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Shaping the Stone:
Experimental Approaches to the Plain of Jars Megaliths, Lao PDR.

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Abstract

Archaeological interest in the Plain of Jars has been increasing over the last two decades. Much work has been undertaken in cooperation with UNESCO as part of a long-term heritage management program, culminating in 11 sites being granted World Heritage Status as of 2019. Numerous excavations have been undertaken exploring the area's prehistoric past with a joint research project between Australia (lead from ANU) and Laos (Dept. of National Heritage) being the most recent endeavour in the area. The Plain of Jars is comprised of a large megalithic complex located in upland Laos. The complex includes over 100 megalithic jar sites scattered in the mountains surrounding the plains. The sites remain mostly a mystery with little known about the jars, their purpose, or the people who produced them. Past research has been limited to an investigation during the 1930s before socio-political influences made the sites inaccessible for decades. Recent excavations have built on this groundwork investigation, reiterating many of the interpretations and assumptions. Current dating remains uncertain, with a broad potential range from 3500 BCE through to 1300 CE. The suggestion of Iron Age associations proposed by Madeleine Colani in her key research, *Des Megaliths Du Haut-Laos*, still remains influential on current understandings of the region. This association obviously emphasises the early to late Iron Age dates. The work also proposes iron tools were necessary to produce the jars and create the tool marks present upon them, further directing the narrative to an Iron Age dating.

This research approaches these assumptions with a critical focus, attempting a revision of past interpretation by exploring both extant literature and experimental practice. The research aims to determine the validity of these interpretations through an experimental approach, providing insights into previously unexplored aspects of megalith production. An initial literature review builds a framework for viewing the Plain of Jars megaliths within a diverse – and comparable – global megalithic range. Current literary understandings of megalith production suggest that large stone monuments were in production from very early in prehistory with the earliest identified in the Mesopotamian Pre-Pottery Neolithic (PPN); millennia before metallic tools were first produced. The use of non-metallic tools is not limited to this singular example however, as non-metallic tools were of primary use within eight of the nine contexts explored.

The continued presence of these assumptions in light of the contrary literature prompted the critical review undertaken through this work. The research poses three questions which aim to explore; 1.the jars production methods, 2.the time investment, and 3.the manufacturing detritus produced. From these research questions a number of other ideas can be explored and the data expanded with future work. An experimental archaeological approach was taken throughout the research, producing scaled jars to explore the production process. This research approach is accompanied by the application of elements of Practice Theory, in the form of *Chaîne Opératoire*, emphasising practice and an empirical understandings of jar production.

The research finds that the jars can be easily produced with all manner of tools tested – including steel, iron, bronze, copper and stone – with minor variation in time investment between each of the tools. Contrary to the belief that iron tools were necessary for jar carving, all manner of tools proved capable. The bronze tools experienced fewer breakages and overall required a lower frequency of reworking and sharpening than other examples, making bronze the superior tool throughout this experimental work. The task of jar production is relatively quick with small jars, such as those present at Jar Site 52, taking approximately 22 hours for a single craftsperson to produce. Jars of a more average size (approximately 1.5 meters tall) may take as little as 36-37 hours to produce, with the possibility of shorter production times if more craftspeople were involved. This provides a range of interpretative avenues which are explored in discussions of craft specialisation, cultural significance, and individual experience. Lastly, the research determines that the majority of material debitage produced by the carving process is comprised of fine, highly transient dust and small flakes. All debitage is fragile and highly susceptible to further breakage, adding to the already dominant fine dust debris. This finding may correlate to recent work undertaken at Jar Site 52 where a potential working floor comprised of fine dust was excavated.

These findings and observations lead into a discussion of further questions raised by the experimental work and avenues of future research. Overall, the research finds that the interpretations highlighted by Colani were not supported by the research outcomes. Not only does the research recontextualise these assumptions, it furthers understandings of the Plain of Jars megalithic complex, while offering insight into the lives of those who produced the jars. While little is known regarding the lived experience of past inhabitants of the Plain of Jars, this research provided a window into a small but highly valuable aspect of the community and individual experience.

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Chapter 1.

Introduction

The archaeology of Southeast Asia is an actively growing field of interest. Compared with its northern hemisphere counterparts there remains large gaps in our knowledge of the area's prehistory, but this appears to be changing. Work throughout Southeast Asia has been occurring with greater regularity, with understandings of the area's past being expanded with every excavation. Although this research has been increasing, the prehistory of the Lao PDR, or Laos, remains relatively unexplored with only a small pool of literature regarding the country's prehistory. The past two decades may have seen a rise in archaeological interest into this fascinating corner of the world, yet insights into past cultures and practice have been somewhat limited. Aside from the work undertaken by UNESCO, much of the present work in Laos is being undertaken as a part of two separate projects, the Middle Mekong Archaeology Project and the Joint Australia-Laos Plain of Jars research project. The joint Australia-Laos research Project aims to investigate the numerous jar sites throughout the Xiang Khouang province. The project also aims to uncover new jar sites and identify potential settlement locations associated with the jar production culture. In spite of this project very little is known about the cultures who produced and used the jars. This continued lack of knowledge is fascinating considering the recent awarding of UNESCO World Heritage Status for 11 jar sites within the Xiang Khouang province. Currently it is unknown whether the individuals who produced the jars and the community who buried their dead amongst the jars (principally Jar Site 1) are one and the same. This uncertainty surrounding the cultures who produced and used the jars is augmented by the country's various borders. Sandwiched between Myanmar, Thailand, China, Cambodia and Vietnam; Laos represents an interesting meeting place of different cultures in the past as well as the present. The range of cultural impacts on the regions prehistory can be glimpsed through the three archaeological complexes granted UNESCO World Heritage Status. Firstly, Vat Phou of Champasak which beckons back to the Angkorian (and pre-Angkorian) period of Laos, Thailand and Cambodia represents a key cultural element of Laos' past; while the historical capital of Luang Prabang represents a distinctly separate cultural element of the country during the pre-Angkorian period. The Plain of Jars beckons to another, older, culture shrouded in mystery.

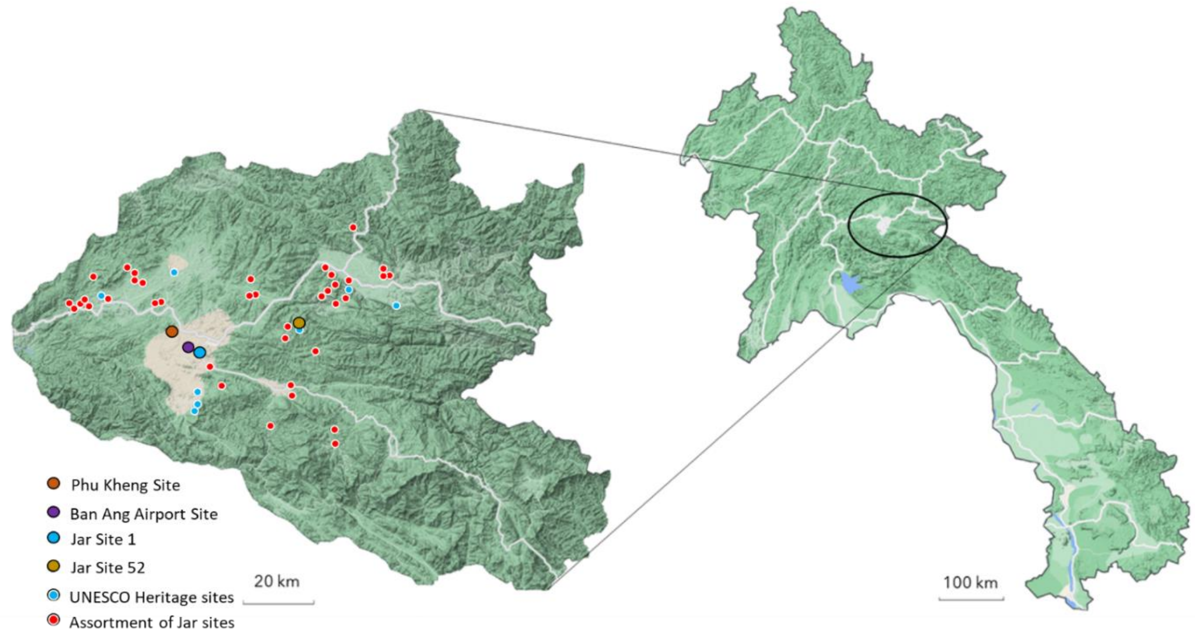

Figure 1. Map of Xiang Khouang with key sites marked.

Amongst the most famous archaeological complexes of Laos, the Plain of Jars has fascinated archaeologists and the general public alike. The large stone jars which speckle the countryside of the Xieng Khouang province (with a few extending into the neighbouring Luang Prabang Province) are the centrepiece of the region and its prehistoric past. Radiocarbon dates suggest the sites may be dated from the early Bronze Age (1050BCE-450CE), throughout the Iron Age (450 BCE- 500CE) and well into the Proto-historic (500CE- 1000CE) (Higham & Kim 2022:501). While the sites have such a wide range of dates many archaeologists defer to the dating of Jar Site 1 which ranges from 800 CE to 1300 CE (O'Reilly *et al.* 2019: 985-7) (dating issues around the site are discussed in more detail in chapter 2). The artefacts buried around the jars are ubiquitous with the Southeast Asia Iron Age, further supporting the dating range present at Jar Site 1. Although this site is the most heavily explored, it remains an outlier regarding locale. Most sites are scattered throughout mountain tops and saddles surrounding the plains region while Jar site 1 is situated within the centre of the plain. Over 100 jar sites have been uncovered throughout the region, however, only a small number have been excavated. Currently the most heavily explored sites are those granted UNESCO World Heritage Status, those being jar sites 1, 2, 3, 8, 12, 21, 23, 25, 28, 42 and 52. While these sites are few in number, they represent a range of site locales and display a variety of jar size, form and distribution. Some sites contain only singular jars while others contain upwards of 400, with jars of between 1-2 meters in height being the average size. Some sites are comprised of jars of consistent size and form, such as a portion of site 52 which is comprised entirely of small jars only 50cm in height, or site 2 which contains a consistent square shape across all of the jars within.

Various myths surround the jars' production, some suggesting the jars were used by giants as cups while others suggest the jars were produced to commemorate a victory by local king or ruler. While these myths add to the wonder and mystery of the sites recent research suggests the jars were used in a portion of the local mortuary practice of the region (O'Reily *et al.* 2019; Genovese 2019b; Shewan *et al.* 2021). The theory suggests jars were employed in both cremations and de-fleshing of deceased individuals before secondary deposition within the ground surrounding the jars (see Colani 1935; O'Reilly *et al.* 2019; Genovese 2019b). The presence of a limestone cave used for cremations within the centre of the Jar Site 1 assemblage also builds into the interpretations of mortuary practices (Colani 1935; O'Reilly *et al.* 2019).

Figure 2. Jar Site 1, The Plain of Jars.

The interpretation of the Plain of Jars as a mortuary complex has been present in the literature since the initial excavation of Jar Site 1 in the 1930s by Madeleine Colani (1935a; 1935b). The work undertaken by Colani underpins the current understandings of the complex with many of the ideas surrounding the purpose, usage and production of jar sites stemming from her initial publications. While the work of Colani is almost 100 years old it remains the most comprehensive investigation into the region's prehistoric sites. Numerous sites identified and reported by Colani were damaged or lost during the Vietnam War, referred to as the American War within Laos, which heavily impacted the Xiang Khouang province due the strategic location of the region. Although socio-political tensions in the region have subsided, long-term impacts upon jars sites and the landscapes have further restricted excavation proceedings. Currently Laos remains one of the most heavily bombed country's in world *per capita*, (Genovese 2012: 3) with a large portion of the Unexploded Ordnance (UXO) being situated within the Xiang Khouang province with approximately 25% of the provinces total land being contaminated by UXO (Box 2003: 95).

As a result of these socio-political influences, largescale work within the region has only been achievable for a short period over recent years with progress slowed by dangerous UXO riddled landscapes. The new work undertaken is mostly comprised of the joint project between Australia and Laos, run by the Australian National University (ANU) and the National University of Laos (NUoL) in conjunction with the Lao Department of National Heritage and numerous other universities throughout Australia. Although this new work is underway and gaining traction quickly, the small pool of prior research material results in a high reliance on previous interpretations suggested by Colani. Some of these interpretations have been drawn into question by archaeologists in the field (Genovese 2019a) yet many still remain.

Much of the work being undertaken by archaeologists in the region centres upon the material remains surrounding the jars, forgoing investigations regarding the jars themselves, which remain largely unexplored. When considering the dating of the jar sites, each example of older dates appears to be discounted while dates situating the sites within the Iron Age are reinforced throughout recurrent literature (O'Reilly et al 2019; 983- 987; Sayavongkhamdy & Bellwood 2000: 105). This practice can be back traced to Colani's original suggestion that Jar Site 1 was produced using iron tools (Colani 1935a: 134). While Colani discusses the likelihood of iron tool usage as a certainty for Jar Site 1 and as a possibility for sites 2, 3 and 7; she offers no alternatives to these sites and discounts the possibility of earlier production (Colani 1935b: 123.). Subsequent work identified supporting data giving some backing for the claims made, while still relying on Colani's interpretations as foundations (O'Reilly 2019a; UNESCO 2019:17, 35). The narrative of Iron Age production and use not only ignores the wider array of data present within the Plain of Jars (see Genovesse 2019a; Shewan *et al*. 2021; Bellwood and Sayavongkhamdy 2000), but the data from global megalithic examples. This research thesis aims to review these past theories, providing data to verify their accuracy and provide deeper understandings of the people who produced the jars and used them.

The research strives to better understand the process and material consequences of jar production through the application of experimental archaeology. A revision of past research provides the basis for this thesis, offering insights into understandings of the Plain of Jars itself alongside analogous data from global megalithic case studies. These case studies offer insights into megalith production as a whole while offering more particular insights into the usage of different tool materials, different stone types within the megaliths themselves, and some insights into the lives of the stone workers to a smaller degree.

The experimental work at the core of this thesis attempts to answer a number of key question regarding the production of the Plain of jars megaliths, with each focus question exploring a distinct element of jar production:

(1) What are the mechanics of jar production?
(2) Considering production time, how where the jars valued by the people who produced them?
(3) What debris is created by the jar production process?

These foci provide other accompanying questions; what tools are required for the carving? How long does jar carving take? Are jar carving workshops identifiable through debris? As such the focus of this research is to provide a greater level of understanding of the Plain of Jars megaliths and the processes involved within their production. Undertaking experimental carving work to produce a jar of similar form and dimensions is the most insightful analytical process available. As with other megalithic analysis, the employment of experimental archaeology will provide guidelines and clear variables for the production of a jar. Undertaking this research in this format allows for a highly detailed account of the process and provides the opportunity for further assessments to be undertaken. Archaeological analysis of megaliths has often been shaped by Actualistic approaches (Van Tilburg & Ralston 2005; Routledge 1919; Lavachery 1935; Heyerdahl *et al*. 1989) which promote exploration of production practices and allow a critical analysis of site interpretations.

Production of a scaled jar allows a detailed understanding of the production process itself and the material consequences of the practice. Poised mostly around the analysis and understanding of practice without the assumptions that often accompany analysis of meaning; the use of Actualistic approaches aims to enhance understanding of practice without the bias and assumptions which are present in other frameworks. Actualism shapes both the review of existing literature in its critical evaluation of past assumptions as well as the experimental work undertaken. The use of analogues data from other megalithic examples provides a basis for the experimental research while also giving data to cross-reference against.

The research is designed to answer the above questions while also acting as a baseline study for future work to build upon. The application of Experimental Archaeological approaches with the addition of analytical elements of Practice Theory achieves the necessary degree of data collection while providing a framework to develop a comprehensive understanding of jar production. The methodology builds on experimental creation of scaled jars exploring the variance in tool capabilities, resulting tool marks, impact of size on time investment and debris production.

Using both existing literature and the data from the experimental work, a range of interpretations may be explored. Not only does the research review and revise the past theories surrounding the Plain of Jars, the research produces new hypotheses to be tested by future experimental work. The experimental work is structured as an empirical analysis of jar production, employing *chaîne opératoire* to provide a rigorous carving procedure based on findings in the Plain of Jars. The data is then used to view likely practices and estimate the necessary time investment. The research explores the idea that the jars had to be produced with ron tools, effectively limiting the earliest production to the regional Iron Age. This research works to provide an earliest production time, based on tool material necessity. Furthermore, the research explores the identifying tool marks produced by different tool materials, offering insights into Colani's belief that iron tools produced Jar Sites 1, 2, 3, and 7 (Colani 1935a: 134, 144; Colani 1935b: 123).

This experiment offers insight into the lives of those who manufactured the jars, their potential role within cultural practice, and the resources and time devoted to the jars' production. While most of the data in current literature displays technological complexity and potential dating ranges of the jars, none of the data addresses the lives of those who produced the jars. Not only does this research offer empirical data which greatly reworks understandings of jar production, it also offers a phenomenological window into the lives of those who produced the jars, recontextualising their place in cultural practice.

Chapter 1 has provided a brief introduction to the research project and its core focus. Chapter 2 will continue to explore this focus through an analysis of past archaeological literature regarding the Plain of Jars while offering comparative analysis to a wider megalithic repertoire. Cross comparison offers numerous insights into mechanical and structural complexity of stone carving practice throughout time with interesting implications for past theories in the Plain of Jars region. Chapter 3 provides an explanation of applied theoretical frameworks regarding literature revision and experimental practice. Flowing from this Chapter 4 details the method employed and a further description of particular elements of the methodological framework developed for this research as well as materials involved. Experimental results and implications are then provided in Chapter 5 before a discussion of the implications and their impact on our understanding of the prehistory of Laos and the wider world within Chapter 6. Lastly, Chapter 7 offers a conclusive recap of research findings and implications.

Chapter 2.

Background

Megaliths are one the most fascinating elements of the archaeological record. They are viewed by the world as beacons of the past, of forgotten rituals and practices left behind. This mysticism is not lost on the archaeologists who study these monuments of the past, remaining enigmatic to academics also. The uses of megaliths have been speculated on by seasoned archaeologists, astronomers and practitioners of neo-Druidism alike. Yet many aspects of megalith production and their roles in society remain a mystery. Theories surrounding the utility and purpose of megaliths are not the only mystifying aspects of megaliths; much energy is also devoted to trying to understand processes such as quarrying, transport and final production practices. Academic approaches to these aspects will be explored, while also discussing the less academic ideas and beliefs which surround these fascinating creations of the past. These understandings of the world of megaliths will provide a broader context for subsequent enquiries into the Plain of Jars, and centrally the jars themselves. As with sites such as Stonehenge, the Plain of Jars sites are heavily loaded with meaning for a number of contemporary communities. Thus it is important to acknowledge these alongside the specific archaeological questions of who, when and why with regards to the original creators of the jars.

2.1 Megaliths

To understand the complex history of megalithic structures it is important that a definition of megaliths be laid out in full. What is considered a megalith? Anything from the Deer Stones of the Mongolian Steppes to the famous stone circles of Stonehenge are called megaliths by academics. The definition of the term remains highly subjective. The term megalith is used to describe a number of archaeological formations and has become synonymous with key sites such as Göbekli Tepe, the Moai of Easter Island and, most prominently, Stonehenge. Stonehenge remains synonymous with the term 'megalithic' due to the earliest use of the term referring to the famed site by Algernon Herbert in 1849.

First used as a descriptor of Stonehenge in Herbert's 1849 book *Cyclops Christiannus*, Megalithic is a term with a relatively simple origin. The etymology of the term is derived from English and Greek, with *Lithos*, meaning 'stone', which is also a key element of a number of descriptors used within the study of archaeology (i.e. Lithic, Neolithic, Paleolithic, etc.). The straightforward translation of Megalith means large (Mega) stone (Lithos), and is most commonly applied to large stone structures or monuments. Renfrew (2000) suggests the term was first used in its German form, *Megalithismus*, by

German scholars and was adopted into the English vocabulary in a further Latinized form (Renfrew, 2000: 726).

Determining what is and is not considered a megalith is not so simple a task as translating the word meaning. There have been attempts to further define the term and categorise the structures it includes into more refined categories. There appears to be little use or success with the implementation of these refined categories however.

It has been suggested that the term Megalith is indicative of a number of aspects such as:

> (1) Anthropogenic facilities, immovable cultural monuments, (2) built in the Chalcolithic, Bronze or Early Iron Age (VI – mid I mill. BC) (3) of rough poorly processed stone blocks, monoliths of various form – pillars, slabs, polyhedrons (4) using the minimum possible and sufficient quantity of building components (5) by grouping rough stone orthostats on the terrain (menhirs, cromlechs) or by front assemblage of slabs which get in contact not at their walls but along their periphery only (dolmens). Megaliths are specific constructions, buildings realized without rock carving and without dry masonry.' (Tsonev, 2019: 1)

Tsonev (2019:3), further argues that structures that incorporate drystone masonry and rock carving can instead be considered 'quasi-megaliths'. In contrast, I argue that this definition is too narrow, especially in regards to carvings. For example, many megaliths incorporate carved elements or edifices into their production, including the carved axes on some of the Stonehenge elements. Similarly, drystone masonry is present in numerous pinnacle megalithic examples, chiefly the numerous pyramid traditions. Although each of these elements are definitely present within megalith production, drystone masonry is of lesser consequence to this review.

Others have suggested the stone and production elements themselves are of little importance. Rather, arguing that the modern use of the term is focused more heavily upon the socio-religious purpose and cultural aspects associated with the structures (Moorti, 2008:746). The socio-religious role of megalithic structures cannot be understated with monumental structures being key to both social cohesion and cultural practice the world over. While this element is key, Moorti (2008:746) further suggests that the presence of iron artefacts associated with the structures is of greater importance than the use of stone in the construction. This concept contradicts both the Neolithic dating of a large number of megaliths – including some of the most famous megaliths such as Stonehenge (3800 BCE) and, even earlier, Göbekli Tepe (9000 BCE) and the lithic element of megaliths which is a definitive feature.

