Source of the Stone: Lithic Procurement and Provisioning at a Desert Refugium in the Azraq Basin, Jordan

by

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Abstract

Changes in mobility patterns by hunter-gatherers in water-stressed regions of the world has long been viewed as a risk mitigation strategy. Tied into these decisions are the ways in which they provision themselves and procure resources. Foragers of the distant past are no exception, but the nature of their survival is not fully understood. The Middle Pleistocene site of C-Spring in the Azraq Basin, Jordan, is an appropriate case study at which to investigate such issues. C-Spring, excavated by Dr. Andrew Garrard, is located directly adjacent to the only stable water source in the region, the Azraq wetlands, and has yielded an impressive cache of Acheulean remains. In order to reconstruct the mobility patterns, a provenance analysis is conducted to reveal the catchment areas most frequently utilized by the hominins. This was performed with data collected by Individual Attribute Analysis (IAA) and Laser Ablation-Inductively Coupled Plasma-Mass Spectrometry (LA-ICP-MS) of both the known sources in the region and the lithic artifacts. The results show that the majority of raw material was procured locally (5-10 km). This suggests hominins tethered themselves to water in the region for resource security, yet still ventured among the surrounding landscape, remaining within a day's range to the secure resources offered by the Azraq wetlands. As such, C-Spring offers unique insight into how hominins of the Middle Pleistocene survived in marginalized desert environments.

Keywords: Paleolithic, Azraq, Levant, Acheulean, Geoarchaeology, Provenance, Lithics, Chert, Mobility, Provisioning

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Acknowledgments

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1. Introduction

Survival for prehistoric hunter-gatherers in marginal environments often depended on the acquisition of a few key resources. In desert environments this deciding factor is typically access to reliable sources of water. Provenance analysis of lithic artifacts from these ancient desert sites can provide incredible insight into the nature of resource procurement, provisioning, and mobility patterns utilized by past forager populations (e.g., Adams & Brooke, 2009; Brandl, 2016; Ekshtain et al., 2013; Evans et al., 2007; Finkel et al., 2019; Gurova et al., 2014; Luedtke, 1979; Shackley, 1988). Lithics occupy an ideal place for these studies. Given their relative ubiquity among *Homo sapien* and other hominin forager societies, it is extremely likely that at any given archaeological site there will be some form of lithic artifact left over. The geological durability of stone when compared to organic artifacts ensures they remain geochemically accurate for far longer, degrading at a fraction of the rate of even the most durable of organics. Weathering is also far less of a concern in lithic artifacts. Given these factors, successful provenance studies draw from robust data sets, using distinct geochemical elements to discriminate between parent sites and/or sources of these lithic artifacts. Aiming to determine the most probable site of origin for the tools. This is often done through a combination of macroscopic, petrological, and geochemical methods (Brandl, 2016; Malyk-Selivanova et al., 1998). Within cherts there is arguably no one best method of discrimination. It is a notoriously difficult material to characterize and, as such, a suite of different discriminating factors have been described (Brandl, 2016; Luedtke, 1979, 1992). A side effect of this is the tendency for provenance studies examining chert to become frustratingly complicated.

Within the Levant, (modern Israel, Palestine, Syria, Jordan, and Lebanon), the provenance of artifacts has recently become an issue of interest. This region connects Africa to Europe and Asia through several biogeographic corridors that run through the Arabian and Sinai peninsulas (Cordova, 2007). As such, this region likely played a significant role in the story of hominin migration out of Africa (López et al., 2015). The biogeographic corridors facilitated the movement and survival of hominins and animals during times of environmental stress enabling residual populations to survive harsh conditions (Nowell et al., 2016). Along these corridors archaeologists have found evidence of Paleolithic hominins acquiring artifacts from both local and non-local procurement ranges (e.g., Ekshtain et al., 2013, 2017; Finkel et al., 2019). For example, Ekshtain et al., (2017) used geochemical analysis of Paleolithic artifacts recovered the Neanderthal site of Amud cave to demonstrate artifact sources within their daily exploitation area of the site, as well as those from considerably long distances (>60km).

The Azraq Basin in the eastern desert of modern Jordan was a place of concentrated hominin occupation during the Middle (781-126 kya) and Upper (126-12 kya) Pleistocene. This has been well documented by almost a century's worth of intermittent archaeological research in the region (Beller, 2020; Copeland & Hours, 1989d; Kirkbride, 1989; Nowell et al., 2016; Rollefson et al., 1997). At the heart of the basin lies the Greater Azraq Oasis Area (GAOA), a perennial spring-fed wetland complex. Archaeological research in the 1950-80s discovered the Acheulean site of C-Spring next to the GAOA, which now represents one of the most interesting finds. The lithic assemblage was first analyzed by L. Copeland who evaluated the raw material based on their macroscopic characteristics into various lithic series. The nature of the assemblage has led to its interpretation as a dedicated knapping locale (Copeland 1991) and, as such, allows us a unique glimpse into the material culture of the hominins around a desert oasis.

With the uniqueness of this site in mind, this project will look to address provisioning methods used by the hominins that lived at C-Spring as well as examine the effectiveness of Individual Attribute Analysis at determining meaningful artifact groups in this specific region. To do this I will aim to answer three primary research questions: *What is the nature of lithic procurement and provisioning at C-Spring? From where are the hominins at C-Spring acquiring the raw material for their artifacts? How applicable are the lithic "series" established by Copeland (1989) for determining artifact provenance?*[1]

The study of provisioning and land use has a long history. I would argue that since the very beginning of Anthropological study, where and how people have acquired resources has been a question archaeologists have sought to answer when studying cultures. However, for the purposes of this paper I will be primarily drawing from the work of Binford (1980), Kelly (1983, 2013), and Kuhn (1992, 1995) for theoretical grounding to analyze mobility patterns and procurement strategies. These works have been chosen as all have either withstood much scrutiny through their age or offered new insights to build off of the previous authors, as in the

[1] This type of analysis places my study directly into the field of archeology with very little overlap into cultural or linguistic anthropology. The only major overlap with biological anthropology comes from the understanding that provisioning strategies and land use patterns shown in the stone archeological record will also provide information regarding hominin evolution and possible changes to behaviors the land use may suggest. Within the graduate themes this project fits firmly in the Evolution and Ecology subsection.

case of Kelly (2013). Procurement strategies have been shown through ethnoarchaeological works such as Binford (1980) to serve as useful tools to interpret different behaviors used by hunter-gatherer societies and can reflect the unique ways people adapt to their environments. By synthesizing these ethnoarchaeological insights with the pure archeological sourcing methods found in Malyk-Selivanova et al. (1998), I provide insight into the nature of interaction between the hominins of C-Spring and their environment.

2. Literature Review

2.1 Mobility

Mobility refers to the movement of foragers throughout their landscapes, typically on an annual (or seasonal) and daily basis. This idea has always been of great interest to archaeologists but for the purposes of this study the mobility types as defined by Binford (1980) and (Taylor, 1964) will be of key interest. Beginning with Binford's model, he noticed during his research with Inuit communities in Alaska and the San of southern Africa, that groups tended to fall along one of two distinct styles of movement and resource utilization in their landscape. He describes these as either logistical groups, who move resources to residential camps, or residential groups who move camps to resources. Binford noted there seemed to be an inverse relationship between the patterns and that groups would tend to fall somewhere between the two extremes. He argued that these differing patterns would lead to distinct patterns in the archaeological record (Binford, 1980). He termed the two differing types of forager mobility: *logistical/collectors* and *residential/foragers* (Binford, 1980).

Binford described logistical mobility as a style of movement wherein a wide distribution of steady, reliable resources necessitated the creation of “special task groups” (Binford, 1980), who would leave camp in a strictly organized manner to acquire specific resources at these widespread locales. After acquisition, these groups would return to the central camp location and distribute their goods to the whole. Through several of these highly specialized task groups working together the entire camp could be supplied with essential resources that would otherwise be impossible to acquire in a timely fashion. This type of mobility led to a characteristically large main camp located somewhere between these resource pockets (Binford, 1980; Kelly, 1983). This main camp would be a permanent/semi-permanent location where all facets of hominin life could be observed. As this main camp was in an optimal location it would rarely be moved except for periods of large environmental change such as the switch from winter to summer where the resource pockets were also likely to be in new locations or otherwise inaccessible. Here, there is a very high degree of individual movement, with foragers traveling far into the landscape before returning to the main camp, but a very low degree of camp movement as it remains in place for long periods of time (Binford, 1980).

In contrast to the above mobility pattern, Binford classified other hunter-gatherer models of organization as, residential/forager groups. In these situations, widely, yet equally dispersed food resources necessitate larger movements of forager bands which may or may not return to “residential” sites each night (Binford, 1980). In this case, dedicated task groups are not possible and overexploitation of a single area is easy. Consequently, smaller collections of the larger group tend to band together and disperse into the landscape (Binford, 1980; Kelly, 1983). With this pattern of mobility archaeological evidence may be widely spread throughout the landscape necessitating different methods of collection when compared to logistical groups. This mobility pattern is characterized by a low degree of individual movement, as foragers tend to remain quite close to the temporary camp location, but a very high degree of camp movement (Binford, 1980).

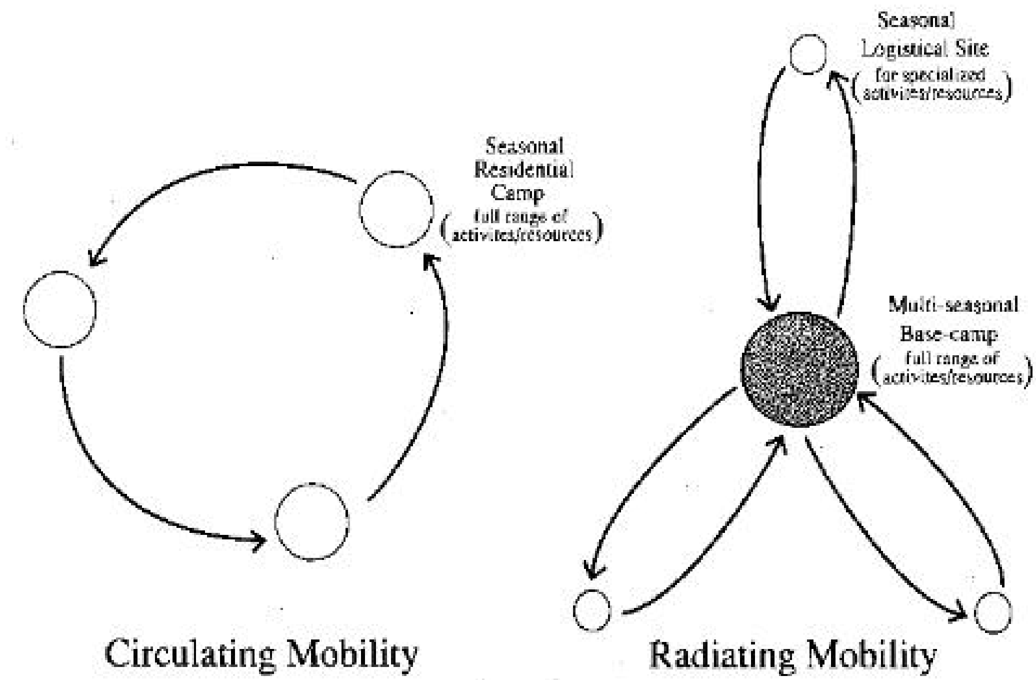


Figure 2.1: Example of Logistical (Radiating) and Residential (Circulating) Mobility Site Patterns from (Lieberman & Shea, 1994)

A related pattern of mobility to residential is *tethered mobility*. Tethered mobility, as defined by Taylor (1964), is a pattern where the movements of hominins are restricted and limited by access to a key resource, most frequently water (Kelly, 2013; Taylor, 1964). In groups that are tethered to a resource, we expect to see a pattern of movement that indicates they radiate from the location where it can be accessed. Their maximum foraging ranges are directly limited and controlled by access to reliable sources of water (Kelly, 2013). In turn, these foragers often have a wider foraging range, (greater than 10 km), than comparable non-tethered foraging groups. As they trade reliable access to water for foraging efficiency in other resources (Kelly, 2013). Sites left by these groups would show excessive exploitation of resources surrounding the tether location but few to no exotic resources as travel and collection beyond the zone of security is not viable.

With all of this in mind another goal of this study will be to attempt to determine the mobility patterns of the hominins of C-Spring. Binford's models have been the most helpful in interpreting my findings. While in the case of C-Spring we only have the stone record of the activities there, my findings help us to place the hominins there somewhere on the spectrum between these two extremes. Additionally, Taylor's '(1964)' model provides, nuance to Binford's structure accounting for patterns that reflects. By analyzing the distance that the C-Spring artifacts are from their original sources I hope to place the hominins there behaviorally near to one of these example groups. This will inform later interpretations of land use and movement throughout the landscape that the C-Spring hominins were using.

2.2 Procurement

Procurement refers to the strategies, travel distances, and decision making that goes into the acquisition of raw materials for lithic tools (Binford, 1979; Blades, 2002; Ekshtain et al., 2013; Gould & Saggers, 1985). Binford (1979) discusses raw material procurement 'embedded' within other behaviors hence the name. Building off of this idea, Blades (2002) suggests 'direct' lithic procurement, with trips dedicated to the acquisition of raw materials. finally, Gould (1978) proposes the *exotic stone hypothesis* which claims that 'indirect' procurement, for 'non local' or 'exotic' raw materials could explain the presence of foreign raw materials where the group in question could not acquire the material themselves and must find another method of acquisition such as long distance exchange (Gould & Saggers, 1985).

Embedded procurement, refers to a method of raw material acquisition where the foragers in question are practicing some other behaviour or activity and acquire the raw material during the process of doing so (Binford, 1978, 1979). Given that lithic sources by their very nature are stationary, it is often the case that mobile hunting or fishing opportunities represent a more pressing issue in hunter-gatherer societies. Due to their sedentary nature the raw material sources can simply be a factored cost in the expedition to the exploitation grounds of other resources (Binford, 1978, 1979). This type of procurement occurs most frequently in regions with limited mobile resources such as food, but abundant sources of raw materials for tools.

Direct procurement is where foragers are traveling to raw material sources for the express purpose of acquiring raw materials (Blades, 2002). These sources are most frequently contained within the larger territory the foragers control or otherwise explore. As these quarrying sites are often far from the main exploitation area, in an attempt to cut down on excess weight tool creation will often be conducted at the quarry site itself. This means that direct procurement behaviors can often be identified by the quarry as a high volume of debitage and other manufacturing implements will be found at the site (Barkai et al., 2006).

The last style of provisioning important to mention for this paper is indirect procurement. Indirect procurement can be summed as the acquisition of raw materials through alternative means beyond traveling to the source location. The most common theory being that some form of long distance exchange is involved (Gould & Saggers, 1985). As such, hominins who practiced indirect procurement can often be identified by the presence of whole tools made of materials from a ‘long’ distance away, although the definition of long remains up to the researcher. It should be noted that material quality does not influence this interpretation as both low and high quality raw materials have been identified as objects of long distance exchange (Gould & Saggers, 1985).

Each of these suggested methods of lithic procurement carry with them several district traits and implied aspects about the people and land utilization of the groups associated with them. As Kandel et al., (2016) demonstrates, each of the three types of procurement have associated average distance from source to site. In this paper the authors find that local procurement occurs between a distance of (0-5km), regional exploitation occurs from (6-20km), Supra-regional exploitation stretches from (21-100km), and extreme distance are anything beyond that (100+km) (Kandel et al., 2016). As previously mentioned, embedded procurement will most frequently occur associated with shorter procurement distances as foragers are unlikely to choose to exploit further sources (Binford, 1979, 1980; Kandel et al., 2016). Direct procurement is more likely to be found in association with regional and supra-regional distances as hominins are forced to travel further into the landscape to these scarce and valuable sources of raw material (Blades, 2002; Kandel et al., 2016). Lastly, large supra-regional and extreme distances are indicative of indirect procurement as hominins are forced to find alternative methods to acquire raw materials as travel to the source location becomes infeasible (Gould & Saggers, 1985; Kandel et al., 2016). Kandel et al., (2016) also details an argument that increasing distance between artifact sources and their eventual use sites can serve as an indication of increasing behavior complexity.

Range	Distance
Local	0-5 km
Regional	6-20 km
Supra-regional	21-100 km
Extreme	100+ km

Figure 2.2: Table of Raw Material Source Locations to Site from (Kandel et al., 2016)

2.3 Provisioning

Procurement is largely performed for the purposes of provisioning. Provisioning refers to the strategies surrounding tool creation and the various methods of hominins preparing for tasks. (Kuhn, 1992, 1995, 2004, 2020) outlines three distinct forms of provisioning strategies: individual, place, and activities. Provisioning of the *individual* relates to how foragers will outfit themselves with personal gear, a specific toolkit that can be carried on their person for anticipated tasks (Kuhn, 1992, 1995). Since individuals are mobile, artifact utility and transport cost must be considered heavily with this provisioning strategy. However, due to individuals outfitting themselves with a specific task in mind this tends to lead to far less waste. Sites where individuals are provisioning themselves are likely to have a few indicative tool types associated with them as well as a high amount of debitage as tools are created/resharpend at the site (Kuhn, 1992, 1995, 2020). One also expects to find many exhausted or otherwise destroyed cores at this site as they are discarded on site once they are no longer useful.

Provisioning of *place* pertains to how foragers stockpile raw materials, blanks, cores, or even tools for later reduction and anticipated use. This is often done at strategic points on the landscape or at their camp where the future need for tools necessitates a necessary but not yet known tool kit (Kuhn, 1992, 1995, 2020). This is done in an effort to create more available sources of raw materials within the extent of their territory and decrease the necessity of future mobility (Kuhn, 1995; Potts, 1991). Identification of this type of provisioning is dependent on several factors. The first of which is an extremely high frequency of primary stage reduction lithics, cores and blanks for example, as well as finished tools within the assemblage. This is combined with a relatively low frequency of debitage and short distance the lithics have been moved. It should be noted that a 'high frequency' is never defined by even the most extensive of descriptions (Hovers, 2003; Kuhn, 1995). There is also no minimum number of lithics that need to be recovered before such inferences can be made. In assemblages where we see hominins provisioning places we can assume there is a guaranteed minimum degree of planning as materials are stockpiled and tools are manufactured for future use.

Lastly, provisioning of *activities* involves little or no planning and occurs only when the need or opportunity for resource exploitation is encountered (Kuhn, 2004). This low-cost strategy eliminates the risk of overproduction and is suitable in landscapes with well-known or abundant raw materials sources. This is also a strategy of provisioning we would expect to encounter in regions where foragers do not necessarily require tools to access resources (Kuhn, 2004). This type of provisioning is characterized by many ad hoc or informal tools as manufacture is not structured in any way. This also directly leads to tools of a lower quality or skill in the assemblage. Lastly, applied provisioning strategies may be dependent upon the types of tool intended for manufacture. It may not be directly linked to the quality or availability of raw materials but this does not have to be mutually exclusive. Visits to a source location may lead to the production of a certain tool type and the transportation of cores back to camp. Naturally, these behaviours are all heavily influenced by the nature of the environment these foragers were living in and so in the next chapter I will discuss the context of the site and the region it was discovered in.

3. Context of study

3.1 The Azraq Basin

The modern Kingdom of Jordan is divided into six large physiographic units (Figure 3.1). Among these are the low elevation Dead Sea Rift Valley, and the adjacent Western Highlands which run along the western border of the nation. In the south of the nation, massive, heavily weathered beds of sandstone make up the region aptly named the Sandstone Mountains and Valleys. The northeastern 'pan-handle' is largely divided based on the types of rock that cover the region, most notably the Northern Basalt Plateau (Harrat Ash-Shamm) and the Northeastern Limestone Plateau. Near the center of the Kingdom, the large Central Plateau extends from the western highlands to the eastern border that connects Jordan to Saudi Arabia. This constitutes the largest of the physiographic units in the country. Within the Central Plateau there exists two large topographic basins: the Al-Jafr Basin in the south and the far larger Azraq-Wadi Sirhan Basin to the northeast (Figure 3.1). The latter of which represents a structural depression within the continental Arabian Plate and includes the closely named Azraq Basin. The Azraq Basin is a large (~13,000^{2}km) endorheic depression and in this region there is no water outflow. Instead, many of the streams, (locally known in Arabic as wadi) become concentrated near the center in a large mudflat called Qa' Azraq. During wet periods this region would have expanded into a large lake. However, during dry periods, the lake would evaporate leaving behind an extensive mudflat.

