, 24. Tepe Rahmatabad, 25. Sha'ar Hagolan, 26. Lomekwi 3, 27. Lokalalei 2c, 28. Kanjera, 29. NY 18 Nyabusosi, 30. Hugub KK51, 31. Nor Geghi 1, 32. Torre in Pietra level M, 33. Qesem Cave, 34. Torre in Pietra level D, 35. Koilomot locus 2, 36. Wallertheim West Concentration, 37. Ein Qashish, 38. Geissenklosterle Cave Gravettian, 39. Sujula and 40. GFJ .

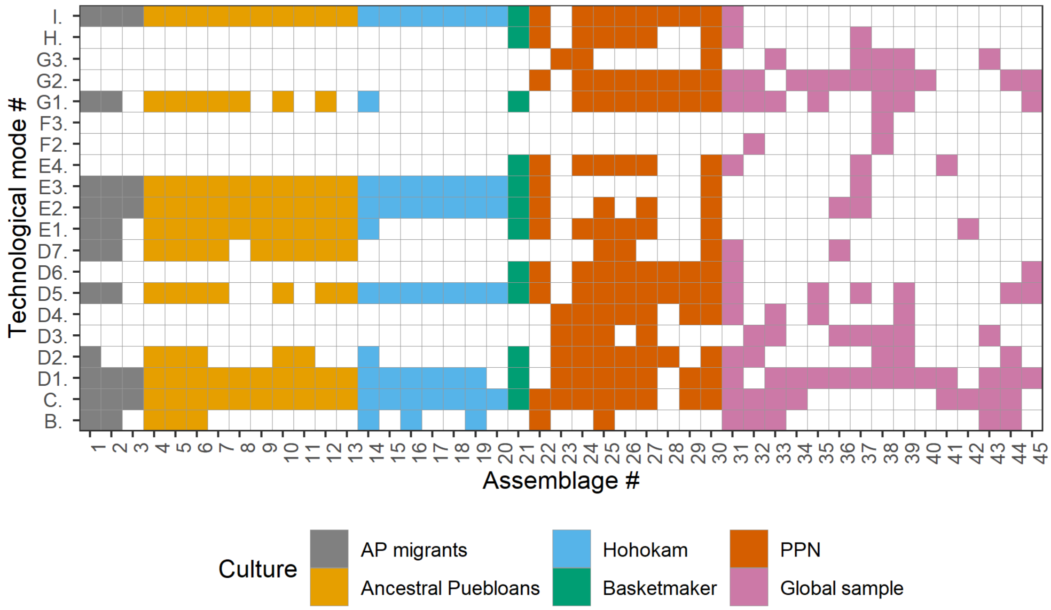


**Figure 4.9:** Technological mode presence and absence for each assemblage. Presence or absence of 20 traits is recorded in each row. See Table 2 for mode descriptions. Columns represent each assemblage in the study. Assemblage key: 1. AZ BB:11:26, 2. AZ BB:11:36, 3. Griffin Wash A V:5:90, 4. NA 11047, 5. NA 11057, 6. Lava Ridge Ruin, 7. Granary House, 8. Andrus Canyon, 9. Corn Cob, 10. Coyote, 11. Site 232, 12. Peter's Pocket, 13. To'tsa, 14. AZ BB:2:19, 15. Pyramid Point V:5:1, 16. Meddler Point V:5:4, 17. Hedge Apple V:5:189, 18. Eagle Ridge A V:5:104, 19. Eagle Ridge B V:5:104, 20. Porcupine Site V:5:106, 21. 5LP110 and 111, 22. Catal Huyuk, 23. Tepe Rahmatabad, 24. Byblos, 25. Ain Ghazal, 26. Beidha I-VI, 27. Kfar HaHoresh, 28. Nahal Hemar, 29. Nahal Issaron, 30. Sha'ar Hagolan, 31. Abu Ghosh, 32. Panga Ya Saidi Levels 1-4, 33. Wadh Lang'o 1, 34. Strashnaya Cave 4, 35. Arta 2 Layers 1-3, 36. Tyumechin 4 tempo 1, 37. Ogonki 5 Layer 3, 38. Tor Aeid , 39. Sefunim Layer D.8, 40. Shibazhan C, 41. Fanzenshanyan Layer 2, 42. Xinxiangzhuanchang Layer 4, 43. Shuidonggou Loc.8 Layer 2, 44. Meigou Lower and 45. Haga Layer 2 .

The single Basketmaker Site from the Durango District of Colorado also has high overlap in technology between the other Southwest Assemblages, though it has two technological modes present, that are absent elsewhere in the Southwest sample. These include bifacially flaked celts (Mode E4), and tanged flakes (Mode D6), both coded as present based on examples of bifacially flaked axes with retouched bits, and hafting elements shaped through notching. One of which is on a large flake blank (Love-dePeyer, 1980). Single platform cores with facetted platforms are also described as present, which would be distinct from other Southwest assemblages in the sample (PU 2).

While Southwest assemblages tend to be relatively similar to one another, they are distinct from Pre-Pottery Neolithic groups, who were also farmers adapted to arid environments. Groups in the Southern Levant had developed blade technologies (Mode G2), microblade technologies (G3), and various ways of preparing and rejuvenating cores, including modifying the convexity of a core face in advance of blade removals (procedural units 4, 5, 6, 7 and 8). Retouched tools found among PPN contexts and not found in the Southwest include backed blades (Mode D2), and backed microliths (Mode D3). Comparison of sites in the Southwest to assemblages drawn randomly from the global record further highlights the distinctiveness of the technological pattern in the Southwest. Traits associated with making pressure flaked projectile points through bifacial flaking are rare in the global record, and most of the lack of overlap between technological modes and procedural units between sites in the Southwest, and sites drawn from the global record reflects this (Figures 4.8 and 4.9).

Between both procedural units and technological modes, there are no particular traits that are definitive shared derived characters that could be diagnostic specifically to Ancestral Puebloan groups. One procedural unit is found only in Ancestral Puebloan samples, and not in Hohokam groups, is the use of abrasion during flintknapping.

However, abrasion is commonly employed over the course of pressure flaking thinned bifacial points to strengthen edges, and prevent crushing while applying pressure (Sheets, 1973). The lack of abrasion in the Hohokam sample could be due in part to a smaller number of Hohokam sites, and research biases in the sampled literature. For example, even in depth discussions of masterfully crafted Hohokam bifaces do not explicitly mention the practice of platform abrasion as part of their production sequence (Sliva, 2010), despite almost certainly requiring that technique. These distinctions between both could also be due to differences in raw material availability between sites in the North, where cherts are more readily available, as opposed to the South where obsidian, quartzite and rhyolite raw materials are more common.

The above summary of the technological patterning within the Southwest, and among the outgroups highlights the distinctiveness of the Southwest record. However, the between group variability within the Southwest is subtle. Most assemblages share similar sets of technological practices. This suggests the scales at which we are likely to be able to use lithic technology to infer population processes is above the scales of ceramics and architecture. In the following sections, I more formally explore whether the technological patterning within the Southwest reflects Southwest population history.

## Does technology reflect population history?

If lithic technologies do retain evidence of Ancestral Puebloan migrations in the Southwest, we should expect Ancestral Puebloan groups above the Mogollon Rim to be most similar to Ancestral Puebloans below the rim, relatively dissimilar to Hohokam groups, and most dissimilar to the outgroups sampled (i.e. Agro-pastoralists in the Levant, and assemblages drawn randomly from the global record). Below, I assess whether this is the case through several approaches, all based on measuring the relative similarities between assemblages.

First, I summarized technological similarity between each pair of archaeological assemblages in terms of Jaccard distances. Jaccard distances are calculated as $1 - J(A,B) = |A \cap B|/|A \cup B|$, where A and B are the presence absence vectors for two separate archaeological assemblages. In this case the number of traits in both assemblages is divided by the number of possible traits realized in either assemblage, with the result subtracted from 1. Every assemblage in the sample's technological distance to every other assemblage was measured, and recorded. The result is a symmetric pairwise distance matrix. Assemblages were divided into the same groups as in the previous section: Ancestral Puebloans above the Mogollon Rim, Ancestral Puebloan migrants below the rim, A Hohokam groups, Basketmaker, Pre-Pottery Neolithic, and a random sample of assemblages from the global record.

This pairwise distance matrix is then treated as input for a non-metric multidimensional scaling analysis (NMDS), an ordination approach designed to characterize the relative distances between multivariate observations in two dimensions.

This analysis is an iterative processes. It repeatedly attempts to spatially orient observations in two dimensions, while preserving information about their relative rank order distances between one another. After each iteration, the relationship between the original rank order, and the proposed two dimensional relationship between observations is assessed through linear regression. The process is repeated for some number of iterations (here it is 999). The degree to which the two-dimensional relationships and true distances between groups differ after the final iteration is characterized in terms of a stress statistic. The higher the value, the poorer the two-dimensional representation of true between observation distances. For example, two-dimensional representations with stress values above 0.4, would have an $R^2$ value of 0.6 or smaller between the observed distances, and distances as projected in 2-D space.

I then tested for whether there were significant between group differences in lithic technology. The method taken here is a permutational multivariate analysis of variance test (PERMANOVA). PERMANOVA is a non-parametric method of assessing whether the distances between centroids for all groups are equivalent (Anderson, 2001). Rather than comparing variability to a reference distribution, the data themselves are permuted: individual assemblages are assigned to other groups, and distances from each site to the group centroids are assessed. I used the adonis() function in the R package vegan in this study (Oksanen et al., 2020). In order to evaluate which pairs of groups have more pronounced between group differences, I performed a post-hoc PERMANOVA test between each pair of archaeological groups using the pairwise.adonis package (Arbizu, 2021), and used a Bonferroni correction for the resulting p-values. I excluded the single Basketmaker assemblage, since there is no within group variability.

The most important patterns within the NMDS space, as well as the PERMANOVA results and post-hoc tests, is the relative position of Ancestral Puebloan migrant technologies to the other groups sampled. Thus it is important to more closely assess whether the raw data reflect the lack of evidence for greater similarity between Ancestral Puebloan migrants, Ancestral Puebloans above the Mogollon Rim, and their ancestors relative to Hohokam groups. As a final check of the results for this section, I then compared distributions of pairwise distances between Ancestral Puebloan migrants to every other cultural group sample to see if the raw similarities and dissimilarities between groups was congruent with the multidimensional scaling and PERMANOVA findings.

### ***Results: mixed evidence for technology reflecting migration history in the Southwest***

The position of assemblages in the NMDS solutions for both procedural unit, and technological mode data has relatively low stress (Figures 4.10, and 4.11). This means that the position of assemblages in the two-dimensional morphospace is, overall, a good reflection of the relative Jaccard distances between each pair. Within the procedural unit inventories, the Ancestral Puebloan migrant, Ancestral Puebloan, Hohokam, and Basketmaker assemblages all occupy a region of the morphospace more closely associated with making pressure flaked bifaces (e.g. bifacial retouch, pressure flake retouch, invasive retouch, heat treatment and platform abrasion) (Figures 10 and 11). The patterns are similar among technological modes. The Southwest culture-group assemblages still cluster relatively close together, and are distinct from both the PPN and global sample outgroups. The positions of Southwest groups together, and outside the range of the Pre-Pottery Neolithic is in large part driven by the practice of making pressure flaked bifaces (modes E1, E2, E3) and the lack of flake production on cores aside from pebble cores (mode C).

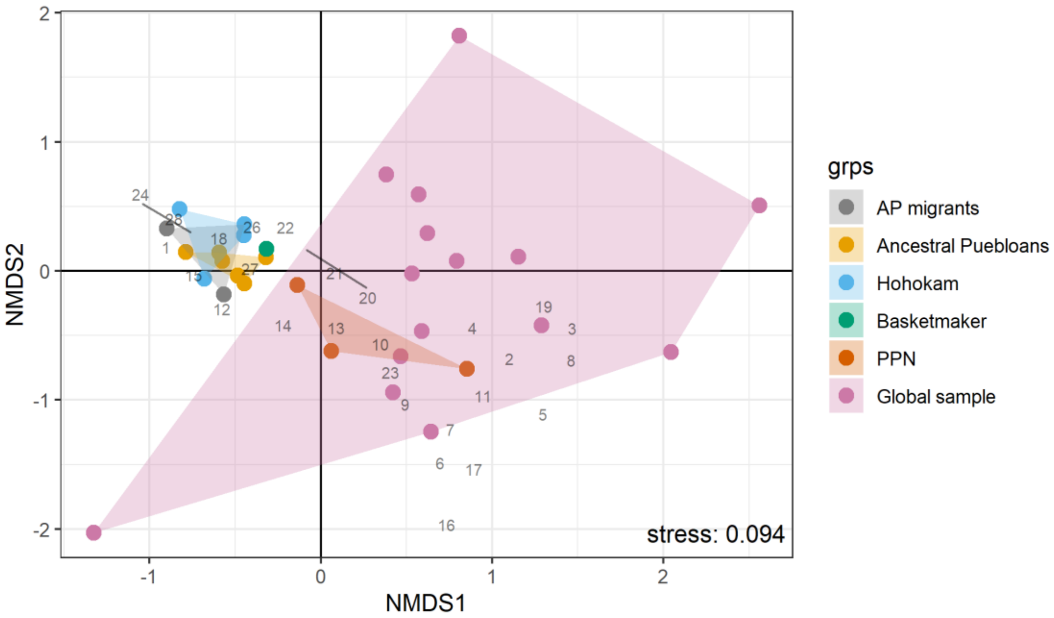


**Figure 4.10:** Non metric multidimensional scaling of presence/absence of procedural units. Each point represents one archaeological assemblage, and each is coded by color according to the culture group to which it belongs. The relative position of assemblages in the NMDS space is an approximation of their relative, rank order Jaccard distances to one another projected in only two of many possible dimensions. Trait scores are listed as numbers on the plot. Each trait in the NMDS space highlights the greater frequency of that trait in that region of the space. The first four groups: Ancestral Puebloans, Ancestral Puebloan migrants, Hohokam, and Basketmaker, each are culturally related, though we expect the Ancestral Puebloans and Ancestral Puebloan migrants to be the closest related culturally. The last two groups, the Pre-Pottery Neolithic (PPN), and a random sample

from the global record (Global sample), represent assemblages made by essentially unrelated people to those in the Southwest. Trait key: 1. Heat treatment, 2. Platform facetting, 3. Centripetal shaping, 4. Lateral shaping, 5. Distal shaping, 6. Back shaping, 7. Cresting, 8. Debordante shaping, 9. Overshot flaking, 10. Kombewa flaking, 11. Core tablet, 12. Abrasion, 13. Trimming platform overhang, 14. Use of an anvil, 15. Soft hammer percussion, 16. Indirect percussion, 17. Flaking through pressure, 18. Hammer dressing, 19. Invasive flaking, 21. Retouch, 22. Backing, 23. Notching, 24. Burination, 25. Tanging, 26. Tranchet, 27. Bifacial retouch, 28. Invasive retouch and 29. Pressure flaked retouch

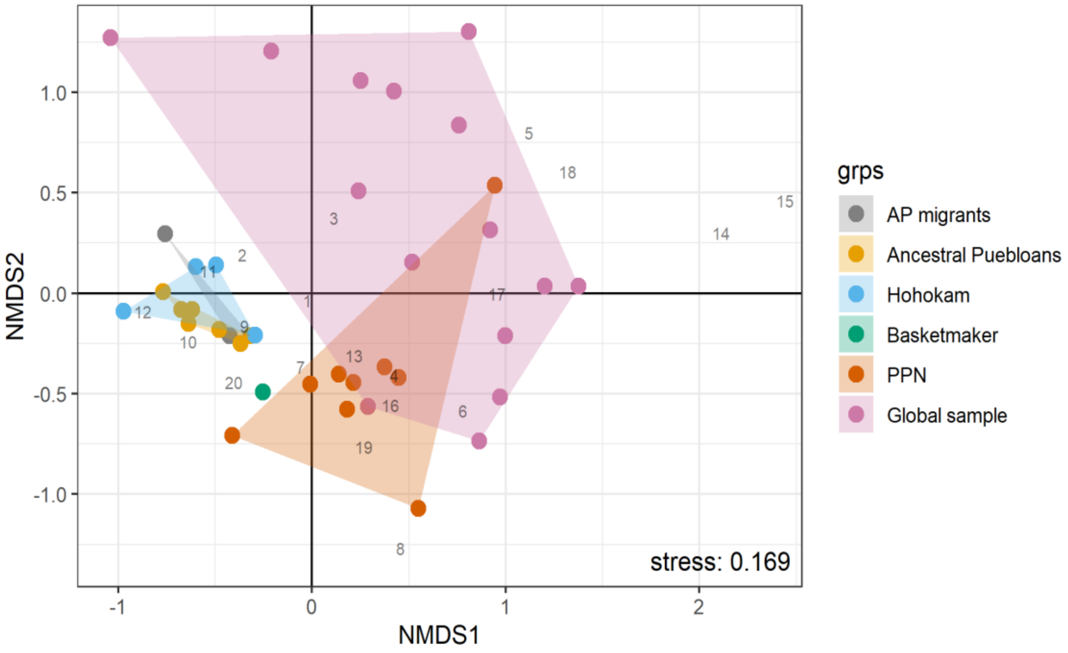


**Figure 4.11:** Non metric multidimensional scaling of presence/absence of technological modes. Each point represents one archaeological assemblage, and each is coded by color according to the culture group to which it belongs. The relative position of assemblages in the NMDS space is an approximation of their relative, rank order Jaccard distances to one another projected in only two of many possible dimensions. Trait scores are listed as numbers on the plot. Each trait in the NMDS space highlights the greater frequency of that trait in that region of the space. The first four groups: Ancestral Puebloans, Ancestral Puebloan migrants, Hohokam, and Basketmaker, each are culturally related, though we expect the Ancestral Puebloans and Ancestral Puebloan migrants to be the closest related culturally. The last two groups, the Pre-Pottery Neolithic (PPN), and a random sample from the global record (Global sample), represent assemblages made by essentially unrelated people to those in the Southwest. Trait key: 1, B. Bipolar cores, 2, C. Pebble cores, 3, D1. Retouched pieces with acute edges, 4, D2. Backed pieces, 5, D3. Microliths,

6, D4. Burins, 7, D5. Points, 8, D6. Tanged piece, 9, D7. Core-on-flake, 10, E1. Large cutting tool, 11, E2. Thinned biface, 12, E3. Tanged biface, 13, E4. Celt, 14, F2. Recurrent laminar bifacial hierarchical core, 15, F3. Radial centripetal bifacial hierarchical core, 16, G1. Platform unidirectional hierarchical core, 17, G2. Blade core, 18, G3. Microblade core, 19, H. Edge abraded tool and 20, I. Groundstone

The southwest also occupies an area of the technological morphospace not sampled in the global record, and distinct from the PPN outgroup who shared similar subsistence strategies and environments. This is important because it highlights that the similarity between groups in the Southwest likely is not driven by there being only a few possible technological solutions to being an arid environment adapted food producer. Furthermore, it reflects the shared history of groups within the Southwest, who were Uto-Aztecan speaking populations with a shared history that extends to the early Agricultural period. Further in the past, these groups also share the same heritage as ancestors of the first people in the Americas, a continent that was entrenched in biface technology from the Late Pleistocene through European contact. The wide overlap between Southwest assemblages suggests that these Uto-Aztecan speakers developed similar technologies between one another, likely in part due to their shared history, and their continued cultural interactions with one another. Also, it may also be due to the shared heritage, and shared historical reliance on bifaces of groups in America more generally.

The area of the technological morphospace occupied by each group also likely reflects the very different spatio-temporal scales represented by the assemblages in each group. The global sample spans millions of years of time, Africa and Eurasia. As we might expect from hominins exploring different technologies over the course of so long a time, in so many different environments, the area of the technological morphospace represented in the global sample is far larger than that explored in any of the other single archaeological cultures. Similarly, the PPN assemblages span several thousand years, including different culture-historical sub-stages (PPNA, PPNB, PPNC), and include assemblages from both Anatolia, and the Southern Levant. In contrast, the assemblages within the Southwest all fall within a relatively narrow region, and within that region, there is substantial overlap between the groups sampled, suggesting relatively subtle between group variability. This is consistent with the relatively narrow spatio-temporal scale represented, and is also broadly consistent with all agricultural groups in the Southwest likely sharing common history, and the history of migrations and trade between groups in the region (Mills et al., 2016a). The presence of these more spatio-temporally broad groups may be in part masking significant between group variability in the Southwest.

To explore whether the presence of highly variable outgroups was obscuring variability between groups in the Southwest, I repeated the same analysis multidimensional scaling analysis, but focused just on assemblages within the American Southwest (Figures 4.12-4.13). When the outgroups were excluded, there was some wider separation between groups in the Southwest. Despite revealing between group variability within the Southwest, there is mixed evidence for between group patterning reflecting migration histories. Within the procedural unit data, there is greater overlap between Hohokam groups, and Ancestral Puebloan migrant groups, than between migrant, and Ancestral Puebloan groups above the Mogollon rim (Figure 4.12). Furthermore, while there are statistically significant differences between groups in the Southwest (PERMANOVA p-value<.001, $R^2 = 0.46$), the significant differences are not patterned in a way that reflects the population history of the region. There are significant differences between Ancestral Puebloan migrants and Ancestral Puebloans above the Mogollon Rim, as well as between Ancestral Puebloans and Hohokam groups (Table 4.5). No significant difference was detected between Ancestral Puebloan migrants and the Hohokam sample. Differences between Ancestral Puebloan migrants, and Ancestral Puebloans in Northern Arizona, as well as the lack of difference between Ancestral Puebloan migrants and their new neighbors below the Mogollon Rim is most consistent with either convergence between migrants and the Hohokam, or integration of migrants into more traditionally Hohokam ways of producing tools via horizontal transmission. Whatever the underlying cause, this is most consistent with migrants changing their technologies in such a way that historical connection to their ancestors in lithic technology is weakened.

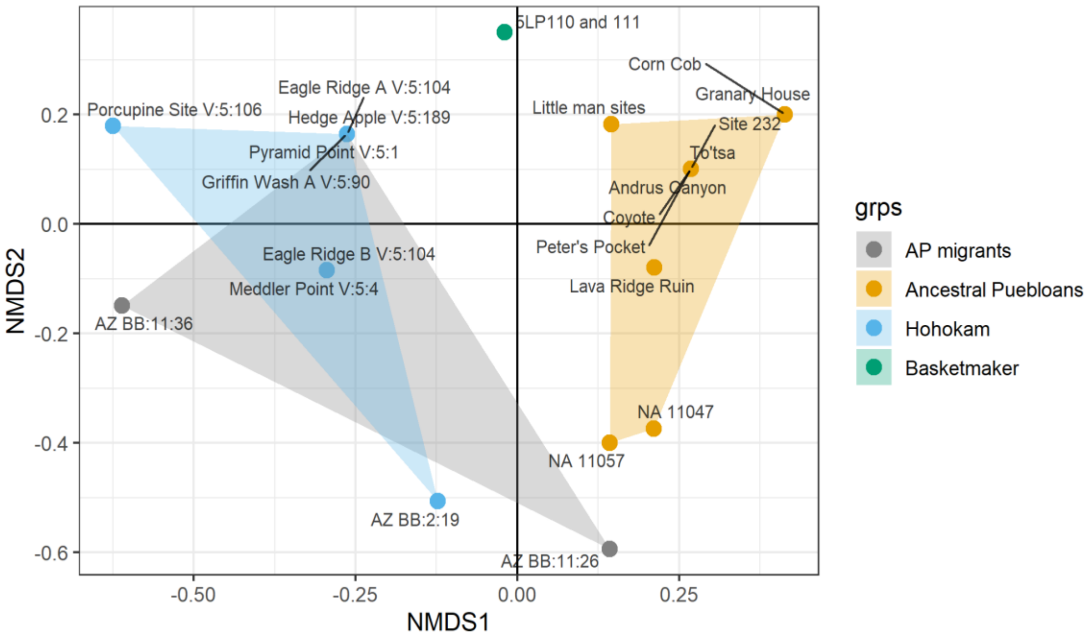


**Figure 4.12**: Non metric multidimensional scaling of presence/absence of procedural units. Each point represents one archaeological assemblage, and each is coded by color according to the culture group to which it belongs.

**Table 4.5**: Permanova post-hoc tests among procedural units

| Treatment | $R^2$ | P-value | Adjusted P-value |
|---|---|---|---|
| **AP migrants vs Ancestral Puebloans** | **0.33** | **0.013** | **0.038** |
| AP migrants vs Hohokam | 0.08 | 0.505 | 1.000 |
| **Ancestral Puebloans vs Hohokam** | **0.50** | **0.000** | **0.000** |

In contrast, the technological mode data have stronger evidence for historical connection between migrants and groups above the Mogollon rim. In the technological morphospace, migrants appear to be closer to Ancestral Puebloan groups above the rim than they are to Hohokam groups in Central Arizona (Figure 4.13). This pattern is driven largely by the greater numbers of assemblages with platform cores in Ancestral Puebloan and Ancestral Puebloan migrant contexts, compared to the Hohokam, as well as greater numbers of assemblage with evidence for points on flake blanks in the Hohokam assemblages, compared to the Ancestral Puebloan assemblages. While these differences may be due to divergent histories, it could also be that be most points in the southwest were produced on flake blanks. However, it may be that differences in reduction intensity between assemblages results in evidence for the original blank type being visible at some sites (which get coded as D5) whereas other points are fully covered in bifacial flake scars, obscuring the original blank type. In this instance, the points would be coded under mode E.

As we might expect for technologies of migrants who are relatively well integrated with neighboring Hohokam groups, the Griffin Wash A assemblage is relatively distinct from the range of variability seen on the Colorado Plateau. In contrast neighboring San Pedro sites BB:13:36 and BB:13:26 are very similar or identical to assemblages on the Colorado Plateau.

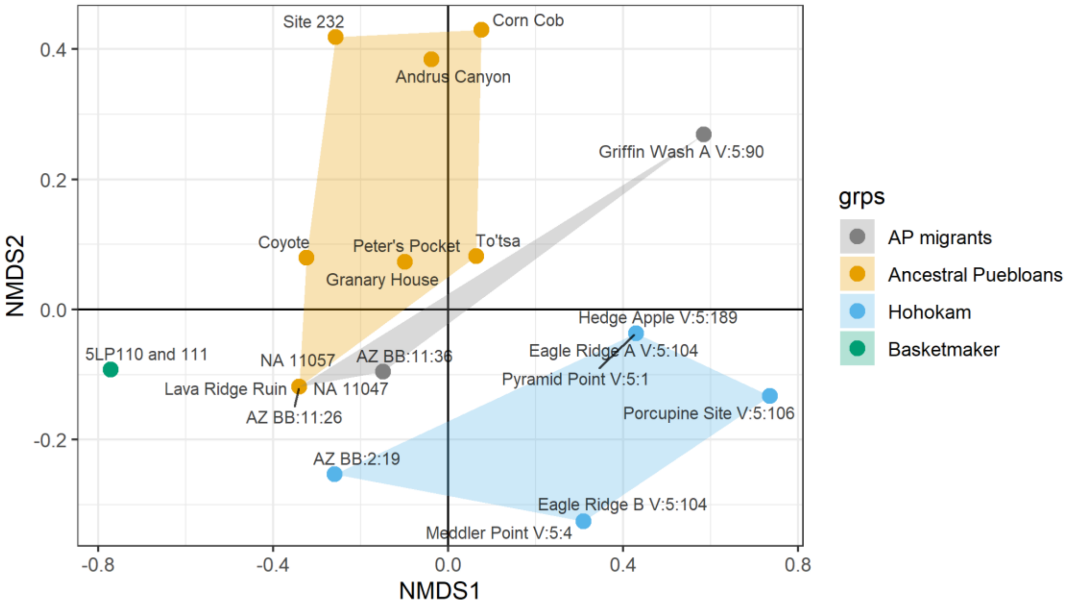


**Figure 4.13**: Non metric multidimensional scaling of presence/absence of technological modes. Each point represents one archaeological assemblage, and each is coded by color according to the culture group to which it belongs. The relative position of assemblages in the NMDS space is an approximation of their relative, rank order Jaccard distances to one another projected in only two of many possible dimensions. Trait scores are listed as numbers on the plot. Each trait in the NMDS space highlights the greater frequency of that trait in that region of the space. The first four groups: Ancestral Puebloan migrants, Ancestral Puebloans, Hohokam, and Basketmaker, each are culturally related, though we expect the Ancestral Puebloans and Ancestral Puebloan migrants to be the closest related culturally. Trait key: 1, B. Bipolar cores, 2, C. Pebble cores, 3, D1. Retouched pieces with acute edges, 4, D2. Backed pieces, 5, D3. Microliths, 6, D4. Burins, 7, D5. Points, 8, D6. Tanged piece, 9, D7. Core-on-flake, 10, E1. Large cutting tool, 11, E2. Thinned biface, 12, E3. Tanged biface, 13, E4. Celt, 14, F2. Recurrent laminar bifacial hierarchical core, 15, F3. Radial centripetal bifacial hierarchical core, 16, G1. Platform unidirectional hierarchical core, 17, G2. Blade core, 18, G3. Microblade core, 19, H. Edge abraded tool and 20, I. Groundstone

**Table 4.6**: Permanova post-hoc tests among technological modes

| Treatment | $R^2$ | P-value | Adjusted P-value |
|---|---|---|---|
| AP migrants vs Ancestral Puebloans | 0.05 | 0.599 | 1.000 |

| Treatment | $R^2$ | P-value | Adjusted P-value |
|---|---|---|---|
| AP migrants vs Hohokam | 0.20 | 0.227 | 0.680 |
| **Ancestral Puebloans vs Hohokam** | **0.51** | **0.000** | **0.000** |

Among technological modes, migrants are technologically closer to Ancestral Puebloans above the rim, and while there are significant differences between groups in the Southwest (p-value < 0.001, $R^2 = 0.42$), the significantly different pair is more consistent with population history than was the case among procedural unit inventories (Table 4.6). The only significantly different set of assemblages are between Ancestral Puebloans in Northern Arizona, and Hohokam groups. Ancestral Puebloan migrants are not significantly different from either group. This, again, could reflect that changes after the migration into Central Arizona weakened evidence of historical continuity, but not so much that there is greater overlap between Hohokam and migrants, than between migrants and their ancestors.

Finally, the raw pairwise distances between assemblages also show mixed evidence for retaining evidence of migration history, while also further illustrating the distinctiveness of assemblages in the Southwest relative to outgroup assemblages. If we focus only on the technological distances within and between Ancestral Puebloan migrants and others in the raw distance data, then the same broad pattern is found. Here, each assemblage made by migrants, was compared to each assemblage of each of the other groups. The result is one distribution of distances for each set of pairwise comparison between assemblages made by Ancestral Puebloans migrants and assemblages made by the other groups (Figures 4.14 and 4.15).

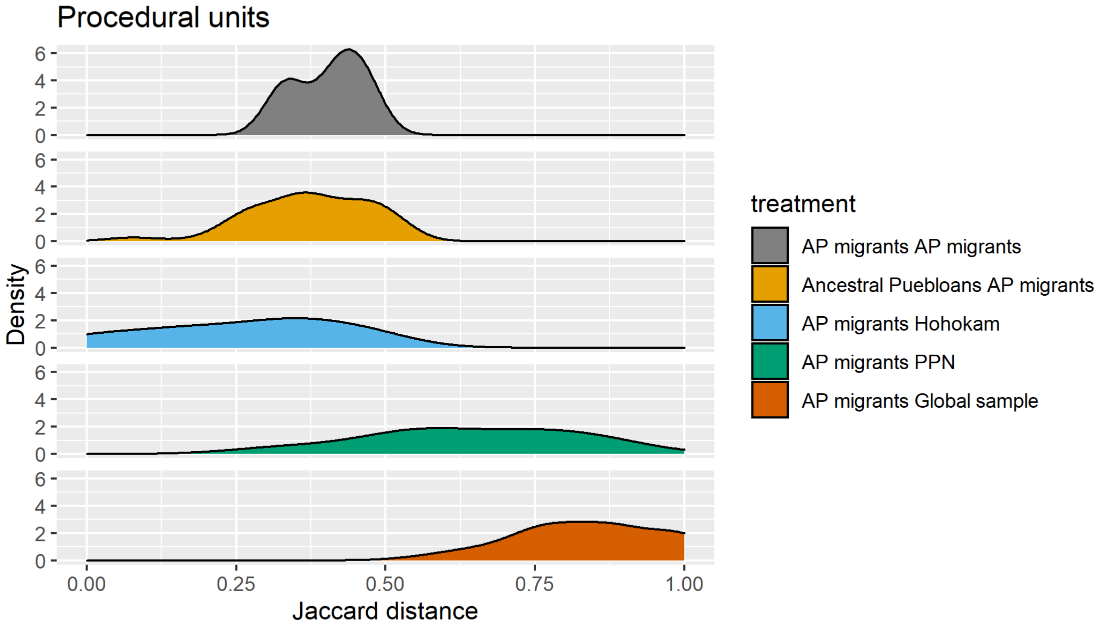


**Figure 4.14**: Ancestral Puebloan migrants tended to have more procedural units in common with one another, and with other groups in the Southwest, than they do with the sampled outgroups. Pairwise Jaccard distances between assemblages characterized in terms of presence or absence of procedural units between the focal group, Ancestral Puebloan migrants, and each cultural group sampled. The comparisons between groups of assemblages sorted from top to bottom in order of increasingly distant cultural relatedness.

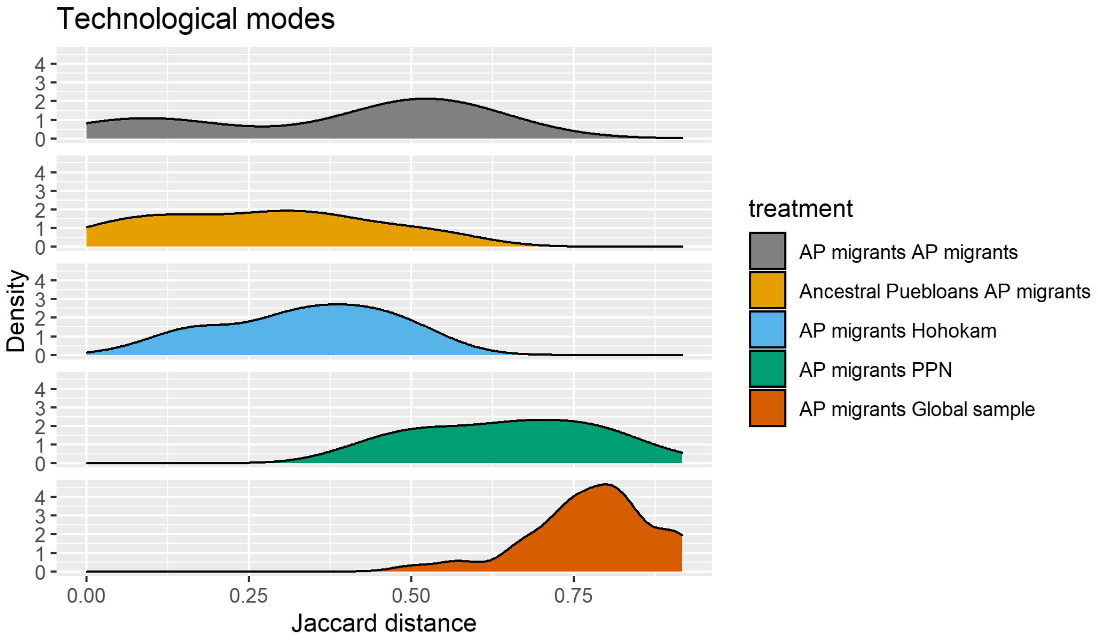


**Figure 4.15**: Pairwise Jaccard distances between assemblages characterized in terms of presence or absence of technological modes between the focal group, Ancestral Puebloans migrants, and each cultural group sampled. The comparisons between groups of assemblages sorted from top to bottom in order of increasingly distant cultural relatedness. The top row in black is the distribution of pairwise Jaccard distances between all Ancestral Puebloan migrant assemblages, with no self comparisons.

For the procedural unit data, the technological distances between Ancestral Puebloan migrant communities, and either Ancestral Puebloan or Hohokam groups fall below a Jaccard distance of .6 (Figure 4.14), which is well below the distribution of distances between Ancestral Puebloan migrant groups and the Pre-Pottery Neolithic, or Global sample outgroups. This highlights, as we expect, that assemblages within the Southwest tend to be more similar to one another than they are to assemblages made by unrelated peoples. The pattern is similar within the technological mode dataset (Figure 4.15).

However, there is again mixed evidence for the relative distances between Ancestral Puebloan migrant groups and other groups within the American Southwest reflecting population histories. In the procedural unit data, there is wide overlap, for example, between the distances between Ancestral Puebloans, and Ancestral Puebloan migrants and the distances between Ancestral Puebloan migrants and the more distantly related Hohokam groups (Figures 4.14). There are similar patterns in the technological mode data. Some migrant groups, for example, are more similar to neighboring Hohokam groups than other migrant groups, and more similar than they are to other Ancestral Puebloans in Northern Arizona (Figure 4.15).

By assessing overlap between different cultural groups in the technological morphospace, we learned a few things about how technology relates to population history. First, relative to the global sample, and the Pre-Pottery Neolithic sample, groups in the Southwest occupy a relatively narrow region of the technological morphospace. This is not necessarily surprising given the narrow spatio-temporal range of sites sampled in the Southwest compared to those in the outgroups, and also not surprising given the shared history, history of trade and exchange, and similar subsistence and cultural practices across the southwest.

We found there is also only subtle between group variability within the southwest. In terms of procedural units, Ancestral Puebloan migrants have at least as much, if not more, overlap technologically with their new neighbors, Hohokam groups, than they do with people above the Mogollon Rim. This could be because migrants integrated quickly into societies below the Mogollon, retaining some aspects of their technological identity, but forming others to adapt to new environments or it could be because they quickly adopted technological practices of their neighbors. It may also be that the differences between assemblages are subtle enough such that any significant patterns between groups are driven in part by sampling error, or other study biases. It may also be simply due to the nature of chipped stone technology. Unlike architecture, and even ceramics, there is far less time and energy and planning necessary to produce chipped stone tools. As such, variability may be more likely to only reflect physical constraints and raw materials available across the Southwest as opposed to population history.

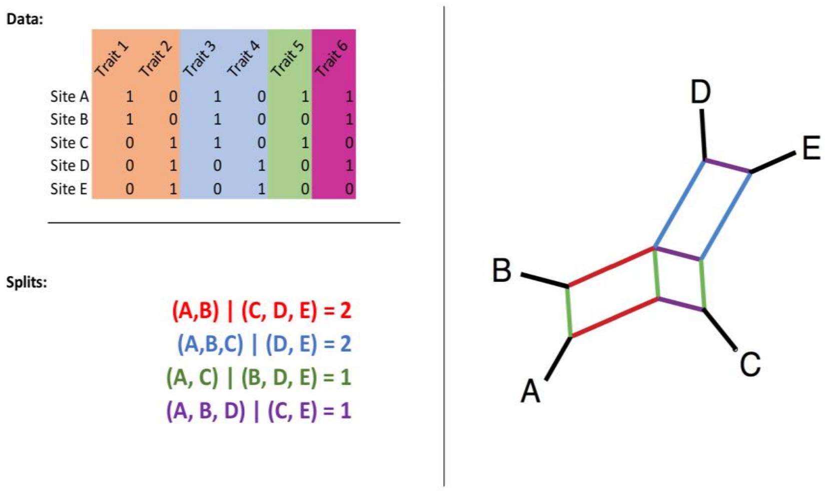
Finally, lithic technologies may just be less likely to retain fine grained evidence of history than architecture and ceramics. Chipped stone tools take a short time to make, and raw material is relatively abundant across each of the study areas sampled in the southwest. As such, design decisions were likely much less important than would have been the case for architecture, or ceramics, which would likely have had to accommodate norms and attitudes about space and aesthetics in a way that would not be required for manufacturing a cutting or perforating tool.

Nonetheless, the above analyses do not fully take into account the dependencies between technological variation, and history. For example, PERMANOVA is a permutation based procedure which assumes data are exchangeable. However, exchangeability is violated in cases where observations within groups are autocorrelated with one another, as in the case of time series, or in the case of data with phylogenetic or historical structure (as we expect the technological data to have). Thus, it is important to also investigate the technological overlap between archaeological groups while taking into account the historical processes that produced technological traditions, which I do in the following section.

### Do historical reconstructions based on lithic data reflect population history?

In this final analysis, I generate historical reconstructions based on the lithic variability across the Southwest and outgroup samples. I then assess congruence with the current population history in the Southwest. Culture-evolutionary research has borrowed methods of phylogenetic reconstruction from evolutionary biology. These methods tend to assume culture evolves through splitting of lineages, leading to the cultural diversity observed. However, as outlined above, we cannot necessarily assume that such a branching structure was the predominate mode of cultural evolution within the Southwest, movements across group boundaries, shifting identities, and cultural exchange between groups all played a strong role in the development of societies within the Southwest prior to the migration of Ancestral Puebloans below the Mogollon Rim. Thankfully, there are tools meant to propose evolutionary relationships between entities in such cases where this kind of reticulation may have been more dominant, or to characterize uncertainty about the “truest” evolutionary hypothesis.

The Neighbornet algorithm is an exploratory tool designed to characterize uncertainty in evolutionary hypotheses based on trait data. It is an extension of agglomerative Neighbor-Joining methods popular in phylogenetic models. The product of the algorithm is a splits-network, whose goal is to visualize conflicting evolutionary explanations for the observed similarities and dissimilarities in sets of traits. The basic unit in a splits network is a single split. One split separates taxa that have a trait, from those that do not. Splits can have varying degrees of support. Poorly supported splits divide groups that might differ in a small number of traits. Others may have strong support, with taxa on either side of the split having many differences in traits (Gray et al., 2010). Splits are also some of the fundamental units of phylogenetic trees. However, splits graphs differ from cladograms in that each split is represented by one or many parallel edges (Gray et al., 2010), the lengths of which scale with the support of the split. Parallel edges of very short length mean the split is not well supported, while long edges represent splits with stronger support. Figure 16 is a simplified example of a situation where five sites are analyzed, and six characters are counted as present or absent. This structure is the same as the technological data analyzed below. This splits network includes four different splits. The first, in red, divides the network into two groups, one set with trait 1 and without trait 2 (A and B), and one set with trait 2 and without trait 1 (C, D, and E). Since this represents two differences in traits, the weight and length of the edge equals 2. The second split is similarly well supported. Groups A, B, and C, have trait 3 and no trait 4, while sites D and E have no trait 3, and do have trait 4. The remaining splits are relatively weak in that the groups differ in only one trait, and share the rest in common (Figure 4.16). Generally, if splits tend to be weak in a network, then the splits will tend to be short, and the network will tend to look more like a web in which there are few distinct clusters. Importantly, the algorithm has now knowledge about groups given to it. Clusters emerge solely from assessment of similarities and dissimilarities between individual taxa.



Data:

| | Trait 1 | Trait 2 | Trait 3 | Trait 4 | Trait 5 | Trait 6 |
|---|---|---|---|---|---|---|
| Site A | 1 | 0 | 1 | 0 | 1 | 1 |
| Site B | 1 | 0 | 1 | 0 | 0 | 1 |
| Site C | 0 | 1 | 1 | 0 | 1 | 0 |
| Site D | 0 | 1 | 0 | 1 | 0 | 1 |
| Site E | 0 | 1 | 0 | 1 | 0 | 0 |

Splits:

(A,B) | (C, D, E) = 2
(A,B,C) | (D, E) = 2
(A, C) | (B, D, E) = 1
(A, B, D) | (C, E) = 1

**Figure 4.16:** Example of how a splits-graph represents the similarities and dissimilarities between taxa.

Strongly supported splits will tend to be found in areas where there is greater between group variability. For example, among cognate sets across Austronesian languages, some languages both are grouped close to one another, and are widely separated from other groups of languages (Figure 4.17). The main such groups are those in Eastern Polynesia, and Fiji, which are disconnected from the remainder of the graph by relatively long splits. What this means is that evolutionary hypotheses that treat Eastern Polynesian and Fijian languages as distinct historical entities, similar within themselves, and distinct from other cognate sets, are relatively well supported. In contrast, Western

Polynesian Languages like Samoan, and Tongan, are not so distinct from languages in Wallis and Futuna, or Tikopia. In this latter case, there are many conflicting possible evolutionary scenarios, and all have relatively weak support, suggesting that some other processes such as horizontal transmission across languages, and migration between groups, may have prevented the development of distinct between group variability (Figure 4.17).

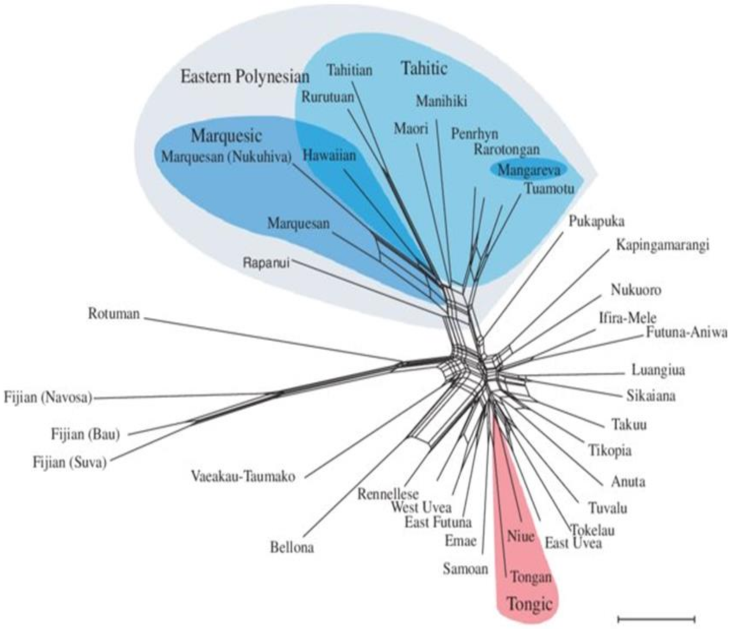


**Figure 4.17:** Example of Neighbornet generated splits-graph outlining relative support for evolutionary relationships between Austronesian languages based on cognate sets. Image from Gray et al. 2010.

In this case, I am interested in whether the positions of Ancestral Puebloan migrants, and their ancestors above the Mogollon Rim are close and form a distinctive evolutionary group. More generally we are also interested if the relative historical relationships of groups within, and outside the Southwest is congruent with the lithic data. To explore this, I performed a Neighbornet analysis on 25 archaeological assemblages summarized through the procedural unit system (28 distinct traits), and 30 archaeological assemblages summarized through the technological mode system (21 distinct traits). I converted the presence absence data for each archaeological assemblage into a FASTA format file, and processed that file in the program splitstree (version 5.0). Similarities between assemblages were measured using the Jaccard method. To generate the splits-graph I performed the Neighbor Net method of generating hypothetical relationships (Bryant and Moulton 2004) and performed weighting of splits following the 2004 implementation ("NNet2004"). To generate splits, I used the Splits Network Algorithm following Dress and Hudson 2004. The procedural unit network has 263 nodes and 469 edges, while the technological mode network has 242 nodes, and 414 edges.

### *Results: Evolutionary networks show mixed support for historical signal of Ancestral Puebloan migration.*

The evolutionary network generated for the procedural unit data shows consistent separation between the Pre-Pottery Neolithic Outgroups in the sample, (orange in Figure 18), and the remainder of sites in the American Southwest. This is consistent with the sites associated with both regions belonging to two distinct historical entities, with a broadly similar set of technologies shared within them, and relatively many technological differences between groups. Within the Southwest, Ancestral Puebloan groups on the Colorado Plateau tend to group closely with one another: there are few splits that separate them from one another, and those splits tend to have short edges, suggesting weak support (Figure 18). Some, however, have better supported splits associated with them. Among Ancestral Puebloan sites on the Colorado Plateau, the two from the Klethla Valley in Northern Arizona (NA 11057 and NA 11047) are relatively distinct from the sites on the Shivwitz Plateau, and Virgin River (the Little Man sites, as well as other sites clustered near Lava Ridge Ruin) (Figure 18). Both the Klethla Valley sites are more closely associated with the Kayenta Cultural complex, which is argued to be the source of many Ancestral Puebloan migrant communities, including those sampled in this project. One of those proposed Kayenta enclaves is Reeve Ruin (AZ BB 11:26), (Clark & Lyons, 2012), which clusters alongside the Klethla Valley sites. The proximity of one migrant enclave to the Klethla Valley sites is consistent with their shared history. However, other migrant communities do not cluster as strongly with either the Klethla Valley assemblages or Ancestral Puebloan groups more broadly. This is likely because there is within group variation among both Ancestral Puebloan migrants, and the Hohokam groups they lived near that approaches the level of between group variability across the Southwest. For example, AZ BB 2:19 (Ash Terrace) is a Hohokam Platform mound complex in the Aravaipa district of the Lower San Pedro with no strong evidence for Kayenta migrants. Nonetheless, it clusters relatively closely with both the Klethla Valley sites in the Colorado Plateau, and Reeve Ruin just 50 or so Kilometers upstream, and relatively distantly from Hohokam assemblages in the Tonto Basin (Eagle Ridge, Pyramid Point, Hedge Apply). Furthermore, Davis Ranch, (AZ BB 11:36), located a short walk from Reeve Ruin, is situated more closely with other Hohokam sites in Tonto Basin (Eagle Ridge, Hedge Apple, Meddler Point), than it is with the neighboring Kayenta Enclave, Reeve Ruin. Finally, Griffin Wash locus A is a proposed Ancestral Puebloan migrant community in the Eastern Arm of Tonto Basin. However, it clusters more closely with other neighboring Hohokam groups in Tonto Basin, than it does with either the Klethla Valley, Virgin River, or Shivwitz Plateau Ancestral Puebloan groups (Figure 4.18). In summary, the relative positions of Ancestral Puebloan Migrants, Ancestral Puebloan, and Hohokam assemblages to one another in the procedural unit evolutionary network, show a lack of fit with a scenario in which lithic technology retains evidence of the migration.

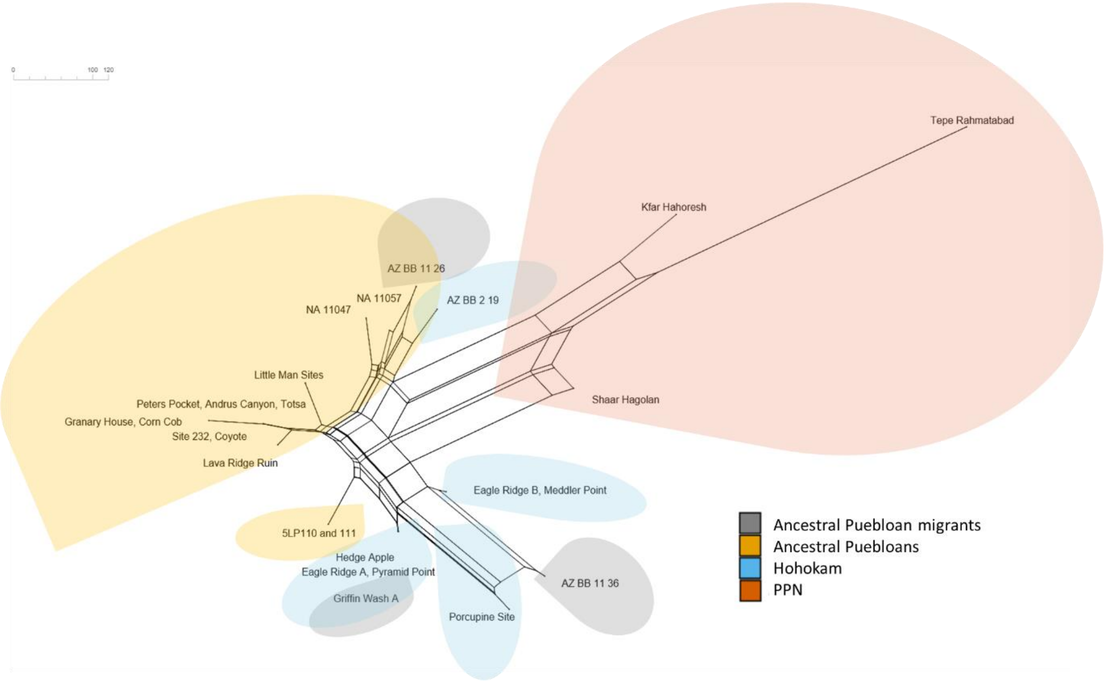


**Figure 4.18:** Splits-network illustrating the proposed evolutionary relationships between groups in the Southwest and PPN groups in the Levant based on procedural unit data.

The technological mode data show more support for a greater similarity between migrants and their ancestors than between migrants and Hohokam. In the technological mode network (Figure 4.19), as in the procedural unit network, the Pre-Pottery and Southwest sites are distinct from one another. However, Hohokam sites, and Ancestral Puebloan sites (both on the Colorado Plateau, and among migrant communities) tend to be clustered apart from one another, with a couple of exceptions. The split with the greatest support that divides the Southwest into two groups is between Tonto Basin sites, including the Tonto Basin migrant community at Griffin Wash A, and the remainder of Ancestral Puebloan and Ancestral Puebloan migrant assemblages. The remainder of assemblages in the Southwest cluster relatively closely to one another, they are separated by splits with relatively weak support. These include the remainder of Ancestral Puebloan sites, as well as the remainder of migrant enclaves in the San Pedro Valley. One Hohokam site is also classified within this group: the San Pedro site Ash Terrace (AZ BB 2:19). Overall, the results are promising but they might represent only the similarity within regions, regardless of cultural affiliation. All of the sites sampled in the San Pedro Valley are close to one another, as are most of the Shivwitz assemblages, and the assemblages in the Tonto Basin all cluster together, even the migrant enclave.

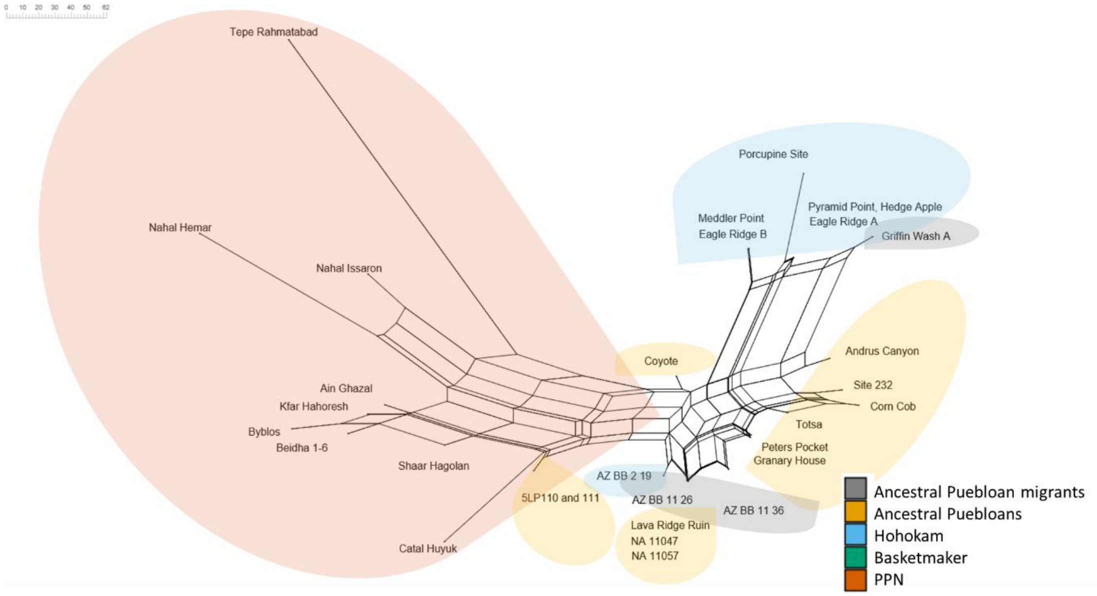


**Figure 4.19:** Splits-network illustrating the proposed evolutionary relationships between groups in the Southwest and PPN groups in the Levant based on technological mode data.

Overall, there is relatively weak support for a distinction between Ancestral Puebloan/Ancestral Puebloan migrant and other groups in the Southwest in either procedural units or technological modes. This could be due to the reticulate nature of cultural relationships within the Southwest. Technological variability is likely best fit by a reticulate network, as opposed to a branching phylogeny. While Ancestral Puebloan groups tend to group separately from the Hohokam assemblages, splits separating both archaeological cultures tend to have weak support, especially relative to the splits between the Southwest groups, and the outgroups. In the case of Austronesian languages (Figure 4.19), even though much of the evolution of languages is argued to have been reticulate in nature, with some branching events, there remain coherent, closely related groups that are similar among themselves, and distinct from the languages of more distantly related groups. The stone tool data within the American Southwest present a more ambiguous pattern. There is subtle between group variability that can be accommodated by many different evolutionary hypotheses, most with weak support. That uncertainty reflects the fact that Ancestral Puebloan migrations likely did not leave a strong diagnosable signal within the archaeological record, at least within the technological traits studied here.

## Summary and Discussion

Archaeologists interested in reconstructing population histories, migrations, and cultural exchange rarely have the opportunity to test those reconstructions against records where we know population histories a priori because there are so few records where this is possible. The Southwest, given the high quality of its record, and rich research history serves as a useful testing ground for answering various questions about cultural evolution, and how technological traditions behave. In this study, I assessed whether we could detect the migrations of Ancestral Puebloan peoples though lithic data alone. However, I did not find strong evidence that we would be able to detect the migration.

The Southwest has a suite of technologies shared above and below the Mogollon Rim, and distinct from the PPN, and global sample of assemblages. These are all consistent with the potential for diagnostic features of lithic technology to be tied to particular groups. However, the Southwest assemblages also fall within a relatively narrow sliver of the technological morphospace for both procedural units, and technological modes. The present, but subtle between group variability among sites in the southwest is in part explained by the close cultural relationships between groups within the southwest. The region had a long history of migration, trade, and cultural exchange that may have prevented the development of between group differences in lithic technology, while still facilitating differences in architecture and ceramics (Mills et al., 2015, 2016b). This means that there may not have been either strong, or long lived extrinsic or intrinsic mechanisms to isolate cultural lineages long enough for strong differences in technology to develop. Also, groups above, and below the Mogollon Rim relied on farming a similar range of crops, built irrigation systems (though these are very different above and below the plateau), and hunted wild game. All were also sedentary. As a result, it may be that the fitness landscape of lithic technology in the southwest, and developmental constraints did not favor the evolution of distinct technological practices above and below the Mogollon rim. These factors, lack of social forces that kept lineages culturally separated, and lack of ecological factors to favor divergence, likely helped dampen the development of between group differences in lithic technology. Though they had less of an effect on other technologies like ceramics, and architecture (Adler et al., 1996).

Nonetheless there is some between group variability in lithic technology within the Southwest, though there is mixed evidence about whether that variability reflects population history. In the technological mode data, Ancestral Puebloan migrants do tend to be more similar to their ancestors above the Colorado Plateau than they are to neighboring Hohokam groups. This is consistent with there being evidence of population history retained in lithic technology. However, the relationship is weaker in the procedural unit data. Procedural unit inventories among migrants are more similar to Hohokam groups than they are to their ancestors and other Ancestral Puebloan groups in Northern Arizona. It may be that Ancestral Puebloan groups, when they migrated into existing communities, quickly adopted local knapping techniques, while still practicing their own methods of making and decorating ceramics, and constructing settlements. The procedural unit findings are consistent with other studies of arrowheads in the Southwest (Ryan 2017) which found Puebloan migrants did not bring significantly different projectile points with them into the river valleys of Central Arizona. Instead, enclave sites could not be distinguished from sites with no evidence for Ancestral Puebloan migrants (Ryan 2017).

The distinctiveness of the Southwest pattern, and the relatively low between group variability within the Southwest, give us important information about the spatio-temporal scale at which stone tools might be useful as means of reconstructing population histories. The subtle technological variation across the Southwest may mean that we need to zoom out to a broader spatio-temporal scale to begin to find strong between-group variability appropriate for making inferences about population processes, like population expansions, and migrations. Because this study focused on the southwest has a relatively narrow spatio-temporal scope, I could not identify the spatio-temporal boundaries of the Southwest pattern, or the abruptness of that boundary. The lack of between group variability in chipped stone technology reflects prior work that found particular kinds of chipped stone technologies often cross cut group boundaries (Maher & Macdonald, 2020; Spinapolice, 2020). Cultural traditions based largely on lithic variation (the American

Archaic, Paleoindian, Middle Stone Age/Middle Paleolithic) tend to have vast spatio-temporal scope, well beyond what tends to be the scope of traditions defined based on multiple other kinds of material remains like ceramics, or architecture. The distinctiveness of Southwestern Assemblages may highlight something about the scales at which we might be able to detect migrations, or other aspects of population history. Lithic technologies may cross cut group boundaries within the Southwest, but it may also be that the broader Southwest network is well differentiated from other groups in the Great Plains, Great Basin, California Coast and Central Valleys, and Edward's Plateau or Gulf Coastal Plain. It might be at this scale where more informative studies investigating culture-contact, and population expansions would be valuable.

There are few records within North America where population histories are so well reconstructed at a broader, thousand year, multi-regional scale. There are also, generally, few well understood population expansions in prehistory where groups both relied on lithic technology, and where that lithic technology is well studied. This is why to investigate lithic variation at a broader spatio-temporal scale, we need to leave North America and focus on another set of migrations and population expansions that are very well studied through multiple lines of evidence, incorporating linguistics, genetics, and material culture: the Austronesian Expansion.