The literature review demonstrates a range of views regarding what is and is not considered a megalithic structure. Interestingly, some of these articles directly contradict the earliest use of the term with regard to Stonehenge (for example, Moorti's (2008) claim that megaliths are always associated with iron). As this short review demonstrates, there are a range of views on what constitutes a megalith. This review will focus more closely with the earlier uses of the term and define a megalith as a monumental structure, produced chiefly from large stone elements. Considering the earliest application of the term; a megalith is any structure with one or more construction elements (including menhirs and capstones) produced using large stone elements. Megaliths hold strong association with particular dating periods and socio-religious elements yet these are not always present and have not always been proven (regarding socio-religious purposes). With the past definitions in mind I can now discuss the range of megaliths across global prehistory to provide a broad context for the Plain of Jars.

The megalithic sites focused on throughout this review are;

(1) Large cultural monuments with varied social, religious and cultural values. The sites are (2) comprised of large stone components featuring a small number of megalithic elements that often demonstrate evidence of stone carving, both iconographic and structural, with (3) emphasis being placed upon the stone itself, rather than the stone being purely a construction medium (drystone masonry) and (4) dating from as far back as 12000 years to recent history.

If stone is the construction component and has been used in a large and somewhat unrefined form then the structure can be considered a megalith within this review. Some structures with more heavily refined stone elements such as the Egyptian pyramids, Mesoamerican monumental structures and the numerous temples of Southeast Asia will not be included in this overview as they are considered to fall into another category of engineered buildings or structures. Further, these stone structures are not directly relevant to the aim of better understanding the Plain of Jars monuments. These latter megaliths are more consistent with the general definition of the term discussed above.

Before going on to discuss specific case studies of megaliths, it is useful to discuss in more detail some general aspects of the study of megaliths, in particular, their purpose in society and investigations of quarrying and transportation. These will be referred to within the discussion of individual site also as they represent key elements of megalithic inquiry.

Purpose of Megaliths

Megaliths represent a strange phenomenon in the archaeological field of study due to the range of non-archaeologists who interact with the monuments and develop their own ideas surrounding the sites. Monuments like those spread throughout the United Kingdom have a variety of associations connecting them with other fields of study. It has previously been suggested that the design of Stonehenge displays some relation to celestial bodies. Astronomers were amongst the first group to draw on Stonehenge as a structure of interest to their discipline. These connections were initially based on little more than notes made by Julius Caesar regarding the cosmology and astronomical knowledge of the druids who the monuments are very commonly associated with (Michell, 1999: 7). The general consensus of academic opinion now is that Stonehenge represents a site of ritual importance which also accommodated the burial of chieftains in the vicinity (Cusack 2012: 139). Although elements of Stonehenge's celestial connections have been disproven, namely the predictive capacity regarding solar and lunar eclipse, the megaliths' solar alignment remains important to archaeoastronomy (North 1997). In contrast to ideas of celestial connections which remains, it is clear that original construction of Stonehenge preceded the rise of druidism in the British Isles (Michell, 1999: 7). However, outside of the archaeological community many people still believe that Stonehenge and similar sites are, and have always been, a key element in the practice of druidism. Some of these proponents have developed Neo Druidism and other systems of belief surrounding the megaliths as ritual areas and points of gathering. This is clearly displayed by the mass initiation of 650-700 members into the Albion Lodge of the Ancient Order of Druids in 1905 which was a largescale ceremony that took place at Stonehenge (Mohen 1999: 26).

Making associations between belief and megalithic structures is challenging, as proving connections between specific cosmological ideas and the physical remains of megaliths is nearly impossible. Associations can be drawn between the stones' orientation and positioning throughout the environment yet little of this evidence is substantial enough to produce a solid foundation of the claims of astronomical insights (see Bender 1992 and Fagan 1998). At the core of these connections and associations is the idolisation of these sites as something of cosmic importance. The very nature of megaliths builds a sense of wonder and mystery and it is this mystery that many are drawn to, placing megaliths at the centre of their own cosmologies. Few other elements of the archaeological record invoke such a sense of wonder and fascination from the general public and those of non-archaeological scholarly backgrounds. The appropriation of Stonehenge by Druids (in Caesar's time) and later neo-Druids illustrates that meaning and use of megaliths will change over time – the solidity of the structure mean they continue to exist as landscape features long after their original creators have gone. This is just as important a consideration for the Plain of Jars as it is for Stonehenge. While the jars of Laos have been potentially identified as mortuary vessels by archaeologists (O'Reilly et al. 2019; Colani 1935a; Colani 1935b; Shewan et al. 2020; Bellwood and Sayavongkhamdy 2000), local legend of kings and wine production continue to shape understandings of the region and its past (Colani 1935a: 120-122).

Common threads of thought regarding the purpose of megaliths include the belief that megalithic structures are either directly linked to mortuary rituals, or, are points of socio-religious importance for the surrounding communities. In terms of their use in mortuary practices, some of the associations can be clearly proven through archaeological remains. Examples of megalithic structures serving as tombs and burial vessels are relatively common and widespread in a number of countries around the world (see O'Reilly et al 2019, Genovese 2019b, Fitzhugh 2017, Hasanuddin 2016, Barbier 1987 & Prasetyo 2012). During initial investigations of megalithic with the United Kingdom it was argued that the structures acted as both tombs and territorial markers of sorts. It was proposed that increased competition and higher population pressures meant that megalithic mortuary structures displayed social cohesion and provided a territorial advantage to the groups which produced them (Renfrew 1983: 162-

163). Others have critiqued this approach, suggesting it neglects the meaning of the tombs and what they signified in a particular cultural context (Hodder 1984: 55). Furthermore, the viewing of megaliths themselves as a phenomenon of social development forces an evolutionary view upon the structures, making them purely a stage within social development or emerging as a response to local problems or pressures (Sherratt 1990: 147).

Surrounding material remains, orientation and (in some cases) carvings and iconography offer insights into the roles played by these highly important megaliths. Extensive work has been focused upon the role megalithic structures have played in key cultural developments (see Fitzhugh 2009; Clare *et al.* 2018; Schmidt 2010; Adams 2019; Wright 2014; Busacca 2017; Dietrich *et al.* 2012), as will be discussed below. The site of Göbekli Tepe has been extensively discussed as a key pre-agricultural meeting and feasting area which brought about a reconsideration of the understandings of the transition to agriculture in the Near East (see Schmidt 2010; Dietrich *et al.* 2012; Clare *et al.* 2018). The role of megaliths may not be easily attributed with certainty, but they are highly valuable nonetheless. Practice surrounding megaliths is not relegated to finished products however, with just as much practice and importance being found within the building and transport of megaliths.

While many of the ideas explored above are of little interest to archaeologists, the narratives of megalithic structures remain a prominent part of their history. While many modern beliefs transposed upon the structures are not supported by archaeological findings, they remain important to discuss. These ideas show that while the peoples and culture who produced megaliths may disappear, as is the case within Laos, the structures remain and are attributed new meaning and purpose, well into the modern day. Reuse of megalithic structures for different purposes can be seen in the modern use of Stonehenge as a place of ritual. Similar occurrences are very much a possibility within the context of Laos and are precisely why further research regarding the jars themselves, rather than the material around them, are of great importance.

Quarrying and Transportation

The processes involved in the production of megaliths vary greatly across the globe. However, one key aspect is almost always necessary, the quarrying of the stone. Further, the process of transporting the stone from quarry to final use site is also a common factor.

Working backwards from the finished production, transportation represents the most tested element of megalith production. In some instances, the stone used to produce megaliths is erected in the final form only meters away from the quarrying location. Yet other instances show long distance transportation, as seen in the transportation of the spotted dolerite, known as ‘preselite’, used in the production of Stonehenge. This stone was believed to be quarried some 230km away from its final placement (Parker

Pearson *et al.* 2019: 46). Archaeologists have used a number of methods to investigate the provenance the original location of megalithic stone and in some instances experimental work has been undertaken to recreate their transportation methods (see Lipo, Hunt & Rapa Haoa 2013; Hazell 2013; Van Tilburg & Ralston 2005) with others applying modern technology to track potential routes and stone sources (see; Hazell & Brodie 2012; Parker Pearson *et al.* 2015; Parker Pearson *et al.* 2019; Gillings & Pollard 2016). In other studies, ethnographic analysis of modern megalith builders focused on providing insights into past practices (see; Adams 2019; Genovese 2019b; Steimer-Herbet 2018, Adams & Kusumawati 2010). Each of these approaches provided insights into the transportation methods and distances, with ethnographic work providing insight into participant numbers and the role these practices play within community. Exploration of megalith transport, either ethnographic or experimental, is likely one of the most heavily explored elements of megalithic production.

Returning to the practices of quarrying, the analysis of how the stones were removed from their initial outcrops and stone deposits has been the focus of a number of exploratory studies (see; Parker Pearson *et al.* 2019; Mens 2007). Some experimental work has been undertaken to replicate the quarrying procedures believed to have been used in different regions of the world. Other approaches have been employed to analyse the ways in which the original location of the stone within their original outcrops effects the final form of the megaliths (Parker Pearson *et al.* 2015; Gillings & Pollard 2016; Mens 2007). Some of these approaches have been borrowed from other areas of archaeological enquiry, such as refitting, which is traditionally a method for analysing the processes involved in stone tool production. In Mens (2008: 27), a technique of 'mental refitting' has been used to produce a *chaîne opératoire* regarding the stone's removal from the original outcrops. Mental refitting approaches megalith quarrying in a similar fashion to lithic tool production, with the stone employed within the megalith representing a flake and the quarry representing the core. Mental refitting sees the megalithic elements refit into their original position within the quarry, to provide insights on quarrying order and quarrying methods. This approach is useful for understanding the procedure for removing multiple elements from a singular source of stone.

A subtle distinction also exists between the terms quarried and extracted, with each indicating slight deviations in the acquisition of stone. Extraction involves less invasive channelling prior to the stone being dislodged from the outcrop. This is the process suggested by Parker Pearson et al (2019:54) for the acquisition of the spotted dolerite from Presli Hills for Stonehenge. In this instance, stone wedges made from sandstone or mudstone were used to lever away the naturally forming pillars from the parent outcrop (Parker Pearson *et al.* 2019:54). The natural pillar-like formation of the dolerite at Carn Goedog (as shown in Fig 3.) allowed for extraction to take place, removing the need for large scale quarrying processes.

Figure 3. Unmodified in situ dolerite pillars from Carn Goedog, Viewed from north-west (Photograph by Adam Stanford in Parker Pearson et al. 2019:53)

Quarrying differs from extraction mostly in the time and tools required for the task. Quarrying is far more invasive and requires large scale waste-stone removal to allow the final form to be dislodged form the outcrop. Extraction relies on pre-existing separation in stone layers, reducing the required labour significantly. Within the case studies explore below, quarrying is the more common process (see Gobekli Tepe, Moai, Mongolian Deer stones and the Plain of Jars). The easier method of extraction is less common as appropriate stone formations which can easily be dislodged in this form are relatively scarce. The practice of stone extraction is mostly seen in the British Isles alongside evidence of quarrying also occurring in localised contexts (Daniel 1963:19).

Quarrying practice in Southeast Asia

Although the Khmer temples of Thailand are not explored as megaliths within this research, stone quarrying practice employed for these monuments demonstrate the difference between quarrying and extraction. Furthermore, the similar quarrying methods employed between Thailand and the Plain of Jars display parallels.

Figures 4 & 5 display the quarrying of rectangular blocks from stone outcrops in both Thailand (Fig 4.) and Laos (Fig 5.). A theory proposed by the former Director of the Lao Department of National Heritage, Thongsa Sayavongkhamdy, suggested that the jars were quarried and partially shaped at the quarry location (in Chang 2017; Chang 2018). The jars were believed to have then been transported to a workshop in closer proximity to their final site placement, with the last shaping of the stone occurring within these workshop locations. As of yet no workshops have been clearly identified.

The images show the clear difference within extraction and quarrying practice as extensive addition work is required to remove the stone blocks from their bedding in the contexts of Thailand and Laos.

Figure 4. Sandstone quarries in Khorat Province, NE Thailand. Stone blocks are approximately 1.5 m in length (Photograph by Nigel Chang 2018)

Figure 5.Quarry site Associate with Jar Site 23, with partially worked jar on left side (Photograph by Nigel Chang 2018)

Current understandings of megaliths range greatly between sites and throughout the time periods and diverse cultural contexts they represent. While the range of megaliths is vast and varied there are some similarities between different sites. Exploring common elements such as transportation and stone acquisition alongside analysis of megalith purpose and value are some of the more heavily employed approaches to these stone marvels. The labour-intensive nature of megalith production draws the sites into parallels with each other, also building into the associated value placed upon the structures by both the modern observer and the people of the past. While the practices of megalith production likely differ greatly around the world, an understanding of a range of megalithic examples offers analogous insights into the Plain of Jars. The range of megalithic repertoires also add to the production of a *chaîne opératoire* to explore the Plain of Jars context. *Chaîne opératoire* has been used explicitly to explore other megalithic examples previously (see Mens 2008), but can also be seen implicitly with discussions of other megalithic productions (Van Tilburg & Ralston 2005). This chapter will continue to explore the global phenomenon of megaliths in greater detail, providing context from which to build and refine the ideas explored within the experimental portion of this thesis.

2.2 Megalithic Case Study

Megaliths exist across every occupied landmass of the world. The range of megalithic form and function varies as greatly as their geographic locales if not more so. While this range of sites is vast and varied, some are more relevant to this thesis and the questions it poses. Following is a discussion of key megalithic sites and their variance and commonality. The sites explored are determined by an overarching criteria (explained above in 2.1) applicable to each form discussed. Exploring the megaliths below offers a range of applicable data and reliable analogous insights for the Plain of Jars.

What sites are of importance to this review?

The scope of this inquiry has been limited to the megaliths which provide insight for the subsequent study of the Plain of Jars sites. There are numerous other sites which also carry the title of a megalith yet they have been excluded from the research focus for one reason or another. As such the previously identified criteria narrows the scope of enquiry applied within this research.

For the most part, the excluded sites are those constructed from numerous stone elements in a more structured form. Examples of these megaliths include; Nan Madol (in the islands of Micronesia), numerous pyramid traditions (in the Middle East, North Africa and South America) as well as other structures which incorporate dry stone masonry in their production. While these sites can be defined as megalithic in nature, their production does not emphasise the stone used. Rather than raw stone blocks or carved stone imagery, these sites employ stone purely as a construction medium for large structures. As such these sites are of less consequence to this thesis.

When discussing the megalithic complexes below, four key aspects will be emphasised; the supposed social role of the site; site dating; the construction techniques; and lastly the materials used (and their origins). Each of these aspects offers particular opportunity for cross comparison and analogy independently, but also as a collective. The case studies will be explored in chronological order aside from the megaliths of mainland and island Southeast Asia which will be explored in a collective subsection due to the uncertainty surrounding the age of the megalithic productions as well as their similar megalithic form.

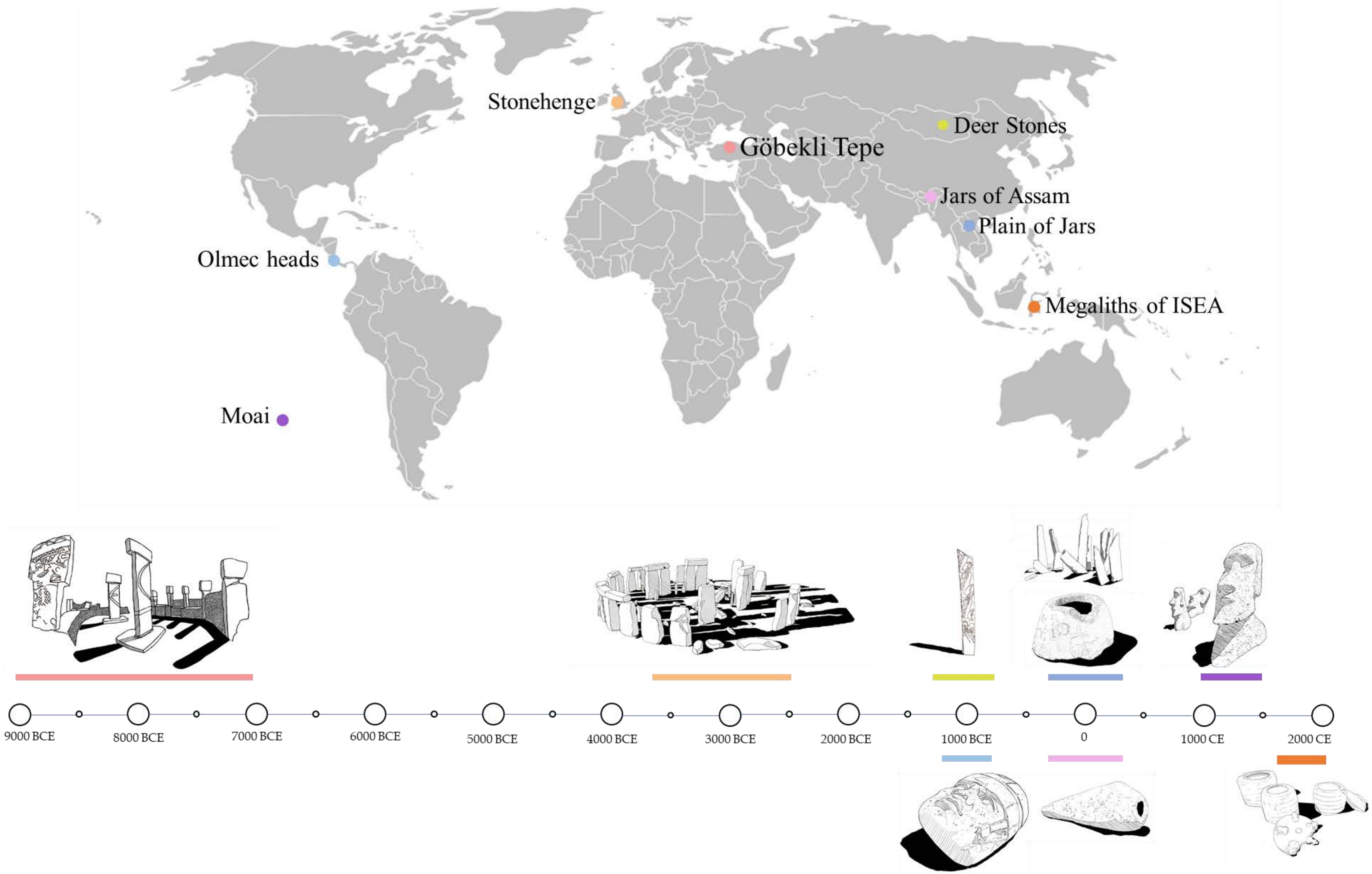

Figure 6. Chronological and Geographic spread of megaliths

Göbekli Tepe

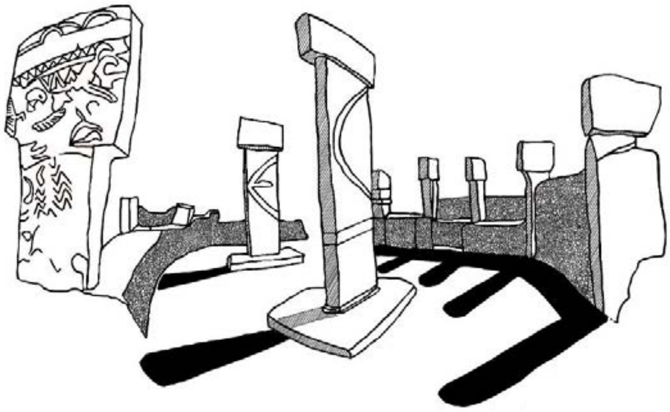

Figure 7. Illustration of Göbekli Tepe

Göbekli Tepe is a monumental temple like site with large megalithic elements. A large-scale collaboration between numerous separate groups, requiring the estimated collaborative work of over 600 people for some of the larger megalith elements (Clare *et al.* 2018:121). The site's identification as a temple or meeting place for ritual feasting stands in contrast to the Pre-Pottery Neolithic dating of the site. With an agreed date of 9000 BCE for the earliest phase, Göbekli Tepe has shaken the understandings of the Neolithic transition to agriculture. The earliest dates associated with Göbekli Tepe represent a Pre-pottery Neolithic A (PPNA) ritual site, dating between 9000 BCE and 8800 BCE, which saw the congregation of hunter-gatherer communities from a large area in surrounding upper Mesopotamia.

Figure 8. Göbekli Tepe main excavation area (Photograph by Nico Becker in Schmidt 2010)

During the second period, classified as early to mid-Pre-Pottery Neolithic B (PPNB), which dates between 8800 BCE and 6500 BCE, the site changes with the scale of monumental 'T pillars' reducing (to 1.5 meters in height) with only two 'T pillars' attributed with this later phase (Deitrich *et al.* 2012: 675 & Clare *et al.* 2018: 117). Associations have also been made between the later phases of the site and the development of agriculture. A number of sickles are present within the material originally used to fill the site which is related to the later stages (Schmidt 2000: 51) and the presence of potential beer brewing may indicate further connections with early farming (Dietrich *et al.* 2012: 687).

A key element of Göbekli Tepe's construction is the tools used in the production of the site's 'T pillars.' While much of the site's ringed structure is produced using small boulders and drystone masonry techniques, the 'T pillars' differ from this greatly. The site's 'T pillars' feature large carvings of anthropomorphic figures measuring between 5.5 and 1.5 meters in height, depending on their construction period (Schmidt 2000:49; Clare *et al.* 201:121). These pillars are adorned with numerous carvings of animals from throughout the Mesopotamian region (Dietrich *et al.* 2019; Clare *et al.* 2018; Schmidt 2010; Busacca 2017). Furthermore, the imagery found throughout this site has been thoroughly examined and potential connections have been drawn to regional sculptures throughout Upper Mesopotamia, building into the interpretation of Göbekli Tepe as a regional hub and key ritual centre (Schmidt 2000:48). The proposed role of the site has been heavily influenced by analyses of the many high and low relief carvings spread throughout the site. A total of 149 sculptures have been uncovered within the site with 86 depicting animals, 38 humans, four anthropomorphic masks, three phalli, nine human-animal composites and nine remaining indeterminate (Dietrich et al. 2019:153).