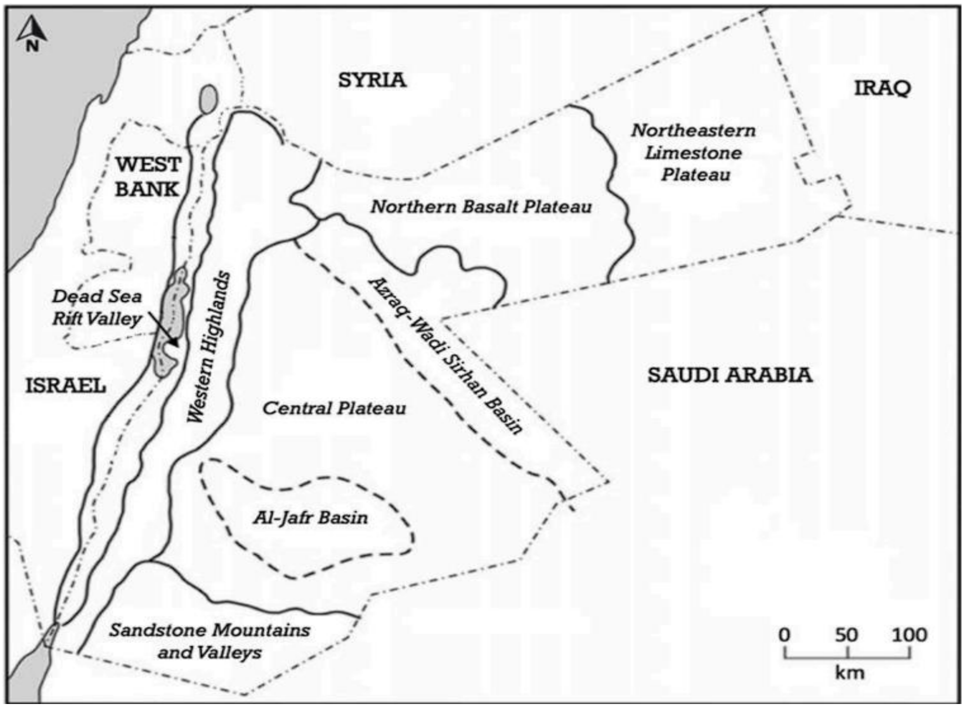


Figure 3.1: Map of Physiographic Units Within Jordan. Figure modified from (Cordova & Ames, 2017, p. 532)

The Azraq Basin, taken as part of the Azraq-Wadi Sirhan basin, is largely within the northern portion of the Central Plateau and it extends into the Northern Basalt Plateau (Harrat Ash-Shaam) (Figure 3.1). Its dominant geology is a mosaic of both igneous and sedimentary rocks which have been covered by layers of alluvium and topsoils (Bender, 1974; Worzyk & Huester, 1987). While there are a number of geological formations in the Azraq Basin, for the purposes of this study I will be focusing on three: The Muwaqqar Chalk-Marl, Umm Rijam Chert-Limestone, and Wadi Shallala Chalk formations (Figures 3.2-3.3). These are the chert bearing formations in the Azraq Basin and as such are the only sources of chert hominins in the region could have been acquiring raw materials from. Their formation was largely influenced by eustatic fluctuations of the Arabian-Nubian shield and the later placement of the Tethys Sea in the north-west during the Upper-Cretaceous-Eocene epoch (Moumani, 2005; Sonnefeld, 1978).

The Wadi Shallala Chalk Formation (WSC) is the youngest of the three chert-bearing formations. It dates to the Middle-Late Eocene based on the fossil record that has been recovered from within and it's sequence is largely made from chalk and dolomitic limestone layers (Andrews, 1992; Delage et al., 2019), which has been found to yield chert nodules between approximately 5-15 cm in size (Sánchez de la Torre et al., 2019). The WSC Formation was most likely deposited in a mid-to-outer shelf marine environment (Alsharhan & Nairn, 2003), and today is exposed primarily along the Yarmouk River in the northwest of Jordan with other, sparse exposures within the Azraq Basin, primarily in the south (Sánchez de la Torre et al., 2019).

The Umm Rijam Chert-Limestone Formation (URC) is located in the middle of the WSC and Muwaqqar Chalk-Marl formations where it overlies the latter where the two meet. This formation dates to the Early-Middle Eocene and extends across much of the Central Plateau including the Wadi Sirhan and Azraq basins (Alsharhan & Nairn, 2003). This formation can be incredibly thick, (>100 m), in places and contains a rhythmic sequence of chalk, cherts of various color, and limestone layers (Ibrahim, 1996; Qudaira, 1997, 2000). In this formation there is an overall low chert to limestone ratio (1:10) (Abed et al., 2002; Abed, 1982), this is particularly apparent when compared to other formations in the Levant. An abundance of calcareous nannoplankton and other benthic planktonic fossils suggest that the URC formation was deposited in a deep-water, likely pelagic environment (Alsharhan & Nairn, 2003).

The last of the three formations, the Muwaqqar Chalk-Marl (MCM) Formation, is the oldest, dating back to the Upper-Cretaceous. Due to the extremely limited number of exposures it is the most poorly understood of the three. This formation is informally divided into two distinct but related units, (upper and lower). The upper unit is subdivided into 66 repeated sequences of partly fossiliferous and chalky limestone (Al-Hunjul, 2001; Ibrahim, 1996). The depositional environment of this until having been interpreted as a deep-water, outer shelf marine environment (Andrews, 1992). The lower bed largely consists of argillaceous and fossiliferous limestone deposits (Andrews, 1992), in contrast to the upper unit, these beds were believed to have been slowly deposited in a low energy, broad shelf environment (Alsharhan & Nairn, 2003). It should be noted that Sánchez de la Torre et al. (2019) reported finding more chert nodules than beds as well as a gradual decrease in silifications as outcrops as one heads from south to north.

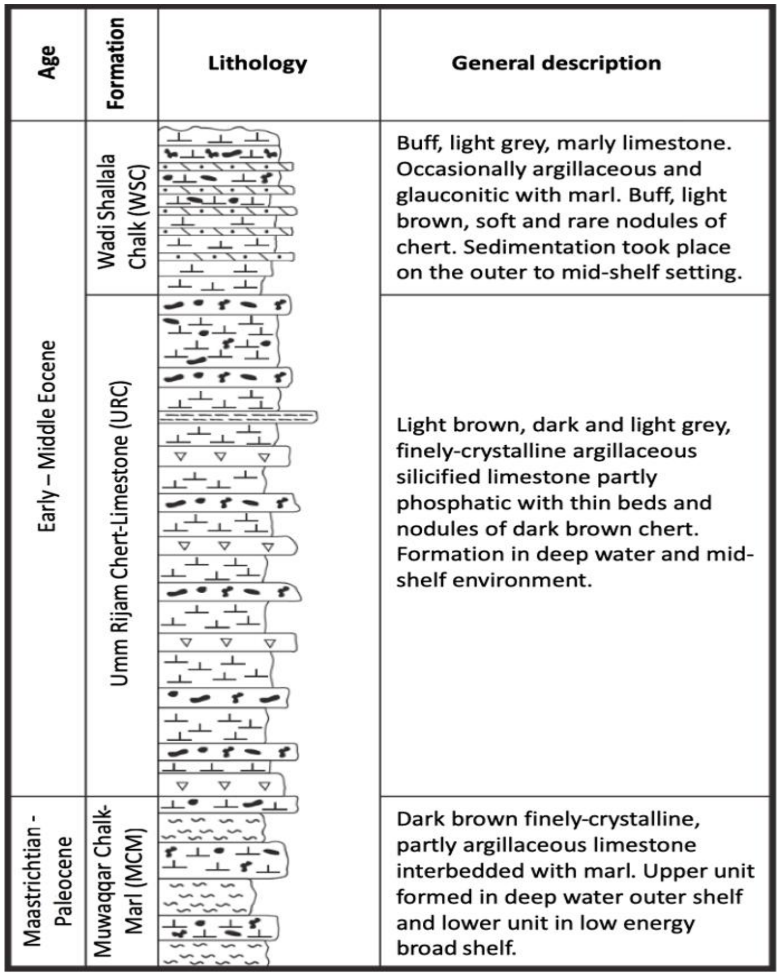


Figure 3.2: Striplog of Sedimentary Rocks Within the Azraq Basin. Figure Modified from Sánchez de la Torre et al. (2019) with Descriptions from Alsharhan & Nairn (2003: 432).

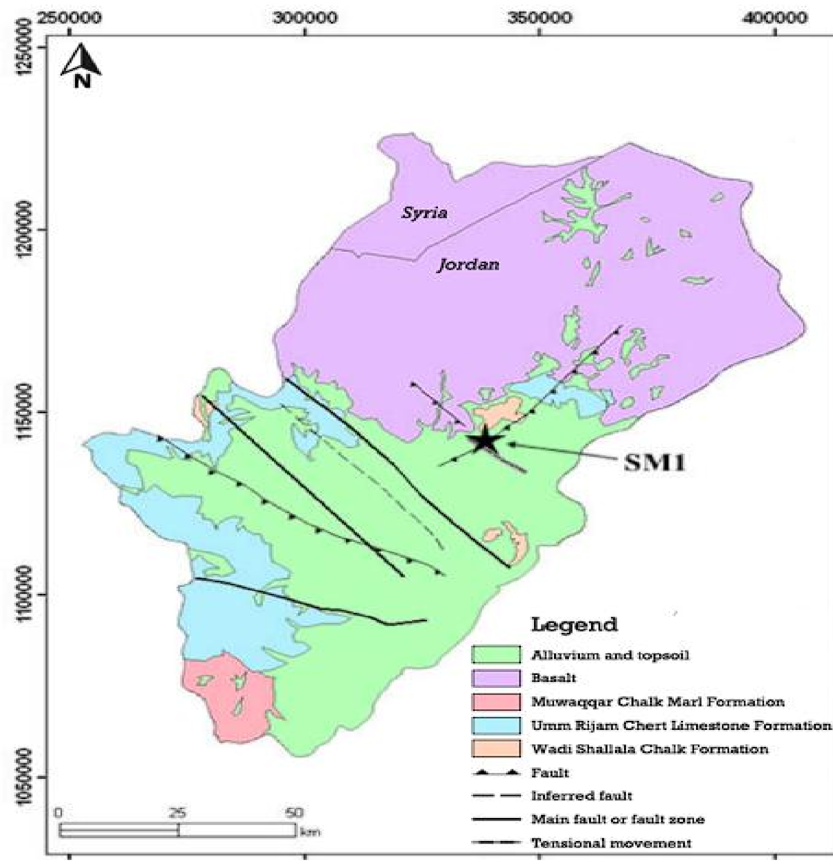


Figure 3.3: The Geology of the Azraq Basin Modified from (Ta'any, 2013, p. 198).

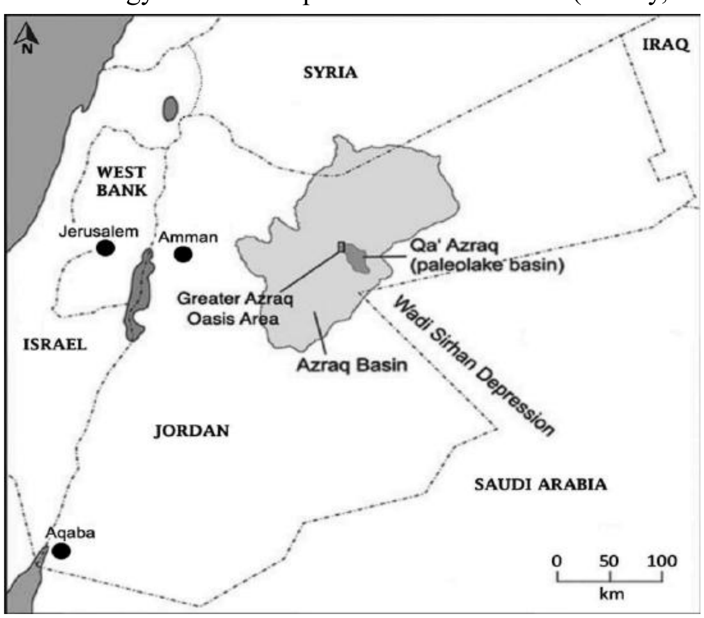


Figure 3.4: Map of Azraq Basin and Greater Azraq Oasis Area from (Ames et al., 2014)

3.2 Greater Azraq Oasis Area

Within the Azraq Basin lies the Greater Azraq Oasis Area (GAOA). Located in the northwestern portion of the Qa' Azraq mudflat, this encompasses the area around the historical Druze Marsh and the recently rehabilitated Shishan Marsh (Cordova et al., 2013). These marshes are fed by springs created by the local aquifer that maintained their presence as a source of fresh water during arid environmental periods. However, in the wet season, overflow from Qa' Azraq can spill into the GAOA which can have an effect on the salinity of the water in the marshes (Cordova et al., 2013). However, this is only temporary as the evaporation of the qa' causes the waters to recede and the marshes become more fresh without the salinated inflow. While temporally limited, this has important implications for the GAOA as this means that not only is the area affected by long-term regional climate changes but also by smaller term changes caused by the seasons. The aquifer system of the Azraq Basin is one of the most important for modern populations in Jordan, however, this has had unfortunate consequences as in the 1980's excessive over exploitation of the aquifer led to both marshes rapidly drying until both were completely gone by the 1990's (Cordova et al., 2013). Unfortunately, the Druze marsh has not been restored. The Shishan Marsh, however, has a slightly better outlook as restoration efforts by the Royal Society for the Conservation of Nature have been successful in restoring a small portion (<10%) of the marsh (France, 2010) and native wildlife is once again beginning to return to the location. These marsh complexes have been consistent for the last several hundred thousands of years and allowed the GAOA to be a source of freshwater in the past, much as it is now.

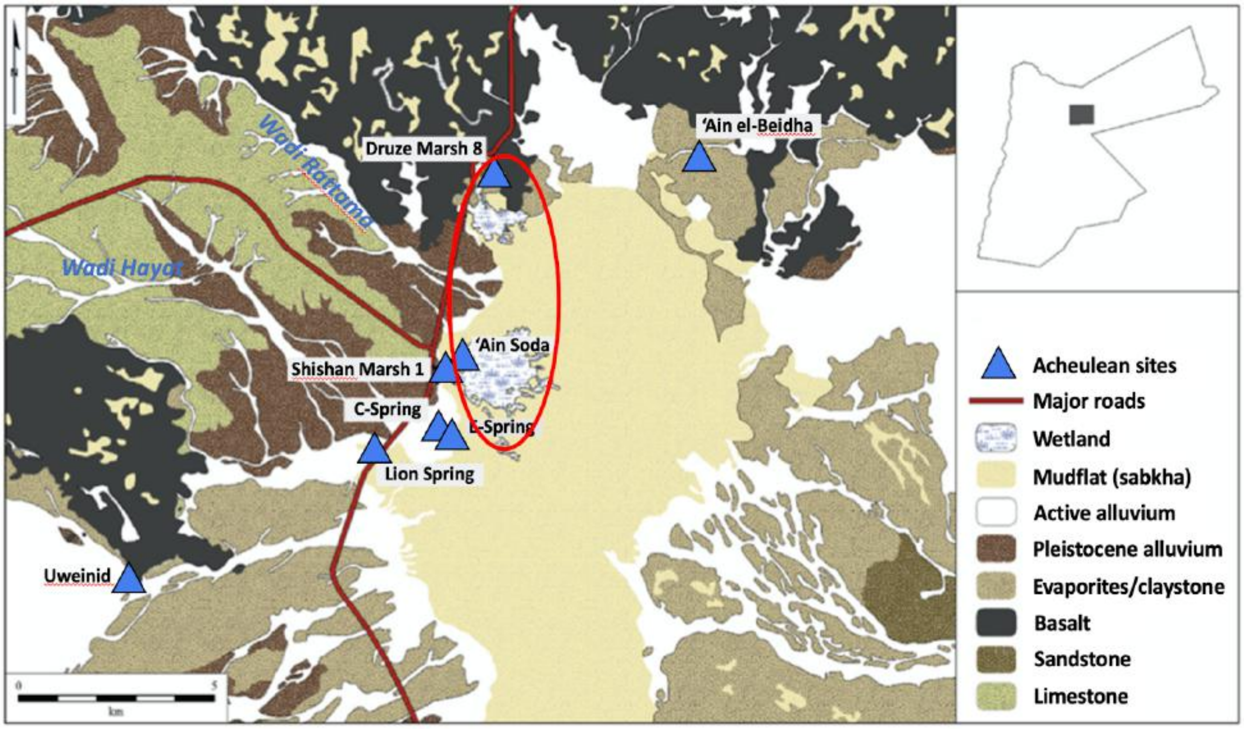


Figure 3.5: Map of the GAOA and Archaeological Sites Modified from (Nowell et al., 2016)

3.3 Acheulean of the Azraq Basin

The chaos and destruction from WWII caused much of the archaeological potential in Jordan and the Azraq Basin to be temporarily obscured. This changed in 1956 when a chance discovery occurred during the construction of a large irrigation system by the U.S. Aid Point IV Princess Alia Project conducted by Baker & Harza Engineering Company (1958). Then foreman R. Pannell noticed the regular occurrence of lithic artifacts in many of the dredging buckets in the excavations from Ain-el-Assad, which is more commonly known by its English name of 'Lion Spring'. Pannell informed G. Harding, the director of the Department of Antiquities of Jordan at the time of his discovery. After traveling to the site, Harding was stunned by the sheer volume of bifaces, describing seeing "six or seven hundred axes" and "several hundred" other lithic artifacts (Harding, 1958). Shortly after this visit, D. Kirkbride also examined the irrigation project to collect more of the exhumed materials and record the geomorphic contexts (Copeland

& Hours, 1989e; Kirkbride, 1989). During this investigation, clusters of lithic and faunal remains were discovered approximately 240-180 cm below the surface (Kirkbride, 1989).

Additional trenches contributed to a large canal system, most namely at C-Spring, D-Spring, and E-Spring. From these sites, an additional 160 lithic artifacts were collected from the surface and backdirt piles. These assemblages were later analyzed by L. Copeland (Copeland & Hours, 1989b, 1989c, 1989a), who found they consisted of bifaces, cores, and scrapers, the majority of which were consistent with the Achulean tradition.

In 1979, two more visits were conducted by G. Rollefson (1980). These trips allowed the collection of an additional 538 lithic artifacts, including 62 bifaces, from piles of backfill. Over the next two years, 1980-1981, Rolleffson conducted two formal seasons of excavation at Lion Spring. They were ultimately unsuccessful at relocating the Achulean bearing deposits, but were able to recover additional bifaces and Levallois lithics in reexamined backfill (Rollefson, 1980, 1983).

In the mid-1970's, a team led by A.Garrard undertook what is known as the 'Azraq Project', with the goal of examining the long term nature of environment, settlement, and subsistence during the late Pleistocene and early Holocene (Copeland et al., 1975; Garrard et al., 1994). This project consisted of surveys and probes along several river beds, most notably Jilat, Usaykhim (Aseikhim), and Uweinid (Uwaynid), over four seasons (1975, 1982, 1984, 1985).

The techno-typological consistency of the spring site assemblages led to their categorization as the Late Acheulean of Azraq (LAA) facies. These facies were initially identified in the collective C-Spring assemblage (Copeland, 1991). The assemblages from Lion Spring, D-Spring, and E-Spring contained similar traits but were too small to confidently make any specific claims regarding the sites. To sum, the LAA is defined by many small-medium handaxes, cleavers, Quina scrapers, Levallois-esq flakes, and an almost absence of blades. This toolkit exhibits a progressive trend towards greater use of the Levallois technique. After this, research was completed over-exploitation of the Azraq aquifer during the 1980-1990's led to a large reduction in the local water table, completely drying both the Shishan and Druze marshes. This oversight led to the exposure of previously submerged deposits.

Paleolithic remains were initially discovered in 1996 by a palaeoenvironmental team performing work for the 'Madaba Plains Project'. While extracting sedimentary cores in the 'Ain Soda' (Sawda) section of the Shishan Marsh, the team noticed bifaces on the surface as well as the distinct protrusions of bifaces still in situ which had been exposed from bulldozer activity. The team then contacted Rollefson and a more substantial crew began to systematically recover the artifacts from 'Ain Soda' and the nearby 'Ain Qasiyya. Lower Paleolithic artifacts (n>400) were recovered from 'Ain Soda while only a single biface was discovered at 'Ain Qasiyya (Rollefson et al., 1997). While initial documentation of the stratigraphy was done in 1996, it would not be until 2007 that a more formal study would be performed (Cordova et al., 2009; Rollefson et al., 1997). A formal excavation of 'Ain Soda was led by Rollefson in 1997 but the full results of the excavations have not yet been published. Though preliminary results suggest consistency with the 1996 findings and the other spring sites to the south (Rollefson et al., 1997).