# CHAPTER 5: MIGRATION AND LITHIC TECHNOLOGY ACROSS THE AUSTRONESIAN EXPANSION

In the previous chapter, I studied lithic variability across the American Southwest around the 12th-14th centuries A.D., in order to test whether we could identify evidence for the migration of Ancestral Puebloan groups from the Colorado Plateau, into the river valleys of the Sonoran Desert. The American Southwest has a distinctive set of lithic technologies that set it apart from other assemblages sampled from the global record, and distinct technologies from other arid environment adapted food producers who lived in small villages. However, there was limited evidence for variability in lithic technology reflecting migration history in the Southwest, in part because there was not the kind of within and between-group variability necessary for a strong historical signal.

In many ways, the lack of technological differentiation within the Southwest is not surprising. I only sampled technological variability at the scale of a few generations, within a relatively small region, and within one connected metapopulation made up of people who belonged to the same language family. It may be that to detect strong evidence of migrations in lithic technology, we need to investigate population movements that happen at a broader spatio-temporal scale.

Here I focus on the expansion of Austronesian speakers across the Pacific in two major pulses. In contrast to the American SW, this case represents a focus to a broader, thousand-year, and thousand-kilometer scale of cultural change and population movement, spanning many regions, and distinct ecologies. The first is the expansion of Austronesian speakers associated with the Lapita Cultural Complex from Melanesia into Remote Oceania and West Polynesia ~3000 bp. The second is the expansion of the descendants of those Austronesian speakers from West Polynesia, into the remainder of the Polynesian triangle ~800 bp. (Gray et al., 2009). This span of time and space allows us to assess whether lithic technologies retain evidence of population history at a broader spatio-temporal scale, where we are more likely to capture between group variability.

## Background: The Austronesian Expansion

By the 18th Century, the Austronesian language family spanned half of the earth's circumference, from Rapa Nui at the Southeast corner of Polynesia, to Madagascar at the Western margin of the Indian Ocean. Austronesian languages were carried by farmers, and fishermen adapted to a maritime, sailing way of life, over the past 3,500 or so years (Bellwood, 2011). Austronesian influence extended beyond the extant boundaries of the language family. Phenotypically Polynesian human remains have been recovered from contexts just off the coast of South America, consistent with other lines of evidence for interaction between South America and Polynesia (Jones et al., 2011; Matisoo-Smith & Ramirez, 2010; Storey et al., 2007). Austronesian loanwords are also likely found among Bantu languages on the coast of the Indian Ocean (Blench, 2008; Crowther et al., 2016; Walsh, 2021), within the Torres Strait (Wood, 2018), and within Pama-nyungan speakers in Arnhem land (Walker & Zorc, 2011).

This chapter focuses on the record of Melanesia and Polynesia (figure 1). The two areas have the best resolved record of the movements of Austronesian speakers in the archaeological record. The root of the Austronesian language family is likely in Island Southeast Asia, and current dominant models point to the Formosan languages of Taiwan as the most closely related to the Ancestral, Proto-Austronesian languages from which the remainder in Oceania, Island Southeast Asia, and Madagascar are derived (Wolff, 2018). Within much of Micronesia, Melanesia, and Polynesia, all Austronesian speakers belong to a distinctive sub-branch of the Austronesian family, Oceanic, which has a shared set of innovations that distinguish it from other, mostly Malayo-Austronesian languages in Western Micronesia, and Island Southeast Asia (Crowley et al. 2001, Ross 1998, Blust 2009). Oceanic languages make up the majority of languages in the Austronesian family. There are about 500 spoken (Lynch et al., 2002).

Several lines of evidence connect the appearance of Oceanic Austronesian languages to the expansion of Neolithic groups from Island Southeast Asia, into Near and Remote Oceania. The archaeological culture that is the most likely to have been associated with this population expansion is the Lapita Cultural Complex. The cultural markers that distinguish Lapita sites from others are predominately ceramics with dentate stamped geometric markings (Summerhayes, 2000a), though other traits, reliance on shell adze technology, and domestic animals like pigs, chickens and dogs (Greig et al., 2018; Lum et al., 2006) are emblematic of Lapita sites. Lapita-bearing groups also relied heavily on oceangoing for their economy, and were engaged in exchange networks that spanned hundreds of kilometers of archipelagos in Near Oceania (Summerhayes, 2000b).

As I outline below, there is still disagreement about how many of these cultural traits are "intrusive", or brought in as a package from Island Southeast Asia, and how many developed within Near Oceania through interactions between pre-existing groups in Near Oceania, and Austronesian Speakers.

The earliest Lapita sites are found in Near Oceania, within the Bismarck Archipelago off the East Coast of Papua New Guinea ~3500 BP. Where people associated with the Lapita culture came from is still a source of disagreement, though Neolithic populations in Taiwan, and the Northern Philippines are likely source populations (Bedford & Sand, 2007b). Lapita pottery designs, and technique of production are tied very closely to the kinds of pottery produced on Luzon, in the Northern Philippines ~4000-3800 BP, all predating the Lapita Horizon in Near Oceania. Very similar kinds of pottery were produced in the Marianas Islands associated with the first people in Micronesia ~3500 bp. This is coeval with the start of the Lapita Horizon in Near Oceania (Carson et al., 2013). A source in Taiwan or the Philippines would be consistent with linguistic evidence associating Formosan languages of Taiwan as most closely resembling the root of later Malayo-Austronesian and Oceanic-Austronesian languages (Blust, 2009; Crowley et al., 2001). However, the extent of similarity between Marianas/Luzon ceramics and Bismarck Archipelago Lapita assemblages is a source of disagreement (Clark & Winter, 2019). Other assemblages in Island Southeast Asia, like dentate stamped ceramics in Sulawesi, for example, may be more similar to Lapita instances than the cases in the Marianas and Luzon (Clark & Winter, 2019). While we cannot say with certainty where Austronesians associated with the Lapita cultural complex came from, we can say a bit more about the population history of Austronesian speaking peoples within Near and Remote Oceania once they arrived.

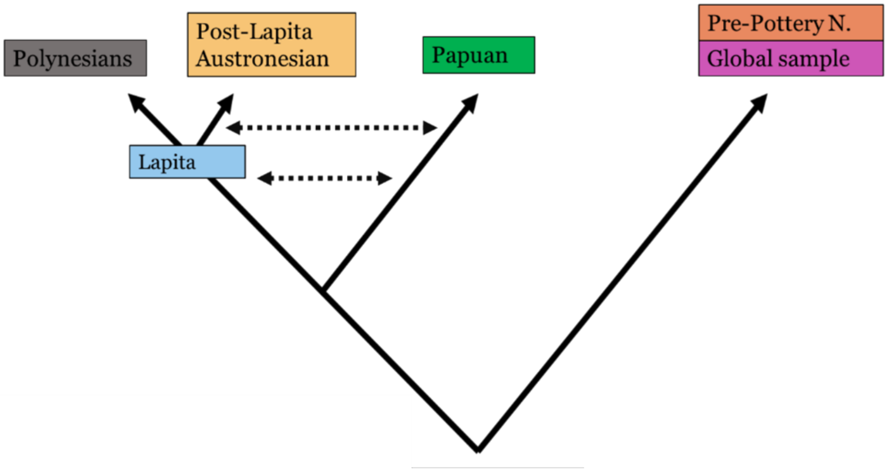


**Figure 5.1**: Simplified schematic outlining the population history Oceania. Polynesians, Post-Lapita Austronesians belonging to the Oceanic branch, and Lapita groups should be considered relatively closely related, while Papuan groups might be slightly more distantly related.

In most cases, people carrying the Austronesian language with them did not expand into unoccupied areas. The earliest securely dated human settlement in Near Oceania, in what is now Island Melanesia, and what would have been the Eastern Margin of the Sahul continent during the Pleistocene, is found on the Huon peninsula at the northern margin of Papua New Guinea ~40,000 years ago (Groube et al., 1986), around time of the earliest and clearest evidence for modern humans outside of Africa. The earliest expansions into what were during the Pleistocene, and remain major islands East of Papua New Guinea/Sahul: New Britain, New Ireland, and the Solomon Islands likely occurred by ~30-35,000 years ago (Loy et al., 1992; Pavlides, 1993; Spriggs, 1997).

Partly due to the relatively deep antiquity of human settlement in the region, and due to those human populations representing samples of African genetic variation, modern human populations in Near Oceania are exceptionally biologically and culturally diverse to the point where many of the languages in West Papua, Papua New Guinea, the Bismarck Archipelago, and Timor Leste belong to isolate families, with no clear genetic relationship to one another. Most of the languages in Near Oceania, that do not belong to the Austronesian family are all collected under a broad rubric of “Papuan” more-so because of geographic proximity, than due to shared derived characteristics of the languages themselves (Pawley et al., 2005). Biologically, the indigenous populations in Near Oceania are also aggregated under one analytical category: “Papuan” which masks the profound biological variation in the region (Pedro et al., 2020).

By ~3,600bp, we have the first evidence of the Lapita Culture, representing the expansion of Austronesian speakers from Asia into the Bismarck Archipelago and the northern margin of the Solomon islands (Patrick Kirch, 1987). However, the Lapita culture was likely not simply an intrusive population/culture. The current best supported model that explains the origin and expansion of the Lapita culture, and its relationship to Austronesian expansion is the Triple-I model (Bedford & Sand, 2007a; Elizabeth Matisoo-Smith, 2015). The Triple-I model proposes that newly arrived Austronesian groups, while they may have introduced particular ways of making ceramics, as well as domesticated pigs, and chickens, developed many of the features of the Lapita complex within Near Oceania as a result of interactions with indigenous Papuan groups, and those interactions persisted as Austronesian speaking groups expanded to Remote Oceania. The three I's in this case refer to *intrusion*, *integration* and *innovation*. Austronesian speakers arrived Near Oceania, interacted, and integrated with non-Austronesian indigenous groups in the area, and developed new phenotypic traits and cultural practices in the process (Addison & Matisoo-Smith, 2010; Spriggs, 1984). This helps to explain why many of the traits that would later become part of the Lapita cultural complex already existed in various forms within Island Southeast Asia and Melanesia. Pelagic fishing, canoe manufacture, shell adze production, horticulture, all had antecedents within Melanesia/Island SE Asia prior to the expansion of Lapita bearing/Oceanic-Austronesian speakers (Denham, 2011; Pawlik et al., 2015; Shipton et al., 2020). It also helps to explain Papuan DNA among Oceanic-Austronesian speaking groups in remote Oceania and Polynesia (Matisoo-Smith, 2015; Ohashi et al., 2006). People bearing these new traits, including the Lapita Cultural Complex then expanded out into Remote Oceania. Indeed, based on ancient DNA analysis of a small number of individuals from the Lapita site, Teouma, some individuals in Remote Oceania had little to no DNA markers consistent with an Asian origin. Instead, they fall well within the range of variability seen among genetically "Papuan" groups in the Bismarck Archipelago, which is consistent with Papuan groups in Near Oceania becoming integrated into the Lapita Culture, and the Oceanic-Austronesian language family (Bedford et al., 2018; Posth et al., 2018).

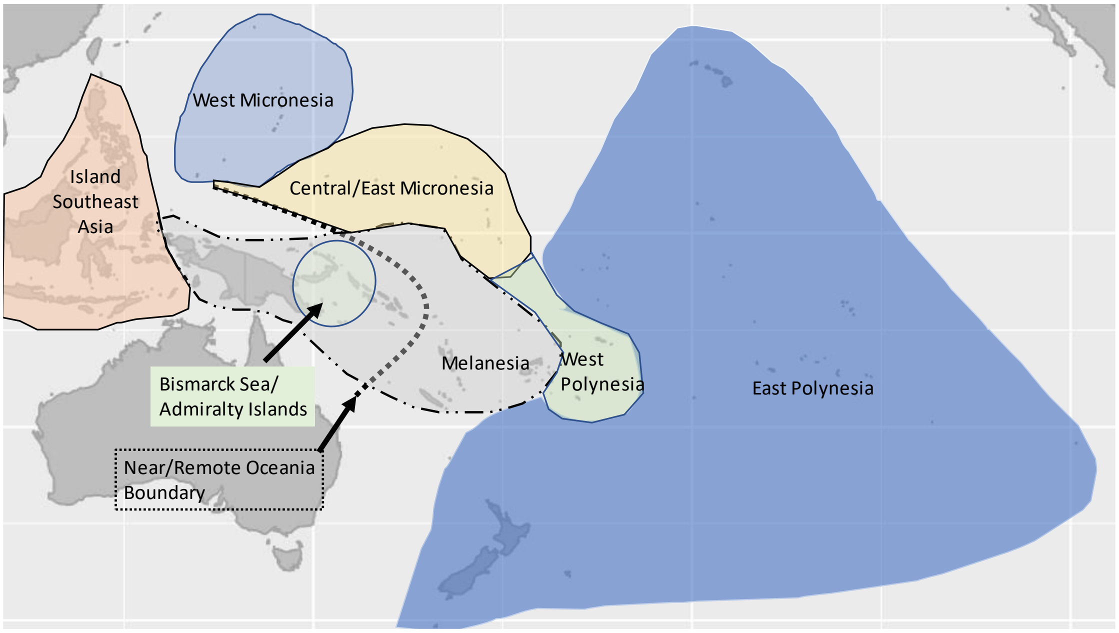


**Figure 5.2.** Regions of Oceania discussed in this chapter.

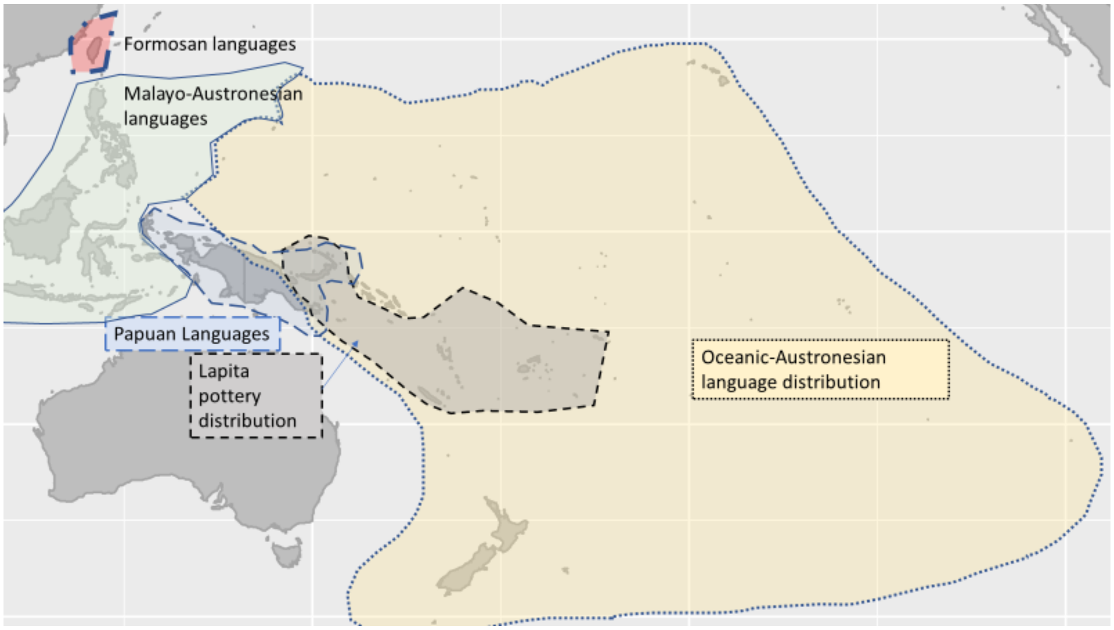


**Figure 5.3**. Map of important language groupings discussed in this chapter with reference to the maximal areal extent of the Lapita cultural complex.

A few centuries after the development of the Lapita Culture, people practicing that culture expanded out into “Remote Oceania”, the area of Oceania Southeast of the Solomon Islands (Figure 5.2). These islands include the island chains of Vanuatu, Fiji and New Caledonia, well as surrounding minor islands like the Reef Islands, and Santa Cruz chain (Sheppard, 1993). All were occupied by Lapita bearing groups by ~3000 bp, and all of which were uninhabited prior to the arrival of Lapita bearing groups. Today, the indigenous languages in this area all belong to the Oceanic sub-branch of the Austronesian language family, from which later Polynesian languages originated (Blust, 2009) (Figure 5.3). In the process of that expansion from the Bismark islands into Remote Oceania, Oceanic-Austronesian speaking groups likely skipped over the main Solomon Islands of Guadalcanal, San Cristobal, Malaita, Santa Isabel, New Georgia and Choiseul (Sheppard & Walter, 2006). Interactions between Lapita groups, and their movements in near and remote Oceania continued for some centuries (Summerhayes, 2004; Summerhayes, 2000b). Soon after the initial arrival of Austronesian groups in Remote Oceania, there was further gene flow, likely involving people more closely affiliated genetically with Papuan populations into remote Oceania (Posth et al., 2018; Valentin et al., 2016, 2014). The earliest sites dated in West Polynesia are found ~2850 bp, at sites in Tonga like Tongatapu, Nukuleka, and Vava’u which bear Lapita material culture (Burley et al., 2015, 2012). In the early period, population sizes, especially in Samoa, were likely relatively small, and focused on the coastal margins of high islands in West Polynesia.

After the first settlements in West Polynesia, there was continued flow of people from the Bismarck Archipelago into Remote Oceania, and from Remote Oceania back into Near Oceania into the main Solomon Islands, likely bringing with them Oceanic-Austronesian languages after ~2500bp (Pawley, 2009). The result of these later migrations is Oceanic-Austronesian languages are spoken in the Solomon Islands in areas where there were no Lapita sites. There were also likely further expansions of groups who were now settled for hundreds of years in the Bismarck Archipelago into remote Oceania, resulting in further Papuan gene flow from Near Oceania into Island chains of New Caledonia, Vanuatu, Fiji and Tonga (Bedford & Sand, 2007a).

In summary, I outlined a model for the population history of Near and Remote Oceania. People from Island Southeast Asia arrived in Near Oceania ~3500 bp. Through interactions with local Papuan groups as well as local cultural development, the Lapita Cultural Complex formed. That cultural complex was then carried further into Remote Oceania, as far as West Polynesia by ~2800 bp. Interaction networks, and complex interaction between strongly structured Papuan populations, and groups bearing more Asian DNA, continued throughout the Lapita period. As a result, we cannot consider Austronesian speakers in Remote Oceania as historically distinct entities from Papuan groups. These interactions help explain the genetic overlap between Oceanic-Austronesian speakers in Remote Oceania and Papuan groups.

But the expansion of the Lapita Complex into Remote Oceania and West Polynesia is only half of the story. Much of the remainder of the Pacific, including Hawaii, the Marquesas, Mangereva, Easter Island, New Zealand, Cook Islands and Tahiti remained uninhabited for centuries after the Lapita cultural complex ended. The time between the end of the Lapita complex, and the expansion of people into the remainder of Polynesia saw a great deal of cultural change. I outline these changes, and the expansion of Oceanic-Austronesian speakers into the Polynesian triangle below.

### *Austronesian expansion into Polynesia*

In contrast to the high complexity, and diversity of Papuan and Austronesian groups in Near and Remote Oceania, Polynesian groups in East Polynesia (Hawaii, Rapa Nui/Easter Island, Aotearoa/New Zealand, and all the islands between them) speak extremely similar, in some cases near mutually intelligible, languages with many shared cognate terms, despite being separated by thousands of kilometers (Blust, 2009). These languages all fall under the same Oceanic-Austronesian branch as other Austronesian groups in Near and Remote Oceania. Polynesians also share similar cultural practices among one another, that distinguishes them from Oceanic-Austronesian groups outside Polynesia (the “Hawaiian” type system of reckoning kin (Passmore & Jordan, 2020), centralized power with particular chiefs and their lineages, intensive agriculture including irrigation systems, that tend to differ from those of Austronesian speakers outside Polynesia (Sahlins, 1963; but see Sand, 2002). These shared derived features of Polynesia highlight the shared history of Polynesian groups, though there has been longstanding debate on who the ancestors of Polynesians were, and what processes led to the bio-cultural patterning seen between Polynesia, and the rest of Oceania.

The dominant model of Polynesian origins today is the Lapita only model (Kirch et al., 1987; Kirch & Green, 2001; Harris et al. 2020a; Green 1967; Valentin et al. 2016). In this scenario, Lapita groups arrived in West Polynesia ~2800bp and their descendants developed many of the hallmarks of Polynesian society in place. This Lapita derived West Polynesian population developed into what is termed the “Ancestral Polynesian Society” (Connaughton, 2015; Kirch & Green, 2001). Over the course of several centuries, cultural traits that later became widespread across Polynesia developed within West Polynesia (Kirch et al., 1987; Kirch & Green, 2001; Smith, 2002). These populations gradually shifted their ceramic technology away from Lapita motifs to Polynesian Plainware which endured until ~1500 bp. Groups also shifted settlements to include more intensive farming of uplands areas. By around 1000 bp, population sizes increased substantially (Harris et al., 2020b), and were associated with more intensive farming of uplands areas, landscape modification, and monumental architecture (David V. Burley, 1998; Quintus, 2015; Quintus et al., 2016). These subsistence and settlement changes were associated with a new type of social organization based on complex chiefdoms rare elsewhere in Oceania (Kirch et al., 1987; Kirch & Green, 2001; Sand, 2002).

In the Lapita-only model, these changes were the result of cultural evolution within one West Polynesia population or a closely related set of populations who were the ancestors of Oceanic-Austronesian speaking peoples who brought the Lapita cultural complex with them. After the hallmarks of Polynesian society developed in West Polynesia, Polynesians expanded out into East Polynesia, as well as West into Micronesia and Melanesia into what are now called Polynesian Outlier communities (Kirch, 2002:142–147). In the Lapita only model, similarities in language and biology between Polynesians and Central/Eastern Micronesians, and similarities in their material culture between archaeological sites dating to ~ 2000 bp, is argued to be the result of late-Lapita Austronesian groups from Near Oceania, expanding into Central/Eastern Micronesia (Kirch, 2002).

The second model is another Triple-I model, involving the “intrusion” and “integration” of Oceanic-Austronesian speakers who did not carry the Lapita culture with them into West Polynesia, after which the features of Polynesian society were “innovated” (Addison & Matisoo-Smith, 2010). In this Triple-I model, Lapita bearing groups arrive ~2800bp, but occupation is ephemeral and their small population sizes leave room for more groups to arrive (Burley, 2007). Subsequently, there was one or more migrations of Oceanic-Austronesian speakers from Micronesia, who were more genetically closely affiliated with Asian populations than Papuan populations, into West Polynesia before 1000 BP introducing dogs, bringing about changes in subsistence, language, and social structure (Gray et al., 2010; Matisoo-Smith, 2007; Pugach et al., 2021). This process involved both intrusion of Micronesian groups, their integration into West Polynesia, and resulted in innovations associated with Ancestral Polynesian society. The Triple-I model better incorporates information about the biology of Central and Eastern Micronesian populations, who have stronger genetic affinity to Asian populations than groups in New Caledonia, Fiji, and Vanuatu who had seen greater admixture with

Papuan populations, both as a result of Lapita interaction with Papuan groups, and as a result of later movements of peoples throughout near and remote Oceania.

The Triple-I model of Polynesian origins as described above is newer than the Lapita only model, though elements of it are much older. Decades before the first Lapita pots were identified and studied, the prolific early 20th century Ethnologist Te Rangi Hiroa (Sir Peter Buck), proposed the source population for later Polynesians was in Micronesia, based on skeletal and cultural evidence, and excluded Melanesia as that source population (Buck, 1938, 1944). Later archaeological research tying the Lapita complex to both the Bismarck Archipelago and to West Polynesia would cause scholars to reject this proposal for Polynesian origins, and found other explanations for the similarities between Micronesia and Polynesia, such as earlier movements of Oceanic-Austronesian groups from the Bismarck Archipelago into Micronesia (Addison & Matisoo-Smith, 2010; Kirch, 2002).

In both models, the Lapita only, and Triple-I model, Austronesian speakers from West Polynesia, now distinct from other groups in Near and Remote Oceania in terms of both genes, and culture, expanded into East Polynesia. The earliest settlements in East Polynesia were likely in central Polynesia, in the Cook and Society Islands, where there are dates as early as 800 A.D. (Rolett, 1989; Sear et al., 2020). The corners of the Polynesia triangle were not occupied until several hundred years later: in the 1200s A.D. for Hawaii, (Kirch & Mccoy, 2007; Rieth et al., 2011), 1300s for New Zealand (Jacomb et al., 2014), and 1200s for Easter Island (Hunt & Lipo, 2008). A formal comparison of lithic technology spanning Papuan, Lapita, and Polynesian assemblages, spanning the past ~4000 years of cultural change in those regions, should give us some greater insight into the rates at which technologies change as populations expand into new areas and whether there remains reliable evidence of shared history across these expansion events.

### ***Lithic technology and the Austronesian expansion***

The cultural and biological diversity of people in Near Oceania is not reflected in the lithic technology. Between ~40,000 and 3,600 bp in Near Oceania prior to the development of the Lapita Culture, most assemblages have few kinds of tools, and few ways of reducing cores, and there is little evidence of hierarchical core reduction. In the early to mid-Holocene, groups made flaked tools on non-hierarchical cores at Pamwak, and Peli Louson (Fredericksen, 1994), or through bipolar percussion in Pleistocene era sites like Matanbek Cave (Summerhayes & Allen, 1993). Prior to the development of the Lapita complex, groups also made axes produced through sawing, grinding, and pecking often with minimal flaking (Specht et al. 2014). Similarly produced adzes are found in the Southeastern portion of the Solomon Islands ~3000bp (Blake et al., 2015). Most assemblages have relatively few stone artifacts, few cores, and little evidence for shaping of tools (Maloney, 2021). There are exceptions that include the stemmed tools of New Britain. These were produced on prismatic blades, and on large Kombewa flakes, mostly on locally available Obsidian. These were produced until ~3000 bp (Maloney, 2021; Rath & Torrence, 2003).

Early Lapita sites in Near Oceania also tend to have very few chipped stone artifacts, though assemblages that have been studied and reported have broadly similar technological strategies to the pre-Lapita assemblages in Near Oceania. There is little evidence of hierarchical core reduction, some evidence for bipolar percussion, and retouch is rare. For example, one of the richer Early Lapita lithic assemblages in Near Oceania was recovered from the Lapita site Tamuarawai on Emirau island in the Bismarck archipelago. All excavated sediments were passed through a 7mm screen, and a total of 157 chipped stone artifacts of any kind were recovered, while over 2000 ceramic sherds were recovered. The assemblage bears some evidence for bipolar percussion, only one flake with potential retouch, no flakes with evidence for use wear, and three cores (Summerhayes et al., 2010). This pattern is broadly representative of other Papua New Guinea sites (Maloney, 2021).

Tamuarawai and other early Lapita assemblages likely represent a strategy of low effort flaking centered around producing sharp edges, and quickly discarding used flakes before edges were damaged (Summerhayes et al., 2010). The obsidian at the site, as well as at other Lapita sites in the Bismark archipelago, is consistent with smaller flakes and cores being brought to sites, where they were further flaked to produce more sharp edges (Summerhayes, 2003; Summerhayes et al., 2010). Recent intensive research among later Lapita sites in the Caution Bay area has highlighted more intensive reduction of raw material. Lapita groups in that area likely performed unidirectional single platform reduction to make relatively large flake tools, and those cores were further recycled through bipolar percussion (David et al., 2019; Mialanes et al., 2016).

There is little evidence of strong differences between Lapita adze technologies, and Papuan adze technologies. Green argued that the Lapita culture was associated with a novel adze toolkit, distinct from neighboring groups in the region, and consistent with the intrusive nature of Austronesian speakers in Near Oceania (Green, 2003; Reepmeyer et al., 2021). The Lapita adze toolkit has been argued to include adzes formed by cutting, grinding, and polishing with few, if any flaking phases, with cross sections including lenticular, and plano-convex forms. The result being fully abraded adzes with no remnant negative flake scars. However, this model is muddled by reliance on undated surface assemblages, rarity of adzes in general dating to before and after the development of the Lapita culture, and likely exchange and long distance transportation of adzes throughout Near Oceania (Reepmeyer et al., 2021). Plano-convex and lenticular adzes formed predominately by grinding are also found prior to the development of the Lapita culture within highland Papua New Guinea, as well as some possible examples within the Bismarck Archipelago (Shaw et al., 2020; Specht et al., 2014).The Lapita adze technology, then could be explained as a result of cultural exchange between newly arrived Austronesian groups, and Papuan groups in Near Oceania.

Remote Oceania adze technologies in the Lapita period are broadly similar to those in Near Oceania. While adzes in dated secure contexts are rare, quadrangular, or square sectioned adzes more typical of later Polynesian assemblages remain absent. In New Caledonia and Fiji, early groups made predominately lenticular and plano-convex adzes, which were ground almost completely. Though, in some instances, incomplete grinding revealed the presence or earlier flaking phases in Fiji (Birks & Birks, 1968).

Lithic assemblages associated with the Lapita Cultural Complex of the Reef Islands, New Caledonia, and Vanuatu in Remote Oceania are similar in their reliance on non-hierarchical flake production to Lapita assemblages in Near Oceania (Forestier, 1999a; Reepmeyer et al., 2010). Some of the flakes produced through non-hierarchical sequences were subsequently retouched to form backed tools, and drills, for example. At WKO-13a on Grand Terre in New Caledonia, flake production was focused on centripetal reduction, and more opportunistic multi-directional reduction of raw material blocks. These cores show little evidence of platform preparation (Forestier, 1999a; Lagarde & Sand, 2013). The produced flakes were then retouched to form scrapers, notches, denticulated tools, and “gravers”. Gravers were formed by retouching two shallow notches to form a small point at their intersection. Gravers similar to those identified at WKO-13A have also been identified in the Reef Islands at Lapita sites SZ-8 and RF-2, and at Teouma on the island of Efate in Vanuatu (Reepmeyer et al., 2010; Sheppard, 1993). There is also some evidence of microlith production among Lapita sites in Remote Oceania. At WKO-013a, flakes <5cm in their longest dimension were often backed. There is one example of a similar backed tool found from Lapita contexts at Teouma (Reepmeyer et al., 2010). Similar to other sites in Remote Oceania, Lapita adzes in West Polynesia were lenticular or plano-convex, and were ground almost completely. Though, in Tonga some adzes appear to have some evidence of early flaking stages, exposed as a result of incomplete grinding (Reepmeyer et al., 2010).

Late and post-Lapita assemblages show some evidence for hierarchical reduction, and in some cases more evidence of retouched tools compared to earlier periods. Within the Bismarck Archipelago, groups living after the end of the Lapita complex ~2500bp manufactured blades and, unifacial and trifacial points at sites like Kohin Cave, the Mouk Site, and Sasi (Antcliff, 1988; Fredericksen, 1994; McEldowney & Ballard, 1991). Similar trifacial points are found on Sohano Island in the Northwest Solomon Islands at site DAF (Wickler, 1995), and some may also be present as far east as Fiji (Moore, Pers. Comm.). Bipolar percussion is also found in post-Lapita contexts at Oposisi (Vanderwal, 1973). In post-Lapita contexts, we also begin to see the first examples adzes formed predominately by flaking One example on obsidian is illustrated by Fredericksen from the Sasi site, in contexts post-dating 2500 bp (Fredericksen, 1994). Similarly, within post-Lapita contexts in the Solomon Islands cherts are used to produce flaked tools, including flaked adzes in the late prehistoric period between 700bp, and 300bp (Tomasso & Moser, 2020; Walter & Green, 2011). The assemblage from Su'ena is the best studied (Dodd, 1998; B. Jones, 1997; Walter & Green, 2011), though similar adzes are found on across Ulawa, San Cristobal, Malaita in areas where the indigenous languages are Austronesian (Dodd, 1998; Ward, 1976). Furthermore, post-Lapita adze technologies in Tonga also have early flaking phases preserved due to incomplete grinding (Reepmeyer et al., 2010).

While there are two distinct models explaining the evolution of Polynesian culture in West Polynesia, the predictions for lithic technological patterning would be somewhat similar between both models. If the Lapita only model best describes the population history in West Polynesia, then we may expect that lithic assemblages produced by Lapita bearing groups in Near and Remote Oceania have direct cultural linkages to assemblages produced by the first Polynesians in say, New Zealand, though they may be separated by almost two thousand years of complex, structured cultural and genetic change. However, if the Micronesian Triple-I model best reflects reality, we might expect that while Lapita assemblages in Near Oceania and in West Polynesia were made by related people belonging to the same language family, there may have been a cultural break between the people who made Lapita assemblages in West Polynesia, and later Polynesians. That break, though, is not argued to be more than subtle: involving the introduction of new groups from Micronesia, rather than wholesale population replacement (Addison & Matisoo-Smith, 2010). Nonetheless, there could have been rapid cultural change within West Polynesia erasing signs of common history between groups in East Polynesia, and Near Oceania.

Put simply, if the Lapita only model is correct, and if there is historical signal reflecting population history in lithic technology, then Polynesians should be expected to have technology similar to Central and Eastern Micronesian groups, given their shared heritage in later and post-Lapita Austronesian populations. If the Micronesian triple-I model is true, then we would *also* of course expect central and eastern Micronesian groups to be relatively similar to West Polynesian groups. Though in that case, we might expect Micronesian groups to be more similar to West Polynesian groups than Late Lapita groups in West Polynesia and elsewhere.

Unfortunately, thorough descriptions of lithic assemblages in Central and Eastern Micronesia are exceptionally rare, so I do not compare Micronesian and Lapita assemblages in the below analysis. This makes fully evaluating the Triple-I model for Polynesian populations beyond the scope of this study. The rarity of stone tools in

Central and Eastern Micronesia is in part due to many of the islands being low atolls, with no flakeable stone. However, even on islands with abundant stone useful for flaking, tools manufactured on shell were far more prevalent. In Pohnpei, for example, shell tools are common, and stone tools like adzes are rarer, but not absent (Ayers & Mauricio, 1987a). Some adzes, like the Retik stone adze recovered from Nan Madol have the quadrangular cross section typical of square sectioned Polynesian adzes. However, none are from dated contexts, and so it is not possible to determine if they are the result of interaction with people in West Polynesia, or Polynesian outlier communities (as would be expected in the Lapita only model) or possibly predate examples in West Polynesia and the outlier communities, which we might expect if the Polynesian triple-I model is correct. Either way, non-Polynesian type adzes with lenticular cross sections, more typical of Southeast Melanesia are more common finds (Ayers & Mauricio, 1987a). Obsidian from the Admiralty Islands is also found at Pohnpei, shortly after the area was first colonized. (Nagaoka 2008). At Nan Madol groups also produced large flakes, blade-like in their proportions. They tend not to be from prepared cores, however, but are knapped along ridges of columnar basalt blocks (Ayers & Mauricio, 1987b). Similar techniques are reported from elsewhere in Polynesia where columnar basalts are found, such as in Mangareva (Kirch et al., 2010). However, this is unlikely to be indicative of anything more than competent knappers adapting to the forms of raw material on different islands.

The lithic technologies of the first groups in West Polynesia are not well understood, in part because lithic assemblages tend to be very small, and the record sparse. Chipped stone artifacts are rare among the very earliest sites in Samoa. Especially since the number of candidates for contexts older than 2000 bp has been winnowed significantly through chronometric hygiene (Rieth & Hunt, 2008) down to three sites, Malifuna, AS-13-1, and AS-12-18. Only Malifuna has Lapita Pottery, the latter two have Polynesian wares consistent with post-Lapita occupation. Substantial numbers of lithics were only recovered from AS-13-1. Ground and polished adzes were excavated from the pre-2000bp contexts, as well as basalt flakes, some from polished adzes, and some not. Volcanic glass is described as present in very small nodules, and only a single core is described as present, though the nature of this assemblage is not described further (Kirch & Hunt, 1993).

In contrast to the earliest record, the stone tool technologies of Polynesia in the past 800 years include rich and diverse methods of producing quadrangular, trihedral and other kinds of adzes (Jones, 1984). While assemblages in Near Oceania, and Remote Oceania tended to be lenticular in cross section, Polynesian adzes are argued to be distinctive as a result of being shaped so as to have three to four sides, as well as in other shape attributes (Green, 1974; Jones, 1984). According to historic, oral history, and ethnographic reports, adze making in the late prehistoric period in Polynesia was likely the domain of craft specialists (Gill, 1876:117–119; Cleghorn 1984; Malo, 1903), and involved a long, difficult *chaînes opératoires* with considerable variability between island chains (Brigham, 1902, 1902; Cleghorn 1984; Leach, 1990) Chipped stone technology outside the domain of adze production is not as well studied in Polynesia.

While retouched flakes are commonplace across Polynesia, including perforators, and scrapers (Clark & Michlovic, 1996), hierarchical core reduction tends to be absent with a few exceptions. In the Archaic period of New Zealand, represented at sites like Shag River Mouth and Oterehua (Leach & Leach, 2019; Smith et al., 1996) macro-blades were produced on prepared silcrete cores. In Rapa Nui, mata'a or tanged points, were produced on large obsidian cores with little preparation, or hierarchical organization (Bollt et al., 2006). However, in some cases, the Kombewa method was likely used to produce the flake blank prior to retouching the point (Charleux, 1986).

In summary, migrations of Austronesian speakers represent an opportunity to measure variability across related peoples, across diverse environments. In terms of lithic technology, the above summary suggests there is little evidence for strong distinctions between Papuan, and Lapita assemblages within near Oceania, though this may be largely due to the relatively small sample sizes of relevant assemblages in the region. Larger Lapita assemblages are more common in Remote Oceania, and in the Late to post-Lapita periods. Within Near and Remote Oceania assemblages post-dating ~3000 BP show a greater diversity of tool types, with some groups developing flaked adze technologies, and some evidence for hierarchical core reduction techniques, including formalized blade production, and bifacial and trifacial points. The strong similarities between sites across Melanesia after the development of the Lapita culture could have resulted from integration between Austronesian and Papuan groups (as predicted in the Lapita Triple-I Model) as well as later sustained linkages between islands. Nonetheless, there has been no systematic comparison of Lapita, and Papuan sites spanning Near and Remote

Oceania to determine how much within and between group variability there may have been.

Finally, while we can say little about lithic technology of Micronesia or early assemblages in West Polynesia shortly after first colonization, Polynesian assemblages appear variable. Some island chains experimented with distinctive prepared-core methods of producing tools, and others producing similarly low-effort flake tools as other sites in Melanesia. Ubiquitous across Polynesia are carefully prepared, flaked square section adzes, as well as other kinds of cross sections and forms not seen in Lapita, or post-Lapita contexts in Near or Remote Oceania.

The above discussion gives us some clues as to how lithic variability could relate to population history in Oceania. However, as we did in the previous chapter, we need to assess technological overlap in the morphospace between these different culture groups. We also must compare technological overlap among related groups in Oceania, to the degree of overlap with unrelated outgroups.

Below I outline this chapter’s analysis, which encompasses Near Oceania, through Polynesia, and incorporates ecologically analogous outgroups in Australia and North America, Neolithic populations in Jordan, as well as samples drawn randomly from the global record. This study will help us better understand how rapidly groups moved across the morphospace of lithic technology as they expanded into new, diverse ecologies of Oceania, and whether across that expansion there was strong historical signal relating to population history.

## Measuring technological variability across Oceania

The results of this chapter follow a sequential results format. There are two sections, each including the background, methods and results addressing one part of the broader problem. The first section involves a simple overview of what technologies are present across the sampled assemblages. Here, I explore in detail which cultural groups have what technologies, and note potential between group differences, and what technologies are associated with those differences. In this section, I evaluate whether there may be shared derived cultural traits that reflect the population history of Oceania.

In the second section I evaluate whether the within and between-group variability in technology reflects population history. To do so, I quantify similarity and dissimilarity between the sampled assemblages using Jaccard distances, and assesses the within and between group variability of assemblages through a multidimensional scaling analysis approach. I test whether there are significant between-group differences using a PERMANOVA approach, and outline which pairs of groups are significantly different through post-hoc tests.

Finally, in the third section I produce proposals for the evolutionary relationships between cultural groups within and outside of Oceania based on lithic technology following the same Neighbor net method as described in the prior chapter. By producing historical proposals based only on lithic technology, we can further assess whether there is reliable historical signal of the Austronesian and Polynesian expansions within lithic technology.

The data collection strategy for the Oceania study is much the same as the strategy for the Southwest study, and the same kind of data were collected: procedural units and modes through the literature, and through my own studies of assemblages. Technological data were collected from assemblages made by groups for which anthropologists have developed broadly accepted models of their cultural relationships and population histories. These include Polynesian groups, Oceanic-Austronesian groups in Near and Remote Oceania dating to after the Lapita period, assemblages from the Lapita complex, and assemblages produced by Papuan groups pre-dating the Lapita complex. The variability across these related cultural groups was then compared to outgroups. These include the same outgroup assemblages as studied in the Southwest case: Pre-Pottery Neolithic groups in the Southern Levant. In addition, I also gathered data from coastal, or island sites dating the late Holocene, but occupied by non-Papuan, and Non-Austronesian groups: A Chumash assemblage in the Channel Islands of Southern California, one site in Coastal Australia, and two sites in Tasmania (Figure 5.4, Tables 5.1 and 5.2). Finally, I included the same sites randomly sampled from the global record as studied in the previous chapter.

### ***Sites sampled: Polynesia***

Polynesian sites sampled in this study include early Polynesian artifacts in West Polynesia dating to older than 1700 BP, but post-dating the Lapita period, and later Polynesian assemblages in East Polynesia dating to the past 800 years. AS.13.1 Unit 4 is an Early Polynesian context excavated in Ofu Village, on the Island of Ofu in American Samoa (Quintus et al., 2016) (Figure 5.4). These test units and prior research on the island have highlighted human occupation as early as the 2649 through 950 A.D (Quintus et al., 2016). The lower levels of unit four contain Polynesian pottery, which ceased being produced by ~1700 bp, and an assemblage of volcanic glass and basalt debitage, as well as finished basalt adzes and other flake tools. I collected data on this assemblage in person.

East Polynesian assemblages sampled for this study include several sites on the Southern Island of New Zealand, including the Archaic settlement of Shag River Mouth, dating to ~1200 BP, and occupied for only two generations (Atholl Anderson, Smith, Allingham, et al., 1996; Atholl Anderson, Smith, & Higham, 1996; Atholl Anderson & Smith, 1996). Data from this site was collected both in person, and from prior descriptions of the assemblage (Ian Smith et al., 1996). Data from other South Island assemblages were collected from the literature. These include Oterehua, Cat's Eye Point, and Riverton adze quarry (Figure 13) which span the Archaic through contact periods ~300 BP (H. M. Leach & Leach, 1980,; B. F. Leach & Leach, 2019; Wilson, 1999).

Outside of New Zealand, I also sampled materials collected by Peter Gathercole from Pitcairn Island in 1964. These materials include basalts and volcanic glass material associated with quarry sites across the Island, likely dating to between 800 and 300 BP. There is no radiocarbon chronology for Pitcairn, or neighboring Henderson island that has undergone rigorous chronometric hygiene. However, the ages of earliest occupation in both the Gambier Island chains to the West (750-650 BP. (Atholl Anderson et al., 2003), and the Easter Island dates to the East (~1200 A.D.) are likelier estimates for human presence than the earliest published estimates for Henderson and Pitcairn (~1150-

950 (Roger Curtis Green & Weisler, 2002; Wiessler, 1995). By 450 neighboring Henderson Island, had been abandoned, and by the time of the Bounty Mutiny in the late 18th century, Pitcairn Island had also been abandoned. Both islands are small and ecologically marginal, which may explain their abandonment while neighboring archipelagos had flourishing populations by the historic period (Wiessler, 1995). I analyzed the Pitcairn assemblage in person.

Finally, one quarry site on the Island of Moloka'i in Hawaii is also included. Ka'eo is one of the most dense quarry sites in the Hawaiian islands outside of Mauna Kea in terms of both the number of tools recovered, and density of debitage. Associated habitation contexts have been dated to the 19th century suggesting the site may have been used through the early historic period (Clarkson et al., 2015, 2014; Weisler, 2011).

### ***Sites sampled: Post-Lapita Austronesian assemblages in Near Oceania***

Next are post-Lapita assemblages likely produced by Oceanic-Austronesian speaking groups in Near Oceania. These include sites in the Bismarck Archipelago, Coastal Papua New Guinea, and Solomon Islands dating to the past two thousand years in areas where modern groups speak Oceanic Austronesian languages. These assemblages are: GAC layers 1-3, and Pamwak Rockshelter phase I on Manus Island in the Bismarck Archipelago, Oposisi on the Coast of the Gulf of Papua, Northwest of Port Moresby, and Su'ena in the Solomon Islands.

GAC and Pamwak Rockshelter phase I are both Late Holocene assemblages on Manus Island, at the Northwesternmost margin of the Bismarck Archipelago. These assemblages post-date the end of the Lapita complex, and contain later Sasi and Puian ceramics typical of assemblages less than 2500 years old (Clayton Frederick Keith Fredericksen, 1994; Pavlides & Kennedy, 2007). Modern groups on the Island speak Oceanic-Austronesian languages, distinct from Papuan languages more typical of the Papua New Guinea mainland and highlands.

Oposisi is a coastal Papua New Guinea Site, near the Westernmost limit of the the many Oceanic-Austronesian languages that are found throughout coastal Papua New Guinea (Vanderwal, 1971). These coastal Austronesian languages were possibly introduced through later movements of post-lapita Oceanic-Austronesian speakers from the Bismarck Archipelago, west along the coast of Papua New Guinea (Irwin, 1991). The site dates to ~2000 bp, marking the start of the Early Papuan Pottery Phase in Coastal Papua New Guinea (Allen et al., 2011).

Su'ena is a modern village with occupations dating as far back as 600 BP on Ugi Island, in the Solomon Islands (Walter & Green, 2011). A rich midden, with abundant chert artifacts was excavated by Roger Green in 1971. The description of this midden is sampled for this study (Walter & Green, 2011). While Lapita bearing groups likely skipped over this part of the Solomon Islands on their way to the reef islands, post-lapita Austronesian speakers belonging to the Oceanic branch, expanded into the area later on. As a result, the indigenous languages of islands like Ugi, and much of the Solomon Islands include Oceanic branches of Austronesian languages (Pawley, 2009; Walter & Green, 2011).

### ***Sites sampled: Lapita***

Four Lapita assemblages are included, one in Near Oceania and three in Remote Oceania. The one site in Near Oceania, Moiapu 3, is a terminal Lapita settlement near the coast of Caution Bay, Northwest of Port Moresby, dating to ~2630-2400 BP (David et al., 2019). The three Lapita sites in Remote Oceania are WKO013A in New Caledonia, the Reef Island Assemblages, and Teouma in Vanuatu. The site WKO013A is Located on the Kone peninsula of Grand Terre in New Caledonia. The site is part of a larger archaeological landscape including both Lapita and later Kanak archaeological material. I focused on analyzing chipped stone material from the lower layers of the eastern excavation units (zones 1 and 2) of 13A, recovered during the 1996 excavations of the site. In these eastern squares, Lapita occupation contexts below ~30cm are argued to be less mixed and these underwent wet sieving through a 2mm screen (Sand et al., 2019). The technological summary of the site presented here are based on my own analysis, in addition to previous published descriptions (Forestier, 1999b; Lagarde & Sand, 2013). The Reef Island "assemblage" represents an aggregation of data from three sites excavated by Roger Green in 1972, and 1976-1977 in the Santa Cruz and Reef Island chains Southeast of the Solomon Islands. Two were excavated in the Reef Islands, SE-RF-2, SE-RF-6, and one on Santa Cruz, SE-SZ-8 (Sheppard, 1993). Due to the relatively small sample size of all, and their relative proximity, I aggregated the presence/absence data for all into one broader inventory. Finally, the Lapita assemblage of Teouma on Vanuatu was recovered during excavations in 2004-2006. The occupation layers date between 3100 and 2500 bp (Reepmeyer et al., 2010).

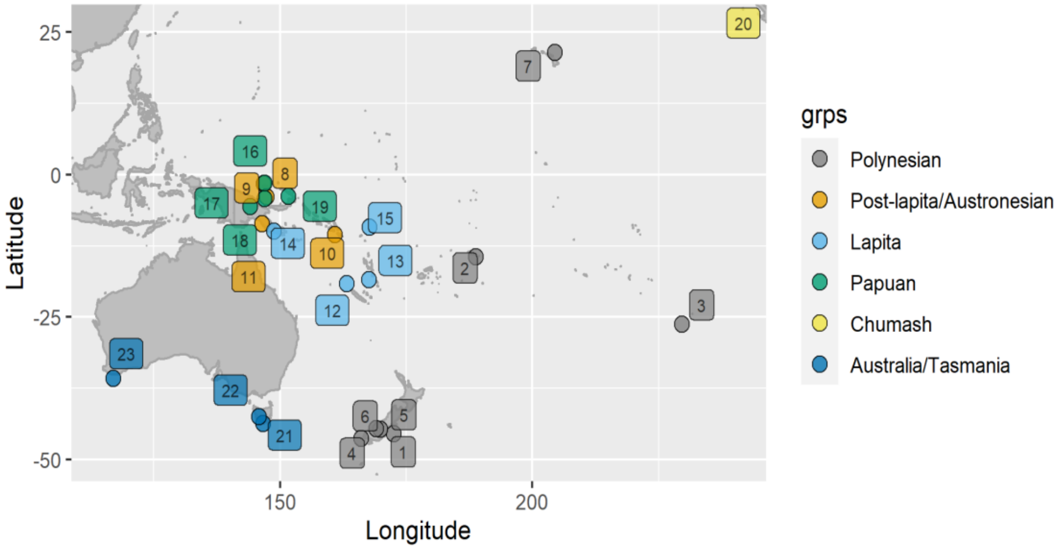


**Figure 5.4**: Assemblages sampled across Oceania, including one outgroup in North America. Colors correspond to six different cultural groups. These include Polynesian, Lapita, Post-Lapita/Austronesian, and Papuan assemblages, which are all likely culturally connected to one another. The last two groups includes a single Chumash assemblage, and three assemblages in Australia/Tasmania. These latter two assemblages are treated as ‘outgroups’. Assemblage key: 1. Shag River Mouth, 2. AS.13.41 XU-4, 3. Pitcairn sites, 4. Riverton adze quarry, 5. Cat’s eye point, 6. Oterahua, 7. Ka’eo quarry, 8. GAC Layers 1-3, 9. Pamwak Rockshelter Phase I, 10. Su’ena, 11. Oposisi, 12. WKO013A, 13. Teouma, 14. Moiapu 3, 15. Reef Island Sites, 16. Pamwak Rockshelter Phase II-IV, 17. Kiowa levels 10-12, 18. Kiowa levels 2-6, 19. Willaumez Peninsula, 20. Eel Point early, 21. Bone Cave Upper Levels, 22. Cave Bay Cave and 23. Devil’s Lair Cave.

**Table 5.1**: sites sampled: procedural units

| Context | Source | Cultural group |
|---|---|---|
| AS.13.41 XU-4 | This study | Polynesian |
| Oterahua | Leach and Leach 2019 | Polynesian |
| Cat's eye point | Wilson 1999 | Polynesian |
| Shag River Mouth | Smith et al. 1996 | Polynesian |
| Riverton adze quarry | Leach and Leach 1980 | Polynesian |
| Ka'eo quarry | Clarkson et a. 2015 | Polynesian |
| Pitcairn sites | This study | Polynesian |
| GAC Layers 1-3 | Pavlides and Kennedy 2007 | Post-lapita/Austronesian |
| Oposisi | Allen et al. 2011 | Post-lapita/Austronesian |
| Su'ena | Walter and Green 2011 | Post-lapita/Austronesian |
| Reef Island Sites | Sheppard 1993 | Lapita |
| Teouma | Reepmeyer et al. 2010 | Lapita |
| WKO013A | This study and Lagarde and Sand 2013 | Lapita |
| Moiapu 3 | David et al. 2019 | Lapita |
| Kiowa levels 10-12 | Gaffney et al. 2015 | Papuan |
| Pamwak Rockshelter Phase II-IV | Fredericksen 1994 | Papuan |
| Kiowa levels 2-6 | Gaffney et al. 2015 | Papuan |
| Willaumez Peninsula | Araho et al. 2002 | Papuan |

| Context | Source | Cultural group |
|---|---|---|
| Eel Point early | Cassidy et al. 2014 | Chumash |
| Kfar HaHoresh | Barzilai and Goring-Morris 2010 | PPN |
| Tepe Rahmatabad | Nishiaki et al. 2013 | PPN |
| Sha'ar Hagolan | Ariel-Shatil 2006 | PPN |
| Lomekwi 3 | Harmand et. al. 2015 | Global sample |
| Lokalalei 2c | Delagnes and Roche 2005 | Global sample |
| Kanjera | Plummer and Bishop 2016 | Global sample |
| NY 18 Nyabusosi | Texier 1995 | Global sample |
| Hugub KK51 | Gilbert et al. 2016 | Global sample |
| Nor Geghi 1 | Adler et al. 2014 | Global sample |
| Torre in Pietra level M | Villa et al. 2016 | Global sample |
| Qesem Cave | Barkai et al. 2005 and Barzilai et al. 2011 | Global sample |
| Torre in Pietra level D | Villa et al. 2016 | Global sample |
| Koilomot locus 2 | Tryon et al. 2005 | Global sample |
| Wallertheim West Concentration | Conard and Adler 1997 | Global sample |
| Ein Qashish | Malinsky-Buller et al. 2014 | Global sample |
| Geissenklosterle Cave Gravettian | Hahn and Owen 1985 | Global sample |
| Sujula | Rankama and Kankaanpaa 2011 | Global sample |
| GFJ | Pavlides and Kennedy 2007 | Global sample |

**Table 5.2**: sites sampled: technological modes

| Context | Source | Cultural group |
|---|---|---|
| Shag River Mouth | This study and Smith 1996 | Polynesian |
| AS.13.41 XU-4 | This study | Polynesian |
| Pitcairn sites | This study | Polynesian |
| Riverton adze quarry | Leach 1980 | Polynesian |
| Cat's eye point | Wilson 1999 | Polynesian |
| GAC Layers 1-3 | Pavlides et al. 2007 | Post-lapita/Austronesian |
| Pamwak Rockshelter Phase I | Fredericksen 1994 | Post-lapita/Austronesian |
| Su'ena | Walter and Green 2011 | Post-lapita/Austronesian |
| Oposisi | Allen 2011 | Post-lapita/Austronesian |
| WKO013A | This study and Lagarde and Sand 2013 | Lapita |
| Teouma | Reepmeyer 2010 | Lapita |
| Moiapu 3 | David 2019 | Lapita |
| Reef Island Sites | Sheppard 1993 | Lapita |
| Pamwak Rockshelter Phase II-IV | Fredericksen 1994 | Papuan |
| Kiowa levels 10-12 | Gaffney et al. 2015 | Papuan |
| Kiowa levels 2-6 | Gaffney et al. 2015 | Papuan |
| Eel Point early | Cassidy et al. 2004 | Chumash |

| Context | Source | Cultural group |
|---|---|---|
| Bone Cave Upper Levels | Shea 2013 | Australia/Tasmania |
| Cave Bay Cave | Shea 2013 | Australia/Tasmania |
| Devil's Lair Cave | Shea 2013 | Australia/Tasmania |
| Catal Huyuk | Shea 2013 | PPN |
| Tepe Rahmatabad | Shea 2013 | PPN |
| Byblos | Shea 2013 | PPN |
| Ain Ghazal | Shea 2013 | PPN |
| Beidha I-VI | Shea 2013 | PPN |
| Kfar HaHoresh | Shea 2013 | PPN |
| Nahal Hemar | Shea 2013 | PPN |
| Nahal Issaron | Shea 2013 | PPN |
| Sha'ar Hagolan | Ariel-Shatil 2006 | PPN |
| Abu Ghosh | Shea 2013 | Global sample |
| Panga Ya Saidi Levels 1-4 | Shea 2020 | Global sample |
| Wadh Lang'o 1 | Shea 2020 | Global sample |
| Strashnaya Cave 4 | Nishiaki 2021 | Global sample |
| Arta 2 Layers 1-3 | Nishiaki 2021 | Global sample |
| Tyumechin 4 tempo 1 | Nishiaki 2021 | Global sample |
| Ogonki 5 Layer 3 | Nishiaki 2021 | Global sample |
| Tor Aeid | Nishiaki 2021 | Global sample |
| Sefunim Layer D.8 | Nishiaki 2021 | Global sample |
| Shibazhan C | Nishiaki 2021 | Global sample |
| Fanzenshanyan Layer 2 | Nishiaki 2021 | Global sample |

| Context | Source | Cultural group |
|---|---|---|
| Xinxiangzhuanchang Layer 4 | Nishiaki 2021 | Global sample |
| Shuidonggou Loc.8 Layer 2 | Nishiaki 2021 | Global sample |
| Meigou Lower | Nishiaki 2021 | Global sample |
| Haga Layer 2 | Nishiaki 2021 | Global sample |

### ***Sites sampled: Papuan assemblages***

I also sampled four assemblages produced by Papuan groups. These assemblages were all produced by likely non Oceanic-Austronesian speakers in Near Oceania. These all include assemblages that pre-date the Lapita complex, and presumed arrival of Austronesian speakers. These include Bismark Archipelago assemblages of Pamwak rockshelter phases II-IV on Manus Island dating to ~5-12.5 kya (Clayton Fredericksen et al., 1993; Clayton Frederick Keith Fredericksen, 1994), and the Willaumez Peninsula assemblages on New Britain dating to ~3.5-6 kya (Araho et al., 2002). I also sampled descriptions of the Late Pleistocene to Mid Holocene highland Papua New Guinea site, Kiowa which was divided into levels 2-6 (dating to ~7.1-5.3 kya) and levels 10-12 (dating to 10.2-12.5 kya) (Gaffney et al., 2015).

### ***Sites sampled: Australia, Tasmania, California outgroups.***

Finally, as ecologically analogous outgroups, I sampled assemblages from early to Late Holocene Island and Coastal groups. Most of these cases were gathered from Shea's 2013 book. These samples include the Late Pleistocene Upper Layers of Bone Cave and Late Pleistocene assemblage of Devil's Lair Cave in Tasmania, as well as Late Pleistocene layers of Devil's Lair Cave near the Southwestern most corner of Australia, near Cape Leeuwin (Shea, 2013). In North America, I included the Early Holocene assemblage from Eel point, on San Clemente island in the Southern California Bight. Finally, I included the same outgroups as included in the previous chapter: a random sample of assemblages drawn from the global record, and a set of Pre-Pottery Neolithic assemblages from the Southern Levant (Tables 5.1 and 5.2).

### ***Results***

In sharp contrast to the record of the American Southwest, there is substantial within and between group variability across Oceania. Polynesian assemblages, for example, tend to have more procedural units, and more technological modes than other Austronesian and Papuan sites sampled. Furthermore, some assemblages in Near and Remote Oceania have very few procedural units and modes, consistent with a low-effort strategy in reducing raw materials.

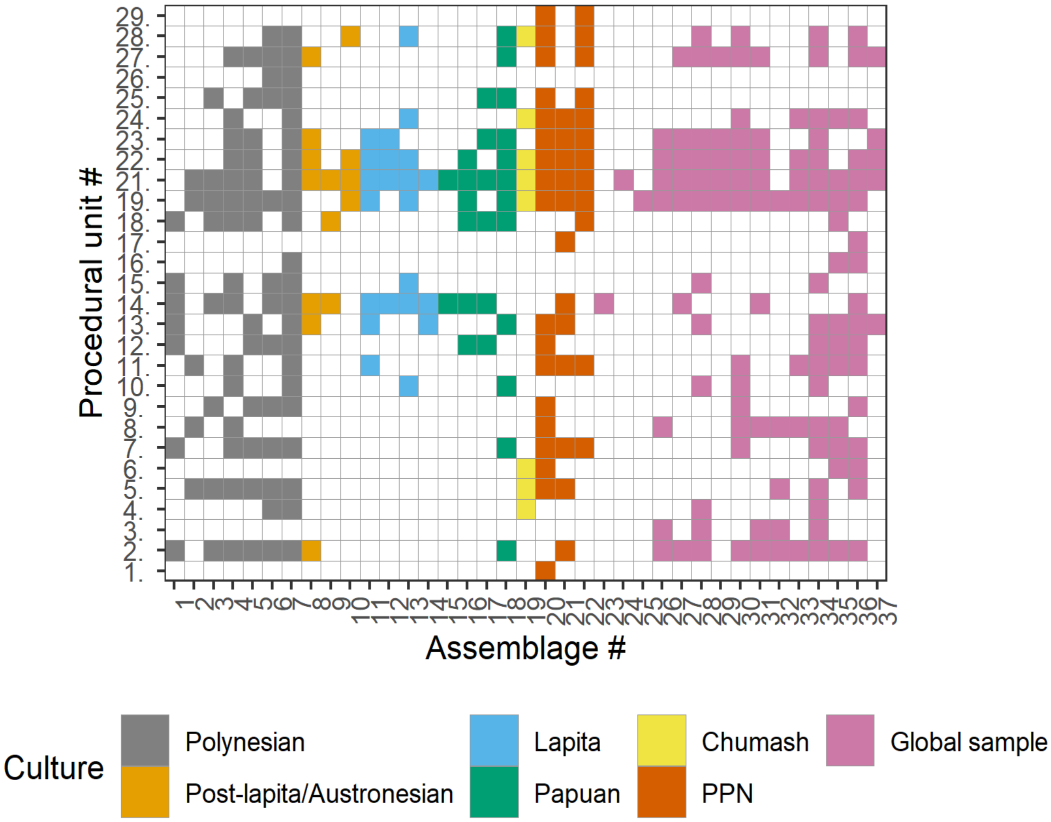


**Figure 5.5**: Procedural unit presence and absence for each assemblage. Presence or absence of each procedural unit is recorded in each row. See table 1 for summary of traits. Assemblage key: 1. AS.13.41 XU-4, 2. Oterahua, 3. Cat's eye point, 4. Shag River Mouth, 5. Riverton adze quarry, 6. Ka'eo quarry, 7. Pitcairn sites, 8. GAC Layers 1-3, 9. Oposisi, 10. Su'ena, 11. Reef Island Sites, 12. Teouma, 13. WKO013A, 14. Moiapu 3, 15. Kiowa levels 10-12, 16. Pamwak Rockshelter Phase II-IV, 17. Kiowa levels 2-6, 18. Willaumez Peninsula, 19. Eel Point early, 20. Kfar HaHoresh, 21. Tepe Rahmatabad, 22. Sha'ar Hagolan, 23. Lomekwi 3, 24. Lokalalei 2c, 25. Kanjera, 26. NY 18 Nyabusosi, 27. Hugub KK51, 28. Nor Geghi 1, 29. Torre in Pietra level M, 30. Qesem Cave, 31. Torre in Pietra level D, 32. Koilomot locus 2, 33. Wallertheim West Concentration, 34. Ein Qashish, 35. Geissenklosterle Cave Gravettian, 36. Sujula and 37. GFJ.