Figure 9. & Figure 10. Pillar 18 approximately 5.4 m in height (left) and Pillar 43 (right) (Schmidt 2012:243, 244)

The 'T pillars' are believed to have been produced with stone tools. No metal implements were present at the site, consistent with the dating of the early phase of Göbekli Tepe to a period where metallurgy was potentially none existent. It is believed that stone tools were used to not only carve the depictions of animals into the hard limestone, but also to quarry the stone. Many of the stone tools uncovered within the site are consistent with tools of the PPNA being found within the fill (Schmidt 2001: 51).

Analysis of Sanliurfa Limestones (used for the construction of the T pillars) shows the material boasts a high strength yet can easily be cut by a hand-held saw or a rock cutting machine (Agan 2015: 13), suggesting a potentially low Measure of Hardness (MoH). The dry compressive strength (MPa) of Sanliurfa Limestones ranging between 15 and 18 indicates that the stone can be categorised as a medium hard rock, suggesting it cannot be easily peeled or scraped with a knife but can be worked using picks or other semi forceful processes (Rock Mass 2014). Considering these characteristics as well as the naturally low MoH's of limestone (2-3 MoH) many stone tools employing the same or harder material were likely well equip to carve the stone, relying predominantly on pecking and percussion to chip away at the stone rather than cutting the stone.

Table 1. Physical characteristics of Sanliurfa limestone (Agan 2015)

Material properties	Turgut et al. (2008)	Agan (2011)	Agan et al. (2013)
Dry compressive strength, UCS (MPa)	17.8 ± 1.70	15	15.62 ± 2.40
Saturated compressive strength (MPa)	14.7 ± 2.20	–	14.10 ± 1.21
Dry Brazilian tensile strength (MPa)	–	–	1.83 ± 0.21
Saturated Brazilian tensile strength (MPa)	–	–	0.81 ± 0.09
Dry bending strength (MPa)	–	–	3.77 ± 0.56
Saturated bending strength (MPa)	–	–	1.47 ± 0.19
Dry UCS after freeze–thaw (MPa)	16.3 ± 1.20	–	–
Saturated UCS after freeze–thaw (MPa)	12.7 ± 1.30	–	–
Dry Schmidt rebound (MPa)	21 ± 2	–	–
Saturated Schmidt rebound (MPa)	16 ± 2	–	12.6 ± 0.60
Modulus of elasticity (GPa)	13.9 ± 2.60	18	13.1 ± 3.50
Poisson's ratio	0.31 ± 0.03	0.24	0.22 ± 0.03
Slake durability index Id_2 (%)	–	–	87.5 ± 2.80

Göbekli Tepe provides a clarifying example of human ingenuity, artistry and craftsmanship. Considering the dating of the site, Göbekli Tepe represents the first known example of a megalithic structure and the first identified temple location. Since its discovery Göbekli Tepe has continued to provide evidence necessitating a reconsideration of previously held interpretations of prehistory, with past archaeological theory failing to comprehend the significance of the site and the role it has in wider understandings of social development.

Stonehenge

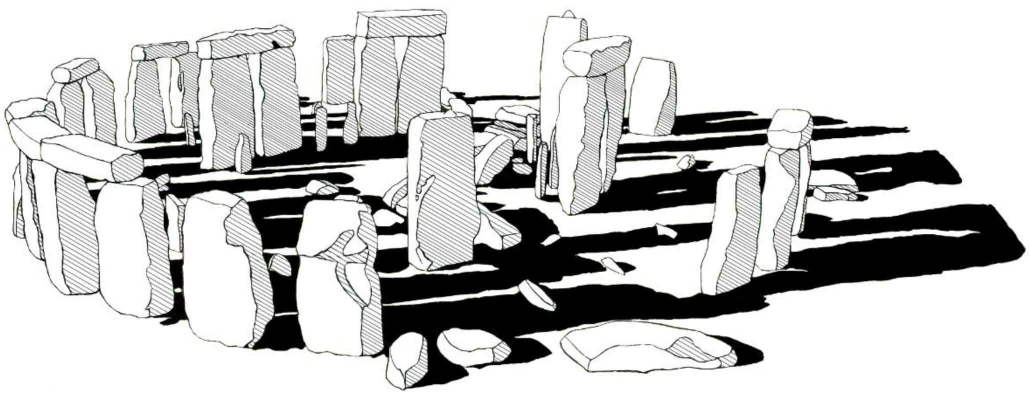

Figure 11. Illustration of Stonehenge

Taking a considerable leap forward in time we arrive at Stonehenge. The famed site differs greatly from Göbekli Tepe in both locale and age. Monumental architecture did not vanish between these dates yet large-scale megalithic examples appear less frequently between these two periods of time. Within the Mesopotamian context a stone carving tradition continues with potential varying forms as explored by Schmidt (2010), yet the scale of these endeavours is easily eclipsed by more prominent examples of megalithic structure, such as Stonehenge.

Although Stonehenge is the most famous megalithic monument of the British Isles there are a number of other megalithic structures spread throughout the landscape. Stonehenge's reputation as the most famous megalithic monument in the British Isles, if not the world, is not in question; yet megalithic production was a tradition which emerged much earlier in the Neolithic. Megalith production in the Avebury area stretches back to 3700 BCE with the construction of chambered tombs such as the West Kennet long barrow. Examples of small-scale megalith production was present as far back as 4000 BCE resulting in the construction of 25 stone chambers, earthen long mounds and three earthwork enclosures (Gillings & Pollard 2016:540). Later examples of megaliths were of larger scale with the Avebury region being one of several ceremonial foci located in close geographic proximity, with the others being Stonehenge, Knowlton and Dorchester landscapes (Gillings and Pollard, 2016:540). The earlier examples of megalithic production in the Avebury region saw the use of local sarsen, a quartz-based sandstone, which was highly abundant in the local region. While some of the material employed within Stonehenge were local sarsen stones other materials employed were employed within the structure, some of which were collected from quite a distance away. The spotted dolerite known as 'preslite', used for the altar stone was provenanced to Presli Hills some 230 km away from Stonehenge (Parker Pearson *et al.* 2019: 46) while the larger sarsens are sourced from only 20km away (Parker Pearson *et al.* 2015:1332). These large sarsens, which make up the majority of the site can reach up to 8 meters in height and can weigh as much as 30 tons (Shillito 2019: 1054).

Stonehenge itself is thought to represent a ritual and political centre in the Neolithic through to the local Bronze Age (Cusack 2012:139). It has also been suggested that the surrounding vicinity was employed in burial practices and it has been proposed that the original monument was "a cremation cemetery" (Parker Pearson *et al.* 2009:34 & Cusack 2012: 141). The presence of 52 cremation burials and over 40 fragments indicated with a total number of estimated individuals being 240 or 150 with more conservative single-individual cremation burials (Parker Pearson *et al.* 2009: 23). As discussed in the previous section there have been theories tying Stonehenge to celestial observation with more recent archeoastronomy demonstrating the lack of evidence behind many of these theories (North 1997). Aside from these constellational connections there existed numerous legends tied to the site with many of these branching from connections to druids and also Arthurian legends (Cusack 2012:143). The relationship between Stonehenge and druidic practice directly contradicts understandings of actual druidic practice, with there being no mention made by classical authors associating druids with stone monuments (Parker Pearson 2013:75).

One of the major differences between the Neolithic megaliths of the United Kingdom and other megaliths around the world is that the stone used to produce these megaliths were *extracted* rather than *quarried*. As previously discussed, quarrying is a harder process which involves the removal of large quantities of stone, whereas extracting involves less stone removal and requires a different toolset. Although there were later examples of quarrying within the British Isles for the production of megaliths, the earlier examples were all likely to have been extracted, including the stone used in the production of Stonehenge (see Park Pearson *et al.* 2019). In spite of this easier extraction method, it is important to note extensive carving was still undertaken upon the stones of Stonehenge with lintels, mortice holes and tenons all requiring extensive carving to allow the construction of the site. The main sarsen stones employed within the production of Stonehenge are a silified sandstone material (Parker Pearson *et al.* 2015: 1332:46; & Shilliato 2019: 1054) likely displaying higher hardness and dry compressive strength to average sandstones. The naturally soft nature of most sandstones (3-4 MoH) would allow the stones to be easily carved by most hard stone tools with minimal effort.

Although the Avebury complex and other similar megalithic arrangements found throughout the British Isles are older, Stonehenge still remains the most famous and intriguing to most people. Strangely it appears this fascination is ubiquitous among both the general public and scholars alike. More archaeologists focus upon Stonehenge and the acquisition of the distinct dolerite, rather than the more 'mundane' production of the Avebury complex and the acquisition of local sarsens (Gillings & Pollard 2016:552). Even the potential acquisition of sarsen for Stonehenge within the Avebury region reflects an emphasis upon the stone moving away from Avebury and a disinterest in the stone left behind (Gillings & Pollard 2016: 552). It is also suggested that the interpretation of the movement of stone is too simplistic as it is often described in terms of time and effort, without consideration of the social importance and activity of the monument. Considering practice in megalith production has seen some interest (see Gillings & Pollard 2016) yet this remains a seldom explored element.

Figure 12. Stonehenge (Photograph by Adam Stanford in Parker Pearson 2013)

Stonehenge and the Avebury complex draw inherent issues of exploring monumentality into focus. The fascination and emphasis placed upon Stonehenge bleeds from the wider world into the archaeological realm, reducing interest in more 'mundane' stone monuments and sites like Avebury. Some archaeologists claim that due to the fame and focus on Stonehenge, complexes like Avebury have been reduced to little more than stone on its way to Stonehenge, in spite of the older date of the site and its own role in the local past (Gillings and Pollard 2016: 552).

While Stonehenge remains the most famous megalithic complex of the modern era, it is now considered a later stage of tradition which began in the far north of the British Isles. While not the oldest megalith in either the world or more locally the British Isles, Stonehenge remains one of the most awe-inspiring and arguably most famous examples of megalithic construction throughout the world.

Mongolian Deer Stones

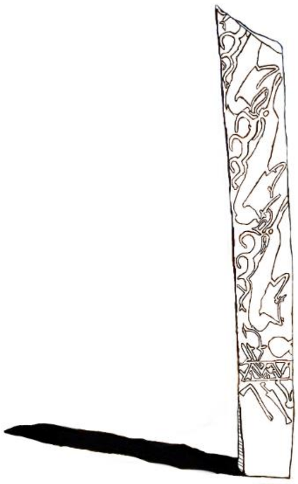

Figure 13. Illustration of a Deer Stone

Taking a second, smaller step forward in time to the Mongolian Deer Stones. Dated to approximately 1300-700 BCE these stones represent one of the more delicately carved megalithic traditions present at the time. While the Deer Stones are a later monumental development within the Asiatic Steppe, other large monumental projects were in use during the late Bronze Age of the region.

The Deer Stones are believed to depict warriors or ancestors, the imagery found among these stones including human faces, belts with tools and weapons, and the highly stylised deer motifs these monuments are famous for (Tiskin 2020:459). Aside from the diverse designs present upon the megaliths it has been proposed that the megaliths contain 'anthropomorphic features' built into the structure before the individual stylising (Volkov 2002:18 in Tiskin 2020:2). These megalithic monuments reach a height of over 4 meters in some instances, yet many are closer to human height. Some of these monuments stand alone and in other cases they are accompanied by large burial mounds known as *Khirigsuurs.* The Deer Stones represent one of the more prominent features of the culture complex, often referred to as the Deer Stone-Khirigsuur complex (DSK) (Tiskin 2020; Fitzhugh 2017; & Fitzhugh 2009). The Deer Stones can be found in small numbers but have also been present in clusters of over 30 Deer Stones (Bayan Zurkh) (see Tishin 2020:458). Aside from Deer Stones and *Khirigsuurs*; associated artefacts, settlement patterns and evidence for subsistence economies have only recently begun to be explored by researches (see Broderick *et al.* 2016 and Hanks & Linduff 2009). Further monuments are also associated with *Khirigsuurs*, chiefly stone circles, but these are also dated to the local Bronze Age (1500-800 BCE) and have no clear connections to the Deer Stones (see Broderick *et al.* 2016).

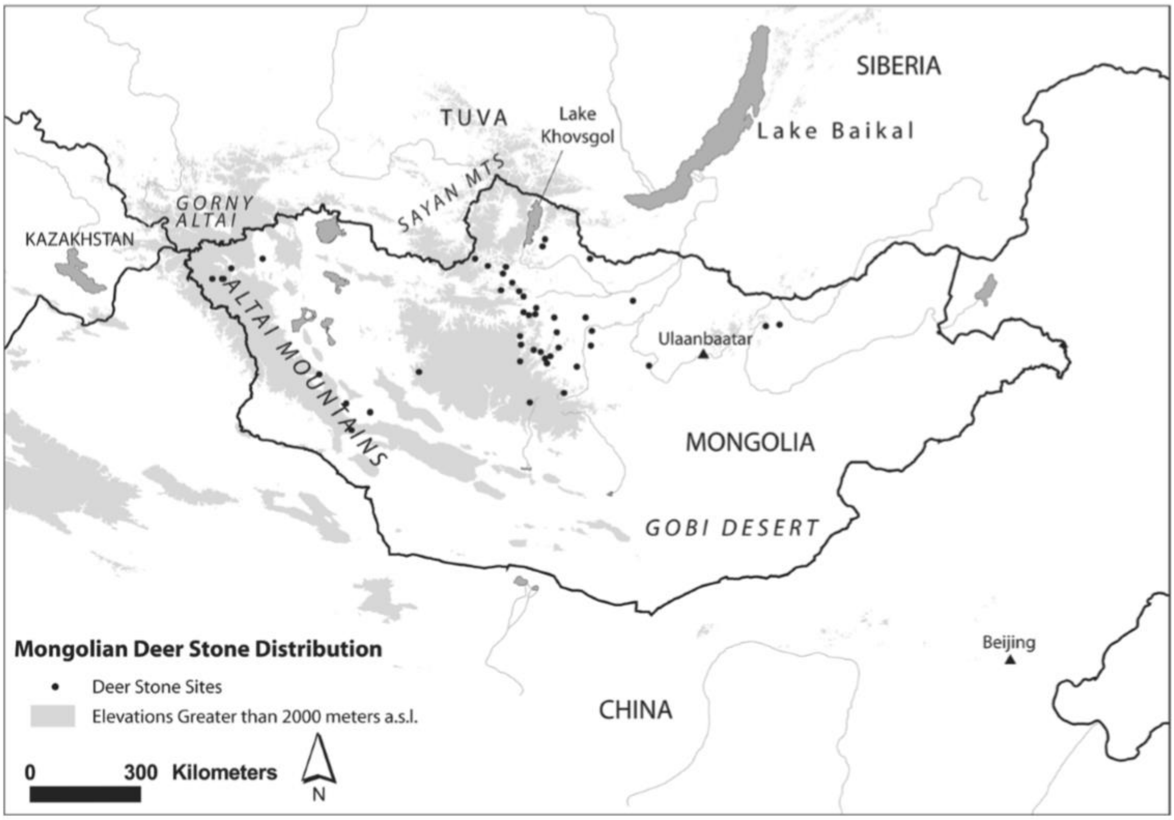

Figure 14. Distribution map of Deer Stone site in Mongolia (After Volkov 1981 in Fitzhugh 2017: 158)

Individual analysis of a small number of Deer Stones has been undertaken, yet this does not represent the true range of variance present. Detailed analysis of the carvings mirrors analysis practices at Göbekli Tepe, with emphasis revolving around unique elements of the carvings. A number of interpretations of the deer stones have been proposed; suggesting they represent ancestors, chiefs, warriors or mythological figures (Tiskin 2020: 454 & Fitzhugh 2019:77). The high level of variability seen among the carvings on the stone have given support to the argument that each stone represents a highly personalised individual, likely a warrior ancestor rather than mythological figures (Fitzhugh 2017:163). Of all the Deer Stones analysed none share the same detail in the style of belt carving, yet most show similar representations of the anthropomorphic deer figures present on the structures. The Deer Stones also display a consistent set of weaponry including a dagger, a hatchet and a gorytos with bow (Tishan 2020: 469). While each of these elements is consistently present there are a number of elements which are present on some stones but not others. Additional axes, knives, belts, sharpeners, hooks and headbands have also been identified on some examples (Tishan 2020: 496; Fitzhugh 2019:74).

The stones used for the production of the Deer Stones varied by region; with stones in northern Mongolia being predominantly granite and greywacke and slate in western Mongolia (Fitzhugh 2009:76). This may be due to stone availability as most monument traditions of Mongolia tend to be built with locally available stone (Wright 2017:553). Deer stones appear to be consistent with other monuments as they have been produced from slabs of granite, basalt or slate taken from local quarries (Fitzhugh 2017:160). While dated to the Iron Age, the range of artefacts uncovered within the region are limited to a very small number of copper and bronze artefacts (Tishan 2020: 453). The high hardness of granite (7-8 MoH) represents one of the hardest stone examples in this review (equal to the basalt of the Olmec heads), unfortunately due to lack of artefact availability it is impossible to comment upon the tools used. It may be possible that the deer stones were produced with any tools which can be produced from the Neolithic through to the Iron Age, possibly including stone, copper, bronze and iron.

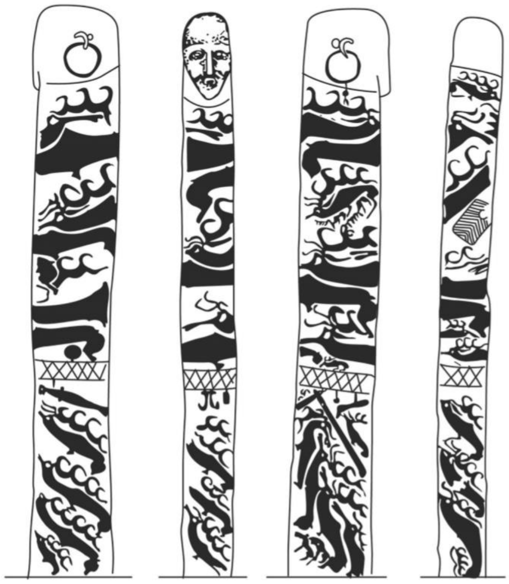

Figure 15. Uushigiin Övör site, Deer Stone 14 (Volker 1981 in Fitzhugh 2017)

The association between the Deer Stones and *Khirigsuurs* parallels other megaliths as key mortuary monuments. The presence of associated burial remains correlates with the individual nature of the carvings found on the deer stones. Burials and Deer Stones could correspond directly with one another in memorialising the individuals buried within the *Khirigsuurs*. This could also explain the instances where Deer Stones are found without burials, representing warriors whose bodies were not recovered or ancestors who died before the tradition began. It has been suggested that the DSK also served to provide a sense of local social cohesion upon the Steppes (Wright 2014:146). This may have been a necessary element to maintain social cohesion within the nomadic society of the steppe and potentially offer the opportunity of self-aggrandisement (Allard & Erdenebaatar 2005:561). Unfortunately, the limited nature of artefacts accompanied by the ancient looting and modern destruction of the *Khirigsuurs* further obfuscates understandings of the region's past burials and megalithic practices.

Olmec Monumental Culture

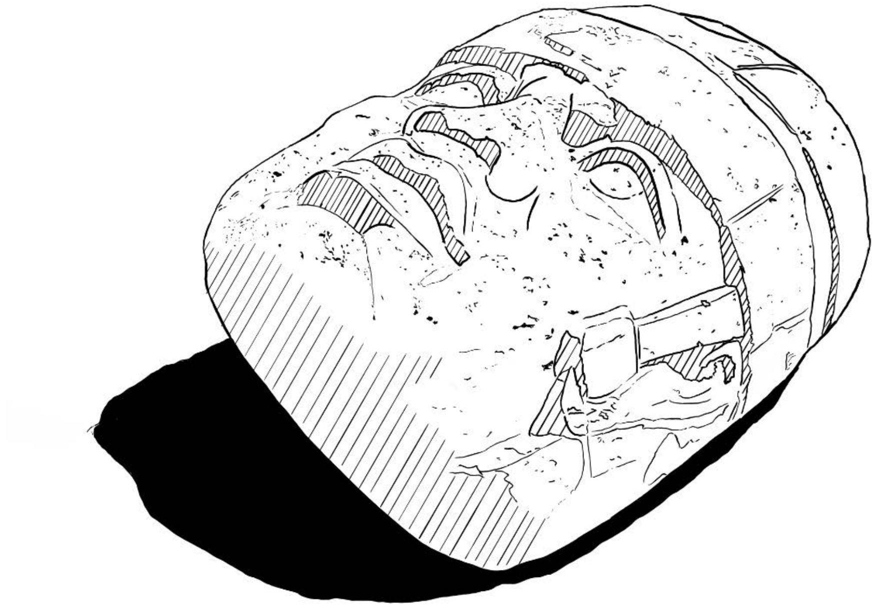

Figure 16. Illustration of San Lorenzo Olmec head

Occurring at around the same time as the Mongolian Deer Stones is the production of Olmec monumental structures, predominantly the megaliths known as the Olmec heads.

The monuments considered within the Olmec style are numerous and varied with a variety of stylistic differences and megalithic forms. The Olmec style, or culture as it is commonly labelled, has been one of the most contentious and intensively debated examples of archaeological investigation (Grove 1997: 53). The term Olmec which was initially employed to categorise the style of iconography present on greenstone artefacts (jadeite, greenstone, schist, green quartz and others (in Jaime-Riveron 2010)) of the Gulf coast of Mexico was commandeered by some who employed the term in reference to a widespread culture. This remains a contentious topic with no consensus on proper use of the term (Grove 1997: 53). For the purpose of this literature review the focus will be predominantly upon the term Olmec as a style, with some insights drawn from the wide Mesoamerican context regarding technological complexity.

It has been suggested that the Olmec culture is one of archaeology's most explored mysteries. Unfortunately, the great majority of these studies are centred upon the same aspect of the Olmec culture, examination and analysis of the Olmec iconography. There remains a small volume of work investigating other elements of the culture and the monuments themselves (see; Grove 1997; Hazell & Brodie 2012; Hazell, 2013; Coe & Diehl 1980).