In addition, Rollefson and colleagues surveyed the Shishan Marsh and identified additional sites near ‘Ain Soda. The success of Rollefson’s excavations and surveys highlighted to potential of the (former) marshes to reveal in situ archaeological sites and in 2008-2011, the Druze Marsh Archaeological and Paleoecological Project (DMAPP) led by A. Nowell created several soundings within the northern Druze Marsh. Several of these produced small collections of Lower Paleolithic lithics. Most notably, Achulean handaxes and cleavers which were associated with a transition from deep marsh to dryer conditions (Ames & Cordova, 2015; Cordova et al., 2013). Subsequent excavations from 2013-2015 for the ‘Azraq Marshes Archaeological and Paleoecological Project (AMAPP) also led by Nowell focused on the site of Shishan Marsh 1 (SM1). Altogether, ten sedimentary units were identified with two being found to contain abundant Lower Paleolithic remains approximately a meter below the surface (Boyd et al., 2022; Nowell et al., 2014). Dates obtained using optically stimulated luminescence places the occupation within 266 ± 40ka (layer 8), 125 ± 12 ka (layer 7b), and 119 ± 40 ka (layer 7a) (Boyd et al., 2022; Nowell et al., 2016).

The artifacts recovered from ‘Ain Soda are described as being of the “Late and Final Acheulean” (Rollefson et al., 1997) as is the assemblage from SM1 (Nowell et al., 2016). Interestingly, it was noted that there was a far higher frequency of cleavers (10-15x) at ‘Ain Soda, C-Spring, and Lion Spring than within other sites in the Levant (Gilead, 1973; Rollefson et al., 1997; Rollefson, 1984). These tools contain deliberately dulled lateral edges, a minimum of one tranchet scar across the distal end, and often a bifacial base. These modifications create a dual function tool with the base being used for chopping/hacking and the distal end being used for slicing. These distinct features led to this tradition being termed the "Azraq Achulean cleaver" (Rollefson et al., 1997)

3.4 C-Spring

The first set of "key" readings this project will be drawing from are Copeland (1991), Copeland (1988), and Copeland (1989). I have chosen to group these articles together as they will all fulfill a very similar role providing background information about the site and artifacts. All of these articles will serve to guide my understanding of the site of C-Spring itself and the artifacts found there. These articles will also provide the historical understanding of the site as the first descriptions of C-Spring come from this series of papers. From Copeland (1989) I will be drawing the lithic "series" from her description of the collection. In this reading there are also black and white sketches of all the artifacts from C-Spring which will be helpful when I am creating my own IAA table. From Copeland (1991) and (1989), I will draw information on the stratigraphy of C-Spring and the particulars of the artifact culture found within them. These papers also contain some information about the likely paleoenvironment found there which I may use later in the study to help inform my interpretation of the results of my study.

As previously noted, C-Spring was first discovered in 1956 during the construction of an irrigation system by the U.S Aid Point IV Princess Alia Project in the 1950s. After this initial discovery, additional trenches were put in at C-Spring, D-Spring, and E-spring, where more lithic caches were identified. The materials were later analyzed by Copeland (1989, 1991), and includes bifaces, cores, and scrapers, which are consistent with the Late Acheulean. A later team led by A. Garrard returned to the site in the mid-1970's as a piece of what was termed the 'Azraq Project' with the goal of discovering the long term nature of environment, settlement, and subsistence during the Late Pleistocene and Holocene (Copeland et al., 1975). This included a small-scale excavation of C-Spring in 1985 where further evidence of Lower Paleolithic occupation was found. A 3 x 1.5 m sounding was opened that was separated from the original C-Spring trenches by a distance of 30 m. (Copeland & Hours, 1989c; Garrard et al., 1994; Garrard & Hunt, 1989). At an approximate depth of 3 m, layers of blue-grey silt (Levels Q and P), contained sparse Middle Paleolithic and Lower Paleolithic artifacts. Below, further layers of silt (levels S and R) contained a large trove of artifacts, (n>4000), (Copeland & Hours, 1989c; Garrard & Hunt, 1989) the density and amount leading to the site being described as a “river of flint” (Copeland, 1991).

The initial discovery pit was named C-Spring-BH after the Baker and Harza engineering firm responsible for its discovery. Due to the haphazard nature of this site's discovery and initial recording, it is far less understood than C-Spring-AG. Here, a total of 115 individual artifacts were found. 17 of these were bifaces, cleaver and handaxes, that clearly represented a Lower Paleolithic tradition (Copeland & Hours, 1989b). The vast majority of these artifacts however, are unretouched flakes/debitage (n=72), in addition several discarded cores (n=7) were recovered. These artifacts were reported as being analogous to the style found at the other site (Copeland, 1991). There were also several fragments of bone recovered, many from megafauna species that are now extinct in the region such as rhinoceros and various species of wild cattle (Clutton-Brock, 1970, 1989). While interesting, these finds were not substantial enough in quantity or consistency to represent a serious faunal assemblage at this site. Copeland (1991) suggests these bones may have been the remains of meals as most are from young animals but importantly, there is no evidence of any large scale butchery at this site.

The second investigative pit at C-Spring was dug by a team led by Andrew Garrard in 1985 30m south of the original find. This pit was dubbed C-Spring-AG after the head researcher responsible for the project. These lithics were then analyzed by Copeland & Hours, (1989a), she found the assemblage consisted of handaxes, unutilized flakes, cores, and debitage. The style of which was consistent with the Acheulean. Many of these artifacts were described as “mint-fresh” or “razor sharp” (Copeland, 1991). She also noted that many of the cores from the site had been aborted and thrown away or worked down into a disc, possibly for the creation of bifaces. These observations, when taken in consideration with the large number of preparation and finishing debitage, led to her interpreting the site as a knapping floor (Copeland, 1991). Later, a travertine layer above the Achulean-bearing sediments at C-Spring was thought to be consistent with a similar layer found in the Shishan Marsh. The latter was found to have a minimum age of 220 ± 30 ka produced through uranium-series dating (Macumber, 2008). It should be noted that at this site bifacial cleavers represent 25% of the total retouched ‘tool’ assemblage. This is quite a significant difference when compared with other Levantine sites such as Tabun F where they make up 5%, Qatafa with 12%, and Ma^{c}ayan Barukh where only 2-3% of the artifacts are bifacial cleavers (Copeland, 1991). In her initial assessment of the site, Copeland described the artifacts as falling into one of four lithic series (Copeland & Hours, 1989d). These artifacts are described as being either; Brown, Olive, Light Grey, or Dark Grey (ex. Figure 3.6). While Copeland did define the lithic series and the number of artifacts contained within each group. She has never published an assessment of the collection with the artifacts by label. Therefore it is not known which artifacts she sorted into each of the groups

Figure 3.6: Examples of Copeland's Lithic Series: Dark Grey (top left), Brown (top right), Pale Grey (bottom left), and Olive (bottom right). Photographed by Jeremy Beller and courtesy of Andrew Garrard. Used with permission.

The C-Spring collection in total consists of an assemblage of more than 4000 total lithic artifacts (Copeland & Hours, 1989c). While the entire collection has not been presented in a quantified table Copeland (1991 p. 4) reports “2000 unretouched flakes, 101 cores, 62 bifaces, 100 other retouched tools on flakes or nodules and 700 chips, chunks and debris” from the ‘R’ level alone. Of these retouched tools over 40% are handaxes (Copeland, 1991). This is a remarkably dense concentration of lithic artifacts which instantly elevates C-Spring into being one of the most interesting sites in the region.

4. Methods and Materials

4.1 Provenance Analysis

Provenance investigations seek to determine the raw material source locations of lithic artifacts. There are two primary methods used in analysis of chert to do this: Geochemical analysis and Petrographic analysis. The geochemical approach works by comparing element concentrations, element ratios, and comparative trends in artifacts and known sources (Malyk-Selivanova et al., 1998). By building off the proven assumption that intra-source variation is likely to be smaller than inter-source variation, finding the source the artifact most closely resembles makes a strong argument that this source is likely to have been where the raw materials were acquired from. Petrographic analysis follows the same logical steps of intra vs inter source variation, but instead of examining geochemical traits this method examines physical characteristics. These are most commonly fossils, minerals, and detrital inclusions as in some regions, different depositional environments during the formation of the chert bearing beds will have left noticeable differences (Malyk-Selivanova et al., 1998). For this study, the main readings I will be drawing from for my own analysis are (Malyk-Selivanova et al. 1998) and to a lesser extent (Milne et al. 2009; Shackley 2008). These three articles detail the trace elements that are most likely to occur in detectable and distinguishable amounts within chert formations. In addition, (Malyk-Selivanova et al. 1998) contains a flowchart detailing the process of geological-geochemical sourcing which will be heavily influencing my own approach. This paper also contains a series of graphs and tables which detail some of the variability within and between chert sources which will be useful when I am trying to interpret the geochemical data of C-Spring and surrounding source locations. By utilizing the information and methodologies found within these three papers I should be able to build a strong argument for my findings. As the C-Spring collection and surrounding sources have not yet been analyzed using Petrographic methods this study will be using geochemical sourcing exclusively.

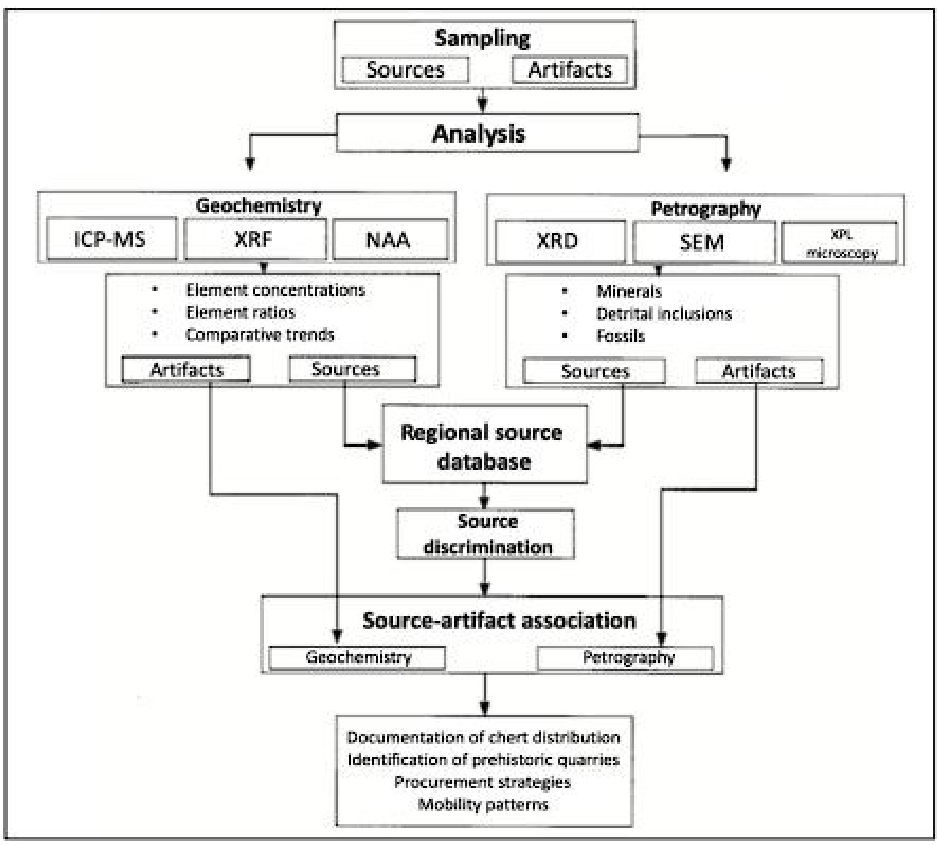


Figure 4.1: Sample Provenance Procedure from (Malyk-Selivanova et al., 1998 p. 678)

4.2 The C-Spring Collection

While this study was not able to observe all of the C-Spring collection, a sample of 32 flake and tool artifacts were made available for this project. As previously mentioned, while Copeland did define the lithic series, an assessment of the collection with the labeled artifacts sorted into this series has never been published. However, several bags containing reference debitage were also provided with the collection. The description of each artifact and the context they were found in can be seen in Figure 4.3.

Figure 4.2: Example Bifacial Cleaver from the C-Spring Collection, Photographed by Jeremy Beller and Courtesy of Andrew Garrard. Used with permission.

New ID	Level	Context	Content	Type	Color Series
38	19	Late Acheulean Floor	Lithic	Biface	Dark grey
40	19	Late Acheulean Floor	Lithic	Biface	Brown
66	19	Late Acheulean Floor	Lithic	Biface	Brown
31	19	Late Acheulean Floor	Lithic	Biface	Olive
C101	16	Late LP - Early MP	Lithic	Biface	Dark grey
C102	16	Late LP - Early MP	Lithic	Biface	Brown
25	19	Late Acheulean Floor	Lithic	Core	Pale grey
55	19	Late Acheulean Floor	Lithic	Core	Brown
61	19	Late Acheulean Floor	Lithic	Core	Olive
60	19	Late Acheulean Floor	Lithic	Biface	Brown
C103	19	Late Acheulean Floor	Lithic	Cleaver?	Olive
C104	19	Late Acheulean Floor	Lithic	Cleaver?	Brown
BSK	16	Late LP - Early MP	Lithic	Blade	Brown
BSF-1	16	Late LP - Early MP	Lithic	Flake	Brown
OS1	16	Late LP - Early MP	Lithic	Debitage	Olive
OS2	16	Late LP - Early MP	Lithic	Debitage	Olive
DGS-1	16	Late LP - Early MP	Lithic	Debitage	Dark Grey
DGS-2	16	Late LP - Early MP	Lithic	Debitage	Dark grey
C105	16	Late LP - Early MP	Lithic	Scraper?	Pale grey
65	19	Late Acheulean Floor	Lithic	Biface	Brown
57	19	Late Acheulean Floor	Lithic	Core	Dark grey
62	19	Late Acheulean Floor	Lithic	Core	Dark grey
26	19	Late Acheulean Floor	Lithic	Core	Pale grey
C106	16	Late LP - Early MP	Lithic	Biface	Olive
C107	16	Late LP - Early MP	Lithic	Biface	Brown
C108	16	Late LP - Early MP	Lithic	Biface	Brown

59	19	Late Acheulean Floor	Lithic	Core	Brown
56	19	Late Acheulean Floor	Lithic	Core	Pale grey
34	19	Late Acheulean Floor	Lithic	Cleaver	Dark grey
36	19	Late Acheulean Floor	Lithic	Cleaver	Brown
C109	19	Late Acheulean Floor	Lithic	Cleaver	Olive
C110	19	Late Acheulean Floor	Lithic	Cleaver	Olive
C111	19	Late Acheulean Floor	Lithic	Cleaver	Brown
'Heavy duty' tool	19	Late Acheulean Floor	Lithic	Chopper	
C112	19	Late Acheulean Floor	Lithic	Chopper	Olive

Figure 4.3: Descriptive Table of The C-Spring Collection

4.3 Individual Attribute Analysis (IAA)

The key reading for my understanding of chert is Luedtke (1992). In this paper the author gives an extremely useful overview of chert as a material including particulars around its formation process and common trace elements that can be found within. She also describes a list of physical characteristics that can be used to analyze chert macroscopically, it is upon these traits that I will base my IAA. This paper will also serve to inform my later interpretations of the quality of the chert for tool making later in the project.

Individual Attribute Analysis (IAA) was performed on 32 lithic artifacts from the C-Spring collection. This analysis examined the color, texture, and macroscopic inclusions following the guidelines of Luedtke (1992) and Milne et al., (2009). This was done through observation with the naked eye and touch, as well as a handheld lens capable of 25x magnification. The colors were recorded using the lithic series established by Copeland & Hours (1989) instead of the standard Munsell Color chart to ensure that an assessment of the geochemical validity of Copeland's lithic series would be possible for the purposes of determining artifact provenance. This assessment was guided by comparing individual artifacts to reference samples for each of the four color descriptions that were included in the sample of the assemblage.

4.4 Laser Ablation Inductively Coupled Plasma Mass Spectrometry (LA-ICP-MS)

The basis for the inductively coupled plasma-mass spectrometry comes from studies such as Brandl (2016) and Neff (2012). These have shown this method of mass spectrometry to be highly reliable and effective at determining trace elements within chert. While I will not be directly performing any mass spectrometry analysis on the artifacts, as this information has already been collected by Dr. Beller using the aforementioned method, it is important to include proofs as the geochemical research performed for this study will be utilizing data generated by this instrument. These two papers along with Luedtke (1992) will form the core of the proofs for my research. By utilizing them I hope to form a strong base for the data I will present in my own work.

The geochemical profiles of 3 geological sources, and the 15 artifacts were produced through laser ablation-inductively coupled plasma-mass spectrometry (LA-ICP-MS). Ablating the sample with a laser has provided a viable alternative to other sample digestion methods that involve time-consuming combinations of strong acids and/or heat (Speakman and Neff 2005). It offers rapid analytical time, high sample throughput, minimal damage to the sample, and low detection limits (Neff 2012; Speakman and Neff 2005). It is sensitive to a wide range of elements (^{6}Li-^{238}U) and provides processing on all elements simultaneously, with multi-element detection limits below parts per million (ppm, 10^{-6}) (Pollard et al. 2007). LA-ICP-MS analysis was conducted at the ICP-MS and Laser Ablation Facility in the School of Earth and Ocean Sciences at the University of Victoria, Canada, by Dr. Beller and Dr. Jody Spence. Each sample was struck to produce a small flake (or (Luedtke, 1992) subsample), <1 cm^2 in surface area, from the most homogenous (or purest) portion. This permitted access to the interior and avoided ablating the dust covered, weathered, and occasionally patinated or glazed exterior surface (Brandl 2016). Samples were ablated 6-8 times. For both sources and artifacts, each ablation occurred in a different spot and inclusions were avoided.

The elements were measured in a quadrupole Thermo X-series 2 ICP mass spectrometer. An internal standard-independent calibration strategy was applied which mirrored Chen et al. (2011). The samples were ablated by a New Wave UP-213 Laser Ablation System with a laser beam diameter of 100 µm and a pulse frequency of 10 Hz. The energy density of ablation was 10 J/cm^2. NIST Glass 611, 613, and 615 (all SRM) were utilized for external calibration and precision was ensured by the repeated analysis of NIST Glass 611 and periodic analysis of NIST Glass 613 and 615. Argon operated as the carrier gas. The raw data were collected using Thermo Plasmalab v. 2.6.1 software and data reduction was performed offline with Microsoft Excel.

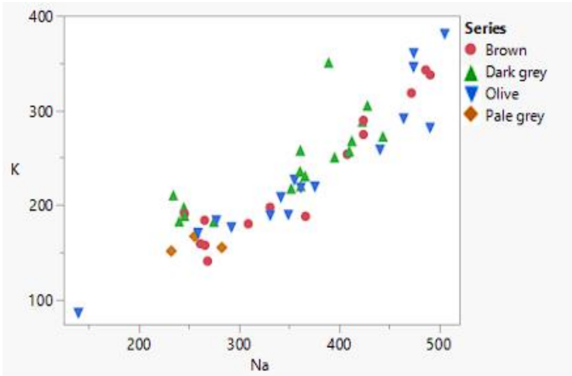
In addition, geochemical data on 11 previously published geological sources from (Beller, 2020, 2023) and Beller et al. (2020). These had been run at the same facility and by the same instrument as those above.

5. Results

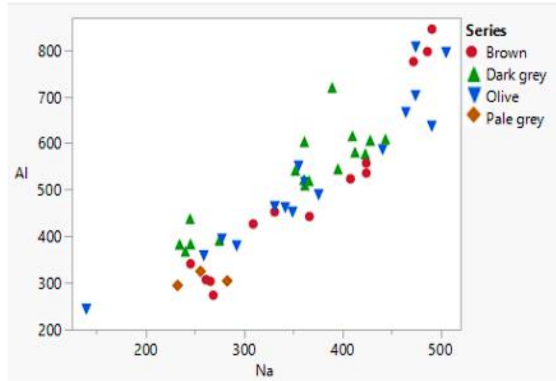
5.1 Copeland's Series Assessment

Initial assessment of Copeland's lithic series appeared promising. The artifacts were easy to sort using IAA and appeared to be fairly distinct. However, once this data was combined with the geochemical suite of the artifacts a different story was revealed. In this assessment, bivariate plots were used to search for possible relationships and chemical composition. This was to no avail, even examining the four most commonly used elements for chert analysis (Al, K, Mg, Na), (Gurova et al., 2014) no such relationships appeared. As the bivariate plots show (Figure 5.1), there appears to be no correlation between lithic series assignment and geochemical composition. These plots only represent a small sample of the total number of relationships analyzed. All available elements were checked in this manner but none produced a relationship. This lack of geochemical backing for Copeland's lithic series indicates that for the purposes of determining artifact provenance, there is no link between lithic series and artifact source and therefore lithic series designation cannot provide insight into raw material origin.

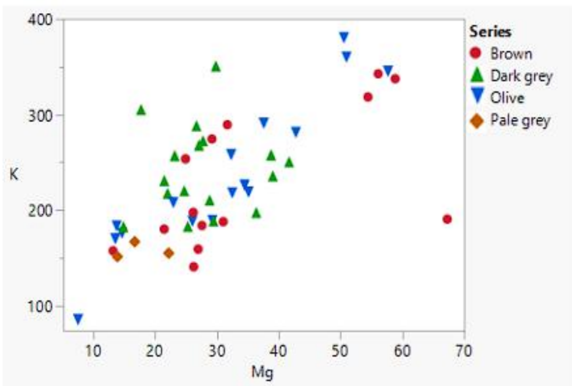
During the assessment of these artifacts it was noted that the texture and grain structure of these artifacts remained largely consistent and were characterized by a glossy feel. Large calcite inclusions were found in several of the artifacts but no additional patterns in the calcite distribution between lithic series were observed. This suggests that in this assemblage, other petrographic methods may not be useful for determining artifact provenance either.