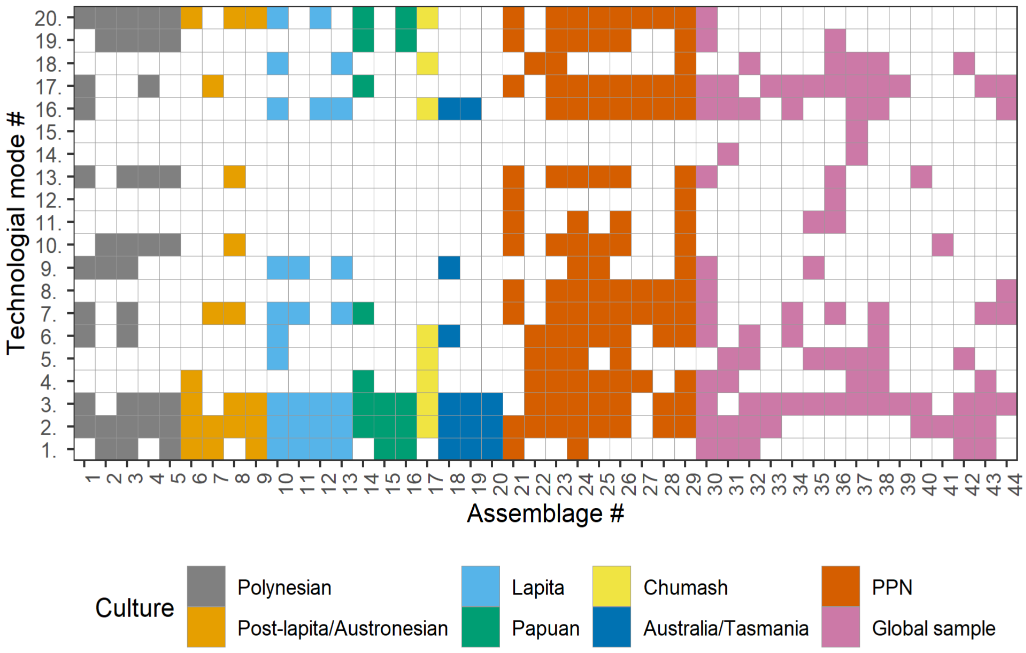


**Figure 5.6**: Technological mode presence and absence for each assemblage. Presence or absence of 21 traits is recorded in each row. See table 2 for summary of traits. Assemblage key: 1. Shag River Mouth, 2. AS.13.41 XU-4, 3. Pitcairn sites, 4. Riverton adze quarry, 5. Cat's eye point, 6. GAC Layers 1-3, 7. Pamwak Rockshelter Phase I, 8. Su'ena, 9. Oposisi, 10. WKO013A, 11. Teouma, 12. Moiapu 3, 13. Reef Island Sites, 14. Pamwak Rockshelter Phase II-IV, 15. Kiowa levels 10-12, 16. Kiowa levels 2-6, 17. Eel Point early, 18. Bone Cave Upper Levels, 19. Cave Bay Cave, 20. Devil's Lair Cave, 21. Catal Huyuk, 22. Tepe Rahmatabad, 23. Byblos, 24. Ain Ghazal, 25. Beidha I-VI, 26. Kfar HaHoresh, 27. Nahal Hemar, 28. Nahal Issaron, 29. Sha'ar Hagolan, 30. Abu Ghosh, 31. Panga Ya Saidi Levels 1-4, 32. Wadh Lang'o 1, 33. Strashnaya Cave 4, 34. Arta 2 Layers 1-3, 35. Tyumechin 4 tempo 1, 36. Ogonki 5 Layer 3, 37. Tor Aeid , 38. Sefunim Layer D.8, 39. Shibazhan C, 40. Fanzenshanyan Layer 2, 41. Xinxiangzhuanchang Layer 4, 42. Shuidonggou Loc.8 Layer 2, 43. Meigou Lower and 44. Haga Layer 2.

Polynesian groups are distinct from other Austronesian and Papuan groups in their reliance on preparing and rejuvenating cores, as well as in their reliance on quadrangular flaked adzes. Assemblages in Polynesia tend to have more procedural units (median = 13, range =5 - 22) compared to the other Papuan and Austronesian groups (median = 6, range = 2 - 12. The greater number of procedural units across Polynesia is driven in large part by development of square sectioned adzes, which are ubiquitous across West and East Polynesia, as well as the development of blade technology in New Zealand. Both technologies require a similar set of techniques, involving core preparation, rejuvenation, and face shaping. These include rejuvenating cores with core tablets, shaping of the lateral, and distal margins of core faces, preparation of core faces through cresting, debordante, and overshot flaking (procedural units 4, 5, 7, 8, 9). Most of those procedural units are shared with the PPNB assemblages of Kfar Hahoresh, which feature a complex method of producing blades on carefully prepared and rejuvenated bidirectional cores (Figure 5.5).

The addition of square-sectioned adze and blade technology in Polynesia results in slightly larger numbers of technological modes than the other Austronesian and Papuan assemblages. The median number of technological modes in Polynesia is 7, with a range of 6 to 10 modes. This falls within the range of variation in the global sample (median = 5, min = 2, max = 13). The rest of the Austronesian and Papuan sample has a median of 5 and ranges between 3 and 10 technological modes (Figure 5.6). Two technological modes: E1 (bifacial core tools) and E4 (celts) are found typically, only in Polynesia with one exception

In this set of assemblages, the only site with assemblage with bifacial core-tools that are encompassed under modes E1 and E4 are found at Su’ena, in the Solomon Islands, in the past millennium. The Su’ena adzes would not be confused with the quadrangular adzes common throughout Polynesia. Those at Su’ena tend to be much smaller (the largest sampled at Su’ena is 6.4 cm long, while Polynesian adzes tend to be at a minimum 10 cm long) (Leach & Witter, 1987; Walter & Green, 2011). They are also made of chert, and have only lenticular cross sections, never square (Walter & Green, 2011), which is typical of other adzes produced in Near Oceania (Green, 1971; Reepmeyer et al., 2021; Specht et al., 2014). Polynesian adzes are produced on fine grained basalts not available in the Solomon Islands, and while many are lenticular in cross section, trihedral and quadrangular cross sections are common (Green, 1971; Leach & Witter, 1987).

Among Austronesian and Papuan groups, there can be substantial within group variability. Across Lapita, Papuan, and post-Lapita Austronesian groups, assemblages tend to reflect a reliance on non-hierarchical core reduction meaning that most procedural units involving the preparation and rejuvenation of cores are absent. However, Papuan assemblages on the Willaumez peninsula show evidence of careful preparation of cores associated with the production of stemmed tools. Some were produced on kombewa flakes, and then hammer dressed, others were produced on prismatic blades from prepared cores (Araho et al., 2002; Torrence, 2011). In Lapita contexts of WKO013A, there is some evidence for rejuvenating cores through core tablets, platform abrasion, and burination, though those practices are not found in the other sampled Lapita sites.

The variability of assemblages across Oceania is harder to parse than in the case of the American Southwest. In the Southwest, assemblages were distinct from the outgroups, whereas in Oceania, some Polynesian assemblages appear to have more in common with Pre-Pottery Neolithic assemblages, than with either Lapita, Papuan, or other Austronesian assemblages. In the Southwest, there was relatively little between-group variability, and little within-group variability: most assemblages within the southwest were very similar to one another regardless of group affiliation. In Oceania, there appear to be stronger between group differences: there are many traits that distinguish Polynesian assemblages from other assemblages in Oceania. However, there is also more within group variability as well: Papuan assemblages can either involve only a few procedural units and modes involving pebble core reduction, and simple retouch or they can involve unusually complex methods of producing tanged tools, like on the Willaumez Peninsula, where a complex reduction sequence involving Kombewa flaking was used to produce stemmed tools until 3000 bp. Similarly, Post-Lapita Austronesian assemblages may have similarly simple pebble core reduction and a few other technological practices, or distinctive methods of producing small chert adzes, like at Su’ena.

Given the deep history of people within Oceania, and the diversity of ecologies people had adapted to, as well as the broader spatio-temporal scope of observation compared to the Southwest, it is not surprising that there is more variability. However, it is not clear if this greater variability puts us in a stronger position to trace migrations through lithic technology, as much of that variability appears to be within groups, in addition to between groups. The greater within group variability could swamp technological evidence of migration.

## Does technology reflect population history?

If lithic technologies do reflect population history in Oceania, then we might expect Polynesian assemblages to be more similar to Lapita, Papuan, and Post-Lapita Austronesian groups than they are to outgroups that were not involved in the expansion of Oceanic-Austronesian, like Tasmanian, Australian, and Californian assemblages.

In order to more carefully evaluate the degree of within and between-group variability across Oceania. I perform the same multi-dimensional scaling analysis as described in the previous chapter. I generated a pairwise Jaccard distance matrix between all assemblages in the sample. Jaccard distances are calculated as $1 - J(A, B) = |A \cap B| / |A \cup B|$, where A and B are the presence absence vectors for two separate archaeological assemblages. In this case the number of traits in both assemblages is divided by the number of possible traits realized in either assemblage, with the result subtracted from 1. Every assemblage in the sample's technological distance to every other assemblage was measured, and recorded. The result is a symmetric pairwise distance matrix.

This pairwise distance matrix is then treated as input for a non-metric multidimensional scaling analysis (NMDS), an ordination approach designed to characterize the relative distances between multivariate observations in two dimensions. The degree to which the two-dimensional relationships and true distances between groups differ is characterized in terms of a stress statistic. The higher the stress value, the poorer the two-dimensional representation of true between observation distances. Assemblages were divided into the same groups as described above, Polynesian, Post-Lapita

Austronesian, Lapita, Papuan, as well as outgroups: PPN, Global sample, Australia, Tasmania, and California Chumash.

I then tested for whether there were significant between group differences in lithic technology. The method taken here is a permutational multivariate analysis of variance test (PERMANOVA). PERMANOVA is a non-parametric method of assessing whether the distances between centroids for all groups are equivalent (Anderson, 2001). Rather than comparing variability to a reference distribution, the data themselves are permuted: individual assemblages are assigned to other groups, and distances from each site to the group centroids are assessed. I used the adonis() function in the R package vegan in this study (Oksanen et al., 2020). In order to evaluate which pairs of groups have more pronounced between group differences, I performed a post-hoc PERMANOVA test between each pair of archaeological groups using the pairwise.adonis package (Arbizu, 2021), and used a Bonferroni correction for the resulting p-values.

Given the population history of Oceania, and our focus on the population history that led to the development of Polynesians, the most important patterns within the NMDS space, as well as the PERMANOVA results and post-hoc tests, is the relative position of Polynesian assemblages to the other groups sampled. Thus, it is important to more closely assess whether the raw data reflect the lack of evidence for greater similarity between Polynesians and other Austronesians, relative to the outgroups. As a final check of the results for this section, I then compared distributions of pairwise distances between Polynesians to every other cultural group sample, to see if the raw similarities and dissimilarities between groups was congruent with the multidimensional scaling, and PERMANOVA findings.

### *Results: Weak evidence for technology reflecting population history in Oceania*

There is more within and between-group variability in Oceania, compared to the assemblages within the Southwest investigated in the previous chapter. Among both procedural units (Figure 5.7) and technological modes (Figure 5.8), the NMDS solutions have relatively higher stress (0.17 and 0.21 respectively) compared to the Southwest data (.09 and .16 respectively). This means that the relative positions of assemblages in the 2D space is slightly weaker reflection of their rank order distances between each-other than in the Southwest. Nonetheless, in contrast to the Southwest, there is also greater within group, and between group variability in Oceania. As we would expect from the results of the previous section, and from the broad spatio-temporal and ecological scale represented in this sample, Austronesian (Lapita, Post-Lapita, and Polynesian) and Papuan groups encompass a relatively wide area of the technological morphospace in both the procedural unit and technological mode dataset (Figure 5.7 and 5.8).

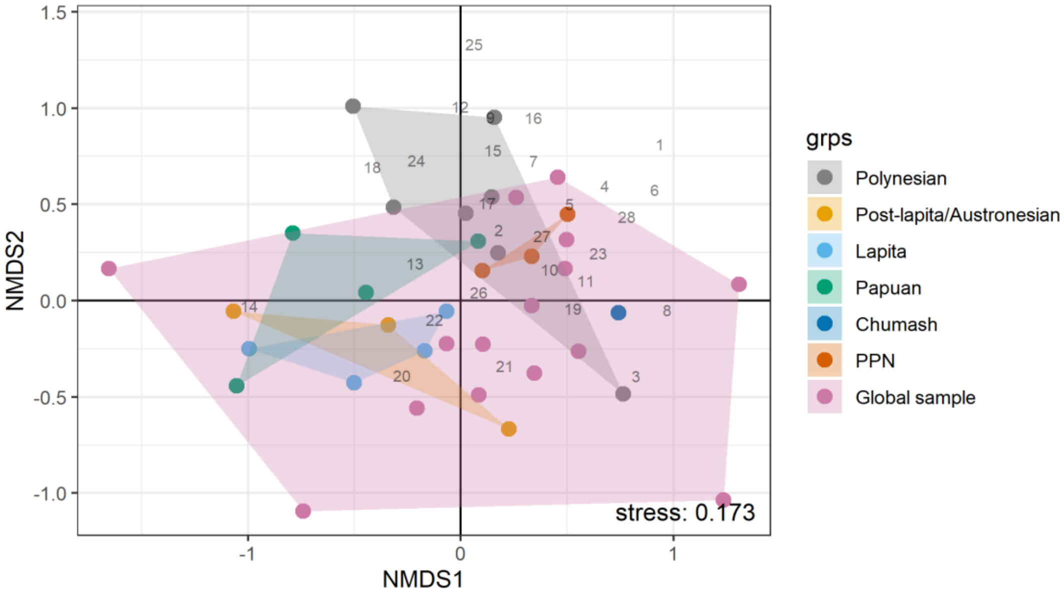


**Figure 5.7**: Non metric multidimensional scaling of presence/absence of procedural units. Each point represents one archaeological assemblage, and each is coded by color according to the culture group to which it belongs. Trait key: 1. Heat treatment, 2. Platform facetting, 3. Centripetal shaping, 4. Lateral shaping, 5. Distal shaping, 6. Back shaping, 7. Cresting, 8. Debordante shaping, 9. Overshot flaking, 10. Kombewa flaking, 11. Core tablet, 12. Abrasion, 13. Trimming platform overhang, 14. Use of an anvil, 15. Soft hammer percussion, 16. Indirect percussion, 17. Flaking through pressure, 18. Hammer dressing, 19. Invasive flaking, 21. Retouch, 22. Backing, 23. Notching, 24. Burination, 25. Tanging, 26. Tranchet, 27. Bifacial retouch, 28. Invasive retouch and 29. Pressure flaked retouch

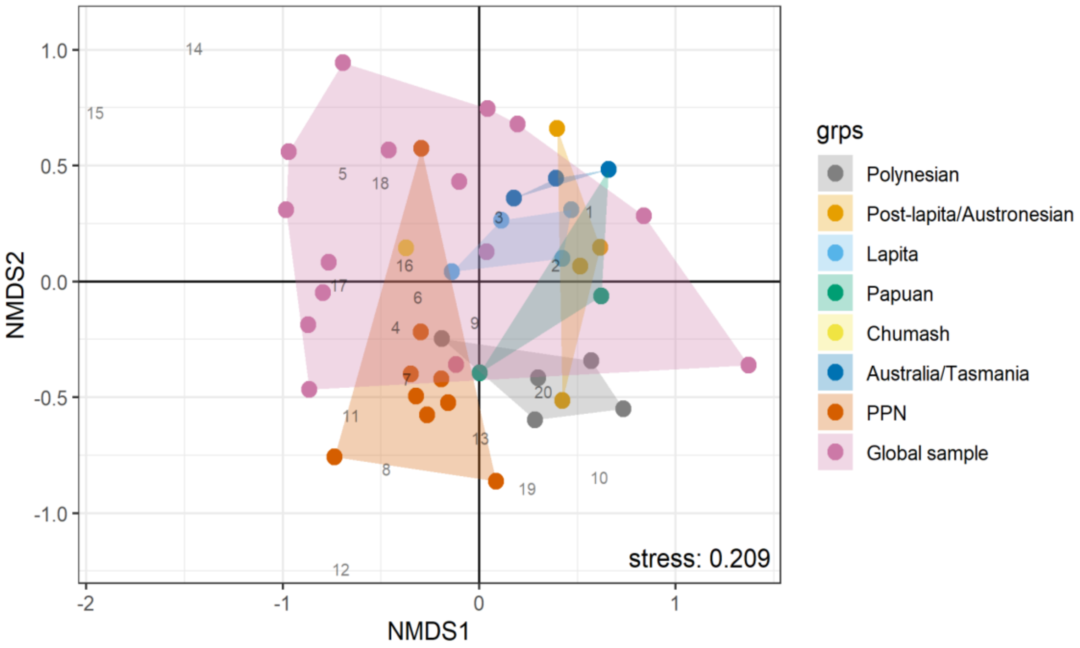


**Figure 5.6**: Non metric multidimensional scaling of presence/absence of technological modes. Each point represents one archaeological assemblage, and each is coded by color according to the culture group to which it belongs. Trait key: 1. B. Bipolar cores, 2. C. Pebble cores, 3. D1. Retouched pieces with acute edges, 4. D2. Backed pieces, 5. D3. Microliths, 6. D4. Burins, 7. D5. Points, 8. D6. Tanged piece, 9. D7. Core-on-flake, 10.E1. Large cutting tool, 11.E2. Thinned biface, 12.E3. Tanged biface, 13.E4. Celt, 14.F1. Preferential bifacial hierarchical core, 15.F2. Recurrent laminar bifacial hierarchical core, 16.F3. Radial centripetal bifacial hierarchical core, 17.G1. Platform unidirectional hierarchical core, 18.G2. Blade core, 19.G3. Microblade core and 21.I. Groundstone

However, as was the case in the Southwest, there is mixed evidence for the within and between group variability reflecting population history. Within the procedural unit and technological mode morphospaces, Papuan groups, Lapita, and Post-Lapita groups cluster relatively closely to one another. The high overlap between Papuan and Lapita/Post-Lapita groups is all broadly consistent with the Triple-I model of the development of the Lapita culture, which proposes it evolved through interactions between Asian Austronesian speakers, and local Papuan groups. It is also consistent with evidence for further gene flow of Papuan groups in Near Oceania, into the Bismarck archipelago and Remote Oceania during the later stages of the Lapita phenomenon.

In contrast to the pattern in Near and Remote Oceania, there is little overlap between the Polynesian technological mode and procedural unit inventories, and the inventories of the Papuan/Lapita datasets. Instead, Polynesian groups appear to cluster more closely with either the Pre-Pottery Neolithic outgroups, or the Chumash assemblage. This highlights the substantial technological changes that occurred between the initial occupation of Western Polynesia by Oceanic-Austronesian speakers, and the first expansions of people into East Polynesia. Polynesian sites are separated in the morphospace in large part because many of the traits associated with careful preparation of core tools are found in Polynesian assemblages, and are rare outside Polynesia.

Again, in this study, as well as in the prior study, the inclusion of the highly variable global sample could be serving to mask evidence for within and between group patterning in the Oceania data. To explore whether this is the case, I repeated the same multidimensional scaling analysis, but excluded the global random sample (Figures 5.9 and 5.10).

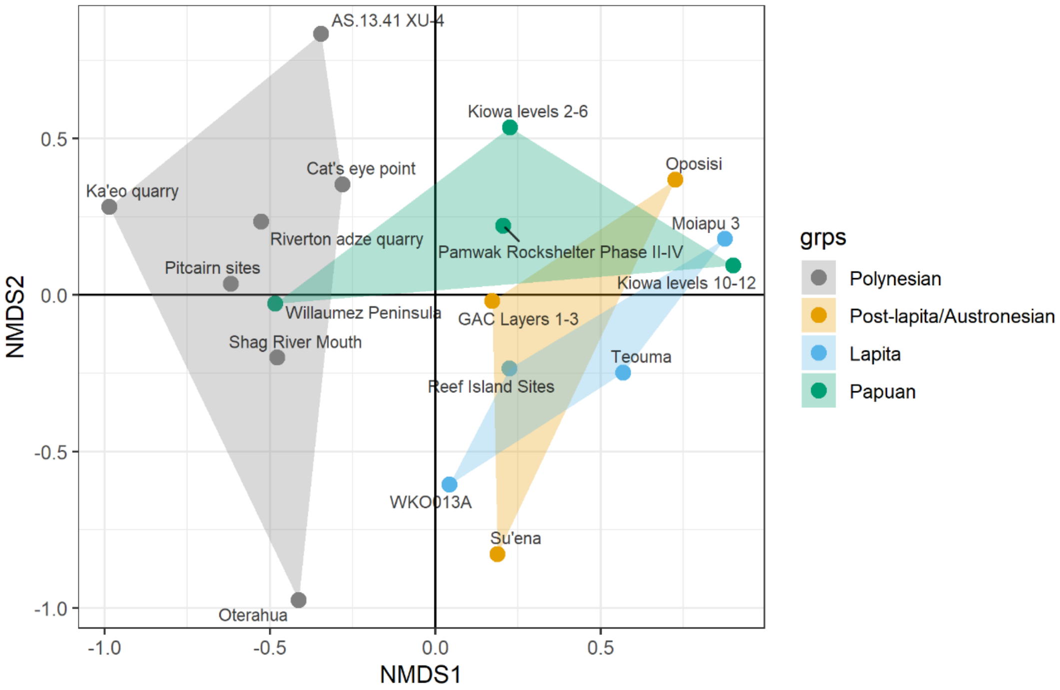


**Figure 5.9**: Non metric multidimensional scaling of presence/absence of procedural units. Each point represents one archaeological assemblage, and each is coded by color according to the culture group to which it belongs. The relative position of assemblages in the NMDS space is an approximation of their relative, rank order Jaccard distances to one another.

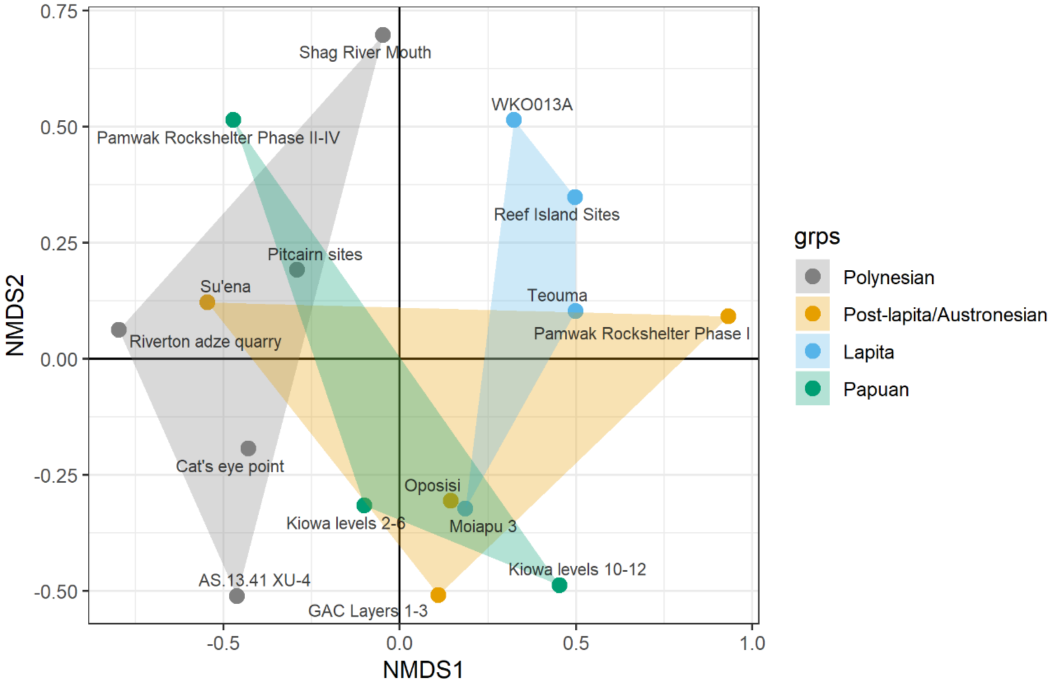


**Figure 5.10**: Non metric multidimensional scaling of presence/absence of technological modes. Each point represents one archaeological assemblage, and each is coded by color according to the culture group to which it belongs. The relative position of assemblages in the NMDS space is an approximation of their relative, rank order Jaccard distances to one another projected in only two of many possible dimensions.

When the global sample is excluded, it reveals conflicting patterns of technological overlap between the procedural unit and technological mode data. There remains a strong distinction between assemblages in Polynesia, and others in Oceania in terms of their procedural unit inventories. Only one assemblage, the Papuan assemblage of the Willaumez peninsula, has any overlap with the range of variability in Polynesia. That assemblage is made up of surface collections argued to date prior to the arrival of Austronesian speakers in the Bismarck archipelago, between about 6000 and 3000 bp. The technologies include large stemmed tools, often made on large, prepared core

Kombewa flakes, and then carefully retouched (Araho et al., 2002). This sequence is unusual in Near Oceania, as it relies heavily on a degree of core preparation, and retouch of flakes, that is uncommon elsewhere in the region during the Holocene. Those additional practices involving core preparation and various methods of retouch, bring the assemblage closer to the range of variation seen among Polynesian assemblages, among which careful core shaping is more common (Figure 5.10).

With the exclusion of the global sample, there is more overlap between Polynesian groups and other groups in Oceania in terms of their technological mode inventories. The presence of flaked chert adzes at Su'ena, in the Solomon Islands, brings the post-Lapita Austronesian distribution into overlap with the Polynesian distribution. Also there remains some near overlap between the highly variable Papuan sample, and the Polynesian sample. Though, there is also a Papuan assemblage, Kiowa levels 10-12, that overlaps with the Tasmania/Australia distribution. Even more so than in procedural unit data, the Lapita assemblages are distinct from the Polynesian and also from the Papuan and Post-Lapita assemblages. Lapita assemblages, in terms of their modes, appear more similar to terminal Pleistocene sites in Tasmania and Australia.

**Table 5.3**: Permanova post-hoc tests among procedural units

| Treatment | $R^2$ | P-value | Adjusted P-value |
|---|---|---|---|
| Polynesian vs Post-lapita/Austronesian | 0.20 | 0.033 | 0.198 |
| **Polynesian vs Lapita** | **0.28** | **0.003** | **0.019** |

| Treatment | $R^2$ | P-value | Adjusted P-value |
|---|---|---|---|
| Polynesian vs Papuan | 0.17 | 0.046 | 0.276 |
| Post-lapita/Austronesian vs Lapita | 0.07 | 0.943 | 1.000 |
| Post-lapita/Austronesian vs Papuan | 0.06 | 0.971 | 1.000 |
| Lapita vs Papuan | 0.14 | 0.420 | 1.000 |

**Table 5.4**: Permanova post-hoc tests among technological modes

| Treatment | $R^2$ | P-value | Adjusted P-value |
|---|---|---|---|
| Polynesian vs Post-lapita/Austronesian | 0.23 | 0.075 | 0.448 |
| Polynesian vs Lapita | 0.39 | 0.018 | 0.105 |
| Polynesian vs Papuan | 0.27 | 0.088 | 0.530 |
| Post-lapita/Austronesian vs Lapita | 0.24 | 0.116 | 0.694 |
| Post-lapita/Austronesian vs Papuan | 0.07 | 0.943 | 1.000 |
| Lapita vs Papuan | 0.32 | 0.114 | 0.686 |

There are statistically significant differences between archaeological groups in both the procedural unit and technological mode data (PERMANOVA p-value <.001 for both data types). The $R^2$ value is also relatively high suggesting that group membership explains moderate amounts of variability (procedural unit $R^2$: 0.26, technological mode $R^2$: 0.35). Post-hoc tests, however, show mixed evidence for patterning between groups reflecting history (Tables 5.3 and 5.4). Within Oceania, the only pairwise comparisons that resulted in a statistically significant difference were Polynesian and Lapita groups in their procedural unit inventories. The lack of strong statistical evidence for differences between groups within near and Remote Oceania, slight evidence for distinctiveness of Polynesians from those groups in Near and Remote Oceania, is again consistent with Papuan, Lapita, and Post-Lapita Austronesian speakers having a shared historical connection reflected in the lithic technology of that region. However, it is also consistent with Polynesian groups having undergone shifts in technology that may have erased reliable evidence of common history with Oceanic groups outside Polynesia.

Finally, the raw pairwise distances between assemblages also show mixed evidence for retaining evidence of migration history, while also further illustrating the distinctiveness of assemblages in Polynesia relative to other sites in Oceania, and the similarity between Polynesian sites, and the outgroups. If we focus only on the technological distances within and between Polynesian assemblages and the other groups in the raw distance data, then the same broad pattern is found. Here, each assemblage made by Polynesian groups was compared to each assemblage of each of the other culture groups. The result is one distribution of distances for each set of pairwise comparison between assemblages made by Polynesians, and assemblages made by the other groups.

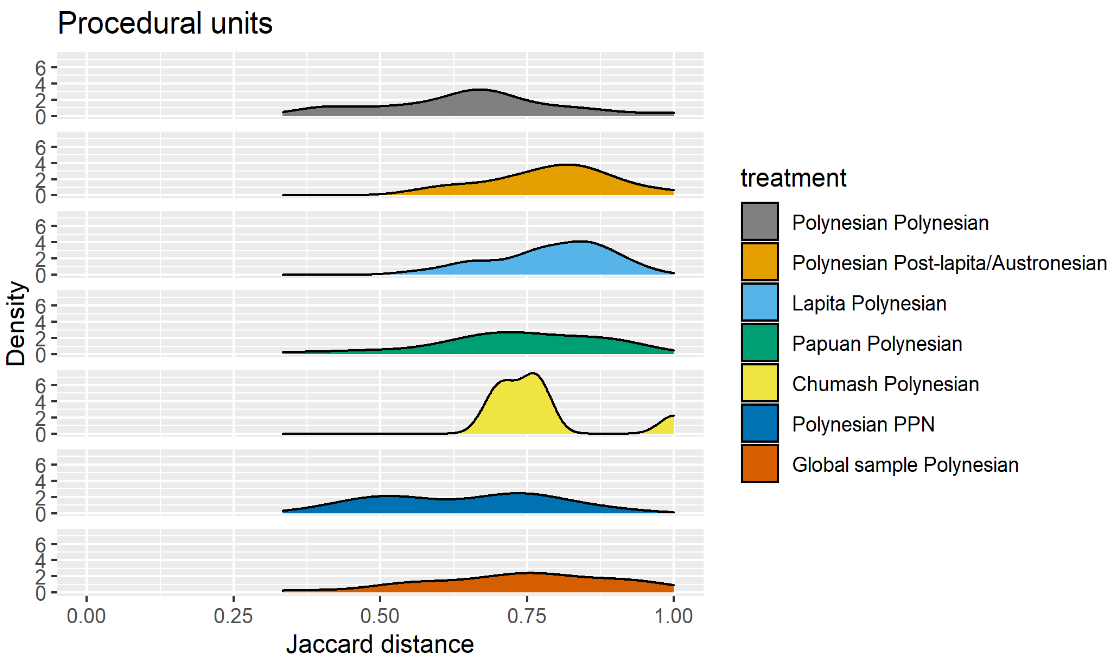


**Figure 5.11**: Pairwise Jaccard distances between assemblages characterized in terms of presence or absence of procedural units between the focal group, Polynesian assemblages and six other groups. The archaeological groups are ordered from top to bottom in rough order of increasingly distant cultural relatedness. The top row in black is the distribution of pairwise Jaccard distances between all Polynesian assemblages in Near Oceania, with no self comparisons. In the second row from the top, the distribution represents Jaccard distances for all pairwise comparisons between Austronesian and Polynesian assemblages. The second the bottom row represents comparisons between all Austronesian assemblages to the outgroup: Pre-Pottery Neolithic assemblages.

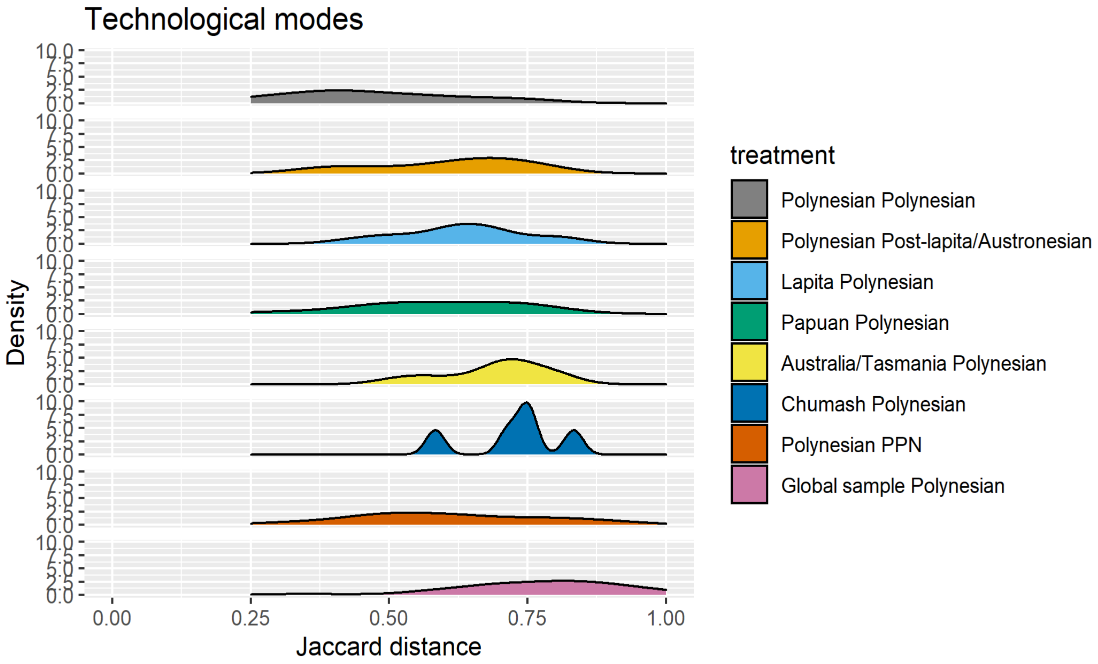


**Figure 5.12**: Pairwise Jaccard distances between assemblages characterized in terms of presence or absence of technological modes between the focal group, Polynesian assemblages and seven other groups. The archaeological groups are ordered from top to bottom in rough order of increasingly distant cultural relatedness. The top row in black is the distribution of pairwise Jaccard distances between all Polynesian assemblages in Near Oceania, with no self comparisons. In the second row from the top, the distribution represents Jaccard distances for all pairwise comparisons between Austronesian and Polynesian assemblages. The second the bottom row represents comparisons between all Austronesian assemblages to the outgroup: Pre-Pottery Neolithic assemblages.

For the procedural unit data, Polynesian assemblages tend to have a relatively high Jaccard distance to one another, greater than .6 (Figure 5.11). That is higher than the between assemblage distances within the Ancestral Puebloan groups in the American Southwest. Furthermore, the distances between Polynesian assemblages, and other Oceanic-Austronesian, Papuan, or Lapita assemblages tends to be high, above .75. This is around the mean value of all pairwise Jaccard distances in the global sample discussed in chapter 2. This means that the degree of technological difference between Polynesian assemblages, and assemblages elsewhere in Near and Remote Oceania made by closely related peoples, is what we might expect if we were comparing randomly drawn assemblages from the global record. The pattern is similar in the technological mode data. Polynesian assemblages tend to be similar to one another, and more different from Post-Lapita/Austronesian, Lapita, and Papuan groups than they are to some outgroups, like the Pre-Pottery Neolithic assemblages (Figure 5.12).

The above results highlight how coherent the Polynesian assemblages are historically, but also highlight how rapid change within the lineage that led to Polynesians resulted in technologies often more similar to those made by unrelated Neolithic groups than the ancestors of Polynesians. This is not consistent with lithic technology being able to reliably retain evidence of migration at the broader, thousand year scale explored in this study. However, the coherence of the Polynesian assemblages may indicate that at the scale of a few hundred years, historical signal of migration could be retained. This is why assemblages on the opposite side of the Polynesian triangle share many of the same technological attributes. The reasons for this mixed evidence of lithic technology retaining evidence of history could be similar to those described in the previous chapter. Lithic technology, in contrast to other traits useful for historical inference, may be limited in that they have to meet certain kinds of functions, and different groups are able to achieve designs that meet those functions independently of one another. Or, they may readily be able to modify their technologies to meet new needs in such a way that we are unlikely to see in systems like language, or in other kinds of material culture.

Nonetheless, the above analyses do not fully take into account dependencies between history, and technological variation. As described in the prior chapter, PERMANOVA assumes that the data do not have a historical structure. In the final analysis below, I again perform an evolutionary network analysis to explore whether historical reconstructions based on technological variability reflect the known population history of Oceania.

## Do historical reconstructions based on lithic data reflect population history?

In this section I explore the congruence between historical reconstructions based on lithic data, and the true population history by using the same evolutionary network techniques described in chapter 3. Phylogenetic statistical techniques explicitly include features that incorporate and help explain how history may contribute to observed patterns, instead of most statistical techniques that will tend to assume groups vary independently of one another, without any sort of historical process structuring within and between group variability.

I again use the agglomerative Neighbor-Joining algorithm, Neighbornet, to produce splits-networks illustrating the reconstructed evolutionary relationships between observations. For more detail, see the prior chapter. The most important feature of splits-graphs for the purposes of this study is extent to which a splits-graph is more or less consistent with there being strongly differentiated evolutionary groups with divergent histories. Splits-networks that have long edges, and broad separation between groups, while also featuring members within groups clustering tightly together, are more consistent with there being a strong historical patterning in the data.

We might expect a similar pattern in the technological data: Polynesian assemblages clustering tightly with one another, and perhaps more variability outside Polynesia, given the deeper and more complex population history of that region. Nonetheless, given the shared history between Polynesian and other Austronesian and Papuan groups in Oceania, we might expect Polynesians to be closer to those groups than they are to outgroups who share no history at all with the Austronesian speakers.

Using the program splitstree (Version 5.0), I again broke the procedural unit and technological mode data into FASTA format files, and processed each in splitstree. Similarities between trait inventories were measured using the Jaccard method, I used the Neighbor Net methods of generating proposed historical relationships between inventories. The generation of splits follows the method proposed by Dress and Hudson (2004) and the weighing of splits was performed following the 2004 implementation of the program.

### *Results: Evolutionary networks show mixed support for historical signal of Austronesian and Polynesian expansion.*

In the prior chapter, we found consistent separation between the ingroups (farmers in the American Southwest) and the outgroups (Pre-Pottery Neolithic groups). Such a clear separation is not present in either the procedural unit or technological mode data. The evolutionary network generated for the procedural unit data shows little clear separation between the PPN assemblage outgroups, and the ingroups, namely the Willaumez Peninsula assemblages, and all of the Polynesian assemblages. Furthermore, the Chumash outgroup: Eel Point, falls in closely with both post-Lapita, Oceanic-Austronesian speakers in the Solomon Islands, as well as blade-making people on the South Island of New Zealand, at Oterahua blade quarry (Figure 5.13). There is slightly more evidence for a coherent Pre-Pottery Neolithic historical cluster in the technological mode data, however that cluster is also not widely separated from the ingroups (Figure 5.14).

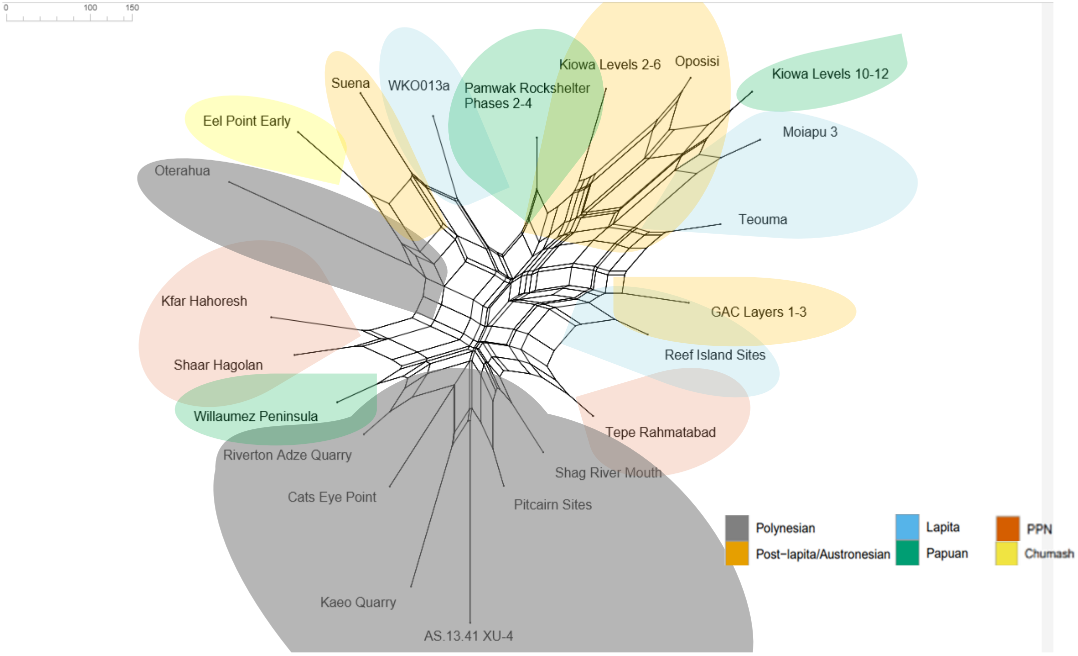


**Figure 5.13**: Splits-network graph illustrating the proposed historical relationships between Polynesian, post-Lapita/Oceanic-Austronesian, Lapita, Papuan, PPNA, and Chumash assemblages. This reconstruction is based on the procedural unit data.

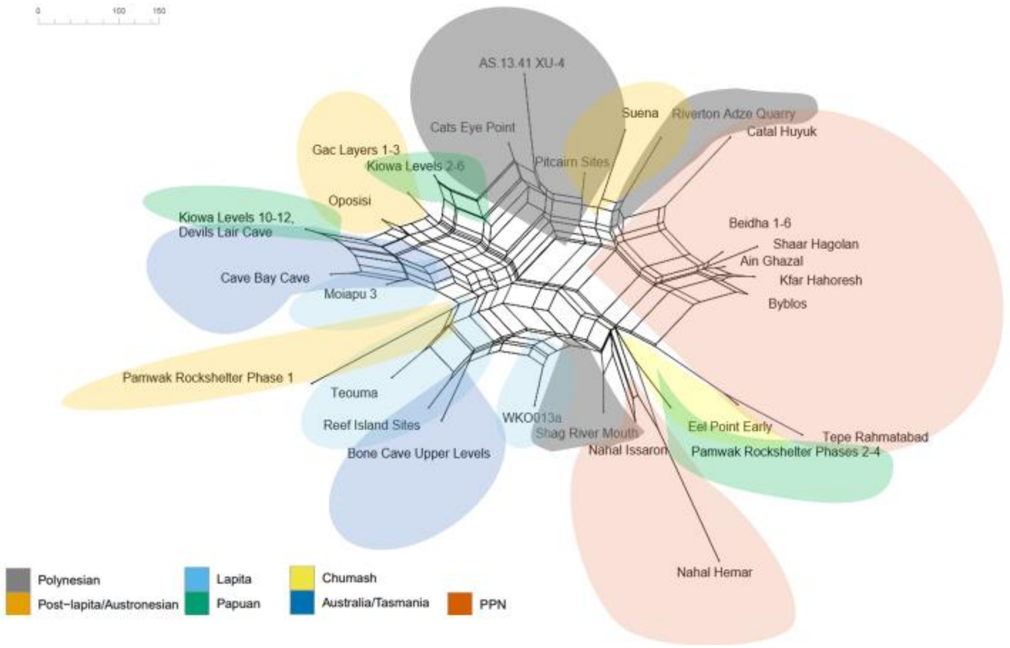


**Figure 5.14**: Splits-network graph illustrating the proposed historical relationships between Polynesian, post-Lapita/Oceanic-Austronesian, Lapita, Papuan, Australian/Tasmanian, Pre-Pottery Neolithic, and Chumash assemblages. This reconstruction is based on the technological mode data.

In both splits-net figures, there is not a strong pattern reflecting the population history in Oceania. Assemblages made by Polynesians, sometimes are closely associated with Papuan groups who lived before Austronesians arrived. Sometimes Lapita group made technologies that cluster them in with Australian and Tasmanian terminal Pleistocene groups, or sometimes they are more closely associated with the kinds of assemblages we would expect from Papuan and post-Lapita Austronesian speakers. Unlike the neighornet example illustrated in the prior chapter, which highlighted the long branches separating tightly organized groups, like East Polynesians, from other Austronesian speakers, these splits networks are more web-like, meaning that the average splits length is relatively short. This means that groups are not strongly differentiated from one another, meaning that there is broad uncertainty about the true historical relationship based only on lithic technology.

## Discussion

Compared to the pattern in the American Southwest, there is greater within and between group variability in lithic technology in Oceania. People who belonged to the same Oceanic-Branch of Austronesian explored a relatively large amount of the technological morphospace comparable to the breadth of the space sampled in the 15 random outgroups selected. A throughline across Melanesia and Polynesia is the reliance on adze technologies. However, across different islands, Oceanic-Austronesian speakers developed distinct technological practices. In some areas they made blades, microliths in others, others relied on simple non-hierarchical cores.

The variability across assemblages is consistent with both the complex population history of the region, as well as the diverse kinds of environments, and circumstances people faced in Oceania. That this amount of variability had developed in a relatively short window of time, over the past ~3500 years, highlights how quickly human populations can shift their technologies to suit new circumstances. The blade technologies of the South Island of New Zealand, for example, were developed very quickly after the Island was first colonized, and were traded out for other techniques within a few generations. However, it also highlights the greater timescale of cultural divergence and interaction within Oceania relative to the Southwest.

We might have expected that the greater variability in technology in Oceania would place us in a stronger position to detect strong historical signal. One of the issues in identifying population processes in the Southwest through lithic technology is the shared history of all groups in the Southwest, and the low degree of between group variation in lithic technology. However, the changes in technology that happened in Polynesia place Polynesians relatively far in the technological morphospace from other Oceanic-Austronesian speakers, including populations that either were, or were closely related to their ancestors. Here, the results are most consistent with rapid technological change in Polynesia eroding evidence for common history. Polynesian sites are often more similar to outgroups than they are to assemblages produced by people closely related to their ancestors.

While Oceania has the benefit of a broader spatio-temporal scale of analysis, its main drawback is that the fine-grained details of population movements and interactions are not as well resolved as in the case of the Ancestral Puebloan migration in the Southwest. As such, it could be that the technological discontinuity between the first groups in West Polynesia, and later East Polynesians, could be driven by the arrival of other groups who introduced distinctive ways of making stone tools. This would not be consistent with the Lapita only model, but could be consistent with the Micronesian Triple-I model (Addison & Matisoo-Smith, 2010). This scenario does have problems. It is not clear that the lithic technology of Central or East Micronesia is any more similar to Polynesian technologies than other Lapita or post Lapita Oceanic Austronesians in Near or Remote Oceania. If we assume the Polynesian triple-I model is correct, then the rate of change from the earliest colonization of West Polynesia, compared to later Polynesian assemblages, could be explained in part by technological discontinuity, and the arrival of groups with distinct technologies from Micronesia. However, we understand too little about lithic variability in Micronesia to assess this possibility any further. These results may always be assessed later again, if the best supported population model shifts.

The results of the Oceania study, taken altogether with the American Southwest case study, and the results of the study on global variability in technology, highlighted the potential for historical signal in lithic technology in some ways. There is broad capacity for between group variability in procedural units and modes, and many different kinds of practices are possible. There is also real between group patterning that appears consistent with population history at some level. Sites in the American Southwest, for example, are distinct from other assemblages drawn from the global record, and assemblages made by Oceanic-Austronesian speakers in Near and Remote Oceania, as well as Papuan groups, have broad overlap as we might expect assuming the Lapita Triple-I model is correct. However, I showed we are unable to detect migrations using lithic technology alone.

One possible explanation was that we might be able to detect population expansions and migrations at broader spatio-temporal scales, where we are comparing not just people within the same language family, within an interacting meta-population, but at a much broader scale, where we have both closely related groups, but also groups who belong to distinct language families, and are historically more separated. I proposed that at this broader spatio-temporal scale, we might be better able to detect migrations using lithic technologies. However, the results of this chapter highlight that when people move into new areas, they are liable to quickly adapt their technologies to new circumstances, resulting in their now being much less like their ancestors than they might be to other, unrelated groups of people. In Oceania, rapid technological change likely eroded evidence for common history between groups in Polynesia, and others in Oceania.

These results highlight the usefulness of systematically measuring lithic variability at multiple scales, from the global and million-year scale, to the scale of particular regions where we know the population and linguistic history *a priori*.

## CHAPTER 6: SUMMARY AND DISCUSSION

This project investigated the timing of the evolution of cumulative culture in the hominin lineage, the potential of lithic technology to retain history, and whether or not technologies reflect population histories in the Late Holocene. This meta-analysis of behavioral variation spans multiple scales, from the very narrow: the scale of a few generations, and hundreds of kilometers in the American Southwest, to a global, and million year scale encompassing the archaeological record.  This approach follows the path of preceding macro-scale approaches to studying the archaeological record (Perreault 2019, Režek et al. 2018), but also includes carefully tailored case studies, and points of reference whose selection stemmed from clearly defined theory. These include the technologies of non-human primates, the results of randomized flintknapping experiments, and the spatio-temporal variability observed across phoneme inventories. Those points of reference help to give the global scale, and million year patterns a clearer interpretation. Without comparisons to language, for example, it is unclear how strong spatio-temporal isolation-by-distance is in lithic technology. Similarly, without comparisons to experimentally produced assemblages, or the technologies of non-human primates, it is unclear how to interpret the complexity of early hominin technologies. They help to answer the question: “is five procedural units a lot”?   The results of this project help to provide a stronger understanding for how our species’ cultural abilities evolved, and how stone tool traditions evolve.

As outlined in Chapter 1, hominins over the past 3 million years explored more and more of the space of possibilities in lithic technology, and by the early Acheulean, were relying on recipes with more procedural units than what we observe in chimpanzee tool-making practices, and more than we would expect to be discovered through randomly flaking cores. This result, along with other lines of evidence, suggests that technological traditions that may meet the extended definition of cumulative culture outlined by Mesoudi and Thornton (2018) may have existed by ~2mya, which suggests selection for the traits that enable cumulative culture was likely ongoing prior to that date. However, it is not until later when we begin to see hominins within the range of technological complexity observed among Pleistocene modern humans. Neanderthals, and Pleistocene modern humans both have similar degrees of technological complexity, suggesting a shared capacity for cumulative culture. This suggests that a modern-human like capacity for cumulative culture was present in the last common ancestor between modern humans and Neanderthals.

Finally, I investigated whether there was strong evidence for a single shift at some point in hominin evolution from slow, to rapid technological accumulation that we might expect to have occurred if some hominin species had evolved a qualitatively distinct ability to transmit and accumulate increasingly complex cultural information. An estimate like this is likely sensitive to various sources of error, and taphonomic biases. When I took those into account using a paired simulation and Bayesian analysis approach, I found that while a shift towards rapid accumulation likely happened in the length of recipes, it likely did not happen in the number of technological recipes, and furthermore, there is widespread uncertainty about when such a shift may have occurred. Nonetheless, the best supported dates are still in the past 1 my. All of these lines of evidence suggest that the various traits that likely enabled hominins to transmit, modify, and accumulate technological behaviors more effectively were evolving early in hominin evolution, though something like the more derived condition of modern humans was not attained until the past million years.

As outlined in chapter 2, there are statistical properties of cultural traits that we can measure that will inform us about whether they are able to retain strong evidence of history or not. To put simply, there needs to be strong potential for between group variability. That is a condition met in human languages, which do retain evidence of history. I compared two basic properties of technological mode and procedural unit inventories to the same statistical properties in the PHOIBLE 2.0 phoneme inventory database, and found that there was evidence for similarity in both the frequency of convergence between the technological and linguistic dataset, as well as evidence for similarity in the strength of isolation-by-distance between the technological and linguistic datasets.  These and other lines of evidence suggest that hominins explored a technological morphospace that was vast, and there were few instances of any two groups developing the same kinds of technological behaviors, and those that did tended to be close in space and time. This tells us something about the potential for technology to retain evidence of history. If lithic technologies vary more as a result of historical contingency than as an adaptive behavior mapping onto the optimal behaviors in particular environments, then we might expect them to retain strong evidence of history simply because there is the kind of between group variability possible for that evidence to be retained. The results of this chapter, however, only outline the potential for historical signal. While this is important, it does not directly assess whether lithic technologies do retain evidence of common history. That is assessed in chapters three and four by measuring technological variability in records where we know the population history *a priori*.

In Chapter 3, I focused on measuring technological change among Ancestral Puebloan groups prior to the depopulation of the Colorado Plateau, and both Ancestral Puebloan migrant groups and Hohokam groups in Central and Southern Arizona. The spatio-temporal scale of this study is relatively narrow, a few generations across a few hundred kilometers between two arid environments, the Sonoran Desert, and the Colorado Plateau. In Chapter 4, I broadened the spatio-temporal scale to thousands of years and kilometers to sample assemblages relating to the Austronesian expansion across Oceania. In both cases, I measured within and between group variation among related groups and compared them to unrelated outgroups. In both case studies, I found a lack of support for technologies reflecting the known population history.

The similarity between spatio-temporal variation in language, and technology, which suggested potential for historical signal, and the lack of historical signal in lithic technology relating to the migration histories of the Southwest and Oceania, may tell us something about the nature of stone tool-making traditions. It seems suggest that technological traditions either react closely to the needs of particular environments, or they are evolutionary entities vary above the scale of the kinds of culture-historical units anthropologists tend to identify using lines of evidence like pottery, language families.

Despite some evidence that lithic technologies might have some potential to retain strong evidence of history outlined in chapter 2, there is little strong evidence for the technology reflecting the known population history

*Future projects*

The main product of the project is a dataset consisting of the presence or absence of different technological traits spanning the earliest archaeological record through the Late Holocene. Most of the data were collected from the literature via coding published descriptions of assemblages. While the codebook was designed to reduce error, and ensure reproducibility, and follows practiced developed at the Center for Disease Control for coding interview transcripts (Macqueen et al. 1999), it remains to be seen whether this particular codebook design achieves those goals. One of the novel features of the codebook is that it includes explicit exclusionary criteria. This is not just information needed to code something as present, but also explicit inner and outer bounds of the kinds of information that is or is not sufficient to code something as present. These additional features help outline the precise contours of each code, and helps to reduce at least some ambiguity in the coding process. However, it is not necessarily clear whether the addition of this feature will reduce within and between coder error. In the future, this should be evaluated by asking small groups of coders to code stone tool reports with a codebook that includes the definition of codes only, and one where both the definitions as well as inner and outer bounds of the kinds of information that meets the definition are represented. A study like this would help also to identify the degree of error we should expect when stone tool reports are coded, and may also highlight particular kinds of technological practices, or ways of describing those practices in the literature, that are more prone to being misunderstood. The result of this study could then be used to parameterize models, similar to the one employed in Chapter 2, to investigate how sensitive some technological pattern might be to the observed degree of coder error.

A theme common throughout the dissertation is the importance of rates of technological change. We can use them to say something about hominin cultural abilities, and they are important in assessing whether there is likely to be evidence of shared history visible in lithic technology. The global database should be useful in more carefully measuring rates of technological change across many regional contexts. Such a study could assess whether rates of change tend to be different as a function of latitude, species membership, or other environmental factors. Many of the archaeological assemblages coded for this project come from deeply stratified tells, and rockshelters, or from regions with a high density of sites spanning thousands of years, mainly in East Africa, the Southern Levant, Western Europe, and East Asia. These contexts should allow for us to measure the rates of technological change at multiple temporal scales, from the generational, to the scale of marine isotope stages. A study like this could help to further explore some of the themes explored in the first chapter: when do hominins begin exploring particularly fast rates of technological change? Are there between species differences in rates? Are rates tied to latitude, or other ecological factors, or is the connection weak? Do farmers change their technologies faster than hunter-gatherers? By answering these questions, we will gain a stronger understanding of the role technology plays in human adaptation.

Finally future studies should also more carefully assess how the nature of assemblages as palimpsests, and as potentially representing only narrow ranges of hominin land use, is likely to cause us to come to the wrong conclusions about processes in the past. For example, the number of technological behaviors we are likely to find at a short-term campsite, as opposed to a quarry site is likely to be different, even if the same cultural group is being sampled (Binford 1979). Assemblages where the initial stages of reduction happened elsewhere might not have strong evidence for core shaping, which could skew our perception of how this assemblage differs from others. To address this, we could focus on assemblages where we are able to measure the amount of the reduction sequence that is represented in the assemblage using the cortex ratio method (Lin et al. 2015, Douglas et al. 2008, Dibble et al. 2005). Here, we estimate the total volume of the lithic assemblage, the total surface area, the total surface area covered with cortex. Those empirical observations can then be compared to a modelled or hypothetical amount of volume and cortical cover we would expect to be present if nodules were reduced only on site and not elsewhere (Lin et al. 2015, Douglas et al. 2008, Dibble et al. 2005). By investigation he relationships between technological richness, and the cortex ratio across many sites, we can come to a stronger understanding of how much of our perception of technological variability could be accounted for by variation in where and when tools were made and rejuvenated.

Another issue with assemblages representing accumulations, is that they could represent many generations of human behavior, possibly representing completely different cultural groups, lumped together into one analytical unit. In this case, we may come to overestimate the technological richness of a human “group” based on assemblage composition. One way to assess how this could skew our perception of technological change would be to focus on assemblages, or archaeological sequences where we have rich knowledge about rates of sedimentation, and a strong chronological model. With these records, we could model the relationship between technological richness, the number of artifacts recovered, and the number of generations that contributed to a given assemblage.

The above studies, especially the ones that attempt to measure how different kinds of biases inherent in the record will skew our perception of technological change, will help us come to a stronger understanding of how lithic technologies evolve, and how they relate to the evolution of the genus *homo*.

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# APPENDIX I

# A CODEBOOK FOR COLLECTING PROCEDURAL UNIT DATA FROM THE LITERATURE

I made this codebook while working on ways of quantifying variation in tool-making sequences across the archaeological record. In this case the unit of analysis is the technique, or procedural unit (Maloney, 2019; Perreault et al., 2013). I coded procedural units as present or absent across archaeological assemblages, based on published reports describing those assemblages. Most systematic, comparative work on lithic technology has focused on units of analysis that are more consistent, and replicable across assemblages. For example flake and biface measurements, and shape variation can be very consistent between studies. Other aspects of lithic technology, like c*haînes opératoire* or reduction sequences that we are interested in, are not as easy to analyze statistically. Similarity and dissimilarity in them is difficult to quantify systematically because they represent qualitative data conveyed through prose descriptions, tables of artifact counts, and illustrations of individual artifacts and schematics of those sequences. How sequences are reported might vary by the research tradition of the analyst, and how I interpret those reports is also shaped by the tradition I am a part of. This is a big hurdle to making systematic comparisons of technology across many assemblages (Reynolds, 2018).

Reliably extracting the presence or absence of procedural units from the complex descriptions of stone tool technologies is a similar problem to that faced by scientists who code interview transcripts, and other texts. There are limits to human abilities to make sense of complex information, and individual scientists may use their own heuristics, and prior experience to collapse and make sense of that information. Those heuristics, and mental shortcuts introduce bias and error into the analysis (Hruschka et al., 2004;

MacQueen et al., 1998; Tversky & Kahneman, 1974). One way to reduce this error is to give clear definitions of each procedural unit. But, this is not enough. If I gave a careful definition of the procedural unit “core tablet“, there may be many forms that could be accomodated into that definition that I do not know exist, and cannot anticipate. Likewise, other researchers may have different standards by which they would count a“ core tablet“ as being present in an assemblage. Some may be happy to find flakes that have the features of a core tablet, and count them as a core tablet. Others may only count flakes with those features if there are also cores with negative removals consistent with core tablet removals. Others may have very different ideas of what the features of a core tablet are. The problem with using only definitions, is that it does not give enough guidance on what forms do *not* meet that definition, and when we should code “core tablet“ as present. Social scientists at the Center for Disease Control encountered similar problems while coding interview transcripts and other texts for qualitative analysis. Their solution was to develop codebooks with excplicit inclusion, and exclusion criteria.