The Olmec Heads have been dated to 1200 BCE -900 BCE placing the megaliths within Mesoamerica's early formative to middle formative period (Grove 1997: 55). Some aspects of the Olmec society which have been investigated include the source and transportation of the raw material and the lifestyle and subsistence economy of the communities but mostly stylistic diversity of artefacts attributed to the 'Olmec Culture'. The stone used for the heads is believed to have been acquired approximately 80 km from their final placement in the La Venta context (William & Heizer 1965:3; Hazell & Brodie 2012: 3476). The movement of the more than 20-ton stone from the quarry approximately 80 km away has been viewed as a highly challenging task. This is mostly due to the extreme shifts in elevation along with numerous challenging river crossings (Hazell & Brodie 2012; Hazell 2013). Transportation using log rafts was first suggested by Sterling (1943) during a 10-day excavation at La Venta where he suggested columnar basalt may have been sourced from the Tuxtla Mountains (Sterling in Grove 1997:58). These suggestions were later proven accurate with the source of the stones being traced to fine-grained basalt deposits in the Tuxtla Mountains (Williams & Heizer 1965:3). The proposed use of log rafts to achieve the numerous river crossings, as well as the analysis of human labour necessary for the movement of the stone has been analysed. GIS has been used to produce a potential transportation route and examine some of the issues surrounding the task (Hazell & Brodie 2012), while other work has explored the performance of proposed log rafts (Hazell 2013).

The heads at San Lorenzo are believed to represent different rulers due to their distinctive and individual features (Hazell 2013:141). Little was known about the Olmec society other than speculations about the social systems necessary to organize the mass human labour needed to quarry and transport the stones for the megaliths (Grove 2014:167). The lack of knowledge surrounding the megaliths of La Venta has been rooted in a lack of understanding of the Olmec society as a whole. Yet recent excavations in San Lorenzo have provided a deeper understanding of the subsistence patterns associated with the Olmec culture. Such as the perusal of fishing, hunting, gathering and plant cultivation within El Remolino, a lower order Olmec site associated with San Lorenzo (Wendt 2005:176). Previous excavations at San Lorenzo also provided data on subsistence, mostly exploring faunal remains (Coe & Dahl 1980:375-386).

Currently a total of seventeen colossal heads have been found, with ten being uncovered at San Lorenzo, these ten heads weigh between 6 and 25 tons (Clewlow *et al.* 1974: 85). The stone employed to produce the heads is consistently basalt. The hardness of basalts are naturally high (7-8 MoH) although the overall strength of the stone is highly dependent upon its homogeneity, with coarse basalt examples being much softer and easier to carve (personal observations). The dominant focus upon stylistic analysis accompanied by the non-systematic categorisation of sites, cultures and styles leaves the literature relatively sparse regarding the production of the Olmec megalithic monuments. It has been suggested that the lack of metal tools would indicate production of the monuments was predominantly carried out by percussion and grinding (Coe & Dahl 1980:296).

Figure 17. Marion Sterling (left), Philip Ducker (right) and unidentified man (centre) examining colossal head 1 at San Lorenzo (Richard Hewitt Stewart 1946)

There is a small body of work surrounding the selection criteria for the monuments, mostly exploring the basalt of the Tuxtla Mountains as well as suggestions of how the stones could have been worked. For example, it is believed the blanks for the Olmec heads were not quarried but were obtained from alluvial fans were the boulders had been detached and smoothed (Williams & Heizer 1965:5; Coe & Dahl 1980:295). Tool usage remains speculative, supposing the use of stone on stone percussion (Coe & Dahl 1980: 296) although it is suggested that tools made of hard sandstone and obsidian were uncovered, the obsidian was believed to have been used for woodworking while the sandstones were suggested as the main tools used for lapidary (Coe & Diehl, 1980:390-391). There is a lack of metal within the region including an absence of any weapons associated with warfare (Coe & Diehl, 1980:392). As such it is likely that either hard stone, obsidian or potentially sandstone tools were used for the production of the Olmec heads, employing percussion and grinding to form the final shape.

Moai

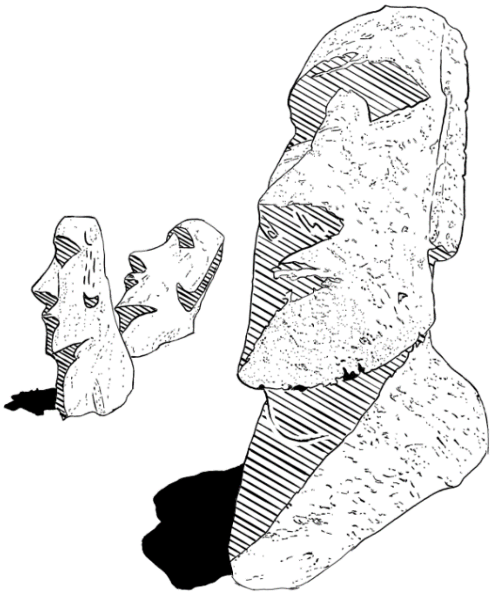

Figure 18. Illustration of three Moai

The Moai of Rapa Nui are both temporally and geographically distant from the Olmec heads, representing one of the later megalithic traditions covered in this review. Appearing as anthropomorphic figures, the Moai consist of stone heads and torsos dotted along prehistoric roads and encircling the island's coastline. It required extensive structural carving to produce the large heads and torsos of these colossal stone figures. Hundreds of Moai overlook the coasts of Rapa Nui, located upon platforms known as *Ahu*, while nearly 1000 carvings in total are spread across the island (Lipo *et al.* 2013: 2861; Hixon *et al.* 2018: 148). Initial colonisation of Rapa Nui is believed to have occurred during the 13th century CE, much later than suggested previously. The previous dating of the island was impacted by inaccuracies in radiocarbon dating samples collected, with recent work resulting in a late date of early 1200 CE (see Hunt & Lipo 2006: 1605-1606). Production of Moai was believed to have begun shortly after colonisation, with some researchers attributing Moai production to ecological degradation of the island (see Bahn & Fleney 1992; Diamond 2005). These interpretations have since been revaluated, attributing the ecological collapse to the islands poor soil nutrients (Ladefoged *et al.* 2005; Sherwood *et al*. 2019) and the combined impact of fire and rats upon seeds of native plants (Lipo & Hunt 2007: 494).

The Moai are one of the few megaliths which have been reproduced for experimental analysis, although this was predominantly focused on the transportation of the megaliths. Moai transportation using wooden rollers and similar forms has been tested (Van Tilburg & Ralston 2005) while others propose the Moai were 'walked' to their final placement at *Ahu* using a leaning and rocking motion (Lipo & Hunt 2013:286). Although these megaliths are dated to a later period than other megaliths discussed there was no evidence of metal tools used on the island. The sites spread across Rapa Nui continue to support the idea that metal tools were not necessary in the quarrying and carving of hard stone. The example of Moai production also offers insights into practice and ritual through ethnographic studies. The activity of Moai production was a specialist craft performed by a group of men known as *tangata maori anga moai maea* (Métraux 1940:137). Moai production was believed to be a seasonal activity, undertaken with a consistent tool set which included *Toki*, a stone adze with a particular tang-less shape and hafting method, as well as coral abraders known as *Punga* and potentially some obsidian hand tools for fine carving work (Van Tilburg & Ralston 2005: 231-2). Although metal was absent at the time the Moai were carved a geological analysis of the raw material describes the stones as light and easily worked (Gioncada *et al.* 2010: 865). Other stone types found throughout the island would have proved difficult to work due to the rocks being either too heavy (Mafic to intermediate lavas), too fragile (obsidian), or too loose (unconsolidated cinder and scoria cones), making the material of the Rano Raraku area the only viable material (Gioncada *et al.* 2010: 865). There has been recent suggestions that the Moai were produced in multiple phases, with work occurring at both Rano Raraku and their final coastal resting place (Lipo *et al.* 2013:2861). This may have been done to better facilitate the walking transport method and to stabilise the Moai in their placement at *ahu*.

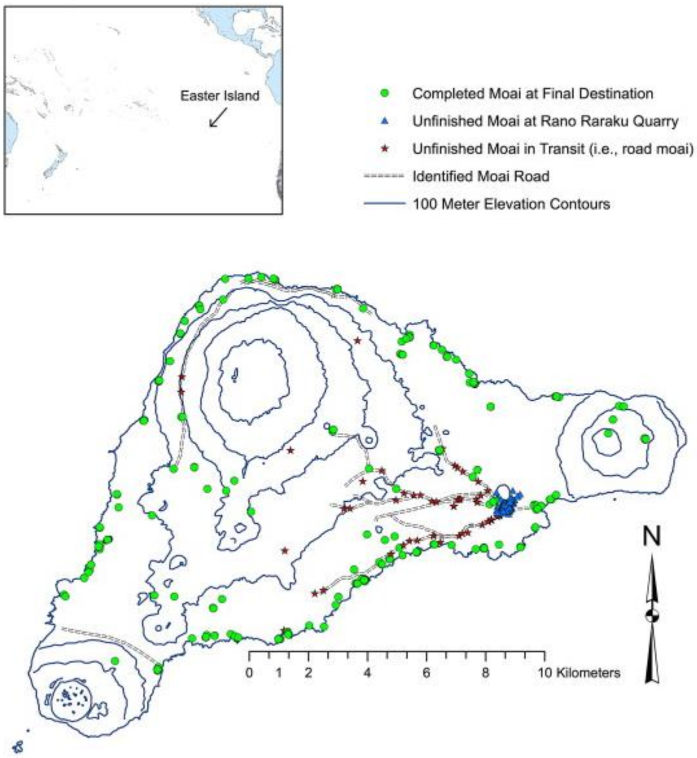

Figure 19. Map of Moai distribution on Rapa Nui (Lipo, Hunt & Rapu Haoa 2013:2860)

Unlike the other megaliths discussed, the Moai also offer insight into production times through past analysis and calculation during the 1900s. The first analysis and calculation of time investment for Moai production was undertaken by William Scoresby Routledge during 1913-15. Routledge (1919) believed a master carver and a team of 54 men could carve a 30ft long Moai in 15.5 days or around a month with a team half the size (Routledge 1919: 179-180 in Van Tilburg & Ralston 2005: 285). The Norwegian Archaeology Expedition to the island hired a team of six local men to demonstrate quarrying techniques. After observing the quarrying and speed of material removal the team theorised that the production of a Moai 5m in height would take over a year to complete for a full team of craftsmen (54 men) (Heyerdahl *et al.* 1989: 36). This second calculation was not awarded complete credibility as members of the research team believed the experiment and estimates unreliable (Skjölsvold 1961: 368 in Van Tilburg & Ralston 2005:285).

The Moai themselves are comprised of a singular megalithic element with additional elements in some instances. Many of the Maoi located on *Ahu* throughout the island are also adorned with hats known as *pukao*. *Pukao* are large cylindrical caps made from red scoria. It is proposed these hats were rolled up earth ramps and deposited upon the coastal Moai (Hixon *et al.* 2018: 156). It is proposed the movement of the *pukao* mirrors the technological process of Moai movement, with the *pukao* being dragged and rolled with rope without the need for wooden rollers, offering further support to dismantling the suggestions that Moai represent a leading cause of deforestation as was previously theorised (Hixon *et al.* 2018: 156).

Figure 20. Moai with painted 'mata' or eyes and Pukao (Dua & Singh 2008)

It is believed that the Moai served a similar purpose to the Deer Stones, as they represent ancestors. This re-birth of ancestors through stone is understood as a ritual transaction between people and gods. It has further been suggested that the path of the Moai roads may have been used to represent the pathways, known as *ara,* taken by spirits to coastal locations before 'jumping off' and returning to *Hawaiki* (Richards *et al.* 2011: 196). The road leading from Rano Raraku is comparable to this path with Rano Raraku also representing a conduit of *Hawaiki* (or *Hiva* as it is known in Rapa Nui) the place of creation (Richards *et al.* 2011: 196-202).

2.3 Mainland & Island Southeast Asia

While the previous examples represent a range of megalithic examples without direct connections to the Plain of Jars, the following megalithic examples may display some form of cultural continuity or connection. For each of the sites discussed below, cultural connections have been suggested to varying degree. These sites are mostly identifiable by their similar megalithic form, that of a cup or jar shape, alongside infrequent examples of similar iconography. The strength of many of these connections are yet to be thoroughly explored but they are afforded particular attention within this review.

The sites covered here are the megalithic jars of Assam, the jar form megaliths of Island Southeast Asia – most notably Sumatra, Sulawesi and Sumbawa – and lastly the megaliths of Laos: the Menhirs of Hin Tang and the Plain of Jars.

The connection between Laos and Assam was suggested by Madeleine Colani following the initial excavation of the Plain of Jars. Similarly, the connections between Laos and the megalithic examples of Island Southeast Asia were discussed by Walter Kaudern (1938), an archaeologist who explored the region during the 1910s-20s. While prior to Colani's work in Laos, Kaudern discussed connections between the regions during the publication of his findings in the 1930s, shortly after Colani. While these connections are commonly referenced in the Plain of Jars literature, little work has been undertaken to verify these connections.

Island Southeast Asia

Figure 21. Illustration of Kalabas, located in Pokekea

Island Southeast Asia provides evidence of numerous megalithic traditions, with different megalithic forms found across the island chain of Indonesia in particular. There are three regions that are of particular importance to this research as each of these regions displays jar megaliths. The megalithic jar traditions present are those on central Sulawesi, North Sumatra and Sumbawa. Each of these traditions appears to serve a mortuary purpose which is consistent with the traditions of Laos, both the Sulawesi and Sumatra sites are believed to have played a role in a two-stage burial practice.

Connections have been drawn between Laos and the megaliths of several valleys of central Sulawesi. The sites located in the Besoa, the Bada and the Napu valleys are comprised of 147 megaliths collectively, with 60 being centred in the village of Pokekea. These megaliths have been identified as 6 megalithic forms including; cup-marked stones referred to as *Kalambas*, *Kalamba* lids, Stelae, ornamented and unornamented blocks and agglomerations of diverse blocks (Kirlies *et al.* 2012:). The *Kalambas* show similarities in form to the jars of Laos, although some minor differences are present. The *Kalambas* of Sulawesi are jars shaped with wide openings and parallel walls. The dimensions are larger on average than the jars of Laos.

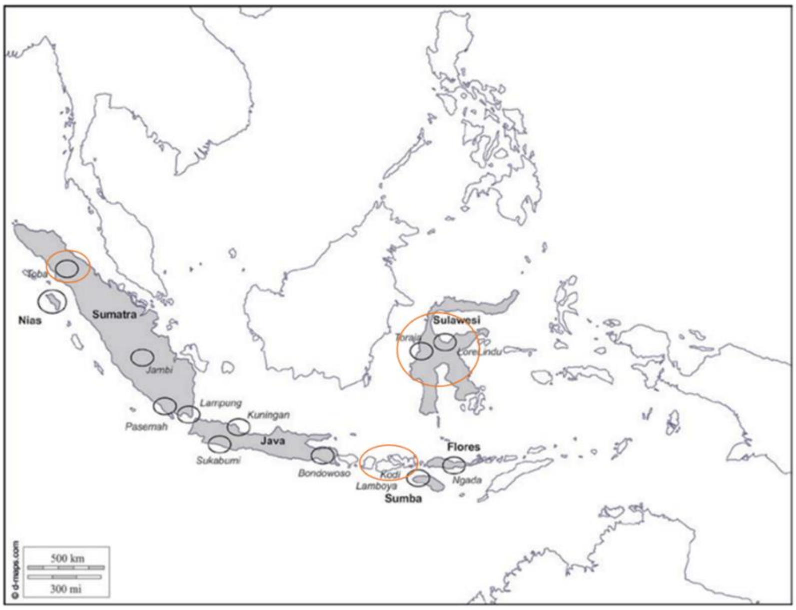

Figure 22. Map of megalith distribution of Indonesia, orange circles indicate jar megalith sites (after Steiner-Herbet 2018)

Figure 23. Stone Vat, Pad Pokekea, Behoa (Kaudern 1938:68)

Archaeologists have noted that the *Kalambas* are surrounded by the remains of domestic refuse which is potentially indicative of placement or construction within a domestic context (Kirleisetal *et al.* 2012: 3). Both the *Kalambas* and their proposed lids, referred to as *Toetoena* by the locals, are produced from granite (Kaudern 1938: 85). These monuments are described as "metal age megaliths", with some suggesting they belong to the metal age (Bellwood in Kirleistel *et al*. 2012: 6) and others suggesting the Iron Age more particularly (Van der Hoop in Colani 1935b:121-122). While it was argued that the megalith producers 'knew certainly of bronze and probably of iron' the megaliths are still suggested to be built using stone tools (Van der Hoop 1932: 164 in Colani 1935b: 121-122).

Figure 24. Kalamba and lids, Pokekea in Besoa Valley (Steimer-Herbert 2018:39)

Unlike other megalithic examples reviewed earlier there are a variety of megalithic forms spread throughout these regions. However, for the focus of this research the *Kalambas* and *Toetoenas* are of most interest. The sites in Island Southeast Asia are typically smaller, with fewer jars in comparison to the Plain of Jars with the largest of the sites only containing 27 *Kalamba*. There may be fewer megaliths at these sites but they are no less grand. The largest example in Pokekea is 4.7 meters in height (Steimer-Herbet 2018: 33), easily eclipsing the King's Cup from the Plain of Jars which stands at around 3 meters. In addition to the similar megalithic form there also appears to be similarities between the iconography found within the megalithic structures (Colani 1935: 247, 215). Figures present on the Kalamba lids are highly reminiscent of similar figures found upon the ground disks of the Plain of Jars (Colani 1935b: 247, 215; Kauldern 1938: 69, 72, 73, 121, 187). Although this similarity of iconography exists, Kauldern felt the claims of connection were unsubstantiated regarding the similar form of the Kalambas and the jars of Laos (1938: 185-186)

The range of diverse megalith forms differs from that of Laos, yet both regions share similarities in the jars and their lids, a unique feature of the megalithic sites in these regions. Research surrounding the sites suggests megalith traditions in the region originated in the 2nd century CE and lasted until the 10th-13th century CE (Hasanuddin 2016: 191-2) indicating the kalamba may have been contemporaneous with the later dates suggested for the Plain of Jars (900 CE-1200 CE). A *terminus ante quem* has also been determined through radiocarbon pollen analysis suggesting the jars were in final placement between 766 CE and 1272 CE (Kirleistal 2012: 17). Whether these traditions developed independently or share a connected origin is yet to be thoroughly explored.


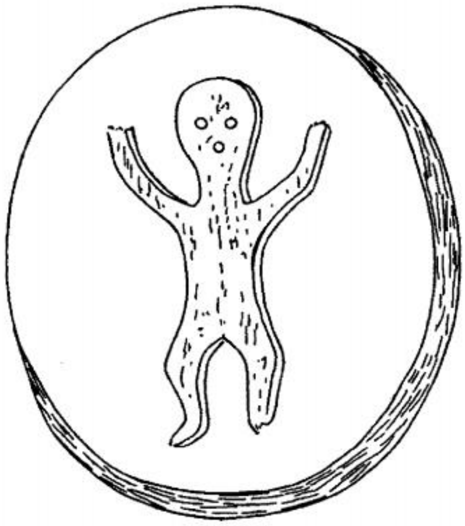

Figure 25. & Figure 26. Kalamba lid with decorations Besoa Valley (Steiner-Herbet 2018:40) and Oval stone slab, Jaentoe Valley, Central Sulawesi (Klaudern 1938:121)

While the examples present within Sulawesi are the most heavily documented there are other traditions which also display similar megalithic form. One such example is the stone vats of Sumatra. These vats are believed to have been employed for primary deposition of burial, with the remains being removed and a secondary burial occurring for people of importance (high social status) (Barbier 1987: 44-46). Although there is a larger scale tradition of stone quadrangular sarcophagi, known as *Tambak*, spread throughout the Toba-Batak region of Sumatra. There are two examples of these stone vats which share similarity of form to the Plain of Jars and potentially to the jars of Sulawesi. According to ethnographic inquiry, the quadrangular stone sarcophagi required more workers and more time than stone vats, making them too expensive for some people (Barbier 1987: 47). It was previously suggested by Heine-Geldern (1928) in his diffusionism theory that the urns used for the bones of ancestors represents an 'ornamental' tradition, resulting from the influence of the Đông Sơn cultural group with the antiquated theory being abandoned in recent years. More recent publications have continued to make comparisons between some of the megalithic traditions present within Island SEA and the traditions of Laos (see Genovese 2019b, Kirlies *et al.* 2012).

The third megalithic jar tradition is found on the island of Sumbawa. The megaliths of Sumbawa also share this jar shape and appear similar to the jars of Laos. It is suggested the jars of Sumbawa may have been produced using metal tools (Prasetyo 2012: 6-7). While these megalithic traditions reportedly show stylistic parallels and similar iconographic examples, much work is necessary across ISEA and Laos to further explore these potential connections.

Assam

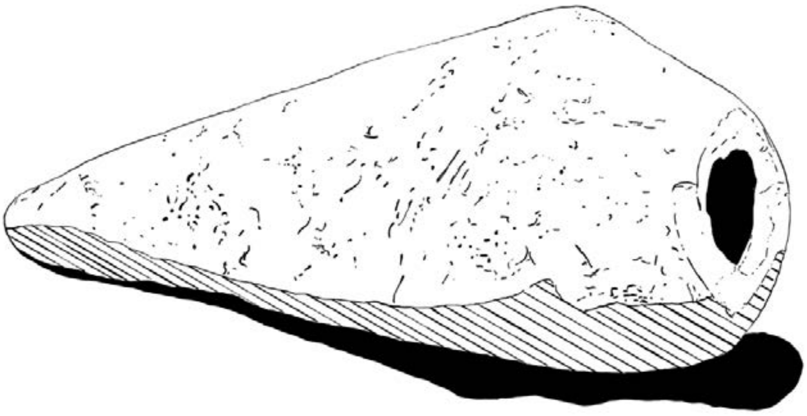

Figure 27. Illustration of elongated Jar of Assam

Literature surrounding the Plain of Jars often alludes to the connection between the jars of Laos and the jars of Assam. The jars of Assam represent another example of the megalithic jar form, the only mainland example aside from those of Laos. The jars present within the region of Assam, a region of India, located between Bangladesh and Myanmar, were the first of the jar form megalith to be identified and explored (Mills & Hutton 1929). Speculations that the cultures who produced both the megaliths of Laos and those of Assam were connected with the culture originating in the Assam region have been explored by Colani (Colani 1935b: 223-236). Further notes were made pointing to the similarity between iconography in the megaliths of Assam and central Sulawesi, although Colani did caution the assumed connection as iconography on the Assam jars may not have been contemporary with the jars production (Colani 1935b: 247). The jars share a similar cylindrical form with some variation as seen in Laos as well. Some of the jars appear square in form and others appear to be of a conical shape with wider bases and narrower tops.