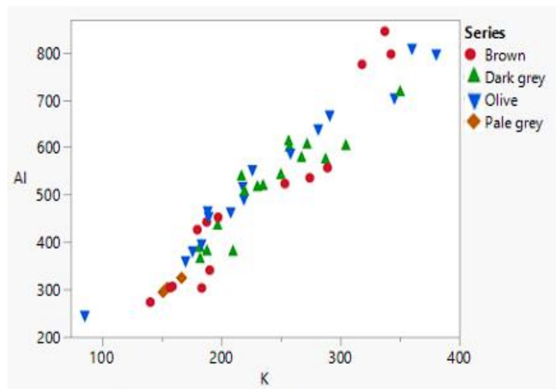
Bivariate plot of Potassium by Sodium



Bivariate plot of Aluminium by Sodium



Bivariate plot of Potassium by Magnesium



Bivariate plot of Aluminium by Potassium

Figure 5.1: Bivariate Plots of Copeland's Lithic Series

5.2 Artifact Provenance

Following the previous established patterns of geochemically distinct catchment areas from Beller (2023) I also decided to examine the catchment areas. Initial investigation using bivariate plots revealed that two source areas could be distinguished geochemically (Figure 5.2): the western and north-eastern. There appears to be some overlap in the middle but there are clearly geochemical differences between these two catchment areas as I expected to find based on previous investigations in the area (Beller, 2023). This was reinforced by examining bivariate plots where we see the western catchment area and the majority of the artifacts clustering on the lower left of the graphs. This indicated that there is enough of a difference for us to proceed with the investigation.

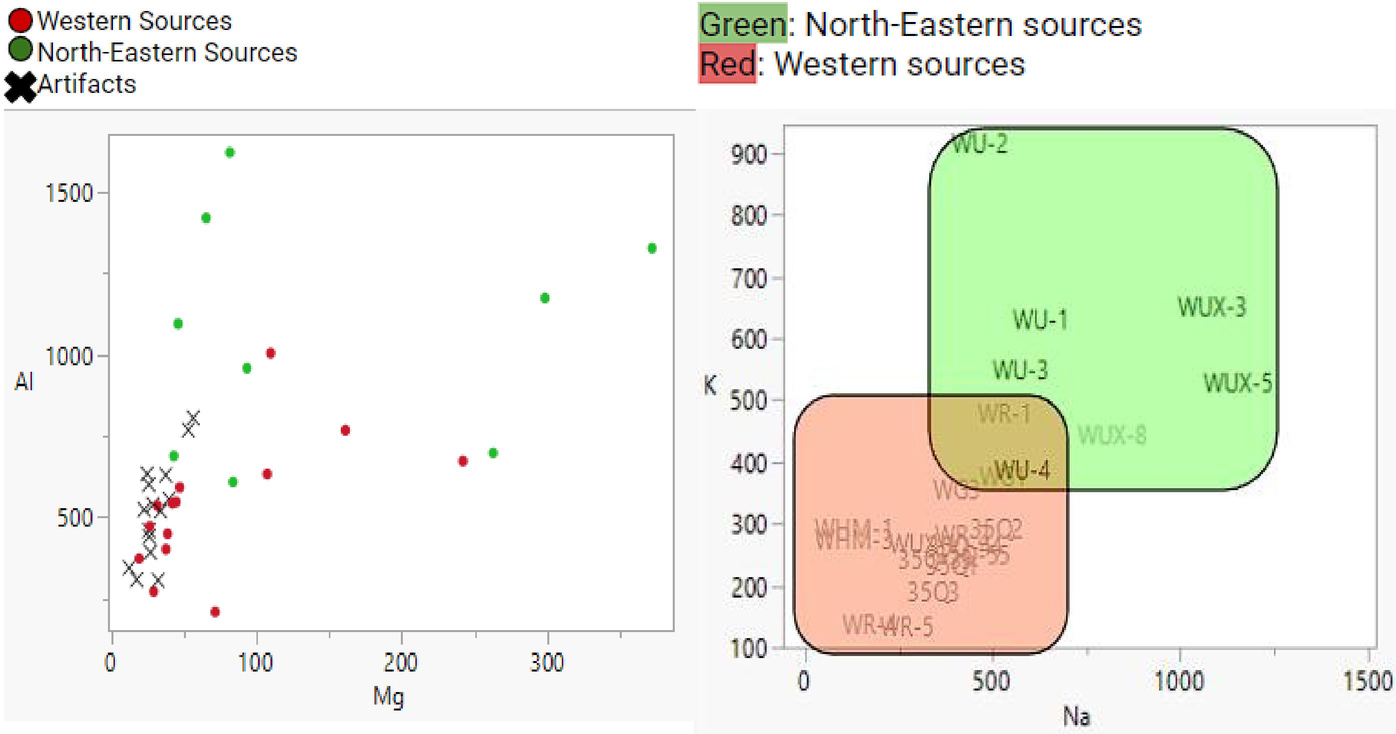


Figure 5.3: Bivariate plots of North-Eastern vs Western Catchment Areas. Shaded Areas Represent Different Catchment Areas

Due to the bivarite plots showing strong evidence of geochemical differences between source locations, I proceeded with a hierarchical analysis of all of the artifacts and sources (Figure 5.3). Hierarchical clustering is done by taking a suite of traits, in this case the quantity of Aluminium, Potassium, Sodium, and Magnesium, in all of the objects and grouping them based on similarity. These four elements were selected by drawing from the previous works of Beller (2023), and Andreeva et al. (2014), as well as my own assessment of all the available elements in the samples. It should be noted that the Rare Earth Elements were under the limit of detection in these samples and therefore could not be used.

I chose to use Ward's method as it produces minimum variance between joined clusters which should provide the most accurate results. This reinforced the geochemical separation of the Western and North-Eastern sources as we can see based on the large degree of separation. It should be noted that in these graphs (Figure 5.3) the highlighted yellow objects represent individual artifacts while the rest are potential source locations. This was done individually for each of the artifacts; these graphs are just samples.

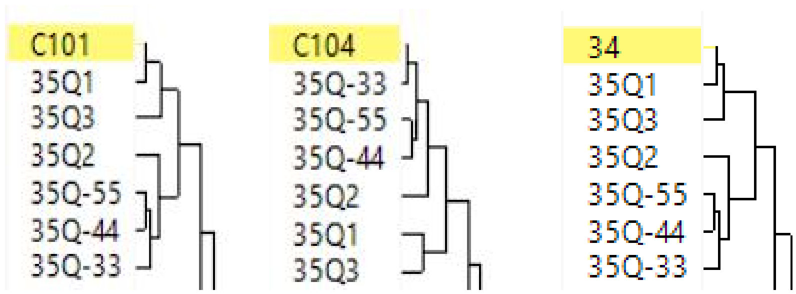
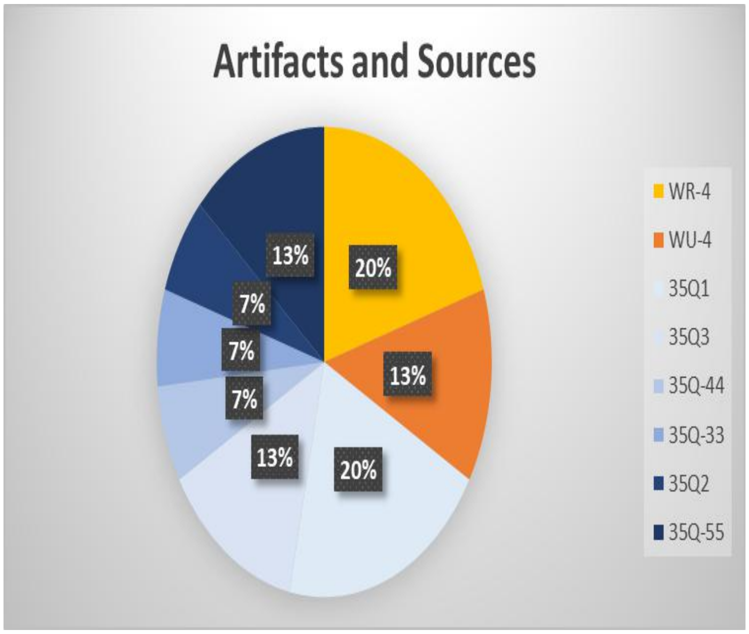


Figure 5.4: Examples of Hierarchical Dendrograms results

After the most likely source for each artifact was found, I discovered that over 80% of the artifacts studied were from the western catchment area (Figure 5.4). This follows logically as it is roughly half the distance to C-Spring as the north-eastern one. Interestingly, there were no artifacts from the identified sources outside of these two areas which indicates that the C-Spring hominins may have been acquiring their raw material nearly exclusively from these two areas. While the first results graph shows an extreme variable distribution; all of the 35Q sources which are shown in blue to white are acquired from the same area. They represent different layers of stratigraphy but in anthropogenic terms are effectively from the same source as they can be traced to within 50m of each other and for my purposes this was more than sufficient for gleaning insights into provisioning and mobility patterns.



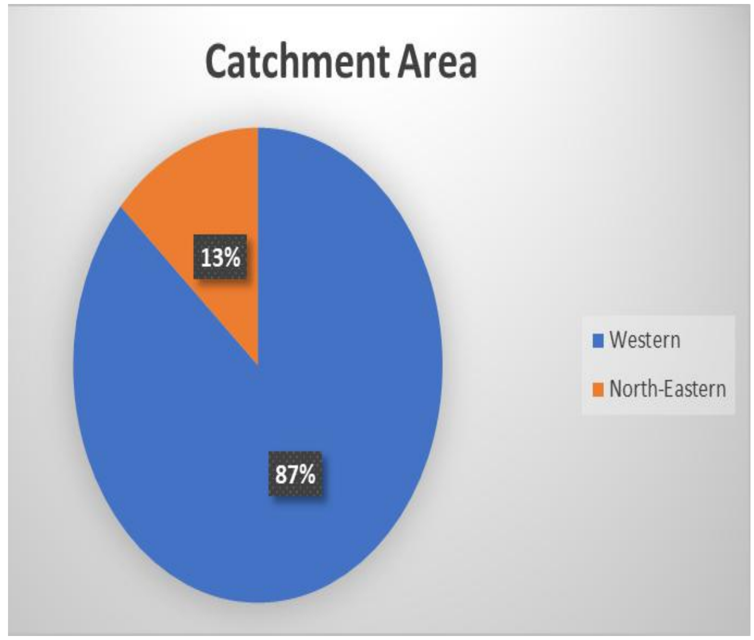


Figure 5.5: Pie Charts Detailing Raw Material Source (left) and Catchment Area (right) of C-Spring Artifacts

6. Discussion

6.1 Procurement

At C-Spring the vast majority of artifacts appear to be coming from the western catchment area. This indicates that the hominins were moving up to 7.8 km from the catchment areas to C-Spring (Figure 6.1). Following the guidelines of Kandel et al., (2016) this indicates that these hominins were acquiring the majority of their artifacts from nearby regional sources (5-20km). However, a small portion of the artifacts were also found to be consistent with sources 18.7 km away from C-Spring which falls on the higher end of Kandel's regional source spectrum. This indicates that these hominins remained decently mobile throughout their landscape. Traveling out into the areas surrounding the marshes in the search for lithic material sources and other resources. However, the lack of any artifacts from supra-regional distances

(21-100km) (Kandel et al., 2016) indicates these hominins were not likely to be traveling far beyond the GAOA, remaining within a day's travel to C-Spring when acquiring raw materials for lithic tools. It is important to note that as C-Spring does not represent a 'home' site, we can only indicate unidirectional movement. We know the hominins were traveling these distances from the catchment areas to C-Spring but we do not know where the groups were originating from or where they were going after leaving the marsh.

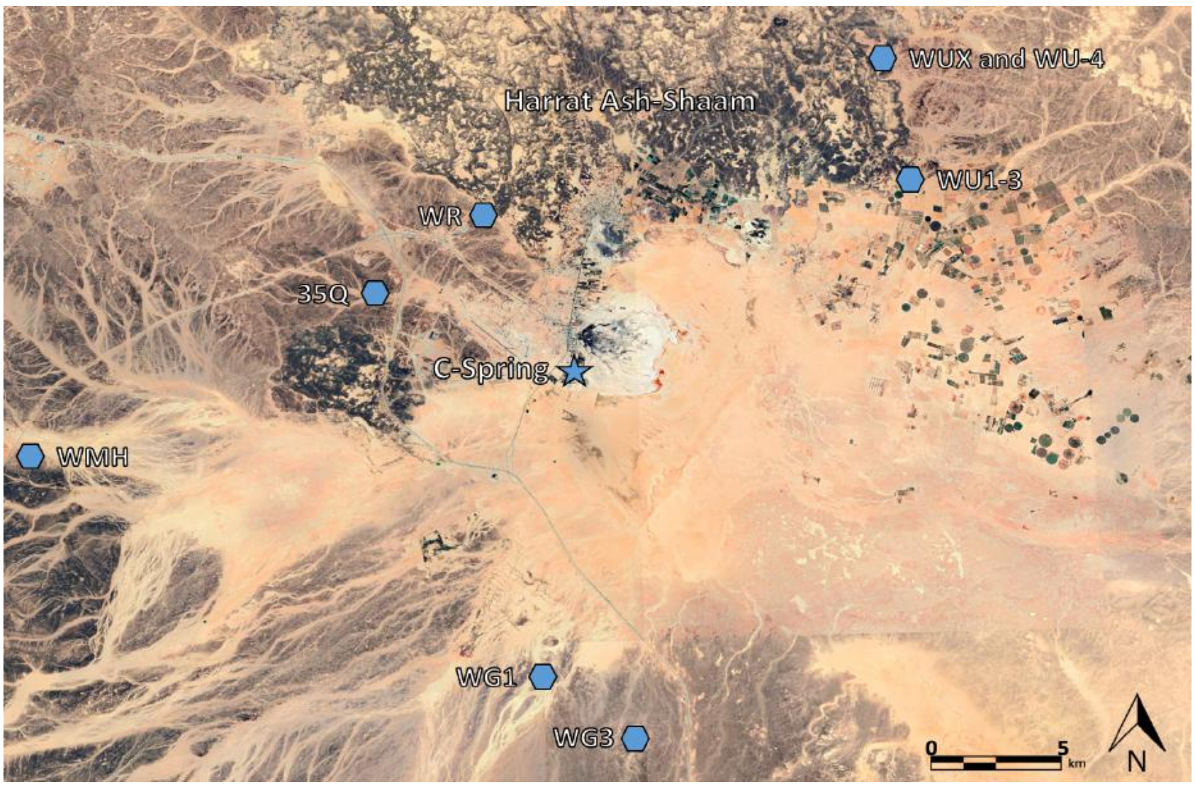


Figure 6.1: Map of C-Spring and Surrounding Raw Material Source Locations

6.2 Provisioning

At C-Spring, what we see is indicative of Provisioning of Individuals. As Khun (1992, 1995, 2020) demonstrates, sites where hominins are actively looking to outfit themselves have several defining features, the first of which is an abundance of debitage in the archaeological assemblage. Due to hominins transferring raw materials to the site in question and creating the tools there with the intention of immediate use, one of the major components should be waste material from tool creation. This is what we see at C-Spring, with the R-level collection containing 2963 individual lithic artifacts and roughly 90% of this total assemblage ,(2000 unretouched flakes, 700 chunks, scraps, or other waste) (Copeland, 1991), being classified as debitage or unutilized flakes. Another defining feature is a large quantity of failed or otherwise exhausted cores. Again, the C-Spring assemblage matches this assumption as over 60 discarded cores were recorded (Copeland, 1991).

This suggests that the hominins in the region were using C-Spring as a staging ground. They were traveling from these catchment areas further out in the landscape, to C-Spring with raw materials, before settling down. They would then create the tools they would need for their anticipated tasks, as indicated by the assemblage, this was most commonly some form of handaxe or cleaver as they represent more than 40% of the total number of retouched 'tools' found at C-Spring (Copeland, 1991). After tool creation, these hominins were most likely traveling into the marshes for high value hunting and water collection opportunities before retreating back into the wider landscape. Importantly, it appears the hominins were not returning to C-Spring for butchery or other tasks as indicated by the almost total lack of faunal remains and relative scarcity of other processing tools. This has led to C-Spring as being interpreted exclusively as a staging ground/knapping locale (Copeland, 1991).

C-Spring is contrasted with and complemented by the nearby site of SM1. Here, the large quantity of finished bifaces and ready to knap cores provides evidence that at this site the hominins were provisioning the location itself (Beller, 2020). The hominins likely used this site as a base for a large variety of interchangeable tasks, such as butchery, plant processing, and tool creation. However, at both C-Spring and SM1 there has been no evidence of residence, (hearths or sleeping locations), discovered leaving the question of where these hominins were living a lingering question.

6.3 Mobility

With the procurement and provisioning strategies of this site being considered it seems that the hominins of C-Spring likely practiced tethered mobility as described in Taylor (1964). What we see at this site is that hominins are traveling to C-Spring from raw material sources under 10km away with the occasional foray from approximately 20 km away. There is no evidence at C-Spring of travel any further than 20km which indicates these hominins were likely tethered to the Shishan and Druze marshes (Kelly, 2013; Taylor, 1964). Their usable territory and foraging directly controlled and constrained by necessitated trips to either of these locations for water. However, this indicates that even during extremely arid environment periods hominins remained mobile throughout their landscape as these trips would take them several hours away from the nearest water source. This total lack of artifacts from supra-regional (21-100km) (Kandel et al., 2016) distances indicates these hominins may have been confined to the landscape around the GAOA. The hominins were unable to reliably travel outside of this small pocket of the Azraq Basin as water sources were either non-existant or too unreliable to allow for these larger journeys. It is in this way that we see the GAOA act as a place of refugium (Cordova et al., 2013). By concentrating extremely valuable resources around a small area, in this case the marshes, small pockets of hominins and other animal life were able to subsist in a region that was otherwise unlivable.

7. Conclusion

7.1 Utility of Copeland's Lithic Series for Determining Artifact Provenance

One of the questions this study investigated was whether Copeland's lithic series, essentially an IAA, would be useful for provenance. Through this study I have demonstrated that for the purposes of determining artifact provenance the lithic series established in Copeland & Hours, (1989c) is not useful. This was investigated through bivariate analysis of the entire suite of elements detected using LA-ICP-MS and comparing them to the lithic series designation of the artifacts. Through this I was able to demonstrate that no elements were suitably diagnostic of the particular "colors". Due to the lack of correlation between lithic series and elemental concentration, Copeland's lithic series is not suitable for geochemical determination of provenance.

7.2 Survival Around a Desert Oasis

This research is currently important for a number of reasons. The first of which being the unique circumstance within the Azraq Basin that has exposed C-Spring and other nearby sites. These sites have been made accessible due to overexploitation of local aquifers (Cordova et al., 2013), this has led to a rapid drop in the water table exposing these deep stratified sediments. However, it is unknown for how long these conditions will persist as sites such as C-Spring-BH have already been reclaimed by the marshland (Copeland, 1991). As such research should be done with haste. This area holds much potential to address intrinsically important questions about human evolution and in particular to help illuminate possible behavioral changes hominins underwent to survive in desert environments, in a vital time in their development. While this is one site of many in this area the unique nature of this site as one where the provisioning of individuals occurred and it's use exclusively as a knapping locale illuminates the vital question of how hominins structure their labour and residences in relation to key resources in their environments in distinctive ways.

Through this project we were able to get an incredible view into how the hominins of C-Spring likely utilized the site and their environment. Due to the relatively short average distance (7.8 km) these hominins were traveling to acquire their raw lithic raw materials it appears that this behavior was embedded in other activities. However, as C-Spring does not represent a residential site we cannot offer other robust conclusions about habitual residence. What we were able to find very concretely is that C-Spring is a site where individuals were provisioning themselves. This was determined by examining the lithic remains found at the site. The extremely high amount of debitage, (~90% of total), found at this site along with the large number of failed or exhausted cores indicates the hominins were transporting materials to C-Spring with the intention of making tools at the site for immediate use. Moreover, the lack of faunal remains and 'home' indicators indicates that after tool creation the hominins were leaving C-Spring to perform whatever anticipated task they had created the tools for, but not returning to C-Spring after. This indicates C-Spring was strictly a knapping locale, reinforcing the interpretation of (Copeland, 1991). The lack of any exotic or supra-regional raw materials at this site indicates that while hominins were traveling into the landscape, they remained tethered to the marshes following the tethered mobility pattern as outlined in Taylor (1964). However, raw materials from close to 20 km away have been found indicating that while the hominins were tethered to the marshes they did not stop moving, instead they remained highly mobile in their landscape despite the arid conditions. Taking this all together one gets an image of hominins moving in a push and pull motion centered around the marshes. Traveling to C-Spring from these catchment areas further out in the landscape, creating tools at the site, moving into the marshes for high value hunting or other resource extraction opportunities, before retreating back out into the wider landscape but not to C-Spring.