This codebook follows a format developed at the CDC to ensure reliability in coding texts (MacQueen et al., 1998). Each procedural unit has a short, and longer definition (if needed). Additionally, each also has inclusion criteria. These inclusion criteria describe what features need to be present in a report for us to count the procedural unit as present. Each also has exclusion criteria. These describe what features in the text would be grounds to count the procedural unit as absent. For example, many procedural units only make sense to count as present if hierarchical core reduction is present. So, one exclusion criteria for those procedural units would be the absence of any evidence for hierarchical core reduction.  Each entry may also include typical, and atypical examples of the procedural unit. These may be illustrations, or text examples. These two help to further outline when it is appropriate to code a procedural unit as present. Finally, there is a “close, but no“ entry, which outlines what kinds of cases might be confused with the procedural unit. Some of these inclusion criteria are more exhaustive than others, especially in cases where I noticed that I came to different conclusions about how a procedural unit should be coded multiple times while double checking data.

Whether or not you agree with all the definitions, and coding criteria, you should be able to come very close to the same conclusions about how to code the presence or absence of any of these procedural units if you follow the standards outlined in the codebook. The codebook should evolve over time, as new logical inconsistencies or points of confusion are discovered. However, whatever version was used to code the data that then ends up in a final analysis, should be archived and made available to readers. Version 1.0 was used for my dissertation work. This version of the codebook does not have example illustrations for procedural units to avoid copyright issues, but references to the illustrations are retained.

Definitions:

Hierarchical cores.

Cores with platforms established to strike flakes that shape the main flaking surface of a core, or the main platform itself in preparation for removals across the main flaking surface.

Main flaking axis.

On hierarchical cores, this is the axis parallel to the face along which most target pieces were produced. On a naviform core, for example, the main flaking axis is that along which bidirectional blades are taken. Radial cores have no main flaking axis. Centripetal levallois cores also have no main falking axis, while preferential levallois cores do.

Main flaking surface.

On hierarchical cores, this is the surface from which targetted blanks were removed.

Core platform.

Any of the edges percussed or applied with pressure to remove flakes.

Main core platform(s)

The platforms used to produce target pieces. Blade platforms on blade cores. Facetted platform on a preferential levallois.

Core back

Posterior surface relative to the main flaking surface, roughly parallel to the main flaking surface.

Core bottom

Distal surface of a core, opposite the main core platform.

Code Title: Raw material treatment

**Short Description:** Heat treatment of raw material

**Definition**: Heating of raw material in order to improve workability. This process alters the fracture mechanics of raw material, and often causes changes in texture, and color.

**Inclusion criteria**: If heat treatment is described as present, code as yes. If heating is described, and reference made to glassy/glossy texture of raw material as a result of heating, code as present.

**Exclusion criteria**: Heat treatment not mentioned in text.

**Typical exemplars**: “Flint was/was likely heat treated”

**Atypical exemplars**: “flint was glossed/waxy/greasy from heating”

**Close but no**: “material was fired”, “material bears signs of thermal alteration”, Images of pieces that appear to have been heat treated, but without accompanying text describing them as heat treated. “Some flints had a glossy/waxy/greasy appearance”.

Code Title: Faceting of core platform

**Short Description:** Shaping of a core platform by striking flakes into the platform from the face of the core.

**Definition**: Removal of two or more flakes struck into the face of a core across the platform, forming a platform with two or more parallel facets.

**Inclusion criteria**: Include in cases only where hierarchical core reduction is described. Code if facetting of platforms is described in the text as a method of preparing platforms. Code if illustrations show evidence of faceting.

**Exclusion criteria**: Determining presence based on illustrations alone requires illustrations of the platforms themselves. Inferring platform faceting from dorsal or ventral views of a flake are inappropriate. Do not code if no mention of faceting of platforms.  Do not code if no other evidence of hierarchical core reduction described. Do not code if the flakes were likely not struck into the face of the core

**Typical exemplars**: Figure 1. Pieces a, c, d, e, f, g, h.

**Atypical exemplars**: Figure 1. Piece b. Figure 2. Pieces 1, 3-7, Figure 3. Step D.

**Close but no**:  Phrases like “platforms were carefully prepared” without additional supporting information about the nature of that preparation. Single or very sparse instances of facetted or dihedral platforms, especially where no other evidence of hierarchical reduction: “Nevertheless it is important to mention that within the excluded material of the ‘MSA base-complex’ (see above) one flake… shows characteristics of a

Levallois preferential flake with centripetal dorsal scars and a facetted striking platform...” (Schmidt, 2011, p. 92). All examples in figure 4 would be insufficient to code as present.

Code Title: Face shaping through radial removals

**Short Description:** Shaping of the face of a core through centripetal removals along the perimeter of a core face.

**Definition**: Flakes taken to modify the distal, lateral, medial convexities of a round core face, to prepare it for preferential removals. The preferential removals could be unidirectional or bidirectional blades, or preferential flakes.

**Inclusion criteria**: Consistent evidence for radial scars on blanks. Cores with evidence of centripetal preparation and hierarchical setup. Core faces should be rounded/oval, not rectilinear. Description of centripetal preparation of cores.

**Exclusion criteria**: radial cores without evidence for preferential removals, presence of only lateral trimming, or distal trimming flakes on a prepared core.

**Typical exemplars**: Figure 5. Pieces 1, 2, 4, 7.

**Atypical exemplars**:

**Close but no**: Figure 5. Pieces 3, 5, 6. Discoid cores, non-hierarchical core faces, biface thinning, cores of a rectilinear shape with both lateral trimming and distal trimming.

Code Title: Lateral trimming

**Short Description:** Lateral convexity of core face is shaped with flakes initiated from platforms along lateral margins of core.

**Definition**: The lateral convexities of the face of a core are trimmed through the removal of flakes from the lateral margin of the face (i.e. from platforms parallel to main flaking axis)

**Inclusion criteria**: Explicit descriptions of lateral trimming on hierarchical cores, and unambiguous illustrations of cores with lateral trimming.

**Exclusion criteria**: Do not count if: lateral flakes were struck only during radial/centripetal preparation of a core face, If lateral convexities are only trimmed through *debordante* removals, or if part of lateral margin of a core has flake removals on it, but that core is not preferential, or hierarchical. Also do not count if the lateral margin of a core has flake scars perpendicular to the main flaking axis, but those flakes originated from a crest used to establish the core face, or otherwise did not originate from a platform at the lateral margin of the core.

**Typical exemplars**: Figure 6, no. 4.

**Atypical exemplars**: Figure 5. Piece 3.

**Close but no**: descriptions of *debordant*, but without further specifics about the orientation of trimming flakes.

Code Title: Distal trimming

**Short Description:** Face shaped with flakes initiated from platform at distal margin of core

**Definition**: Distal convexities of the face of a hierarchical core are managed through the removal of flakes from a platform at the distal margin of the core (i.e. the platform is perpendicular to the main flaking axis).

**Inclusion criteria**: Core faces show evidence for flake removals from distal margin. Must be on hierarchical cores, and must be in context of managing distal convexities of the core.

**Exclusion criteria**: Do not count if: the core could be reasonably characterized as centripetally prepared, if these are flakes initiated from the distal margin that trim the lateral margins of a core, like what we might find in a Nubian Levallois core. Do not count as present if no hierarchical cores are present.

**Typical exemplars**: Figure 5, Levallois cores numbers 5, 6., Figure 6, Levallois core with lateral trimming, number 4. Figure 7. Step 4 in blademaking sequence.

**Atypical exemplars**: Figure 8. Step 3 in Chazan's description of La Ferrassie bladelets. Notching a bladelet, to supply end point of microblades taken from lateral margin of that bladelet core. Controls length of flaking surface by establishing/shaping a distal convexity.

**Close but no**:

Code Title: Back shaping

**Short Description:** Back of the core is shaped.

**Definition**: Back of core is shaped, as is case among naviform cores, and Asian microblade cores. All examples so far identified are cases where a nodule was bifacially flaked. One of the flaked crests then is used to remove one or two crested blades to establish a platform and face. Then flakes are removed from that platfom until exhausted. When exhausted there remains evidence of original bifacial flaking at the back of the core.

**Inclusion criteria**: Back of hierarchical core is shaped, typically bifacially.

**Exclusion criteria**: Crested blades are present, but no illustrations of cores showing evidence for a modified back/non-flaking surface.

**Typical exemplars**: Figure 9. Piece 2b.

**Atypical exemplars**: NA

**Close but no**:  NA

Code Title: Cresting

**Short Description:** Cresting to shape core face during initial steps of core preparation.

**Definition**: A core is bifacially or unifacially flaked along one axis. That crest establishes an artificial ridge along which an elongated flake, with a crested (entirely or partially) dorsal surface is removed.

**Inclusion criteria**: Cresting of core faces is described as present and/or figures show elements flakes bearing a crest, with at least a partial crest platform present.

**Exclusion criteria**: Cresting of core faces is described as absent. No mention in the text, and there are no illustration of crested pieces. For example: from Shimelmitz et. Al. 2011: "The reduction takes advantage of the natural shape of the raw material and does not include pre-shaping and decortication".

**Typical exemplars**: Figure 10. Flakes whose dorsal surface bears a full bifacially flaked crest. Pieces 1, 2, 4, 5, 6, 7.

**Atypical exemplars**: From Wilkins and Chazan: "The rarity of crested blades (0.3%, Table 7) and the presence of blades with centripetal flake dorsal scars on one side only (4.2%, Fig. 9e,h) are most consistent with a reduction strategy that generally prepared the blade exploitation surface with centripetal flake removals"(Wilkins & Chazan, 2012: p. 10). This is enough to code cresting as present in the assemblage.

"Crested elements (n=26) provide some details of the methods used for initial core preparation. The relatively low number of these pieces compared to the high number of cores used to produce blade/bladelet suggests that, in general, cresting was not necessary, and the natural shape of cobbles/nodules allowed the production of elongated debitage without cresting."(Smith et al., 2016).

**Close but no**: flakes with laterally oriented dorsal scars. Partially crested blades, where no element of the platform of the crest is present. Ski spall flakes removed during reduction of naviform cores which were prepared through cresting. Flakes with unifacial cresting, either complete or partial as in the case of striking platform removals as described in Smith et al. 2016.

Code Title: *Debordante*

**Short Description:** Elongated flakes along lateral margins of core face, knapped along the axis of the main flaking surface.

**Definition**: Elongated flakes removed from lateral margins of core face, knapped along the axis of the main flaking surface. *Debordantes* only include materials that maintain lateral and distal and sometimes proximal convexities of a core face. These can be removed either from the proximal/main core platform (more common), or distal area of the core (see atypical exemplars below). These tend to have a triangular cross section. In near eastern traditions these are sometimes refered to as naturally backed blades or knives

(Shimelmitz et al., 2011; Smith et al., 2016) though these sometimes might refer to elements that are not from hierarchical preferential cores, that happen to have a wedge shaped cross section.

**Inclusion criteria**: Must be in association with description/illustration of hierarchical preferential cores. If that condition is met, and the term *debordante* is used and likely is not referring to what we would otherwise code as lateral trimming, count as present. If backed flake/knife is used, only count as present if there is further discussion about the role they play in managing convexities of core face, OR if core faces show clear evidence of *debordante* removals in illustrations. If "*debordante*" is not used, but there are phrases like "elongated flakes were used to alighn the core face/modify lateral and distal convexities/modify core edges" count as present.

**Exclusion criteria**: Naturally backed flakes described as present, but there is no mention of their function in maintaining the face geometry of the core, or convexities of the core. Flakes are described as debordante, but there is otherwise no mention illustration or description of the nature of cores. Or, there is description of cores and they are non-hierarchical/amorphous.

**Typical exemplars**: From Wilkins and Chazan: "Débordant flakes/blades with unidirectional or bidirectional dorsal scars and a preserved lateral platform surface are also present in the assemblage (n ¼ 13, 1.3%, Fig. 9a) and may have sometimes been used to rejuvenate core edges"(Wilkins & Chazan, 2012). Figure 5. Pieces 5, 6, and 9 in figure below.

**Atypical exemplars**: Naturally backed blades described in Shimelmitz et al. 2011. Pieces that are described as backed but in context of discussion about managing lateral convexities. For example: “Only one elongated flake could be attributed to the Taramsa reduction method. The presence of many backed pieces (N=10) confirms this trend, since these flakes are removed to maintain the strong lateral convexity of the core”(Spinapolice & Garcea, 2013).

Figure 5. Piece 8.

**Close but no**: Discussion of face shaping with flake removals or discussion of naturally backed blades/knives/flakes without mention of the role they served in maintaining face shape/convexity.

Code Title: Overshot flakes

**Short Description:** Elongated flake removals that clip or remove the distal margin of the core.

**Definition**: Medial and distal convexities of a core face on a preferential hierarchical core are modified with an invasive flake that removes the distal end of the core, which may bear a platform (often opposed to its own) on the distal margin.

**Inclusion criteria**: Flakes or blades that extend across the entire face of the core must be in association with hierarchical blade/bladelet/microblade cores, discussion must include discussion of overshot blades/flakes, and/or include illustrations of overshot flakes/blades.

**Exclusion criteria**: No argument for presence. No Hierarchical preferential cores. No overshot blades/flakes in illustrations. No discussion of overshot blade/flake role in modifying distal convexity/rejuvenating distal platform.

**Typical exemplars**: Shimelmitz et al. 2011: "The frequent removal of laminar items with an overpassing end termination along the reduction in order to control core convexities."

**Atypical exemplars**: From Wilkins and Chazan. "Blades preserving a distal striking platform (Fig. 7d) further attest to the bidirectional production of blades.". This phrase has enough information for us to code this as an overshot blade, but there is also supporting information in the figure showing overshot blades.

**Close but no**:  Blades that are thick at the distal end, but do not bear the distal end of the core. Flakes that have a distal end of core, but the distal end is cortex. Overshot flakes are present in an assemblage, but there is no evidence for hierarchical core reduction.

Code Title: Kombewa

**Short Description:** Removal of flake from ventral surface of a flake

**Definition**: Ventral surface of a flake is treated as a core face

**Inclusion criteria**: Kombewa technique described as present, “janus flakes” and the processes to make them are described

**Exclusion criteria**: Discussion of removal of flakes from flakes is ambiguous about whether or not kombewa technique is present. No mention of janus flakes.

**Typical exemplars**: “cleavers were made on sometimes completely unmodified Kombewa flakes”

**Atypical exemplars**:

**Close but no**: Core on flake described as present without discussion of where the flaking surface is on that flake. Flakes from retouching large flakes, which be initiated at dorsal margin, and capture some of the ventral surface. Scars not propagated across ventral surface. Burin spalls, or tranchet spalls taken from flakes.

Code Title: Core tablet removals

**Short Description:** Flake removals that rejuvinate or prepare a core platform, by removing some or all of the core platform.

**Definition**: Striking a flake into the face of a core, where the dorsal surface of that flake is the main platform of a core. These are intended to rejuvinate the core platform by establishing a fresh flaking surface.

**Inclusion criteria**: Descriptions of core tablets, or illustrations of core tablets themselves and the function they served in rejuvenating core platforms, or illustrations of cores with strong evidence for core tablet removals.

**Exclusion criteria**: Coding as present should not be based only on illustrations of pieces that look like tablets. It should also not normally be based on illustrations of cores that have a single scar as the platform without supporting evidence that that scar was made to rejuvenate the platfrom (see atypical exemplars below). Do not code as present if only evidences are: flakes that happen to remove platforms, but no other evidence for hierarchical cores, Flakes with large facetted proximal margins without any other information in the text about rejuvenation of platforms.

**Typical exemplars**: Figure 11. Cores a and d. Phrases like, ‘the assemblage has several core tablets’.

**Atypical exemplars**: Figure 11. Cores b and e. In Figure 12 we can see that a flake was taken across the top of the core (the negative bulb of the flake is present) and this flake erased the negative bulbs of several of the blade scars (the flake did not just establish a platform, but was taken after several blades had been struck. These lines of evidence on a single platform hierarchical core are sufficient to infer that these cores were rejuvenated with tablets.

**Close but no**: Figure 12. Pieces 1-4. Without additional information about the geometry of the core from which these were taken, we should not call these core tablets (though the paper from which the figure is borrowed provides enough context to call these tablets).

Code Title: Abrasion/grinding

**Short Description:** Abrasion or grinding performed at any point in reduction sequence.

**Definition**: Core was abraded/ground to strengthen platform, or tools were abraded or ground as part of production sequence.

**Inclusion criteria**: any discussion of the abrasion, rubbing, of the core platform in relation to platform preparation in the text, or the presence of grinding/abrasion to finish a tool.

**Exclusion criteria**: No explicit description of abrasion as the strategy used to prepare the platform. Platform preparation described, but the kind of preparation not explicitly described. Tools appear ground/abraded but no discussion of the technique in text.

**Typical exemplars**: ‘platforms were prepared by abrasion.’

**Atypical exemplars**: “These bifaces have several common attributes. All were primarily shaped by abrasion by rubbing with a coarse material, leaving parallel striae on their surface” (Rosenthal, 1996).

**Close but no**: NA

Code Title: Overhang removal/microchipping of area below platform

**Short Description:** Removal of chips to modify area below platform.

**Definition**: Removal of chips initiated from platform to modify proximal margin of core face/proximal convexities, and modify the platform angle.

**Inclusion criteria**: Illustrations show small flakes removed at proximal margin of flakes, or on areas below core platforms. Descriptions of overhang removal, or microchipping of platform in text.

**Exclusion criteria**: No evidence of microchipping, overhang removal described in text, or in illustrations. Microchipping described in text, but this refers to what we would otherwise code as faceting.

**Typical exemplars**: NA

**Atypical exemplars**: NA

**Close but no**: NA

Code Title: Percussion by striking with hard hammer

**Short Description:** Use of a hard hammer

**Definition**: Use of a hard hammer strike onto some substrate, whether it is a core, held in the had, mounted on an anvil, or whether the hammer itself was struck on an anvil (as in case of passive hammer technique)

**Inclusion criteria**: If flakes are produced in assemblage, count as present unless explicitly stated as absent

**Exclusion criteria**: Explicit statement in text saying hard hammer use was absent

**Typical exemplars**: NA

**Atypical exemplars**: NA

**Close but no**: NA

Code Title: Core supported by hand

**Short Description:** Any stage of tool manufacture includes holding the core in hand while striking it (i.e. use of anvil is absent).

**Definition**: NA

**Inclusion criteria**: Count as present if bipolar percussion is not described as present, if description of freehand percussion in text.

**Exclusion criteria**: Explicit statement in text saying only bipolar, or passive anvil technique was employed, or description only of flake removals while core was mechanically mounted, or otherwise not supported by hand.

**Typical exemplars**: NA

**Atypical exemplars**: NA

**Close but no**: NA

Code Title: Use of anvil to support core

**Short Description:** Any incorporation of an anvil in the reduction process.

**Definition**: Use of an anvil at any point in the tool reduction sequence.

**Inclusion criteria**: Any discussion of anvil use, all cases of bipolar percussion, except where bipolar refers to flake removals from two opposing platforms where an anvil is not used (i.e. a bidirectional core without bipolar percussion). Cases where bipolar is mentioned must also have some visual evidence for bipolar percussion with an anvil (in the form of scaled pieces, for example).

**Exclusion criteria**: Bipolar percussion not mentioned in text. No mention of use of anvil to support core in any way.

**Typical exemplars**: "…many of our early replications were performed with the aid of an anvil (Figure 5), and this was found to be a successful technique for creating the initial steep sides on large flakes and cobbles. Anvil resting was more successful than true bipolar flaking in generating steep-angled edges and moving flaking on to new edges" (Clarkson et al., 2015: p.74)

**Atypical exemplars**: NA

Code Title: Core rotation

**Definition**: Core rotated at any point in reduction sequence

**Inclusion criteria**: Any evidence of flakes removed across two or more distinct axes.

**Exclusion criteria**: Single platform cores are present without evidence of removals across the top of the core.

**Typical exemplars**: NA

**Atypical exemplars**: NA

**Close but no**: NA

Code Title: Soft Hammer

**Short Description:** Use of a soft hammer

**Definition**: use of a soft hammer (whether the material be wood, bone, soft stone, etc).

**Inclusion criteria**: Authors explicitly state that soft hammer percussion was likely used OR soft hammers present in the archaeological assemblage, and forms of pieces appear consistent with use of soft hammers. For example, if delicate, thin, wide flakes present and soft-hammers were recovered from related contexts.

**Exclusion criteria**: No mention of soft hammer use, no soft-hammers present in the assemblage.  Evidence for soft hammer use described as unclear.

**Typical exemplars**: ‘Soft hammer use likely occurred’

**Atypical exemplars**: ‘Soft hammers are necessary for producing these forms, also see Figure x. for soft hammers recovered from the archaeological record’

**Close but no**: ‘Soft hammer use could have been employed/other assemblages with similar forms have soft hammers’

Code Title: Indirect percussion

**Short Description:** Use of a punch to remove flakes

**Definition**: Use of a punch of any given material placed on a platform, and struck with a hammer to punch flakes from the core.

**Inclusion criteria**: Authors explicitly state that indirect percussion was likely used.

**Exclusion criteria**: No mention of indirect percussion, statements like “indirect percussion is one method that could produce the forms here”.

**Typical exemplars**: ‘The blades in this assemblages would have likely required indirect percussion’, ‘experimental reconstructions of the stitching pattern on these Danish daggers indicate that indirect percussion/use of a punch would have been required’

**Atypical exemplars**: NA

**Close but no**: ‘Indirect percussion could have been employed’

Code Title: Flaking with application of pressure

**Short Description:** Removal of flakes through application of pressure on core platform

**Definition**: Use of typically soft indentor, bone, metal, or hard wood, to press flakes off cores.

**Inclusion criteria**: Discussion of pressure flaking as means of producing flakes.

**Exclusion criteria**: no evidence of scars consistent in pressure flaking AND no discussion of pressure flaking in the text.

**Typical exemplars**: ‘Microblades were struck through application of pressure’

**Atypical exemplars**:

**Close but no**: ‘Other assemblages with similar forms have pressure flakers’

Code Title: Pecking/hammer dressing

**Short Description:** Modification of core or tool through pecking

**Definition**: NA

**Inclusion criteria**: Hammer dressing, or pecking described in text as method employed at any point in tool manufacture. Hammer dressing is unambiguously present in illustrations.

**Exclusion criteria**: No hammer dressing or pecking described in text. Illustrations show no unambiguous presence of hammer dressing.

**Typical exemplars**: Figure 13.

**Atypical exemplars**: NA

**Close but no**: NA

Code Title: Invasive flaking

**Short Description:** Removal of non-cortical flakes that extend beyond the midpoint of the core face

**Definition**: NA

**Inclusion criteria**: Examples of invasive negative flake scars present in core illustrations.

**Exclusion criteria**: No illustrations of invasive negative flake scars on cores, no description of flakes invasive to the degree that they extend beyond midline. Invasive flakes are cortical.

**Typical exemplars**:

**Atypical exemplars**:

**Close but no**: Invasive flaking described only in text, but without further information about how invasive the flake are.

Code Title: Ochre use

**Short Description:** Use of ochre in any stage of tool making

**Definition**:Use of ochre as a pigment or as a binding agent.

**Inclusion criteria**: Ochre applied to tool.

**Exclusion criteria**: No mention of ochre in text, and

**Typical exemplars**: ‘Ochre was applied to points’, ‘the adhesive residues include ochre’

**Atypical exemplars**: NA

**Close but no**: NA

Code Title: Asphalt use

**Short Description:** Use of aslphalt at any stage of the tool making process.

**Definition**: Use of asphalt as a binding agent

**Inclusion criteria**: Asphalt adhered to tool, typically at its base/tang.

**Exclusion criteria**: No mention of asphalt residue on tools in the text.

**Typical exemplars**: ‘asphalt was applied to points’, ‘the adhesive residues include asphalt’

**Atypical exemplars**: NA

**Close but no**: NA

Code Title: Tanging

**Short Description:** Retouching base of piece to form a tang

**Definition**: Retouching a piece, typically through backing and notching at the base of a piece in order to facilitate hafting the piece.

**Inclusion criteria**: Description of retouch as forming a tang for the purpose of hafting.

**Exclusion criteria**: No mention of tanging, or hafting. Pieces bearing notches are not described as hafted.

**Typical exemplars**: NA

**Atypical exemplars**: No mention of tanging, but pieces with basal modifications consistent with a tang are described as frequent or have many illustrations.

**Close but no**: NA

Code Title: Invasive retouch

**Short Description:** retouch that extends to the midline of the artifact.

**Definition**: NA

**Inclusion criteria**: Illustrations of retouched pieces showing retouch extending to midline of tool.

**Exclusion criteria**: No illustrations of retouched pieces.

**Typical exemplars**:

**Atypical exemplars**: Burin spalls that extend to the midline of the artifact. Tranchet spalls.

**Close but no**:  Retouch described as invasive, but retouch scars in illustrations extend short of the midline of the artifact.

Code Title: Retouch (unifacial)

**Short Description:** Retouch of flake (unifacial only)

**Definition**:

**Inclusion criteria**: Retouch described as present. Illustrations of pieces show unambiguous evidence of retouch.

**Exclusion criteria**: Bifacial retouch is present. No unambiguous illustrations of unifacially retouched pieces, and no mention of retouch.

**Typical exemplars**: NA

**Atypical exemplars**: NA

**Close but no**:  NA

Code Title: Backing

**Short Description:** Retouch forms an abrupt, scraper-like margin

**Definition**: Retouch that increases the angle of the margin to ~70-90 degrees.

**Inclusion criteria**: Presence of artifacts with retouch that forms an angle greater than 70 degrees. Description of scrapers in assemblage.

**Exclusion criteria**: Lack of evidence for artifacts with retouch forming greater than 70 degree angle. Or evidence is ambiguous. No mention of scrapers, or illustrations of retouched tools.

**Typical exemplars**:

**Atypical exemplars**:

**Close but no**: Abrupt retouch on flat thin flakes.

Code Title: Notching

**Short Description:** Retouch forms round concavity.

**Definition**: Retouch, either unifacial or bifacial, forms a round concavity, or series of concavities.

**Inclusion criteria**: Description of notches, or denticulates. Illustration of pieces with notches formed.

**Exclusion criteria**: Lack of evidence for artifacts with retouch forming greater than 70 degree angle. Or evidence is ambiguous. No mention of scrapers, or illustrations of retouched tools.

**Typical exemplars**: Figure 14. Piece 1. Figure 15. Pieces E, F.

**Atypical exemplars**:

**Close but no**: Abrupt retouch on flat thin flakes.

Code Title: Burination

**Short Description:** Removal of spalls along the margins of other flakes.

**Definition**: Removal of flakes where the core face is the sharp margin of the flake. Flakes from this process have two ventral surfaces, the parent flake's, and its own.

**Inclusion criteria**: Illustrations of flakes with evidence of spalls taking across their lateral, proximal, or distal margins. Burins, or burin spalls described as present.

**Exclusion criteria**: No description of burins, burin spalls, or microburin technique, and no illustrations showing burins as described above. Do not count if the burination could be coded as *tranchet* resharpening

**Typical exemplars**: Figure 16. from Smith et al. 2016. all examples.

**Atypical exemplars**: NA

**Close but no**:  Mention of 'impact burnation', 'spalling', 'core-on-flake'.

Code Title: *Tranchet* removal.

**Short Description:** Retouch of a core-tool by removing a flake across the face at the distal margin or bit.

**Definition**: Retouch of a core-tool by removing a flake across the face at the distal margin or bit. The spall removed in this process is typically curved, and may be trihedral in a way similar to a burin spall. One lateral margin of the spall will be the distal margin/bit of the core-tool. The opposite face of the core tool will have a remnant on one face of the spall, adjacent to the ventral surface of the spall.

**Inclusion criteria**: Description of tranchet resharpening in text. illustration of core-tools with negative from tranchet spall visible. Illustration of tranchet spalls themselves with further description that these represent tranchet spalls.

**Exclusion criteria**: Do not count if there is no evidence in illustrations for tranchet resharpened core tools, and there is no mention of tranchet spall in text, or otherwise no mention of resharpening of bit through removal of transverse flake.

**Typical exemplars**: Figure 17. Pieces 1-3.

**Atypical exemplars**: Illustrations of core-tools with unambiguous examples of tranchet resharpening, but no description of this method of resharpening in text.

**Close but no**: Illustrations of what appear to be tranchet spalls, in context of a site with core-tools that could reasonably have been resharpened with such spalls, but no description in the text that these spalls served that purpose.

Code Title: Pressure retouch

**Short Description:** Pressure flaking retouch

**Definition**: Retouching a piece (core-tool or flake) with application of pressure.

**Inclusion criteria**: Invasive flake scars on retouched pieces that are extremely narrow (~.5mm), thin (<.1mm, and relatively invasive (~5mm) OR description of pieces as pressure flaked.

**Exclusion criteria**: no evidence of scars consistent in pressure flaking AND no discussion of pressure flaking in the text.

**Typical exemplars**: 'There were x pressure flaked bifaces in the assemblage'

**Atypical exemplars**: 'Burin spalls removed through pressure flaking', or 'microblade manufacture on end nosed scraper were removed through pressure flaking.'

**Close but no**: 'biface was thinned through invasive and delicate removals', 'delicate burin spalls removed'.

Code Title: Bifacial retouch

**Short Description:** Retouch on both faces of a flake or core-tool.

**Definition**: Retouch on both faces of a flake or core-tool, struck from the same platform.

**Inclusion criteria**: Descriptions of bifacial retouch, illustrations of pieces with retouch on both faces.

**Exclusion criteria**: No mention of bifacial retouch, no illustrations of retouched pieces showing bifacial retouch.

**Typical exemplars**: NA

**Atypical exemplars**: NA

**Close but no**:  NA

**Other notes**: Never count both bifacial and unifacial retouch on same piece.

References to codebook figures:

Figure 1. Figure 23 illustrating levallois point variation from Kibish formation (Shea, 2008).

Figure 2.  From figure 5 illustrating levallois flake and centripetal flake diversity (Picin & Vaquero, 2016).

Figure 3. Figure 2 illustrating schematic drawings of blade manufacture methods in Queensland (Moore, 2003).

Figure 4. Figure 4 on technological blade classifications at Rose Cottage Cave (Soriano et al., 2007).

Figure 5. Figure 1 in in description of Levallois technology (Bordes, 1980).

Figure 6. Figure 2 in description of Levallois technology (Bordes, 1980).

Figure 7. Figure 5 description of bladelet core preparation at 'Ein Qashish with distal preparation at step 4.(Malinsky-Buller et al., 2014)

Figure 8.  Figure 2. Schematic illustrating busqued burin production methods at La Ferrassie (Chazan, 2001).

Figure 9. Figure 2. Microblade core variability at Amakomanak.(Coutouly, 2017)

Figure 10. Initial blade subtypes from Kfar HaHoresh (Barzilai & Goring-Morris, 2010).

Figure 11. Figure 4 in description of blade cores from Fumane cave (Falcucci & Peresani, 2018).

Figure 12. Figure 14 illustrating platform spalls from bidirectional blade cores recovered from Kfar HaHoresh (Barzilai & Goring-Morris, 2010)

Figure 13. Figure 2 illustrating hammer dressing on stemmed obsidian tool from Biak Island, West Papua (Robin Torrence et al., 2009).

Figure 14. Figure 13 illustrating projectile points recovered from Motza (Khalaily et al., 2007).

Figure 15. Figure 8 illustrating some retouched tool tyles from Ayn Abu Nukhayla (Henry & Mraz, 2020).

Figure 16. Figure 5 illustrating burin variation at the PPNA site El Hemmeh (Smith et al., 2016).

Figure 17. Figure 14 illustrating tranchet axe variability at Motza (Khalaily et al., 2007).

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# APPENDIX II

# PROCEDURAL UNIT DATA

While the data produced over the course of this dissertation will be hosted online on Zenodo and tDAR, I also include the raw form of the primary datasets in the document itself. Note that the latitudes and longitudes of each site have been resampled to select a random point within a radius of 10 kilometers from the original site location. These obfuscated site locations were also used in all the spatial analyses in this dissertation. While the data below are not presented in a beautiful way, they should be easier to copy into R, or the spreadsheet program of your choice, than if the data were represented in a formatted table. Copy the below, save it in a program like notepad as a .txt file, and then you should be able to open it with something like excel as a delimited comma separated dataset.

The procedural unit data includes two broad kinds of data. One is the number of procedural units inferred across an entire assemblage (used in analyses in chapters 3-5), and one is the number of procedural units in particular reduction sequences (used in chapter 2). These are differentiated by the “Single.chain” column.

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Cite.text,Sitename,KA.young,KA.old,Lat,Long,Descr.,Species.attribution,Single.Chain,PU.RM,PU.facetting,PU.faceshaping.rad.,PU.lat.trimming,PU.dist.trimming,PU.back.shaping,PU.cresting,PU.debord,PU.overshot,PU.kombewa,PU.tablet,PU.abrasion,PU.overhang,PU.hard.hammer.percussion,PU.use.of.hand.to.support.percussed.object,PU.use.of.anvil.to.support.percussed.object,PU.core.rotation,PU.Soft,PU.indirect,PU.Flaking.through.pressure,PU.pecking,PU.invasive,PU.ochre,PU.asphalt,PU.retouch,PU.backing,PU.notching,PU.burin,PU.tang,PU.tranchet,PU.rt.bif,PU.rt.invasive,PU.rt..pressure.flake
Moore 2003,Georgina River Bridge Site,0.001,1,-19.84257141,138.0151246,Camooweal sharktooth method,H. sapiens,Yes,0,1,0,0,0,0,0,1,1,0,0,0,1,1,1,0,1,0,0,0,1,0,0,1,0,0,0,0,0,0,0,0
Moore 2003,Georgina River Bridge Site,0.001,1,-19.96876633,138.1306436,Camooweal standard method,H. sapiens,Yes,0,0,0,0,0,0,0,1,1,0,0,0,1,1,1,0,1,0,0,0,1,0,0,1,0,0,0,0,0,0,0,0
Moore 2003,Georgina River Bridge Site,0.001,1,-19.9550104,138.2321576,All blade techs,H. sapiens,No,0,1,0,0,0,0,0,1,1,0,0,0,1,1,1,1,1,0,0,0,0,1,0,0,1,1,1,0,0,0,0,0,0
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Stout et al. 2010,EG12,2500,2600,11.04122529,40.28981124,Oldowan pebble cores with rotation. ,?,Yes,0,0,0,0,0,0,0,0,0,0,0,0,0,0,1,1,0,1,0,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0

Stout et al. 2010,EG12,2500,2600,11.17126009,40.11267713,Oldowan pebble cores without rotation. ,?,Yes,0,0,0,0,0,0,0,0,0,0,0,0,0,0,1,1,0,0,0,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0

Stout et al. 2010,EG12,2500,2600,11.13933063,39.84445078,All reduction sequences,?,No,0,0,0,0,0,0,0,0,0,0,0,0,0,0,1,1,0,1,0,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0

Hogberg et al. 2011,Hollow Rockshelter,72,80,-32.1387214,19.0626513,Unifacial Still bay points. Bifacially flaked predominately shaped by freehand hard hammer percussion but in late stages there's retouch to form the tang and some of that retouch is invasive and pressure flaked. ,?,Yes,0,0,0,0,0,0,0,0,0,0,0,0,0,0,1,1,0,1,0,0,0,0,1,0,0,1,0,0,0,1,0,0,1,1

Sørensen 2006,Saqqaq culture represented at Itinnera,3,4.4,64.30708772,-51.91208049,Arctic small tool tradition. Burins made on little bifaces. hafted. burin spalls taken through pressure. ,H. sapiens,Yes,0,0,0,0,0,1,0,0,0,0,0,1,0,1,1,0,1,0,0,0,0,0,0,0,0,0,0,1,1,0,1,1,1

Villa et al. 2010,Klasies cave 1A lower HP,53,68.1,-34.07089424,24.32468893,Howieson's poort backed pieces on blade segments made from blades produced on hierarchical cores displayed in fig 16 and 15. And supp fig 5. characteristic of HP D sample Upper and lower. ,?,Yes,0,1,1,0,0,0,1,1,0,0,1,1,1,1,1,0,1,1,0,0,0,1,0,0,1,1,0,0,0,0,0,0,0

Villa et al. 2010,Klasies cave 1A lower HP,53,68.1,-34.1660777,24.35892083,all HP tech described. nothing from MSAiii.,?,No,0,1,1,0,0,0,1,1,0,1,1,1,1,1,1,0,1,1,0,0,0,1,0,0,1,1,1,0,0,0,0,0,0

Villa et al. 2010,Klasies cave MSA III deacon exc.,50,60,-34.12091056,24.39728232,MSA III materials. all,?,No,0,1,0,0,1,0,1,1,0,0,0,0,1,1,1,0,1,0,0,0,0,1,0,0,1,1,1,1,0,0,0,0,0

Tryon et al. 2005,Kapthurin LHA FS,284,509,0.501192434,36.04056419,Early Levallois at Kapthurin LHA fig. 3. Centripetally prepared preferential cores with ventral thinning. ,?,Yes,0,1,1,0,0,0,0,0,0,1,0,0,0,1,1,0,1,0,0,0,0,1,0,0,1,0,0,0,0,0,0,0,0

Tryon et al. 2005,Kapthurin LHA FS,284,509,0.503128516,35.92994654,Whole assemblage,?,No,0,1,1,0,1,0,0,0,0,1,1,0,0,1,1,0,1,0,0,0,0,1,0,0,1,0,0,0,0,0,1,1,0

Tryon et al. 2005,Koilomot locus 2,200,250,0.513624512,36.06360587,Kapthurin preferential hierarchical flake cores. fIG 4 Core C. Prepared through debordante removals distal convexities managed by distal flakes no lateral trimming though its common on other cores. No mention of platform abrasion or overhang trimming. No retouch in Koilomot locus 2 either. ,?,Yes,0,1,0,0,1,0,0,1,0,0,0,0,0,1,1,0,1,0,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0

Tryon et al. 2005,Koilomot locus 2,200,250,0.476477627,36.00938246,Whole assemblage,?,No,0,1,1,0,1,0,0,1,0,0,0,0,0,1,1,0,1,0,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0

Goren-Inbar et al. 2008,Gesher Benot Ya'aqov,760,860,33.05921188,37.30524504,Scrapers on massive flakes,?,Yes,0,0,0,0,0,0,0,0,0,0,0,0,0,1,1,0,1,0,0,0,0,0,0,0,1,0,0,0,0,0,0,0,0

,Gesher Benot Ya'aqov,760,860,33.08011422,34.54407365,Handaxes from kombewa flakes and only handaxes,?,Yes,0,0,0,0,0,0,0,0,0,1,0,0,0,1,1,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,1,0,0

Goren-Inbar et al. 2008,Gesher Benot Ya'aqov,760,860,32.9533306,34.90822719,Whole assemblage,?,No,0,0,1,0,0,0,0,0,0,1,0,0,0,1,1,0,1,0,0,0,0,1,0,0,1,0,0,0,0,0,1,0,0

Li et al. 2015, Canteen Koppie,800,1100,-28.54365943,24.55494855,Victoria west type 1 cleaver. Core is centripetally prepared with one preferential removal taken. No retouch afterwards. ,H. sapiens,Yes,0,1,1,0,0,0,0,0,0,0,0,0,0,1,1,0,1,0,0,0,0,1,0,0,1,0,0,0,0,0,0,0,0

Pleurdeau 2006,Porc epic,60,80,9.650233395,41.86619385,Bifacially retouched points that are unidirectionally flaked made on first scheme cores  that are centripetally prepared (like Fig. 5.1) fig. 8.,H. sapiens,Yes,0,1,1,0,0,0,0,1,0,0,0,0,1,1,0,1,1,0,0,0,1,0,0,0,0,0,0,1,0,1,1,0

Pleurdeau 2006,Porc epic,60,80,9.551986128,41.92688621,Scheme 4 blade production where core is prepped with crested blades. Blanks are from bidirectional reduction. Those blanks are backed to form backed pieces. ,H. sapiens,Yes,0,0,0,0,1,0,1,1,0,0,0,0,1,1,0,1,0,0,0,1,0,0,1,1,0,0,0,0,0,0,0

Pleurdeau 2006,Porc epic,60,80,9.498034468,41.87238572,whole assemblage,H. sapiens,No,0,1,1,0,1,0,1,1,0,0,0,0,0,1,1,0,1,1,0,0,0,1,0,0,1,1,1,0,1,0,1,1,0

Harmand et. al. 2015,Lomekwi 3,2510,3300,3.902550648,35.6584157,Bipolar unifacial core (LOM3-2012-H18-1 3.45 kg) bipolar technique. S,?,Yes,0,0,0,0,0,0,0,0,0,0,0,0,0,1,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0

Harmand et. al. 2015,Lomekwi 3,2510,3300,3.764528673,35.72138051,whole assemblage,?,No,0,0,0,0,0,0,0,0,0,0,0,0,0,1,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0

Delagnes and Roche 2005,Lokalalei 2c,2290,2390,3.865725473,35.80783689,Lokalalei 2c Fig. 6. Refitting group 2,?,Yes,0,0,0,0,0,0,0,0,0,0,0,0,0,1,1,0,1,0,0,0,0,0,0,0,1,0,0,0,0,0,0,0,0

Delagnes and Roche 2005,Lokalalei 2c,2290,2390,3.976053501,35.84420536,Whole assemblage,?,No,0,0,0,0,0,0,0,0,0,0,0,0,0,1,1,0,1,0,0,0,0,0,0,0,1,0,0,0,0,0,0,0,0

Plummer and Bishop 2016,Kanjera,1950,2300,0.327658727,34.57679881,Kanjera retouched flakes from centripetal cores Fig 2,?,Yes,0,0,0,0,0,0,0,0,0,0,0,0,0,1,1,0,1,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0

Plummer and Bishop 2016,Kanjera,1950,2300,0.342550745,34.45504223,Whole assemblage,?,No,0,0,0,0,0,0,0,0,0,0,0,0,0,1,1,0,1,0,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0

Diez-Martin et al. 2009,Olduvai Bed II BK,1645,1805,-3.001202524,35.40829161,Olduvai Bed II Bifacial multipolar centripetal hierarchized cores from BK 3. Look like recurrent centripetal levallois. ,?,Yes,0,1,0,0,0,0,0,0,0,0,0,0,0,1,1,0,1,0,0,0,0,1,0,0,1,0,0,0,0,0,0,0,0

Diez-Martin et al. 2009,Olduvai Bed II BK,1645,1805,-3.042133845,35.31561176,Hierarchized cores and bipolar reduction. ,?,No,0,1,0,0,0,0,0,0,0,0,0,0,0,1,1,1,1,0,0,0,0,1,0,0,1,0,0,0,0,0,0,0,0

Isaac 1977,Olorgesaillie,500,1200,-1.501914402,41.08782164,Olorgesaillie Biface with invasive scarring. Plate 59. Tr. Tr. 140-150 floor. ,?,Yes,0,0,0,0,0,0,0,0,0,0,0,0,0,0,1,1,0,1,0,0,0,0,1,0,0,0,0,0,0,0,0,1,0,0

Clark 1971,Starr Carr,10.4,10.7,54.20112928,-0.379615792,backed and burinated bladelets from bladelet cores rejuvintd through debordant ,H. sapiens,Yes,0,0,0,0,0,0,0,1,0,0,1,1,1,1,1,0,1,0,0,0,0,1,0,0,1,1,0,1,1,0,0,0,0

Barzilai and Ashkenazy 2015,Nahal Sekher VI,11.8,13.6,31.08834531,34.87432341,bifacially Backed lunates made on mbt bladelets struck from single platform cores like those illustrated in figure 15. Though we code facetting as present given their description in the text and in core figure 16. Rejuvinated with tablets and established with crested bladelets. no debordantes,H. sapiens,Yes,0,1,0,0,0,0,1,0,1,0,1,0,1,1,1,1,1,0,0,0,0,1,0,0,0,1,1,1,0,0,1,0,0

Barzilai and Ashkenazy 2015,Nahal Sekher VI,11.8,13.6,31.19148723,34.91715588,Whole assemblage,H. sapiens,No,0,1,0,0,0,0,1,0,1,0,1,0,1,1,1,1,1,0,0,0,0,1,0,0,1,1,1,1,0,0,1,0,0

Stout et al. 2014,Boxgrove,478,524,50.82444281,-0.765522751,Handaxes with tranchet sharpening knapped with hard and softhammers.Platforms are prepared through facetting but little sign of abrasion and microchipping.,H. heidelbergensis,Yes,0,1,0,0,0,0,0,0,0,0,0,0,1,1,0,1,1,0,0,0,1,0,0,0,0,0,0,0,1,1,1,0

Pasda 2017,Munzingen,18,20,48.030389,7.722025098,Blades from prepared unidirectional blade cores with nflksrfc prepared platform and face shaped. including microchipping. Fashioned into burinated and retouched pieces. Fig 2. 11 fig 6. 1.Overall not a full description of the reductions equence but rich description of the kinds of artifacts present and some of their relationships. ,H. sapiens,Yes,0,0,0,0,1,1,0,1,0,0,0,0,1,1,1,0,1,0,0,0,0,1,0,0,1,0,0,1,0,0,0,0,0

Pasda 2017,Munzingen,18,20,47.95400725,7.712557543,Whole assemblage,H. sapiens,No,0,0,0,0,1,1,1,1,0,0,0,0,1,1,1,0,1,0,0,0,0,1,0,0,1,1,1,1,0,0,0,0,0

Hahn and Owen 1985 ,Geissenklosterle Cave Aurignacian,38.7,41.7,48.40400952,9.882094108,Aurignacian blade cores in figure 2. Most codin gbased on description of tech.,H. sapiens,Yes,0,0,0,0,0,0,1,0,0,0,1,0,1,1,1,0,1,1,0,0,1,1,0,0,1,0,0,0,0,0,0,0,0

Hahn and Owen 1985 ,Geissenklosterle Cave Aurignacian,38.7,41.7,48.39233411,10.00971029,Whole assemblage,H. sapiens,No,0,1,0,0,0,0,1,0,0,0,1,0,1,1,1,0,1,1,0,0,1,1,0,0,1,0,0,0,0,0,0,0,0

Hahn and Owen 1985 ,Geissenklosterle Cave Gravettian,28.75,29.25,48.33299478,9.970586817,Gravettian blade cores. Most coding based on description. ,H. sapiens,Yes,0,1,0,0,0,1,1,1,0,0,1,1,1,1,1,0,1,0,1,0,1,1,0,0,1,0,0,1,0,0,0,0,0

Hahn and Owen 1985 ,Geissenklosterle Cave Gravettian,28.75,29.25,48.40146289,9.952123182,Whole assemblage,H. sapiens,No,0,1,0,0,0,1,1,1,0,0,1,1,1,1,1,0,1,0,1,0,1,1,0,0,1,0,0,1,0,0,0,0,0

Aubrey et al. 2008,Maitreaux ,19,21,46.85834206,0.928711358,Solutrean points on cobble blanks,H. sapiens,Yes,0,1,0,0,0,0,0,0,1,0,0,1,1,1,1,0,1,1,0,1,0,1,0,0,0,0,0,0,1,0,1,1,1

Gallotti 2013,Garba Ivd,1458,1918,8.689099442,38.66121201,Retouched flakes from centripetally prepared cores. flakes with facetted butts. retouched. ,?,Yes,0,1,1,0,0,0,0,0,0,0,0,0,0,1,1,0,1,0,0,0,0,1,0,0,1,0,0,0,0,0,0,0,0
Gallotti 2013,Garba Ivd,1458,1918,8.655066746,38.65549215,Whole assemblage including flakes that are retouched to notches/scrapers as well as lct,?,No,0,1,1,0,0,0,0,0,0,0,0,0,0,1,1,0,1,0,0,0,0,1,0,0,1,1,1,0,0,0,1,0,0
Conard and Adler 1997,Wallertheim West Concentration,92,105,49.8892154,8.075372037,Unidirectional blade production where blades are retouched and burinated. On gray andesite figure 11. Figure 10. discussion in160-,H. neanderthalensis,Yes,0,1,0,0,0,0,0,1,0,0,1,0,0,1,1,0,1,0,0,0,0,1,0,0,1,1,0,1,0,0,0,0,0
Conard and Adler 1997,Wallertheim West Concentration,92,105,49.89014236,8.103696376,Whole assemblage,H. neanderthalensis,No,0,1,0,0,0,0,0,1,0,0,1,0,0,1,1,0,1,0,0,0,0,1,0,0,1,1,0,1,0,0,0,0,0
Torre et al. 2008,RHS-Mugulud Peninj,1100,1500,-2.352467566,35.96428936,Large cutting tool on flake that is retouched through rough facconage. ,?,Yes,0,1,0,0,0,0,0,0,0,0,0,0,0,1,1,0,1,0,0,0,0,1,0,0,0,0,0,0,0,0,1,0,0
Torre et al. 2008,RHS-Mugulud Peninj,1100,1500,-2.214826886,35.95103387,Whole assemblage,?,No,0,1,0,0,0,0,0,0,0,0,0,0,0,1,1,0,1,0,0,0,0,1,0,0,1,0,0,0,0,0,1,0,0
Villa et al. 2016,Torre in Pietra level M,331,359,42.34214179,11.56923551,Large cutting tool on a limestone cobble. Figure P. pigorini museum catalogue number 184769,?,Yes,0,0,0,0,0,0,0,0,0,0,0,0,0,1,1,0,1,0,0,0,0,1,0,0,0,0,0,0,0,0,1,0,0
Villa et al. 2016,Torre in Pietra level M,331,359,42.23595284,12.31086158,Whole assemblage,?,No,0,0,0,0,0,0,0,0,0,0,0,0,0,1,1,0,1,0,0,0,0,1,0,0,1,1,1,0,0,0,1,0,0
Villa et al. 2016,Torre in Pietra level D,240,270,42.25081699,11.46287703,Levallois flaking no parallel unidirectional,?,Yes,0,1,1,0,0,0,0,1,0,0,0,0,0,1,1,0,1,0,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0
Villa et al. 2016,Torre in Pietra level D,240,270,42.24757529,12.20203046,Whole assemblage,?,No,0,1,1,0,0,0,0,1,0,0,0,0,0,1,1,1,1,0,0,0,0,1,0,0,1,1,1,0,0,0,1,0,0
Gilbert et al. 2016,Hugub KK51,500,600,9.739806098,40.14464856,Large cutting tool on a flake. invasive removals. lots of retouch. Facetted butt. likely from prepared core but that part of the chain operatoire was not here. ,?,Yes,0,1,0,0,0,0,0,0,0,0,0,0,0,1,1,0,1,0,0,0,0,1,0,0,0,0,0,0,0,0,1,0,0
Gilbert et al. 2016,Hugub KK51,500,600,9.807666685,40.18616487,Whole assembladge,?,No,0,1,0,0,0,0,0,0,0,0,0,0,0,1,1,1,1,0,0,0,0,1,0,0,1,1,1,0,0,0,1,0,0
Texier 1995,NY 18 Nyabusosi,1500,2000,1.008611326,30.33154062,Oldowan flake production on prepared radial cores with some evidence for debordante removals. While retouch is described in the paper it isn't clear if the prepared core flakes were retouched. ,?,Yes,0,1,1,0,0,0,0,1,0,0,0,0,0,1,1,0,1,0,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0
Texier 1995,NY 18 Nyabusosi,1500,2000,0.921753611,30.28919958,Whole assemblage,?,No,0,1,1,0,0,0,0,1,0,0,0,0,0,1,1,0,1,0,0,0,0,1,0,0,1,1,1,0,0,0,0,0,0
Schimelmitz et al. 2011,Qesem Cave,194,420,32.03142208,34.94413403,Systematic blade production from core prepared with a crest rejuvinated with tablets face is shaped with debordantes. Distal convexities managed with overshot flaking.  Where the product

is retouched and burinated.  Based on figure 11. number 4 a prismatic core. ,?,Yes,0,1,0,0,0,0,1,1,1,0,1,0,0,1,1,0,1,0,0,0,0,1,0,0,1,1,0,1,0,0,0,0,0

Barkai et al. 2005 and Barzilai et al. 2011,Qesem Cave,194,420,32.06710765,34.9077329,Whole assemblage blades and bifaces. Nahr Ibrahim tech. NO levallois. ,?,No,0,1,0,0,0,0,1,1,1,1,1,0,0,1,1,0,1,0,0,0,0,1,0,0,1,1,1,1,0,0,1,1,0

Chazan 2001a,La Farressie,26.7,28.7,44.96674484,0.796992475,Bladelet production on a blade whose face is shaped and is invasively flaked. Figure 3. Vachons burin production method. The initial steps of the blade core production are not fully described the platforms are described as well prepared but not specified about whether this involves facetting abrasion. Cresting is present in early stages but in lateral form. ,H. sapiens,Yes,0,0,0,0,0,1,0,1,0,0,0,0,0,0,1,1,0,1,1,0,0,0,1,0,0,1,1,1,1,0,0,0,1,0

Fernandez 2005,Cueva Morin levels 9-10,35,38,43.44649092,-3.864256223,Blade/ Bladelet production on prismatic cores,H. sapiens,Yes,0,1,0,0,1,0,1,1,0,0,1,1,1,1,1,0,1,0,0,0,0,1,0,0,1,0,0,1,0,0,0,0,0

Chazan 2001b,Hayonim cave level D. ,21,30,32.82934561,34.7407334,Bladelet production on endscraper on a flake. notched to manage lateral convexities and narrow working surface. step 4 include debordante removals. ,H. sapiens,Yes,0,0,0,0,0,0,1,0,0,0,0,0,0,1,1,0,1,0,0,0,0,1,0,0,1,1,1,0,0,0,0,0,0

Clarkson et a. 2015,Ka'eo quarry,0.3,0.6,21.15494686,-157.164503,Quadrangular adze production on flake.   ,H. sapiens,Yes,0,1,0,1,1,0,1,0,1,0,0,1,0,1,1,1,1,1,0,0,0,1,0,0,0,0,0,0,1,1,1,1,0

Clarkson et a. 2015,Ka'eo quarry,0.3,0.6,21.20660355,-157.1671596,Whole assemblage (only adze prod).,H. sapiens,No,0,1,0,1,1,0,1,0,1,0,0,1,0,1,1,1,1,1,0,0,0,1,0,0,0,0,0,0,1,1,1,1,0

Malinsky-Buller et al. 2014,Ein Qashish,55,65,32.73627806,35.19586178,Blades/bladelets from narrow fronted single platform cores. As in figure 5. With abraded and microchiped platforms. Retouch is conservatively assessed by the authors given taphonomic history of site. So I counted only rt as present no more. ,H. neanderthalensis,Yes,0,1,0,0,1,0,1,1,0,0,1,1,1,1,1,0,1,1,0,0,0,1,0,0,1,0,0,0,0,0,0,0,0

Malinsky-Buller et al. 2014,Ein Qashish,55,65,32.61870156,35.13366668,Whole assemblage,H. neanderthalensis,No,0,1,1,1,1,0,1,1,0,1,1,1,1,1,1,0,1,1,0,0,0,1,0,0,1,1,1,1,0,0,1,1,0

Shimelmitz and Kuhn 2013,Tabun IX D,231,283,32.72625747,35.17384984,"Levallois points from elongated levallois cores through unidirectional convergence method.  Figure 4 shows good example of debordante and facetting plus tablet scars. In text they discuss how distal convexities were sometimes managed from distal removals Debordantes seem to be treated as the same as NBK but not sure. Either way there's discussion of debordants. Really good example of needing a coding system to interpret phrases. ""Maintaining the core’s distal convexity through intentionally striking over- passing flakes and blades is a delicate business. In some cases small flakes also were removed from the end of the core opposite the main striking platform to help maintain the required distal convexity of core faces.""",?,Yes,0,1,0,0,1,0,0,1,0,0,1,0,1,1,1,0,1,0,0,0,0,1,0,0,1,0,0,0,0,0,0,0,0

Spinapolice et al. 2014,Jebel Gharbi SJ-00-58A,27,85,32.04753254,12.05314845,Aterian tanged flakes made on blade cores. This paper is light on the full details but references boeda to indicate that all steps are present. ,H. sapiens,Yes,0,1,0,0,0,0,0,1,0,0,0,0,1,1,1,0,1,0,0,0,0,1,0,0,0,1,0,0,1,0,1,0,0

Groucutt 2014,Tor Faraj,50,70,29.81825628,36.2660302,Levallois points from preferential unidirectional convergent prepared cores. Reported top right of fig 4. Deb. prep of lat margins. overshot of points repreps the distal convexity. Some bidirectional prep /management of disatl convexity that way. Retouch is limited. no mention of soft. ,?,Yes,0,1,0,0,1,0,0,1,1,0,0,0,1,1,1,0,1,0,0,0,0,1,0,0,1,0,0,0,0,0,0,0,0

Hublin et al. 1987 and Richter et al. 2017,Jebel Irhoud,281,349,32.33706632,-9.127997611,"preferential levallois points lots of preparation trimming of lateral and distal convexities no mention of debordantes no soft hammer percussion. Invasive retouch. removal of butt. Lots of color in the description of the tech. On soft hammer: "" Il n'y a qu'un éclat pouvant avoir été débité au percuteur tendre... donc il n'y en a pas ! "". No cores. ",H. sapiens,Yes,0,1,1,0,0,0,0,0,0,0,0,0,1,1,1,0,1,0,0,0,0,1,0,0,1,0,0,0,0,0,0,0,0

Wilkins and Chazan 2012,Kathu Pan 1,464,682,-27.65578558,23.01764231,Blades made on levallois cores. retouched,?,Yes,0,1,1,0,0,0,0,1,0,0,0,1,1,1,1,0,1,0,0,0,0,1,0,0,1,0,0,0,0,0,0,0,0

Wilkins and Chazan 2012,Kathu Pan 1,464,682,-27.73565551,22.93277084,Whole,?,No,0,1,1,1,0,0,0,1,0,0,0,1,1,1,1,0,1,0,0,0,0,1,0,0,1,0,0,0,0,0,1,0,0

Coutouly 2017,Amakomanak,9.4,9.6,67.02837346,-156.6127474,Microblade manufacture. inferred from description in text and based on figure 4. microblade core number 21976. ,H. sapiens,Yes,0,1,0,0,1,1,1,1,0,0,1,1,1,1,1,0,1,0,0,1,0,1,0,0,0,0,0,0,0,0,0,0,0

Wilson et al. 2011,High River,8,9,50.63881871,-113.8200091,Marlan's F1 sequence 1970. Microblade reduction figure 5 core 3 in 2011 text.,H. sapiens,Yes,0,1,0,0,1,1,1,1,0,0,1,0,0,1,1,0,1,1,0,1,0,1,0,0,0,0,0,1,0,0,0,0,0

Wilson et al. 2011,High River,8,9,50.59671428,-113.7582802,Whole assemblage only microblade tech,H. sapiens,No,0,1,0,0,1,1,1,1,0,0,1,0,0,1,1,0,1,1,0,1,0,1,0,0,0,0,0,1,0,0,0,0,0

Desrosiers and Gendron 2004,GhGk-63,1.6,2.1,55.25888388,-78.04654236,Microblade manufacture then retouched into point. for example figure 5.5,H. sapiens,Yes,0,1,0,1,0,1,1,1,1,0,1,0,1,1,1,0,1,1,0,1,0,1,0,0,1,1,0,0,1,0,0,0,0

Desrosiers and Gendron 2004,GhGk-63,1.6,2.1,55.23330312,-77.97867641,Whole assemblage,H. sapiens,No,0,1,0,1,0,1,1,1,1,0,1,0,1,1,1,0,1,1,0,1,0,1,0,0,1,1,0,1,1,0,1,1,1

Rankama and Kankaanpaa 2011,Sujula,9.7,10.5,69.7398619,27.2985125,Blade manufacture on carefully prepared blade cores bifacial crest no debordantes mentioned. abrasion and microchipping (described as core edge trimming flakes) of platform are nearly universal. NO flake tech here. core tablets and distal convexity management are common. RT coded as pieces with backing and burination. ,H. sapiens,Yes,0,1,0,0,1,1,1,0,1,0,1,1,1,1,1,1,1,0,1,1,0,1,0,0,1,1,0,1,0,0,0,1,0

Rankama and Kankaanpaa 2011,Sujula,9.7,10.5,69.70784943,27.2270632,Whole assemblage. Blade manufacture on carefully prepared blade cores bifacial crest no debordantes mentioned. abrasion and microchipping (described as core edge trimming flakes) of platform are nearly universal. NO flake tech here. core tablets and distal convexity management are common. ,H. sapiens,No,0,1,0,0,1,1,1,0,1,0,1,1,1,1,1,1,1,0,1,1,0,1,0,0,1,1,0,1,0,0,1,1,0

This study,Reeve Ranch Ruin,0.6,0.7,32.31329082,-110.5830401,Bipolar percussion of obsidian cobble some of those bipolar flakes are set aside platforms abraded pressure flaked to form arrowheads with tangs. ,H. sapiens,Yes,0,0,0,0,0,0,0,0,0,0,0,0,1,0,1,1,1,1,0,0,0,0,1,0,0,0,0,0,0,0,0,1,1,1

This study and Lagarde and Sand 2013,WKO013A,2.15,3,-21.06393684,164.9890262,Conical and biconical discoid core reduction without platform preparation. Likely soft hammer included. Flakes have removals across ventral and along lateral margins often. ,H. sapiens,Yes,0,0,0,0,0,0,0,0,0,0,1,0,0,0,1,1,0,1,1,0,0,0,1,0,0,1,1,0,1,0,0,0,0,0

This study and Lagarde and Sand 2013,WKO013A,2.15,3,-21.06215543,164.9897814,Whole assembl.,H. sapiens,No,0,0,0,0,0,0,0,0,0,0,1,0,0,0,1,1,1,1,1,0,0,0,1,0,0,1,1,0,1,0,0,0,1,0

Adler et al. 2014,Nor Geghi 1,304,435,40.28481294,44.58552401,Preferential levallois points made on cores on flakes. Debord is described as present but in my classification these are lateral trimming flakes. Flakes are facetted. The assembalge is heavily patinated and worn so less clear about association between pref levall and retouch. Scrapers are common though/ ,?,Yes,0,1,1,1,0,0,0,0,0,0,0,0,1,1,1,0,1,0,0,0,0,1,0,0,1,1,0,0,0,0,0,0,0