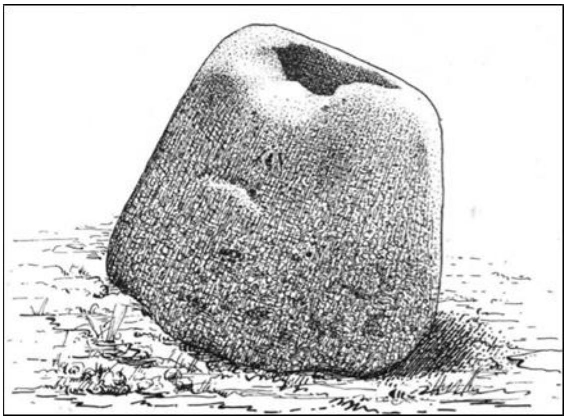

Figure 28. Illustration of Assam Jar (Mills and Hutton 1929:286)

The jars of Assam were under investigation by Mills and Hutton at the same time as Colani was exploring the Plain of Jars region. The first publication discussing the Assam sites was published in the late 1920s to early 1930s. The jar sites of Assam follow a similar distribution pattern to those observed at the Plain of Jars, with most of the sites being located upon hilltops and elevated regions (Thakuria 2014: 206). In a strikingly similar scenario to that of Laos, a large gap in research is present after the initial discovery of the sites in the 1920s. Yet unlike Laos, the jars of Assam have not received the same increased interest in recent years as the Plain of Jars has experienced.

Due to the limited work undertaken within the region there is little known about the jars of Assam. Despite the limited research that has been undertaken on the Assam megaliths there exists a range of interpretations similar to those produced by Colani. The jars are believed to have been used as mortuary vessels for the deposition of human remains after cremation (Thakuria 2014:207; Mills & Hutton in Colani 1935b: 228). This interpretation was suggested following the discovery of a skull fragment within one of the jars alongside ethnographic examples occurring in the region (Thakuria 2014: 207; Mills & Hutton in Colani 1935b: 228). Ethnographical observed burial practices in the surrounding region shows ancestral remains placed in clay receptacles (Thakuria 2014; Mills & Hutton 1929).

While cultural connections have been supposed the flow of cultural influence remains a mystery. It has been suggested that the culture responsible for the jar production in both Laos and Assam migrated from the Vietnamese coast into the Uplands of Laos and further to Assam (see Thakuria 2014). While Colani's initial interpretation showed this cultural flow occurring in the opposite fashion with Assam being the progenitor leading to later examples in the Plain of Jars (see Colani 1935a:). Regardless of the direction, the potential connections may be supported by the presence of a Mon-Khmer speaking people, the Khasi people, who currently reside near the Assam Jars (Thakuria 2014:209). They are also one of the communities who Mills and Hutton (1929) explored ethnographically when analysing cremation as a mortuary practice in the region. Connections between the stone tools of the Assam region and the Bacsonian industry which originated in Vietnam (Sengupta & Sharma 1946:360) have also been noted, suggestion some flow of culture or technology.

There appears to be a strong case for arguing a connection between the Plain of Jars and the jars of Assam. Similarities in the theorised practice of cremation rituals and the use of megalithic jars offer a potential link between the sites. Further support stems from the influence of Mon-Khmer speaking cultural groups throughout Southeast Asia as well as the modern-day presence of the Mon-Khmer speaking Khasi people within Assam. One aspect which is drawn into question with this potential link is the dating of the sites. As no radiocarbon dating has been undertaken within Assam, there is no clear sign that this site represents a continuation of the Laos cultural tradition rather than a precursor. These questions are still to be answered and are heavily dependent upon continued work in Laos and reinvigorated attention on the jars of Assam.

Hin Tang

Figure 29. Illustration of Hin Tang Menhirs

Hin Tang, which can be translated as 'stones standing' or 'enduring stones', is a megalithic site close to the Plain of Jars region. Located in Hua Phan, the adjacent province to Xieng Khouang, the site shares some similar megalithic elements yet there is no definitive connection between the sites. It is possible that the standing stones of Hin Tang are simply a variation of the megalithic complexes of the Plain of Jars. The site of Hin Tang also contains numerous standing stones alongside these disks. These standing stones, mostly referred to as menhirs, make up the majority of the megalithic components of this site. There are any number of reasons this site differs from the Plain of Jars monuments, the areas these sites are found within are much further than any jar sites tend to be and the environments they appear in are markedly different. There are no plains near the Hin Tang site with the site located on the high peak of a mountain range overlooking the surrounding valleys with mountains in all directions. The orientation of the stones seems of little importance in some areas of the site yet in other areas there are clearly defined lines of standing stones running alongside the few discs found in proximity.

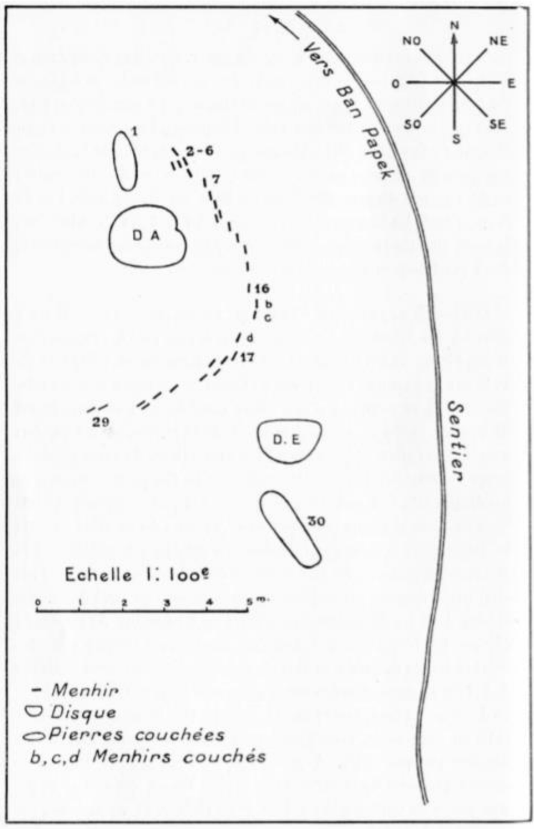

Figure 30. Map of Menhir Distribution at Vieng Noc Khoun in Hua Phan Province (Colani 1931:50)

Excavations at the Hin Tang sites have been relatively scarce yet there is an understanding of the sites purpose due to the works of Madeleine Colani (1935a: 29-95) and, more recently, Anna Källén (2015). It has been suggested that the site represents a mortuary complex with large burial chambers hollowed out from the bedrock beneath the capstone disks (Colani 1935a: 30-36). A range of artefacts have been uncovered within these burial chambers; these finds included a number of bronze and iron artefacts, as well as pottery (Colani 1931: 39-41). The megaliths of Hin Tang are not obviously similar to the Jars yet aspects of the megalithic array appear similar in nature. The use of capstones within Hin Tang may parallel mortuary practices noted within the Plain of Jars. Excavation beneath a limestone slabs in the Plain of Jars Jar Site 1 (O'Reilly *et al.* 2019: 980) displays some similarity to the use of capstones within Hin Tang. Furthermore, it has been suggested that the capstones present within the Plain of Jars may be ground stone covers in some instances. An excavated pit covered by a flat stone contained human bones and teeth within an incised ceramic jar (Nitta 1996: 16; O'Reilly *et al.* 2019: 973). It can be noted that potential burial practices within the Hin Tang context may have differed from that of the Plain of Jars, as teeth and bone recovered within the burial pits displayed no sign of cremation activity (Colani 1935a: 90), commonly found within the Plain of Jars.

It may be possible that these sites represent contemporary burial activity, and that the difference in megalithic form is due to the limitations of the local materials. The material employed for the menhirs and capstones of Hin tang is exclusively shale. While this material may not have been appropriate for stone jars, it would likely have been easy to collect through extraction rather than quarrying. The similar form of the iron and bronze artefacts is one of the few linking elements between the Hin Tang and Plain of Jars sites as well as the close proximity. The limited extent of work undertaken upon the Hin Tang sites remains the major hindrance for understanding this complex of sites and its connection to the wider megalithic context of Laos.

Figure 31. Menhirs of Hin Tang province

Plain of Jars

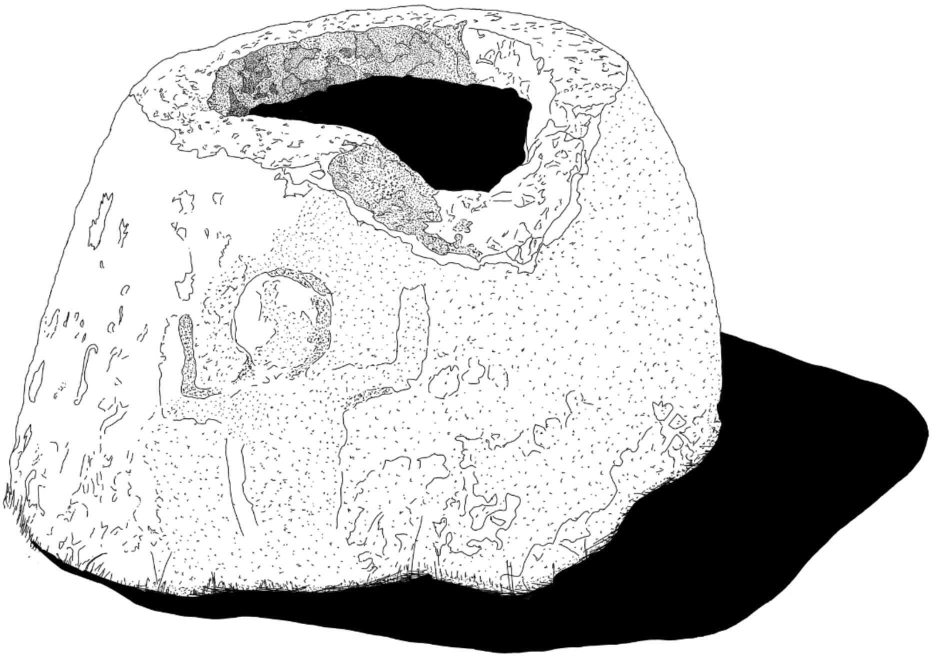

Figure 32. Illustration of Jar from Jar Site 1, including carved man

The Plain of Jars is known for its distinct form of megalith, appearing in the form of cups or jars. The moniker of the region was popularised with the exploration and subsequent excavations of the region's sites by French archaeologist Madeleine Colani in the early 1930s. Colani was the first to refer to these megalithic stones as jars and the name has remained since her publication of the excavation report under the name *Mégaliths Du Haut-Laos* (1935a, 1935b). The megalithic jars have a variety of shapes ranging from truly cylindrical to rectangular with slightly curved edges. The jars also vary greatly in size, from small examples around 50 cm in height (Fig 33) to the largest example known as the King's Cup which stands approximately 3 meters tall (Fig 35). The jars differ greatly from many of the other megaliths discussed (apart from, of course, the Assam and ISEA examples) due to their extensive structural carving to achieve the hollowed centre, and conical and cylindrical shape. Some rare examples also display iconographic carvings of people as displayed in Figure 34. There are examples of stylised carving found on the disks uncovered at some of the sites also.

Figure 33. Example of small jar from Jar Site 52, pen for size reference. (Photograph by Nigel Chang)

Aside from the megaliths themselves, numerous excavations have focused on the ground surrounding the jars resulting in the excavation of a variety of burial forms (O'Reilly *et al.* 2019:975-983; Shewan *et al.* 2021:2). Some of these burials are accompanied by a range of burial goods and other artefactual finds. These items and the soil which surrounds them have provided the majority of the dates for the stone jars. Some attempt has been made to date the jars themselves using optically stimulated luminescence (OSL) on the sediment below the jar and radiocarbon dating on charcoal found directly beneath the jars which has yielded varying degrees of success. Although the artefacts are often considered contemporary with the jars production, there is no clear evidence to verify this interpretation (O'Reilly *et al*. 2019: 986; Shewan *et al.* 2021:2). There are other elements which contributed to the proposed Iron Age date of the sites, most notably material culture ubiquitous with the Southeast Asian Iron Age present within the range of artefacts. Building from the range of artefacts and analysis of several jar sites Colani suggested that iron tools were employed to shape the stone jars at numerous sites, further reinforcing Iron Age associations (1935a:134, 144; 1935b:123). This would suggest that the earliest date for the jars would be around the beginning of the regional Iron Age (500 BCE). During Colani's excavation of a cave used for cremations within Jar Site 1, she recorded numerous iron and bronze tools and noted there is little cut stone, polished stone and almost no clear lithic tools at all (Colani 1935a: 134). Colani's suggestion that the jars required iron tools for production of jars at sites 1, 2, 3, and 7 (suggesting the finish quality indicated iron tool usage) has been reiterated throughout subsequent publications (1935a: 144; 1935b: 123), turning what was initially an interpretation of the jar's production into a key piece of the Plain of Jars narrative (see Sayavongkhamdy & Bellwood 2000:105; Shewan *et al.* 2021: 16; UNESCO 2019: 17, 35).

Figure 34. Example of carving on outer surface of jar, potentially depicting a human figure. The figure is approximately 50 cm tall and carved in relief, making the figure protrude from the side of the jar. Jar located at Jar Site 1.

As with other megaliths, stories of grandeur surround the sites on the plains. From tales of giants who made the jars and used them as cups (Colani 1935a: 94, 121-123), to claims that they were made to accommodate the festivities commemorating a great victory by the local ruler (Sayavongkhamdy & Bellwood 2000: 105), numerous legends have circled the jars. The purpose of the jars is still being deliberated by archaeologists but the majority agree the jar sites served as mortuary sites to some degree (Colani 1935a; Colani 1935b; O'Reilly *et al.* 2019; Shewan *et al*. 2021; Sayavongkhamdy & Bellwood 2000). Whether or not the jars are contemporary with the human remains and artefacts which surround them is still being investigated.

Figure 35. The King's Cup, located at Jar Site 1, is the largest documented jar.

As with a range of Colani's work, archaeologists have slowly been re-evaluating the data she produced and the interpretations proposed. The initial analysis of the artefacts she excavated from Jar Site 1 in the 1930s suggested a relative date from between 200 BCE – 200 CE, relying on Otley Beyers regional typology, placing the artefacts within the local Iron Age (Colani 1935b:123). Colani believed the jars could be placed "within the first century of our era noting the deposits would be contemporary with the Đông Sơn culture" (Colani 1935b:122). It should be noted while Colani provided suggestions regarding site dating she recognised and displayed that many of these suggestions were speculative and cautioned against assumptions and general attributions on site purpose (Colani 1935a: 92, 152). The accuracy of these dates has subsequently been questioned following the radiocarbon dates produced from the most recent excavations of Jar Site 1 undertaken by a joint ANU – University of Laos team. A variety of dates ranging from 8200 BCE–1300 CE were recorded, yet the researchers believe the data suggests a more reliable dating for human occupation of 800 CE–1300 CE (O'Reilly *et al.* 2019: 984). Throughout recent years numerous samples have been radiocarbon dated, providing a wide range of dates. Currently there is no clear consensus regarding the cause of this variance. Alternative radiocarbon dates retrieved from the Plain of Jars include 2280 BCE–1294 BCE (Sayavongkhamdy & Bellwood 2000) and 3140 BCE–2910 BCE (Van den Burgh in O'Reilly *et al.* 2019) which are much older dates than those proposed by the most recent research (O'Reilly *et al.* 2019; Shewan *et al.* 2021).

While the dating of the jar sites remains inconclusive, interpretative connections between the jars and the material around them remain. Attempts to directly date the jars have been undertaken with researchers undertaking Optically Stimulated Luminescence (OSL) and radiocarbon dating on material directly beneath a jars at sites 1 and 2. Attempts to produce a *Terminus Post Quem* for the last placement of one of the jars at Jar Site 1 has provided a date of the late thirteenth CE. Although this date fits the interpretation of the Plain of Jars development, the dating method can produce erroneous results if the soil sampled has previously been exposed to light by movement of the jar and bioturbation (O'Reilly *et al.* 2019:986). Consequently, the date provided may not be considered conclusive due to the close proximity of burial activity occurring within the 800 CE–1300CE range. This date was also taken from beneath a single jar and a larger sample would be required to produce a chronology of the site with any certainty. An intensified dating programme is scheduled for future excavations to address the variance (O'Reilly *et al.* 2019:986). Further attempts using OSL have provided potential dates of 1240 BCE–660BCE at Jar Site 2, representing a much earlier date than previously expected (Shewan et al. 2021:28). The context of surrounding burial activity appears similar to those of Jar Site 1, but the dates would suggest jar placement hundreds, if not thousands of years earlier.

Many of the dates, including the *Terminus Post Quem* from Jar Site 1 fit with the interpretation that the jars were produced much later than initially thought. The 800 CE–1300CE dating also corresponds with the Iron Age artefacts uncovered throughout Jar Site 1, furthering the interpretation that the burials around the jars are associated with the jar production culture itself. Furthermore, the theory that iron tools were necessary to produce the jars (at sites 1, 2, 3, and 7 based on finish quality) add to a narrative of late Iron Age to Proto-historic production and use for the jars. While there is clearly circumstantial evidence to support this interpretation of site production and occupation, there is also a large pool of data (both direct and analogous) which contradicts it.

Production and material selection

Some geological analysis of the material used for the Plain of Jars megaliths has been undertaken. There appears to be three main materials as well as two less common materials used to produce jars within the region. Sandstone, granite and conglomerate contribute to the main jars with sandstone being the most heavily employed material (Baldock & Van Den Bergh 2009: 147-148). The sandstone present within the Plain of Jars region has an assumed density of 2.3 Mg/m^3 and is described as a fine-grained sandstone (grain of 0.06mm-0.2mm) (Baldock & Van Den Bergh 2009: 147).

The megaliths of the Plain of Jars follow a consistent general form. The jars display a similar height to diameter ratio of approximately 1.5:1, with most jars being slightly taller than they are wide (Baldock & Van Den Bergh 2009:147). The construction of completed jars tends to follow a pattern of thin walls and a thick base yet there is slight variation. Some examples noted by Colani (1935a:139, 231, 249) have a base thickness of up to half of the jars' overall height while others have a base as thin as 6% of the overall height. However, Sayavongkhamdy & Bellwood (2000:105) suggested most jars have a base thickness of one quarter to one third of their overall height.

The presence of some capstone disks have led to the suggestion that lids for the jars existed, yet it is unclear how many of these assumed lids are in fact lids. As at Hin Tang, it is likely many of the discs (if not all in some sites) are capstones for underground burial chambers (see Colani 1935a: 152-156).

The suggestion that the discs were potentially used as lids on the jars has been drawn into question (See Colani 1935; Sayavongkhamdy & Bellwood 2000). This idea is one of the few which was not proposed but discounted by Madeleine Colani in her first volume of *Mégalithes du Haut-Laos*, where she questioned the practicality of the removal and replacement of the stones in the context of rice or wine storage, claiming some might have weighed as much as 2,500 kg (Colani, 1931: 123). The previous examples reviewed above would suggest the presence of lids is not completely unrealistic as all examples of ISEA jar megaliths have some form of lid. The function of these disks is another question currently being considered by archaeologists, the answer to which so far remains elusive.

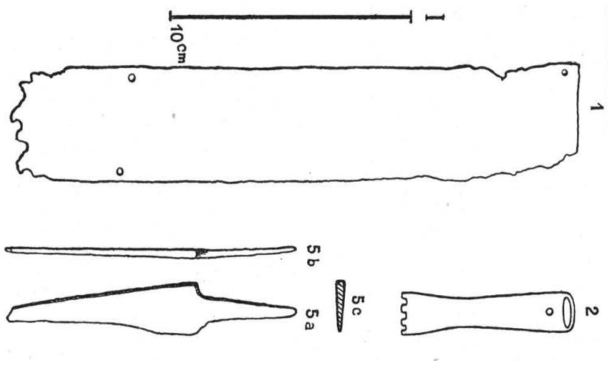

Figure 36. Metal artefacts excavated at Jar Site 1, items 1 and 2 are identified as bronze chisels. Item 5 is a iron blade (Colani 1935b: 50).

Tool usage for the Plain of Jars megaliths remains ambiguous in nature. Limited work explores this element of the megaliths production, with Colani's working being the main example. Only two examples of potential chisels exist in the artefacts uncovered within the Plain of jars. Each of the potential chisels uncovered are cast bronze, with only one being clearly identified as a stone working tool. A small bronze tooth chisel (item 2 in Figure 36) is the sole example of a clear stone working tool identified within the Plain of Jars excavations. Colani suggests there is a second chisel (item 1 in Figure 36) but this item differs in design and has suffered considerable damage.

Locale

Attempting to analyse the placement of these megaliths is challenging even though some potential placement criteria have been noted. It is nearly impossible for archaeologists to view areas in the same way as peoples of the past due to the numerous and extensive ecological and environmental modifications of modern times. Accompanied by shifting borders and natural landscape change, exploring the ways past people interacted and valued their landscapes is made a troublesome endeavour. Even with the uncertainty surrounding the changes to landscape, there is a clear element consistently displayed across the vast majority of the sites. The elevated locale of the sites' placement is consistent across the vast majority of the Plain of Jars sites, with jar sites situated upon mountain sides and saddles, mostly overlooking the plains below (Shewan *et al.* 2021; O'Reilly et al. 2019). There are some outliers within this observation, most notably Jar Site 1 which is situated in the centre of the plain. However, these outlier sites still display long view distances, being elevated on slight rises above the surrounding lower plains. It is clear from the consistently similar locale of jar sites that some importance exists with these elevated areas, prompting the placement of jars within these areas. It should also be noted that many jar sites are in close proximity to their quarries (Sites 42, 52, 3, 2, 24, and others). Many instances show some movement of the jars to provide direct views of the lower landscape around their mountain perch.