7.3 Directions for Future Research

In this study we have discovered that the vast majority (87%) of the C-Spring lithic assemblage available for this research originates from the western catchment area with a small portion originating from the north-eastern catchment (13%). This indicates these hominins may have been exclusively using these two areas as quarry locations for their raw material needs. This is reinforced by the lack of any artifacts from other primary source locations outside of these two areas as well as the absence of raw material from any secondary sources. However, given the relatively small size of the available assemblage additional work at this site incorporating more of the C-Spring assemblage could be extremely valuable.

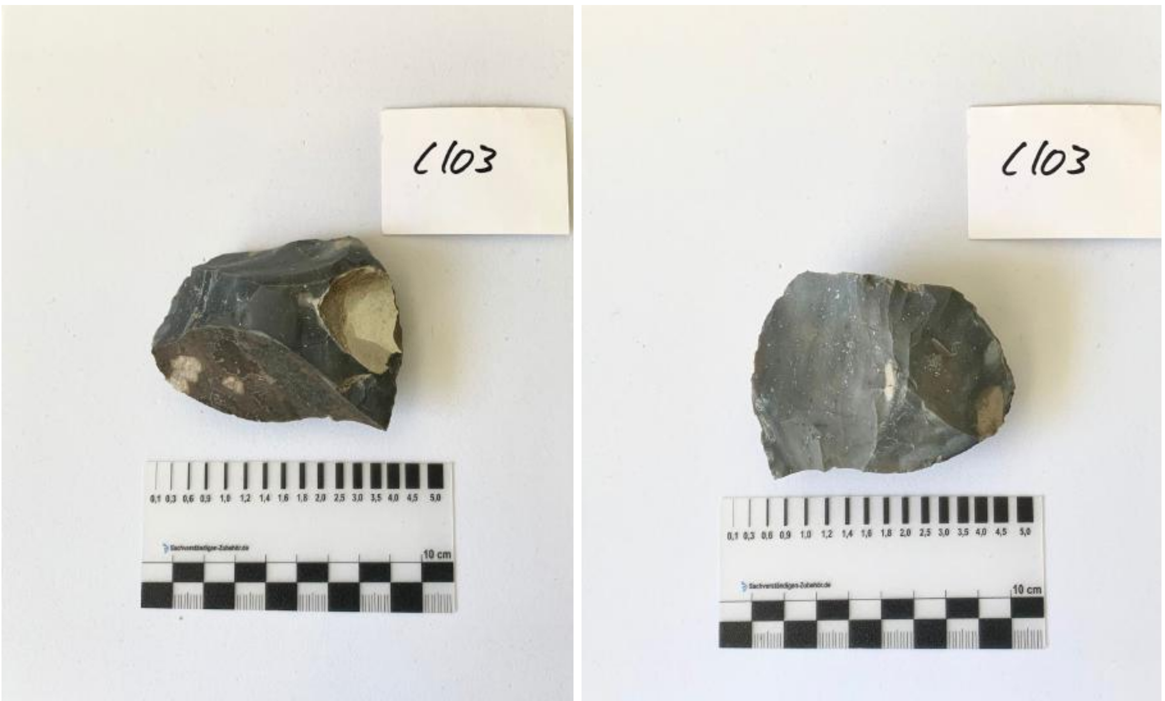
Over the course of this research several other extremely interesting directions for future research became apparent. The first is the work needed for determining the actual cause of the color change Copeland describes. Through this research it was determined that the lithic color series did not have the correct geochemical origin to be used in provenance research but that actual origin of the color change was never discovered. Further research on the lithic series using petrography or other geochemical tools may be able to discover the reason for these colors.

Another direction is to address the apparent lack of ‘home’ sites in the region. There are numerous possible explanations for why no home sites have yet been discovered. It could be that these hominins remained so mobile throughout their landscape that permanent residential camps were never established thus leaving no evidence for us to find. Or possibly there are residential locations we simply have not found yet; either way the lack of residential sites in and around the GAOA remains a lingering issue.

Lastly, as with any provenance analysis, the more research into as of yet unknown source locations only compounds the power of future research as geochemical links become more and more robust. Further provenance studies of other archaeological sites in the region, or even another one on C-Spring that integrates more of the total assemblage has the potential to reveal extremely interesting patterns and relationships.

8. Appendices

Appendix 1: Images of the C-Spring collection used in this study. Photographed by Andrew Bell and courtesy of Dr. Andrew Garrard. Used with permission.

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34
10 cm


55
10 cm


55
10 cm


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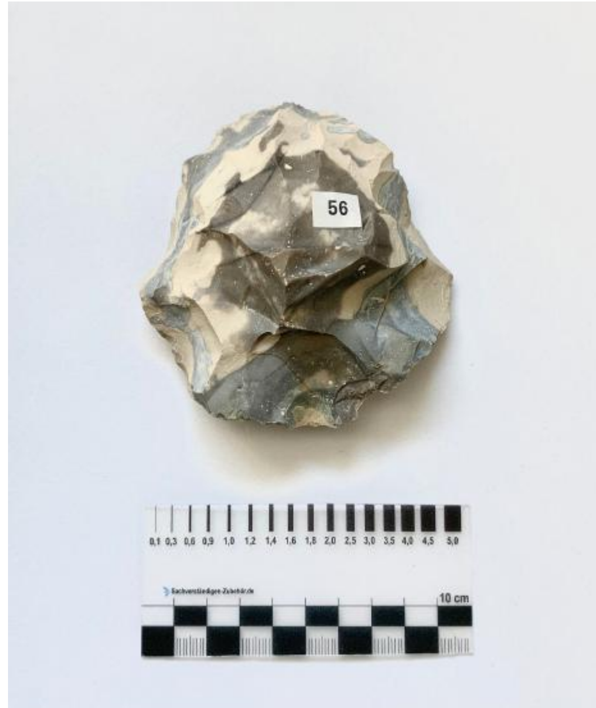
56
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59
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62
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C101
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C101
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C104
10 cm

C104
10 cm


DGS-2
CM


DGS-1
CM


C108
10 cm


C108
10 cm


C105
10 cm


C105
10 cm


65
10 cm


65
10 cm


C 19
HDTool
? Chopper
10 cm


C 19
HDTool
? Chopper
10 cm


25
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25
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57
10 cm


57
10 cm


36
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36
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26
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26
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38
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38
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C110
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C106
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C106
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C102
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C102
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C109
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C109
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40
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C112
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10 cm


C112
0,1 0,3 0,6 0,9 1,0 1,2 1,4 1,6 1,8 2,0 2,5 3,0 3,5 4,0 4,5 5,0
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66
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10 cm


66
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10 cm


C107
0,1 0,3 0,6 0,9 1,0 1,2 1,4 1,6 1,8 2,0 2,5 3,0 3,5 4,0 4,5 5,0
10 cm

C107
0,1 0,3 0,6 0,9 1,0 1,2 1,4 1,6 1,8 2,0 2,5 3,0 3,5 4,0 4,5 5,0
10 cm

31
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10 cm

31
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10 cm

Appendix 2: Photographs of newly sampled sources Photographed by Dr. Jeremy A. Beller. Used with permission.

Photograph of Wadi Usaykhim X (WUX) exposure, northeastern area.

Photography of chert beds of Wadi Usaykhim X (WUX).

Photograph of lower chert beds at 35Q (quarry next to highway 35, western area), designated as 35Q-4, 35Q-5, and 35Q-6 in descending order from the top. Note the tabular nature of the clasts.

Appendix 3: Geochemical data of sources (ppm), reproduced in part from Beller (2023). Asterisks indicate newly run sources.

Sample ID	Li	B	Na	Mg	Al	Si	K	Ca	Sc	Ti	V
35Q-1a	7.52	61.49	376.09	22.38	470.14	464330.08	224.49	1695.56	5.38	60.62	9.12
35Q-1b	6.52	61.29	425.57	34.15	467.49	460677.83	225.88	4971.36	5.84	41.16	11.39
35Q-1c	6.57	59.02	384.86	25.50	488.47	463549.08	230.24	2293.81	5.53	49.92	11.12
35Q-1d	6.41	60.75	404.96	27.14	488.21	462645.63	232.24	3207.41	5.89	53.07	9.04
35Q-1e	5.04	59.65	370.34	23.52	449.71	464075.95	252.49	1956.35	5.88	46.27	10.88
35Q-2a	10.02	40.95	599.44	32.45	606.70	459400.87	347.14	5463.31	5.18	35.57	12.10
35Q-2b	6.59	40.64	535.87	42.14	610.37	460210.10	325.10	4912.40	5.23	54.43	17.08
35Q-2c	9.91	42.09	509.44	32.80	596.46	461637.28	310.12	3005.61	5.03	65.86	74.98
35Q-2d	7.94	47.04	424.49	17.02	378.99	464005.14	221.65	1997.78	5.76	35.02	8.74
35Q-2e	8.18	42.25	487.60	34.68	485.64	459278.53	262.21	4405.81	5.32	39.87	146.52
35Q-3a	10.69	66.76	317.00	15.03	351.22	465028.08	181.26	1057.97	5.40	31.19	16.03
35Q-3b	9.93	71.56	357.43	26.28	416.10	462985.31	209.02	2763.13	5.54	40.12	12.92
35Q-3c	9.21	71.71	314.53	17.28	362.23	464598.82	183.85	1515.81	5.22	32.28	10.95
35Q-3d	7.68	71.25	302.24	18.93	357.44	464429.40	185.38	1557.21	5.03	33.64	15.55
35Q-3e	5.76	66.33	441.73	18.72	376.70	463650.69	195.53	1786.42	5.72	40.30	38.78
35Q-5a*	11.67	28.00	474.96	74.46	591.16	460688.01	271.58	4378.35	0.27	68.01	29.62
35Q-5b*	10.33	37.02	412.06	34.22	599.71	462318.25	236.82	2786.27	0.35	55.85	55.58
35Q-5c*	13.64	38.57	451.19	32.72	585.52	460887.89	244.21	3877.04	0.47	59.98	52.63
35Q-4a*	6.28	58.90	388.91	35.82	563.14	461623.82	264.20	3847.60	0.44	53.98	11.73
35Q-4b*	4.74	61.03	488.54	56.68	486.56	453745.30	246.94	10687.86	0.63	43.54	13.50
35Q-4c*	5.22	45.11	398.44	33.87	581.01	460703.78	278.22	4507.78	0.58	75.70	11.89

35Q-6a*	4.35	40.26	334.33	41.74	553.40	461319.07	255.11	3886.60	0.45	48.58	43.40
35Q-6b*	6.35	36.65	377.70	53.82	576.55	460835.97	254.31	4275.22	0.45	48.72	35.97
35Q-6c*	4.26	40.47	330.39	38.44	511.16	462794.80	214.63	2730.57	0.37	44.24	27.09
WR-1a	13.99	36.06	532.97	95.77	919.24	460993.43	426.52	5687.62	12.65	45.40	29.34
WR-1b	13.82	39.02	479.24	119.93	996.16	455180.27	433.88	12664.60	11.51	85.88	29.26
WR-1c	15.27	31.89	703.22	130.01	1108.37	455923.29	510.61	10444.69	10.22	52.03	29.72
WR-1d	17.52	31.15	590.25	135.27	1288.87	457356.73	622.19	8794.28	9.86	73.50	25.95
WR-1e	12.94	33.68	495.26	98.53	918.92	461355.25	469.51	5089.47	9.73	45.45	23.84
WR-1f	10.40	34.11	363.86	56.42	633.23	464054.02	299.08	2480.45	9.16	24.25	38.77
WR-1g	15.91	32.20	586.06	131.52	1171.24	458613.86	581.21	7206.17	9.38	68.77	37.08
WR-2a	10.00	55.14	379.38	98.12	538.47	463941.77	230.21	1937.98	4.94	29.46	28.13
WR-2b	11.21	65.74	407.34	121.51	673.61	464164.89	276.39	1193.98	5.07	42.11	41.96
WR-2c	10.59	63.12	483.06	102.11	687.17	463466.95	334.77	2234.03	5.37	51.01	8.71
WR-3a	0.94	82.52	1064.31	90.74	242.53	460537.34	166.04	4106.01	4.82	17.90	29.87
WR-3b	0.87	83.99	1033.77	120.57	230.84	461007.55	150.45	3492.02	5.29	29.48	90.61
WR-3c	0.78	72.69	700.97	111.45	221.31	459130.71	151.08	5922.30	5.00	18.61	49.17
WR-4a	5.64	49.40	150.11	25.60	287.27	465671.34	167.28	1034.87	2.96	14.38	7.67
WR-4b	6.09	47.79	160.85	26.36	251.94	465859.69	124.01	795.84	3.19	21.63	18.14
WR-4c	6.56	41.09	197.66	35.17	291.07	462904.77	139.57	2719.68	3.14	35.20	100.27
WR-4d	6.26	37.88	202.94	33.48	276.36	463774.07	138.06	2701.63	3.09	13.45	12.39
WR-4e	7.41	42.08	161.09	25.29	250.74	466032.55	119.97	759.10	3.22	17.32	6.52
WR-5a	1.41	53.08	220.59	67.29	187.85	464198.73	123.33	1975.21	5.17	11.88	26.47
WR-5b	1.85	55.08	252.06	76.38	238.19	462718.50	145.24	3927.55	5.07	15.53	16.79
WR-5c	1.03	57.28	344.09	70.75	199.53	458441.13	131.60	7005.77	5.07	18.51	19.97

WU-1a	17.78	32.02	606.99	53.40	1128.33	461040.66	596.77	1170.95	5.99	106.95	161.68
WU-1b	20.11	30.27	625.00	45.24	1093.72	461050.66	577.47	1897.12	6.93	86.19	55.67
WU-1c	27.59	33.36	647.86	47.32	1153.67	461354.45	648.82	1145.12	6.62	81.78	37.92
WU-1d	27.02	34.75	722.37	53.99	1250.19	461115.13	670.40	2861.69	6.92	73.45	20.26
WU-1e	19.54	106.10	558.63	126.69	2479.16	453604.99	648.17	8005.97	5.65	102.97	39.36
WU-2a	19.94	14.52	522.02	79.28	1678.13	459445.54	1007.01	3796.11	7.43	70.31	71.01
WU-2b	22.62	20.12	426.87	66.39	1462.97	461270.84	823.53	2481.27	6.80	79.69	78.43
WU-2c	19.61	17.78	439.61	80.05	1532.09	458936.30	846.44	4557.51	6.64	175.78	44.76
WU-2d	15.37	17.15	441.97	70.06	1527.47	460707.42	827.03	3435.74	6.60	62.95	36.48
WU-2e	18.17	18.46	512.87	112.33	1912.70	457335.28	1064.86	6067.37	6.96	70.45	31.98
WU-3a	25.25	28.04	571.21	53.05	1184.61	460094.21	578.69	1383.54	5.61	127.75	48.62
WU-3b	19.08	32.69	538.95	42.46	1013.58	462406.08	497.89	998.41	5.55	114.44	45.28
WU-3c	20.26	36.51	556.61	39.96	1052.20	462687.24	513.06	923.61	6.11	59.43	46.95
WU-3d	19.06	34.44	605.58	45.85	1060.59	461163.53	562.41	1494.49	5.98	65.36	68.15
WU-3e	18.16	29.85	627.33	48.83	1167.81	463140.01	596.80	1159.25	5.83	114.98	48.70
WU-4a	23.11	39.76	662.12	58.12	680.65	453713.87	406.23	8741.00	2.93	49.79	109.23
WU-4b	21.68	37.75	533.55	34.34	656.33	461610.97	363.39	3672.68	2.88	41.44	63.78
WU-4c	19.99	37.75	564.19	46.38	713.28	458209.09	390.63	6278.13	3.12	47.37	90.62
WU-4d	18.95	38.25	584.03	40.36	688.71	459071.69	403.74	5369.87	3.08	31.25	116.49
WU-4e	21.25	37.86	558.32	36.18	704.37	460321.30	374.16	3850.06	2.86	44.23	47.06
WUX-1a	5.84	29.20	389.27	94.59	744.60	462739.53	330.24	2611.82	0.39	62.88	91.40
WUX-1a	4.03	36.84	321.04	89.45	627.73	463505.60	266.19	2294.98	0.28	39.07	82.50
WUX-1a	3.08	44.84	238.21	67.25	453.21	464657.66	207.03	1399.91	0.37	32.67	85.37

WUX-3a	9.98	39.91	1036.08	283.57	1185.62	463080.11	619.19	1684.10	0.53	89.59	78.60
WUX-3b	8.39	47.00	1117.93	323.41	1292.59	462791.67	744.60	1747.21	0.52	111.22	81.89
WUX-3c	8.40	37.83	1108.98	288.02	1045.24	462147.59	585.31	2332.89	0.55	79.66	113.44
WUX-5a	9.64	31.30	1180.45	280.69	674.58	449830.50	514.27	19761.17	0.53	49.76	71.71
WUX-5b	12.62	28.37	1057.58	249.95	719.30	454840.67	551.13	14603.94	0.44	58.95	67.14
WUX-5c	8.30	39.96	1229.87	257.17	699.29	450519.91	513.70	18652.81	0.57	51.71	61.75
WUX-10a	13.41	30.33	2669.50	439.78	1442.61	433934.25	736.26	26102.72	1.22	83.38	72.56
WUX-10b	21.80	24.11	2238.05	397.40	1536.52	458567.40	692.07	3978.78	0.64	83.06	119.59
WUX-10c	19.61	38.95	1558.59	278.46	1005.79	462566.96	412.47	1824.21	0.35	49.19	44.57
WG1a	18.02	19.74	583.94	199.51	664.27	463051.15	351.94	640.29	3.87	54.17	84.54
WG1b	16.58	19.76	411.39	278.61	599.15	462756.05	391.38	1355.99	3.87	48.39	38.49
WG1c	13.31	19.01	494.83	226.34	627.15	463209.60	324.49	963.99	3.71	78.38	77.83
WG1d	18.22	19.68	611.82	296.91	722.47	464187.98	376.11	949.60	3.64	46.00	39.40
WG1e	19.06	20.34	493.69	165.25	643.63	465290.94	358.28	536.66	3.81	38.22	22.96
WG1f	19.65	19.38	580.66	284.61	779.44	463713.92	455.21	562.53	3.58	35.99	20.62
WG3a	15.38	18.13	379.82	137.13	735.03	463808.33	329.74	1921.80	5.55	75.45	6.02
WG3b	15.59	17.97	428.53	198.40	945.17	462814.78	449.81	1863.30	6.14	61.43	20.33
WG3c	15.22	18.58	444.66	148.59	702.34	460068.59	333.64	5070.31	6.16	45.20	17.61
WG3d	15.83	19.24	388.00	137.96	671.79	463439.49	341.43	2146.82	6.05	50.41	6.28
WG3e	15.48	22.44	397.34	183.50	784.02	461922.77	313.34	2867.82	5.45	88.65	32.22
WMH-1a	5.04	12.11	126.99	35.68	381.68	466233.82	286.91	488.02	3.45	24.84	5.29
WMH-1b	5.32	11.22	135.75	44.98	391.48	465778.85	286.77	783.95	3.55	23.15	9.03
WMH-1c	4.73	11.29	127.57	32.33	431.84	466058.78	301.90	607.86	3.61	34.13	7.19

WMH-3a	5.75	12.41	130.06	47.57	465.81	465089.16	284.26	747.20	3.67	32.75	33.15
WMH-3b	5.07	11.37	125.40	32.83	427.90	465920.88	265.21	614.05	3.58	25.57	9.71
WMH-3c	4.21	11.95	142.39	35.94	453.94	465167.32	271.54	1150.85	3.72	28.07	13.61

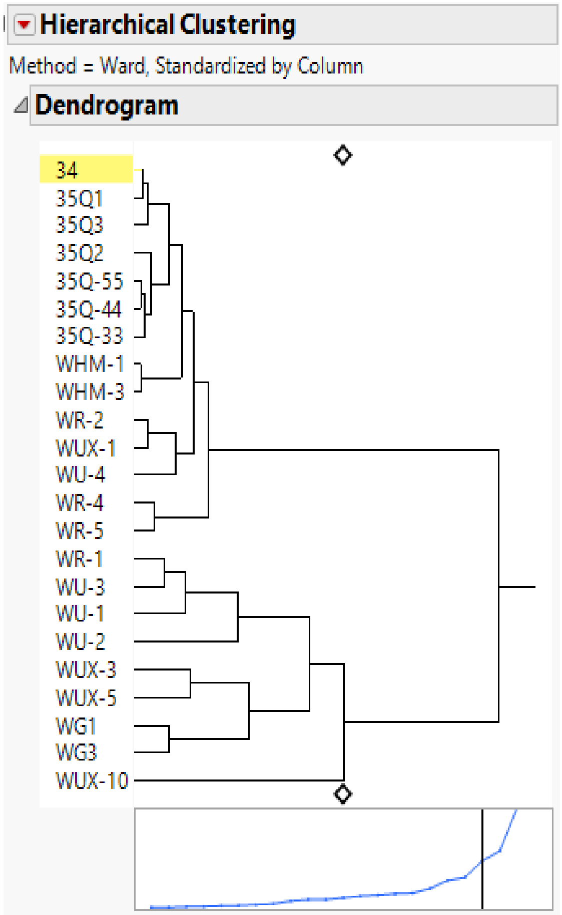
Appendix 4: Geochemical Data of Artifacts (ppm)