Adler et al. 2014,Nor Geghi 1,304,435,40.25654415,44.61048988,Whole assemblage,?,No,0,1,1,1,0,0,0,0,0,1,0,0,1,1,1,0,1,1,0,0,0,1,0,0,1,1,1,0,0,0,1,1,0

Dietler 2013,China Harbor,0.1,0.8,34.06811766,-119.6092747,Microblade manufacture on amorphous core.  Figure 7 of Dietler 2003 thesis with bevelled platform preparation. fig 8. on core on flake. ,H. sapiens,Yes,0,1,0,1,0,0,1,0,1,0,0,0,1,1,1,0,1,1,0,1,0,1,0,0,0,0,0,0,0,0,0,0,0

Cassidy et al. 2014,Eel Point early,7.95,8.55,32.54285752,-118.2500226,Wedge shaped microblade core in figure 6a. ,H. sapiens,Yes,0,0,0,1,1,1,0,0,0,0,0,0,0,1,1,0,1,0,0,0,0,1,0,0,1,0,0,1,0,0,0,1,0

Cassidy et al. 2014,Eel Point early,7.95,8.55,32.50685299,-118.0309959,Whole assemblage,H. sapiens,No,0,0,0,1,1,1,0,0,0,0,0,0,0,1,1,0,1,0,0,0,0,1,0,0,1,1,0,1,0,0,0,1,0

Pavlides and Kennedy 2007,GAC Layers 1-3,2,4.4,-2.0462223,147.2796609,discoidal technology with some platform prep of flakes in form of facetting and backing of tools,H. sapiens,Yes,0,1,0,0,0,0,0,0,0,0,0,0,1,1,1,0,1,0,0,0,0,0,0,0,0,1,0,0,0,0,1,0,0

Pavlides and Kennedy 2007,GAC Layers 1-3,2,4.4,-2.065916269,147.2699546,Whle assemblage,H. sapiens,No,0,1,0,0,0,0,0,0,0,0,0,0,1,1,1,1,1,0,0,0,0,0,0,0,1,1,1,0,0,0,1,0,0

Pavlides and Kennedy 2007,GFJ,2,4.7,-2.082327947,147.0246165,discoidal technology and backing of tools,H. sapiens,Yes,0,0,0,0,0,0,0,0,0,0,0,0,1,1,1,0,1,0,0,0,0,0,0,0,0,1,0,0,0,0,1,0,0

Pavlides and Kennedy 2007,GFJ,2,4.7,-2.030782126,147.0290497,Whole assemblage litle ,H. sapiens,No,0,0,0,0,0,0,0,0,0,0,0,0,1,1,1,0,1,0,0,0,0,0,0,0,1,1,1,0,0,0,1,0,0

Braun et al. 2019,Bokol Dora 1,2580,2610,11.33165518,40.88022214,Simple flake production on rotated cores. no platform prep facetting retouch. ,?,Yes,0,0,0,0,0,0,0,0,0,0,0,0,0,1,1,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0

Braun et al. 2019,Bokol Dora 1,2580,2610,11.30496329,40.77365283,Whole assemblage,?,No,0,0,0,0,0,0,0,0,0,0,0,0,0,1,1,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0

Proffitt et al. 2016,Oitenta,0,0.5,NA,NA,Striking of hammers onto anvil/substrate resulting in flake removals. ,S. libidinosus,Yes,0,0,0,0,0,0,0,0,0,0,0,0,0,0,1,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0

Mercader et al. 2006,Noulo,2.5,4.5,NA,NA,hard hammers and used to strike nuts on anvils,P. troglodytes,Yes,0,0,0,0,0,0,0,0,0,0,0,0,0,0,1,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0

Visalberghi et al. 2015,Tai,0,0,NA,NA,hard hammers and used to strike nuts on anvils,P. troglodytes,Yes,0,0,0,0,0,0,0,0,0,0,0,0,0,0,1,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0

Visalberghi et al. 2015,Fazenda Boa Vista,0,0,NA,NA,hard hammers and used to strike nuts on anvils,S. libidinosus,Yes,0,0,0,0,0,0,0,0,0,0,0,0,0,0,1,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0

Gumert and Malaivijitnond 2012,Lameson National Park,0,0,NA,NA,hard hammers and used to strike nuts on anvils,M. fascicularis aurea,Yes,0,0,0,0,0,0,0,0,0,0,0,0,0,0,1,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0

Moore and Perston 2015,Spandrels experiment,0,0,NA,NA,Acheulean handaxe no retouch invasive flaking.,,Yes,0,0,0,0,0,0,0,0,0,0,0,0,0,1,1,0,1,0,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0

Moore and Perston 2015,Spandrels experiment,0,0,NA,NA,Proto-levallois core convexities arguably shaped through centripetal removals but no facetting of platform/preparation. No retouch. ,,Yes,0,0,1,0,0,0,0,0,0,0,0,0,0,1,1,0,1,0,0,0,0,1,0,0,0,0,0,1,0,0,0,0,0

Roussell et al. 2016,Quinçay Cave,40,45,46.58398956,0.195720308,Chatelperronian retouched bladelets from cores prepared by cresting some examples of distal convexities managed and core tablets. and debordantes,H. neanderthalensis,Yes,0,1,0,0,1,0,1,1,0,0,1,0,1,1,1,0,1,0,0,0,0,1,0,0,1,1,0,0,0,0,0,0,0

Otte 1990 and 1994,Rocourt,50,70,50.69598512,5.425447734,Laminar flakes that are burinated and backed. produced through a recurrent blade production sequence with initial cresting lat convexity and distal convexity maintenance through debordantes. No sign of soft hammer or indirect hammer. ,H. neanderthalensis,Yes,0,1,0,0,0,0,1,1,1,0,0,0,0,1,1,0,1,0,0,0,0,1,0,0,1,1,0,1,0,0,0,0,0

Slimak 1999,Champ Grande,50,71,46.04172111,4.024501706,Blades relying on initial shape of cobble with natural dihedral corner. shaping is slight some cresting to form corner better. Examples in fig. 8. 2 3 4. facetting performed. some bipolar percussion Slimak suggests is used to maintain distal convexity. Cautious in describing tablets as present. So no tablets. Soft hammer seems maybe but they don't say for sure present as far as I can tell. ,H. neanderthalensis,Yes,0,1,0,0,1,0,1,0,0,0,0,0,0,1,1,0,1,1,0,0,0,1,0,0,1,0,0,1,0,0,0,0,0

Slimak 1999,Champ Grande,50,71,45.96446778,4.018863746,Whole assemblage,H. neanderthalensis,No,0,1,0,0,1,0,1,0,0,0,0,0,1,1,1,0,1,1,0,0,0,1,0,0,1,1,1,1,0,0,0,0,0

Leach and Leach 2019,Oterahua,0.72,1,-45.35223749,170.0648364,Blade reduction at Oturehua,H. sapiens,No,0,0,0,0,1,0,0,1,0,0,1,0,0,1,0,0,1,0,0,0,0,1,0,0,1,0,0,0,0,0,0,0,0

Smith et al. 1996,Shag River Mouth,0.55,0.75,-45.45886807,171.0774654,Whole assemblage,H. sapiens,No,0,1,0,0,1,0,1,1,0,1,1,0,0,1,1,1,1,1,0,0,1,1,0,0,1,1,1,1,0,0,1,0,0

Smith et al. 1996,Shag River Mouth,0.55,0.75,-45.4744417,169.7598902,blade reductoin bidirectional no cresting initiation and retouch of burinated blades,H. sapiens,yes,0,1,0,0,1,0,0,1,0,0,1,0,0,1,1,0,1,0,0,0,0,1,0,0,1,0,0,1,0,0,0,0,0

Walter and Green 2011,Su'ena,0.45,0.6,-10.16849668,161.7653324,"Chert ""tranchet"" adzes",H. sapiens,yes,0,0,0,0,0,0,0,0,0,0,0,0,0,1,1,0,1,0,0,0,1,0,0,0,1,1,0,0,0,1,0,1,0

Walter and Green 2011,Su'ena,0.45,0.6,-10.15949548,161.6615692,All includes chert adzes ad hoc rt on flakes mentions of blades but not description of features aside from prismatic cross section. ,H. sapiens,No,0,0,0,0,0,0,0,0,0,0,0,0,0,1,1,0,1,0,0,0,0,1,0,0,1,1,0,0,0,0,0,1,0

Nishiaki et al. 2013,Tepe Rahmatabad,7.7,8.7,30.15829549,53.18732812,Whole assemblage,H. sapiens,No,0,1,0,0,1,0,1,0,0,0,1,0,1,1,1,1,1,0,0,1,0,1,0,0,1,1,1,1,0,0,0,0,0

Fredericksen 1994,Pamwak Rockshelter Phase II-IV,5,12.5,-2.096399811,146.9882254,Whole assemblage,H. sapiens,No,0,0,0,0,0,0,0,0,0,0,0,1,0,1,1,1,1,0,0,0,1,1,0,0,1,1,0,0,0,0,0,0,0

Ariel-Shatil 2006,Sha'ar Hagolan,7,7.4,32.68996622,35.57355857,Whole assemblage,H. sapiens,No,0,0,0,0,0,0,1,0,0,0,1,0,0,1,1,0,1,0,0,0,1,1,0,0,1,1,1,1,1,0,1,1,1

This study and Stebbins 1986,NA 11047,0.7,0.9,36.56487847,-110.5840265,Whole assemblage,H. sapiens,No,0,0,0,0,0,0,0,0,0,1,0,1,1,1,1,1,1,1,0,0,1,0,0,0,1,1,1,0,1,0,1,1,1

This study and Stebbins 1986,NA 11057,0.7,0.9,36.47795545,-110.9008653,Whole assemblage,H. sapiens,No,0,0,0,0,0,0,0,0,0,0,0,1,1,1,1,1,1,1,0,0,1,0,0,0,1,1,1,1,1,0,1,1,1

Allen et al. 2011,Oposisi,1.5,2,-8.86280511,146.504627,Whole assemblage,H. sapiens,No,0,0,0,0,0,0,0,0,0,0,0,0,0,1,1,1,1,0,0,0,1,0,0,0,1,0,0,0,0,0,0,0,0

Reepmeyer et al. 2010,Teouma,2.5,3.2,-17.75163141,168.340968,Whole assemblage,H. sapiens,No,0,0,0,0,0,0,0,0,0,0,0,0,0,1,1,1,1,0,0,0,0,0,0,0,1,1,1,0,0,0,0,0,0

David et al. 2019,Moiapu 3,2,2.55,-9.352347619,147.0739003,Whole assemblage,H. sapiens,No,0,0,0,0,0,0,0,0,0,0,0,0,0,1,1,1,1,1,0,0,0,0,0,0,0,1,0,0,0,0,0,0,0

Leach and Leach 1980,Riverton adze quarry,0.5,0.7,-46.30029151,167.917795,Whole assemblage,H. sapiens,No,0,1,0,0,1,0,1,0,1,0,0,1,1,1,1,0,1,0,0,0,1,1,0,0,1,1,1,0,1,0,1,0,0

Wilson 1999,Cat's eye point,0.5,0.9,-45.22089247,171.0104432,Whole assemblage,H. sapiens,No,0,1,0,0,1,0,0,0,1,0,0,0,0,1,1,1,1,0,0,0,1,1,0,0,1,0,0,0,1,0,0,0,0

Walling 1988,Little man 1,0.95,1,37.25185198,-113.4187682,Whole assemblage,H. sapiens,No,0,0,0,0,0,0,0,0,0,0,0,1,0,1,1,0,1,1,0,0,1,1,0,0,1,0,0,0,0,0,1,1,1

Walling 1988,Little man 2,0.95,1,37.12205008,-113.3972176,Whole assemblage,H. sapiens,No,0,0,0,0,0,0,0,0,0,0,0,1,0,1,1,0,1,1,0,0,1,1,0,0,1,1,1,0,1,0,1,1,1

Walling 1988,Little man 3,1,1.2,37.17524615,-113.3509298,Whole assemblage,H. sapiens,No,0,0,0,0,0,0,0,0,0,0,0,1,0,1,1,0,1,1,0,0,1,1,0,0,1,1,1,0,1,0,1,1,1

Walling 1988,Little man sites,0.5,1.2,37.14021725,-113.2878829,Whole assemblage,H. sapiens,No,0,0,0,0,0,0,0,0,0,0,0,1,0,1,1,0,1,1,0,0,1,1,0,0,1,1,1,0,1,0,1,1,1

Wambach 2014,Lava Ridge Ruin,0.8,0.95,36.02508839,-113.1230757,Whole assemblage,H. sapiens,No,1,0,0,0,0,0,0,0,0,0,0,1,0,1,1,1,1,1,0,0,1,0,0,0,1,1,1,0,1,0,1,1,1

Wambach 2014,Granary House,0.85,1,36.13505053,-111.8806371,Whole assemblage,H. sapiens,No,1,0,0,0,0,0,0,0,0,0,0,1,0,1,1,0,1,1,0,0,1,0,0,0,1,0,1,0,1,0,1,1,1

Wambach 2014,Andrus Canyon,0.8,0.95,36.00499034,-114.0868959,Whole assemblage,H. sapiens,No,1,0,0,0,0,0,0,0,0,0,0,1,0,1,1,0,1,1,0,0,1,0,0,0,1,1,1,0,1,0,1,1,1

Wambach 2014,Corn Cob,0.7,0.8,36.05417945,-112.7989358,Whole assemblage,H. sapiens,No,1,0,0,0,0,0,0,0,0,0,1,0,1,1,0,1,1,0,0,1,0,0,0,1,0,1,0,1,0,1,1,1

Wambach 2014,Coyote,0.7,0.8,36.06372806,-111.5546725,Whole assemblage,H. sapiens,No,1,0,0,0,0,0,0,0,0,0,1,0,1,1,0,1,1,0,0,1,0,0,0,1,1,1,0,1,0,1,1,1

Wambach 2014,Site 232,0.85,1,36.15603739,-112.7259377,Whole assemblage,H. sapiens,No,1,0,0,0,0,0,0,0,0,0,1,0,1,1,0,1,1,0,0,1,0,0,0,1,1,1,0,1,0,1,1,1

Wambach 2014,Peter's Pocket,0.85,1,36.02824023,-114.5423536,Whole assemblage,H. sapiens,No,1,0,0,0,0,0,0,0,0,0,1,0,1,1,0,1,1,0,0,1,0,0,0,1,1,1,0,1,0,1,1,1

Wambach 2014,To'tsa,0.7,0.8,36.13239593,-113.8315757,Whole assemblage,H. sapiens,No,1,0,0,0,0,0,0,0,0,0,1,0,1,1,0,1,1,0,0,1,0,0,0,1,1,1,0,1,0,1,1,1

Love-dePeyer 1980,5LP110 and 111,1.17,1.2,37.30130165,-107.8535436,Whole assemblage,H. sapiens,No,0,1,0,0,0,0,0,0,0,0,1,0,1,1,0,1,0,0,0,1,0,0,0,1,1,1,0,1,0,1,1,1

Araho et al. 2002,Willaumez Peninsula,3.5,6,-5.186251062,150.0622268,Whole assemblage,H. sapiens,No,0,1,0,0,0,0,1,0,0,1,0,0,1,1,1,0,1,0,0,0,1,1,0,0,1,1,1,0,1,0,1,1,0

Araho et al. 2002,Willaumez Peninsula,3.5,6,-5.256978406,150.1505262,Type 1. tools. Stemmed blades,H. sapiens,Yes,0,0,0,0,0,0,1,0,0,0,0,0,0,1,1,0,1,0,0,0,0,1,0,0,1,1,1,0,1,0,1,1,0

Araho et al. 2002,Willaumez Peninsula,3.5,6,-5.24890777,149.9349916,Type 2. tools,H. sapiens,Yes,0,1,0,0,0,0,0,0,0,1,0,0,1,1,1,0,1,0,0,0,1,1,0,0,1,1,1,0,1,0,1,1,0

This study,AZ BB:2:19,0.5,0.7,32.84102469,-110.3098841,Whole assemblage,H. sapiens,No,0,0,0,0,0,0,0,0,0,0,0,1,1,1,1,1,1,0,0,1,0,0,0,1,1,0,0,1,0,1,1,1

This study,AZ BB:11:26,0.57,0.7,32.33844901,-110.4568765,Whole assemblage,H. sapiens,No,0,0,0,0,0,0,0,0,0,0,1,1,1,1,1,1,1,0,0,1,0,0,0,1,1,0,1,1,0,1,1,1

This study,AZ BB:11:36,0.57,0.7,32.30905322,-110.4838312,Whole assemblage,H. sapiens,No,0,0,0,0,0,0,0,0,0,0,0,0,1,1,1,1,0,0,0,1,0,0,0,1,0,0,0,1,0,1,1,1

This study,AS.13.41 XU-4,1,2.7,-14.10273712,-168.107941,Whole assemblage,H. sapiens,No,0,1,0,0,0,0,1,0,0,0,0,1,1,1,1,1,1,1,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0

This study,Pitcairn sites,0.3,0.6,-25.04299085,-130.1609328,Whole assemblage,H. sapiens,No,0,1,0,1,1,0,1,0,1,1,1,1,1,1,1,1,1,1,0,1,1,0,0,1,1,1,1,1,1,1,1,0

Lindeman 1995 and Adams 1995,Pyramid Point V:5:1,0.6,0.7,33.6650459,-111.0774212,Whole assemblage,H. sapiens,No,0,0,0,0,0,0,0,0,0,0,0,0,1,1,0,1,0,0,0,1,0,0,0,1,1,1,0,1,0,1,1,1

Lindeman 1995 and Adams 1995,Meddler Point V:5:4,0.65,1.2,33.71921504,-111.0071531,Whole assemblage,H. sapiens,No,0,0,0,0,0,0,0,0,0,0,0,0,1,1,1,1,0,0,0,1,0,0,0,1,1,1,0,1,0,1,1,1

Lindeman 1995 and Adams 1995,Griffin Wash B V:5:90,0.65,0.7,33.60748322,-111.0537662,Whole assemblage,H. sapiens,No,0,0,0,0,0,0,0,0,0,0,0,0,1,1,0,1,0,0,0,1,0,0,0,1,1,1,0,1,0,1,1,1

Lindeman 1995 and Adams 1995,Griffin Wash A V:5:90,0.6,0.7,33.74410681,-110.9633263,Whole assemblage,H. sapiens,No,0,0,0,0,0,0,0,0,0,0,0,0,1,1,0,1,0,0,0,1,0,0,0,1,1,1,0,1,0,1,1,1

Lindeman 1995 and Adams 1995,Hedge Apple V:5:189,1.1,1.2,33.60195345,-110.8960023,Whole assemblage,H. sapiens,No,0,0,0,0,0,0,0,0,0,0,0,0,1,1,0,1,0,0,0,1,0,0,0,1,1,1,0,1,0,1,1,1

Lindeman 1995 and Adams 1995,Eagle Ridge A V:5:104,0.6,1,33.57784763,-110.9421212,Whole assemblage,H. sapiens,No,0,0,0,0,0,0,0,0,0,0,0,0,0,1,1,0,1,0,0,0,1,0,0,0,1,1,1,0,1,0,1,1,1
Lindeman 1995 and Adams 1995,Eagle Ridge B V:5:104,1.45,1.85,33.61781034,-111.0126885,Whole assemblage,H. sapiens,No,0,0,0,0,0,0,0,0,0,0,0,0,0,1,1,1,1,0,0,0,1,0,0,0,1,1,1,0,1,0,1,1,1
Lindeman 1995 and Adams 1995,Porcupine Site V:5:106,0.65,0.7,33.57496526,-111.0063121,Whole assemblage,H. sapiens,No,0,0,0,0,0,0,0,0,0,0,0,0,0,1,1,0,1,0,0,0,1,0,0,0,1,0,0,0,1,0,1,1,1
Gaffney et al. 2015,Kiowa levels 10-12,10.2,12.5,-6.101221787,145.2146416,Whole assemblage,H. sapiens,No,0,0,0,0,0,0,0,0,0,0,0,0,0,1,1,1,1,0,0,0,0,0,0,0,1,0,0,0,0,0,0,0,0
Gaffney et al. 2015,Kiowa levels 2-6,5.3,7.1,-6.091368104,145.223828,Whole assemblage,H. sapiens,No,0,0,0,0,0,0,0,0,0,0,0,1,0,1,1,1,1,0,0,0,1,0,0,0,1,0,1,0,1,0,0,0,0
Sheppard 1993,Reef Island Sites,2.8,3.3,-10.39283801,166.3038181,Whole assemblage,H. sapiens,No,0,0,0,0,0,0,0,0,0,0,1,0,1,1,1,1,1,0,0,0,0,1,0,0,1,1,1,0,0,0,0,0,0