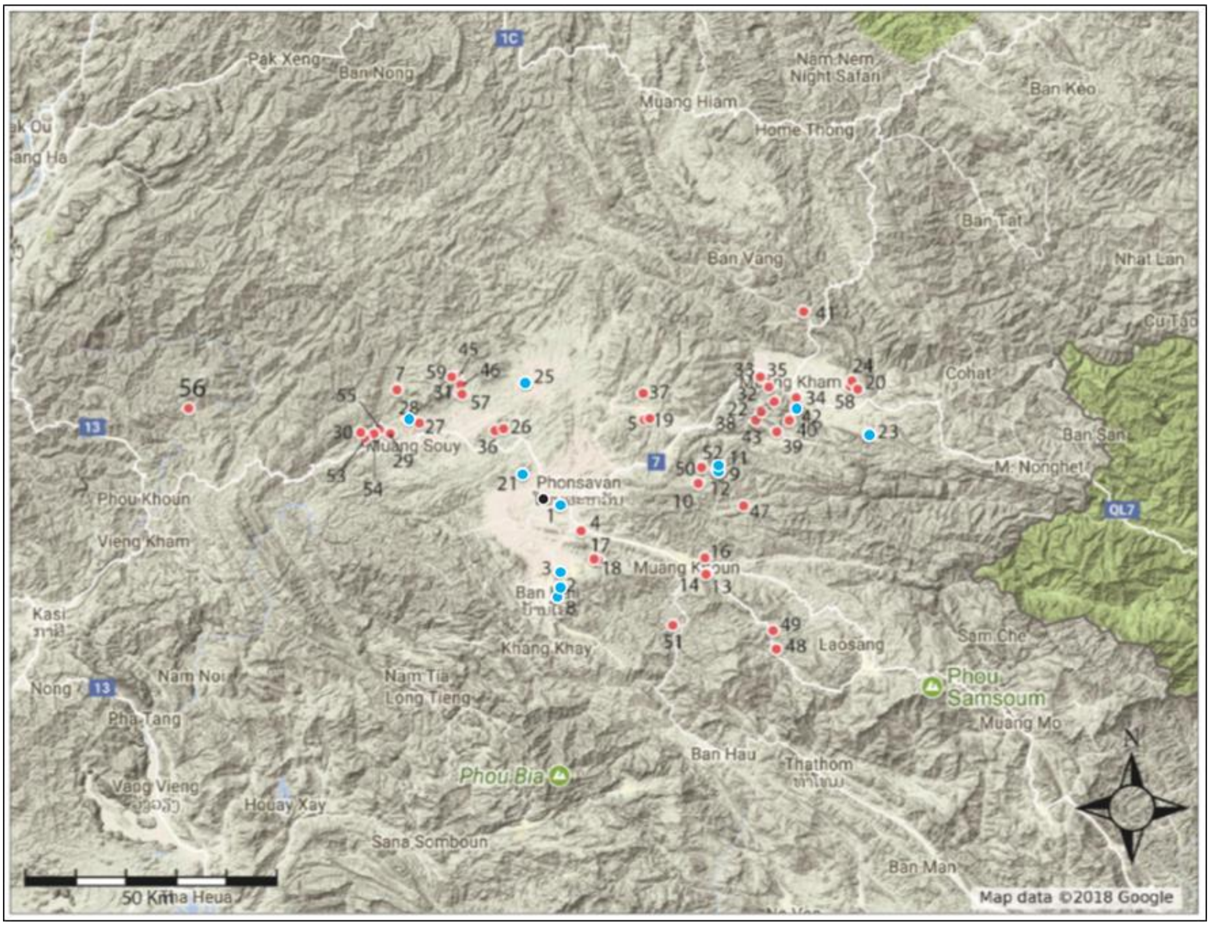

Figure 37. Map of Jar site distribution in Xieng Khouang Province, blue dots represent UNESCO World Heritage Sites (after O'Reilly et al. 2019)

2.4 Discussion

The megaliths explored offer a window into different elements of technological complexity, social roles and more nuanced elements like subsistence and ritual importance. Exploring these key aspects allows for a preliminary understanding of megaliths, and the differences and similarities between them. Exploring the shared features and differences may provide insights into the knowledge gaps of the Plain of Jars. The range of megaliths discussed offers insights into elements key to the thesis, providing analogous data to fill some of the gaps in the Plain of Jars literature.

Potential role of the megaliths; the tools materials necessary and employed; the stone selected for the structures; and the potential connections between some of the megaliths discussed are important factors of importance when considering time and tool investment for jar production.

Role of Monumentality

Determining the role of megaliths with any certainty is an impossible task, yet some signs and common features can be used to determine potential roles megaliths played. Many megaliths fall into the category of ritual activity which carries a range of interesting associations. Often megaliths are viewed as foci of ritual practice by archaeologists, as the scope and scale of these structures often defies explanation. Although it can be claimed that the title of ritual is used when no other explanation appears viable, there is reason to apply this title to sites of this nature. Megaliths retain an important role within community development and are thus woven into their history from the ancient past all the way to the modern day. The role which megaliths played within the ancient past are hard to determine with any certainty, yet interpretations of the individual role of the sites do exist within the archaeological literature. It should be noted that attributing a general role to megaliths is firstly not the purpose of this review, and secondly is a grave error as suggested by Colani herself (1935a: 152). Although megaliths share similar form it is not appropriate to assume they share similar function.

The role of monumentality within community development cannot be understated, initially monumentality can act as an indicator of societal development, as seen in Childe's *Urban Revolution* (1950: 12). Yet as Göbekli Tepe shows, there are cases where megaliths act as the impetus for community connectivity and development. The prompting of agriculture in the regions associated with Göbekli Tepe directly contradicts the earlier models which have monumentality as result of statehood rather than an impetus for cultural and technological development. The production of Göbekli Tepe also contradicts Childe's rules regarding the development of craft specialists and artists (1950:15-16) as each are necessary for the carving of the iconography present in the site. Similarly, Stonehenge can be viewed as a ritual centre for community gathering and likely ritual practice during the Neolithic. As such it is clear that megaliths are not just a display of grandeur produced by developed states and stratified societies, they may have a far more influential role within ancient societies. It should be noted, within current archaeological discourse the criteria proposed by Childe is not viewed as universal, yet remains the most widely applicable model for exploring statehood.

While some of the megaliths discussed above act as ritual centres or temples, others serve a different purpose. The Plain of Jars, the Mongolian Deer stones, Hin Tang, the Olmec heads and the Moai have all been associated with either mortuary practices or ancestor worship. These remain places of high ritual importance yet they serve distinctly differing purposes to the sites of Göbekli Tepe and Stonehenge which are believed ritual centres. Mortuary rituals surrounding these sites may act as active physical entities within rites of passage, built to commemorate one's life or aid in the transition from the world of the living to that of the dead. The Moai are the most ethnographically explored example discussed, with some insights into the purpose of Moai coming from this work. It is suggested that the Moai represent ancestors and past members of the community. Their production within Rano Rakaru has been associated to the beginning of life starting at *Hiva*, the place of the gods, before they walk the *ara* to the coast where their souls jump into the sea and return to *Hiva* (Richards *et al.* 2011:196-202). The path taken by the Moai can be seen as a physical display of the path taken by spirits of the dead. While practices in the other regions likely differ, the Moai act as an example of the ways in which megaliths go beyond the physical world, playing directly into ritual action and the realms of spirits and gods. Each of these communities interact with their megaliths in distinct ways, with megaliths and practice melded together into a key element of culture and ritual practice.

Materials and technological complexity

The sites outlined above also display more tenable elements of discussion. The megaliths' physical elements including their production processes, material requirements, quarrying, and transportation can also provide insights into community life and technological development. As stated previously, it has become a common belief the jars of Laos were carved using iron tools due to a suggestion by Madeleine Colani in the 1930s alongside the material culture often assumed contemporary with the jars (Colani 1935a: 134, 144; Colani 1935b: 123; Sayavongkhamdy & Bellwood 2000:105; Shewan *et al.* 2021: 16), yet there remains little concrete evidence for this interpretation. Furthermore, there remains little contextual evidence that the burials around the jars are associated with the jars initial production. While this belief has become ingrained within the narrative of the Plain of Jars, it should be noted that Colani remained cautious in attributing a common age upon all sites within the region. Colani attributed only sites 1, 2, 3 and 7 to the regional Iron Age (Colani 1935a: 134, 144), yet with continued reference in subsequent publication this attribution was spread to a general belief of the majority of sites within the region. The presence of iron and bronze artefacts within Jar Site 1 has previously been viewed as confirmation that the jars are dated to the regional Iron Age although these connections between jars and surrounding artefacts have yet to be verified and the confirmation of the dating of a singular site does not indicate the other sites are also Iron Age in nature. This literature review sought to explore the technical elements of megalith production in a wider context; chiefly tool materials employed in the process.

Among the sites reviewed a range of stone types with varying degrees of hardness (according to Measure of Hardness (MoH)) ratings have been employed. The materials hardness and density have direct impacts upon their carving capabilities and overall strength. Considering the range which starts with a low rating of 3 for limestone of Göbekli Tepe and concludes with a high rating of 9 for the Olmec heads, one could assume that the materials required different quality tools to accurately carve the range of stone. Although different tool materials were used to carve these different stone types, there is nothing that suggests iron, or any metal, was necessary for any of these megalithic productions. This fact is clearly displayed by the Olmec heads. The artefacts of the Olmec culture do not include worked metal within any aspect of the society. Consequently, there is a definite absence of metal carving tools, with craftspeople relying on stone and potentially obsidian tools (Coe & Dahl 1980:296, 390). Furthermore, when metal was available it appears that megalith builders continued to use stone tools, as is the case proposed for the megalith builders of central Sulawesi by Van der Hoop, where it was suggested bronze and possibly iron production knowledge existed, yet stone tools were believed to be employed by megalith builders (1932: 164 in Colani 1935b: 121-122). The range of megaliths explored displays the capability for stone tools for carving, and suggests that stone tools were one of the more prominent – and in some instances preferred – material of megalith builders.

It should be noted that Colani approaches broad claims with much caution throughout her work (Colani 1935a: 92, 152). The overarching claim that the jar sites 1, 2, 3 and 7 had to be made with iron tools because of their finish quality (Colani 1935a: 134,144) and the jar production culture itself is of the Iron Age (Colani 1935b:123) provides a narrative which has been reiterated and heavily relied upon for years past. While the archaeological literature of the Plain of Jars emphasises the role iron plays within jar production (Colani 1935a: 134, 144; Colani 1935b: 123; Sayavongkhamdy & Bellwood 2000:105; Shewan *et al.* 2021: 16), the global megaliths explored offers an alternative. Throughout the examples explore only a single example, that of the Mongolian Deer Stone, employed metal tools within its production. In the instance of the Mongolian Deer Stones, it is also suggested that in spite of the Iron Age dating, the artefacts excavated throughout the region are predominantly copper and bronze (Tishkin 2020: 455). All other examples employed stone tools or remain uncertain. While this may not be true for the Plain of Jars context, the research offers analogous examples throughout time and space, providing support for an alternative form of jar production. To assume that lithic tools are used within the context of Laos is just as problematic as assuming iron is the primary tool of use, as such this thesis aims to explore the jars production using a variety of tool materials.

South China Sea Interaction Sphere

Among the sites discussed there are also a variety of megalithic forms present. From stone circles and temples to menhirs and henges, there is a large array of megalithic construction demonstrated. Some of the sites however, show similar megalithic forms to those present within the Plain of Jars with this shared form producing interpretations of connected origin or continuation of practice. The shared jar forms of Island Southeast Asian megalithic examples as well as Assam and the Plain of Jars have been discussed as potentially connected within archaeological literature (see Colani 1935b: 211-236, Thakuria 2014, Kaudern 1938:185-186 1, Genovese 2019b, and Sukendar 1987). Although these connections have been alluded too and discussed in part, they remain mostly speculative in nature with some outright disagreeing with the possibility (Kaudern 1938: 185-186).

From the earliest excavations at the Plain of Jars it has been suggested that the site shows similarities to the stone jars of Assam, which were being investigated contemporaneously. Suggestions of a cultural continuation originating in Assam and spreading southeast towards the Vietnamese coast were proposed by Colani in the second volume of Des Megalithes Du Haut-Laos. This interpretation proposed a connection to the Sa Huynh cultural group, displayed by the use of large pottery vessels for the deposition of human remains (Colani, 1935: 237-243). It was suggested the use of these large pottery vessels may be connected to the stone jars mortuary purpose within the Plain of Jars context.

Although evidence supporting these proposed connections are lacking, the presence of similar megalithic examples in ISEA has provided another potential cultural link. Sulawesi, Sumatra and Sumbawa display megalithic traditions with similarities to the Plain of Jars, most notably the jar form megaliths. There also appears to be parallels between the two-stage burial practices which continue in modern day Sumatra and the potential burial practices identified within Laos. The placement of human remains within a stone sarcophagus or stone jar is the first stage of the two-stage burial process (Barbier 1987:44-46). The body remains within the sarcophagus or jar until decomposition is complete before being buried. This practice is highly reminiscent of the mortuary ritual practices potentially connected to the Plain of Jars. Dispersion of culture, practice and people could all be reliable causes of the similarities witnessed between these megalithic traditions. The increased trade activity which occurred from the late Bronze Age into the Iron Age may have facilitated the spread of practices from the Vietnamese coast, the mainland end of the purposed cultural spread, into Island Southeast Asia. The South China Sea interaction sphere, may have been established as early as 1500 BCE and continued throughout the Bronze and Iron Age (Hung *et al.* 2013: 384-385). It is clear that Laos was highly connected to neighbouring and distant principalities with the presence of rare bronze coils only found within the Noen U-Loke site being present in the artefacts uncovered by Colani at the Plain of Jars (image in Colani 1935b: 19; pers. comm. Nigel Chang). Through the potential connections between

Laos and the Sa Huynh culture of Vietnam, cultural traditions and practices may have spread throughout ISEA, as Sa Huynh played a pivotal role in the exchange network (Hung *et al.* 2013: 386). It may be possible the cultural practice of megalithic jar carving was transported via the exchange routes of the South China Sea Interaction Sphere although the validity of this possibility is yet to be explored and would require extensive data to be verified. Such a cultural spread could explain the recurrent megalithic form as well as the consistent carved iconography which is seen within these distinct contexts.

Summary

Monumentality can be an important part of societal development and cultural identity, in some instances prompting developments in society or resulting from them. Megaliths represent one of the most mystifying elements of the archaeological record, enticing academics and the general populous alike. Research surrounding megaliths take a variety of forms from direct analysis of megaliths to analysis of associated artefacts. Current understandings of the Plain of Jars megaliths are heavily dependent upon the artefactual finds surrounding the jars rather than research on the jars themselves. Exploring megaliths themselves has proven to be a productive pathway as evidenced by the literature. Furthering understandings of megalithic sites and the surrounding societies alike, the collected works display a range of approaches to megalithic analysis. Analysis of carvings and imagery; construction and analysis of transportation methods and routes; exploration of quarrying and extracting; and identification of purpose have all proven to provide promising results within their individual contexts. Currently few of these approaches have been attempted regarding the Plain of Jars context. With a deepened understandings of the roles' megaliths play within society; it is clear that sites like the Plain of Jars act as key meeting places and ritually significant elements of the prehistoric landscape. Centres of trade, community, and ritual practice, megaliths serve important purposes within cultural practice and remain a key piece of the archaeological landscape to the modern day. Understanding the production and subsequent use of the jars would provide archaeologists with insights into the people who lived within it.

Exploring aspects like quarrying, transportation, purpose, and production are insightful methods for viewing the surrounding societies in greater detail. The literature also confirmed experimental archaeology is a highly effective method for exploring megaliths and the societies which produced them. While much of the previous work has drawn its data from artefacts surrounding the jars, the insights provided by this endeavour only offer a select view of the region's past. Exploring the Plain of Jars through an Experimental Archaeological framework offers an avenue for exploring previously invisible elements of practice, culture, and technological complexity. Application of this theoretical approach alongside *chaîne opératoire* offers further opportunities for experiential analysis, providing insights into the individual and the lived experience of jar carvers. The following chapter will detail the range of theories employed within this research, discussion their strengths, limitations and purpose within this thesis.

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Table 2. Overview of megalithic production data

	[1]*Göbekli Tepe*	[2]*Stonehenge*	[3]*Deer Stone Complex*	[4]*Olmec heads*	[5]*Moai*	[6]*Sulawesi*	[7]*Assam*	[8]*Hin Tang*	[9]*Plain of Jars*
Dating	9000-7000BCE	3700-2500BCE	1300-700 BCE	1200-900 BCE	1300- 1500 CE	200 CE- 1300 CE	2000 BCE-300 CE	300 BCE-300CE	3140 BCE-1300 CE
Size	12 meters tall	Longest bluestone 9 meters	1-4.1 meters tall	6 – 26 tons	10 meters tall	*Kalamba* 1-4 meters tall	Unknown	1-3 meters tall	0.5-3 meters tall
Distribution	Built into the top of a mountain overlooking a semi plains environment	Found upon large open fields	Found within the Steppe regions – never in forested areas	Found at predominantly at two monumental sites, La Venta and San Lorenzo	Spread across Easter Island with many found along coastlines and main roads	Found within 3 valley regions, Bada Valley, Besoa Valley and Napu Valley	Found in mountainous regions	Found upon the tops of mountain ridges and saddles overlooking steep valleys	Found on mountain saddles and ridges with long view distances
Number of sites	3 distinct site areas	1, 3-tiered stone circle	>1000 but only half remain standing		>1000	Spread across 3 valleys	50 have been rediscovered	Unknown	>100

Number of megaliths total	5 separate rings	3 semi-intact rings	>1000	17	>1000	147	Unknown	Unknown	<1000
Number of components	2 central T Pillars with 12 surrounding pillars of smaller dimensions in each site area.	Stonehenge	Single menhirs, sometimes found with a set of material remains	Singular carved stone heads	Individual *Moai*	Individual components mostly, *Kalamba* and *Toetoena* are complimentary elements	Singular jars	Individual menhirs and disks	Individual jars and disks
Quarry distance	1.2 km	Up to 230km	Surrounding area	80 km	Up to 18 km	Up to 20 km	Unknown	Unknown	Up to 12 km
Transportation method	Unknown	Wooden rollers	Unknown	Log Rafts	The Moai ‘walked’	Unknown	Unknown	Unknown	Unknown
Rock type	Limestone	Dolerites and a range of bluestones (sarens)	Granite,	Fine-grained Basalt	Volcanic hyalotuff bedrock	Granite, white granite?	Unknown	Slate	Granite, fine-grained Sandstone and Breccia
Measure of Hardness	Limestone 3-4	Sandstone 4-5	Granite 7-8	Basalt 7-8	Unknown	Granite 7-8	Unknown	Slate 5	Granite 7-8 Sandstone 4-5

Tools used	Stone tools Antler tools	Wood and Mudstone wedges, hammer stones	Bronze (assumed)	Hard stone tools, sandstone tools or obsidian tools	*Toki* (distinct stone adze), obsidian and coral abraders.	Stone (assumed)	Iron (assumed)	Unknown	Iron (assumed)
Megalithic form(s)	T pillar menhirs	Cromlech	Menhirs	Craved stone heads	*Moai* distinct form	*Kalambas*, Lids, steleas,	Jars	Menhirs and disks	Jars and disks

[1] Busacca 2017, Clare *et al.* 2018, Dietrich 2012, Dietrich *et al.* 2018, Dietrich et al. 2019, Schmidt 2000, Schmidt 2010.
[2] Bender 1992, Cusack 2012, Fagan 1999, Gillings & Pollard 2016, Parker Pearson 2013, Parker Pearson *et al.* 2015, Parker Pearson *et al.* 2019, Michell 1999, Mohen 1999, North 1997, Shillito 2019.
[3] Fitzhugh 2009, Fitzhugh 2017, Hanks & Linduff 2009, Tishkin 2020, Volkov 2002, Wright 2014.
[4] Coe & Diehl 1980, Grove 1997, Grove 2014, Hazell & Brodie 2012, Hazell 2013, Wendt 2005, Williams & Heizer 1965.
[5] Gioncada *et al.* 2010, Lipo *et al.* 2013, Richards *et al.* 2011, Van Tilburg & Ralston 2005.
[6] Adams 2019, Barbier 1987, Hasamuddin 2016, Kaudern 1938, Kileis *et al.* 2012, Prasetyo 2012, Steimer-Herbet 2018, Sukendar 1987.
[7] Mills & Hutton 1929, Sengupta 1946, Thakuria 2014.
[8] Colani 1931, Källén 2015.
[9] Baldock & Van Den Bergh 2009, Colani 1931, Colani 1935, Genovese 2006, Genovese 2019a, Genovese 2019b, O'Reilly *et al.* 2018, O'Reilly *et al.* 2019, O'Reilly *et al.* 2020, Sayavongkhamdy & Bellwood 2000.

Chapter 3.

Theory

The core aim of this research is to explore and revise interpretations of jar production through an experimental approach. To correctly interpret the past data and revisit the assumptions surrounding the jars and the remains around them, it is appropriate to employ a critical approach in both theory and method. The centrepiece of this research is past assumption and its continued impact on the narrative of the Plain of Jars. Evaluating these past interpretations and beliefs imposed upon the jars allows for a more comprehensive understanding of the region and its archaeological past. The research not only provides an empirical, scientific approach for hypothesis testing, it also provides an experiential opportunity for phenomenological analysis of practice. Reliance upon experimental archaeology allows the creation of detailed descriptions and rigorous data collection while also providing the opportunity for the experiential and Phenomenological analyses.