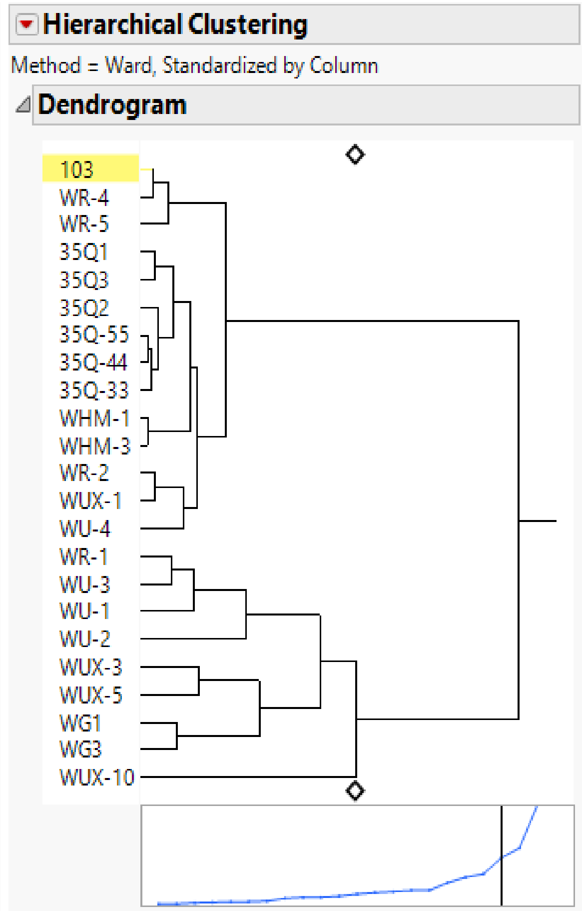
Copeland Series	Sample ID	Li	B	Na	Mg	Al	Si	K	Ca	Sc	Ti	V
Olive	103a	9.89	44.47	277.42	13.75	394.47	464561.73	183.58	1406.48	0.42	25.86	18.84
Olive	103b	7.00	41.94	259.11	13.54	359.04	464881.92	170.16	1289.29	0.37	40.37	20.60
Olive	103c	9.76	45.44	139.53	7.51	243.67	466695.90	85.58	25.81	0.24	6.57	1.08
Olive	103d	6.39	47.92	292.54	14.63	379.77	464210.34	176.16	1624.70	0.37	70.37	16.45
Olive	34a	4.20	60.26	349.44	29.25	452.04	459677.62	189.52	5441.37	0.53	38.41	110.96
Olive	34b	3.55	49.38	331.30	26.02	463.86	463679.53	188.75	2219.25	0.28	37.13	34.84
Olive	34c	6.70	43.76	341.93	22.94	461.93	462258.77	208.09	2613.01	0.28	42.74	121.99
Brown	55a	15.18	28.89	486.74	56.09	796.39	459752.87	342.62	4504.36	0.57	65.41	49.80
Brown	55b	11.41	38.31	472.46	54.44	774.98	459893.07	318.28	5392.72	0.54	54.62	25.79
Brown	55c	12.59	35.89	491.25	58.85	844.73	457728.51	337.42	6247.34	0.52	61.10	20.06
Pale gray	56a	7.79	35.07	282.95	22.19	304.33	460089.32	154.88	5571.70	0.59	18.23	15.93
Pale gray	56b	7.34	30.47	232.43	13.89	294.59	464559.22	151.20	1635.81	0.41	28.49	12.47
Pale gray	56c	9.33	35.44	255.76	16.68	324.76	465209.77	166.85	1149.98	0.39	39.25	35.73
Brown	59a	3.59	33.60	265.74	27.57	303.37	462158.50	183.76	3862.85	0.39	55.40	24.90
Brown	59b	4.91	38.23	268.74	26.23	273.53	461242.08	140.54	4905.72	0.52	30.34	29.05
Brown	59c	3.93	32.76	261.40	26.95	306.75	462951.19	159.08	3225.67	0.36	25.93	36.49
Brown	59d	2.81	47.31	266.08	13.17	304.01	463154.09	157.33	2968.39	0.47	25.02	23.68
Brown	59e	4.79	45.72	245.58	67.27	340.89	463230.54	190.46	2722.55	0.51	33.44	24.65
Olive	61a	6.39	39.36	355.56	34.47	551.20	461540.35	226.31	3578.81	0.37	53.92	65.45

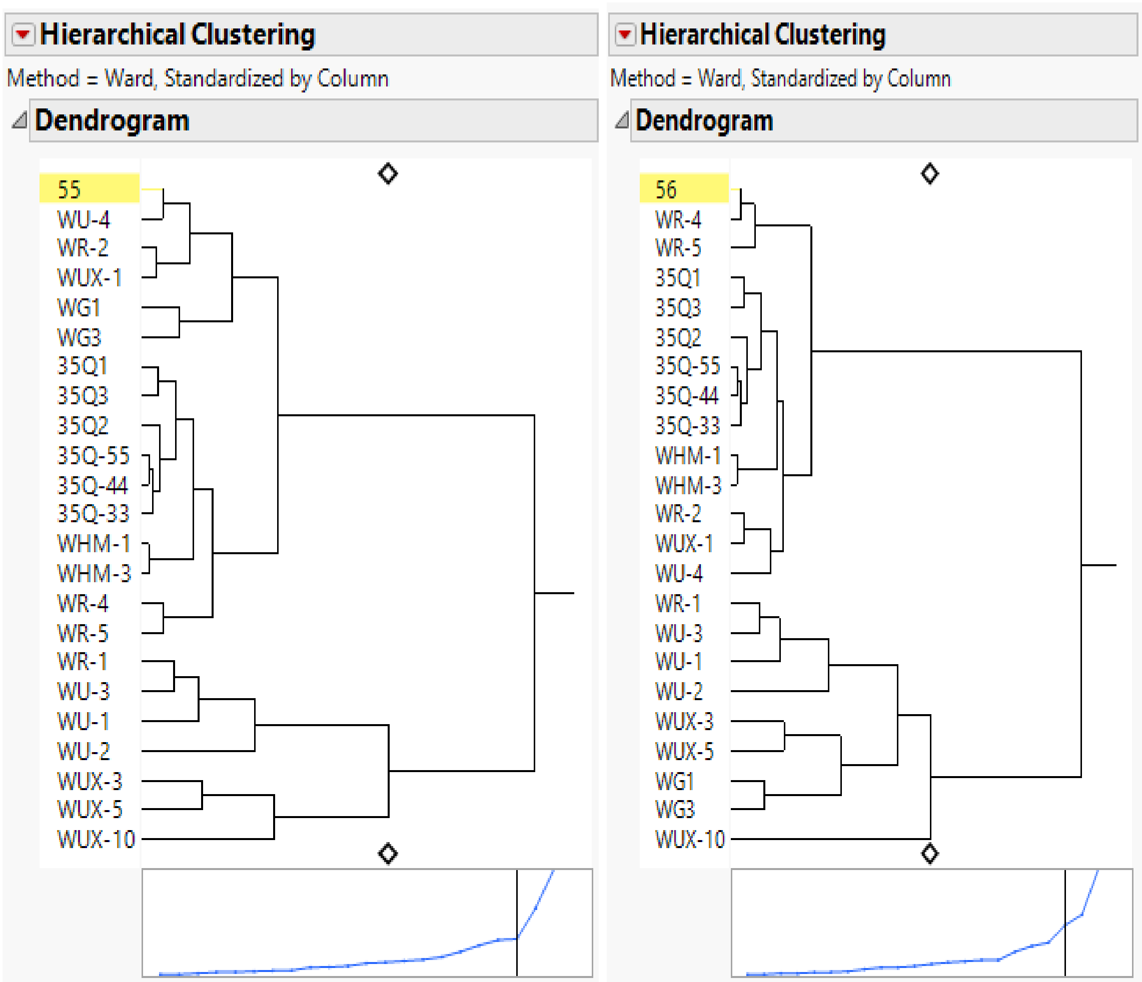
Olive	61b	10.13	43.80	376.00	35.10	489.54	459880.70	219.16	4652.75	0.48	52.28	70.43
Olive	61c	4.24	37.98	361.99	32.48	515.92	462051.57	218.25	2682.12	0.33	63.05	84.44
Dark gray	62a	19.02	35.66	245.07	36.35	437.19	461474.56	197.08	4280.40	0.76	41.22	19.27
Dark gray	62b	16.41	34.60	240.30	25.28	366.89	462977.42	182.40	2847.74	0.59	42.39	16.04
Dark gray	62c	22.76	34.48	234.43	28.82	382.32	462489.39	210.00	3116.51	0.56	42.48	28.20
Dark gray	62d	15.66	40.67	245.60	29.44	383.15	461399.61	188.12	3751.44	0.56	36.53	34.96
Dark gray	62e	10.86	41.28	275.00	14.87	391.00	464976.55	182.19	1047.86	0.45	35.76	15.80
Brown	BSF-1a	8.70	36.71	309.34	21.45	426.41	463343.74	180.03	2708.16	0.33	32.08	19.71
Brown	BSF-1b	7.68	37.92	331.17	26.15	452.30	463241.80	197.49	2049.47	0.29	72.24	65.67
Brown	BSF-1c	8.26	31.42	366.60	31.01	442.52	460155.32	187.88	4733.73	0.22	42.02	18.56
Brown	BSKa	5.46	50.73	408.35	24.90	523.46	461988.39	253.53	3559.93	0.35	53.39	34.58
Brown	BSKb	3.82	51.69	424.42	31.67	557.00	461290.26	289.33	3804.82	0.50	59.46	54.00
Brown	BSKc	6.66	43.13	424.50	29.18	535.71	460843.87	274.41	4030.79	0.34	81.16	61.80
Dark gray	C101a	6.41	44.75	361.86	24.70	509.09	462427.20	219.69	2653.91	0.27	39.12	78.33
Dark gray	C101b	5.53	51.21	352.31	22.00	541.10	462901.88	217.11	2281.92	0.40	24.32	88.89
Dark gray	C101c	4.44	53.25	366.14	21.46	518.68	451956.67	230.44	8628.57	0.52	39.06	108.81
Dark gray	C104a	4.61	32.18	361.44	38.77	602.37	460125.11	257.36	4525.97	0.46	64.84	27.39
Dark gray	C104b	6.61	51.49	395.64	41.67	544.22	458609.24	250.18	5590.94	0.63	51.25	32.99
Dark gray	C104c	10.67	36.52	361.04	39.04	521.30	460217.21	235.21	4804.81	0.42	45.98	20.43
Dark gray	DGS-1a	13.00	55.30	389.66	29.82	718.88	463249.55	350.29	2012.18	ud	54.57	13.46
Dark gray	DGS-1b	12.09	50.31	423.42	26.68	576.77	464045.66	287.74	1553.51	0.27	56.17	19.43
Dark gray	DGS-1c	16.64	48.80	428.50	17.71	605.67	464068.60	304.77	1524.48	0.36	38.94	18.93

Dark gray	DGS-2a	15.82	48.66	410.32	23.16	614.87	463162.73	256.64	2056.18	0.30	45.40	30.84
Dark gray	DGS-2b	13.18	41.95	443.98	27.73	607.85	460314.59	272.14	4684.10	0.39	44.82	24.72
Dark gray	DGS-2c	11.49	38.94	412.92	27.08	580.02	463316.35	267.57	2217.06	0.30	44.60	23.29
Olive	OS1a	6.65	30.06	491.09	42.78	636.57	459419.76	281.56	4722.01	0.39	39.10	39.55
Olive	OS1b	10.14	32.87	441.08	32.29	586.24	459839.51	258.30	3760.46	0.33	55.59	58.57
Olive	OS1c	7.63	48.76	464.66	37.57	666.24	461287.28	291.19	3566.42	0.35	49.81	40.47
Olive	OS2a	9.70	29.87	505.74	50.55	794.73	457823.83	380.60	5519.56	0.43	59.42	87.99
Olive	OS2b	14.14	38.51	474.78	50.96	806.62	460243.68	360.29	4482.84	0.37	63.10	65.31
Olive	OS2c	18.68	33.77	474.58	57.69	702.51	459918.97	345.55	4437.87	0.22	97.96	54.47

Appendix 5: Hierarchical Cluster Dendrograms of Artifacts With Artifacts Highlighted in Yellow






Hierarchical Clustering
Method = Ward, Standardized by Column
Dendrogram
55
WU-4
WR-2
WUX-1
WG1
WG3
35Q1
35Q3
35Q2
35Q-55
35Q-44
35Q-33
WHM-1
WHM-3
WR-4
WR-5
WR-1
WU-3
WU-1
WU-2
WUX-3
WUX-5
WUX-10
Hierarchical Clustering
Method = Ward, Standardized by Column
Dendrogram
56
WR-4
WR-5
35Q1
35Q3
35Q2
35Q-55
35Q-44
35Q-33
WHM-1
WHM-3
WR-2
WUX-1
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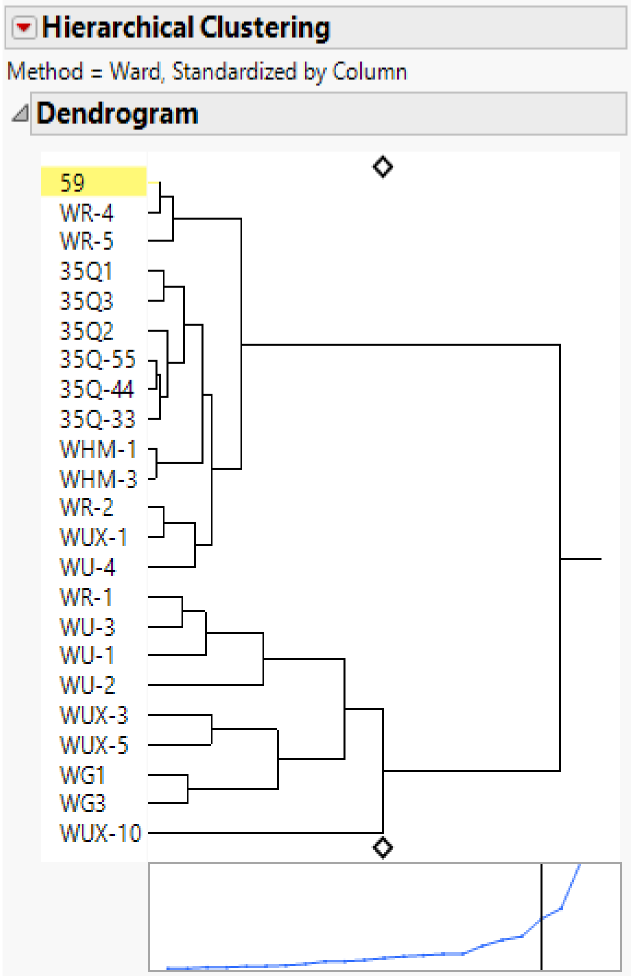
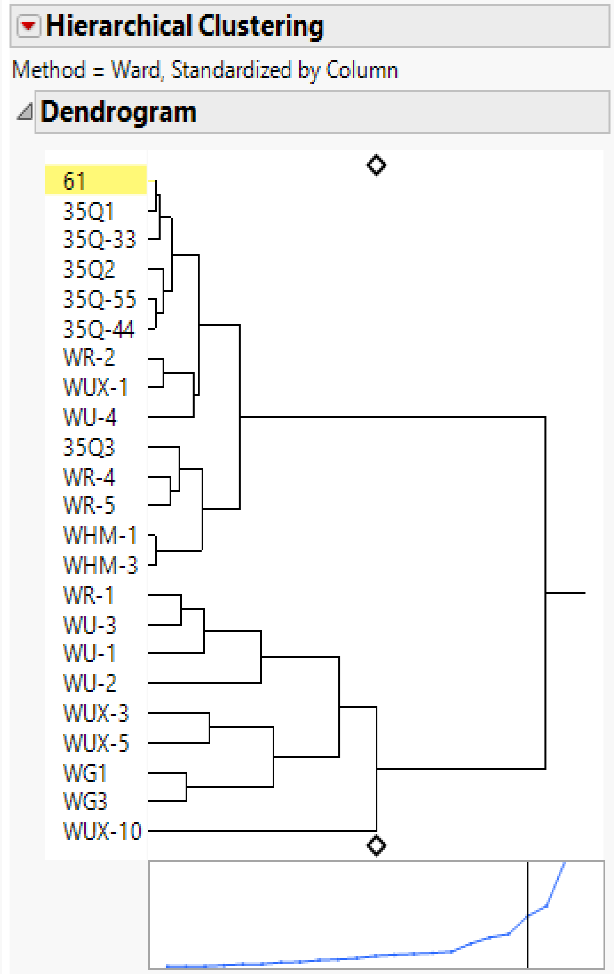
WUX-5
WG1
WG3
WUX-10



Hierarchical Clustering
Method = Ward, Standardized by Column
Dendrogram
59
WR-4
WR-5
35Q1
35Q3
35Q2
35Q-55
35Q-44
35Q-33
WHM-1
WHM-3
WR-2
WUX-1
WU-4
WR-1
WU-3
WU-1
WU-2
WUX-3
WUX-5
WG1
WG3
WUX-10



Hierarchical Clustering
Method = Ward, Standardized by Column
Dendrogram
61
35Q1
35Q-33
35Q2
35Q-55
35Q-44
WR-2
WUX-1
WU-4
35Q3
WR-4
WR-5
WHM-1
WHM-3
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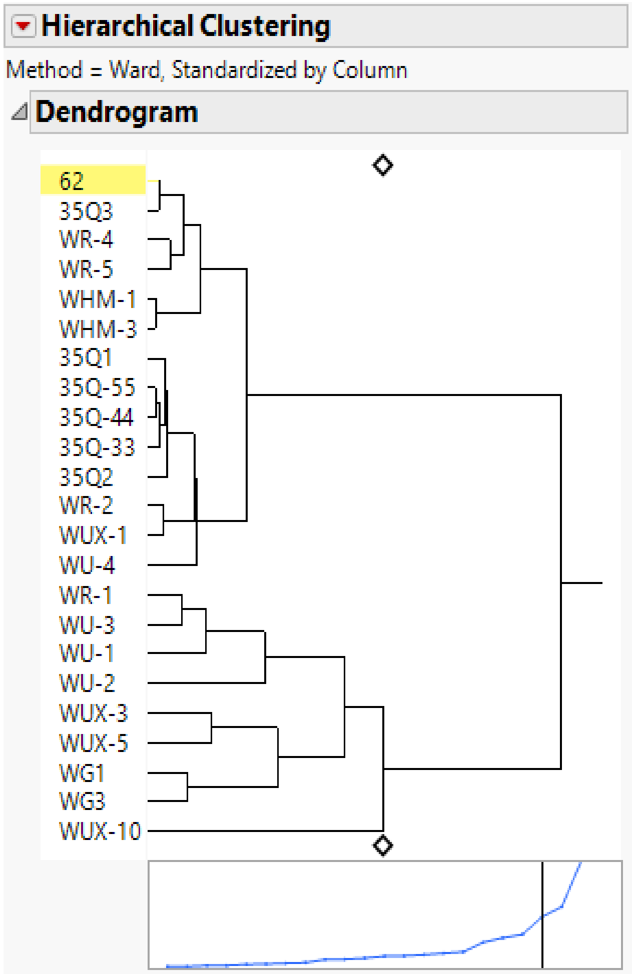
WG1
WG3
WUX-10