# APPENDIX III

# TECHNOLOGICAL MODE DATA

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Collected,Cite.text,Sitename,KA.young,KA.old,Lat,Long,Species.attribution,MODE.B.B
ipolar,MODE.C.PebCore,MODE.D1.SNDs,MODE.D2.Bkd.Trnc,MODE.D3.Micro,MO
DE.D4.Burin,MODE.D5.Point,MODE.D6.Tanged,MODE.D7.Core.Flk,MODE.E1.LCT,
MODE.E2.Thin.BFC,MODE.E3.TangedBF,MODE.E4.Celt,MODE.F1.Pref.BHC,MODE
.F2.RecLam.BHC,MODE.F3.Rad.Cent.BHC,MODE.G1.PltfrmUHCr,MODE.G2.BladeC
R,MODE.G3.MicrobldCR,MODE.H.Edge.Abrd,MODE.I.Grndstn
JS,Shea 2013,Ebo Forest,0,0,NA,NA,P. trog,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
JS,Shea 2013,Bossu,0,0,NA,NA,P. trog,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
JS,Shea 2013,Diecke,0,0,NA,NA,P. trog,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
JS,Shea 2013,Tai¯ Forest,0,0,NA,NA,P. trog,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
JS,Shea 2013,Sapo Forest,0,0,NA,NA,P. trog,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
JP,Perston and Moore 2016,Randomized flaking
experiment,0,0,NA,NA,NA,0,1,0,0,0,1,0,0,1,1,0,0,0,1,0,0,0,0,0,0,0
JS,Shea 2013,Sacoglotis B,1,1,NA,NA,P. trog,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
JP,This study and Stebbins 1986,NA 11047,0.7,0.9,36.51475614,-110.7088995,H.
sapiens,1,1,1,1,0,0,1,0,1,1,1,1,0,0,0,0,1,0,0,0,1
JP,This study and Stebbins 1986,NA 11057,0.7,0.9,36.4235781,-110.9785013,H.
sapiens,1,1,1,1,0,0,1,0,1,1,1,1,0,0,0,0,1,0,0,0,1
JP,This study,AZ BB:2:19,0.5,0.7,32.7828286,-111.0196604,H.
sapiens,1,1,1,1,0,0,1,0,0,1,1,1,0,0,0,0,1,0,0,0,1
JP,This study,AZ BB:11:26,0.57,0.7,32.33505914,-110.6022953,H.
sapiens,1,1,1,1,0,0,1,0,1,1,1,1,0,0,0,0,1,0,0,0,1
JP,This study,AZ BB:11:36,0.57,0.7,32.41092235,-110.3248187,H.
sapiens,1,1,1,0,0,0,1,0,1,1,1,1,0,0,0,0,1,0,0,0,1
JP,This study and Smith 1996,Shag River Mouth,0.65,0.7,-45.48322099,170.9094955,H.
sapiens,0,1,1,0,0,1,1,0,1,0,0,0,1,0,0,0,1,1,0,0,1
JP,This study,AS.13.41 XU-4,1,2.7,-14.17986419,-169.1990228,H.
Sapiens,1,1,0,0,0,0,0,0,1,1,0,0,0,0,0,0,0,0,0,1,1
JP,This study and Lagarde and Sand 2013,WKO013A,2.5,3,-
21.13454902,164.7969356,H. sapiens,1,1,1,0,1,1,1,0,1,0,0,0,0,0,0,0,1,0,1,0,1
JP,This study,Pitcairn sites,0.3,0.6,-25.04475536,-130.1742272,H.
sapiens,1,1,1,0,0,1,1,0,1,1,0,0,1,0,0,0,0,0,0,1,1
JP,Cassidy et al. 2004,Eel Point CA-SCLI-43 Late Holocene,0.1,3.5,32.50533006,-
118.1007477,H. sapiens,0,1,1,1,0,0,1,0,0,0,1,1,0,0,0,0,1,0,0,0,1
JP,Pavlides et al. 2007,GAC Layers 1-3,0.2,4,-2.017279374,147.5444495,H.
sapiens,1,1,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,1
JS,Shea 2013,Noulu,2,4,NA,NA,Pan trog.,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
JS,Shea 2013,Panda 100,2,4,NA,NA,Pan trog.,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
JP,Cassidy et al. 2004,Eel Point CA-SCLI-43 Late to Middle
Holocene,3.5,4.6,32.49772424,-118.1177341,H.
sapiens,0,1,1,1,0,0,0,0,0,1,1,0,0,0,0,1,0,0,0,1
JS,Shea 2020,Korounkorokale,1,5.1,12.41083713,-8.219352329,H.
sapiens,0,1,1,1,1,0,1,0,0,1,0,0,1,0,0,0,1,0,1,1,1
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JP,Cassidy et al. 2004,Eel Point CA-SCLI-43 Middle Holocene,5.5,6.4,32.46801042,118.1388098,H. sapiens,0,1,1,1,0,0,0,0,0,0,1,1,0,0,0,0,1,0,0,0,1
JP,Shea 2020,El Zafrin,6.3,6.5,35.23910837,-2.385895433,H. sapiens,1,1,1,1,1,0,1,0,0,0,0,0,0,0,0,1,0,1,1,1,1
JS,Shea 2013,Catal Huyuk,6.2,7.5,37.70884643,32.75503316,H. sapiens,1,1,0,0,0,0,1,1,0,1,1,1,1,0,0,0,0,1,0,1,1
JS,Shea 2013,Ain Rahub,6.5,8.4,32.47498945,35.76125551,H. sapiens,0,1,1,1,0,1,1,1,1,1,0,0,1,0,0,0,1,1,0,0,0
JS,Shea 2013,Ashkelon,6.5,8.4,31.71607337,34.48214718,H. sapiens,1,1,1,1,0,1,1,1,1,0,0,0,1,0,0,0,1,1,0,1,1
JS,Shea 2013,Jericho PN,6.5,8.4,31.80519584,35.41359729,H. sapiens,0,0,1,1,1,0,1,1,0,0,1,1,1,0,0,0,0,0,0,1,1
JS,Shea 2013,Munhata Levels 2-6,6.5,8.4,32.64487588,35.57920812,H. sapiens,1,1,1,1,0,1,1,1,1,1,0,0,1,0,0,0,1,1,0,1,1
JS,Shea 2013,Shar Hagolan,6.5,8.4,32.71902168,35.68114284,H. sapiens,1,1,1,1,0,1,1,1,1,0,0,0,1,0,0,0,1,0,1,1,1
JS,Shea 2013,Umm Meshrat I,6.5,8.4,31.68461341,35.8052795,H. sapiens,1,1,1,1,0,1,1,1,1,0,0,0,0,0,0,1,1,1,0,0
JP,Cassidy et al. 2004,Eel Point early,7.9,8.5,32.52571752,-118.3610431,H. sapiens,0,1,1,1,1,1,0,0,0,0,0,0,0,0,0,0,1,0,1,0,1
JP,Shea 2013,Tepe Rahmatabad,7.7,8.7,30.11546341,53.13950157,H. sapiens,0,1,1,1,1,1,0,0,0,0,0,0,0,0,0,0,0,0,1,0,0
JS,Shea 2013,El Inga Lower,9,9,0.046680146,-78.56315699,H. sapiens,0,0,1,0,0,1,1,1,0,0,1,1,1,0,0,0,1,0,0,0,0
JP,Tsydenova and Piezonka 2015,Krasnaya Gorka,9.1,9.5,52.71009709,113.8573911,H. sapiens,0,1,1,1,1,1,1,0,0,1,1,0,0,0,0,0,0,0,1,0,0
JS,Shea 2013,Sloan,10,10.5,35.7868759,-90.45119684,H. sapiens,1,1,1,1,0,1,1,0,0,1,1,1,1,0,0,0,0,0,0,1,1
JS,Shea 2013,Lindenmeier Colorado,10.6,10.7,40.90238472,-104.9231803,H. sapiens,1,1,1,1,0,1,0,0,0,0,1,1,0,0,0,0,0,0,0,0,1
JS,Shea 2013,Dry Creek Levels I-II,9,11,64.10297625,-149.3359238,H. sapiens,0,1,1,1,0,0,0,0,0,0,1,1,0,0,0,0,1,0,1,0,0
JS,Shea 2013,Vail Maine,10,11,45.00785664,-70.87788694,H. sapiens,1,0,1,1,0,0,1,0,1,0,1,1,0,0,0,0,0,0,0,0,0
JS,Shea 2013,Debert,10,11,45.4007058,-63.01879672,H. sapiens,1,1,1,0,0,1,1,0,0,0,1,1,0,0,0,0,1,0,0,0,0
JS,Shea 2013,Hanson,10,11,44.7195009,-108.0179495,H. sapiens,0,1,1,0,0,1,1,0,0,0,1,1,0,0,0,0,0,0,0,0,0
JS,Shea 2013,Murray Springs,10,11,31.53175989,-110.1691704,H. sapiens,0,1,1,0,0,0,1,0,1,1,1,0,0,0,0,0,0,1,0,0,0
JS,Shea 2013,Topper,10,11,33.01141103,-80.98756995,H. sapiens,0,1,1,1,0,0,1,0,0,1,1,1,0,0,0,0,1,1,0,0,0
JS,Shea 2013,Liang Bua Level 9,3,11,-8.595009542,120.3424448,H. sapiens,1,1,1,1,0,0,1,0,0,0,0,0,1,0,0,0,0,0,0,1,0
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JS,Shea 2013,Byblos,11,11.5,34.11816679,35.62254653,H.
sapiens,0,1,1,1,1,1,1,1,0,1,0,0,1,0,0,0,1,1,1,1,1
JS,Shea 2013,Mureybit Phases III-IV,11,11.5,36.11631178,38.5727715,H.
sapiens,1,1,1,1,0,1,1,1,1,0,0,1,1,0,0,0,1,1,1,0,1
JS,Shea 2013,Abu Ghosh,11,11.5,31.83522254,35.08167988,H.
sapiens,1,1,1,1,0,1,1,1,1,0,0,0,1,0,0,0,1,1,0,1,1
JS,Shea 2013,Ain Ghazal,11,11.5,31.97318357,35.98566607,H.
sapiens,1,1,1,1,1,1,1,1,1,1,1,0,1,0,0,0,1,1,0,1,1
JS,Shea 2013,Beidha I-VI,11,11.5,30.40729326,35.46124242,H.
sapiens,0,1,1,1,0,1,1,1,1,1,0,0,1,0,0,0,1,1,0,1,1
JS,Shea 2013,Jericho  PPNB,11,11.5,31.84346549,35.52694755,H.
sapiens,0,0,1,1,0,1,1,0,0,1,0,1,1,0,0,0,0,0,0,1,1
JS,Shea 2013,Kfar HaHoresh,11,11.5,32.67571989,35.06292309,H.
sapiens,0,1,1,1,1,1,1,1,0,1,1,0,1,0,0,0,1,1,0,1,1
JS,Shea 2013,Nahal Hemar,11,11.5,31.06423798,35.34661135,H.
sapiens,0,0,0,1,0,0,1,1,0,0,0,0,0,0,0,0,1,1,0,0,1
JS,Shea 2013,Nahal Issaron,11,11.5,29.89871389,33.32140665,H.
sapiens,0,1,1,0,0,1,1,1,0,0,0,0,0,0,0,0,1,1,0,0,1
JS,Shea 2013,Tel 'Ali,11,11.5,32.65653729,35.47357882,H.
sapiens,1,1,1,1,0,1,1,1,0,0,1,0,1,0,0,0,1,1,1,0,1
JS,Shea 2013,Mesa,11,12,67.92619787,-156.0998984,H.
sapiens,0,1,1,1,0,1,1,0,0,0,1,1,0,0,0,0,0,0,0,0,0
JS,Shea 2013,Walker Road,11,12,64.1516726,-149.4459927,H.
sapiens,0,0,1,0,0,0,1,0,0,0,0,1,0,0,0,0,1,1,0,0,0
JS,Shea 2013,Turrialba,10,12,9.901515142,-83.58152684,H.
sapiens,0,1,1,1,0,1,1,0,0,1,1,1,0,0,0,0,1,1,0,0,0
JS,Shea 2013,Guitarrero Cave Levels I-II,10,12,-9.244222593,-77.69884135,H.
sapiens,0,1,1,0,0,1,1,0,0,1,1,1,1,0,0,0,1,1,0,0,1
JS,Shea 2013,Shawnee-Minisink Units 1-4,11,12,41.04213848,-75.10151463,H.
sapiens,1,1,1,0,0,0,1,0,0,0,1,1,0,0,0,0,1,0,0,0,0
JS,Shea 2013,Old Riverbed Delta,9,12,40.5839177,-113.4593103,H.
sapiens,1,1,1,1,0,0,1,0,0,1,1,1,1,0,0,0,0,0,1,0,0
JS,Shea 2013,Dhra,11,12.2,31.18769053,35.55465668,H.
sapiens,0,1,1,1,0,0,1,1,0,1,0,0,1,0,0,0,0,1,1,1,1
JS,Shea 2013,Gilgal I,11,12.2,31.97579592,35.52203827,H.
sapiens,1,0,1,1,1,1,1,1,1,0,1,0,1,0,0,0,0,1,1,1,1
JS,Shea 2013,Hatoula L.2 PPN,11,12.2,31.85183263,35.14255022,H.
sapiens,0,1,1,1,1,1,1,1,1,0,0,0,1,0,0,0,0,1,1,1,1
JS,Shea 2013,Iraq ed-Dubb,11,12.2,32.37531223,35.71438594,H.
sapiens,0,0,1,1,1,1,1,1,1,0,0,0,1,0,0,0,1,1,1,0,0
JS,Shea 2013,Jericho  PPNA,11,12.2,31.87758583,35.50569016,H.
sapiens,0,1,1,1,0,1,1,0,0,1,0,1,1,0,0,0,1,1,0,1,1
JS,Shea 2013,Jericho Proto-Neolithic to PPNA,11,12.2,31.87302178,35.53002394,H.
sapiens,0,0,1,1,0,1,1,0,0,1,0,1,1,0,0,0,1,1,0,0,1
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JS,Shea 2013,Netiv Hagdud,11,12.2,31.87293617,35.46068355,H. sapiens,1,1,1,1,1,1,1,1,0,1,0,0,1,0,0,0,1,1,1,1,1
JS,Shea 2013,Salibiya IX,11,12.2,31.93425292,35.43633418,H. sapiens,1,1,1,1,1,1,1,1,0,0,0,0,0,0,0,0,0,1,1,0,1
JS,Shea 2013,Wadi Feinan 16,11,12.2,30.66135197,35.58233537,H. sapiens,0,1,1,1,1,1,1,1,0,1,0,0,1,0,0,0,1,1,1,1,1
JS,Shea 2013,Abu Hureyra 1,11.5,12.5,35.88211297,38.17701677,H. sapiens,0,1,1,1,1,1,1,0,0,0,0,0,1,0,0,0,1,1,1,0,1
JS,Shea 2013,Abu Salem SMU-G12,11.5,12.5,30.64841549,34.44767461,H. sapiens,0,1,1,1,1,1,1,1,1,0,0,0,0,0,0,0,0,1,1,0,1
JS,Shea 2013,Salibiya I,11.5,12.5,31.78947764,35.42701211,H. sapiens,0,0,1,1,1,1,1,0,0,0,0,0,0,0,0,0,1,1,1,0,0
JS,Shea 2013,Monte Verde Level II,12.4,12.8,-41.42997364,-73.19728128,H. sapiens,0,1,1,0,0,0,0,0,0,1,1,0,0,0,0,0,0,0,0,0,1
JS,Shea 2013,Fell's Cave Levels 18-20 or Bird's Layer V,12.1,12.8,-52.69689241,-70.16366152,H. sapiens,0,0,1,0,0,0,1,0,0,0,0,1,1,0,0,0,0,0,0,0,0
JS,Shea 2013,Gault Level 3 Texas,12,13,30.93268521,-97.68444939,H. sapiens,0,0,1,1,0,0,0,0,0,0,1,1,1,0,0,0,0,1,0,0,0
JS,Shea 2013,Quebrada Tacahuay,12,13,-17.86957678,-70.7307022,H. sapiens,0,0,1,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0
JS,Shea 2013,Quebrada Jaguay,11,13,-16.34261154,-73.07687199,H. sapiens,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
JS,Shea 2013,Crowfield,12,13,42.85067878,-81.55168324,H. sapiens,0,0,1,0,0,0,1,0,0,1,1,1,0,0,0,0,0,0,0,0,0
JP,Jayez and Nasab 2016,Khomishan cave levels I-XIII,12.6,13.7,36.68881235,53.30216248,H. sapiens,0,1,1,1,1,1,1,1,1,0,0,0,0,0,0,1,0,1,1,0,0
JS,Shea 2013,Ushki 1 Levels V-VII,9,14,55.73299741,159.9393375,H. sapiens,0,0,1,1,0,1,0,0,0,0,1,1,0,0,0,0,0,1,1,0,0
JS,Shea 2013,Swan Point,11.4,14.5,64.28486534,-147.1770333,H. sapiens,1,1,1,1,0,1,1,0,0,0,0,1,0,0,0,0,1,1,1,0,0
JS,Shea 2013,Pushkari I,15,15,53.07342892,34.17137028,H. sapiens,0,0,1,1,1,1,1,0,1,0,0,0,1,0,0,0,1,1,1,0,0
JS,Shea 2013,Timonovka I,14,15,53.12059142,34.55609853,H. sapiens,0,0,1,1,1,1,1,0,0,0,0,0,0,0,0,0,0,1,1,0,0
JS,Shea 2013,Timonovka II,15,15,53.0689291,34.70578969,H. sapiens,0,0,1,1,1,1,1,0,0,0,0,0,0,0,0,0,0,1,1,0,0
JS,Shea 2013,Ain Mallaha,12,15,32.99868678,35.593682,H. sapiens,1,1,1,1,1,1,1,0,1,1,0,0,1,0,0,0,1,1,1,0,1
JS,Shea 2013,Baaz Rockshelter AH II-III,12,15,33.34241118,35.71401192,H. sapiens,0,1,1,1,1,0,1,1,0,0,0,0,0,0,0,1,1,1,1,0,1
JS,Shea 2013,Hatoula Locus 3,12,15,31.83532646,35.02480758,H. sapiens,0,1,1,1,1,1,1,0,0,0,0,0,0,0,0,0,0,1,1,0,0
JS,Shea 2013,Hayonim Cave Level B,12,15,32.80438915,35.21251162,H. sapiens,0,1,1,1,1,1,1,0,0,1,0,0,1,0,0,0,1,1,1,0,1
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JS,Shea 2013,Jericho Natufian,12,15,31.9591069,35.45172243,H.
sapiens,0,0,1,1,1,1,0,0,0,0,0,0,0,0,0,0,0,1,0,0
JS,Shea 2013,Mureybit Phases I-II,12,15,36.08007921,38.02363834,H.
sapiens,1,1,1,1,1,1,1,1,1,1,0,1,1,0,0,0,1,1,0,0,1
JS,Shea 2013,Rosh Horesha,12,15,30.68709624,34.68273282,H.
sapiens,0,1,1,1,1,1,1,0,1,0,0,0,0,0,0,0,1,1,1,0,1
JS,Shea 2013,Rosh Zin,12,15,30.95553067,34.88952873,H.
sapiens,0,1,1,1,1,1,1,0,0,0,0,0,1,0,0,0,1,1,1,0,1
JS,Shea 2013,Wadi Hammeh 27,12,15,32.52551267,35.54413942,H.
sapiens,0,1,1,1,1,1,1,0,0,0,0,0,1,0,0,0,0,0,1,0,1
JS,Shea 2013,Wadi Judayid J2,12,15,29.90969298,34.85585979,H.
sapiens,0,1,1,1,1,1,1,0,0,0,0,0,0,0,0,0,0,1,1,0,1
JS,Shea 2013,Klithi,10,16,39.9985557,20.5567121,H.
sapiens,0,1,1,1,1,1,1,0,1,0,0,0,0,0,0,0,1,1,1,0,0
JS,Shea 2013,Radomyshl',16,16,50.97995478,29.85965862,H.
sapiens,0,0,1,1,1,1,1,0,1,0,0,0,1,0,0,0,1,1,1,0,0
JS,Shea 2013,Dyuktai Cave,12,16,60.315227,134.6082658,H.
sapiens,0,1,1,1,0,1,0,0,0,1,1,1,0,0,0,0,1,1,1,0,0
JS,Shea 2013,Bone Cave Upper Levels,15,17,-43.0082335,146.4709395,H.
sapiens,1,1,1,0,0,1,0,0,1,0,0,0,0,0,0,0,1,0,0,0,0
JS,Shea 2013,Liang Bua Level 7,11,17,-8.590717674,120.4813977,H.
sapiens,0,1,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
JS,Shea 2013,Suyannggeae,15,18,37.01638776,128.487769,H.
sapiens,0,1,1,1,1,1,1,1,0,0,0,0,1,0,0,0,0,1,1,1,0
JS,Shea 2013,Azariq IX,15,18,30.94598864,34.32367166,H.
sapiens,0,1,1,1,1,1,0,0,0,0,0,0,0,0,0,0,0,1,1,0,1
JS,Shea 2013,Azariq XVI,15,18,30.94168334,34.50184998,H.
sapiens,0,1,1,1,1,1,1,0,0,0,0,0,0,0,0,0,0,1,1,0,0
JS,Shea 2013,Kharaneh IV C-D,15,18,31.75945372,36.53027992,H.
sapiens,0,1,1,1,1,1,0,0,0,0,0,0,0,0,0,0,0,1,1,0,0
JS,Shea 2013,Lagama N VII,15,18,30.44086656,33.44673362,H.
sapiens,0,1,1,1,1,0,0,0,0,0,0,0,0,0,0,0,0,1,1,0,1
JS,Shea 2013,Mushabi V,15,18,30.46761559,33.23343129,H.
sapiens,0,1,1,1,1,1,0,0,0,0,0,0,0,0,0,0,0,1,1,0,1
JS,Shea 2013,Shunera II,15,18,30.99016434,34.65081488,H.
sapiens,0,1,1,1,1,1,0,0,0,0,0,0,0,0,0,0,0,1,1,0,0
JS,Shea 2013,Shunera IV,15,18,31.04414829,34.648908,H.
sapiens,0,1,1,1,1,1,1,0,0,0,0,0,0,0,0,0,0,1,1,0,0
JS,Shea 2013,Shunera VII,15,18,31.04094319,34.55849324,H.
sapiens,0,1,1,1,1,1,0,0,0,0,0,0,0,0,0,0,0,1,1,0,1
JS,Shea 2013,SMU-D101C,15,18,30.75465608,34.77886327,H.
sapiens,0,1,1,1,1,0,1,0,0,0,0,0,0,0,0,0,0,1,0,0,0
JS,Shea 2013,SMU-D5,15,18,30.90977884,34.80101895,H.
sapiens,1,1,1,1,1,1,1,0,1,0,0,0,0,0,0,0,1,1,1,0,0
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JS,Shea 2013,Wadi el Jilat 22 B-E,15,18,31.50849247,36.40056961,H.
sapiens,0,1,1,1,1,1,1,0,0,0,0,0,0,0,0,0,1,1,0,1
JS,Shea 2013,Broken Mammoth,13,19,64.2521943,-146.2908861,H.
sapiens,0,1,1,1,0,1,1,0,0,0,1,1,0,0,0,0,0,1,1,0,0
JS,Shea 2013,Kutakina Cave,15,20,-42.56085771,145.7840271,H.
sapiens,0,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
JS,Shea 2013,Afontova Gora II upper,13,20,55.98866049,92.27130212,H.
sapiens,0,0,1,1,0,1,1,0,0,0,0,0,0,0,0,0,0,1,1,0,0
JS,Shea 2013,Wolseong-don,19,20,35.74977463,128.3758152,H.
sapiens,0,1,1,1,1,1,1,1,0,0,0,0,1,0,0,0,0,1,1,0,0
JS,Shea 2013,Eliseevichi,15,20,53.05218883,33.4924756,H.
sapiens,0,0,1,1,1,1,0,0,0,0,0,0,0,0,0,0,0,1,1,0,0
JS,Shea 2013,Mezerich,14,20,49.62005615,31.32662893,H.
sapiens,0,0,1,1,1,1,1,0,0,0,0,0,0,0,0,0,1,1,1,0,0
JS,Shea 2013,La Riera Cave Levels 1-20,15,21,43.53105894,-5.262069849,H.
sapiens,1,1,1,1,1,1,1,1,0,0,1,1,0,0,0,0,1,0,1,0,0
JS,Shea 2013,Afontova Gora II lower,21,21,55.99043308,92.81641479,H.
sapiens,1,0,1,1,0,1,1,0,0,0,0,0,1,0,0,0,0,1,1,0,0
JS,Shea 2013,Tunnel Cave Levels 7B-10a,15,22,-34.11079222,115.0359561,H.
sapiens,1,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
JS,Shea 2013,Laugerie Haute Levels H-G,17,22,44.91264898,1.118343396,H.
sapiens,0,1,1,1,1,1,1,1,0,0,0,0,0,0,0,0,0,1,1,0,0
JS,Shea 2013,Toca de Tira Peia,17,22,-8.812349403,-42.34840784,H.
sapiens,0,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
JS,Shea 2013,Cave Bay Cave,15,23,-40.48162598,144.7887041,H.
sapiens,1,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,1,0,0,0,0
JS,Shea 2013,Ein Gev I-III,18,24,32.73563146,35.53876611,H.
sapiens,1,1,1,1,1,1,1,0,1,0,0,0,0,0,0,0,1,1,1,0,1
JS,Shea 2013,Kharaneh IV A-B,18,24,31.7342203,36.51330639,H.
sapiens,0,1,1,1,1,1,0,0,0,0,0,0,0,0,0,0,0,1,1,0,0
JS,Shea 2013,Ohalo II,18,24,32.67953385,35.28856712,H.
sapiens,0,1,1,1,1,1,1,0,0,1,0,0,0,0,0,0,0,1,1,0,1
JS,Shea 2013,Shunera XVI,18,24,31.02699689,34.66867017,H.
sapiens,0,1,1,1,1,1,0,0,0,0,0,0,0,0,0,0,1,1,1,0,0
JS,Shea 2013,Tor Hamar J431 Level E,18,24,29.97732724,34.6096175,H.
sapiens,0,1,1,1,1,1,1,0,0,0,0,0,0,0,0,0,0,1,1,0,0
JS,Shea 2013,Wadi el Jilat 6,18,24,31.51980157,36.38172583,H.
sapiens,0,1,1,1,1,1,1,0,0,0,0,0,0,0,0,0,0,1,1,0,1
JS,Shea 2013,Wadi Humeima,18,24,29.94354201,35.53200268,H.
sapiens,0,1,1,1,1,1,1,0,0,0,0,0,0,0,0,0,0,1,1,0,0
JS,Shea 2013,Mandu Mandu Creek Unit 2,20,25,-22.19300255,113.9192668,H.
sapiens,0,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,1,0,0,0,0
JS,Shea 2013,Shimaki LC 1,23,25,43.23661087,143.4283998,H.
sapiens,0,1,1,1,0,1,0,0,1,0,0,0,0,0,0,0,0,1,1,0,0
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JS,Shea 2013,Sinbock,18,25,34.55407511,126.8136512,H.
sapiens,0,1,1,1,1,1,1,1,0,1,1,0,1,0,0,0,0,1,1,1,1
JS,Shea 2013,Sitio de Meio,13,25,-8.782552287,-42.5898137,H.
sapiens,1,1,1,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0
JS,Shea 2013,Tolbor 15 Levels 4-5,15,26,49.29834453,101.8078707,H.
sapiens,0,1,1,1,1,0,1,0,1,0,0,0,0,0,0,0,0,1,1,0,0
JS,Shea 2013,Vale de Pedra Furada,15,26,-8.88570744,-42.54318411,H.
sapiens,1,1,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
JS,Shea 2013,La Ferrassie Levels J-L,23,27,44.85322632,0.893427405,H.
sapiens,1,1,1,1,1,1,1,1,0,0,0,0,0,0,0,0,1,1,1,0,0
JS,Shea 2013,Pavlov I,25,27,48.8237754,16.19058373,H.
sapiens,1,1,1,1,1,1,1,1,0,0,0,0,0,0,0,0,0,1,1,0,0
JS,Shea 2013,Dolni Vestonice II,25,27,48.79061003,16.77612039,H.
sapiens,1,1,1,1,1,1,1,1,1,0,0,0,0,0,0,0,0,1,1,0,0
JS,Shea 2013,Kashiwadai 1,22,27,42.77408255,141.9923259,H.
sapiens,0,1,1,1,0,1,0,0,0,0,0,0,0,0,0,0,0,1,1,0,0
JS,Shea 2013,Kawanishi-C,26,27,42.88313446,142.8738933,H.
sapiens,0,1,1,1,0,1,1,0,0,0,0,0,0,0,0,0,0,1,0,0,0
JS,Shea 2013,Marukoyama,26,28,42.86523583,141.6938527,H.
sapiens,0,1,1,1,0,1,0,0,0,0,0,0,0,0,0,0,0,1,0,0,0
JP,Berillon et al. 2007,Garm Roud 2,23.7,28.7,36.42213655,52.40899581,H.
sapiens,0,0,0,0,0,1,0,0,1,0,0,0,0,0,0,0,0,0,1,0,0
JS,Shea 2013,Bone Cave Lower Levels,24,29,-42.96091002,146.4034546,H.
sapiens,1,1,1,0,0,0,0,0,1,0,0,0,0,0,0,0,1,0,0,0,0
JS,Shea 2013,Yana RHS,27,29,70.66232615,138.7776723,H.
sapiens,1,1,1,1,0,1,1,0,0,0,0,0,0,0,0,0,1,1,0,0,0
JS,Shea 2013,Nunamira Cave,12,30,-42.6522578,146.5838819,H.
sapiens,0,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
JS,Shea 2013,ORS 7,11,30,42.40536981,147.0318641,H.
sapiens,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
JS,Shea 2013,Starosele Levels 1-4,20,30,44.78473467,33.8357741,H.
sapiens,1,1,1,1,0,1,1,0,1,1,1,0,0,0,0,1,0,0,0,0,0
JS,Shea 2013,La Ferrassie Levels F-H,27,30,44.95588022,1.043036155,H.
sapiens,0,0,1,1,1,1,1,1,0,0,0,0,0,0,0,0,1,1,1,0,0
JS,Shea 2013,Tolbaga Levels 1-4,25,30,51.26772199,109.2276589,H.
sapiens,1,1,1,1,0,1,1,0,1,0,0,0,1,1,1,0,0,1,0,0,0
JS,Shea 2013,Mezin,15,30,52.31887948,33.15356013,H.
sapiens,0,0,1,1,1,1,1,0,1,0,0,0,1,0,0,0,0,1,1,0,0
JS,Shea 2013,Fern Cave,17,31,-17.08351569,143.8843548,H.
sapiens,1,1,0,0,0,0,0,0,0,0,0,0,1,0,0,0,0,0,0,0,0
JP,Bazgir et al. 2017,Kaldar Cave Layer 4,19.8,31.7,33.60208039,48.15311105,H.
sapiens,0,1,1,0,0,0,1,1,0,0,0,0,0,0,0,1,0,1,1,0,0
JS,Shea 2013,Yongho-dong Levels 1 and 3,32,32,36.40970242,127.5672518,H.
sapiens,0,1,1,1,0,0,1,1,0,0,0,0,0,0,0,0,0,1,0,0,0
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JS,Shea 2013,Tolbor 4 Levels 4-6,26,33,49.3093456,101.7149121,H.
sapiens,1,1,1,1,0,1,1,0,1,0,0,0,0,0,1,1,1,1,1,0,0
JS,Shea 2013,Tolbor 15 Levels 6-7,26,33,49.29965318,101.9239775,H.
sapiens,0,1,1,1,0,0,1,0,1,0,0,0,0,0,1,0,1,1,0,0,0
JS,Shea 2013,Monte Verde Level I,33,33,-41.52015788,-73.09634149,H.
sapiens,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
JS,Shea 2013,Abri Pataud Levels 6-14,24,34,44.93582524,1.141436253,H.
sapiens,0,1,1,1,1,1,1,0,1,0,0,0,0,0,0,0,1,1,1,0,0
JS,Shea 2013,Le SolutrÃ©,15,34,46.24515966,4.729800393,H.
sapiens,1,0,1,1,1,1,1,1,0,0,1,1,0,0,0,0,0,1,1,0,0
JS,Shea 2013,Puritjarra Units 2b-2d,18,35,-23.87534223,130.714078,H.
sapiens,0,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,1,0,0,0,0
JS,Shea 2013,Vogelherd IV V,30,35,48.51695909,10.64400331,H.
sapiens,1,1,1,1,1,1,1,1,1,0,0,0,0,0,0,0,1,1,1,0,0
JP,Tsanova 2013,Yafteh,24.5,35.5,33.61694756,48.25635785,H.
sapiens,0,1,1,1,1,1,1,0,1,0,0,0,0,0,0,0,1,1,1,0,0
JS,Shea 2013,GeiÃŸenklÃ¶sterle,23,36,48.37069145,9.598454388,H.
sapiens,1,1,1,1,0,1,1,0,1,0,0,0,0,0,0,0,0,1,1,0,0
JS,Shea 2013,Cueva MorÃ-n Levels 3-9,15,36,43.43913948,-3.900992513,H.
sapiens,1,1,1,1,1,1,1,1,1,0,0,0,0,0,0,0,1,1,1,0,0
JS,Shea 2013,Abri Facteur Tursac Levels 10-21,25,36,44.98592397,1.130726488,H.
sapiens,1,0,1,1,1,1,1,0,0,0,0,0,0,0,0,0,0,1,1,0,0
JS,Shea 2013,GRE8 Units 5-9,19,37,-18.94602172,138.6263324,H.
sapiens,0,1,1,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
JS,Shea 2013,Abri Castanet Levels A-C,36,37,44.96589485,1.214763749,H.
sapiens,1,1,1,1,0,1,1,0,0,0,0,0,0,0,0,0,0,1,1,0,0
JS,Shea 2013,Boker ,30,38,30.92630504,34.79223692,H.
sapiens,0,0,1,1,0,1,1,0,0,0,0,0,0,0,0,0,1,1,0,0,0
JS,Shea 2013,Willendorf II AH 2-4,31,38,48.37536545,15.26011424,H.
sapiens,1,1,1,1,1,1,1,0,1,0,0,0,0,0,0,0,1,1,1,0,0
JS,Shea 2013,Hwaedae ri,30,38,37.88037291,127.0826373,H.
sapiens,0,1,1,1,0,0,1,1,0,0,0,0,0,0,0,0,0,1,0,0,0
JS,Shea 2013,Kabazai V,30,40,44.86256032,34.06921629,H.
sapiens,0,0,1,1,0,1,1,0,0,0,1,0,0,0,0,1,1,1,0,0,0
JS,Shea 2013,Stranks Skala IIIC,34,40,49.1911611,16.56159325,H.
sapiens,1,1,1,1,0,1,1,0,1,0,0,0,1,1,1,0,1,1,1,0,0
JP,Zhang e t al. 2018,Nwya Devu Site,30,40,31.53083884,88.82045736,H.
sapiens,0,1,1,0,0,0,1,0,0,0,0,0,0,0,0,0,1,1,0,0,0
JS,Shea 2013,Carpenters Gap 3 Levels 8-14,12,41,-17.4652589,124.8268079,H.
sapiens,0,0,1,1,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0
JS,Shea 2013,Devil's Lair Cave,15,43,-34.15733289,115.1203577,H.
sapiens,1,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
JS,Shea 2013,Kara Bom Levels 1-6,32,43,50.79250167,85.42064888,H.
sapiens,0,0,1,1,0,1,1,0,1,0,0,0,0,0,0,0,0,1,1,0,0
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JS,Shea 2013,Parmerpar Meethaner Units 3-4,12,44,-41.62387566,145.8913672,H. sapiens,0,1,1,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
JS,Shea 2013,Kostenki 14 Level Ivb,42,44,51.37781682,39.20751518,H. sapiens,1,1,1,1,1,1,0,0,1,0,0,0,0,0,0,0,0,1,1,0,0
JS,Shea 2013,Pech de L'AzÃ© I  Layer 4,40,45,44.90442126,1.360419904,H. sapiens,0,1,1,1,0,0,0,0,0,1,1,0,0,1,0,1,1,0,0,0,0
JS,Shea 2013,Vedrovice V AH 2,37,45,48.97453979,16.39609676,H. sapiens,1,1,1,1,1,1,1,0,1,1,1,1,0,0,0,0,0,1,1,0,0
JP,Niang et al. 2018,Tiemassas,41,46.6,14.04995325,-17.7997725,H. sapiens,0,0,1,0,0,0,1,1,1,0,1,1,0,1,0,1,0,0,0,0,0
JS,Shea 2013,Boker Tachtit 1-4,38,47,30.80504875,34.72708413,H. sapiens,0,0,1,1,0,1,1,0,0,0,0,0,0,0,1,1,1,1,0,0,0
JS,Shea 2013,Kosipe,44,49,-8.459476213,147.1427297,H. sapiens,0,1,1,0,0,0,0,0,0,0,0,0,1,0,0,0,0,0,0,0,0
JS,Shea 2013,Grotta Sant' Agostino Levels 1-4,40,50,41.27439474,13.57170699,H. neanderthalensis,1,1,1,1,0,0,1,0,0,0,0,0,0,0,1,1,0,1,0,0,0
JS,Shea 2013,Parnkupiriti Site 3,37,50,-20.1395564,127.7886818,?,0,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
JP,Bazgir et al. 2017,Kaldar Cave Layer 5,36.8,54.4,33.49108431,48.28113335,H. neanderthalensis,0,1,1,0,0,0,1,0,0,0,0,0,0,1,0,1,1,0,0,0,0
JS,Shea 2013,Malakunanja II,50,60,-12.53387569,132.9782442,H. sapiens,1,1,1,0,0,0,1,0,0,1,1,0,0,0,0,0,0,0,0,1,0
JS,Shea 2013,Combe Capelle Bas,50,60,44.78167735,0.818177519,H. neanderthalensis,0,1,1,1,0,1,1,0,0,1,0,0,0,1,0,1,0,0,0,0,0
JS,Shea 2013,Champ Grand Levels B D,40,60,46.06191312,3.955073525,H. neanderthalensis,0,1,1,1,0,1,1,0,0,1,1,0,0,1,1,1,1,1,0,0,0
JS,Shea 2013,Bobongara Huon NG,47,61,-6.188811247,147.515191,H. sapiens,0,1,0,0,0,0,0,0,0,0,0,0,1,0,0,0,0,0,0,0,0
JS,Shea 2013,Willadra Lakes,30,62,-33.71927406,143.0400302,H. sapiens,0,0,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
JS,Shea 2013,Tor Faraj Level C,45,65,29.85370398,36.93209118,?,0,1,1,1,0,1,1,0,1,0,0,0,0,1,1,1,1,1,0,0,0
JS,Shea 2013,Kabazai II Units I-III,30,70,44.81000422,33.91178653,?,0,0,1,1,0,0,1,0,1,0,1,0,0,1,1,1,1,0,0,0,0
JS,Shea 2013,Liang Bua Level 4,61,74,-8.631996528,120.4500635,?,1,1,1,1,0,1,1,0,0,0,0,0,0,1,0,0,0,0,0,0,0
JS,Shea 2013,Grotta Guattari Levels 1-5,,77,41.17119551,13.10230843,H. neanderthalensis,0,1,1,1,0,0,1,0,0,0,0,0,0,0,1,1,0,1,0,0,0
JS,Shea 2013,Tabun Cave Level B,50,80,32.6320216,35.17593239,?,0,1,1,1,0,1,1,0,0,1,0,0,0,1,1,1,1,0,0,0,0
JS,Shea 2013,Porc Epic Cave,60,80,9.58139402,41.85586365,H. sapiens,0,1,1,1,1,1,1,0,1,0,1,1,0,1,1,1,1,1,0,0,0
JS,Shea 2013,Sibudu,50,80,-29.48192003,21.20750423,?,1,0,1,0,0,1,1,0,1,0,1,0,0,1,1,1,0,1,0,0,0
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JP,Petraglia et al. 2011,Jebel Qattar
JQ1,70,80,27.96466933,41.00811928,?,0,0,1,0,0,0,1,0,0,1,0,0,0,1,0,1,0,0,0,0,0
JP,Delagnes et al. 2012,Wadi
Surdud,38.4,94,15.24121381,43.39958019,?,1,1,1,0,0,0,1,0,1,0,0,0,0,1,1,1,0,1,0,0,0
JS,Shea 2013,La Cotte de St. Brelade Levels 6-C,50,100,49.14774448,-2.325018883,H.
neanderthalensis,0,1,1,1,0,1,1,0,0,1,0,0,0,1,0,1,0,0,0,0,0
JS,Shea 2013,Wallertheim D,75,100,49.84456427,8.030564833,H.
neanderthalensis,0,0,1,1,0,1,1,0,0,0,0,0,0,1,0,0,1,0,0,0
JS,Shea 2013,Aduma Ardu Beds,80,100,10.30652763,40.51210924,H.
sapiens,0,1,1,1,0,0,1,0,0,1,1,0,0,1,1,1,1,1,0,0,0
JS,Shea 2013,Liang Bua Level 3,95,100,-
8.559698092,120.4198021,?,1,1,1,1,0,0,0,0,0,0,0,0,0,1,0,0,0,0,0,0,0
JP,Mercader et al. 2009,Ngalue Cave,42,105,-
13.10875422,35.45888565,?,0,1,1,0,1,1,1,1,0,0,0,0,0,0,0,1,0,0,0,0,1
JS,Shea 2013,Grotta Moscherini Levels 1-6,75,106,41.20995041,13.43130056,H.
neanderthalensis,1,1,1,1,0,0,1,0,0,0,0,0,0,0,1,1,0,1,0,0,0
JS,Shea 2013,Skhul Cave Level B,80,120,32.53838087,34.99946519,H.
sapiens,0,1,1,1,0,1,1,0,0,1,0,0,0,1,1,1,0,0,0,0,0
JS,Shea 2013,Contrebandiers Cave Levels 4-6,87,120,33.79175772,-7.012905586,H.
sapiens,0,1,1,1,0,1,1,1,1,0,1,1,0,0,0,1,1,0,0,0,0
JS,Shea 2013,Haua Fteah Middle Paleolithic,50,130,32.90740997,22.07857536,H.
sapiens,0,1,1,1,1,1,1,1,0,1,0,0,0,1,0,1,1,1,0,0,0
JS,Shea 2013,Klasies River Mouth,60,130,-
34.08535306,24.33822073,?,0,1,1,1,1,1,1,0,1,0,1,1,0,0,1,1,1,1,0,0,0
JS,Shea 2013,Liang Bua Level 2,100,130,-
8.554116798,120.5061205,?,0,1,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
JS,Shea 2013,Tabun Cave Level
C,130,160,32.68080073,34.94740987,?,0,1,1,1,0,1,1,0,0,1,0,0,0,1,1,1,1,0,0,0,0
JS,Shea 2013,Herto Upper,154,160,10.27265952,40.57129453,H.
sapiens,0,0,0,0,0,0,1,0,0,1,0,0,0,1,0,1,1,1,0,0,0
JP,Hu et al.
2018,Guanyindong,80,170,26.90634599,106.1796674,?,0,1,1,1,0,0,0,1,0,0,0,0,0,1,0,1,0,0
,0,0,0
JS,Shea 2020,Omo Kibish Members 1-3,104,195,5.285380025,36.29785347,H.
sapiens,1,1,1,1,0,0,1,0,1,1,1,0,1,1,1,1,1,1,0,0,0
JS,Shea 2013,Abri Vaufrey Levels IV-VIII,74,200,44.78099549,1.207563678,H.
neanderthalensis,0,0,1,1,0,1,1,0,0,0,0,0,0,1,1,1,1,0,0,0,0
JS,Shea 2013,Rosh Ein
Mor,191,208.7,30.80712957,34.73391969,?,0,0,1,1,0,1,1,0,0,0,0,0,0,1,1,1,1,1,0,0,0
JS,Shea 2013,La Cotte de St. Brelade Levels D-H,240,240,49.09506749,-2.256205033,H.
neanderthalensis,0,1,1,1,0,1,1,0,0,0,0,0,0,1,0,1,0,0,0,0,0
JS,Shea 2013,Abri Vaufrey Levels IX-XI,200,240,44.78966731,1.175794101,H.
neanderthalensis,0,1,1,1,0,1,0,0,0,1,0,0,0,0,0,0,1,0,0,0,0
JS,Shea 2013,Tabun Cave Level D Unit IX,130,245,32.61775532,34.88415231,H.
neanderthalensis,0,1,1,1,0,1,0,0,0,1,0,0,0,1,1,1,1,0,0,0,0
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JP,Ravon et al. 2015,Menez-Dregan I Layer 4,200,246,47.99721011,-4.404766444,?,1,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
JP,Zaidner and Weinstein-Evron 2016. ,Misliya EMP,160,250,32.79934531,34.83083813,H. sapiens,0,1,1,1,0,1,1,1,1,0,0,0,0,1,1,1,0,1,0,0,0
JS,Shea 2013,Terra Amata,300,300,43.69097359,7.218898429,?,1,1,1,0,0,0,1,0,0,1,0,0,0,0,0,0,1,0,0,0,0
JS,Shea 2013,Gademotta,100,300,7.867652099,38.39296057,?,0,1,1,1,0,1,1,0,1,1,1,1,0,1,1,1,1,0,0,0,0
JS,Shea 2013,Tabun Cave Level F,350,350,32.7329054,34.92388998,H. neanderthalensis,0,1,1,1,0,1,0,0,0,1,0,0,0,1,0,0,0,0,0,0,0
JS,Shea 2013,Tabun Cave Level Eb-Ed,300,350,32.67420523,35.2135776,H. neanderthalensis,0,1,1,1,0,1,0,0,0,1,0,0,0,1,0,0,1,0,0,0,0
JS,Shea 2013,Tabun Cave Level Ea,200,350,32.67715506,34.86273105,H. neanderthalensis,0,1,1,1,0,1,0,0,0,1,0,0,0,0,0,0,1,0,0,0,0
JS,Shea 2013,Tabun Cave Level G,400,400,32.65826201,35.22212095,H. neanderthalensis,0,1,1,1,0,1,0,0,0,0,0,0,0,0,0,0,1,0,0,0,0
JS,Shea 2013,Qesem Cave,194,420,32.06665489,35.06811049,?,0,1,1,1,0,1,0,0,0,1,0,0,0,0,0,1,1,1,0,0,0
JP,Ravon et al. 2015,Menez-Dregan I Layer 7,374,424,47.95986431,-4.430183523,?,1,1,1,0,0,0,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0
JS,Shea 2013,Hoxne,360,430,52.35806118,1.25040926,H. heidelbergensis,1,1,1,0,0,0,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0
JS,Shea 2013,Torre in Pietra,300,440,42.23336946,11.83760307,?,0,1,1,1,0,1,0,0,0,1,0,0,0,0,1,1,1,0,0,0,0
JS,Shea 2013,Nor Geghi Units 1-4 and Slope,305,447,40.35026838,44.53602341,?,0,0,1,0,0,0,1,0,0,1,0,0,0,1,1,1,1,0,0,0,0
JS,Shea 2013,Lake Baringo Koimilot Locus 1 and 2,300,500,0.543233113,36.08135244,?,1,1,0,0,0,0,0,0,0,0,0,0,0,1,0,0,1,1,0,0,0
JS,Shea 2013,Lake Baringo upper K3 -LHA GnJh17,300,500,0.605453242,36.00303923,?,0,1,1,0,0,0,0,0,0,1,0,0,0,1,0,0,0,1,0,0,0
JS,Shea 2013,Lake Baringo lower K3 GnJh 42 50,537,548,0.548892696,35.89286301,?,0,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,1,1,0,0,0
JS,Shea 2013,Bilzingsleben,230,570,51.29212569,11.15059702,H. heidelbergensis,0,1,1,1,0,0,1,0,0,1,0,0,0,0,0,0,1,0,0,0,0
JS,Shea 2013,Lantian Chenjiawo,500,600,34.19761766,109.5421051,?,0,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
JS,Shea 2013,Isernia La Pineta,604,620,41.60339955,14.13238789,H. antecessor,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
JS,Shea 2013,Kathu Pan 1,464,682,-27.69375661,23.04282977,?,0,1,1,0,0,0,1,0,0,1,0,0,0,1,1,1,0,1,0,0,0
JS,Shea 2013,Latamne,500,700,35.26468803,36.69046404,?,0,1,1,0,0,1,1,0,0,1,0,0,0,0,0,0,1,0,0,0,0
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JS,Shea 2013,Zhoukoudian Locality 1,400,800,39.71323129,115.9812351,H.
erectus,1,1,1,1,0,0,1,0,0,0,0,0,0,0,0,1,0,0,0,0
JS,Shea 2013,Berekhat
Ram,230,800,33.25963749,35.92711231,?,0,1,1,1,0,1,0,0,0,1,0,0,0,1,0,0,1,0,0,0,0
JS,Shea 2013,Gesher Benot
Yaacov,760,860,33.00285739,32.45646307,?,0,1,1,0,0,0,1,0,0,1,0,0,0,1,0,0,0,0,0,0,0
JS,Shea 2013,Melka Kunture Gombore II,760,860,8.656614932,38.67791518,H.
heidelbergensis,0,1,1,0,0,0,1,0,0,1,0,0,0,0,0,0,0,0,0,0
JS,Shea 2013,Atapuerca Gran Dolina TD6,798,882,42.43841264,-3.142713019,H.
antecessor,0,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
JS,Shea 2013,Mata Menge,873,887,-8.7163888,121.1127288,H.
Floresiensis,0,1,1,0,0,0,1,0,0,0,0,0,0,1,0,0,0,0,0,0
JS,Shea
2013,Xiaochangliang,900,1000,40.14630625,114.9796711,?,0,1,1,0,0,0,0,0,0,0,0,0,0,0,
0,1,0,0,0,0
JS,Shea
2013,Donggutuo,900,1000,40.20511833,115.0601565,?,0,1,1,0,0,0,0,0,0,0,0,0,0,0,0,1,0
,0,0,0
JS,Shea 2013,Vallonet Cave Ensemble
III,1000,1100,43.78421429,7.436409878,?,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
JS,Shea 2013,Olduvai Beds III-IV,700,1200,-2.973540029,35.45332016,H.
erectus,1,1,1,0,0,1,1,0,0,1,0,0,0,0,0,1,0,0,0,0
JS,Shea 2013,Lantian Gongwangling,500,1200,34.25207485,109.549894,H.
erectus,0,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
JS,Shea 2013,Olorgesailie,500,1200,-1.555385718,28.25080559,H.
erectus,1,1,1,1,0,0,0,0,0,1,0,0,0,0,0,1,0,0,0,0
JS,Shea 2013,'Ubeidiya,1200,1500,32.744535,35.49931327,H.
erectus,1,1,1,1,0,1,1,0,0,1,0,0,0,0,0,1,0,0,0,0
JS,Shea
2013,Attirampakkam,1000,1500,13.23169633,79.99041912,?,0,0,1,1,0,0,1,0,0,1,0,0,0,1,0
,0,0,0,0,0,0
JS,Shea 2013,Olduvai Mid-Upper Bed II,1200,1600,-
2.899574008,35.3786859,?,1,1,1,0,0,1,1,0,0,1,0,0,0,0,0,0,1,0,0,0,0
JS,Shea 2013,Konso KGA other
sites,1000,1600,5.495926632,37.38479585,?,0,0,0,0,0,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0
JS,Shea 2013,Koobi Fora Okote Chari
Members,800,1600,3.976884935,36.21194392,?,1,1,1,1,0,0,1,0,0,1,0,0,0,0,0,0,1,0,0,0,0
JS,Shea 2013,Pirro
Nord,1300,1700,41.80843747,15.45681766,?,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
JS,Shea 2013,Koobi Fora KBS Tuff
Complex,1600,1800,3.888031673,36.22807158,?,1,1,1,1,0,0,0,0,0,0,0,0,0,0,0,0,1,0,0,0,0
JS,Shea 2013,Ain
Hanech,1200,1800,36.2537587,8.875864427,?,0,1,1,1,0,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0
JS,Shea 2013,Konso KGA6-A1 Locus
C,1600,1800,5.436325803,37.39429941,?,0,0,0,0,0,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0
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JS,Shea 2013,Olduvai Lower Bed II,1645,1805,-2.967877007,35.43866795,?,1,0,1,0,0,1,1,0,0,1,0,0,0,0,0,0,1,0,0,0,0
JS,Shea 2013,Dmanisi,1750,1850,41.31292687,44.31650679,H.erectus,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
JS,Shea 2013,Olduvai Gorge Bed I,1860,1860,-2.911129955,35.39032492,?,1,1,1,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
JS,Shea 2013,Melka Kunture Garba IV,1458,1918,8.698075989,38.5801137,?,0,1,1,0,0,1,1,0,0,1,0,0,0,0,0,0,1,0,0,0,0
JS,Shea 2013,Kanjera,1950,2300,0.413918871,34.58312917,?,0,1,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
JS,Shea 2013,Omo Shungura Formation Member F,2200,2400,5.226933498,36.0628339,?,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
JS,Shea 2013,West Turkana Lokalalei 1,2300,2400,3.9230168,35.84716148,?,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
JS,Shea 2013,West Turkana Lokalalei 2C,2300,2400,3.972410516,35.70062493,?,1,1,1,1,0,0,0,0,0,0,0,0,0,0,0,0,1,0,0,0,0
JS,Shea 2013,Gona Busidima Formation,2500,2600,11.09063842,39.89298069,?,0,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,1,0,0,0,0
JS,Shea 2013,Hadar Afar AL 894,2350,2900,11.09283027,40.89451185,?,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
JS,Shea 2020,Lomekwi 3 West Turkana,2510,3300,3.834406274,35.619042,?,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
JS,Shea 2020,Fejej FJ-Ia,1900,1900,4.447257661,36.68637504,,1,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,1,0,0,0,0
JS,Shea 2020,Gona Afar Dist.,2300,2600,11.10668983,41.05496561,,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,1,0,0,0,0
JS,Shea 2020,Gona Busidima Formation,2500,2600,NA,NA,,0,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,1,0,0,0,0
JS,Shea 2020,AL 666,2300,2300,NA,NA,,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,1,0,0,0,0
JS,Shea 2020,AL 894,2600,2600,NA,NA,,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
JS,Shea 2020,Omo Shungura Formation Member F,2200,2400,NA,NA,,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
JS,Shea 2020,Ledi-Geraru Bokol Dora 1 Locality,2580,2610,11.37387005,40.8849442,,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,1,0,0,0,0
JS,Shea 2020,Koobi Fora Formation KBS Member Burgi Fmn.,1600,1800,NA,NA,,1,1,1,1,0,0,0,0,0,0,0,0,0,0,0,0,1,0,0,0,0
JS,Shea 2020,Kanjera,2000,2000,NA,NA,,0,1,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
JS,Shea 2020,Kanjera South,2000,2000,NA,NA,,0,1,1,0,0,0,0,0,1,0,0,0,0,0,0,1,0,0,0,0,0
JS,Shea 2020,West Turkana Lomekwi 3,3300,3300,NA,NA,,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,1,0,0,0,0
JS,Shea 2020,West Turkana Naiyena Engol 2,1700,1800,4.110923147,35.78433888,,1,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,1,0,0,0,0,0
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JS,Shea 2020,West Turkana Lokalalei 1,2300,2400,NA,NA,,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
JS,Shea 2020,Olduvai Gorge Bed I and Lower Bed II,1860,1860,NA,NA,,1,1,1,0,0,1,1,0,0,1,0,0,0,0,0,0,1,0,0,0,0
JS,Shea 2020,Nyabosusi NY 18,1500,2000,0.999248907,30.39944978,,0,1,1,0,0,0,0,0,0,0,0,0,0,0,1,0,0,0,0,0
JS,Shea 2020,Gadeb  8D-F,700,700,7.160287826,39.37485548,,0,1,1,0,0,0,1,0,1,1,0,0,0,0,0,1,1,0,0,0,0
JS,Shea 2020,Gadeb 2B C E,700,1500,7.056949861,39.35528839,,0,1,1,0,0,0,1,0,0,1,0,0,0,0,0,1,1,0,0,0,0
JS,Shea 2020,Hugub,500,600,9.71699356,40.06711371,,0,1,1,0,0,0,1,0,0,1,0,0,0,0,0,0,1,0,0,0,0
JS,Shea 2020,Konso-Gardula,1000,1600,NA,NA,,0,0,0,0,0,0,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0
JS,Shea 2020,Konso-Gardula KGA6-A1 Locus C ,1600,1800,NA,NA,,0,0,0,0,0,0,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0
JS,Shea 2020,Middle Awash Bouri A1 BOU-A1,1000,1000,NA,NA,,0,0,0,0,0,0,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0
JS,Shea 2020,Middle Awash Hargufina A4 HAR-A4,500,500,NA,NA,,0,0,1,0,0,0,0,0,1,1,0,0,0,0,0,0,0,0,0,0,0
JS,Shea 2020,Mieso Sites 7 and 31,200,800,9.159793262,40.70490955,,0,0,0,0,0,0,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0
JS,Shea 2020,Chesowanja Chemoigut Fmn.,1400,1600,0.706004878,36.25721977,,0,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
JS,Shea 2020,Chesowanja Chesowanja Fmn.,500,500,NA,NA,,0,0,0,0,0,0,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0
JS,Shea 2020,East Turkana Koobi Fora Formation Okote Member,800,1600,NA,NA,,1,1,1,1,0,0,1,0,0,1,0,0,0,0,0,0,1,0,0,0,0
JS,Shea 2020,Isenya Units V and VI,900,1000,-2.102524852,36.86479658,,0,1,0,0,0,0,0,0,0,1,0,0,0,0,0,0,1,0,0,0,0
JS,Shea 2020,Kariandusi,900,1100,-0.508413569,36.30425907,,0,0,0,0,0,0,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0
JS,Shea 2020,Kilombe EH and AH,700,>700,NA,NA,,0,1,1,0,0,0,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0
,Shea 2020, Olorgesailie Formation Mbrs. 1-14,500,1200,-1.595510565,41.89988351,,1,1,1,0,0,0,0,0,0,1,0,0,0,0,0,0,1,0,0,0,0
JS,Shea 2020,West Lake Baringo lower K3 GnJh 42 50,500,500,NA,NA,,0,1,1,0,0,0,0,0,0,0,0,0,0,0,0,1,1,0,0,0
JS,Shea 2020,West Turkana Kokiselei 1 5-6,1760,1760,NA,NA,,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
JS,Shea 2020,West Turkana Kokiselei 4,1760,1760,NA,NA,,0,1,0,0,0,0,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0
JS,Shea 2020,West Turkana Nadung'a 4,700,700,NA,NA,,0,1,1,0,0,0,0,0,0,1,0,0,0,0,0,0,1,1,0,0,0,0
JS,Shea 2020,Isimila Sands 1-3,260,>260,NA,NA,,0,1,1,0,0,0,0,0,0,1,0,0,0,0,0,0,1,0,0,0,0
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JS,Shea 2020,Makuyuni sites Lake Manyara,400,600,-
3.50254387,36.04044004,,0,1,0,0,0,0,0,0,0,1,0,0,0,0,0,0,0,0,0,0
JS,Shea 2020,Peninj EN and ES
sites,1200,1500,NA,NA,,0,1,0,0,0,0,0,0,0,1,0,0,0,0,0,1,0,0,0,0,0
JS,Shea 2020,Peninj ST Site Complex,1200,1500,-
2.281305967,36.01753631,,0,1,1,0,0,1,0,0,0,0,0,0,0,1,0,1,1,0,0,0,0
JS,Shea 2020,Kalambo Falls Final ESA,250,250,-
8.571750021,31.16122077,,0,1,1,1,0,1,1,0,0,1,1,0,1,0,0,0,1,0,0,0,1
JS,Shea 2020,Muguruk Member
2,200,300,NA,NA,,0,1,1,0,0,1,1,0,0,1,1,0,1,1,0,1,1,0,0,0,0
JS,Shea 2020,Muguruk Member
4,200,300,NA,NA,,0,1,1,0,0,1,1,0,0,0,1,0,0,1,1,1,1,0,0,0,0
JS,Shea 2020,West Lake Baringo Komilot Locus 1 and
2,300,500,NA,NA,,1,1,0,0,0,0,0,0,0,0,0,0,0,1,0,0,1,1,0,0,0
JS,Shea 2020,West Lake Baringo upper K3 -LHA
GnJh17,300,500,NA,NA,,0,1,1,0,0,0,0,0,0,1,0,0,0,1,0,0,0,1,0,0,0
JS,Shea 2020,Kalambo Falls Sangoan,200,250,-
8.554239805,31.24865986,,0,1,1,1,0,1,1,0,0,1,0,0,1,0,0,0,1,0,0,0,0
JS,Shea 2020,Twin Rivers,170,266,-
15.54673922,28.18081777,,1,1,1,1,1,1,1,0,1,1,1,1,0,1,0,1,1,1,1,0,1
JS,Shea 2020,Abdur Reef Limestone
Complex,125,125,NA,NA,,0,0,0,0,0,0,0,0,0,1,1,0,0,0,0,0,0,1,0,0,0
JS,Shea 2020,Gademotta ETH-
72,104,276,7.897920189,39.14213323,,0,0,1,1,0,1,1,0,1,1,1,0,0,1,1,1,1,1,1,0,0
JS,Shea 2020,Gademotta GDM 7
10,183,>183,NA,NA,,0,1,1,0,0,0,1,0,1,0,1,0,0,1,1,1,1,1,1,0,0
JS,Shea 2020,K'one,40,200,NA,NA,,1,1,1,1,0,1,1,0,0,0,1,0,0,1,1,1,1,1,1,0,0
JS,Shea 2020,Kulkuletti ETH 72-
9,104,276,NA,NA,,0,0,1,1,0,1,1,0,0,0,1,0,0,1,0,1,1,1,1,0,0
JS,Shea 2020,Middle Awash Aduma Ardu
Beds,80,100,NA,NA,,0,1,1,1,0,0,1,0,0,1,1,0,0,1,1,1,1,1,0,0,0
JS,Shea 2020,Middle Awash Upper Herto
Formation,154,160,NA,NA,,0,0,0,0,0,0,1,0,0,1,0,0,0,1,0,1,1,1,0,0,0
JS,Shea 2020,Omo mbr 1-3,104,195,NA,NA,,1,1,1,1,0,0,1,0,1,1,1,0,1,1,1,1,1,1,0,0,0
JS,Shea 2020,Porc Epic Cave,60,80,NA,NA,,0,1,1,1,1,1,1,0,1,0,1,1,0,1,1,1,1,1,0,0,0
JS,Shea 2020,Cartwright,440,557,NA,NA,,1,1,1,0,0,1,1,0,1,0,1,0,0,1,0,1,1,1,1,0,0
JS,Shea 2020,East Turkana FwJi
1,>30?,>30?,NA,NA,,0,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
JS,Shea 2020,East Turkana FwJi
2,>30?,>30?,NA,NA,,0,1,1,0,0,0,1,0,0,0,0,0,0,0,0,1,0,0,0,0,0
JS,Shea 2020,East Turkana FwJi
3,>30?,>30?,NA,NA,,0,1,1,0,0,0,1,0,0,0,0,0,0,0,0,1,0,0,0,0,0
JS,Shea 2020,East Turkana FxJj
61,>30?,>30?,NA,NA,,0,1,1,1,0,0,1,0,0,1,0,0,0,0,1,1,0,0,0,0,0
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JS,Shea 2020,East Turkana FxJj
66,>30?,>30?,NA,NA,,0,1,1,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0
JS,Shea 2020,East Turkana GaJj
17,>30?,>30?,NA,NA,,0,1,1,0,0,0,1,0,0,0,0,0,0,0,0,1,0,0,0,0,0
JS,Shea 2020,Enkapune Ya Muto Levels GG to GL,50,>50,-
0.824920366,36.11143537,,1,0,1,0,1,0,0,0,0,0,0,0,0,1,1,1,0,0,0,0,0
JS,Shea 2020,Lukenya Hill GvJm 22 Occ
G.,>47,>47,NA,NA,,0,1,1,0,0,0,0,0,0,0,0,0,0,1,1,1,1,1,0,1
JS,Shea 2020,Lukenya Hill GvJm
22,26,46,NA,NA,,0,1,1,1,1,1,1,0,0,0,0,0,0,0,0,0,1,1,0,0,1
JS,Shea 2020,Mtongwe Upper
Group,5,40,NA,NA,,0,1,1,1,1,0,1,0,0,0,0,0,0,0,0,1,1,1,1,0,0
JS,Shea 2020,Muringa Rockshelter Levels 9-
10,,,NA,NA,,1,1,1,1,1,0,0,0,1,0,1,0,0,0,0,0,0,0,1,0,0
JS,Shea 2020,Olorgesailie Oltulelei Formation,295,325,-
1.648805159,34.36393526,,1,1,0,0,0,0,1,0,0,1,0,0,0,0,0,0,0,0,0,0,0
JS,Shea 2020,Panga Ya Saidi Levels 13-16,58.5,61.5,-
3.657077422,39.76627581,,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,1,1,1,0,0,0
JS,Shea 2020,Panga Ya Saidi Levels 17-19,73,76.5,-
3.592744672,39.74436891,,0,1,0,0,0,0,0,0,0,0,0,0,0,0,1,1,1,1,0,0,0
JS,Shea 2020,Prolonged Drift GrJi
11,>30?,>30?,NA,NA,,1,1,1,1,0,1,1,0,1,0,1,0,0,1,0,0,1,0,0,0,0
JS,Shea 2020,Prospect Farm Spit 16
,>30?,>30?,NA,NA,,0,1,1,0,0,0,1,0,0,0,1,0,0,0,0,0,1,0,0,0,0
JS,Shea 2020,Prospect Farm Spits 22-
23,>30?,>30?,NA,NA,,0,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,1,0,0,0,0
JS,Shea 2020,Prospect Farm Spits 9-
11,>30?,>30?,NA,NA,,0,1,1,0,0,1,1,0,0,0,1,0,0,0,0,0,1,0,0,0,0
JS,Shea 2020,Rusinga Island Nyamita Main Site,36,49,-
0.35285529,34.14689775,,0,1,1,0,0,0,1,0,0,0,1,0,0,1,1,1,0,0,0,0,0
JS,Shea 2020,Rusinga Island Wakondo Beds Bovid Hill
Site,69,69,NA,NA,,0,0,0,1,0,0,0,0,0,0,0,0,0,0,1,0,0,0,0,0,0
JS,Shea 2020,Simbi,40,200,-
0.335235945,35.12977639,,1,1,1,0,0,0,0,0,0,1,0,0,0,0,0,1,0,0,0,0,0
JS,Shea
2020,Songhor,40,300,0.125189534,35.26127507,,0,0,1,0,0,0,0,0,0,0,0,0,1,1,1,0,0,0,0,0
JS,Shea 2020,West Baringo Kapthurin Formation Sibiloi School Road Site GnJh
79,200,200,NA,NA,,0,1,1,0,0,0,0,0,1,1,0,0,0,1,1,1,0,0,0,0,0
JS,Shea 2020,West Lake Baringo Kapthurin Formation upper Member K3 GnJh 17 GnJh
33,300,500,NA,NA,,0,1,1,0,0,0,0,0,0,1,0,0,0,1,0,0,0,1,0,0,0
JS,Shea 2020, upper Member K4 Komilot GnJh-74 Locus 1 and
2,300,500,NA,NA,,1,1,0,0,0,0,0,0,0,0,0,0,0,1,0,0,1,1,0,0,0
JS,Shea 2020,Midhishi
2,40,200,10.17130336,46.85256278,,1,1,1,1,0,1,1,0,1,0,1,0,0,1,1,0,1,1,0,0,1
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JS,Shea 2020,Kisese Rockshelter II Units XXII-XXVII,45,>45,-4.402473811,36.02924432,,1,0,1,1,0,1,1,0,0,0,0,0,0,0,1,1,0,0,0,0,0
JS,Shea 2020,Mumba Cave VI-A,64,64,NA,NA,,1,1,1,0,1,1,1,0,0,0,1,1,1,1,0,0,1,1,0,0,0
JS,Shea 2020,Mumba Cave Unit VI-B,>64,>64,NA,NA,,1,1,1,1,0,0,1,0,0,0,1,1,0,1,0,0,1,1,0,0,0
JS,Shea 2020,Nasera Rockshelter levels 12-25,56,73,-2.807629819,35.24179855,,1,1,1,1,0,1,1,0,0,1,1,0,0,1,0,0,1,0,0,0,0
JS,Shea 2020,Olduvai Ndutu Beds,50,50,NA,NA,,1,1,1,1,0,0,0,0,0,0,0,0,0,0,0,1,1,0,0,0,0
JS,Shea 2020,Kalambo Falls MSA-Lupemban,50,200,-8.546805756,31.31846581,,0,1,1,1,0,1,1,0,0,1,1,0,1,1,1,1,1,1,1,0,1
JS,Shea 2020,Kalemba Cave Unit G,35,35,NA,NA,,0,0,1,0,0,0,1,0,0,0,0,0,0,1,0,1,0,0,0,0,0
JS,Shea 2020,Mumbwa Cave Unit IX,170,170,-14.99477839,26.56951169,,0,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,1,0,0,0
JS,Shea 2020,Mumbwa Cave Unit VII-VIII,105,130,-14.98930021,26.55059606,,1,1,1,1,1,1,1,0,1,1,1,0,0,0,0,1,1,1,0,0,1
JS,Shea 2020,Mumbwa Cave Unit X-XIV,171,171,-15.06663823,26.68270562,,1,1,1,0,0,1,0,0,0,0,0,0,0,0,0,1,1,1,0,0,0
JS,Shea 2020,Goda Buticha Complex Iid-IIf,25,63,9.533054563,41.55417296,,0,0,1,0,1,1,1,0,0,0,1,1,0,1,1,1,0,1,1,0,0
JS,Shea 2020,Mochena Borago Lower T-Group,48,50,6.859010072,37.78833392,H. sapiens,0,1,1,1,0,1,0,0,0,0,1,0,0,1,1,1,1,1,1,0,0
JS,Shea 2020,Mochena Borago R-Group,37,43,6.860227064,37.69301865,H. sapiens,1,1,1,1,1,1,0,0,0,0,0,0,0,1,1,1,1,1,1,0,0
JS,Shea 2020,Mochena Borago S-Group,44,46,6.971681706,37.72711466,H. sapiens,1,1,1,1,1,1,0,0,0,0,1,0,0,1,1,1,1,1,1,0,0
JS,Shea 2020,Mochena Borago Upper T-Group,48,49,6.83647309,37.82612191,H. sapiens,0,1,1,1,1,1,0,0,0,0,1,0,0,1,1,1,1,1,1,0,0
JS,Shea 2020,Enkapune Ya Muto Levels RBL 4.1-4.2,39,50,-0.732469343,36.22021711,,1,0,1,1,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
JS,Shea 2020,Panga Ya Saidi Levels 10-12,48.5,51,-3.70857099,39.7279348,,1,1,0,1,0,0,0,0,0,0,0,0,0,0,0,1,1,1,0,0,0
JS,Shea 2020,Nasera levels 6-7,25,37,-2.551305299,35.23503218,,1,1,1,0,1,1,1,0,0,0,1,0,0,0,0,1,1,1,1,0,0
JS,Shea 2020,Nasera levels 8-11,50,56,-2.497549672,35.30765974,,1,1,1,0,0,0,1,0,0,0,1,0,0,0,0,0,1,1,0,0,0
JS,Shea 2020,Kalambo Falls MSA-LSA Polungu Industry,10,20,-8.575224419,31.35042973,,1,1,1,1,1,1,1,0,0,1,1,0,1,0,1,1,1,1,0,0,1
JS,Shea 2020,Kalemba Cave Units H-K,24,25,-14.13251633,32.93496034,,0,0,1,0,0,0,1,0,0,0,1,0,0,1,0,1,1,1,0,0,1
JS,Shea 2020,Mumbwa Cave Unit V,40,40,-15.0707006,26.60761628,,1,1,1,1,0,1,1,0,1,0,0,0,0,0,0,0,1,0,1,0,0
JS,Shea 2020,Ishango II ZB Holocene,<13,13,NA,NA,,0,1,1,0,1,1,1,0,0,0,0,0,0,0,0,0,1,1,1,0,0
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JS,Shea 2020,Ishango II NT-NFP Late Pleistocene,20,25,0.150735252,29.75672626,,1,0,1,0,1,1,1,0,0,0,0,0,0,0,0,0,1,1,1,0,0
JS,Shea 2020,Matupi Cave Matupi Industry,12,21,0.348361789,29.92266048,,1,1,1,1,1,1,0,0,0,0,0,0,0,0,0,0,0,0,1,0,1
JS,Shea 2020,Asfet F,5.6,5.6,15.19455295,39.70916615,,0,1,0,1,1,0,1,0,0,0,0,0,0,0,0,0,0,1,1,0,0
JS,Shea 2020,Gehlalo NW,7.2,8.4,15.20935287,39.91586955,,1,0,1,1,1,1,0,0,1,0,0,0,0,0,0,0,0,0,1,0,0
JS,Shea 2020,Misse East,7.5,7.8,15.2151547,39.99364591,,1,0,1,1,1,0,0,0,1,0,0,0,0,0,0,0,0,0,1,0,0
JS,Shea 2020,Baahti Nebait Levels 1-2,4,4,14.17741678,39.51838253,,0,1,1,1,1,0,0,0,0,0,0,0,0,0,0,0,1,0,0,0
JS,Shea 2020,Baahti Nebait Levels 4-6,10.9,11.5,14.12471109,38.24202521,,0,1,1,1,1,1,1,0,0,0,0,0,0,0,0,0,0,1,0,0,0
JS,Shea 2020,Bulbula River Late Pleistocene,33,34,7.710028705,39.28573664,,0,0,1,0,0,0,1,1,1,0,0,0,0,0,1,0,0,1,1,0,0
JS,Shea 2020,Bulbula River,11,14,7.819967558,38.31233911,,1,0,1,1,1,1,0,1,0,0,0,0,0,0,0,0,0,1,1,0,0
JS,Shea 2020,Gobedra Rockshelter Unit II b,4,5,14.17084823,38.17060403,,0,1,1,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,1,0,1
JS,Shea 2020,Gobedra Rockshelter Unit III,5,7,14.13591313,37.76768044,,0,1,1,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
JS,Shea 2020,Gobedra Rockshelter Units IV-VI,7,10,14.15115146,42.23716861,,0,1,1,1,0,0,0,0,0,0,0,0,0,0,0,1,0,0,1,0,0
JS,Shea 2020,Goda Buticha Complexl IIc,6,8,9.641025011,41.48102849,,0,0,1,1,1,0,1,0,0,0,0,0,0,1,1,0,0,1,1,0,0
JS,Shea 2020,Lake Besaka Brandt Period 1,19,22,8.7921536,39.90198695,,1,1,1,1,1,1,1,1,1,0,0,0,0,0,0,0,0,0,0,0,0
JS,Shea 2020,Lake Besaka Brandt Period 2,12,12,8.919511497,39.84766257,,0,1,1,1,1,1,0,0,1,0,0,0,0,0,0,1,0,0,0,0,0
JS,Shea 2020,Lake Besaka Brandt Period 3,4,11,8.827015052,39.86155131,,1,1,1,1,1,1,0,0,1,0,0,0,0,1,0,1,0,0,0,0,1
JS,Shea 2020,Lake Besaka Brandt Period 4,3.5,3.5,8.835413206,39.87033819,,1,1,1,1,1,1,0,0,0,0,0,0,0,0,0,1,0,0,0,0,1
JS,Shea 2020,Mochena Borago SD1 SD3,1,5,6.886551047,37.66735134,,0,0,1,1,1,1,1,1,1,0,0,0,0,0,1,1,0,1,1,0,1
JS,Shea 2020,East Turkana GaJj 1,8,9,NA,NA,,1,1,1,0,1,1,1,0,0,0,0,0,0,0,0,1,0,0,0,0,1
JS,Shea 2020,East Turkana GaJj 11,4.2,7.5,NA,NA,,1,1,1,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
JS,Shea 2020,Enkapune Ya Muto Levels BS 1A-RBL 2,3,6,-0.785923484,36.26034529,,1,0,1,1,1,1,0,0,1,0,0,0,0,0,0,0,0,1,0,0,0
JS,Shea 2020,Enkapune Ya Muto Levels DBL 1.2-1.3,19,39,-0.823170101,36.20397439,,1,1,1,1,1,1,1,0,0,0,1,0,0,0,0,0,0,0,1,0,0,0
JS,Shea 2020,Enkapune Ya Muto Levels RBL 2.2-3.1,6,7,-0.777703914,36.07826572,,1,0,1,0,1,0,0,0,0,0,0,0,0,0,0,0,0,1,0,0,0
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JS,Shea 2020,Gamble's Cave 2 level 12,4,6,-
0.552079624,36.19587962,,0,0,1,1,1,1,0,0,1,0,0,0,0,0,0,0,0,1,0,0,0
JS,Shea 2020,Gamble's Cave 2  Level 14 lower,8,8.5,-
0.548144548,36.04467029,,1,0,1,1,1,1,1,0,1,0,0,0,0,0,0,0,0,1,1,0,0
JS,Shea 2020,Gamble's Cave 2 level 14 upper,6,7.8,-
0.595608712,36.12271698,,0,0,1,1,1,1,1,0,1,0,0,0,0,0,0,0,0,1,1,0,1
JS,Shea
2020,Lopoy,1,2,3.187272204,36.05333126,,1,1,1,1,1,1,1,0,1,0,0,1,0,0,0,0,0,0,1,0,1
JS,Shea 2020,Lothagam
Lokam,8,11,2.707978071,35.91656125,,0,1,1,1,1,1,1,0,0,1,0,0,0,0,0,0,1,1,1,0,1
JS,Shea
2020,Lowasera,3,5,3.075276444,36.64379698,,1,1,1,1,1,0,0,0,0,1,0,0,0,0,0,0,1,0,0,0,1
JS,Shea 2020,Lukenya Hill GvJm 22 Occ. E,23,24,-
1.507804945,37.8477325,,1,1,1,1,1,1,0,0,0,0,0,0,0,0,0,0,1,1,0,0,1
JS,Shea 2020,Lukenya Hill GvJm 62 Unit A,20,21,-
1.462708202,37.3136748,,1,1,1,1,1,1,1,0,0,0,1,0,0,0,0,0,1,1,1,0,0
JS,Shea 2020,Masai Gorge Spits 1-2,9,10,-
0.634105357,36.20428812,,1,0,1,1,1,1,1,0,1,0,0,0,0,0,0,0,0,1,1,0,0
JS,Shea 2020,Masai Gorge Spits 12-18,2,3,-
0.643170058,36.24345668,,1,0,1,1,1,1,0,0,0,0,0,0,0,0,0,0,0,1,0,0,0
JS,Shea 2020,Masai Gorge Spits 3-10,6,7,-
0.745957637,36.30924741,,1,1,1,1,1,1,1,0,0,0,0,0,0,0,0,0,1,1,1,0,0
JS,Shea 2020,Mtongwe Lower Group,40,200,-
4.389950518,39.4796216,,0,1,1,0,0,1,0,0,0,0,0,0,0,1,0,1,0,0,0,0,0
JS,Shea 2020,Muringa Rock Shelter Levels 4-
8,Typol,Typol,NA,NA,,1,1,1,1,1,1,1,0,1,0,0,0,0,0,0,0,0,0,1,0,0
JS,Shea 2020,Nderit Drift GsJi 2T
LSA,14,14,NA,NA,,1,0,1,1,1,1,1,0,0,0,0,0,0,0,0,0,1,1,0,0,0
JS,Shea 2020,Panga Ya Saidi Levels 1-4,0.7,7.5,-
3.643401321,39.70551304,,1,1,0,1,1,0,0,0,0,0,0,0,0,0,1,0,1,1,0,0,0
JS,Shea 2020,Panga Ya Saidi Levels 5-7,14.5,14.5,-
3.642616,39.72565229,,1,1,0,1,1,0,0,0,0,0,0,0,0,0,0,0,1,1,0,0,0
JS,Shea 2020,Panga Ya Saidi Levels 8-9,23,33,-
3.662013245,39.75933449,,1,1,0,0,1,0,0,0,0,0,0,0,0,0,0,0,1,1,0,0,0
JS,Shea 2020,Tunnel Rockshelter Levels 5-
11,2.1,2.8,NA,NA,,0,0,1,1,1,1,1,0,1,0,0,0,0,0,0,1,1,1,1,0,0
JS,Shea 2020,Bur Harkaba Rifle Range Site Layer
D,Typol.,Typol.,NA,NA,,1,0,1,0,1,1,0,0,0,0,1,1,0,0,0,1,0,1,0,0,1
JS,Shea 2020,Bur Harkaba Rifle Range Site Layer
F,Typol.,Typol.,NA,NA,,1,0,1,0,1,1,1,0,0,0,1,1,0,0,0,1,0,1,0,0,1
JS,Shea 2020,Gur Warbei or Bur Eibe
Doian,Typol.,Typol.,NA,NA,,1,1,1,1,1,1,1,0,0,1,1,0,0,0,0,0,0,0,0,0,1
JS,Shea 2020,Gur Warbei or Bur Eibe
Magosian,Typol.,Typol.,NA,NA,,0,0,0,0,1,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0
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JS,Shea 2020,Gur Warbei or Bur Eibe Magosio-Doian,Typol.,Typol.,NA,NA,,0,0,0,0,1,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0
JS,Shea 2020,Las Geel Shelter 7 Unit 708,13,13,9.921575046,43.90670144,,1,1,1,1,1,0,0,0,0,0,0,0,0,0,0,0,1,0,0,0
JS,Shea 2020,Las Geel Shelter 7 Units 703-702,5,5,9.893718568,44.07485039,,1,1,1,1,1,0,0,0,0,0,0,0,0,0,0,0,0,1,0,0
JS,Shea 2020,Las Geel Shelter 7 Units 709-711,13,42,9.904287624,44.04211611,,0,0,1,1,0,0,1,1,1,0,0,0,0,1,1,0,0,1,1,0,0
JS,Shea 2020,Baura 1 Units 1-4,2.5,2.5,NA,NA,,1,1,1,1,1,1,1,0,0,0,0,0,0,0,0,0,0,1,0,0,0,0
JS,Shea 2020,Kirumi Isumbirira Levels 13-15,2.8,2.8,NA,NA,,0,0,1,1,1,1,1,0,1,0,0,0,0,0,0,0,1,0,0,0,1
JS,Shea 2020,Kirumi Isumbirira Levels 5-13,0.2,>0.2,NA,NA,,0,0,1,1,1,1,1,0,1,0,0,0,0,0,0,0,1,0,0,0,1
JS,Shea 2020,Kisese Rockshelter II Units III-X,18,20,-4.532070059,35.79673402,,1,0,1,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,1,0,1
JS,Shea 2020,Kisese Rockshelter II Units XI-XXI,22,45,-4.486755443,35.62152404,,1,0,1,1,1,1,1,0,0,0,0,0,0,0,0,1,0,0,1,0,0
JS,Shea 2020,Kuumbi Cave Phase 2,12,13,-6.334252045,39.47225389,,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
JS,Shea 2020,Kuumbi Cave Phase 3,17,20,-6.407787863,39.51678843,,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
JS,Shea 2020,Kwa Mwango-Isanzu,3.5,3.5,-4.180529721,34.73268968,,0,0,1,1,1,1,1,0,1,0,0,0,0,0,0,0,0,0,0,0,1
JS,Shea 2020,Lusangi 1 Unit 1 LSA,1,1,NA,NA,,1,1,1,1,1,1,1,0,0,0,0,0,0,0,0,0,0,1,0,0,0,0
JS,Shea 2020,Magubike Rockshelter,40,100,-6.311652084,37.10448674,,1,1,1,1,0,0,1,0,0,0,0,0,0,0,1,1,1,0,0,0,0
JS,Shea 2020,Markasi Lusangi 2 Unit 3 LSA,1,4.5,-4.708993445,39.0150762,,1,1,1,1,1,1,1,0,0,0,0,0,0,0,0,0,1,0,0,0,0
JS,Shea 2020,Mlambalasi Rockshelter LSA,15,20,-7.634540582,35.32703669,,1,1,1,1,0,1,0,0,0,0,0,0,0,0,0,0,1,0,0,0
JS,Shea 2020,Mumba Cave lower bed II,37,37,-3.5781172,35.23184654,,1,1,1,0,1,0,1,0,0,0,1,0,0,1,1,1,1,1,0,0,1
JS,Shea 2020,Mumba Cave Unit V,49,57,-3.51923878,35.26607318,,1,1,1,1,1,1,1,0,0,0,1,0,0,1,0,0,1,1,0,0,1
JS,Shea 2020,Mumba Cave Upper Bed III,1,12,-3.597869059,35.28726201,,1,1,1,1,1,1,1,1,0,0,0,0,0,0,0,0,0,0,0,0,1
JS,Shea 2020,Nasera Rockshelter 3B,12,16,-2.542925594,35.17381787,,1,1,1,1,1,1,1,0,1,0,0,0,0,0,0,0,1,1,1,0,0
JS,Shea 2020,Nasera Rockshelter levels 4-5,16,24,-2.516942209,35.35313882,,1,1,1,0,1,1,1,0,0,0,1,0,0,0,0,1,1,1,1,0,0
JS,Shea 2020,Olduvai Naisusu Beds,17,17,NA,NA,,1,0,1,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
JS,Shea 2020,Gwisho Site A,,,NA,NA,,1,1,1,1,1,1,1,0,0,0,0,0,1,0,0,0,1,0,0,1,1
JS,Shea 2020,Gwisho Sites B and C,4,5.5,NA,NA,,1,1,1,1,1,0,1,0,0,0,0,0,0,0,0,0,0,1,1,1,0
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JS,Shea 2020,Kalambo Falls LSA-Kaposwa Industry,4,10,-
8.641199606,31.15590066,,1,1,1,1,1,0,0,0,0,0,0,0,1,1,0,0,1,0,0,1,1
JS,Shea 2020,Kalemba Cave Levels 5-6,10,22,-
14.05297767,34.58077991,,0,1,1,1,1,0,0,0,0,0,0,0,0,0,0,0,1,0,0,0,1
JS,Shea 2020,Kalemba Cave Levels 8-10,22,24,-
14.15962377,32.34587606,,1,0,1,1,1,0,1,0,0,0,1,0,0,0,0,0,1,0,1,0,1
JS,Shea 2020,Kalemba Cave Lower Level 2,3,3,-
14.17301911,30.2993878,,1,1,1,1,1,0,1,0,0,0,0,0,0,0,0,0,1,0,1,0,1
JS,Shea 2020,Kalemba Cave Lower Level 4,9.7,9.7,-
14.18830838,33.71493035,,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,1
JS,Shea 2020,Kalemba Cave Units L-N,11,14,-
14.07591815,35.10037291,,0,1,1,1,1,0,1,0,0,0,1,0,0,1,0,1,0,0,1,0,1
JS,Shea 2020,Kalemba Cave Units O-Q,4,6,-
14.1286041,36.22093881,,1,1,1,1,1,0,1,1,0,0,0,0,0,0,0,1,0,0,1,1,1
JS,Shea 2020,Kalemba Cave Upper Level 4,3.5,3.5,-
14.0683904,31.76671642,,0,0,0,1,1,0,1,0,0,1,0,0,0,0,0,0,1,0,1,1,1
JS,Shea 2020,Makwe Cave Levels 2-5,1,5,-
14.27176309,31.93375045,,0,0,1,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,1,0
JS,Shea 2020,Mumbwa Cave Unit II-III,6,15,-
3.59273078,35.21621261,,1,1,1,1,1,1,1,0,1,0,1,0,0,0,0,0,1,0,1,1,1
JS,Shea 2020,Mwela Rockshelter Level RBSD,7,13,-