The theoretical frameworks employed stem from both processual and post-processual schools of archaeological theory. Employing positivist scientific approaches for detailed data collection and hypothesis testing alongside subjectivist views of individual action and agency. This dual approach not only provides the research with validity and accuracy but also provides opportunity to view the lived experience of past people. The divisive nature of processualism and post-processualism results in a division within my approach. While completing the experiment work much of the data collection will be empirical in nature. Clearly defined variables throughout the experimental work provide a consistent framework for data collection while lived practice offers additional interpretative capabilities once work has been completed. The research has a slightly higher reliance on empiricist approaches but seeks to enrich experiential understandings of the jar carvers and those who lived around the megalithic structures. The theoretical approaches employed within the research encompass this range of approaches and seeks to provide an unbiased assessment of past theory without being devoid of discussions of experience and individual interpretation.

3.1 Experimental archaeology

Found within the range of actualistic approaches, experimental archaeology seeks to understand the material past and the lived experiences of people in the past through the replication of past practice. Accompanied by ethnographic analogy, taphonomy and cautionary tales, experimental archaeology is often considered within the Processual school of archaeological theory. While some argue actualistic approaches should emphasise empirical evidence and objectivity throughout their use (Malmer

1997:14), others critique this direction believing it to be one of the approaches main drawbacks (Wylie 2002:161). While objectivity was central during the revival of experimental archaeology during the 1960s and 70s, this approach has seen a shift in recent years (O'Sullivan & Souyoudzoglou-Haywood 2019:1). While retaining the highly empirical nature of hypothesis testing, the approach has seen an increased emphasis placed upon the lived experience. Experimental archaeology approaches the archaeological record in an empirical scientific fashion, while remaining intrinsically linked to humanistic interpretations (Millson 2010: 1). While the scientific approach is appropriate in some instances it has been argued that to consider all aspects of the past one must also consider the lived experience (Millson 2010:1; O'Sullivan & Souyoudzoglou-Haywood 2019: 1; Ghergiu & Children 2011).

Experimental archaeology in current practice can be described as the (re)construction of past objects, structures and environments based on archaeological evidence (O'Sullivan & Souyoudzoglou-Haywood 2019: 1; Mathieu 2002). This practice is often undertaken to explore particular elements of material culture, test hypotheses regarding sites or artefacts, and as a method for verifying data collection methods used to view past material (Millson 2010: 3; Mathieu 2002; Paardekooper 2019:9). While each of these elements has purpose and merit, the main application within this thesis focuses on the production of a particular artefact form, the megalithic jars, to test past theories regarding their production. Specifically, how long do they take to make and what tools are required.

The research seeks to produce analogous tools to test their capability in megalith production. The use of said analogues provides parameters for this and future testing while limiting variance between the experiments and actual past practice. Although every effort is taken to guarantee accuracy, use of analogy has been critiqued for the inability to accurately replicate conditions both across experiments and relative to past practice (Frisk in Paardekooper 2019:3). Although true, analogy is an ever-present element of archaeological work. It has been suggested that analogy is wholly unavoidable in archaeological research (Johnson 2011: 65), with much archaeology being analogical in nature with associated inferences being analogical as a result (Wylie 1985:64). While potential for inconsistency exists, every effort is taken to avoid inter-experiment inconsistencies. Analogy is also employed when considering the wider archaeological record. Although cross-cultural data is not directly applicable to the examples of Laos, exploring past megalithic examples throughout time and space allows insights into human ingenuity as a whole. A large portion of the literature review has therefore been dedicated to viewing the global megalithic repository and inferring production practice. While this should not be used to assume what practice *was* occurring within Laos, it can safely be used to see what *could* have been occurring. The central use of analogy within the literature review shows that megalith production is achievable with lithic tools, while also cautioning the assumption that this is the case in Laos. While potentially possible, it would be inappropriate to explore potentially unbacked theories surrounding the sites, while also producing a different range of unsupported claims. The approach to existing literature aims to remain unbiased by suggesting possible practice devoid of inferences about active practice.

This research employs experimental archaeology predominantly for its ability to produce new data from existing understandings of archaeological material and past practices. One of the unsung merits of experimental archaeology is the approach's non-destructive nature, relying on replicated material to provide new insights. While many archaeological approaches are inherently destructive in nature, experimental archaeology extrapolates data from past research and excavations through (re)construction in the present using tools and techniques analogous to past practice. This not only allows the extrapolation and exploration of past archaeological understandings, but also offers potential investigation avenues for future excavations (this will be explored in detail within the discussion). A multi-faceted approach allows for reductions in inconsistent practice and allows greater depths of inference be produced from the work. As such Experimental archaeology is intertwined with elements of Practice Theory to better develop the research avenues and reduce inconsistencies and redundancy within the experimental work.

3.2 Practice theory

Practice theory strives to decentralise models of economic and strategic decision making, emphasising practice over purpose. Practice theory avoids notions such as economic strategy, ideology and political organisation (Pauketat 2001:76). This focuses heavily on *what* people do and *how* they do it rather than *why* actions are taken. Decentralizing the social aspect of action allows the attribution of new meaning at the individual level rather than the societal (Bourdieu 1977: 81, Pauketat 2001:79). Both practice theory (Bourdieu 1977) and agency theory (Gidden 1979) suggest action of practice, or interactions with social elements are shaped by culture and inherently shape culture itself, supposing a multidirectional flow of purpose and intention. This suggests alterations to cultural practice are not simply associated with tactical decisions or strategies but form a more complex relationship between individual action and societal action (Harker & Alt 1990: 15).

Practice theory's aim of separating action from purpose is predominantly concerned with notions of economic and strategic purpose. Individual practice is emphasised, with importance being placed upon the processes involved within artefact production and implementation. While exploration of economic value is useful for viewing the investment and potential socio-cultural value of the jars, these explorations should be conducted after the experimental work. By relegating this assessment to the later stages, practice and outcomes are emphasised and bias towards strategic decision making during the experimental work is avoided.

Practice theory's application alongside experimental archaeology allows a further opportunity for individual assessment, viewing the jars as an element of practice shaped by culture which shapes culture in turn. Practice theory provides a key method for approaching jar carving practice, allowing for a more consistent assessment within the current research and subsequent research. Practice theory also offers complimentary methods for application with experimental archaeology, with *chaîne opératoire* being the most applicable. *Chaîne opératoire*, often employed in assessment of lithic reduction and use, offers a consistent procedural process for replication of jar production, resulting in consistency throughout the experimental process. *Chaîne opératoire* can be described as the chronological segmentation of actions, practice and mental processes in the production, usage and discard of archaeological artefacts (Sellet 2016: 106). Within this thesis *chaîne opératoire* is primarily employed as an analytical tool to accompany the experimental approach taken. Three analytical approaches are available within the production segment of the *chaîne opératoire*; refitting, diacritical studies and experimentation (Sellet 2016:108). The dense and descriptive nature of *chaîne opératoire* cooperates naturally with experimental approaches, resulting in an approach focused on practice and consequence, offering room for inferences to be made at the individual and societal levels. The analytical method has previously been applied to megalithic production; Mens (2008) applies *chaîne opératoire* when mentally refitting megalithic elements to their core outcrops. The *chaîne opératoire* employed within this thesis differs from the above example in both context and analytical approach, yet offers similar insights into the procedure applied to megalith production.

The production procedure applied is one developed through personal observations within the subject area. *Chaîne opératoire* aids greatly in empirical analysis of the experimental work but also raises a range of questions about past choices and lived experience. Although not heavily employed within this research, a portion of the discussion chapter will discuss the lived experience and draw upon Phenomenological concepts to aid in interpretation.

3.3 Phenomenology

Unlike the previous frameworks which employ some form of empirical analysis, phenomenology is entirely concerned with the lived experience and what it can tell us. Much of phenomenology focuses upon the subjective interpretations of environment. Stemming from Landscape archaeology (David & Thomas 2008: 28), phenomenology branches away from the empirical cartesian approaches undertaken by processual theorists and goes as far as to critique the empirical nature of landscape archaeology (Fleming 2006: 268; Wylie 2002: 161; Johnson 2012:274). Phenomenology's interest in landscape is mostly focused on wider social practice that mediated experiences of landscape in the past (Tilley 2016). Phenomenology has been employed previously in research surrounding the placement of megaliths within the landscape (see Jones: 2012; Gillings & Pollard 2016; McFayden 2008). Phenomenology creates a discussion of landscape that borders on ontological or cosmological understandings of land use and experience. Although the theory is mostly concerned with land and landscapes, ideas and concepts from the theory work well to augment the humanistic insights and discussion of lived experience created by the experimental approach. Building into the experiential aspects of experimental recreation, phenomenology offers a wider range of approaches to viewing past experience. While a distinction between phenomenology and ontology can be made, the practice involved within each of these approaches are heavily inter connected. As such elements of the discussion chapter will shift between these approaches when traversing experiential discussions of land and objects.

Employing elements of phenomenology, the research will explore megalith placement and production while emphasising the experiences connected to the landscape and the megaliths themselves. While not central to the research itself, the application of this theory furthers insights into the feelings past people may have experienced within their landscapes as well as the practices that shaped it.

3.4 Theoretical applications

Each framework discussed is employed to provide a different avenue of research and allow a comprehensive understanding of the thesis subject matter. The theoretical frameworks provide direction for research and guidelines for critical assessment regarding past data and interpretation. Key to the research is the critical revision and exploration of past theory. Determining the accuracy of past claims is the primary goal of the thesis, with deepened understandings of megalithic production and purpose rising from it. Exploration of past theory is predominantly undertaken using an analogous approach, determining potential tool capabilities and investment of time from a wider pool of megalithic examples.

The literature review predominantly focused upon the assessment of analogous examples. While this data is not directly applicable to the Plain of Jars context, it displays the capabilities of other cultures throughout prehistory. The research displays the earliest possible production of the megaliths, indicating that lithic tools were adequate to carve stone in some capacity. The literature review is undertaken with a critical focus, working to assess the past theories. It is important to note that the critical nature of the review is not only imposed on past theories but also the development of personal interpretation. Critically assessing personal interpretations of the data is necessary to avoid inadvertently impacting the experimental outcomes. Attempts to reduce these impacts were undertaken and all personal theory produced by the literature review was thoroughly tested through the experimental work.

The experimental work employs a rigorous data collection model, aimed at collecting all achievable data throughout the work. Stemming from each of the focal questions the research aims to test a number of ideas, supposed both by past archaeological discourse and by the author. While exploring these ideas, critical assessment of outcomes and decentralisation of purpose allow analytical emphasis be placed upon the carving practice itself. Reliance upon a *chaîne opératoire* for carving procedure reduces redundancies in experimental work and increases consistency across all experiments performed. The experimental work has been performed by the author in its entirety, to remain consistent in carving capability, physical fitness and desired finish quality.

Attempting to provide insight to the lived experience of the carvers and those who lived around the jars remains for the later stages of work. This delayed application of experiential and phenomenological approaches purposefully aims to reduce potential impacts to the validity of the experimental work. Undertaking these assessments later also allows a complete view of the process, with all variables concerned. While the theories offer avenues for research and aids in the production of ideas and inferences, the method remains the main director of the experimental work. Building from this discussion of theory and archaeological practice, the following chapter details the methods employed within the research, building into a research methodology developed to explore each of the questions central to the research.

Chapter 4.

Methods

This research aims to explore past and present assumptions through the use of experimental archaeology. Throughout this research, theory and method are heavily intertwined resulting in a close connection between the previous chapter and this one. As such this chapter will continue to explore the approaches previously discussed in conceptual terms, in more practical terms. It is the author's hope that past assumptions and ideas pertaining to jar production can be tested and verified by this experimental undertaking. A methodological approach is developed around the central theories and method of experimental (re)construction, employing elements of practice theory – namely *chaîne opératoire* – to provide data centric research approaches and reliable outcomes.

4.1 The Methodology

Using experimental (re)construction, we can evaluate the time, energy, and tool requirements of the jar production process within a controlled environment. The experiment has been designed with consistent variables between carvings with only tool material being changed between jars. There will be some underlying changes in proficiency of the craftsperson yet these were mitigated by additional work being undertaken before the main experiments as well as after, in an attempt to determine how greatly the craftsperson's improvement have affected the data gathered. As this is an isolated carving activity undertaken by a single craftsperson it could be argued that the data produced regarding time and energy requirements is anecdotal and does not represent the actual conditions of past activities on a large scale. At its core, this experiment aims to verify the assumption that the jars spread across the Plain of Jars were carved using iron tools. As it stands the only explanation which has been provided as a basis for this interpretation is proposed by Colani (1935a: 134) in her first publication in regards to Jar Site 1;

> "Their tools had to be metal, iron; indeed, in the cave and in the ground around the monoliths lie objects of bronze and iron, few polished or cut stone, almost on stone tools at all. On the jars, the marks of blows given by craftsmen are those produced by chisels or other iron objects."

No further explanation or supporting data appears to be provided for this interpretation, although Colani further suggests sites 2, 3 and 7 are also produced using iron tools (Colani 1935b: 123; Colani 1935b: 144). A further sentence states that 'The jar civilization dates well back to the Iron Age' (1935b: 123).

This was somewhat referring to the Jars of Laos as well as the Jars of Island Southeast Asia. There is currently no published work analysing tool marks at the Plain of Jars sites[1].

As previously discussed, the framework of experimental archaeology allows for the testing of hypotheses using modern experimental practice analogous to past practice. While employing Experimental archaeology often includes the use of hypotheses, the approach can be used to explore more general ideas and questions also. While Colani's above statement is not a hypothesis – it is spoken as factual – Experimental archaeology can still be used to explore these ideas. Some of Colani's key ideas are;

(1) The carving of sandstone jars was undertaken with iron tools, suggesting that the jar production culture belongs to the regional iron age (1935b: 123).
(2) The tool marks visible on the Plain of Jars assemblages are those produce by iron tools (1935a: 134, 144; 1935b: 123).

While exploring Colani's interpretations of the Plain of Jars assemblages, there are other important ideas and questions that can also be explored with the research. Other ideas which arose as a result of reviewing the megalithic case studies and personal work in the Plain of Jars are;

(1) What are the mechanics of jar production?
(2) Considering production time, how where the jars valued by the culture who produced them?
(3) What debris is created by the jar production process?

The second question evokes further questions regarding craft specialisation and economic value which will be explored in the discussion. These questions offer a range of interpretive angles for the initial stages of the work but are built upon within the discussion chapter. During the literature review, mention was made to past experimental archaeological practice, below is a brief discussion of key experiments which provided analytical variables for the work.

Past experimental examples

Initially research involving experimental stone carving appeared to be few and far between but as the experiments began a small supply of insightful articles were discovered. These articles mirror some of the ideas developed regarding the working ability of some tool materials and the resulting tool marks from each tool type.

[1] Work regarding tool mark analysis has been undertaken by an Australian National University Student at the honours level, although this work remains unpublished. The work suggests tool marks produced by both iron chisels and picks are present upon jars at sites 1, 2, 3, 8, and 21 (Tener 2020: 55). The work also suggested a Chaîne Opératoire for jar production which resembles the Chaîne Opératoire employed within this research (discussed on page 75).

Experimental research on the production of stone sarcophagi in the context of prehistoric Egypt showed the inability for most tools to carve hard stone. Experiments with carving igneous rock such as basalt and granite proved that copper, iron and steel tools were all ineffective at carving these stones (Stocks 1986: 26). Due to the high MoH's rating of both granite and basalt (both hardness 7-8), even steel tools proved incapable of effectively carving the material. One of the key findings of Stocks' (1986:26) work suggested that while metal tools were ineffective at drilling high hardness materials, stone tools were capable where these metallic tools were not. This suggests that stone tools would be capable of carving many of the jars, including the less frequent examples of granite jars. Unfortunately, the research was fairly sparse in methods and detailed data collection, providing explanations of the experiments' results but little supporting data. During the initial practice phase of the experimental carving work by myself using a range of stone types it became apparent to myself that carving granite using steel tools would be a slow and arduous process. This observation, accompanied by the efficient nature of basalt stone tools in sandstone jar carving explored later within the experimental process may provide supporting evidence for the findings proposed by Stocks (1986). These observations will be explored more extensively within the discussion chapter. The collection of work undertaken by Stocks appears to be the only research dedicated to analysing carving capabilities of different tool materials (see Stocks 2003; Stocks 1999; Stocks 1986). This particular data and personal observations draw emphasis to this experimental undertaking as a a living process that adapted and changed with time. The experiments expanded to accommodate further investigation of stone tools in the later stage.

Some smaller experiments identified as potentially insightful centred on the production of stone milling tools, which included the carving of slight recesses into mill stones to increase their efficiency. Each of these mills was worked through stone-on-stone percussion and abrasion (Buonasera 2015, Squitieri & Eitam 2016). Each of these experiments (Squitieri & Eitam using basalt, and Buonasera using sandstone and basalt) recorded the volume removed, the overall working time, the number of blows and lastly the rate of material removal. Each of these parameters is important to understanding the speed of work.

While not directly applicable to this study, much of the available research regarding megaliths is centred upon the transportation. A large body of this work concerning the roller hypothesis (one of the hypotheses proposed for megalith transportation) has been produced, both supporting and questioning the validity of the hypothesis (Harris 2018; Van Tilburg & Ralston 2005). The roller hypothesis sees megalithic elements dragged across wooden logs laid perpendicular to the stones travel, allowing the stone to be moved easier than dragging directly upon dirt. Although this research proved insightful for a measure of time investment and person power required for past experimental work there was limited applicability to my research. Aside from the discourse surrounding the roller hypothesis there appeared to be a relatively dense body of work regarding the quarrying of the *Moai* of Rapa Nui, as well as transportation via rollers (Van Tilburg & Ralston 2005) and through 'walking' (Lipo *et al.* 2013). The first analysis of the potential time requirement of Moai production was undertaken by William

Routledge (1919) with an overall suggestion of 15.5 days for a team of 54 men to carve a 30-foot-long statue (Van Tilburg & Ralston 2005; Routledge 1919: 179-180). Unfortunately, the exact calculations and their parameters are inaccessible making them both hard to correctly interpret and relatively inapplicable for my own calculations. These initial calculations were later scrutinised by other academics with some agreeing with the initial outcomes (Lavachery 1935:344-355) while others suggested longer production periods, up to a full year (Heyerdahl *et al.* 1989:36). This range of experiments appears to be some of the few research endeavours focused on large stone artefacts or megaliths.

Using this range of work a number of important variables can be isolated. Each variable offers insight into a particular element of the production process and works to provide a clear description of the experimental process.

Recording methods

The experiment aims to develop a descriptive view of the production of the megalithic jars. To achieve this end with a high degree of accuracy an experimental design is necessary. The design builds on key variables and the relationships between these variables. The variables being explored (Table 3) account for the materials used and allow for empirical analysis of the processes and time invested into the jars production. While not only exploring the variables and their relationships, the research emphasises their impact upon the outcome of the jar.

Table 3. Variables recorded throughout experiments

Variables	*Description*	*Details*
Stone type	Consistent stone type	Sandstone
Tool material	Main tool material employed	Stone, Copper, Bronze, Iron, Steel
Time	Divided into work, break, smoothing and total	Time carving and time smoothing
Number of strikes	Total number of tool strikes	Per session and total
Strikes per minute	Number of tool strikes averaged by minute	Average strikes per session and total average
Weight	Weight of jar in KG	Change per session and total
Weight of debitage	Weight in G	Per session and total
Debitage Distribution	Division between dust and flakes	Per session and total

Material removal rate	Material removal as g/h	Per session and total
Volume	Volume of jar material	Change per session and total
Internal volume	Volume of carved cavity	Change per session and total
Internal depth	Depth of carved cavity	Change per session and total

The experiment aims to identify the effect each variable has on the jars' outcomes and the time required. By changing individual variables within each experimental undertaking, it is possible to develop a measure of the variable's impact. This is a cornerstone practice of experimental archaeology and will allow a better understanding of the relationship between each of the variables explored. Furthermore, each variable not being tested by the experiment will be kept as consistent as possible to prevent inconsistencies within the experiments.

4.2 Experimental Design

The design builds upon those employed by design Buonasera (2015) and Squitieri & Eitam (2016). The design incorporates the variables explored in each of these experiments while also adding key variables such as tool material, debitage weight, debitage distribution and weight changes as detailed in the previous section.

The experimental design also details the phases of experimental work, divided into key sections (Table 4). Each phase contains a different experimental focus which are to be viewed independently or as a collective during the discussion chapter.

Table 4. Experimental Design

Phase 0: Becoming a carver

Develop personal masonry skill to provide a more relevant dataset throughout experiments

- Approximately 100 hours of carving practice on a range of stone materials, using modern steel tools.
- Skills were learn through some minor observation and a large amount of personal experimentation with tools and raw materials.

Phase 1: Initial Experiments

Small scale jar carvings;

approximately 30 x 18 x 18 cm

- Five carvings undertaken with each tool; Steel, Iron, Bronze, Copper and Stone

Phase 2: Scaling up

Medium scale jar carvings; Approximately 40 x 30 x 20 cm o Three carvings undertaken with each tool; Iron, Bronze and Stone

Phase 3: Jar Site 52

Jars comparable in size to those of Jar Site 52; Approximately 50 x 50 x 60 cm o Two carvings undertaken with each tool; Iron and Bronze

Phase 4: Additional and amendments

Additional analytical work or additional jars

Each of the experiment phases aims to identify and explore the effects of a shift in a single variable. As such the size of the stone at each stage is kept consistent and the tool materials are changed between each carving. The final phase of the experimental design allows for finer scale analytical work to be undertaken and for any necessary additions to also be considered.

Data recording

Each carving session involves the collection of a range of data including time, number of blows, weight of debitage, percentage of dust, start and end weights, and lastly internal volume (table 3). For phase 1, the start and end volume of each jar will also be collected. Due to the size of the larger jars it was not possible to collect this data.

4.3 Materials

Verifying variables

Aside from analysing the materials used in the experiments, there will also be consideration taken regarding their similarity or difference to the materials surrounding and comprising the jars. This is to say that each variable, be it stone or metal, is matched as closely as possible to the materials available in the Plain of Jars region. Detailing the differences is key to providing future academics a clear view of the materials present in my research as well as those found within the Plain of Jars itself. As accessing the Plain of Jars directly is not a possibility, due to numerous reasons[2], past research is the most reliable data accessible regarding the material make-up of the jars.