Hierarchical Clustering
Method = Ward, Standardized by Column
Dendrogram
62
35Q3
WR-4
WR-5
WHM-1
WHM-3
35Q1
35Q-55
35Q-44
35Q-33
35Q2
WR-2
WUX-1
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WU-3
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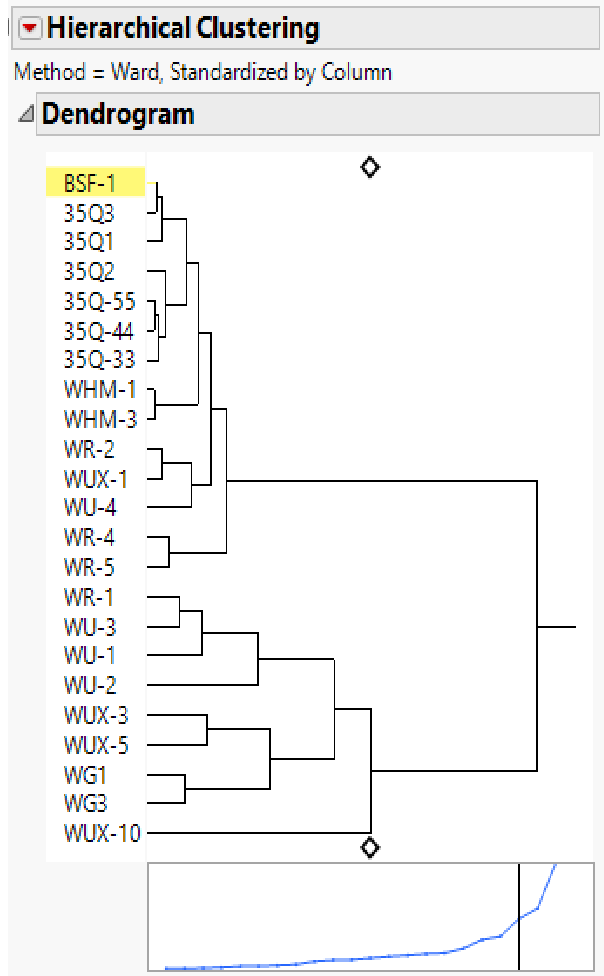
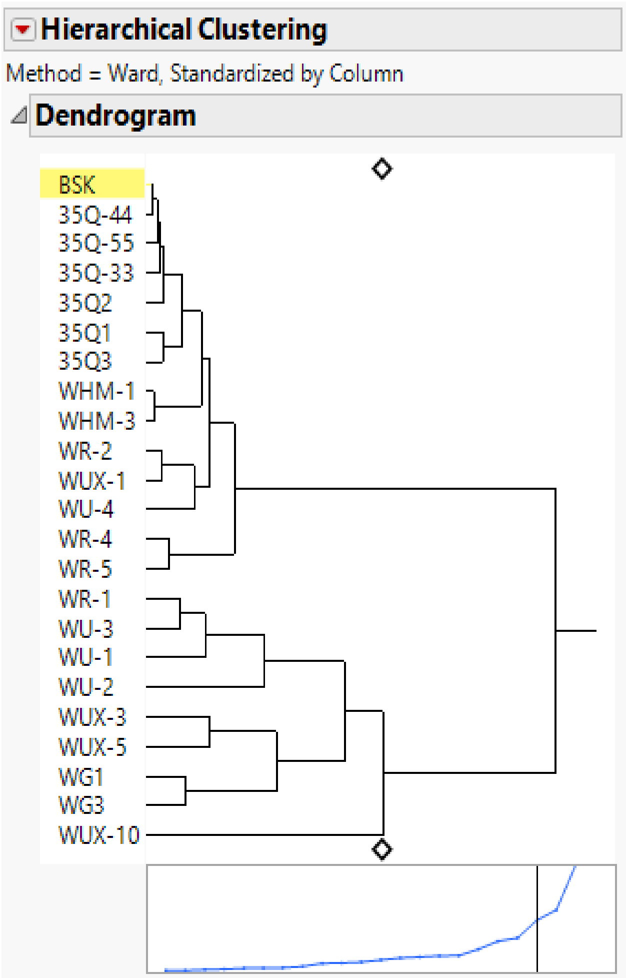
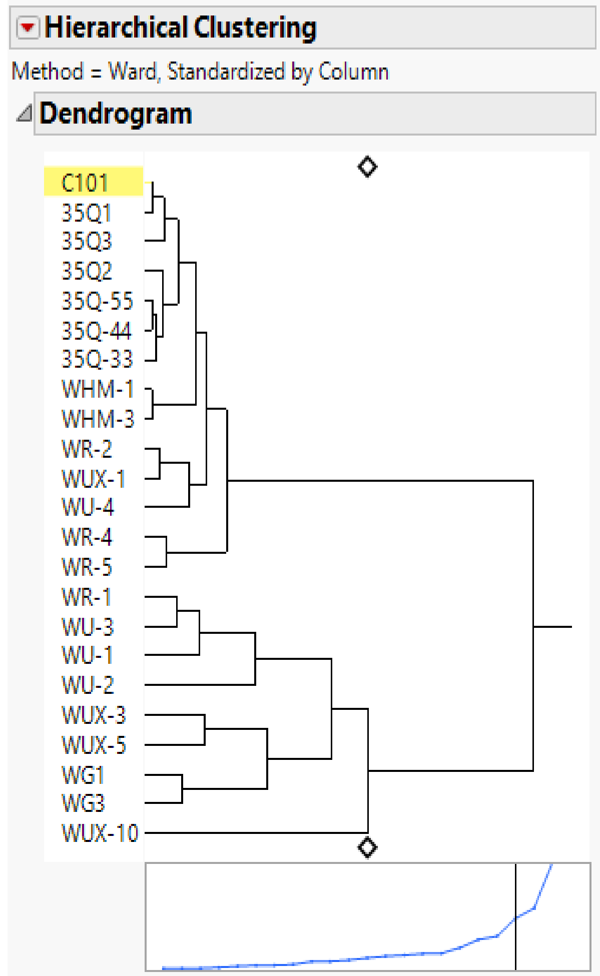
WG1
WG3
WUX-10



Hierarchical Clustering
Method = Ward, Standardized by Column
Dendrogram
BSF-1
35Q3
35Q1
35Q2
35Q-55
35Q-44
35Q-33
WHM-1
WHM-3
WR-2
WUX-1
WU-4
WR-4
WR-5
WR-1
WU-3
WU-1
WU-2
WUX-3
WUX-5
WG1
WG3
WUX-10


Hierarchical Clustering
Method = Ward, Standardized by Column
Dendrogram
BSK
35Q-44
35Q-55
35Q-33
35Q2
35Q1
35Q3
WHM-1
WHM-3
WR-2
WUX-1
WU-4
WR-4
WR-5
WR-1
WU-3
WU-1
WU-2
WUX-3
WUX-5
WG1
WG3
WUX-10


Hierarchical Clustering
Method = Ward, Standardized by Column
Dendrogram
C101
35Q1
35Q3
35Q2
35Q-55
35Q-44
35Q-33
WHM-1
WHM-3
WR-2
WUX-1
WU-4
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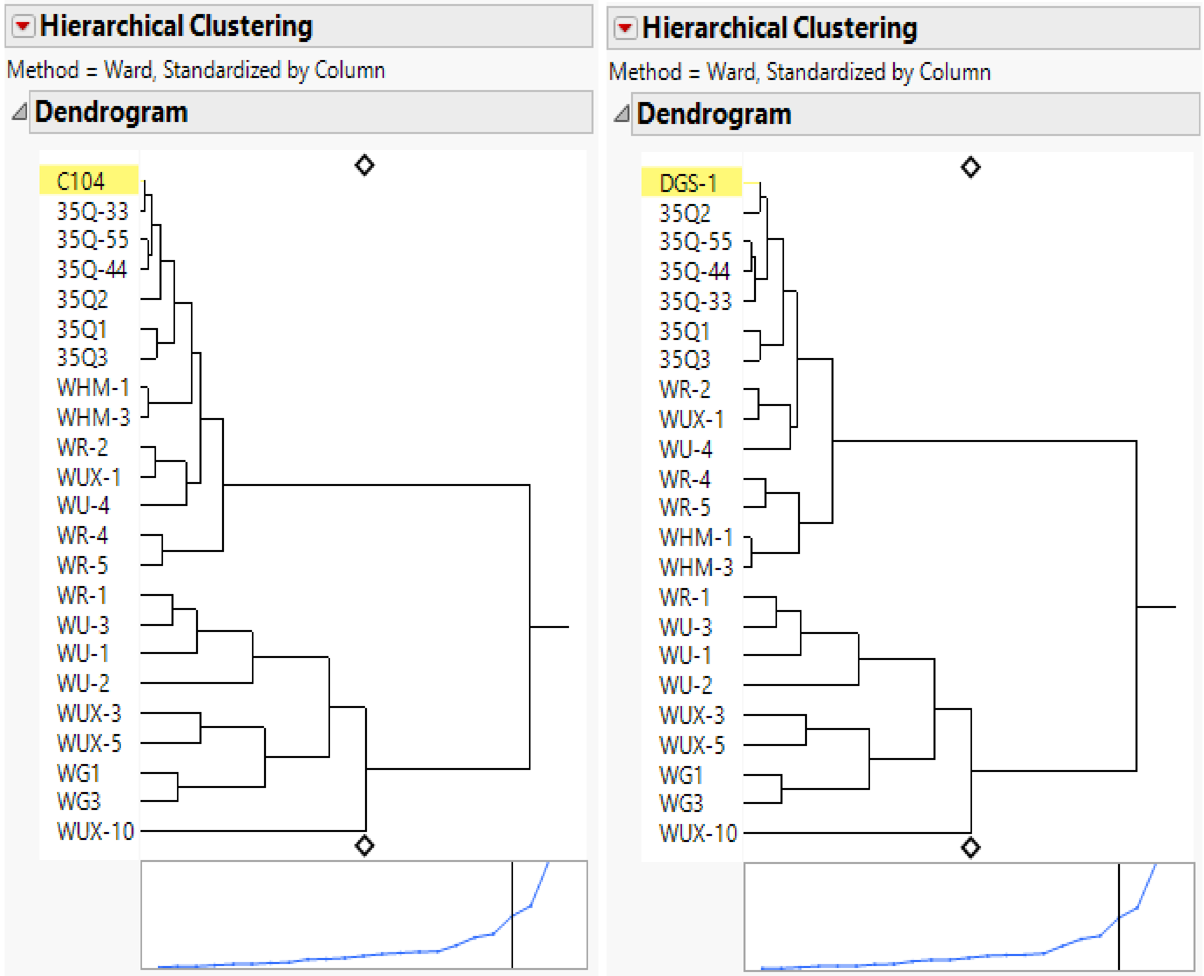
WG1
WG3
WUX-10


Hierarchical Clustering
Method = Ward, Standardized by Column
Dendrogram
C104
35Q-33
35Q-55
35Q-44
35Q2
35Q1
35Q3
WHM-1
WHM-3
WR-2
WUX-1
WU-4
WR-4
WR-5
WR-1
WU-3
WU-1
WU-2
WUX-3
WUX-5
WG1
WG3
WUX-10
Hierarchical Clustering
Method = Ward, Standardized by Column
Dendrogram
DGS-1
35Q2
35Q-55
35Q-44
35Q-33
35Q1
35Q3
WR-2
WUX-1
WU-4
WR-4
WR-5
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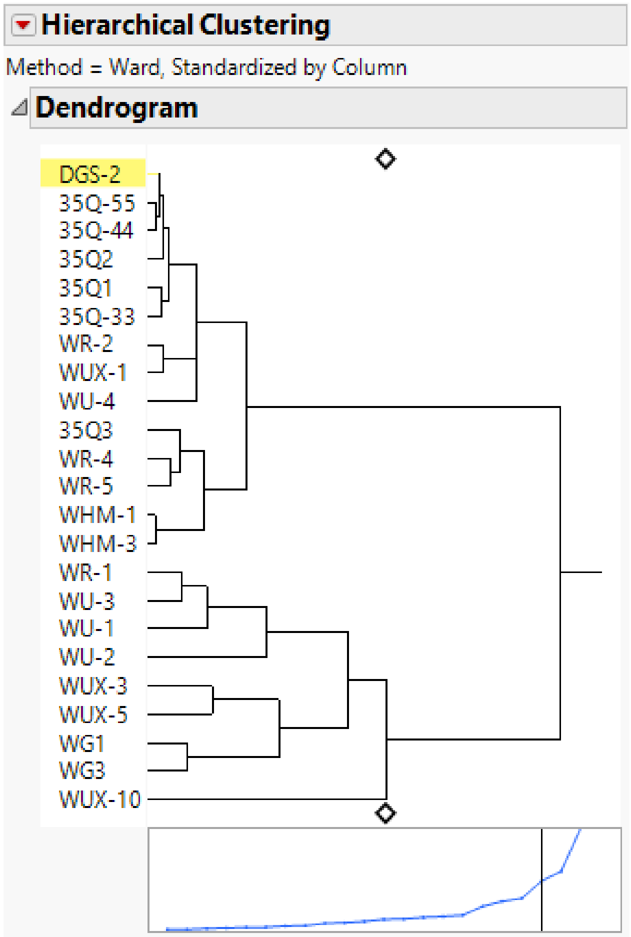
WG1
WG3
WUX-10


Hierarchical Clustering
Method = Ward, Standardized by Column
Dendrogram
DGS-2
35Q-55
35Q-44
35Q2
35Q1
35Q-33
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WUX-1
WU-4
35Q3
WR-4
WR-5
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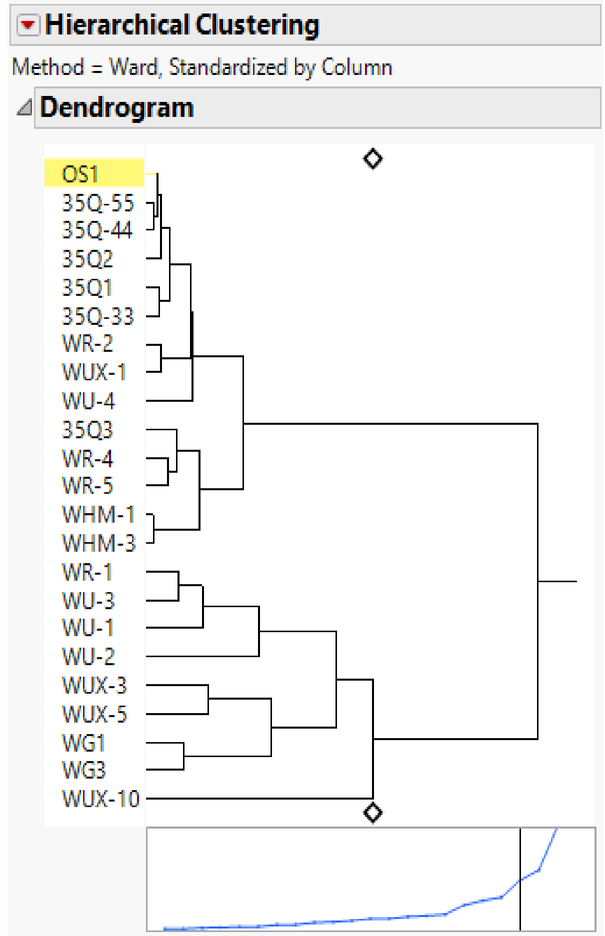
WG1
WG3
WUX-10


Hierarchical Clustering
Method = Ward, Standardized by Column
Dendrogram
OS1
35Q-55
35Q-44
35Q2
35Q1
35Q-33
WR-2
WUX-1
WU-4
35Q3
WR-4
WR-5
WHM-1
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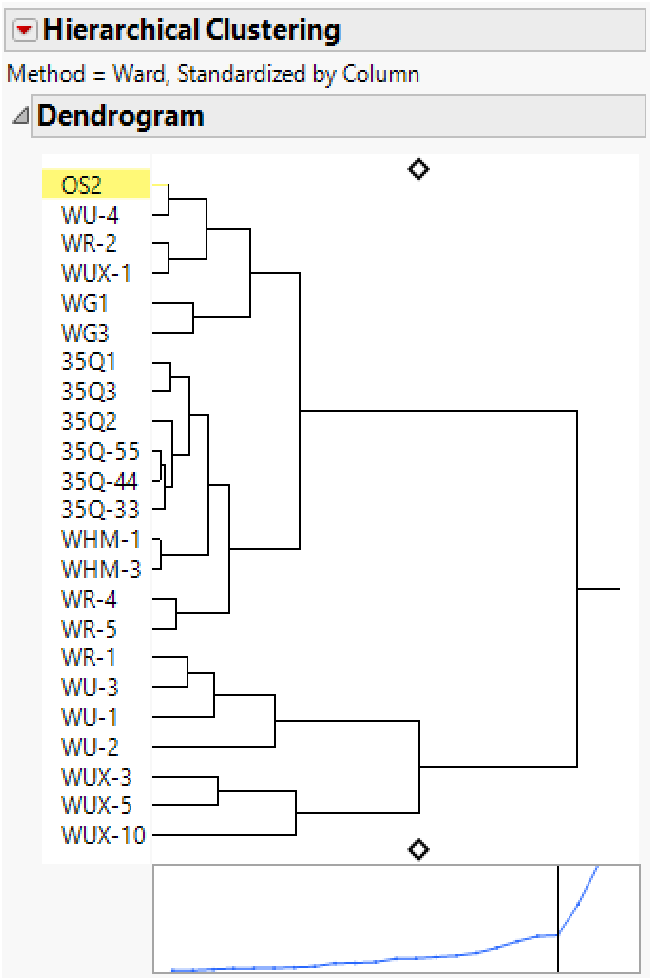
WG1
WG3
WUX-10


Hierarchical Clustering
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Dendrogram
OS2
WU-4
WR-2
WUX-1
WG1
WG3
35Q1
35Q3
35Q2
35Q-55
35Q-44
35Q-33
WHM-1
WHM-3
WR-4
WR-5
WR-1
WU-3
WU-1
WU-2
WUX-3
WUX-5
WUX-10

Bibliography

Abed, A., Barth, H., & Böer, B. (2002). An overview of an inland sabkha in Jordan: The Taba sabkha, southern Wadi Araba. https://www.semanticscholar.org/paper/An-overview-of-an-inland-sabkha-in-Jordan%3A-the-Taba-Abed-Barth/d09f1cb6e3bd17fda43276e3b2086b996a62f9b0

Abed, A. M. (1982). Depositional environments of the early cretaceous Kurnub (Hathira) sandstones, North Jordan. *Sedimentary Geology*, *31*(3), 267–279. https://doi.org/10.1016/0037-0738(82)90061-6

Adams, B., & Brooke, B. (Eds.). (2009). Lithic Materials and Paleolithic Societies. *Blackwell Publishing Ltd.* https://onlinelibrary.wiley.com/doi/book/10.1002/9781444311976

Al-Hunjul. (2001). The Geology of Qasr al Harrana, Map Sheet No. 3253-II. *Geology Directorate, Geological Mapping Division, Bulletin 45. The Hashemite Kingdom of Jordan, Natural Resources Authority, Amman*.

Alsharhan, A. S., & Nairn, A. E. M. (Eds.). (2003). Front Matter. In *Sedimentary Basins and Petroleum Geology of the Middle East* (p. iii). Elsevier Science B.V. https://doi.org/10.1016/B978-0-444-82465-3.50018-8

Ames, C. J., & Cordova, C. E. (2015). Middle and Late Pleistocene landscape evolution at the Druze Marsh Site in northeast Jordan: Implications for population continuity and hominin dispersal. *Geoarchaeology*, *30*(4), 307–329.

Ames, C. J. H., Nowell, A., Cordova, C. E., Pokines, J. T., & Bisson, M. S. (2014). Paleoenvironmental change and settlement dynamics in the Druze Marsh: Results of recent excavation at an open-air Paleolithic site. *Quaternary International*, *331*, 60–73. https://doi.org/10.1016/j.quaint.2013.04.016

Andrefsky, W. (2009). The Analysis of Stone Tool Procurement, Production, and Maintenance. *Journal of Archaeological Research*, *17*(1), 65–103. https://doi.org/10.1007/s10814-008-9026-2

Andrews, I. J. (1992). Cretaceous and Paleogene Lithostratigraphy in the Subsurface of Jordan. *Ministry of Energy and Mineral Resources*.

Barkai, R., Gopher, A., & LaPorta, P. C. (2006). Middle Pleistocene landscape of extraction: Quarry and workshop complexes in northern Israel. *Axe Age : Acheulian Tool-Making from Quarry to Discard*, 7–44.

Beller, J. A. (2020). Hominin survival and lithic procurement strategies at a Pleistocene desert refugium during periods of environmental stress: A case study from Shishan Marsh 1 in the Azraq Basin, Jordan *[Thesis]*. https://dspace.library.uvic.ca/handle/1828/12547

Beller, J., Ames, C., & Nowell, A. (2020). Exploring Mid-Late Pleistocene lithic procurement strategies at Shishan Marsh 1: Preliminary geochemical characterization of chert sources around the Greater Azraq Oasis Area, Jordan. *Journal of Archaeological Science: Reports*, *29*, 102091. https://doi.org/10.1016/j.jasrep.2019.102091

Beller, J. A. (2023). Raw material characterization and lithic provenance from Shishan Marsh 1, a Middle Pleistocene site in the central Azraq Basin, Jordan. *Journal of Archaeological Science: Reports*, *47*, 103800. https://doi.org/10.1016/j.jasrep.2022.103800

Bender, F. (1974). Geology of the Arabian Peninsula, Jordan. *Professional Paper*, Article 560–I. https://doi.org/10.3133/pp560I

Binford, L. R. (1978). Nunamiut Ethnoarchaeology *(Univ. of Wy., Dept. of Anthro. University of Alaska Museum, Fairbanks). Academic Press.*

Binford, L. R. (1979). Organization and Formation Processes: Looking at Curated Technologies. *Journal of Anthropological Research*, *35*(3), 255–273.