10.40542057,31.24254144,,0,0,1,1,1,0,1,0,0,0,0,0,0,0,0,0,0,0,0,1,1
JS,Shea 2020,Kadanga A9,0.2,3.7,NA,NA,,1,0,0,1,1,1,1,0,1,0,0,0,0,0,0,0,0,0,0,0,1
JS,Shea 2020,Kirumi Isumbirira Levels 1-4,0.2,0.2,-
4.34189095,34.86911452,,0,0,1,1,1,1,1,0,1,0,0,0,0,0,0,0,1,0,0,0,1
JS,Shea 2020,Asa
Koma,3.3,4.5,11.01831628,41.00759468,,1,1,1,1,1,0,1,0,1,0,0,0,0,0,0,1,1,1,0,1
JS,Shea
2020,Wakrita,3.7,4.8,11.05997952,42.70347656,,1,1,1,1,1,1,1,0,1,0,0,0,0,0,0,0,1,1,1,0,1
JS,Shea 2020,Anqer Baahti Aksum Context
13,4,6,14.08115768,37.81493063,,0,1,1,1,1,1,1,0,0,0,0,0,0,0,0,0,1,1,1,0,0
JS,Shea 2020,East Turkana Dongodien GaJj
4,4,4,NA,NA,,1,1,1,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,1,0,0
JS,Shea 2020,East Turkana Ileret Stone Bowl Site FwJj
5,4,4,NA,NA,,1,0,1,0,1,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,1
JS,Shea 2020,Enkapune Ya Muto Levels ELM,2.5,2.7,-
0.747394477,36.07173658,,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,1,0,0,0
JS,Shea 2020,Gamble's Cave 2 level 6,1.4,3.2,-
0.488587807,36.16777993,,1,0,1,1,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
JS,Shea 2020,Hyrax Hill Site I,5,6,-
0.350345326,36.10113617,,1,1,1,1,1,1,0,0,0,0,0,0,0,1,0,0,1,1,1,0,1
JS,Shea 2020,Ilkek Gilgil,2,2.2,-
0.492322745,36.37038753,,0,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,1,0,0,1
JS,Shea 2020,Laikipia Horizon I,3,>3,NA,NA,,1,1,1,0,1,1,1,0,1,0,0,0,0,0,0,0,0,0,1,0,0
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JS,Shea 2020,Lemek NE GuJf 13,1.7,2.3,-
1.074619048,35.52193441,,1,1,1,1,1,1,1,0,1,0,0,0,0,0,0,0,1,1,0,0,0
JS,Shea 2020,Lemek NW GuJf 92,2.7,2.7,-
1.045420557,35.29009428,,0,0,1,1,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
JS,Shea 2020,Lemek West GuJf 14,1.9,2.2,-
1.160820298,35.35652356,,1,1,1,0,1,1,1,0,1,0,0,0,0,0,0,0,1,1,0,0,1
JS,Shea 2020,Marula,1,3.3,-
0.708397937,36.17503364,,1,1,1,1,1,1,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0
JS,Shea 2020,Narosura,2.5,2.8,-
1.545478649,32.45901903,,1,1,1,1,1,1,1,0,1,0,0,0,0,0,0,0,1,1,1,1,1
JS,Shea 2020,Ndabibi,1.3,2.2,-
0.807300052,36.33497558,,1,1,1,1,1,1,1,0,1,0,0,0,0,0,0,0,0,0,0,0,0
JS,Shea 2020,Nderit Drift Units 25 and
13,3.5,3.5,NA,NA,,1,1,1,1,1,1,1,0,1,0,0,0,0,0,0,0,0,0,0,0,0
JS,Shea 2020,Ngamuriak GuJf 6,1.7,2.3,-
1.090774175,35.33887858,,1,1,1,1,1,1,1,0,1,0,0,0,0,0,0,0,1,1,1,0,1
JS,Shea 2020,Njoro River Cave,3,3,NA,NA,,1,0,1,1,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,1
JS,Shea 2020,Oldorotua 1 GuJe 4,1,2,-
1.128209023,35.25811103,,1,1,1,0,1,1,1,0,1,0,0,0,0,0,0,0,1,0,0,0
JS,Shea 2020,Oldorotua 3 GuJf 66,1,2,-
1.19142996,35.50826235,,1,1,1,0,1,1,0,0,1,0,0,0,0,0,0,0,1,1,0,0,0
JS,Shea 2020,Olopilukunya,2.3,2.3,-
1.639054688,36.00690594,,1,1,1,1,1,1,0,0,1,0,0,0,0,0,0,0,1,1,0,0,0
JS,Shea 2020,Prolonged Drift formation C,2,3,-
0.553157002,36.10448405,,1,1,1,1,1,1,1,0,0,0,0,0,0,0,0,0,1,1,1,0,1
JS,Shea 2020,Salasun,1,3,NA,NA,,1,1,1,1,1,1,0,0,0,0,0,0,0,0,0,0,1,1,1,0,0
JS,Shea 2020,Sambo Ngige GuJf 17,1.3,1.5,-
1.189609322,35.33142152,,1,0,1,0,1,0,0,0,1,0,0,0,0,0,0,0,0,1,0,0,0
JS,Shea 2020,Sugenya,2,3,-
1.110494588,35.54090829,,1,1,1,1,1,1,1,0,1,0,0,0,0,0,0,0,1,1,1,1,1
JS,Shea 2020,Tsavo Wright's PN sites,1.3,6,-
3.002812294,38.75109051,,1,1,1,0,1,1,1,0,0,0,0,0,0,0,0,0,1,0,0,0,0
JS,Shea 2020,Luxmanda,2.1,3.1,-
4.236389524,35.12970579,,1,0,1,1,1,1,1,0,1,0,0,0,0,0,0,0,0,0,1,1,1
JS,Shea 2020,Nasera Rockshelter 3A,1,4,-
2.486550971,35.3440055,,1,1,1,1,1,1,1,0,0,0,0,0,0,0,0,0,1,1,1,0,1
JS,Shea 2020,Ngorongoro Burial
Mounds,2.3,2.3,NA,NA,,0,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,1,0,0,1
JS,Shea 2020,Abindu Rockshelter,2,2,NA,NA,,1,0,1,1,1,0,0,0,0,0,0,0,0,0,0,0,1,0,0,0,0
JS,Shea 2020,Agoro Rockshelter,2.4,2.4,NA,NA,,1,0,1,1,1,0,0,0,0,0,0,0,0,0,0,0,1,0,0,0,0
JS,Shea 2020,Deloraine,1,2,-
0.166468967,35.84510459,,1,1,1,0,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
JS,Shea 2020,Gogo Falls Trench I,3,7,-
0.7636171,34.20534878,,1,0,1,1,1,1,1,0,0,0,0,0,0,0,0,0,1,1,1,0,1
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JS,Shea 2020,Gogo Falls Trench II,1.7,1.9,-0.72955685,34.24918029,,1,0,1,1,1,1,1,0,0,0,0,0,0,0,0,0,0,1,1,1,0,0
JS,Shea 2020,Gogo Falls Trench III,1.8,2,-0.684404813,34.29522107,,1,0,1,1,1,1,1,0,0,0,0,0,0,0,0,0,1,1,1,0,1
JS,Shea 2020,Gogo Falls Trench V,,,-0.712807667,34.22174934,,1,0,1,1,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
JS,Shea 2020,Haa H1,>4.5,>4.5,0.071014747,34.12415262,,1,1,0,0,1,0,0,0,0,0,0,0,0,0,0,0,1,0,1,0,0
JS,Shea 2020,Haa H2,1.3,1.5,0.176695704,34.10806251,,1,1,0,0,1,1,0,0,0,0,0,0,0,0,0,0,1,0,0,0,0
JS,Shea 2020,Jawuoyo Rockshelter,2,2,NA,NA,,0,0,1,0,1,0,0,0,0,0,0,0,0,0,0,0,1,0,0,0,1
JS,Shea 2020,Laikipia Layers II-V,0.5,3,NA,NA,,1,1,1,0,1,1,1,0,1,0,0,0,0,0,0,0,1,0,1,0,1
JS,Shea 2020,Nyaidha Rockshelter,2.3,2.3,NA,NA,,1,0,1,1,1,0,0,0,0,0,0,0,0,0,0,0,1,0,0,0,0
JS,Shea 2020,Randhore Rockshelter,1.2,1.2,NA,NA,,1,0,1,1,1,0,0,0,0,0,0,0,0,0,0,0,1,0,0,0,1
JS,Shea 2020,Rangong Rockshelter,2.9,2.9,NA,NA,,1,0,1,1,1,0,0,0,0,0,0,0,0,0,0,0,1,0,0,0,0
JS,Shea 2020,Usengi 1-K,>4.5,>4.5,-0.084157024,34.04904983,,1,1,0,0,1,0,0,0,0,0,0,0,0,0,0,0,1,0,1,0,0
JS,Shea 2020,Usengi 3-K,2.6,3.2,0.033384721,33.99961522,,1,1,0,0,1,1,0,0,0,0,0,0,0,0,0,0,1,0,1,0,0
JS,Shea 2020,Usengi 3-U,>4.5,>4.5,-0.03295784,34.01756373,,1,1,0,0,1,1,0,0,0,0,0,0,0,0,0,0,1,0,1,0,0
JS,Shea 2020,Wadh Lang'o 1,3.9,4.4,-0.366689511,35.00815931,,1,1,1,0,1,1,0,0,0,0,0,0,0,0,0,0,1,0,1,0,0
JS,Shea 2020,Wadh Lang'o 2,1.7,2,-0.436334138,34.9397316,,1,1,1,0,1,1,0,0,0,0,0,0,0,0,0,0,1,0,1,0,0
JS,Shea 2020,Mahal Teglinos Kassala,3.5,4.5,15.28853365,36.67387372,,1,1,1,0,1,0,1,0,0,0,1,0,1,0,0,0,0,0,1,0,1
JS,Shea 2020,Baura 1 Units 1-4,0.4,0.4,-4.887095539,36.38064345,,1,1,1,1,1,1,1,0,0,0,0,0,0,0,0,0,1,0,0,0,0
JS,Shea 2020,Lusangi 1 Unit 1 LSA and Iron Age,0.8,0.8,-4.760653696,34.4947839,,1,1,1,1,1,1,1,0,0,0,0,0,0,0,0,0,1,0,0,0,0
JS,Shea 2020,Markasi Lusangi 2 Unit 3 IA,0.7,0.7,-4.784899629,39.05953908,,1,1,1,1,1,1,1,0,0,0,0,0,0,0,0,0,1,0,0,0,0
JS,Shea 2020,Mlambalasi Rockshelter LSA to Iron Age,,,-7.613615533,35.62779986,,1,0,1,1,0,0,0,0,0,0,0,0,0,0,0,0,1,0,0,0,0
JS,Shea 2020,Seronera,1,3,-1.862253174,34.32625092,,0,0,1,1,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,1
JS,Shea 2020,Nsongezi Rockshelter Levels I-IV,0.5,1,-0.926747994,30.73224789,,1,1,1,1,1,1,1,0,0,0,0,0,0,0,0,0,1,1,1,0,1
JS,Shea 2020,Rangi Cave Levels II-III,0.5,3,1.773172575,34.40565213,,1,1,1,1,1,0,1,0,0,0,0,0,0,1,0,0,0,0,1,0,1
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JS,Shea 2020,Kalemba Cave Units R-S,0.5,2,-14.13467378,33.72829196,,1,0,1,1,1,0,1,0,0,0,0,0,0,0,0,1,0,0,1,1,1
JS,Shea 2020,Kalemba Cave Upper Level 2,1.4,1.4,-14.0722123,33.31046904,,1,1,1,1,1,0,1,0,0,0,0,0,0,0,0,0,1,0,0,0,1
JS,Shea 2020,Mumbwa Cave Unit I,0,2,-15.06370853,26.61643935,,1,1,1,1,1,1,0,0,0,0,0,0,0,0,0,1,1,0,1,0,0
JS,Shea 2020,Thandwe Cave Zambia,1,1.7,-13.78808139,32.65724891,,0,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
JS,Shea 2020,Kokan Rockshelter,2.3,2.3,15.45877842,37.84776561,,1,1,1,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,1,0,1
JS,Shea 2020,Sembel Asmara,2.4,2.8,15.39112439,38.91320803,,0,0,1,0,0,1,0,0,0,0,0,0,0,0,0,0,0,1,0,0,0
JS,Shea 2020,Aksum Site D Pre-Aksumite,2.4,2.7,14.06466264,43.17016977,,0,0,1,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,1,0,0
JS,Shea 2020,Aksum Site D Late Aksumite,1.3,1.4,14.08617623,19.34871135,,1,0,1,1,1,0,0,0,0,0,0,0,0,0,0,0,0,1,1,0,1
JS,Shea 2020,Aksum Site K,1.3,1.4,14.20999722,42.3927753,,0,1,1,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
JS,Shea 2020,Gobedra Rockshelter Unit I a,<3,3,14.15220341,35.71871931,,0,1,1,1,1,0,0,0,0,0,0,0,0,0,1,0,0,1,0,0
JS,Shea 2020,Goda Buticha Complex I,0.7,1.9,9.614388315,41.57539586,,0,0,1,1,1,1,0,0,0,0,0,0,0,1,1,1,0,1,1,0,0
JS,Shea 2020,Mai Agam SU 2,2.1,2.1,14.16138602,-5.186237037,,0,1,1,0,1,0,0,0,1,0,0,0,0,0,0,0,1,0,0,0,1
JS,Shea 2020,Medogwe Workshop Locality,1.2,2.7,14.12000022,37.83344302,,0,1,1,1,1,0,0,0,0,0,0,0,0,0,0,0,1,1,0,0,0
JS,Shea 2020,Hyrax Hill Site II,1.6,9,-0.284737641,36.1403491,,1,0,1,1,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
JS,Shea 2020,Kulchurdo Rockshelter Levels 1-2,0.5,0.5,2.300924878,38.06080606,,0,1,1,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
JS,Shea 2020,Masai Gorge Spits 19-21,0.5,1,-0.671419827,36.23288913,,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
JS,Shea 2020,Jangwani I,,,-3.63143664,35.29903269,,1,1,1,1,1,1,0,0,1,0,0,0,0,0,0,0,1,0,1,1,1
JS,Shea 2020,Kuumbi Cave Phase 1,0.5,0.6,-6.289256853,39.52355109,,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
JS,Shea 2020,Malambasi Rockshelter Iron Age,0.5,1,-7.514671838,35.50966381,,1,1,1,1,0,0,0,0,0,0,0,0,0,0,0,0,1,1,0,0,0
JS,Shea 2020,Kalambo Falls Iron Age,0.3,1.9,-8.597046792,31.14226911,,0,1,1,1,1,0,0,0,0,1,0,0,1,0,0,0,1,0,1,0,1
JP,Roberts et al. 1997,Boxgrove,478,524,50.79386533,-0.658427129,,0,1,1,1,0,0,0,0,0,1,1,0,1,0,0,0,0,0,0,0,0
JP,Fredericksen 1994,Pamwak Rockshelter Phase I,0.5,2,-2.183649164,147.0701881,,1,1,0,0,0,0,1,0,0,0,0,0,0,0,0,0,0,1,0,0,0
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JP,Fredericksen 1994,Pamwak Rockshelter Phase II-IV,5,12.5,-
2.200391708,147.0389092,,0,1,1,1,0,0,1,0,0,0,0,0,0,0,0,0,0,1,0,1,1
JP,Ariel-Shatil 2006,Sha'ar
Hagolan,7,7.4,32.76126636,35.67290378,,0,1,1,1,0,1,1,1,1,1,1,1,1,0,0,0,1,1,1,1,1
JP,Walter and Green 2011,Su'ena,0.45,0.6,-
10.19272342,161.6660259,,0,1,1,0,0,0,1,0,0,1,0,0,1,0,0,0,0,0,0,0,1
JP,Allen 2011,Oposisi,1.5,2,-
8.819760214,146.4625684,,1,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,1
JP,Reepmeyer 2010,Teouma,2.5,3.2,-
17.84103147,168.4956279,,1,1,1,0,0,0,1,0,1,0,0,0,0,0,0,0,0,0,0,0,0
JP,David 2019,Moiapu 3,2,2.55,-
9.369940453,147.1081154,,1,1,1,0,0,0,0,0,0,0,0,0,0,0,0,1,0,0,0,1
JP,Leach 1980,Riverton adze quarry,0.5,0.7,-
46.33945547,167.8403621,,0,1,1,0,0,0,0,0,0,1,0,0,1,0,0,0,0,1,0,1,1
JP,Wilson 1999,Cat's eye point,0.5,0.9,-
45.18803762,170.8041111,,1,1,1,0,0,0,0,0,0,1,0,0,1,0,0,0,0,0,0,1,1
JP,Walling 1988,Little man 1,0.95,1,37.27579321,-
113.3368035,,0,1,1,0,0,0,0,0,0,1,1,1,0,0,0,0,1,0,0,1,1
JP,Walling 1988,Little man 2,1,1.2,37.19610872,-
113.4402898,,0,1,1,1,0,0,1,0,0,1,1,1,0,0,0,0,1,0,0,1,1
JP,Walling 1988,Little man 3,0.95,1,37.1506972,-
113.3023167,,0,1,1,1,0,0,1,0,0,1,1,1,0,0,0,0,1,0,0,1,1
JP,Wambach 2014,Lava Ridge Ruin,0.8,0.95,36.04094342,-
114.7417392,,1,1,1,1,0,0,1,0,1,1,1,1,0,0,0,0,1,0,0,0,1
JP,Wambach 2014,Granary House,0.85,1,36.16313128,-
116.4255597,,0,1,1,0,0,0,1,0,1,1,1,1,0,0,0,0,1,0,0,0,1
JP,Wambach 2014,Andrus Canyon,0.8,0.95,36.03193634,-
114.761779,,0,1,1,0,0,0,0,0,0,1,1,1,0,0,0,0,1,0,0,0,1
JP,Wambach 2014,Corn Cob,0.7,0.8,36.03691812,-
113.7972469,,0,1,1,0,0,0,0,0,1,1,1,1,0,0,0,0,0,0,0,0,1
JP,Wambach 2014,Coyote,0.7,0.8,36.08975604,-
115.2136762,,0,1,1,1,0,0,1,0,1,1,1,1,0,0,0,0,1,0,0,0,1
JP,Wambach 2014,Site 232,0.85,1,36.04733504,-
114.2745325,,0,1,1,1,0,0,0,0,1,1,1,1,0,0,0,0,0,0,0,0,1
JP,Wambach 2014,Peter's Pocket,0.85,1,36.00127646,-
114.0232724,,0,1,1,0,0,0,1,0,1,1,1,1,0,0,0,0,1,0,0,0,1
JP,Wambach 2014,To'tsa,0.7,0.8,36.16055294,-
112.6718329,,0,1,1,0,0,0,1,0,1,1,1,1,0,0,0,0,0,0,0,0,1
JP,Love 1980,5LP110 and 111,1.17,1.2,37.23035118,-
107.9451384,,0,1,1,1,0,0,1,1,0,1,1,1,1,0,0,0,1,0,0,1,1
Nishiaki,Nishiaki 2021,Kara Tenesh
3,11,60,51.01093722,86.35839591,NA,0,1,1,1,1,0,1,0,0,0,0,0,0,0,0,0,1,1,0,0,0
Nishiaki,Nishiaki 2021,Okladnikov Cave
3,24,60,51.72882934,84.82234102,NA,0,0,1,1,0,0,1,0,0,0,0,0,0,0,0,1,0,0,0,0,0
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Nishiaki,Nishiaki 2021,Okladnikov Cave 2,24,60,51.69990384,83.51670885,NA,0,0,1,0,1,0,1,0,0,0,0,0,0,0,0,1,0,0,0,0,0
Nishiaki,Nishiaki 2021,Okladnikov Cave 1,24,60,51.70804734,83.6706571,NA,0,0,1,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Okladnikov Cave 6,24,60,51.76921966,83.99380617,NA,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,1,0,0,0,0,0
Nishiaki,Nishiaki 2021,Okladnikov Cave 7 gallery 1,24,60,51.73956299,84.36987326,NA,0,1,1,0,0,0,0,0,0,0,0,0,0,0,1,1,0,0,0,0,0
Nishiaki,Nishiaki 2021,Strashnaya Cave 4,24,60,51.16433399,83.07708577,NA,0,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,1,0,0,0
Nishiaki,Nishiaki 2021,Strashnaya Cave 3,11,60,51.2340165,83.02913707,NA,0,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,1,0,0,0
Nishiaki,Nishiaki 2021,Denisova Cave main chamber stratum11,24,60,51.47181095,84.75130574,NA,0,0,1,0,0,0,0,0,0,0,0,0,0,1,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Denisova Cave main chamber stratum21,130,244,51.32494306,84.59005748,NA,0,1,1,0,0,0,0,0,0,0,0,0,0,0,1,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Denisova Cave main chamber stratum 9,24,60,51.31464371,84.62899614,NA,0,1,1,0,1,0,0,0,0,0,0,0,0,0,0,0,0,1,0,0,0
Nishiaki,Nishiaki 2021,Denisova Cave main chamber stratum14,60,130,51.33208644,84.69906269,NA,0,1,1,0,0,0,0,0,0,0,0,0,0,0,0,1,0,0,0,0,0
Nishiaki,Nishiaki 2021,Denisova Cave main chamber stratum12,24,60,51.36562168,84.74489431,NA,0,0,1,0,0,0,1,0,0,0,0,0,0,0,1,1,0,0,0,0,0
Nishiaki,Nishiaki 2021,Ust Karakol 1 stratum3,24,60,51.33746761,84.81260568,NA,0,0,1,0,1,0,1,0,0,0,1,0,0,0,0,0,0,1,1,0,0,0
Nishiaki,Nishiaki 2021,Ust Karakol 1 stratum5,24,60,51.31835216,84.7743816,NA,0,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Ust Karakol 1 stratum9,24,60,51.44091352,84.80494321,NA,0,0,1,0,0,1,1,0,1,0,0,0,0,0,0,0,0,0,1,1,0,0
Nishiaki,Nishiaki 2021,Ust Karakol 1 stratum10,24,60,51.43798444,84.54312381,NA,0,0,1,0,0,0,0,0,1,0,0,0,0,0,0,0,0,0,1,1,0,0
Nishiaki,Nishiaki 2021,Ust Karakol 1 stratum11,24,60,51.34270459,84.51820016,NA,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,1,1,0,0
Nishiaki,Nishiaki 2021,Ust Karakol 1 stratum13,60,71,51.35622069,84.85396786,NA,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,1,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Ust Karakol 1 stratum18A,93,106,51.39556566,84.88283797,NA,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,1,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Ust Karakol 1 stratum19,130,190,51.2980422,84.70325623,NA,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Dvuglazka ?,11,24,54.0815424,91.09963107,NA,0,0,0,0,0,1,1,0,0,0,1,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Dvuglazka 4,11,60,54.00819871,91.09439371,NA,0,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,1,0,0,0
Nishiaki,Nishiaki 2021,Dvuglazka 6?,11,60,54.12926756,91.03293703,NA,0,0,1,0,0,0,0,0,0,0,0,0,0,0,1,0,0,0,0,0,0
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Nishiaki,Nishiaki 2021,Dvuglazka
7,11,60,54.08973257,91.01858104,NA,0,0,1,0,0,0,0,0,0,0,0,0,0,0,1,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Dvuglazka
5,11,60,54.08092374,90.98243468,NA,0,0,1,0,0,0,0,0,0,0,0,0,0,0,1,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Arta 2  Layers 1-
3,11,24,51.22027164,112.3576916,NA,0,0,1,0,0,1,1,0,0,0,0,0,0,0,0,0,1,1,0,0,0
Nishiaki,Nishiaki 2021,Arta 2 Layer
4,24,60,51.25273451,112.4064768,NA,0,1,0,0,0,0,0,0,0,0,0,0,0,0,1,0,1,0,0,0,0
Nishiaki,Nishiaki 2021,Maloyalomanskaya Cave Layer
2,11,60,50.45550869,86.46340287,NA,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,1,0,0,0
Nishiaki,Nishiaki 2021,Maloyalomanskaya Cave Layer
4,24,60,50.44666538,86.53394252,NA,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,1,0,0,0
Nishiaki,Nishiaki 2021,Anui 2 Layer
3,11,24,51.42665703,84.48044753,NA,0,0,1,0,0,1,0,0,1,0,0,0,0,0,0,0,0,1,1,0,0
Nishiaki,Nishiaki 2021,Anui 2 Layer
6,11,24,51.31529093,84.67173585,NA,0,0,1,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Anui 2 Layer
8,11,24,51.36560086,84.7995974,NA,0,0,0,0,0,0,1,0,0,0,0,0,0,0,0,0,1,1,1,0,0
Nishiaki,Nishiaki 2021,Anui 2 Layer
9,24,60,51.40586354,84.82543728,NA,0,0,1,0,1,0,1,0,0,0,0,0,0,0,0,0,0,1,1,0,0
Nishiaki,Nishiaki 2021,Anui 2 Layer
12,24,60,51.4657768,84.59287829,NA,0,1,1,0,1,0,0,0,0,0,0,0,0,0,0,1,1,0,0,0
Nishiaki,Nishiaki 2021,Anui 2 Layer
7,11,24,51.41320848,84.53072202,NA,0,1,0,0,0,1,0,0,0,0,0,0,0,0,1,1,0,0,0,0,0
Nishiaki,Nishiaki 2021,Anui 2 Layer
11,24,60,51.41223757,84.70800851,NA,0,0,1,0,1,1,0,0,0,0,0,0,0,0,1,1,0,1,1,0,0
Nishiaki,Nishiaki 2021,Anui 2 Layer
10,24,60,51.36697866,84.85764296,NA,0,0,1,0,0,0,1,0,0,0,0,0,0,0,1,1,0,1,0,0,0
Nishiaki,Nishiaki 2021,Afanas'eva
Gora,11,24,54.66116965,90.66081483,NA,0,1,1,0,0,0,1,0,0,0,1,0,0,0,0,0,0,1,1,0,0
Nishiaki,Nishiaki 2021,Aleksievsk
1,11,24,54.042227,105.3880121,NA,0,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,1,1,0,0
Nishiaki,Nishiaki 2021,Anui 1 Layer
6,11,60,51.37590565,84.68040603,NA,0,1,1,0,1,1,0,0,0,0,0,0,0,0,0,0,1,1,0,0,0
Nishiaki,Nishiaki 2021,Anui 3 Layer
12,24,60,51.36884677,84.51800864,NA,0,0,1,0,1,1,0,0,0,0,0,0,0,0,0,0,0,0,1,0,0
Nishiaki,Nishiaki 2021,Anui 3 Layer
11,11,60,51.42766141,84.82812859,NA,0,0,1,0,1,1,0,0,0,0,0,0,0,0,0,0,0,0,1,0,0
Nishiaki,Nishiaki 2021,Bol' shoj Naryn 1 upper
complex,11,60,53.60196484,103.5001153,NA,0,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,1,1,0,0
Nishiaki,Nishiaki 2021,Bol' shoj Naryn 1 lower
complex,24,60,53.56188152,103.6099646,NA,0,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki
2021,Buret',11,24,52.93243036,103.5515259,NA,0,1,1,0,1,1,1,0,1,0,0,0,0,0,0,0,1,1,1,0,0
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Nishiaki,Nishiaki 2021,Tyumechin 4 tempo
1,24,60,50.83274263,85.64353726,NA,0,0,1,0,1,0,0,0,1,0,1,0,0,0,0,0,0,1,0,0,0
Nishiaki,Nishiaki 2021,Igeteisky Log 1 Level
4,11,24,53.58458735,103.4444165,NA,1,0,1,1,0,0,1,0,1,0,1,0,0,0,0,0,0,1,1,0,0
Nishiaki,Nishiaki 2021,Igeteisky Log 1 Level
6,11,24,53.50758684,103.3723746,NA,1,0,1,1,0,0,1,0,1,0,1,0,0,0,0,0,0,1,1,0,0
Nishiaki,Nishiaki 2021,Kamenka
B,24,60,51.73830009,108.0770393,NA,0,1,1,0,0,0,1,0,0,0,0,0,0,0,1,0,1,1,0,0,0
Nishiaki,Nishiaki 2021,Kamenka
A,24,60,51.74615239,108.9117378,NA,1,1,1,0,1,0,1,0,0,0,0,0,0,0,0,0,0,1,0,0,0
Nishiaki,Nishiaki 2021,Khotyk Level
1,11,60,52.16768412,109.4783559,NA,1,0,1,1,0,1,0,0,0,0,0,0,0,0,1,0,0,1,0,0,0
Nishiaki,Nishiaki 2021,Khotyk Level
2,11,60,52.22374428,109.8800295,NA,0,1,1,0,1,0,1,0,0,0,0,0,0,0,1,0,0,1,0,0,0
Nishiaki,Nishiaki 2021,Khotyk Level
3,24,60,52.06313452,109.7564681,NA,0,0,1,0,0,0,1,0,0,0,0,0,0,1,1,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Khotyk Level
4,60,71,52.15333641,109.5073167,NA,0,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Kunalei
3,11,24,50.57751245,107.9072111,NA,0,1,1,0,0,0,1,0,0,0,1,0,0,0,0,0,1,0,0,0,0
Nishiaki,Nishiaki 2021,Kurla 3
1,11,24,55.68910959,109.5210256,NA,0,0,1,0,1,1,0,0,0,0,0,0,0,0,0,0,0,1,1,0,0
Nishiaki,Nishiaki 2021,Kurla 3
2,11,24,55.72343886,109.368333,NA,0,0,1,0,1,1,0,0,0,0,0,0,0,0,0,0,0,1,1,0,0
Nishiaki,Nishiaki 2021,Makarovo 3 Layer
,24,60,54.59031475,105.2544427,NA,0,0,1,0,1,1,1,0,0,0,1,0,0,0,0,0,1,1,1,0,0
Nishiaki,Nishiaki 2021,Makarovo 4
3a,24,60,54.62553122,105.1860806,NA,0,1,1,0,0,0,1,0,0,0,0,0,0,0,0,0,0,1,0,0,0
Nishiaki,Nishiaki 2021,Malaya
Syia,11,60,54.2080255,89.45371149,NA,0,1,1,0,0,0,1,0,0,0,0,0,0,0,0,0,0,1,0,0,0
Nishiaki,Nishiaki 2021,Malita Layer
8,11,24,52.88795142,103.5351462,NA,0,0,1,0,1,0,1,0,1,1,0,0,0,0,1,0,1,1,1,0,0
Nishiaki,Nishiaki 2021,Mamontovaya Kurya Unit
I,24,60,66.82973572,63.80675355,NA,0,1,1,0,0,0,0,0,0,0,1,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Masterov Kliuch sand lying on unit
2,11,24,51.35069159,110.7206729,NA,1,0,1,0,1,0,1,0,1,0,0,0,0,0,0,0,0,1,0,0,0
Nishiaki,Nishiaki 2021,Masterov Kliuch Archaeological component
III,11,24,51.44968488,110.6963649,NA,0,0,1,0,0,1,0,0,0,0,0,0,0,0,0,0,0,1,1,0,0
Nishiaki,Nishiaki 2021,Masterov Kliuch Archaeological component
I,24,60,51.43905903,110.7176098,NA,1,1,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,1,0,0,0
Nishiaki,Nishiaki 2021,Podzvonkaya
2,11,60,50.23789759,107.2512805,NA,1,0,1,0,0,0,0,0,0,0,0,0,0,0,1,0,0,1,0,0,0
Nishiaki,Nishiaki 2021,Podzvonkaya
D,24,60,50.15493626,107.2888768,NA,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
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Nishiaki,Nishiaki 2021,Podzvonkaya Eastern
complex,24,60,50.18986864,107.2674235,NA,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Podzvonkaya SE
complex,NA,NA,50.28465888,107.3290768,NA,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Podzvonkaya Lower
Complex,24,60,50.17594773,107.375798,NA,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,1,0,0,0
Nishiaki,Nishiaki 2021,San'ny Mys Level
7,NA,NA,52.19081539,109.6286572,NA,0,0,1,0,0,0,1,0,0,0,0,0,0,0,1,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Sokhatino 4 Level
7,NA,NA,52.09213884,113.4185728,NA,1,0,1,0,1,0,1,0,0,1,0,0,0,0,0,0,1,0,0,0,0
Nishiaki,Nishiaki
2021,Tarachikha,11,60,55.11056187,90.49001139,NA,0,0,1,0,0,0,0,0,0,0,1,0,0,0,0,0,0,1,
1,0,0
Nishiaki,Nishiaki 2021,Ust Kova Lower
Complex,24,60,58.21437633,100.3597537,NA,0,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Varvarina Gora Level
2,24,60,51.68066415,108.2021949,NA,0,0,1,0,0,0,1,0,0,0,0,0,0,0,1,1,0,0,0,0,0
Nishiaki,Nishiaki 2021,Varvarina Gora Level
3,24,60,51.69000823,107.8781976,NA,0,0,1,0,0,0,0,0,0,0,0,0,0,0,1,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Military Hospital 2
lower,24,60,52.35018615,104.4149167,NA,0,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Zaozerie Layer
,24,60,58.23051541,56.46555012,NA,0,0,1,0,0,0,0,0,0,0,1,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Denisova Cave terrace zone Level
9,71,130,51.38499539,84.52759054,NA,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,1,0,0,0
Nishiaki,Nishiaki 2021,Denisova Cave terrace zone Level
10,71,130,51.37425623,84.55840981,NA,0,1,1,0,0,0,0,0,0,0,0,0,0,0,1,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Denisova Cave terrace zone Level
12,71,130,51.36921424,84.7597631,NA,0,0,1,0,0,0,1,0,0,0,0,0,0,1,0,0,0,1,0,0,0
Nishiaki,Nishiaki 2021,Denisova Cave terrace zone Level
14,130,190,51.36135504,84.5164886,NA,0,0,1,0,0,0,0,0,0,0,0,0,0,1,0,1,0,0,0,0,0
Nishiaki,Nishiaki 2021,Garchi upper Layer
,24,60,59.00077279,56.06440844,NA,1,0,1,0,0,0,1,0,0,0,1,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Bol' shoj Naryn Layer
2,24,60,53.53183327,103.4820647,NA,0,1,1,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0,1,0,0
Nishiaki,Nishiaki 2021,Geographic Society Cave Level
4,24,60,42.84891302,132.9824758,NA,0,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Ikhine 2
IId,24,60,63.15757165,133.9456647,NA,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Ikhine 2
IIb,24,60,63.21145045,133.8592057,NA,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,1,0,0
Nishiaki,Nishiaki 2021,Ikhine 2
?,11,24,63.21338698,133.8572162,NA,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,1,0,0
Nishiaki,Nishiaki 2021,Ust Mill 2 Level C stratum 4 middle
part,24,60,60.02562172,133.8249398,NA,0,0,1,0,0,0,0,0,0,1,0,0,0,0,0,0,0,1,0,0
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Nishiaki,Nishiaki 2021,Ust Mill 2 Level B stratum 4 upper part,11,24,60.03660417,133.9055711,NA,0,0,1,0,0,0,0,0,0,0,1,0,0,0,0,0,0,0,1,0,0
Nishiaki,Nishiaki 2021,Ust Mill 2 Level Astratum 3,11,24,60.05802958,133.9537837,NA,0,0,1,0,0,0,0,0,0,0,1,0,0,0,0,0,0,0,1,0,0
Nishiaki,Nishiaki 2021,Ust Mill 2 stratum 5,24,60,60.09528482,133.8011146,NA,0,1,1,0,0,0,0,0,0,0,1,0,0,1,0,0,0,1,1,0,0
Nishiaki,Nishiaki 2021,Ust Ulma 1,11,24,51.86902917,130.1996909,NA,0,1,1,0,1,0,1,0,0,0,1,0,1,0,0,0,0,1,1,0,0
Nishiaki,Nishiaki 2021,Listvenka Layer 10,11,24,56.00606221,92.3198225,NA,0,1,1,0,1,0,1,0,0,0,1,0,0,0,0,0,0,1,1,0,0
Nishiaki,Nishiaki 2021,Listvenka Layer 9,11,24,55.87343639,92.3680403,NA,0,1,1,0,1,0,1,0,0,0,1,0,0,0,0,0,0,1,1,0,0
Nishiaki,Nishiaki 2021,Listvenka Layer 8,11,24,55.98902959,92.29417828,NA,0,1,1,0,1,0,1,0,0,0,1,0,0,0,0,0,0,1,1,0,0
Nishiaki,Nishiaki 2021,Listvenka Layer 7,11,24,55.94413516,92.4227229,NA,0,1,1,0,1,0,1,0,0,0,1,0,0,0,0,0,0,1,1,0,0
Nishiaki,Nishiaki 2021,Listvenka Layer 6,11,24,55.8805727,92.38388344,NA,0,1,1,0,1,0,1,0,0,0,1,0,0,0,0,0,0,1,1,0,0
Nishiaki,Nishiaki 2021,Listvenka Layer 15,11,24,55.94965027,92.35388534,NA,0,1,1,0,1,0,1,0,0,0,1,0,0,0,0,0,0,1,1,0,0
Nishiaki,Nishiaki 2021,Listvenka Layer 19,11,24,55.87475602,92.38645339,NA,0,1,1,0,1,0,1,0,0,0,1,0,0,0,0,0,0,1,1,0,0
Nishiaki,Nishiaki 2021,Listvenka Layer 20,11,24,55.8694995,92.33111462,NA,0,1,1,0,1,0,1,0,0,0,1,0,0,0,0,0,0,1,1,0,0
Nishiaki,Nishiaki 2021,Kamenny log buried soil,24,60,55.20796221,91.46115726,NA,0,0,1,0,0,0,0,0,0,0,0,0,0,0,1,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Chagyrskaya Cave Layer 5,11,24,51.41112124,82.92241523,NA,0,1,1,0,0,0,0,0,0,1,0,0,0,0,0,1,0,0,0,0,0
Nishiaki,Nishiaki 2021,Chagyrskaya Cave Layer 6a,24,60,51.35586261,83.00834893,NA,0,0,1,0,0,0,0,0,0,1,0,0,0,0,0,1,0,0,0,0,0
Nishiaki,Nishiaki 2021,Chagyrskaya Cave Layer 6b,24,60,51.37016848,82.9215567,NA,0,0,1,0,0,0,0,0,0,1,0,0,0,0,0,1,0,0,0,0,0
Nishiaki,Nishiaki 2021,Chagyrskaya Cave Layer 6c.1,24,60,51.44552606,83.03291276,NA,0,0,1,0,0,0,0,0,0,1,0,0,0,0,1,1,0,0,0,0,0
Nishiaki,Nishiaki 2021,Chagyrskaya Cave Layer 6c.2,24,60,51.44879126,83.24718619,NA,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,1,0,0,0,0,0
Nishiaki,Nishiaki 2021,Sosnovy Bor Level 6,24,60,52.84114405,103.5116561,NA,0,1,1,0,0,0,0,0,0,0,0,0,0,0,1,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Ogonki 5 Layer 2b,11,24,46.73721934,142.4065856,NA,0,0,1,0,1,0,1,0,0,0,1,1,1,0,0,0,0,1,1,1,0
Nishiaki,Nishiaki 2021,Ogonki 5 Layer 3,11,24,46.75106878,142.5396395,NA,0,0,1,0,1,0,1,0,0,0,1,1,1,0,0,0,0,1,1,1,0
Nishiaki,Nishiaki 2021,Sennaya 1 Layer 3,130,190,47.48905341,142.6013209,NA,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
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Nishiaki,Nishiaki 2021,Sennaya 1 Layer
4,130,190,47.35592669,142.6344216,NA,0,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Kolpakov Ruchey
,24,60,58.84213345,100.8628813,NA,0,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,1,0,0,0
Nishiaki,Nishiaki 2021,Tuyana Layer
6,24,60,51.67705078,103.2309315,NA,0,1,1,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,1,0,0
Nishiaki,Nishiaki 2021,Bol' shojZangisan Layer
5,24,60,51.63323693,101.4720654,NA,0,1,1,0,0,0,0,0,1,0,0,0,0,0,0,0,0,0,1,0,0
Nishiaki,Nishiaki 2021,Barun-Alan 1 Layer
6,24,60,52.34885888,109.875264,NA,0,0,1,0,0,0,0,0,0,0,1,0,0,0,1,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Barun-Alan 1 Layer
7a,24,60,52.3530906,109.8774446,NA,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Barun-Alan 1 Layer
7c,24,60,52.44511946,109.9112991,NA,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Barun-Alan 1 Layer
7d,24,60,52.30655653,109.9362368,NA,0,0,1,0,0,1,0,0,0,0,0,0,0,0,0,0,0,1,0,0,0
Nishiaki,Nishiaki 2021,FAY-NE1
A,24,60,25.17391531,55.86161614,NA,0,0,1,0,1,0,0,0,0,0,0,0,0,0,0,0,1,0,0,0,0
Nishiaki,Nishiaki 2021,FAY-NE1
C,93,130,25.16382866,55.83101587,NA,0,0,1,0,0,0,0,0,0,1,0,0,0,0,0,1,0,1,0,0,0
Nishiaki,Nishiaki 2021,Jebel Barakah
surface,71,130,23.94114281,52.09638614,NA,1,0,1,0,0,0,1,0,0,1,0,0,0,1,0,1,0,0,0,0,0
Nishiaki,Nishiaki 2021,Dederiyeh Layer
C,24,71,36.45362452,36.86983623,NA,0,1,1,0,1,0,1,0,0,0,0,0,0,1,1,1,1,0,0,0,0
Nishiaki,Nishiaki 2021,Dederiyeh Layer
D,71,190,36.40158441,36.64238309,NA,0,0,1,0,1,0,1,0,0,0,0,0,0,1,1,1,1,0,0,0,0
Nishiaki,Nishiaki 2021,Dederiyeh Layer
E,130,244,36.39853862,36.9181445,NA,0,1,1,0,1,0,1,0,0,0,0,0,0,1,1,1,1,1,0,0,0
Nishiaki,Nishiaki 2021,Douara Cave Layer
D,NA,NA,34.58333534,38.47238722,NA,0,1,1,1,1,0,1,0,1,0,0,0,0,1,1,1,0,1,0,0,0
Nishiaki,Nishiaki 2021,Douara Cave Layer
E,NA,NA,34.60972727,38.4826915,NA,0,1,1,1,1,0,1,0,0,0,0,0,0,1,1,1,1,1,0,0,0
Nishiaki,Nishiaki 2021,Douara Cave Unit
IVB,NA,NA,34.68562807,38.39718838,NA,0,1,1,1,1,0,1,0,1,0,0,0,0,1,1,1,1,1,0,0,0
Nishiaki,Nishiaki 2021,Douara Cave Layer
III,NA,NA,34.72358718,38.45611599,NA,0,1,1,1,1,0,1,0,1,0,0,0,0,1,1,1,0,0,0,0,0
Nishiaki,Nishiaki 2021,Antelias Cave Layer
II,24,60,33.89927047,35.5327074,NA,0,0,1,1,1,1,1,0,1,0,0,0,0,0,1,1,1,1,0,0,0
Nishiaki,Nishiaki 2021,Antelias Cave Layer
IV,24,60,34.00339127,35.61003671,NA,0,0,1,1,1,0,1,0,0,0,0,0,0,1,1,1,1,1,0,0,0
Nishiaki,Nishiaki 2021,Ras el Kelb Tunnel
H,71,130,33.91463866,35.56987788,NA,0,0,1,1,1,0,1,0,1,0,0,0,0,1,1,1,1,0,0,0,0
Nishiaki,Nishiaki 2021,Ras el Kelb Tunnel
J,71,130,33.94192082,35.61000888,NA,0,0,1,1,1,0,1,0,1,0,0,0,0,1,1,1,1,0,0,0,0
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Nishiaki,Nishiaki 2021,Ras el Kelb Tunnel K,71,130,33.91869142,35.67145092,NA,0,0,1,1,1,0,1,0,1,0,0,0,0,1,1,1,1,0,0,0,0
Nishiaki,Nishiaki 2021,Ras el Kelb Tunnel L,71,130,33.99246419,35.59759909,NA,0,0,1,1,1,0,1,0,1,0,0,0,0,1,1,1,1,0,0,0,0
Nishiaki,Nishiaki 2021,Ras el Kelb Tunnel M,71,130,33.86971488,35.63519292,NA,0,0,1,1,1,0,1,0,1,0,0,0,0,1,1,1,1,0,0,0,0
Nishiaki,Nishiaki 2021,Ras el Kelb Tunnel N,71,130,33.97528064,35.69897254,NA,0,0,1,1,1,0,1,0,1,0,0,0,0,1,1,1,1,0,0,0,0
Nishiaki,Nishiaki 2021,Ras el Kelb Tunnel O,71,130,33.97159601,35.66960903,NA,0,0,1,1,1,0,1,0,1,0,0,0,0,1,1,1,1,0,0,0,0
Nishiaki,Nishiaki 2021,Ras el Kelb Rail A to B,71,130,33.92028643,35.65841347,NA,0,0,1,1,1,0,1,0,1,0,0,0,0,1,1,1,1,0,0,0,0
Nishiaki,Nishiaki 2021,Ras el Kelb Rail B,71,130,33.98719378,35.66629346,NA,0,0,1,1,1,0,1,0,1,0,0,0,0,1,1,1,1,0,0,0,0
Nishiaki,Nishiaki 2021,Ras el Kelb Rail C,71,130,34.00172285,35.5913757,NA,0,0,1,1,1,0,1,0,1,0,0,0,0,1,1,1,1,0,0,0,0
Nishiaki,Nishiaki 2021,Ras el Kelb Rail D,71,130,34.01717751,35.60524032,NA,0,0,1,1,1,0,1,0,1,0,0,0,0,1,1,1,1,0,0,0,0
Nishiaki,Nishiaki 2021,Bezez Layer B,24,71,33.29377789,35.24911132,NA,0,0,1,1,1,0,1,0,1,0,0,0,0,1,1,1,1,0,0,0,0
Nishiaki,Nishiaki 2021,Amud Cave Layer B1,24,60,32.84676237,36.01243398,NA,0,1,1,1,1,0,1,1,1,0,0,0,0,1,1,1,1,0,0,0,0
Nishiaki,Nishiaki 2021,Amud Cave Layer B2,24,60,32.8454941,35.4444964,NA,0,1,1,1,1,0,1,1,1,0,0,0,0,1,1,1,1,0,0,0,0
Nishiaki,Nishiaki 2021,Amud Cave Layer B4,24,71,32.80055552,35.21925814,NA,0,1,1,1,1,0,1,0,1,0,0,0,0,1,1,1,1,0,0,0,0
Nishiaki,Nishiaki 2021,Keoue Cave Layer I,24,71,34.27633372,35.87684273,NA,0,1,1,1,1,0,1,0,1,0,0,0,0,1,1,1,1,0,0,0,0
Nishiaki,Nishiaki 2021,Keoue Cave Layer II,24,71,34.34771429,35.81943596,NA,0,1,1,1,1,0,1,0,1,0,0,0,0,1,1,1,1,0,0,0,0
Nishiaki,Nishiaki 2021,Keoue Cave Layer III,24,71,34.30371555,35.86539712,NA,0,1,1,1,1,0,1,0,1,0,0,0,0,1,1,1,1,0,0,0,0
Nishiaki,Nishiaki 2021,Ksar Akil Layer 26A,24,71,33.93640301,35.66613566,NA,0,1,1,1,1,0,1,0,1,0,0,0,0,1,1,1,1,0,0,0,0
Nishiaki,Nishiaki 2021,Ksar Akil Layer 26B,24,71,33.92881763,35.69163645,NA,0,1,1,1,1,0,1,0,1,0,0,0,0,1,1,1,1,0,0,0,0
Nishiaki,Nishiaki 2021,Ksar Akil Layer 27A,24,71,33.91572169,35.6032461,NA,0,1,1,1,1,0,1,0,1,0,0,0,0,1,1,1,1,0,0,0,0
Nishiaki,Nishiaki 2021,Ksar Akil Layer 28A,24,71,33.90525624,35.71217235,NA,0,1,1,1,1,0,1,0,1,0,0,0,0,1,1,1,1,0,0,0,0
Nishiaki,Nishiaki 2021,Ksar Akil Layer 28B,24,71,33.91162841,35.61419085,NA,0,1,1,1,1,0,1,0,1,0,0,0,0,1,1,1,1,0,0,0,0
Nishiaki,Nishiaki 2021,Ksar Akil Layer 20,24,60,33.89236233,35.54008662,NA,0,0,1,1,1,0,1,0,0,0,0,0,0,1,1,1,1,1,1,0,0
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Nishiaki,Nishiaki 2021,Ksar Akil Layer
7,24,60,33.84890801,35.53349846,NA,0,0,1,1,1,1,1,0,0,0,0,0,0,1,1,1,1,1,0,0
Nishiaki,Nishiaki 2021,Ksar Akil Layer
6,24,60,33.87484717,35.64724556,NA,0,0,1,1,1,1,1,0,0,0,0,0,0,1,1,1,1,1,0,0
Nishiaki,Nishiaki 2021,Ksar Akil Layer
3,11,24,33.89804115,35.58369944,NA,0,0,1,1,1,1,1,0,0,0,0,0,0,1,1,1,1,1,0,0
Nishiaki,Nishiaki 2021,Ksar Akil Layer
2,11,24,33.83800105,35.5601898,NA,0,0,1,1,1,1,1,0,0,0,0,0,0,1,1,1,1,1,0,0
Nishiaki,Nishiaki 2021,Ksar Akil Layer
19,24,60,33.83107222,35.65446477,NA,0,0,1,1,1,0,1,0,0,0,0,0,0,1,1,1,1,1,1,0,0
Nishiaki,Nishiaki 2021,Ksar Akil Layer
18,24,60,33.95321783,35.60410797,NA,0,0,1,1,1,0,1,0,0,0,0,0,0,1,1,1,1,1,1,0,0
Nishiaki,Nishiaki 2021,Ksar Akil Layer
17,24,60,33.9559465,35.63919391,NA,0,0,1,1,1,0,1,0,0,0,0,0,0,1,1,1,1,1,1,0,0
Nishiaki,Nishiaki 2021,Ksar Akil Layer
16,24,60,33.98802,35.58699107,NA,0,0,1,1,1,1,1,0,0,0,0,0,0,1,1,1,1,1,0,0
Nishiaki,Nishiaki 2021,Ksar Akil Layer
21,24,60,33.94583929,35.56461059,NA,0,1,1,1,1,0,1,0,1,0,0,0,0,1,1,1,1,1,1,0,0
Nishiaki,Nishiaki 2021,Ksar Akil Layer
22,24,60,33.85815353,35.64400099,NA,0,1,1,1,1,0,1,0,1,0,0,0,0,1,1,1,1,1,1,0,0
Nishiaki,Nishiaki 2021,Ksar Akil Layer
23,24,60,33.83593699,35.57012395,NA,0,1,1,1,1,0,1,0,1,0,0,0,0,1,1,1,1,1,1,0,0
Nishiaki,Nishiaki 2021,Ksar Akil Layer
24,24,60,33.94167846,35.62224745,NA,0,1,1,1,1,0,1,0,1,0,0,0,0,1,1,1,1,1,0,0,0
Nishiaki,Nishiaki 2021,Ksar Akil Layer
25,24,60,33.92478246,35.68772506,NA,0,1,1,1,1,0,1,0,1,0,0,0,0,1,1,1,1,1,0,0,0
Nishiaki,Nishiaki 2021,Ksar Akil Layer
8,24,60,33.95660042,35.65273528,NA,0,0,1,1,1,1,1,0,0,0,0,0,0,0,1,0,1,1,0,0,0
Nishiaki,Nishiaki 2021,Ksar Akil Layers 10-
9,NA,NA,33.92120521,35.62659621,NA,0,0,1,1,1,1,1,0,0,0,0,0,0,0,0,0,1,1,1,0,0
Nishiaki,Nishiaki 2021,Naame
Upper,71,190,33.67180336,35.50656628,NA,0,0,1,1,1,0,1,0,1,0,0,0,0,1,1,1,1,0,0,0,0
Nishiaki,Nishiaki 2021,Naame
Middle,71,190,33.69097291,35.48500295,NA,0,0,1,1,1,0,1,0,1,0,0,0,0,1,1,1,1,0,0,0,0
Nishiaki,Nishiaki 2021,Naame
Lower,71,190,33.73450326,35.46310696,NA,0,0,1,1,1,0,1,0,1,0,0,0,0,1,1,1,1,0,0,0,0
Nishiaki,Nishiaki 2021,Naame Strombus Enfean
II,71,130,33.68339714,35.49343229,NA,0,0,1,1,1,0,0,0,0,0,0,0,0,1,1,1,1,0,0,0,0
Nishiaki,Nishiaki 2021,Jerf Ajla White
1,130,244,34.69957757,38.21330997,NA,0,1,1,1,1,0,1,0,0,0,0,0,0,1,1,1,1,0,0,0,0
Nishiaki,Nishiaki 2021,Jerf Ajla Brown
2,130,244,34.59538081,38.18747262,NA,0,1,1,1,1,0,1,0,1,0,0,0,0,1,1,1,1,0,0,0,0
Nishiaki,Nishiaki 2021,Jerf Ajla Yellow
1,130,244,34.63638505,38.17015121,NA,0,1,1,1,1,0,1,0,1,0,0,0,0,1,1,1,1,1,0,0,0
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Nishiaki,Nishiaki 2021,Jerf Ajla Brown 1 Units A B C,24,60,34.72928011,38.16745732,NA,0,1,1,1,1,0,1,0,1,0,0,0,0,1,1,1,1,1,0,0,0
Nishiaki,Nishiaki 2021,Quneitra Un-stratified,24,71,33.0854278,35.16647957,NA,0,1,1,1,1,0,1,0,0,0,0,0,0,1,1,1,1,0,0,0,0
Nishiaki,Nishiaki 2021,Far'ah II Floor 1,24,71,31.20378412,34.54017409,NA,0,1,1,1,1,0,1,0,0,0,0,0,0,1,1,1,1,0,0,0,0
Nishiaki,Nishiaki 2021,Ain Difla Layers 1-20,130,244,30.92187325,35.6074928,NA,0,1,1,1,1,0,1,1,0,0,0,0,0,1,1,1,1,0,0,0,0
Nishiaki,Nishiaki 2021,Nahal Aqev Layer 1,130,244,30.77854229,34.80821171,NA,0,0,1,1,1,0,1,0,0,0,0,0,0,1,1,1,1,0,0,0,0
Nishiaki,Nishiaki 2021,Nahal Aqev Layer 2,130,244,30.89386127,34.784609,NA,0,0,1,1,1,0,1,0,0,0,0,0,0,1,1,1,1,0,0,0,0
Nishiaki,Nishiaki 2021,Nahal Aqev Layers 3a-g,130,244,30.82535938,34.72297355,NA,0,0,1,1,1,0,1,0,0,0,0,0,0,1,1,1,1,0,0,0,0
Nishiaki,Nishiaki 2021,Nahal Aqev D,NA,NA,30.81134981,34.68042767,NA,0,0,1,1,1,0,1,0,0,0,0,0,0,1,1,1,1,0,0,0,0
Nishiaki,Nishiaki 2021,Tor Sabiha Layer C,24,71,29.84373034,36.3714501,NA,0,1,1,1,1,0,1,0,1,0,0,0,0,1,1,1,1,0,0,0,0
Nishiaki,Nishiaki 2021,Nahr Ibrahim Main Gallery Layer C,71,190,34.00852483,35.61359836,NA,0,0,1,1,1,0,1,0,1,0,0,0,0,1,1,1,1,0,0,0,0
Nishiaki,Nishiaki 2021,Nahr Ibrahim Main Gallery Layer D,71,190,34.07211712,35.56505365,NA,0,0,1,1,1,0,1,0,1,0,0,0,0,1,1,1,1,0,0,0,0
Nishiaki,Nishiaki 2021,Nahr Ibrahim Main Gallery Layer F,71,190,34.10553064,35.70698993,NA,0,0,1,1,1,0,1,0,1,0,0,0,0,1,1,1,1,0,0,0,0
Nishiaki,Nishiaki 2021,Emireh Eroded,24,60,33.14450261,35.09946214,NA,0,0,1,1,1,0,1,0,0,0,0,0,0,0,1,1,1,1,0,0,0
Nishiaki,Nishiaki 2021,Umm el-Tlel III2A,24,60,35.32088711,38.92152426,NA,0,1,1,1,1,0,1,0,0,0,0,0,0,1,1,1,1,1,0,0,0
Nishiaki,Nishiaki 2021,Umm el-Tlel V =II 1,24,60,35.30102046,38.89009817,NA,0,0,1,1,1,1,1,0,0,0,0,0,0,0,0,1,1,1,1,0,0
Nishiaki,Nishiaki 2021,Umm el-Tlel II Base,24,60,35.35490166,38.9073465,NA,0,0,1,1,1,0,1,0,0,0,0,0,0,1,1,1,1,1,0,0,0
Nishiaki,Nishiaki 2021,Umm el-Tlel II2a,NA,NA,35.23836102,38.9704591,NA,0,0,1,1,1,1,1,0,0,0,0,0,0,0,0,0,1,1,1,0,0
Nishiaki,Nishiaki 2021,Umm el-Tlel II2b,NA,NA,35.2374009,38.7954009,NA,0,0,1,1,1,1,1,0,0,0,0,0,0,0,0,0,1,1,1,0,0
Nishiaki,Nishiaki 2021,Umm el-Tlel XII =II 4?,NA,NA,35.28413964,38.86693351,NA,0,0,1,1,1,1,1,0,0,0,0,0,0,0,0,0,1,1,1,0,0
Nishiaki,Nishiaki 2021,Tor Sadaf Layers IV,24,60,30.8528962,36.01523843,NA,0,0,1,1,1,0,1,0,0,0,0,0,0,1,1,1,1,1,0,0,0
Nishiaki,Nishiaki 2021,Tor Sadaf Layers III,24,60,30.82387223,36.06771423,NA,0,0,1,1,1,0,1,0,0,0,0,0,0,1,1,1,1,1,0,0,0
Nishiaki,Nishiaki 2021,Abu Noshra I ,24,60,28.67223238,33.97561246,NA,0,0,0,1,1,0,0,0,0,0,0,0,0,0,0,0,1,1,1,0,0
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Nishiaki,Nishiaki 2021,Ain al-Buhayla Unit C,11,24,30.8431399,35.87689809,NA,0,0,1,1,1,1,1,1,0,0,0,0,0,0,1,1,1,1,1,0,0
Nishiaki,Nishiaki 2021,Ain al-Buhayla Unit F,11,24,30.92265163,35.91775637,NA,0,0,1,1,1,1,1,0,0,0,0,0,0,0,1,1,1,1,1,0,0
Nishiaki,Nishiaki 2021,Ain al-Buhayla Units H-I,11,24,30.88628075,35.86913612,NA,0,0,1,1,1,1,1,0,0,0,0,0,0,0,1,1,1,1,1,0,0
Nishiaki,Nishiaki 2021,Multaqa al-Widyan,24,60,30.81959425,35.97550021,NA,0,0,1,1,1,0,1,0,0,0,0,0,0,0,1,1,1,1,0,0,0
Nishiaki,Nishiaki 2021,EHLPP1,24,60,30.86432172,35.99076937,NA,0,0,1,1,1,1,1,0,0,0,0,0,0,0,1,1,1,1,1,0,0
Nishiaki,Nishiaki 2021,WHS623X,24,60,30.84178375,35.88712914,NA,0,0,1,1,1,0,1,0,0,0,0,0,0,0,1,1,1,1,1,0,0
Nishiaki,Nishiaki 2021,WHNBS68 ,24,60,30.85456858,35.87642544,NA,0,0,1,1,1,0,1,0,0,0,0,0,0,0,1,1,1,1,1,0,0
Nishiaki,Nishiaki 2021,Thalab al-Buhayla Layer C,24,60,30.87799091,35.91004383,NA,0,0,1,1,1,1,1,0,0,0,0,0,0,0,1,1,1,1,1,0,0
Nishiaki,Nishiaki 2021,Thalab al-Buhayla Layer E,24,60,30.75888759,35.96092458,NA,0,0,1,1,1,1,1,0,0,0,0,0,0,0,1,1,1,1,1,0,0
Nishiaki,Nishiaki 2021,Yabrud II Layer 6,24,60,33.98228486,36.65418507,NA,0,0,1,1,1,0,1,0,0,0,0,0,0,1,1,1,1,1,1,0,0
Nishiaki,Nishiaki 2021,Yabrud II Layer 5,24,60,33.97878858,36.66324815,NA,0,0,1,1,1,0,1,0,0,0,0,0,0,1,1,1,1,1,1,0,0
Nishiaki,Nishiaki 2021,Yabrud II Layer 1,24,60,33.96207814,36.76503168,NA,0,0,1,1,1,1,1,0,0,0,0,0,0,0,0,0,1,1,1,0,0
Nishiaki,Nishiaki 2021,Yabrud II Layer 2,24,60,33.88318039,36.63414281,NA,0,0,1,1,1,1,1,0,0,0,0,0,0,0,0,0,1,1,1,0,0
Nishiaki,Nishiaki 2021,Yabrud II Layer 3,24,60,33.90169576,36.71484149,NA,0,0,1,1,1,1,1,0,0,0,0,0,0,0,0,0,1,1,1,0,0
Nishiaki,Nishiaki 2021,Yabrud II Layer 4,24,60,34.00599045,36.57021314,NA,0,0,1,1,1,1,1,0,0,0,0,0,0,0,0,0,1,1,1,0,0
Nishiaki,Nishiaki 2021,Hayonim Layer D,24,60,32.92880967,35.13625517,NA,0,0,1,1,1,1,0,0,0,0,0,0,0,0,0,0,1,1,1,0,0
Nishiaki,Nishiaki 2021,Hayonim Lower E,190,244,32.88239269,33.82114221,NA,0,1,1,1,1,0,1,0,0,0,0,0,0,1,1,1,1,0,0,0,0
Nishiaki,Nishiaki 2021,Hayonim Upper E,130,190,32.94435882,36.30777759,NA,0,1,1,1,1,0,1,0,0,0,0,0,0,1,1,1,1,0,0,0,0
Nishiaki,Nishiaki 2021,Hayonim F,190,244,32.86855127,34.73461373,NA,0,0,1,1,1,0,1,0,0,0,0,0,0,1,1,1,1,0,0,0,0
Nishiaki,Nishiaki 2021,el-Wad Layer D,24,60,32.68577489,34.98173177,NA,0,0,1,1,1,1,1,0,0,0,0,0,0,0,0,0,1,1,1,0,0
Nishiaki,Nishiaki 2021,el-Wad Layer C,24,60,32.65885328,35.10561152,NA,0,0,1,1,1,1,1,0,0,0,0,0,0,0,0,0,1,1,1,0,0
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Nishiaki,Nishiaki 2021,Raqefet Layer III,24,60,32.75397284,35.07389677,NA,0,0,1,1,1,1,1,0,0,0,0,0,0,0,0,0,1,1,1,0,0
Nishiaki,Nishiaki 2021,Raqefet Layer IV,NA,NA,32.75902808,34.72392763,NA,0,0,1,1,1,0,1,0,0,0,0,0,0,1,1,1,1,1,0,0,0
Nishiaki,Nishiaki 2021,el-Quseir ,24,60,31.40070035,35.16651734,NA,0,0,1,1,1,1,1,0,0,0,0,0,0,0,0,0,1,1,1,0,0
Nishiaki,Nishiaki 2021,el-Khiam E Layers 9-10,24,60,31.68136334,35.39875953,NA,0,0,1,1,1,1,1,0,0,0,0,0,0,0,0,0,1,1,1,0,0
Nishiaki,Nishiaki 2021,Shunera XV ,11,60,30.95182045,34.51880999,NA,0,0,1,1,1,1,1,0,0,0,0,0,0,0,0,0,1,1,1,0,0
Nishiaki,Nishiaki 2021,Meged Unit 3,11,24,32.9329635,33.46822214,NA,0,0,1,1,1,1,1,0,0,0,0,0,0,0,0,0,1,1,1,0,0
Nishiaki,Nishiaki 2021,Ein Aqev East D34 ,11,24,30.66171019,34.84709847,NA,0,0,1,1,1,1,1,0,0,0,0,0,0,0,0,0,1,1,1,0,0
Nishiaki,Nishiaki 2021,Azariq XIII ,11,24,30.92320668,34.52149723,NA,0,0,1,1,1,1,1,0,0,0,0,0,0,0,0,0,1,1,1,0,0
Nishiaki,Nishiaki 2021,Shunera XVI ,11,24,30.96000483,34.47402713,NA,0,0,1,1,1,1,1,0,0,0,0,0,0,0,0,0,1,1,1,0,0
Nishiaki,Nishiaki 2021,Azraq 17 trench 2,11,24,31.95357851,37.24604149,NA,0,0,1,1,1,1,1,0,0,0,0,0,0,0,1,1,1,1,1,0,0
Nishiaki,Nishiaki 2021,Yutil al-Hasa Area A,11,24,30.88905119,35.86222575,NA,0,0,1,1,1,1,1,0,0,0,0,0,0,0,1,1,1,1,1,0,0
Nishiaki,Nishiaki 2021,Yutil al-Hasa Area B,11,24,30.81769753,35.99670315,NA,0,0,1,1,1,1,1,0,0,0,0,0,0,0,1,1,1,1,1,0,0
Nishiaki,Nishiaki 2021,Tor Hamar Layer F,24,60,29.75754561,35.15240536,NA,0,0,1,1,1,0,0,0,0,0,0,0,0,0,1,1,1,1,1,0,0
Nishiaki,Nishiaki 2021,Tor Hamar Layer G,24,60,29.7666339,36.15093448,NA,0,0,1,1,1,0,0,0,0,0,0,0,0,0,1,1,1,1,1,0,0
Nishiaki,Nishiaki 2021,Abu Halka Layer IVe,24,60,33.94895717,35.72733314,NA,0,0,1,1,1,0,1,0,1,0,0,0,0,1,1,1,1,1,0,0,0
Nishiaki,Nishiaki 2021,Abu Halka Layer IVf,24,60,33.9633592,35.62158407,NA,0,0,1,1,1,0,1,0,1,0,0,0,0,1,1,1,1,1,0,0,0
Nishiaki,Nishiaki 2021,et-Taban Layer B,24,60,31.60688089,35.25215867,NA,0,0,1,1,1,0,1,0,0,0,0,0,0,1,1,1,1,1,0,0,0
Nishiaki,Nishiaki 2021,Sde Zin 7 ,24,60,30.82367407,34.96702546,NA,0,0,1,1,1,0,1,0,0,0,0,0,0,1,1,1,1,1,0,0,0
Nishiaki,Nishiaki 2021,Wadi Aghar ,24,60,29.72452631,35.70457335,NA,0,0,1,1,1,0,0,0,0,0,0,0,0,0,0,0,1,1,0,0,0
Nishiaki,Nishiaki 2021,Sde Divshon ,24,60,30.87154561,34.75506921,NA,0,0,1,1,1,0,1,0,0,0,0,0,0,1,1,1,1,1,0,0,0
Nishiaki,Nishiaki 2021,Tor Aeid ,24,60,29.81525737,36.0666531,NA,0,0,1,1,1,0,0,0,0,0,0,0,0,0,1,1,1,1,1,0,0
Nishiaki,Nishiaki 2021,Sefunim Layer D.8,24,60,32.70766824,34.71890485,NA,0,0,1,1,1,1,1,0,0,0,0,0,0,0,0,0,1,1,1,0,0
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Nishiaki,Nishiaki 2021,Sefunim
,24,71,32.70756367,35.00212307,NA,0,0,1,1,1,0,1,0,0,0,0,0,0,1,1,1,1,0,0,0,0
Nishiaki,Nishiaki 2021,Jiftlik
,11,24,32.24744696,35.50386559,NA,0,0,1,1,1,1,1,0,0,0,0,0,0,0,0,0,1,1,1,0,0
Nishiaki,Nishiaki 2021,Hamifgash X
,11,24,31.14814036,34.4092709,NA,0,0,1,1,1,1,1,0,0,0,0,0,0,0,0,0,1,1,1,0,0
Nishiaki,Nishiaki 2021,Abu Sif
,130,244,31.50517677,35.13821308,NA,0,1,1,1,1,0,1,1,0,0,0,0,0,1,1,1,1,0,0,0,0
Nishiaki,Nishiaki 2021,Sahba
,130,244,31.55127302,35.21812912,NA,0,0,1,1,1,0,1,0,0,0,0,0,0,1,1,1,1,0,0,0,0
Nishiaki,Nishiaki 2021,Qseimeh I
,NA,NA,30.69112354,34.33062338,NA,0,0,1,1,1,0,1,0,0,0,0,0,0,0,1,1,1,1,1,0,0
Nishiaki,Nishiaki 2021,Abu Noshra II
,NA,NA,28.64250044,33.90640879,NA,0,0,1,1,1,0,1,0,0,0,0,0,0,0,0,0,1,1,1,0,0
Nishiaki,Nishiaki 2021,Abu Noshra VI
,NA,NA,28.79610513,33.91528507,NA,0,0,0,1,1,0,0,0,0,0,0,0,0,0,0,0,0,1,0,0,0
Nishiaki,Nishiaki 2021,Bronzovaya cave Layer 18 Moustie
II,24,60,42.20830158,42.91407347,NA,0,1,1,1,1,0,1,0,0,0,0,0,0,1,1,1,0,0,0,0,0
Nishiaki,Nishiaki 2021,Bronzovaya cave Layer 20Moustie
III,24,60,42.28276176,42.95101957,NA,0,1,1,1,1,0,1,0,0,0,0,0,0,1,1,1,0,0,0,0,0
Nishiaki,Nishiaki 2021,Djruchula Cave levels II-
VII,NA,NA,42.40631491,42.99973794,NA,0,1,1,1,1,0,1,0,0,0,0,0,0,1,1,1,1,1,0,0,0
Nishiaki,Nishiaki 2021,Dzudzuana Unit
B,11,24,42.38049103,43.04320357,NA,1,0,1,1,1,1,1,0,0,0,0,0,0,0,0,0,0,1,1,0,0
Nishiaki,Nishiaki 2021,Dzudzuana Unit
C,11,24,42.39785396,43.23924185,NA,0,0,1,1,1,1,1,0,0,0,0,0,0,0,0,0,0,1,1,0,0
Nishiaki,Nishiaki 2021,Erevan 1 cave Layer
3,24,60,40.24331992,44.50566945,NA,0,1,1,1,1,0,1,0,1,0,1,0,0,1,1,1,0,0,0,0,0
Nishiaki,Nishiaki 2021,Erevan 1 cave Layer
4,24,60,40.16058055,44.42067254,NA,0,1,1,1,1,0,1,0,1,0,1,0,0,1,1,1,0,0,0,0,0
Nishiaki,Nishiaki 2021,Erevan 1 cave Layer
7,24,60,40.20115568,44.44097841,NA,0,1,1,1,1,0,1,0,1,0,1,0,0,1,1,1,0,0,0,0,0
Nishiaki,Nishiaki 2021,Erevan 1 cave Layer
5,24,60,40.13008715,44.51648546,NA,0,1,1,1,1,0,1,0,1,0,1,0,0,1,1,1,0,0,0,0,0
Nishiaki,Nishiaki 2021,Kudaro 1 Layer
3,24,60,42.44838319,43.20376882,NA,0,0,1,1,1,0,1,0,0,0,0,0,0,1,1,1,0,1,0,0,0
Nishiaki,Nishiaki 2021,Kudaro 3 Layer
4a,71,130,42.59108963,43.36332133,NA,0,0,1,1,1,0,1,0,0,0,0,0,0,1,1,1,0,1,0,0,0
Nishiaki,Nishiaki 2021,Kudaro 3  Layer
4b,71,130,42.52309382,42.90492987,NA,0,0,1,1,1,0,1,0,0,0,0,0,0,1,1,1,0,1,0,0,0
Nishiaki,Nishiaki 2021,Kudaro 3 Layer
4c,71,130,42.56053103,43.76736643,NA,0,0,1,1,1,0,1,0,0,0,0,0,0,1,1,1,0,1,0,0,0
Nishiaki,Nishiaki 2021,Kudaro 3 Layer
4d,71,130,42.60945923,43.89572331,NA,0,0,1,1,1,0,1,0,0,0,0,0,0,1,1,1,0,1,0,0,0
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Nishiaki,Nishiaki 2021,Kudaro 3 Layer
4e,71,130,42.59907531,43.53582203,NA,0,0,1,1,1,0,1,0,0,0,0,0,0,1,1,1,0,1,0,0,0
Nishiaki,Nishiaki 2021,Kudaro 3 Layer
4f,71,130,42.51355043,42.90485428,NA,0,0,1,1,1,0,1,0,0,0,0,0,0,1,1,1,0,1,0,0,0
Nishiaki,Nishiaki 2021,Ortvale Klde Layer
2,11,24,42.2786957,42.54683382,NA,0,0,1,1,1,1,1,0,0,0,0,0,0,0,0,0,0,1,1,0,0
Nishiaki,Nishiaki 2021,Ortvale Klde Layer
3,11,24,42.2777591,42.4343317,NA,0,0,1,1,1,1,1,0,0,0,0,0,0,0,0,0,0,1,1,0,0
Nishiaki,Nishiaki 2021,Ortvale Klde Layer
4b,11,60,42.28377355,42.80200813,NA,0,1,1,1,1,0,1,0,0,0,0,0,0,0,0,1,0,1,0,0,0
Nishiaki,Nishiaki 2021,Ortvale Klde Layer
4c,24,60,42.22810199,43.05491903,NA,0,1,1,1,1,0,1,0,0,0,0,0,0,0,0,1,0,1,0,0,0
Nishiaki,Nishiaki 2021,Ortvale Klde Layer
4d,24,60,42.33902491,44.09651401,NA,0,1,1,1,1,0,1,0,0,0,0,0,0,0,0,1,0,1,0,0,0
Nishiaki,Nishiaki 2021,Ortvale Klde Layer
5,24,60,42.31457959,43.64653436,NA,0,1,1,1,1,0,1,0,0,0,0,0,0,1,1,1,0,0,0,0,0
Nishiaki,Nishiaki 2021,Ortvale Klde Layer
6,24,60,42.35502432,43.02438208,NA,0,1,1,1,1,0,1,0,0,0,0,0,0,1,1,1,0,0,0,0,0
Nishiaki,Nishiaki 2021,Ortvale Klde Layer
7,24,60,42.30788725,42.46175931,NA,0,1,1,1,1,0,1,0,0,0,0,0,0,1,1,1,0,0,0,0,0
Nishiaki,Nishiaki 2021,Sakajiya Layer
3a,24,60,42.33338213,43.07759959,NA,0,1,1,1,1,0,1,0,0,0,0,0,0,1,1,1,0,0,0,0,0
Nishiaki,Nishiaki 2021,Sakajiya Layer
3b,24,60,42.31208423,42.12622798,NA,0,1,1,1,1,0,1,0,0,0,0,0,0,1,1,1,0,0,0,0,0
Nishiaki,Nishiaki 2021,Sakajiya Layer
3c,24,60,42.20780933,42.78658515,NA,0,1,1,1,1,0,1,0,0,0,0,0,0,1,1,1,0,0,0,0,0
Nishiaki,Nishiaki 2021,Sakajiya Layer
3d,24,60,42.34365297,42.68384779,NA,0,1,1,1,1,0,1,0,0,0,0,0,0,1,1,1,0,0,0,0,0
Nishiaki,Nishiaki 2021,Sakajiya Layer
3e,24,60,42.30339294,42.82509973,NA,0,1,1,1,1,0,1,0,0,0,0,0,0,1,1,1,0,0,0,0,0
Nishiaki,Nishiaki 2021,Sakajiya Layer
3f,24,60,42.34002855,42.80441965,NA,0,1,1,1,1,0,1,0,0,0,0,0,0,1,1,1,0,0,0,0,0
Nishiaki,Nishiaki 2021,Tsona Layer
5,71,130,42.46982491,43.61877889,NA,0,0,1,1,0,0,1,0,0,0,0,0,0,1,1,1,0,1,0,0,0
Nishiaki,Nishiaki 2021,Kunji Unit
2,NA,NA,33.38755247,48.43493981,NA,0,1,1,1,1,0,1,0,1,0,0,0,0,1,1,1,1,0,0,0,0
Nishiaki,Nishiaki 2021,Karain E Layer II.1-
3,130,190,37.07362583,30.47597464,NA,0,1,1,1,1,0,1,0,1,0,0,0,0,1,1,1,1,0,0,0,0
Nishiaki,Nishiaki 2021,Karain E Layer
I.7,71,130,37.05018347,30.46486758,NA,0,1,1,1,1,0,1,0,0,0,0,0,0,1,1,1,1,0,0,0,0
Nishiaki,Nishiaki 2021,Karain E Layer I.2-
6,60,71,37.06530657,30.64398321,NA,0,1,1,1,1,0,1,0,0,1,0,0,0,1,1,1,1,0,0,0,0
Nishiaki,Nishiaki 2021,Obi Rakhmat Cave Layers 17-
21,24,130,41.54361716,70.16781287,NA,0,0,1,1,1,0,1,0,1,0,0,0,0,1,1,1,1,1,0,0,0
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Nishiaki,Nishiaki 2021,Obi Rakhmat Cave Layers  2-7,24,130,41.54628371,70.03677117,NA,0,0,1,0,1,0,1,0,1,0,0,0,0,1,1,1,1,1,0,0,0
Nishiaki,Nishiaki 2021,Obi Rakhmat Cave Layers 8-16,24,130,41.64417192,70.14971103,NA,0,0,1,1,1,0,1,0,0,0,0,0,0,1,1,1,1,1,0,0,0
Nishiaki,Nishiaki 2021,Shugnou Layer 1,11,24,38.5498851,70.34296533,NA,0,0,1,1,0,1,1,0,0,0,0,0,0,0,0,0,0,1,1,0,0
Nishiaki,Nishiaki 2021,Shugnou Layer 2,11,24,38.51687853,70.33465939,NA,0,0,1,1,0,1,1,0,0,0,0,0,0,0,1,1,0,1,1,0,0
Nishiaki,Nishiaki 2021,Dodekatym 2 Layer 2,11,24,41.55420026,70.27493397,NA,0,0,1,0,1,1,0,0,0,0,0,0,0,0,0,0,1,1,1,0,0
Nishiaki,Nishiaki 2021,Dodekatym 2 Layer 3,11,24,41.53100363,70.21077146,NA,0,1,1,0,0,1,0,0,0,0,0,0,0,0,0,0,1,1,1,0,0
Nishiaki,Nishiaki 2021,Dodekatym 2 Layer 4,11,24,41.64382755,70.17579304,NA,0,0,1,0,1,1,0,0,0,0,0,0,0,0,0,0,1,1,1,0,0
Nishiaki,Nishiaki 2021,Kulbulak Layer 2.1,11,60,41.03051287,70.05914938,NA,0,0,1,1,1,1,1,0,0,0,0,0,0,0,0,0,1,1,1,0,0
Nishiaki,Nishiaki 2021,Kulbulak Layer 3,60,130,41.00194632,69.97886629,NA,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,1,1,1,0,0
Nishiaki,Nishiaki 2021,Zhoukoudian Loc.15 Layer 2,71,190,39.75962861,116.0340277,NA,1,1,1,0,1,0,1,0,0,1,0,0,0,0,0,1,1,0,0,0,0
Nishiaki,Nishiaki 2021,Zhoukoudian Upper cave ,11,60,39.69762705,115.9379368,NA,1,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Zhaocun tempo 1,24,60,39.94782244,118.6864249,NA,0,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Youfang Layer 3,11,60,40.19046461,114.6566553,NA,0,0,1,1,1,1,1,0,0,0,0,0,1,0,0,0,1,1,1,0,0
Nishiaki,Nishiaki 2021,Kehe Loc. 6056 tempo 1,71,130,34.73069302,110.2047942,NA,0,1,1,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Nanhaiyu,71,130,35.32072686,111.6533174,NA,0,0,1,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Xujiayao Layer II,60,130,40.08835051,114.0650976,NA,1,1,1,0,0,0,1,0,0,0,0,0,0,0,0,1,0,1,0,0,0
Nishiaki,Nishiaki 2021,Fanjiazhuang tempo 1,71,190,37.64103607,112.1887864,NA,0,1,1,0,0,0,1,0,0,0,0,0,0,0,1,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Wutaishan,11,60,39.08097074,113.706013,NA,1,1,1,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Xiaozhan tempo 1,11,60,40.03992649,113.1674503,NA,1,1,1,0,1,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Jiayugou,11,60,37.61814369,112.8893668,NA,0,0,1,1,0,0,0,0,0,0,0,0,0,0,0,1,0,1,0,0,0
Nishiaki,Nishiaki 2021,Shiyu 2,24,60,39.48264485,112.0986008,NA,1,0,1,0,1,0,1,0,0,0,0,0,0,0,0,0,0,1,0,0,0
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Nishiaki,Nishiaki
2021,Suoquanling,11,60,35.45292467,112.4817927,NA,0,1,1,1,0,0,1,0,0,0,0,0,0,0,0,0,0,0
,0,0,0
Nishiaki,Nishiaki
2021,Gulong,11,60,35.43174703,112.3232648,NA,1,0,1,1,1,0,1,0,0,0,0,0,0,0,0,0,1,0,0,
0
Nishiaki,Nishiaki
2021,Qiacun,11,60,35.42959615,112.4878749,NA,0,0,1,1,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,
0
Nishiaki,Nishiaki
2021,Tulouzhuang,11,60,35.51173312,112.3966394,NA,0,0,1,0,0,0,1,0,0,0,0,0,0,0,0,0,0,
0,0,0,0
Nishiaki,Nishiaki
2021,Lamawan,11,60,40.07019992,111.6378463,NA,0,1,1,0,0,0,1,0,0,0,0,0,0,0,1,0,0,0,0,
0,0
Nishiaki,Nishiaki 2021,Dayao Sidaogou East area Layer
3,71,130,40.94583031,111.9513309,NA,1,1,1,0,1,0,1,0,0,0,0,0,0,0,0,1,0,0,0,0,0
Nishiaki,Nishiaki 2021,Dayao Sidaogou West area Layer
3,71,130,41.00689738,112.0373953,NA,0,0,1,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Miaohoushan Layer
7,11,24,40.21918872,124.0699496,NA,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Gezidong tempo
1,60,71,41.22593188,124.8018086,NA,1,1,1,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki
2021,Xibajianfang,11,24,41.1787682,119.5469108,NA,0,0,1,1,1,0,0,0,0,0,0,0,0,0,0,0,0,1,
0,0,0
Nishiaki,Nishiaki 2021,Gulongshan tempo
1,11,24,39.64665309,121.8433282,NA,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Xiaogushan Xianrendong Cave Layer
2,24,60,40.63769145,122.9303483,NA,1,1,1,0,1,0,1,0,0,0,0,0,0,0,0,1,0,0,0,0,0
Nishiaki,Nishiaki 2021,Xiaogushan Xianrendong Cave Layer
3,11,24,40.51621508,122.997869,NA,1,1,1,0,1,0,1,0,0,0,0,0,1,0,0,0,0,1,0,0,0
Nishiaki,Nishiaki 2021,Xiaogushan Xianrendong Cave 2
bottom,24,60,40.61744883,122.9303608,NA,0,0,0,0,0,0,0,0,0,0,0,0,0,1,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Zhoujiayoufang Loc.1
1,24,60,44.7677593,126.2984729,NA,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,1,0,0,0,0,0
Nishiaki,Nishiaki 2021,Guxiangtun tempo
1,24,60,45.66878367,126.7286574,NA,0,0,1,0,0,0,0,0,0,0,0,0,0,1,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Shibazhan
C,11,24,52.37602488,125.4894173,NA,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,1,0,0,0
Nishiaki,Nishiaki 2021,Yanjiagang
,11,24,45.61921669,125.7724617,NA,0,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Liaohe sites tempo
1,71,130,28.82928062,115.642134,NA,0,1,1,0,0,0,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0
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Nishiaki,Nishiaki 2021,Rizhao coastal area sites,11,60,35.09416082,119.4066284,NA,0,1,1,0,1,0,1,0,0,0,1,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Zhuxicun,11,60,35.57594456,119.5531795,NA,1,1,1,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Huixinggou tempo 1,71,130,34.79795067,111.2849176,NA,0,1,0,0,0,0,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Zhuyang,71,130,34.24390824,110.6727976,NA,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Hanguguan,11,60,34.28287879,110.7706661,NA,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Zhangnaodong Layer 4,11,24,32.10824325,110.6967515,NA,1,1,1,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Jiudaohe,71,130,30.26864954,111.4677691,NA,0,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Shizishan tempo 1,71,130,24.6309007,113.5474776,NA,0,0,0,0,0,0,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Fanzenshanyan Layer 2,11,60,22.16737383,111.0825357,NA,0,1,1,0,0,0,0,0,0,0,0,0,1,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Bailiandong west Layer 7,24,60,24.14629935,109.4199943,NA,0,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Bailiandong west Layer 4,24,60,24.18212451,109.495334,NA,0,1,1,0,1,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Bailiandong west Layer 5,11,60,24.20333238,109.4828283,NA,0,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Qilinshan Gaitoudong cave upper Layer ,24,60,23.61005899,108.9871322,NA,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Baojiyandong Layer II,24,60,25.23865847,110.2664103,NA,0,1,1,0,0,0,0,0,0,0,0,0,1,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Aidong,11,60,22.44951922,107.4694041,NA,0,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Fulin,11,60,29.36431017,102.3643408,NA,0,1,1,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Liyuqiao 5,11,60,30.00345322,104.8826641,NA,0,1,1,0,1,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Xiaohuidong Layer 3,71,190,26.77549353,104.8111162,NA,0,0,1,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Xiaoyemaban,11,60,24.72086455,103.2440842,NA,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,1,0,0,0,0,0
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Nishiaki,Nishiaki 2021,Longtanshan 2 cave Layer 4,24,60,24.7856377,102.8501906,NA,0,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0

Nishiaki,Nishiaki 2021,Sijiacun,11,60,25.77857064,101.9404529,NA,0,1,1,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0

Nishiaki,Nishiaki 2021,Danengyu,1,60,25.54335482,101.8427507,NA,0,1,1,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0

Nishiaki,Nishiaki 2021,Laoyatang,1,60,25.58740615,101.8789225,NA,0,1,1,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0

Nishiaki,Nishiaki 2021,Yaotougou tempo 1,71,130,35.29849902,107.8521436,NA,0,0,1,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0

Nishiaki,Nishiaki 2021,Laochihe tempo 1,71,130,34.10784416,109.3440958,NA,0,1,1,0,0,0,0,0,0,1,0,0,0,0,0,1,0,0,0,0,0

Nishiaki,Nishiaki 2021,Yumenkou tempo 1,11,60,34.7735819,110.6206894,NA,0,1,1,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0

Nishiaki,Nishiaki 2021,Niujiaogou,11,60,35.31471465,107.6515689,NA,0,1,1,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0

Nishiaki,Nishiaki 2021,Nanyugou,11,60,35.31377738,107.6249667,NA,1,1,1,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0

Nishiaki,Nishiaki 2021,Sigoukou tempo 1,71,130,35.65915505,107.4869716,NA,0,1,1,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0

Nishiaki,Nishiaki 2021,Liujiacha,24,60,36.44339547,101.9739992,NA,1,1,1,0,1,0,0,0,0,0,0,0,1,0,0,0,0,0,0,0,0

Nishiaki,Nishiaki 2021,Heituliang Layer 3,11,60,35.56704694,106.9788753,NA,0,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0

Nishiaki,Nishiaki 2021,Huohuoxili,1,60,35.41447003,92.1827457,NA,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0

Nishiaki,Nishiaki 2021,Sanyikou,1,60,35.15753525,94.0720447,NA,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0

Nishiaki,Nishiaki 2021,Shuidonggou Locus 1 Layers 3-6,24,60,38.35309667,106.482612,NA,0,1,1,1,1,0,1,0,0,0,0,0,0,0,1,1,0,1,0,0,0

Nishiaki,Nishiaki 2021,Zhoukoudian Loc.22,71,190,39.74107545,116.0073211,NA,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0

Nishiaki,Nishiaki 2021,Zhoukoudian Xindong and Loc.4 tempo 1,71,130,39.71386544,116.0098217,NA,1,0,1,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0

Nishiaki,Nishiaki 2021,Zhoukoudian Loc.25,11,60,39.7254297,115.7914778,NA,1,0,1,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0

Nishiaki,Nishiaki 2021,Sifangdong Lower Layer ,24,60,40.54084939,117.6054652,NA,0,1,1,0,0,0,0,0,0,0,0,0,0,0,0,1,0,0,0,0,0

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Nishiaki,Nishiaki 2021,Sifangdong Upper Layer,11,60,40.51727474,117.7346983,NA,0,1,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Mengjiaquan tempo 1,11,24,39.94691649,117.6934036,NA,0,0,1,1,1,0,1,0,0,0,0,0,1,0,0,0,0,1,1,0,0
Nishiaki,Nishiaki 2021,Xibaimaying Layers 5-7,24,60,40.11941898,114.1488212,NA,0,1,1,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Xigou,24,60,35.70195781,111.6361293,NA,0,1,1,0,1,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Chiyu,71,130,36.12028521,111.2325468,NA,0,1,1,0,0,0,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Gujiao sites,11,60,37.92429362,112.205423,NA,0,1,1,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Nanliang,71,130,35.58170667,111.436971,NA,0,1,1,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Raowangtai,24,130,34.94719694,110.4118358,NA,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Dingcun Loc.54,60,130,35.80425229,111.6355293,NA,0,1,1,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Shenjiatai,24,60,41.13133239,120.821218,NA,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Qianyangdong,11,24,41.00913231,124.2709812,NA,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Hongzuizi,11,24,43.64505992,125.193911,NA,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Daqiaotun,11,60,44.6735737,126.3908539,NA,0,1,1,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Laogouhe,11,60,53.33355804,122.5080678,NA,0,1,1,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Xiaonanshan,11,24,46.76477644,134.0413944,NA,0,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Sanshandao,11,60,31.06480279,120.2162374,NA,1,1,1,0,1,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Lianhuadong 2,71,190,32.14437374,119.0641439,NA,1,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
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Nishiaki,Nishiaki 2021,Qianrendong
UP,11,60,35.03315605,118.1974114,NA,1,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki
2021,Daqingfengyucun,71,130,35.22780324,119.098212,NA,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0
,0,0,0,0,0,0
Nishiaki,Nishiaki
2021,Nanwuyangcheng,11,60,35.49817757,117.5244668,NA,0,1,1,0,0,0,1,0,0,0,0,0,0,0,0
,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Heilongtan Lower Cultural
Layer,11,60,34.68791311,118.3178122,NA,0,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Kaisuanlu Layer
4,24,130,34.54123815,112.4061394,NA,0,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Xiaonanhai Layer D1
tb.6,11,60,35.98458247,114.6522553,NA,1,1,1,0,1,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki
2021,Mengcun,71,130,34.57139762,110.8638549,NA,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
,0,0
Nishiaki,Nishiaki 2021,Xiaokongshan upper cave Layer
3,11,60,33.17042806,111.6799865,NA,1,1,1,0,1,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Xiaokongshan upper cave
,11,24,33.13215432,112.5860178,NA,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki
2021,Xingjiazhuang,11,60,34.50701907,110.856591,NA,0,0,1,0,0,0,1,0,0,0,0,0,0,0,0,0,0,
0,0,0,0
Nishiaki,Nishiaki 2021,Lingjing lower Layer
,71,130,34.05575917,113.5803521,NA,1,1,1,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Lingjing upper Layer
,11,60,34.0851769,113.6830051,NA,1,1,1,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki
2021,Sanwan,60,130,32.01477707,112.0606457,NA,0,1,0,0,0,0,1,0,0,1,0,0,0,0,0,0,0,0,0,
0,0
Nishiaki,Nishiaki 2021,Dashengmiao Layer
3,24,60,29.62150223,111.4781906,NA,0,1,1,0,0,0,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki
2021,Changleping,24,244,27.34012972,109.1810842,NA,0,1,0,0,0,0,0,0,0,1,0,0,0,0,0,0,0
,0,0,0,0
Nishiaki,Nishiaki
2021,Huilongwandong,11,24,26.65075632,101.3400396,NA,0,1,1,0,0,0,1,0,0,0,0,0,0,0,0,
0,0,1,0,0,0
Nishiaki,Nishiaki 2021,Zhangkoudong Layer 4-
5,60,130,25.03132689,104.9116447,NA,0,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Laoyadong Layer
1,11,24,27.33547845,104.8794631,NA,0,1,1,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,1
Nishiaki,Nishiaki 2021,Laoyadong Layer
2,11,24,27.41528923,104.9778226,NA,1,1,1,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0

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Nishiaki,Nishiaki 2021,Laoyadong Layer
3,11,24,27.43321562,105.065472,NA,1,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Laoyadong Layer
4,11,24,27.36559811,105.1289489,NA,1,0,1,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Laoyadong Layer
5,11,60,27.40797922,105.1110041,NA,1,1,1,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,"Laoyadong Layer 7
",24,60,27.26827816,105.0507697,NA,1,1,1,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Laoyadong Layer
8,24,60,27.39593661,105.0648436,NA,1,1,1,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki
2021,Wangjiayuanzi,11,60,26.86606398,104.6508174,NA,0,1,1,0,0,0,1,0,0,0,0,0,0,0,0,0,
0,0,0,0,0
Nishiaki,Nishiaki 2021,Xiaodong Layers 1-
5,11,71,23.82417034,98.94803165,NA,0,1,1,0,0,0,0,0,0,1,0,0,1,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Xiaodong Layer
6,11,71,23.85242496,99.24304507,NA,0,1,1,0,0,0,0,0,0,1,0,0,1,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki
2021,Mujiaqiao,11,60,27.06730386,100.3371398,NA,0,1,1,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0
,0,0
Nishiaki,Nishiaki 2021,Jiangjiawan tempo
1,71,130,35.55385118,107.1938143,NA,0,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Hezhigou tempo
1,11,60,35.25311492,107.4677235,NA,0,1,1,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki
2021,Baxiandong,11,60,23.36842886,121.5828197,NA,1,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
,0,0,0
Nishiaki,Nishiaki 2021,Jinsitai cave Layers 5A-
6,11,24,45.21041427,115.629258,NA,0,1,1,0,0,0,1,0,0,1,0,0,0,0,0,1,0,0,0,0,0
Nishiaki,Nishiaki 2021,Jinsitai cave Layers 7A-
8B,24,60,45.17003631,115.5050428,NA,0,1,1,0,1,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Jinsitai cave Layer
7,24,60,45.21971464,115.5931666,NA,0,1,1,0,1,0,1,0,0,0,0,0,0,0,0,1,0,0,0,0,0
Nishiaki,Nishiaki 2021,Jinsitai cave Layer
8,24,60,45.1736664,115.5293368,NA,0,1,1,0,0,0,1,0,0,0,0,0,0,1,0,1,0,0,0,0,0
Nishiaki,Nishiaki 2021,Xinxiangzhuanchang Layer
4,60,71,43.73467753,127.3171169,NA,0,1,0,0,0,0,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Shoushan Xianrendong upper Layer
,24,60,43.15369278,126.6044548,NA,0,1,1,0,1,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Shoushan Xianrendong Lower Layer
,71,130,43.20569716,126.521031,NA,0,0,1,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Jingshuiwan Layer
,60,71,29.8772588,105.8511372,NA,0,1,0,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Xinglongdong Layer
,71,190,30.6934885,109.1763189,NA,0,1,0,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0
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Nishiaki,Nishiaki 2021,Laishui tempo
1,24,60,39.80052737,115.4086796,NA,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,1,0,0,0,0,0
Nishiaki,Nishiaki
2021,Queergou,71,130,40.15781022,114.5480824,NA,0,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
0,0,0
Nishiaki,Nishiaki 2021,Beiyao Layer 4
S1,71,130,34.75040357,112.4341578,NA,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Wangfujing Dongfang Guangchang upper Layer
,11,24,39.8438339,116.3766315,NA,1,0,1,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Wangfujing Dongfang Guangchang lower Layer
,11,60,39.92484488,116.4842722,NA,1,0,1,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Shuidonggou Loc.2 Layer 2. Stratum
6.,11,60,38.37487525,106.4514598,NA,1,1,1,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Shuidonggou
Loc.7,24,60,38.28723772,106.5695398,NA,1,1,1,0,0,0,1,0,0,0,0,0,0,0,0,1,0,0,0,0,0
Nishiaki,Nishiaki 2021,Salawusu Fanjiagouwan tempo
1,60,130,37.72027297,108.4917821,NA,0,0,1,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Salawusu
Yangsigouwan,24,60,37.81306244,108.5254207,NA,0,0,1,1,1,0,1,0,0,0,0,0,0,0,0,0,0,0,0,
0,0
Nishiaki,Nishiaki 2021,Salawusu
Shaojiagouwan,60,130,37.71657142,108.5823186,NA,1,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
0,0,0
Nishiaki,Nishiaki 2021,Beiyaowan Cave tempo
1,24,60,37.17602272,113.7704872,NA,1,1,1,0,0,0,1,0,0,0,0,0,0,0,0,1,0,0,0,0,0
Nishiaki,Nishiaki 2021,Xiachuan Fuyihegeliang Layer
4,NA,NA,35.45653417,111.9918808,NA,0,1,1,0,0,0,1,0,0,0,0,0,0,0,0,1,0,0,0,0,0
Nishiaki,Nishiaki 2021,Xiachuan Fuyihegeliang Layer
3,24,60,35.52041928,112.035174,NA,0,0,1,0,0,0,1,0,0,0,0,0,1,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Xiachuan Fuyihegeliang Upper Layer 2
Upper,11,60,35.38827129,112.0023235,NA,1,0,1,1,1,0,1,0,0,0,0,0,1,0,0,0,0,1,0,0,0
Nishiaki,Nishiaki 2021,Xiachuan Fuyihegeliang Upper Layer 2
Lower,11,24,35.46792088,112.0544146,NA,1,0,1,1,1,0,1,0,0,0,1,0,1,0,0,0,0,1,1,0,1
Nishiaki,Nishiaki 2021,Tashuihe tempo
1,24,60,35.44570151,113.1084264,NA,1,0,1,0,0,0,1,0,0,0,0,0,0,0,1,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,zhijidong Layer
6,11,24,34.56367074,113.1897483,NA,1,1,1,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,zhijidong Layer 1-
4,24,60,34.62334979,113.276334,NA,1,1,1,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Longquandong Layer
2,24,60,33.84297495,111.5531441,NA,1,1,1,0,0,0,1,0,0,0,0,0,0,0,0,1,0,0,0,0,0
Nishiaki,Nishiaki 2021,Longquandong Layer
3,24,60,33.78552968,111.5087705,NA,1,0,1,0,0,0,1,0,0,0,0,0,0,0,0,0,0,1,1,0,1
Nishiaki,Nishiaki 2021,Bianfudong tempo
1,71,130,33.80776065,111.6080408,NA,1,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
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Nishiaki,Nishiaki 2021,Changweigou surface finds,24,60,35.17377825,105.9415759,NA,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Loufangzi tempo 1,24,60,36.32175698,107.667714,NA,0,0,1,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Jujiayuan tempo 1,24,60,36.72144953,107.9337801,NA,0,1,1,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Jiaohegucheng 4 plateau tempo 1,1,60,42.89609322,89.05371827,NA,0,0,1,0,0,0,1,0,0,0,0,0,0,1,1,0,1,1,0,0
Nishiaki,Nishiaki 2021,Huanglongdong Layer 3,24,130,33.14865739,109.840861,NA,1,0,1,0,1,0,0,0,0,1,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Tongliang tempo 1,24,60,29.92500937,105.3391721,NA,0,1,1,0,1,0,1,0,0,0,0,1,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Longya Layer 4,11,60,30.35831273,104.4031821,NA,1,1,1,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Qianxi Guanyindong A Layer 1-2,24,60,26.77993634,106.1563478,NA,0,1,1,0,1,0,1,0,1,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Qianxi Guanyindong B Layer 3-8,71,130,26.89346635,105.6869582,NA,0,1,1,0,0,0,1,0,1,1,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Shuidonggou Loc.9 Layer 2,24,60,38.17662086,106.5762041,NA,0,0,1,1,0,0,0,0,0,0,0,0,0,1,1,0,1,0,0,0
Nishiaki,Nishiaki 2021,Jigongshan upper,24,60,30.4350018,112.0891938,NA,0,0,1,0,1,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Jigongshan lower,60,71,30.3601732,112.1366071,NA,0,1,1,0,0,0,0,0,0,1,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Xiaochaidan tempo 1,24,60,37.45381052,95.49527243,NA,0,1,1,0,1,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Chuanfandong Layers 5A-5B,24,60,26.23147534,117.6101983,NA,1,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Chuanfandong Layers 6-7,24,60,26.21401966,117.3278248,NA,0,1,1,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Xianrendong East area Layer 2A3,11,24,28.74145476,117.2236473,NA,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,1,0
Nishiaki,Nishiaki 2021,Xianrendong East area Layers 2B-2B1,11,24,28.74213487,117.0743764,NA,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,1
Nishiaki,Nishiaki 2021,Xianrendong East area Layer 2B2,11,24,28.76534207,117.1695705,NA,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,1
Nishiaki,Nishiaki 2021,Xianrendong East area Layer 3A,11,24,28.72983949,117.2605656,NA,0,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,1
Nishiaki,Nishiaki 2021,Xianrendong East area Layer 3B,11,24,28.75316939,117.1067087,NA,0,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,1
Nishiaki,Nishiaki 2021,Xianrendong East area Layer 4A,11,24,28.65256324,117.1486084,NA,1,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Xianrendong East area Layer 4B,11,60,28.74076361,117.0869183,NA,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
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Nishiaki,Nishiaki 2021,Xianrendong East area Layers
5A,11,60,28.70339123,117.2385104,NA,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,1
Nishiaki,Nishiaki 2021,Xiniudong Layer
3,71,130,31.62589584,110.4136084,NA,1,1,1,0,1,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Ziyang man Loc.B Layer
6,24,60,30.12108384,104.3953406,NA,0,1,1,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Huangdikou Layer
3,11,24,34.24483583,113.6920544,NA,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Huangdikou Layer
4,24,60,34.30142852,113.7679775,NA,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Huangdikou Layer
5,24,60,34.3433744,113.7430729,NA,1,0,1,0,0,0,1,0,0,0,0,0,0,0,0,0,0,1,0,0,0
Nishiaki,Nishiaki 2021,Dongyingfang Layer
3,24,60,40.12996174,117.3992673,NA,0,1,1,0,1,0,0,0,0,0,0,0,0,0,0,1,0,0,0,0,0
Nishiaki,Nishiaki 2021,Huangniliang Primary
Loess,24,71,35.57156853,119.5374716,NA,0,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Fangjiagou Layer
G1,24,60,34.41173488,113.1133712,NA,1,1,1,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Shuidonggou Loc.8 Layer
2,24,60,38.35006991,106.5140252,NA,1,1,1,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,1,0,0
Nishiaki,Nishiaki 2021,Shizitan Loc.S12A Layer
3,11,24,35.99179449,110.4063018,NA,1,0,1,0,1,0,1,0,0,0,0,0,0,0,0,0,0,0,1,0,0
Nishiaki,Nishiaki 2021,Shizitan Loc.S29 Layer
2,11,24,36.12996877,110.9330491,NA,1,0,1,0,0,0,0,0,0,0,1,0,0,0,0,0,0,0,1,0,1
Nishiaki,Nishiaki 2021,Shizitan Loc.S29 Layer
7,11,24,35.97206895,111.0528396,NA,1,0,1,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,1,0,1
Nishiaki,Nishiaki 2021,Shizitan Loc.S29 Layer
3,11,24,36.09103214,110.9849988,NA,0,0,1,0,0,0,0,0,0,0,1,0,0,0,0,0,0,0,1,0,0
Nishiaki,Nishiaki 2021,Shizitan Loc.S29 Layer
4,11,24,36.03314477,110.3932557,NA,1,0,1,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,1,0,1
Nishiaki,Nishiaki 2021,Shizitan Loc.S29 Layer
5,11,24,36.02480717,109.998082,NA,1,0,1,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,1,0,0
Nishiaki,Nishiaki 2021,Shizitan Loc.S29 Layer
6,11,24,36.13329497,110.671608,NA,0,1,1,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,1,0,0
Nishiaki,Nishiaki 2021,Shizitan Loc.S29 Layer
8,24,60,36.08537869,111.4632896,NA,1,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,1
Nishiaki,Nishiaki 2021,Xiaogou Layer
3,11,60,32.85714475,110.6902717,NA,0,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Helong
Dadong,11,24,42.04256358,128.8050003,NA,0,0,1,0,1,0,0,0,0,0,0,0,0,0,0,0,0,1,0,1,0
Nishiaki,Nishiaki 2021,Meigou
Lower,11,60,40.13382138,114.4110412,NA,1,1,1,1,0,0,1,0,0,0,0,0,0,0,0,0,0,1,0,0,0
Nishiaki,Nishiaki 2021,Xujiacheng Layer
4A,11,24,35.08821656,105.8700797,NA,1,0,1,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0
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Nishiaki,Nishiaki 2021,Xujiacheng Layer 4B,24,60,35.03786106,105.7491181,NA,1,1,1,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Xujiacheng Layer 4C,24,60,35.06476766,105.7192313,NA,0,1,1,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Xujiacheng Layer 5,24,60,35.06814568,105.7433178,NA,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,1,0,0,0,0
Nishiaki,Nishiaki 2021,Sumiaoyuantou Main,11,24,35.19346116,106.0735928,NA,1,0,1,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Dazhushan Layers 2-3,24,71,35.78715933,119.8321069,NA,0,0,1,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Shuanpuzi Loc.I Layer 3,11,60,35.24739965,105.8758782,NA,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Shuanpuzi Loc.I Layer 2,24,60,35.30917125,106.0188759,NA,0,0,1,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Dingcun Loc.54:90 Layer,71,130,35.81670823,111.648513,NA,0,1,1,0,0,0,1,0,0,1,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Dingcun Loc.54:96 Layer,71,130,35.78605412,111.4593514,NA,0,1,1,0,0,0,1,0,0,1,0,0,0,0,0,1,0,0,0,0,0
Nishiaki,Nishiaki 2021,Dingcun Loc.54:97 Layer,71,130,35.77007099,111.5708533,NA,0,1,1,0,0,0,1,0,0,1,0,0,0,0,0,1,0,0,0,0,0
Nishiaki,Nishiaki 2021,Dingcun Loc.54:98,71,130,35.89193296,111.5132194,NA,0,1,1,0,0,0,1,0,0,1,0,0,0,0,0,1,0,0,0,0,0
Nishiaki,Nishiaki 2021,Dingcun Loc.54:99,71,130,35.79265653,111.6669188,NA,0,1,1,0,0,0,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Dingcun Loc.54:102,71,130,35.79745549,111.3571253,NA,0,1,1,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Dingcun Loc.76:006,71,130,35.78647535,111.3253313,NA,0,1,1,0,0,0,1,0,1,1,0,0,0,0,0,1,0,0,0,0,0
Nishiaki,Nishiaki 2021,Dingcun Loc.76:007,71,130,35.81757861,111.4708073,NA,0,1,1,0,0,0,1,0,0,1,0,0,0,0,0,1,0,0,0,0,0
Nishiaki,Nishiaki 2021,Dingcun Loc.76:008,71,130,35.75466314,111.2683071,NA,0,1,1,0,0,0,1,0,0,1,0,0,0,0,0,1,0,0,0,0,0
Nishiaki,Nishiaki 2021,Dingcun Loc.79:05,71,130,35.86359702,111.3397184,NA,0,1,1,0,0,0,0,0,0,1,0,0,0,0,0,1,0,0,0,0,0
Nishiaki,Nishiaki 2021,Dingcun Loc.80:01,71,130,35.80938319,111.4629954,NA,0,1,1,0,0,0,1,0,0,1,0,0,0,0,0,1,0,0,0,0,0
Nishiaki,Nishiaki 2021,Dingcun Loc.04:02,71,130,35.87498358,111.4667491,NA,0,1,1,0,0,0,0,0,0,0,0,0,0,0,0,1,0,0,0,0,0
Nishiaki,Nishiaki 2021,Zhaojiahuagougoukou Layer S2,24,60,35.30903114,105.9413889,NA,1,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Zhaojiahuagougoukou Layer S4,11,24,35.3330839,105.8978336,NA,1,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
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Nishiaki,Nishiaki 2021,Nongda houshan Layer
2,11,24,41.80871443,123.5652984,NA,0,0,1,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Nongda houshan Layer
5,71,130,41.8027599,123.4489797,NA,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,1,0,0,0,0,0
Nishiaki,Nishiaki 2021,Nongda
baicaoyuan,11,60,41.87023326,123.6950702,NA,1,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Xishi Layer
2,11,24,34.4235793,113.2161064,NA,1,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,1,1,0,0
Nishiaki,Nishiaki 2021,Xishi Layer
3,11,60,34.4633123,113.254762,NA,0,0,1,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Houhedong Layer
3,11,60,35.57537568,113.0700327,NA,0,0,1,0,1,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Majidong Layer
3,24,60,35.54584554,113.1108669,NA,0,1,1,0,0,0,1,0,1,0,0,0,0,0,0,1,0,0,0,0,0
Nishiaki,Nishiaki 2021,Shunwangping
Dayao,11,24,35.46355731,111.9872485,NA,0,0,1,0,1,0,1,0,0,1,0,0,0,0,0,0,0,1,0,0,0
Nishiaki,Nishiaki 2021,Yuzui Layer
2,71,190,32.77839353,110.6449106,NA,0,1,1,0,0,0,1,0,0,1,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Shuiniuwa Upper Layer
,11,60,32.73625693,111.0398582,NA,0,1,1,0,1,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Lixin Layer
2,11,60,42.71780612,127.9651403,NA,1,1,1,0,0,0,1,0,0,1,1,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Zaoziping Layer
4,60,71,29.87732804,106.5502558,NA,0,1,1,0,0,0,1,0,0,0,0,0,0,0,0,1,0,0,0,0,0
Nishiaki,Nishiaki 2021,Houfang Layer
2,71,130,32.86567504,110.5883357,NA,1,1,1,0,0,0,1,0,0,1,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Liuwan Locus I Layer
2,24,130,32.81409125,110.9995208,NA,0,1,1,0,0,0,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Liuwan Locus II Layer
2,24,130,32.83156653,110.6994015,NA,0,1,1,0,0,0,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Qihedong Layers 6 to 7 Stage
1,11,24,25.5339846,117.5697565,NA,1,1,1,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Wuyashan Layer
4,24,60,29.58526199,112.0541273,NA,0,1,1,0,0,0,1,0,0,1,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Tiaotougang Upper Cultural
Layer,24,130,29.50431187,111.4597115,NA,0,1,1,0,1,0,1,0,0,1,0,0,0,0,0,0,0,1,0,0,0
Nishiaki,Nishiaki 2021,Xinwuzui Layer 3vermiculated red
soil,71,190,28.8291019,111.5109451,NA,0,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Yuanjiashan Layer
4,11,24,29.85538426,111.1215551,NA,0,1,1,0,1,0,0,0,0,0,0,0,0,0,0,1,0,0,0,0,0
Nishiaki,Nishiaki 2021,Huaishuping Lower
Layers,71,130,34.11852809,110.177962,NA,0,1,1,0,0,0,0,0,0,1,0,0,0,0,0,1,0,0,0,0,0
Nishiaki,Nishiaki 2021,Wulanmulun
Loc.2,60,71,39.59150163,109.8986925,NA,0,1,1,0,1,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0
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Nishiaki,Nishiaki 2021,Gaojiazhen Layer
4,71,190,29.95357488,107.7355447,NA,0,1,1,0,0,0,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Chibaling lower
gravel,71,190,29.92885221,108.5915392,NA,0,1,1,0,0,0,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki
2021,Maoyadong,11,60,36.71200523,113.3375374,NA,1,0,1,0,1,0,0,0,1,0,0,0,0,0,0,0,0,0,
0,0,0
Nishiaki,Nishiaki 2021,Chunafangdong No.3
tunnel,71,130,26.27707431,117.3099188,NA,0,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Chuanfangdong rock shelter Layer
3,11,60,26.27394134,117.3205759,NA,0,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Linfu Layer
8,11,24,47.75839335,124.4300312,NA,1,1,1,0,1,0,1,0,0,0,0,0,0,0,0,0,0,1,1,0,0
Nishiaki,Nishiaki 2021,Xiaohekou Layer
3,24,60,27.44409618,109.7439888,NA,0,1,1,0,0,0,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Yanerdong Layer
4,11,24,29.66320312,110.8721132,NA,0,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Shiligang layer 3-
5,11,24,29.7719426,111.6098621,NA,0,1,1,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Dudian loc.1 Layers 3-
08,11,60,32.6495692,111.0272785,NA,0,0,1,0,1,0,1,0,0,0,0,0,1,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Yangzhuangxishan Yellow Sandy-
Clay,60,130,40.12222432,117.3806511,NA,0,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Damei Loc.1 Layer
3,11,60,23.74485326,106.8691586,NA,0,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Damei Loc.1 Layer
4,60,71,23.7689889,107.0824777,NA,0,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Yindinggang Upper Lithic
Layer,11,24,31.0532546,119.8518774,NA,1,1,1,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Xinqiao Paleosol
A,24,60,36.66765322,113.4848729,NA,0,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Xinqiao Paleosol
B,71,130,36.71180426,113.4172839,NA,0,1,1,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Xiangbidong Lower Layer
,71,130,26.51055583,100.0191308,NA,0,1,1,0,0,0,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Chenshan Layer
L2,71,130,30.87263413,118.7788348,NA,0,1,0,0,0,0,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Fangniushan Layer
2,71,130,31.96159716,119.3525877,NA,0,0,0,0,0,0,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Yushuwan
UP,11,60,40.05994609,111.5913362,NA,0,0,1,0,0,0,1,0,0,0,0,0,0,0,1,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Xiaokongshan lower cave Layer
2,11,60,33.12560416,111.4099415,NA,1,1,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Guanleixiang
Loc.A,1,60,21.68617683,101.159375,NA,0,1,0,0,0,0,0,0,0,0,0,0,0,0,1,0,0,0,0,0,0
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Nishiaki,Nishiaki 2021,Guanleixiang Loc.B,1,60,21.67331197,101.1560587,NA,0,1,0,0,0,0,0,0,0,0,0,0,1,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Tongtiandong Layers 6-9,24,60,47.2115998,86.10806847,NA,0,1,1,0,0,0,1,0,0,0,0,0,0,1,0,1,0,0,0,0,0
Nishiaki,Nishiaki 2021,Yahuaidong Stage 1,24,60,23.04303445,107.7483992,NA,1,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Yahuaidong Stage 2,11,24,23.07567626,107.5894374,NA,1,0,1,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,1
Nishiaki,Nishiaki 2021,Yahuaidong Stage 3,11,24,23.14405896,107.8040033,NA,1,0,1,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,1
Nishiaki,Nishiaki 2021,Taoshanzui,60,130,35.31286285,107.7248694,NA,1,0,1,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Gujiao,11,60,37.92535559,112.1184958,NA,0,1,1,0,0,0,1,0,0,0,0,0,0,0,0,0,0,1,0,0,0
Nishiaki,Nishiaki 2021,Dayao Erdaogou,11,60,40.89133313,112.0066075,NA,0,1,1,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Honggou Layer 1,71,130,34.76077601,113.0085769,NA,0,1,0,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Shizitan Loc.14 Layer 2,11,24,35.99936993,111.1061542,NA,0,0,1,1,0,0,1,0,0,0,0,0,0,0,0,0,0,0,1,0,1
Nishiaki,Nishiaki 2021,Shizitan Loc.14 Layer 3,11,24,36.05455836,110.2189946,NA,0,0,1,1,0,0,1,0,0,0,0,0,0,0,0,0,0,0,1,0,1
Nishiaki,Nishiaki 2021,Shizitan Loc.14 Layer 4,11,24,35.99775701,110.6180056,NA,0,0,1,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0,1,0,1
Nishiaki,Nishiaki 2021,Shizitan Loc.S12C Layer 2,11,24,35.97311998,111.0294783,NA,0,0,1,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0,1,0,0
Nishiaki,Nishiaki 2021,Xianrendong West area Layer 3B1,11,24,28.72728156,117.1253351,NA,0,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Xianrendong West area Layer 3B2,11,24,28.74469803,117.0740361,NA,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,1
Nishiaki,Nishiaki 2021,Xianrendong West area Layer 3C1A,11,24,28.73111879,117.166517,NA,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Xianrendong West area Layer 3C2,11,24,28.78425002,117.2433259,NA,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Xianrendong West area 4A,11,24,28.76240123,117.2054283,NA,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Diaotonghuan Layer D,11,24,28.66639747,117.1452776,NA,0,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,1,1
Nishiaki,Nishiaki 2021,Diaotonghuan Layer E,11,24,28.70471071,117.1043123,NA,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,1
Nishiaki,Nishiaki 2021,Diaotonghuan Layer F,11,24,28.79905615,117.2118896,NA,0,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Diaotonghuan Layer G,11,24,28.73029354,117.1150753,NA,0,1,1,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0

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Nishiaki,Nishiaki 2021,Diaotonghuan Layer
H,11,24,28.75524829,117.2345588,NA,1,1,1,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Diaotonghuan Layer
J,11,24,28.77502868,117.1720916,NA,1,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Diaotonghuan Layer
K,11,60,28.76301775,117.1022055,NA,1,0,1,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Diaotonghuan Layer
L,11,60,28.80673547,117.1441549,NA,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki
2021,Taohuaxi,11,60,29.45453495,106.4569948,NA,1,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
0,0
Nishiaki,Nishiaki 2021,Yiduquan Layer
2,11,60,40.33723247,114.6549728,NA,0,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Diaozhai Layer
1,24,71,34.28506509,109.1257976,NA,1,1,1,0,0,0,1,0,0,1,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Ganyu Layer
L2,24,71,34.26488034,109.2367723,NA,1,1,1,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Lenghu
Loc.1,24,60,38.69667515,93.45615531,NA,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,1,0,0,0
Nishiaki,Nishiaki 2021,Lianhuachishan Layer
4,24,60,24.54113543,117.7533193,NA,1,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Dishuiyan Layer 3-
4,11,71,32.81364637,110.9043668,NA,0,1,1,0,0,0,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Zhaozhuang Layer
7,24,60,34.22421893,113.7368301,NA,0,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Laonainaimiao Loc.2 Layer
4,24,60,34.60182081,113.6037844,NA,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,1,0,0,0,0
Nishiaki,Nishiaki 2021,Dongshi
UCL,11,24,34.46348514,113.201178,NA,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,1,1,0,0
Nishiaki,Nishiaki 2021,Dongshi
LCL,24,60,34.39410718,113.2049808,NA,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,1,0,0,0,0
Nishiaki,Nishiaki 2021,Xishantou Layer
3,11,24,46.80739627,123.0230333,NA,0,1,1,0,1,0,0,0,0,0,0,0,0,0,0,0,0,1,0,0,0
Nishiaki,Nishiaki 2021,Xishahe Layer
3A,11,24,39.87524815,113.9602592,NA,0,0,1,0,1,0,1,0,0,0,0,0,0,0,0,0,0,1,1,0,0
Nishiaki,Nishiaki 2021,Xishahe Layer
3B,11,60,39.92217978,114.120901,NA,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Nwya
Devu,24,60,31.4665569,88.85853486,NA,0,0,1,0,1,0,1,0,0,0,0,0,0,0,0,0,0,1,0,0,0
Nishiaki,Nishiaki 2021,Xiachuan Xiaobaihuageliang Layer
1,11,24,35.43777568,111.9893241,NA,1,0,1,1,1,0,0,0,0,0,0,0,0,0,0,0,0,1,1,0,0
Nishiaki,Nishiaki 2021,Xiachuan Xiaobaihuageliang Layer
2,11,24,35.36340117,112.062944,NA,1,0,1,1,1,0,1,0,0,0,0,0,0,0,0,0,0,0,1,0,0
Nishiaki,Nishiaki 2021,Xiachuan Xiaobaihuageliang Layer
3,24,60,35.49212165,112.1220591,NA,1,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
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Nishiaki,Nishiaki 2021,Laonainaimiao Loc.3 Layer 4,24,60,34.67358377,113.5595768,NA,1,1,1,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Laonainaimiao Loc.3 Layer 5,24,60,34.6768166,113.6343182,NA,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Hopyeong-dong Layer 3,24,60,37.79495474,127.1428842,NA,1,1,1,0,0,0,0,1,0,0,0,0,0,0,0,0,1,1,0,0,0
Nishiaki,Nishiaki 2021,Hopyeong-dong ,11,24,37.74750631,127.1710099,NA,1,1,1,0,1,1,0,0,0,0,0,0,0,0,0,0,1,1,1,0,0
Nishiaki,Nishiaki 2021,Janghung-ri Layer 2,11,24,38.23020338,127.3389038,NA,0,1,1,0,0,0,1,1,0,0,0,0,0,0,0,0,0,0,1,0,0
Nishiaki,Nishiaki 2021,Hahwagye ri III Layer 2,11,24,37.72375792,127.9358038,NA,0,1,0,0,0,0,1,0,0,0,0,0,0,0,0,0,1,0,1,0,0
Nishiaki,Nishiaki 2021,Hahwagye ri III Layer 6,71,130,37.69425343,127.8333195,NA,0,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Hahwagye ri III Layer 3,24,60,37.6236705,127.8280148,NA,0,1,1,1,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Hahwagye ri III Layer 4,71,130,37.62852257,127.8976802,NA,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Suyanggae Loc3 Layer 7,24,24,36.98985572,128.2387424,NA,0,1,1,0,1,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Suyanggae Loc3 Layer 2,71,130,36.89302386,128.262363,NA,0,1,1,0,0,0,0,0,0,0,0,0,0,0,0,1,0,0,0,0,0
Nishiaki,Nishiaki 2021,Pyongchang-ri Pyeongchang-ri Layer 2,24,60,37.22723247,127.3085479,NA,0,1,1,0,0,0,1,0,0,0,0,0,0,0,0,1,0,0,0,0,0
Nishiaki,Nishiaki 2021,Yullyang-dong Layer 2a,24,60,36.72826442,127.396455,NA,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,1,0,0,0,0,0
Nishiaki,Nishiaki 2021,Yullyang-dong Layer 3a,71,130,36.67426808,127.411914,NA,0,1,1,0,0,0,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Yongho-dong Layer 5,71,130,36.39539222,127.2610625,NA,0,1,1,0,0,0,1,0,0,0,0,0,0,0,0,1,0,0,0,0,0
Nishiaki,Nishiaki 2021,Yongho-dong Layer 3b,24,60,36.43354913,127.3539831,NA,0,1,1,0,0,0,0,1,0,0,0,0,0,0,0,0,1,1,0,1,0
Nishiaki,Nishiaki 2021,Yongho-dong Layer 3a,24,60,36.40405147,127.6063339,NA,0,1,1,0,0,0,1,1,0,0,0,0,0,0,0,0,1,1,0,0,0
Nishiaki,Nishiaki 2021,Yongho-dong Layer 2,11,24,36.49767675,127.2282386,NA,0,1,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,1,0,0
Nishiaki,Nishiaki 2021,Jungnae-ri Layer 6,71,130,35.17462498,127.3511773,NA,0,1,1,0,0,0,1,0,0,1,0,0,0,0,0,0,1,0,0,0,0
Nishiaki,Nishiaki 2021,Jungnae-ri Layer 4 lower,71,130,35.06314587,127.4523568,NA,0,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,1,0,0,0,0
Nishiaki,Nishiaki 2021,Jungnae-ri Layer 4 upper,71,130,35.10930127,127.4567695,NA,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Jungnae-ri Layer 2,11,24,35.1511339,127.4976843,NA,0,1,1,0,1,0,1,0,0,0,0,0,0,0,0,0,1,1,0,0,0
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Nishiaki,Nishiaki 2021,Naechon-ri Layer
2,24,24,35.18415692,127.9961872,NA,0,1,1,0,0,0,0,0,0,0,0,0,0,0,0,1,0,0,0,0
Nishiaki,Nishiaki 2021,Shinsang-ri Layer
6,24,60,36.35676913,128.5135775,NA,0,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Shinsang-ri Layer
5,71,130,36.31078263,128.0781537,NA,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Shinsang-ri Layer
3,190,244,36.3569412,128.3661888,NA,0,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Haeundae Joa-dong Layer
2,11,24,35.1730045,129.2328102,NA,0,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,1,0
Nishiaki,Nishiaki 2021,Haeundae Jun-dong Layer
2,11,24,35.12946714,129.098033,NA,0,0,1,0,0,0,1,0,0,1,0,0,0,0,0,0,1,1,1,0,0
Nishiaki,Nishiaki 2021,Worpyong Walpyeong Layer
2,11,24,34.97497214,127.2679877,NA,0,1,1,1,1,0,0,1,0,1,0,0,0,0,0,0,1,0,0,0,0
Nishiaki,Nishiaki 2021,Bokdae-dong Daenong Layer
7,24,60,36.46391282,127.6850825,NA,0,1,1,0,0,0,1,0,0,0,0,0,0,0,0,0,1,0,0,0,0
Nishiaki,Nishiaki 2021,Bokdae-dong Daenong Layer
8,24,60,36.41307873,127.5442114,NA,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Wolseong-dong
,11,24,35.87766463,128.6126826,NA,0,0,1,0,1,0,0,0,0,0,0,0,0,0,0,0,1,1,0,0
Nishiaki,Nishiaki 2021,Duhak-dong Layer
2,24,60,36.75829516,128.235261,NA,0,1,1,0,1,0,1,1,0,0,0,0,0,0,0,0,1,1,1,0,0
Nishiaki,Nishiaki 2021,Usin-ri Layer
3,24,60,36.93260041,127.1789083,NA,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Usin-ri Layer
4,71,130,36.87805901,127.095735,NA,0,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,1,0,0,0,0
Nishiaki,Nishiaki 2021,Usin-ri Layer
5,71,130,36.85569002,127.1648183,NA,0,1,1,0,0,0,0,1,0,0,0,0,0,0,0,0,1,0,0,0,0
Nishiaki,Nishiaki 2021,Geumsanri Galdun Layer
4,24,60,37.82903246,127.7346289,NA,0,1,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Geumsanri Galdun Layer
5A,24,60,37.94772584,127.6299066,NA,0,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Geumsanri Galdun Layer
6A,71,130,37.88391747,127.7216835,NA,0,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Geumsanri Galdun Layer
6B,71,130,37.86246576,127.6814113,NA,0,1,1,0,0,0,0,0,0,1,0,0,0,0,0,0,1,0,0,0,0
Nishiaki,Nishiaki 2021,Haga Layer
2,11,24,35.68186555,127.0841363,NA,0,0,1,0,0,0,1,1,0,0,0,0,0,0,0,0,1,1,0,0,0
Nishiaki,Nishiaki 2021,Hwadae ri Shimteo Layer
3,11,24,37.99661278,127.3424801,NA,0,1,1,1,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Hwadae ri Shimteo Layer
2,24,60,37.94858194,127.2517187,NA,0,1,0,1,0,0,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Sam-ri
,11,24,37.34720194,127.3627592,NA,0,1,1,0,1,0,1,0,0,1,0,0,0,0,0,0,1,0,1,0,0
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Nishiaki,Nishiaki 2021,Yeonyang-ri Layer 1,24,60,37.32918314,127.651227,NA,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,1,0,0,0,0
Nishiaki,Nishiaki 2021,Yeonyang-ri Layer 2,71,85,37.34146496,127.6745953,NA,0,1,1,0,0,0,0,0,0,1,0,0,0,0,0,0,1,0,0,0,0
Nishiaki,Nishiaki 2021,Yeonyang-ri Layer 3,93,130,37.32466805,127.6919196,NA,0,1,1,0,0,0,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Jengjang-ri Layer 2,24,60,35.61923478,127.8095924,NA,0,1,1,0,1,0,1,0,0,0,0,0,0,0,0,0,1,0,0,0,0
Nishiaki,Nishiaki 2021,Yeonbong-ri Layer 2,11,24,37.73527117,127.8163093,NA,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Yeonbong-ri Layer 3,24,60,37.594791,127.8920627,NA,0,1,1,0,0,0,0,0,0,0,0,0,0,0,0,1,0,0,0,0
Nishiaki,Nishiaki 2021,Yeonbong-ri Layer4,71,130,37.76866852,127.908812,NA,0,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,1,0,0,0,0
Nishiaki,Nishiaki 2021,Suyanggae Loc6 Layer 6,11,24,36.88852751,128.199281,NA,1,1,1,1,0,0,1,0,0,0,0,0,0,0,0,0,1,1,1,0,0
Nishiaki,Nishiaki 2021,Suyanggae Loc6 Layer 7,11,24,36.9424975,128.1835413,NA,1,1,1,1,0,1,1,0,0,0,1,0,1,0,0,1,1,1,1,0,1
Nishiaki,Nishiaki 2021,Suyanggae Loc6 Layer 9,24,60,37.00873538,128.362836,NA,1,1,1,1,0,1,1,1,0,0,0,0,0,0,0,1,1,1,1,0,0
Nishiaki,Nishiaki 2021,Suyanggae Loc6 Layer 13,24,60,36.93083847,128.1847227,NA,1,1,1,1,0,1,1,1,0,0,0,0,0,0,0,1,1,1,0,0,0
Nishiaki,Nishiaki 2021,Darra-i Kur tempo 1,NA,NA,36.75563382,69.60655916,NA,0,0,1,0,0,0,0,0,0,0,0,0,0,1,0,1,1,0,0,0,0
Nishiaki,Nishiaki 2021,Sanghao Layers 12-10,24,60,34.40545944,72.13993735,NA,0,1,1,0,1,0,1,1,0,1,0,0,0,1,1,1,0,0,0,0,0
Nishiaki,Nishiaki 2021,Sanghao Layers 9-5,24,60,34.43135509,72.25976006,NA,0,1,1,0,1,0,1,1,0,0,0,0,0,1,1,1,0,0,0,0,0
Nishiaki,Nishiaki 2021,Sanghao Layers 4-1,11,24,34.45161026,72.17195127,NA,0,0,1,0,0,1,1,1,0,0,0,0,0,0,0,0,0,1,0,0,0
Nishiaki,Nishiaki 2021,Jwalapuram Locality 9 Stratum D,24,60,15.3004557,78.18831876,NA,0,0,1,0,1,0,1,1,0,0,0,0,0,0,0,0,1,0,0,0,0
Nishiaki,Nishiaki 2021,Jwalapuram Locality 9 Stratum C,11,24,15.36479084,78.13782449,NA,0,0,1,0,1,1,1,0,0,0,0,0,0,0,0,0,1,0,0,0,0
Nishiaki,Nishiaki 2021,Patne Level 7,11,24,20.40175206,74.90830983,NA,0,1,1,0,0,1,0,0,0,0,0,0,0,0,0,0,0,1,0,0,0
Nishiaki,Nishiaki 2021,Patne Levels 5-6,11,24,20.31244769,75.4697355,NA,0,0,1,0,1,1,1,1,0,0,0,0,0,0,0,0,0,1,0,0,0
Nishiaki,Nishiaki 2021,Jwalapuram Locality 22,60,71,15.33758969,78.11290796,NA,0,1,1,0,1,0,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Aq Kupruk 2 Layer AK2,11,24,36.04264549,67.4571314,NA,0,0,1,0,0,1,0,0,0,0,0,0,0,0,0,0,1,0,0,0,0
Nishiaki,Nishiaki 2021,Mehtakheri,NA,NA,22.14107927,76.03712418,NA,0,1,0,1,0,0,1,0,0,0,0,0,0,0,0,0,0,0,1,0,0
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Nishiaki,Nishiaki 2021,Mahadebbera 2.03mbs,NA,NA,23.2199373,85.9829195,NA,0,0,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Mahadebbera 1.8mbs,NA,NA,23.16721719,86.22964988,NA,0,0,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Mahadebbera 0.69mbs,NA,NA,23.24653523,86.10842326,NA,0,0,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Kana 1.4mbs,NA,NA,23.10631563,86.28982558,NA,0,0,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Bamburi 1,NA,NA,24.55144335,82.1720127,NA,0,1,1,1,0,0,0,0,0,1,0,0,0,0,0,1,1,1,0,0,0
Nishiaki,Nishiaki 2021,Batadomba-lena Layer 6,11,24,6.83420717,80.4240613,NA,1,0,1,0,0,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Batadomba-lena Layer 7a,11,24,6.78233673,80.44876463,NA,1,0,1,0,0,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Batadomba-lena Layer 7b,11,60,6.858492968,80.39396553,NA,1,0,1,0,0,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Batadomba-lena Layer 7c,24,60,6.830654077,80.38031379,NA,1,0,1,0,0,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Fa Hien Lena Cave ,24,60,6.68422451,80.12969189,NA,1,0,0,0,0,1,0,0,1,0,0,0,0,0,0,0,0,0,1,0,0
Nishiaki,Nishiaki 2021,Lang Rongrien Unit 8,24,60,8.225469944,99.00897732,NA,0,0,1,0,0,0,0,0,0,0,0,0,1,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Lang Rongrien Unit 9,24,60,8.129966208,99.01403775,NA,0,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Lang Rongrien Unit 10,24,60,8.113883267,98.8722672,NA,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Niah cave Layers 72-78,24,60,3.103967351,113.1468685,NA,0,1,1,0,0,0,0,0,0,0,0,0,1,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Leang Burung 2 Layer V,11,24,-5.08263706,119.6341601,NA,1,1,1,1,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Leang Burung 2 Layers IV-V,24,60,-5.050370922,119.4223109,NA,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Leang Burung 2 Layer IV,11,24,-5.007343094,119.8411421,NA,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Leang Burung 2 Layer IIIa,11,24,-4.925319884,119.8067428,NA,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Leang Burung 2 Layer II,24,60,-5.052397487,119.8487887,NA,0,0,1,1,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Nguom Rock Shelter Layer 3,11,24,21.80714941,105.7183662,NA,0,1,1,0,0,0,1,0,0,1,0,0,1,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Callao Cave the lower Layers,11,24,17.77410355,121.7939261,NA,0,1,1,1,1,0,1,0,1,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Jerimalai Square B Spit 66,24,60,-8.378347719,127.2488505,NA,1,1,1,0,1,0,1,0,1,0,0,0,0,0,0,1,0,0,0,0,0
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Nishiaki,Nishiaki 2021,Golo Cave tempo,11,60,-0.060707832,129.3586207,NA,0,1,0,0,0,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Mai Da Dieu tempo,1,24,20.35454085,101.5916052,NA,0,1,0,0,0,0,0,0,0,1,0,0,1,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Hang Cho Cave Layer 13,11,24,20.80290294,105.8177233,NA,0,1,1,0,1,0,0,0,0,0,0,0,1,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Lang Kamnan cave tempo,11,60,14.0105904,99.24449966,NA,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Tham Lod Rockshelter Area 1 Layers 4-8,11,60,19.5122733,98.20595592,NA,0,1,0,0,0,0,0,0,0,0,0,0,1,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Moh Khiew Cave Layers 1-2,11,24,8.266367,98.79058005,NA,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Bukit Bunuh tempo,24,60,5.146080444,100.9053901,NA,0,1,0,0,0,0,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Leang Sarru Layer 2 C2,11,24,3.946153866,126.644137,NA,0,0,1,0,0,0,1,0,1,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Leang Sarru B2 Layer 4,24,60,3.87229975,126.6975621,NA,0,0,1,0,0,0,1,0,1,0,0,0,0,0,0,0,0,0,0,0
Nishiaki,Nishiaki 2021,Leang Sakapao 1 spits 1-4,11,60,-4.786427167,119.2589502,NA,0,0,1,0,0,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0
JP,Lindeman 1995 and Adams 1995,Pyramid Point V:5:1,0.6,0.7,33.56852479,-110.9671018,NA,0,1,1,0,0,0,1,0,0,0,1,1,0,0,0,0,0,0,0,0,1
JP,Lindeman 1995 and Adams 1995,Meddler Point V:5:4,0.65,1.2,33.57341837,-110.9963911,NA,1,1,1,0,0,0,1,0,0,0,1,1,0,0,0,0,0,0,0,0,1
JP,Lindeman 1995 and Adams 1995,Griffin Wash B V:5:90,0.65,0.7,33.68823602,-110.9673979,NA,0,1,1,0,0,0,1,0,0,0,1,1,0,0,0,0,0,0,0,0,1
JP,Lindeman 1995 and Adams 1995,Griffin Wash A V:5:90,0.6,0.7,33.67338803,-111.0953347,NA,0,1,1,0,0,0,0,0,0,0,1,1,0,0,0,0,0,0,0,0,1
JP,Lindeman 1995 and Adams 1995,Hedge Apple V:5:189,1.1,1.2,33.60169453,-110.9089646,NA,0,1,1,0,0,0,1,0,0,0,1,1,0,0,0,0,0,0,0,0,1
JP,Lindeman 1995 and Adams 1995,Eagle Ridge A V:5:104,0.6,1,33.69493659,-111.0388374,NA,0,1,1,0,0,0,1,0,0,0,1,1,0,0,0,0,0,0,0,0,1
JP,Lindeman 1995 and Adams 1995,Eagle Ridge B V:5:104,1.45,1.85,33.6460626,-110.9452622,NA,1,1,1,0,0,0,1,0,0,0,1,1,0,0,0,0,0,0,0,0,1
JP,Lindeman 1995 and Adams 1995,Porcupine Site V:5:106,0.65,0.7,33.63766528,-110.9035826,NA,0,1,0,0,0,0,1,0,0,0,1,1,0,0,0,0,0,0,0,0,1
JP,Gaffney et al. 2015,Kiowa levels 10-12,10.2,12.5,-6.127128728,145.0993277,NA,1,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
JP,Gaffney et al. 2015,Kiowa levels 2-6,5.3,7.1,-6.058848614,145.1059199,NA,1,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,1,1
JP,Sheppard 1993,Reef Island Sites,2.8,3.3,-10.23548589,166.3081327,NA,1,1,1,0,0,0,1,0,1,0,0,0,0,0,0,0,1,0,1,0,0
JP,Smith et al. 2010,El Hemmeh,9.8,12,NA,NA,NA,0,1,1,1,0,1,1,0,0,0,0,0,1,0,0,0,1,1,1,1,1
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