Binford, L. R. (1980). Willow Smoke and Dogs' Tails: Hunter-Gatherer Settlement Systems and Archaeological Site Formation. *American Antiquity*, *45*(1), 4–20. https://doi.org/10.2307/279653

Biró, K. T. (2009). Sourcing Raw Materials for Chipped Stone Artifacts: The State-of-the-Art in Hungary and the Carpathian Basin. In *Lithic Materials and Paleolithic Societies* (pp. 47–53). John Wiley & Sons, Ltd. https://doi.org/10.1002/9781444311976.ch4

Blades, B. S. (2002). Aurignacian Lithic Economy: Ecological Perspectives from Southwestern France. *Springer US.* https://doi.org/10.1007/b110584

Boyd, K. C., Ames, C. J. H., & Cordova, C. E. (2022). The Middle to Late Pleistocene transition in the Azraq Oasis, Jordan: A phytolith-based reconstruction of wetland palaeoecology. *Palaeogeography, Palaeoclimatology, Palaeoecology*, *595*, 110967. https://doi.org/10.1016/j.palaeo.2022.110967

Brandl, M. (2016). The multi layered chert sourcing approach (mla) analytical provenance studies of silicite raw materials. *Archeometriai Muhely*, *13*, 145–156.

Brandl, M., Hauzenberger, C., Postl, W., Martinez, M. M., Filzmoser, P., & Trnka, G. (2014). Radiolarite studies at Krems-Wachtberg (Lower Austria): Northern Alpine versus Carpathian lithic resources. *Quaternary International*, *351*, 146–162. https://doi.org/10.1016/j.quaint.2013.01.031

Brown, G. M. (1991). Embedded and Direct Lithic Resource Procurement Strategies on Anderson Mesa. *Kiva*, *56*(4), 359–384.

Chen, L., Liu, Y., Hu, Z., Gao, S., Zong, K., & Chen, H. (2011). Accurate determinations of fifty-four major and trace elements in carbonate by LA–ICP-MS using normalization strategy of bulk components as 100%. *Chemical Geology*, *284*(3), 283–295. https://doi.org/10.1016/j.chemgeo.2011.03.007

Clutton-Brock, J. (1970). The fossil fauna from an Upper Pleistocene site in Jordan. *Journal of Zoology*, *162*(1), 19–29. https://doi.org/10.1111/j.1469-7998.1970.tb01254.x

Clutton-Brock, J. (1989). A Reconsideration of the Fossil Fauna from C-Spring, Azraq. In *The Hammer on the Rock: Studies in the Early Palaeolithic of Azraq, Jordan* (Vol. 540, pp. 391–397). British Archaeological Reports.

Copeland, L. (1988). Environment, Chronology and Lower-Middle Paleolithic Occupations of the Azraq Basin, Jordan. *Paléorient*, *14*(2), 66–75.

Copeland, L. (1991). The Late Acheulean Knapping-floor at C-Spring, Azraq Oasis, Jordan. *Levant*, *23*(1), 1–6. https://doi.org/10.1179/lev.1991.23.1.1

Copeland, L., Garrard, A. N., & Stanley-Price, N. P. (1975). A Survey of Prehistoric Sites in the Azraq Basin, Eastern Jordan. *Paléorient*, *3*, 109–126.

Copeland, L., & Hours, F. (1989a). Analysis of the Paleolithic artifacts from the sounding of A. Garrard at C-Spring, Azraq; 1985 season. In *The Hammer on the Rock: Studies in the Early Palaeolithic of Azraq, Jordan* (Vol. 540, pp. 325–390). British Archaeological Reports.

Copeland, L., & Hours, F. (1989b). Surface Finds from “Site C” and Other Sheshan Spring Sites. In *The Hammer on the Rock: Studies in the Early Palaeolithic of Azraq, Jordan* (Vol. 540, pp. 305–318). British Archaeological Reports.

Copeland, L., & Hours, F. (1989c). The Artifacts from the Sounding of D. Kirkbride at Lion Spring, Azraq. In *The Hammer on the Rock: Studies in the Early Palaeolithic of Azraq, Jordan* (Vol. 540, pp. 171–211). British Archeological Reports.

Copeland, L., & Hours, F. (Eds.). (1989d). The Harding Collection of Acheulian Artifacts from Lion Spring, Azraq, Jordan: A Quantitative and Descriptive Analysis. In *The Hammer on the Rock: Studies in the Early Palaeolithic of Azraq, Jordan* (Vol. 540, pp. 213–258). British Archeological Reports.

Copeland, L., & Hours, F. (1989e). The Lower and Middle Paleolithic of the desert wadis in the Azraq Basin: Survey results, 1982-1986. In *The Hammer on the Rock: Studies in the Early Palaeolithic of Azraq, Jordan,* (Vol. 540, pp. 65–152). British Archeological Reports.

Cordova, C. (2007). Millennial Landscape Change in Jordan: Geoarchaeology and Cultural Ecology. https://doi.org/10.2307/j.ctv2vdbvr9

Cordova, C. E., & Ames, C. J. H. (2017). Quaternary Sediments and Soils of Jordan: Palaeoclimatic and Geoarchaeological Implications. In O. Bar-Yosef & Y. Enzel (Eds.), *Quaternary of the Levant: Environments, Climate Change, and Humans* (pp. 531–538). Cambridge University Press. https://doi.org/10.1017/9781316106754.058

Cordova, C. E., Nowell, A., Bisson, M., Ames, C. J. H., Pokines, J., Chang, M., & al-Nahar, M. (2013). Interglacial and glacial desert refugia and the Middle Paleolithic of the

Azraq Oasis, Jordan. *Quaternary International*, *300*, 94–110. https://doi.org/10.1016/j.quaint.2012.09.019

Cordova, C., Nowell, A., Bisson, M., Pokines, J., Ames, C., & al-Nahar, M. (2009). The Druze Marsh Paleolithic Project, North Azraq Jordan Stratigraphic Sequences from the 2008 and 2009 Seasons. *ADAJ*, *53*, 311–320.

Delage, C., Sánchez de la Torre, M., Gratuze, B., & Llach, J. (2019). Supplementary Material. The lithic landscape around Kharaneh IV (Azraq Basin, Jordan): Petrographical and geochemical characterization of geological cherts.

Ekshtain, R., Ilani, S., Segal, I., & Hovers, E. (2017). Local and Nonlocal Procurement of Raw Material in Amud Cave, Israel: The Complex Mobility of Late Middle Paleolithic Groups. *Geoarchaeology*, *32*(2), 189–214. https://doi.org/10.1002/gea.21585

Ekshtain, R., Malinsky-Buller, A., Ilani, S., Segal, I., & Hovers, E. (2013). Raw material exploitation around the Middle Paleolithic site of ’Ein Qashish. *Quaternary International*, *331*. https://doi.org/10.1016/j.quaint.2013.07.025

Evans, A. A., Wolframm, Y. B., Donahue, R. E., & Lovis, W. A. (2007). A pilot study of “black chert” sourcing and implications for assessing hunter-gatherer mobility strategies in Northern England. *Journal of Archaeological Science*, *34*(12), 2161–2169. https://doi.org/10.1016/j.jas.2007.03.007

Finkel, M., Barkai, R., Gopher, A., Tirosh, O., & Ben-Yosef, E. (2019). The “Flint Depot” of prehistoric northern Israel: Comprehensive geochemical analyses of flint extraction and reduction complexes and implications for provenance studies. *Geoarchaeology*, *34*(6), 661–683. https://doi.org/10.1002/gea.21727

France, R. L. (2010). Restorative Redevelopment of Devastated Ecocultural Landscapes. *CRC Press*. https://doi.org/10.1201/EBK0415952255

Garrard, A., Baird, D., Colledge, S., Martin, L., & Wright, K. (1994). Prehistoric Environment and Settlement in the Azraq Basin: An Interim Report on the 1987 and 1988 Excavation Seasons. *Levant*, *26*, 73–109. https://doi.org/10.1179/007589194790411591

Garrard, A., & Hunt, C. O. (1989). The 1985 excavation at C-Spring. In *The Hammer on the Rock: Studies in the Early Palaeolithic of Azraq, Jordan* (Vol. 540, pp. 319–324). British Archaeological Reports.

Gilead, D. (1973). Cleavers in Early Palaeolithic Industries in Israel. *Paléorient*, *1*(1), 73–86.

Gould, R. A. (1978). The Anthropology of Human Residues. *American Anthropologist*, *80*(4), 815–835. https://doi.org/10.1525/aa.1978.80.4.02a00030

Gould, R. A., & Saggers, S. (1985). Lithic Procurement in Central Australia: A Closer Look at Binford's Idea of Embeddedness in Archaeology. *American Antiquity*, *50*(1), 117–136. https://doi.org/10.2307/280637

Gurova, M., Andreeva, P., & Stefanova, E. (2014). Chert raw materials and artefacts from NE Bulgaria: A combined petrographic and LA-ICP-MS study. *Journal of Lithic Studies*, *1*, 25–45. https://doi.org/10.2218/jls.v1i2.1129

Harding, G. L. (1958). Recent Discoveries in Jordan. *Palestine Exploration Quarterly*, *90*(1), 7–18. https://doi.org/10.1179/peq.1958.90.1.7

Hovers, E. (2003). The Lithic Assemblages of Qafzeh Cave. *Oxford University Press.*

Hughes, R. E. (2012). *Perspectives on Prehistoric Trade and Exchange in California and the Great Basin*. University of Utah Press.

Ibrahim, K. (1996). The Regional Geology of Al Azraq: Map Sheet No. 3353-II. *Geology Directorate, Geological Mapping Division, Bulletin 36. The Hashemite Kingdom of Jordan, Natural Resources Authority, Amman.*

Kandel, A. W., Bolus, M., Bretzke, K., Bruch, A. A., Haidle, M. N., Hertler, C., & Märker, M. (2016). Increasing Behavioral Flexibility? An Integrative Macro-Scale Approach to Understanding the Middle Stone Age of Southern Africa. *Journal of Archaeological Method and Theory*, *23*(2), 623–668. https://doi.org/10.1007/s10816-015-9254-y

Kelly, R. L. (1983). Hunter-Gatherer Mobility Strategies. *Journal of Anthropological Research*, *39*(3), 277–306.

Kelly, R. L. (2013). The Lifeways of Hunter-Gatherers: The Foraging Spectrum. *Cambridge University Press*. https://doi.org/10.1017/CBO9781139176132

Kirkbride, D. (1989). A Description of Stone Age Sites at Azraq, Jordan. In *The Hammer on the Rock: Studies in the Early Palaeolithic of Azraq, Jordan* (Vol. 540, pp. 153–171).

Kuhn. (1992). On Planning and Curated Technologies in the Middle Paleolithic. *Journal of Anthropological Research*, *48*(3), 185–214.

Kuhn. (1995). Mousterian Lithic Technology: An Ecological Perspective. In *Mousterian Lithic Technology*. Princeton University Press. https://doi.org/10.1515/9781400864034

Kuhn. (2004). Upper Paleolithic raw material economies at Üçağızlı cave, Turkey. *Journal of Anthropological Archaeology*, *23*, 431–448. https://doi.org/10.1016/j.jaa.2004.09.001

Kuhn. (2020). Moving on from Here: Suggestions for the Future of “Mobility Thinking” in Studies of Paleolithic Technologies. *Journal of Paleolithic Archaeology*, *3*(4), 664–681. https://doi.org/10.1007/s41982-020-00060-7

Lieberman, D. E., & Shea, J. J. (1994). Behavioral Differences between Archaic and Modern Humans in the Levantine Mousterian. *American Anthropologist*, *96*(2), 300–332.

López, S., van Dorp, L., & Hellenthal, G. (2015). Human Dispersal Out of Africa: A Lasting Debate. *Evolutionary Bioinformatics Online*, *11*(Suppl 2), 57–68. https://doi.org/10.4137/EBO.S33489

Luedtke, B. E. (1979). The Identification of Sources of Chert Artifacts. *American Antiquity*, *44*(4), 744–757. https://doi.org/10.2307/279116

Luedtke, B. E. (1992). An Archaeologist’s Guide to Chert and Flint. https://escholarship.org/uc/item/7j8387sj

Macumber, P. (2008). Evolving landscape and environment in Jordan. *An Archaeological Reader*, 1–30.

Malyk-Selivanova, N., Ashley, G. M., Gal, R., Glascock, M. D., & Neff, H. (1998). Geological–Geochemical approach to “sourcing” of prehistoric chert artifacts, northwestern Alaska. *Geoarchaeology*, *13*(7), 673–708. https://doi.org/10.1002/(SICI)1520-6548(199810)13:7<673::AID-GEA2>3.0.CO;2-3

Milne, S. B., Hamilton, A., & Fayek, M. (2009). Combining visual and geochemical analyses to source chert on Southern Baffin Island, Arctic Canada. *Geoarchaeology*, *24*(4), 429–449. https://doi.org/10.1002/gea.20273

Moreau, L., Brandl, M., Filzmoser, P., Hauzenberger, C., Goemaere, É., Jadin, I., Collet, H., Hauzeur, A., & Schmitz, R. W. (2016). Geochemical Sourcing of Flint Artifacts from Western Belgium and the German Rhineland: Testing Hypotheses on Gravettian Period Mobility and Raw Material Economy. *Geoarchaeology*, *31*(3), 229–243. https://doi.org/10.1002/gea.21564

Moumani, K. (2005). The Geology of Wadi Al Bahiya Area (Map Sheet NO. 3251-III),1:50,000 *Geological Mapping Series*. https://doi.org/10.13140/RG.2.1.4643.2486

Neff, H. (2012). Laser Ablation ICP-MS in Archaeology. In *Mass Spectrometry Handbook* (pp. 829–843). John Wiley & Sons, Ltd. https://doi.org/10.1002/9781118180730.ch37

Nowell, A., Cordova, C. E., Ames, C. J. H., & Pokines, J. T. (2014). Azraq Marshes Archaeological and Paleoecological Project (AMAPP). Report of the May 22-June 15, 2014 season at Shishan Marsh (SM1). *Department of Antiquities of Jordan*.

Nowell, A., Walker, C., Cordova, C. E., Ames, C. J. H., Pokines, J. T., Stueber, D., DeWitt, R., & al-Souliman, A. S. A. (2016). Middle Pleistocene subsistence in the Azraq Oasis, Jordan: Protein residue and other proxies. *Journal of Archaeological Science*, *73*, 36–44. https://doi.org/10.1016/j.jas.2016.07.013

Pollard, A. M., Batt, C. M., Stern, B., & Young, S. M. M. (2007). Analytical Chemistry in Archaeology. *Cambridge University Press.* https://doi.org/10.1017/CBO9780511607431

Potts, R. (1991). Why the Oldowan? Plio-Pleistocene Toolmaking and the Transport of Resources. *Journal of Anthropological Research*, *47*(2), 153–176.

Qudaira, M. A. (1997). Geological Map of Qasr ʻAmra (3353-IV), Scale 1:50,000. *Geological Mapping Division, National Mapping Project. Natural Resources Authority, Geological Directorate. Ministry of Energy and Mineral Resources. Hashemite Kingdom of Jordan*.

Qudaira, M. A. (2000). The Geology of Qasr Amra, Map Sheet No. 3353-IV. *Geology Directorate, Geological Mapping Division, Bulletin 47. The Hashemite Kingdom of Jordan, Natural Resources Authority, Amman*.

Rollefson, G. O. (1980). Late Acheulian Artifacts from ʿAin el-Assad ("Lion's Spring"), near Azraq, Eastern Jordan. *Bulletin of the American Schools of Oriental Research*, *240*, 1–20. https://doi.org/10.2307/1356535

Rollefson, G. O. (1983). Two Seasons of Excavations at ʿAin el-Assad near Azraq, Eastern Jordan,1980-1981. *Bulletin of the American Schools of Oriental Research*, *252*, 25–34. https://doi.org/10.2307/1356835

Rollefson, G. O. (1984). A Middle Acheulian Surface Site from Wadi Uweinid, Eastern Jordan. *Paléorient*, *10*(1), 127–133.

Rollefson, G., Schnurrenberger, D., Quintero, L., Watson, R. P., & Low, R. (1997). 'Ain Soda and 'Ain Qasiya: New late Pleistocene and early Holocene sites in the Azraq Shishan area, eastern Jordan. *The Prehistory of Jordan*, 45–58.

Sánchez de la Torre, M., Angyal, A., Kertész, Z., Dubernet, S., Le Bourdonnec, F.-X., Papp, E., Szoboszlai, Z., Török, Z., Csepregi, Á., & Szikszai, Z. (2019). Micro-PIXE studies on prehistoric chert tools: Elemental mapping to determine Palaeolithic lithic procurement. *Archaeological and Anthropological Sciences*, *11*(6), 2375–2383. https://doi.org/10.1007/s12520-018-0668-9

Sánchez de la Torre, M., Gratuze, B., Mangado, X., & Delage, C. (2019). The lithic landscape around Kharaneh IV (Azraq Basin, Jordan): Petrographical and geochemical characterization of geological cherts. *Journal of Archaeological Science: Reports*, *26*, 101857. https://doi.org/10.1016/j.jasrep.2019.05.022

Shackley, M. S. (1988). Sources of Archaeological Obsidian in the Southwest: An Archaeological, Petrological, and Geochemical Study. *American Antiquity*, *53*(4), 752–772. https://doi.org/10.2307/281117

Shackley, M. S. (2008). Archaeological Petrology and the Archaeometry of Lithic Materials. *Archaeometry*, *50*(2), 194–215. https://doi.org/10.1111/j.1475-4754.2008.00390.x

Shea, J. J. (2013). *Stone Tools in the Paleolithic and Neolithic Near East: A Guide*. Cambridge University Press. https://doi.org/10.1017/CBO9781139026314

Shiloh, M. U., MacMicking, J. D., Nicholson, S., Brause, J. E., Potter, S., Marino, M., Fang, F., Dinauer, M., & Nathan, C. (1999). Phenotype of Mice and Macrophages Deficient in Both Phagocyte Oxidase and Inducible Nitric Oxide Synthase. *Immunity*, *10*(1), 29–38. https://doi.org/10.1016/S1074-7613(00)80004-7

Shimelmitz, R., Kuhn, S. L., & Weinstein-Evron, M. (2020). The evolution of raw material procurement strategies: A view from the deep sequence of Tabun Cave, Israel. *Journal of Human Evolution*, *143*, 102787. https://doi.org/10.1016/j.jhevol.2020.102787

Shott, M. (1996). An Exegesis of the Curation Concept. *Journal of Anthropological Research*, *52*, 259–279. https://doi.org/10.1086/jar.52.3.3630085

Sonnefeld, P. (1978). Eurasian ophiolites and the Phanerozoic Tethys Sea. In *Zur Plattentektonischen Entwicklung des Indo-Iranischen Raumes (Resultate Palaomagnetischer Untersuchungen in Afghanistan)*. (Vol. 56, pp. 1–88).

Geotektonische Forschungen.
https://www.schweizerbart.de/publications/detail/isbn/9783510500222/Geotekt_Forsch_H_56

Speakman, R. J., & Neff, H. (2005). Laser Ablation ICP-MS in Archaeological Research. *UNM Press*.

Ta'any, R. (2013). Availability of Surface Water of Wadi Rajil as a Source of Groundwater Artificial Recharge: A Case Study of Eastern Badia /Jordan. *Current World Environment*, *Volume 8*(Issue 2). http://www.cwejournal.org/vol8no2/availability-of-surface-water-of-wadi-rajilas-a-source-of-groundwater-artificial-recharge-a-case-study-of-eastern-badia-jordan

Taylor, W. W. (1964). Tethered nomadism and water territoriality: An hypothesis. In *Acts of the 35th International Congress of Americanists – Actas y Memorias 35th Congreso 427 Internacional de Americanistas.* (pp. 197–203). Mexico City: Instituto Nacional de Antropologja e Historia.

Vita, G., Forgia, V., Pinto Vraca, M., Calabrese, N., Divita, D., & Sineo, L. (2022). Petrographic characterization of quartzite tools from the Palaeolithic site of San Teodoro cave (Sicily): Study on the provenance of lithic raw materials. *Journal of Archaeological Science: Reports*, *45*, 103593. https://doi.org/10.1016/j.jasrep.2022.103593

Wilson, L. (2007). Understanding Prehistoric Lithic Raw Material Selection: Application of a Gravity Model. *Journal of Archaeological Method and Theory*, *14*(4), 388–411. https://doi.org/10.1007/s10816-007-9042-4

Worzyk, P. H., & Huester, M. (1987). Geological survey in Azraq area north-east Jordan. *Bundesanstalt fuer Geowissenschaften und Rohstoffe (Federal Institute for Geosciences and Natural Resources)Assigned by the Federal Ministry for Economic Cooperation,* Hannover, Germany.