Each material employed is considered and analogous material is selected for each example, individual materials will be discussed in-depth throughout this chapter. Key to the comparison and assessment of tool capabilities is the Measure of Hardness scale, often called MoH's. A brief precursory discussion of the scale and its impacts on the following chapters is provided.

MoH's hardness of important materials

The Measure of Hardness (MoH's) rating of a material is an indicator of material hardness, determined through its resistance to scratching. The scale ranges from 1 with soft materials such as talc and chalk to 10 with diamonds. The MoH of a material indicates its ability to scratch lower hardness materials and be scratched by higher hardness materials. The MoH rating does not take other material qualities into consideration, but provides a simple indicator of tool hardness (table 5).

Table 5. Measure of Hardness (MoH) of key materials

Material	MoH's rating
Sandstone	3-4
Copper	4
Bronze	4-5
Iron	5
Steel	6
Basalt	7-8
Granite	7-8
Flint	7-8

This rating mostly effects the capability of drills, knives and other cutting tools. The impact the MoH has upon the carving capability of chisels is not heavily reported. The experimental work has indicated consideration of MoH to be of high importance. The work of Denys Stocks (1986) shows that when working with drills and hard stone, iron and steel are ineffective and hard stone tools have a greater efficiency (1986:26).This appears to be mirrored within my own personal experience during the initial

[2] While I have visited many sites within the Plain of Jars personally, it was not possible to access Laos while undertaking my Masters due to Covid-19. Unfortunately, my prior trips provided few adequate photographs displaying tool marks, meaning much of the analysis is based on personal memory.

practice portion of this experiment with steel tools being relatively inefficient for carving granite. Other elements of structural strength and material composition have an impact upon the overall mechanical properties of the stones, yet for this research, MoH's appears to provide a rudimentary explanation for the effectiveness of different carving tools.

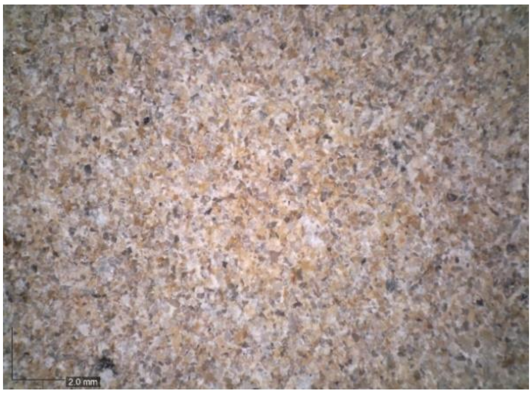
4.4 Jar materials

Within the Plain of Jars complex there are three main jar materials present; these are sandstone, breccia and granite. While there are isolated examples of limestone (two jars), almost the entirety of the jar repertoire is produced from these three rocks, with sandstone being the most common. Sandstone jars were present across 80% of the sites in the region (Baldock & Van Den Bergh: 149). Considering sandstone represents the overwhelming majority of the jar examples, completing sandstone jars carvings provided the most appropriate proxy for exploring jar production in the Plain of Jars.

Sandstone properties

The sandstone used for the experimental work was acquired as blocks, two measuring 120 x 30 x 18 cm for the small and medium jars and one 120 x 50 x 50 cm for the large jars. From these blocks the necessary dimension blocks were cut using modern stone cutting tools to provide consistent blanks for the experimental work. Once the blocks had been divided into their blanks the small jars exhibited horizontal bedding with the medium and large both displayed vertical to sub-vertical bedding. Geological analyses of the jars across 60 sites indicated that most sandstone jars exhibited vertical to sub-vertical bedding (bedding in jar runs from left to right) while a smaller portion displayed horizontal and sub-horizontal bedding (bedding in jar runs bottom to top) (Baldock & Van den Bergh 2009: 150). Throughout this report the sandstone is also described as fine-grained.

While this geological report gives a simple description of the material makeup, there is no comprehensive description of the stones' characteristics in the current literature. While sourcing the material for the experimental undertaking, only sandstone that displayed a fine-grained makeup was considered for the work. The density of the sandstone acquired for the experiments averages around 2.17 g/cm^3 which sits lower on the density scale of sandstone (2.0 to 2.6 g/cm^3), with some samples reaching as high as 2.3 g/cm^3. The sandstone used for this experiment can be defined as fine-grained, with a high distribution of quartz and a lower distribution of feldspar and rock pieces (Stuart Hodgson, *pers. comm*.). Under initial microscopic analysis there appears a wide variance regarding grain size. Simple analysis indicates an average grain size of 0.115mm with larger grains ranging from 0.39mm to 0.2mm present within the composition (See figures 38 and 39).



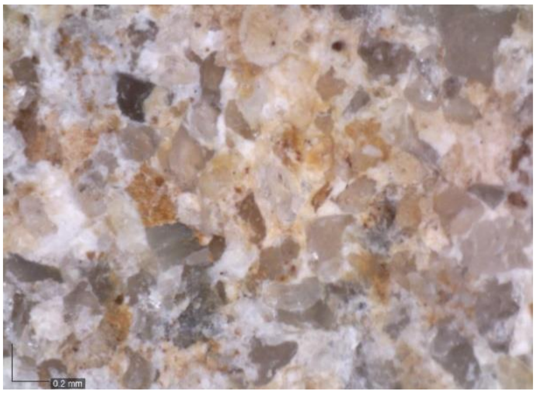
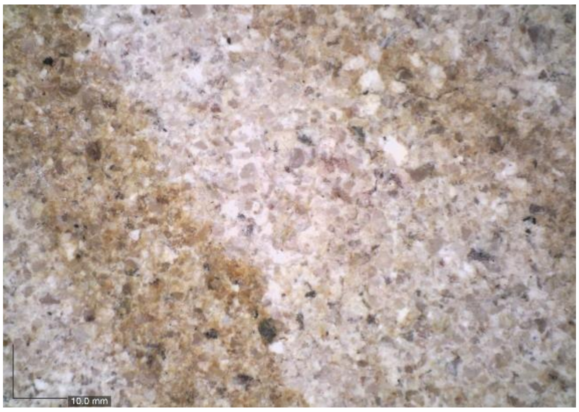


Figure 38. & Figure 39. Sandstone sample at 20x magnification & Sample at 140 x magnification

Likewise stone samples from the Phu Kheng quarry site, the quarry for Jar Site 1, can also be characterised as fine-grained, with a high distribution of quartz and feldspar and a lower distribution of rock pieces. Low magnification microscopic analysis has shown that each of these materials appear to be fairly similar in make-up and density yet further analysis is necessary to confirm this (See figures 40 and 41). Overall the material characteristics discussed offer no suggestion that there are major differences between the sandstone employed within the experiment and that of the Phu Kheng quarry.



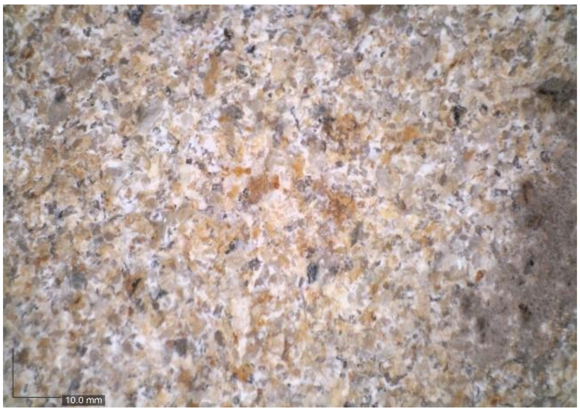


Figure 40. & Figure 41. Sandstone sample from Phu Kheng quarry (left) and sample from material used for experimental carvings (the scale displayed is incorrect due to calibration issues)

Jar design

While the material employed is one element to the experimental work, the desired jar design is also highly important. Striving towards a repeatable jar form will reduce variance and inconsistencies within the experimental data. While there is a variety of jar forms identified by different reports (see Colani

1935a; Baldock & Van den Bergh 2009; O'Reilly *et al.* 2018; Genovese 2019a; O'Reilly *et al*. 2020) a particular jar form was determined by personal observations with some elements informed by particular reports. The desired jar form has been derived from personal experience within the Plain of Jars as well as relevant literature regarding jar dimensions and form. The form sought throughout the carving retains thicker walls to reduce the chances of major breakage and also has a thicker than average base to allow for better balance. While the jars range greatly in size and shape it has been noted that the jars mostly follow a height to diameter ratio of 1.5:1 (Buldock &Van den Bergh 2009: 150).

The 1.5:1 ratio is captured within the phase 1 jars which measure to a height of approximately 30 cm and a diameter of 18 cm. Phase 2 continued to follow this ratio with some slight variance. Phase 2 adopted an ovoid shape with the dimensions 40 cm in height, 20 cm in depth and 30 cm in width. While not strictly following the ratio in both directions, this design still averages with the above ratio (40 cm to 27 cm). This ovoid shape also allowed the exploration of impacts brought about by unusual design. This shape of jar is present within the Plain of Jars assemblage, being encountered by the author personally and recorded by Colani also (1935a:232, 233).

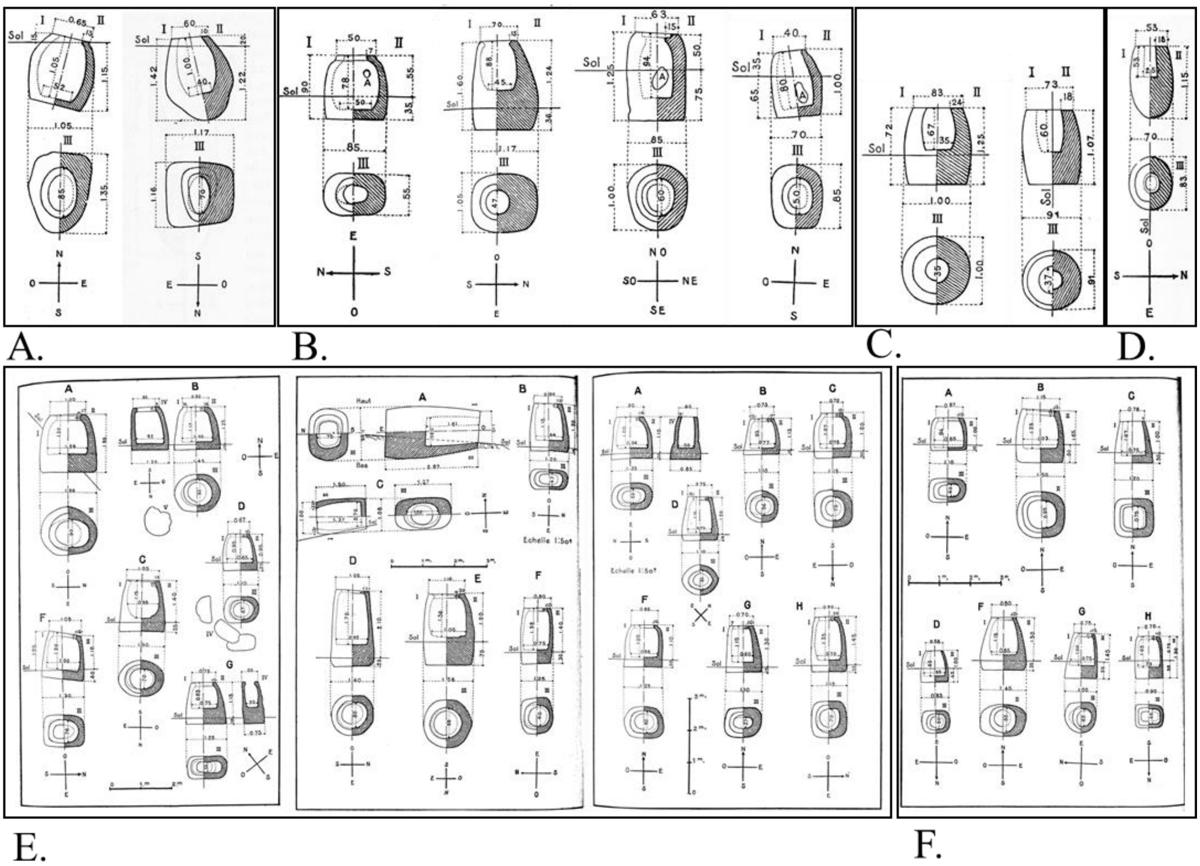


Figure 42. Collection of jar forms reported by Colani across six sites (A. Song Meng, B. Na Nong, C. San Hin Oume, D. Ban Xot, E. Lat Sen, F. Ban Soma) (Colani 1935a:211-249).

The collection of jars recorded by Colani showed a diverse range of forms and sizes as well as a diverse range of base thicknesses. The base thickness ranges from 6.4% of the total height at 8cm to as much as 53.91% at 62 cm (percentage of jar's overall height). The range of base thickness averaged 26.22% across the jars present, with two large groups located around 20% and mid 30%. Different measurements have been noted by other investigations, with Sayanvongkhamdy and Bellwood (2000:105) indicating the jar bases range from one quarter to one third of the jar's overall height. While this range does exist a particular depth range was determined for the experimental work. For the experimental work 30 – 50% base thickness was determined to be both a reliable comparable example and also a safe depth (Colani's measurements used to provide percentages in figure 42).

While thinner bases have been recorded amongst the jars, I felt attempting such thin bases would greatly increase the likelihood of jar breakage. As such the jars throughout this experimental range all feature a thick base, providing additional support and a better centre of gravity, reducing likelihood of jars falling during or after the carving process if left unburied.

While variations in jar size and form are common throughout the Plain of Jars, the experimental work benefits from a consistent overarching design scheme. As the material available for each phase differs dramatically, especially for phase 2, it is appropriate for each phase to have an independent design. Each of the designs conforms to the overarching characteristics of jars witnessed within the Plain of Jars, while further considerations have been taken to prevent jar breakage and data disparities.

Phase 1 design

The material used for the carving of the Phase 1 jar conforms closely to the previously described height to width ratio of 1.5: 1, with a height of 30-25 cm and a width of 20-16 cm. The carving of each jar within phase 1 attempted a consistent base thickness, determined by a percentage of the jar's overall height. The design allows for slight fluctuations but the base thickness should represent between 30-50% of the jar's overall height. While quite thick, this remains within previously identified parameters.

Phase 2 design

The elongated material used for the carving of phase 2 jars continues to conform to the desired ratio in part with a height of 35-30 cm and a width of 30-25 cm and a depth of 18-16cm. The desired base thickness for phase 2 continues to be between 30-50% of the overall height of the jar.

Phase 3 design

The jar design for phase 3 does not conform completely to the prior ratio of 1.5:1 (regarding height to width), with a height of approximately 60 cm and a width of 50 cm, a ratio of 1.2:1. Although this change in design is partially due to material availability, this design shift also conforms closely to the stout nature of the jars of Jar Site 52. The desired base thickness for phase 3 remains consisted with a thickness between 30-50% of the jars' overall height.

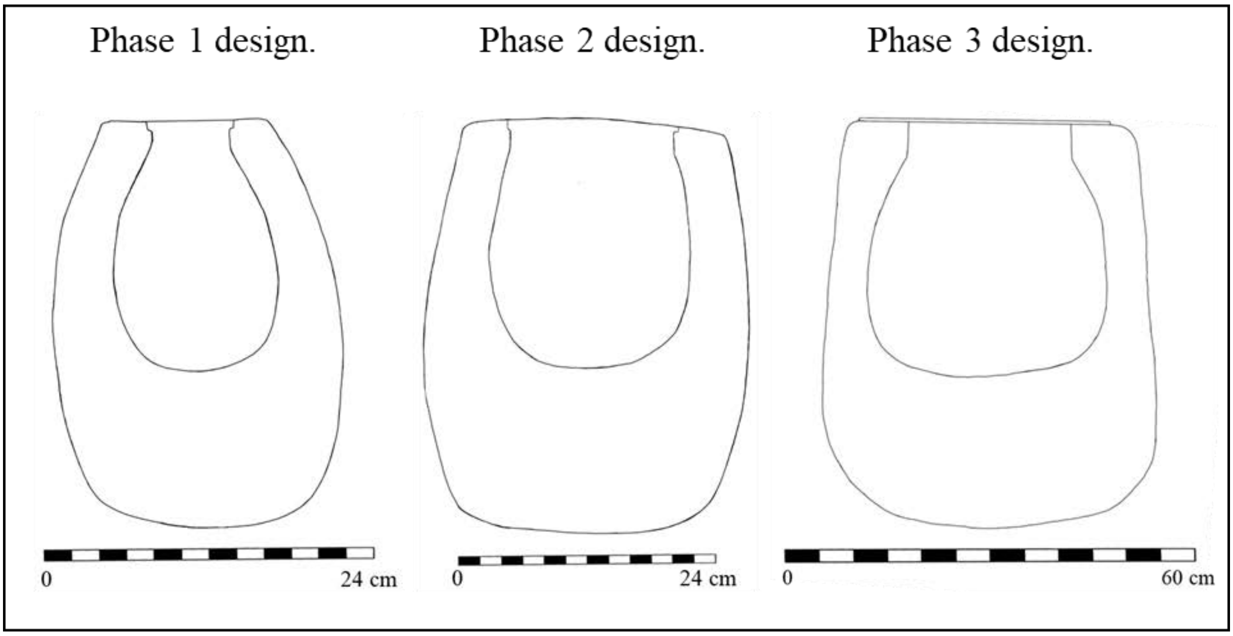


Figure 43. Experimental jar designs by phase. Each phase has its own scale.

Carving Procedure

The use of *chaîne opératoire* in unison with Experimental archaeology allows for a highly detailed analysis of jar production in line with the potential production processes employed in the past. As is customary with the application of *chaîne opératoire*, the work can be first divided into three overarching divisions; raw material procurement; reduction sequences; and use, maintenance and discard. While these terms are designed for application in lithic analysis, they fit quite well with megalith production.

Raw material procurement is undertaken at the quarry sites. While it appears that numerous examples of jar sites display production and usage occurring in close proximity (42, 25, 52) this is not always the case, as witnessed at Jar Site 1 and the Phu Kheng quarry site. Nonetheless, after (1) the identification of adequate material, (2) the quarrying of the jar blocks involves the digging of trenches or channels into the stone outcrop. The channels are then crossed in a perpendicular nature, producing the raw rectangular block, protruding from the stone outcrop. (3) The stone is then dislodged, through fire, wedges or by other means, before being stood vertically at the site.

This is where the reduction stage begins, predominantly with the outer shaping of the jar. (4) The corners are removed and smooth, producing a cylindrical shape. The jar may be undercut prior to this work to aid in raising the jar. Aside from the external carving, (5) the lip of the jar is also roughed in, with a small trough about 5-10 cm deep at this stage.

It is at this point that theories diverge, it may be possible the jars are transported to the their final placement at the jar site and completed there, while ome theories suggest the jars are first deposited at a secondary workshop to be completed (Sayavongkhamdy in Chanag 2017). The secondary workshop theory proposed a location close to Jar Site 1 where the jars were worked to completion before being move a short distance in their more fragile state. This theory was initially proposed by the previous Director of the Lao National Heritage Department, Thongsa Sayavongkhamdy (in Chang 2017; Chang 2018). A small site known as the Ban Ang Airport site was identified as the potential workshop site and was excavated during 2016 and 2017 by a team of JCU students, including myself, without any clear conclusions being drawn. Regardless of the accuracy and validity of these theories there is still a consistent procedure being followed in the jars' production. It may also be possible that some jars were carved entirely at the quarry sites. Although the presence of partially carved jars moved away from their quarry before completion suggests this was not a consistently employed practice (See Figure 45 which displays these differing interpretations). When problems of location are removed, the jar production continues to follow a consistent procedure.

The jars then have the internal shaping completed. The internal carving is suggested to have involved carving from the centre outwards. Firstly, (6) creating a v-shaped cavity before (7) widening the internal cavity. (8) The jar lip would then be undercut creating a bulb shape greatly increasing the jars internal volume. Once shaping is completed (9) the jars' external surface appears to be finished, with the internal tool marks being left relatively unsmoothed (see figure 44 for simplified procedure and figure 45 for complete *chaîne opératoire* of jar production).

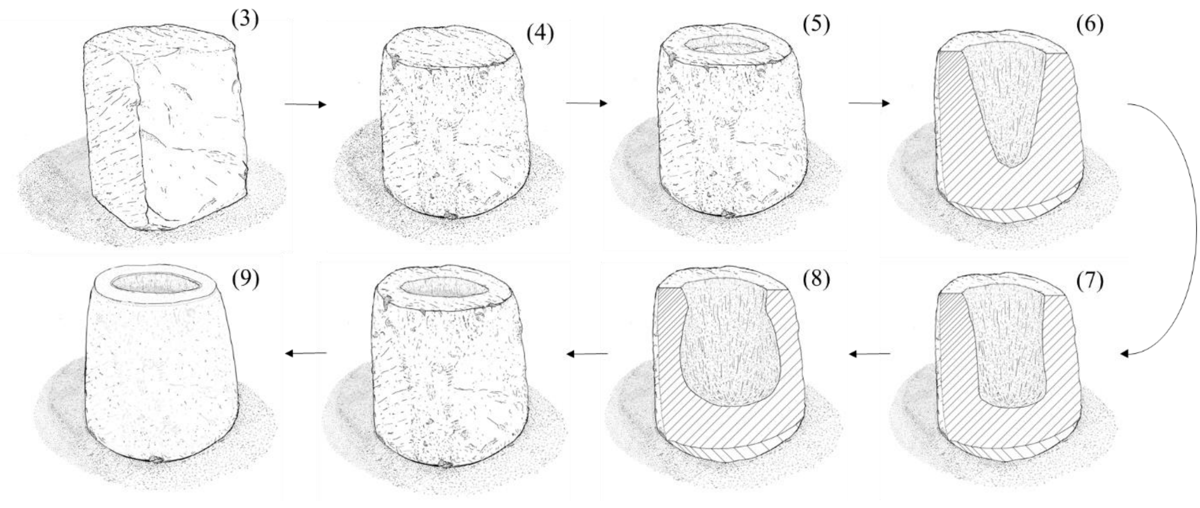
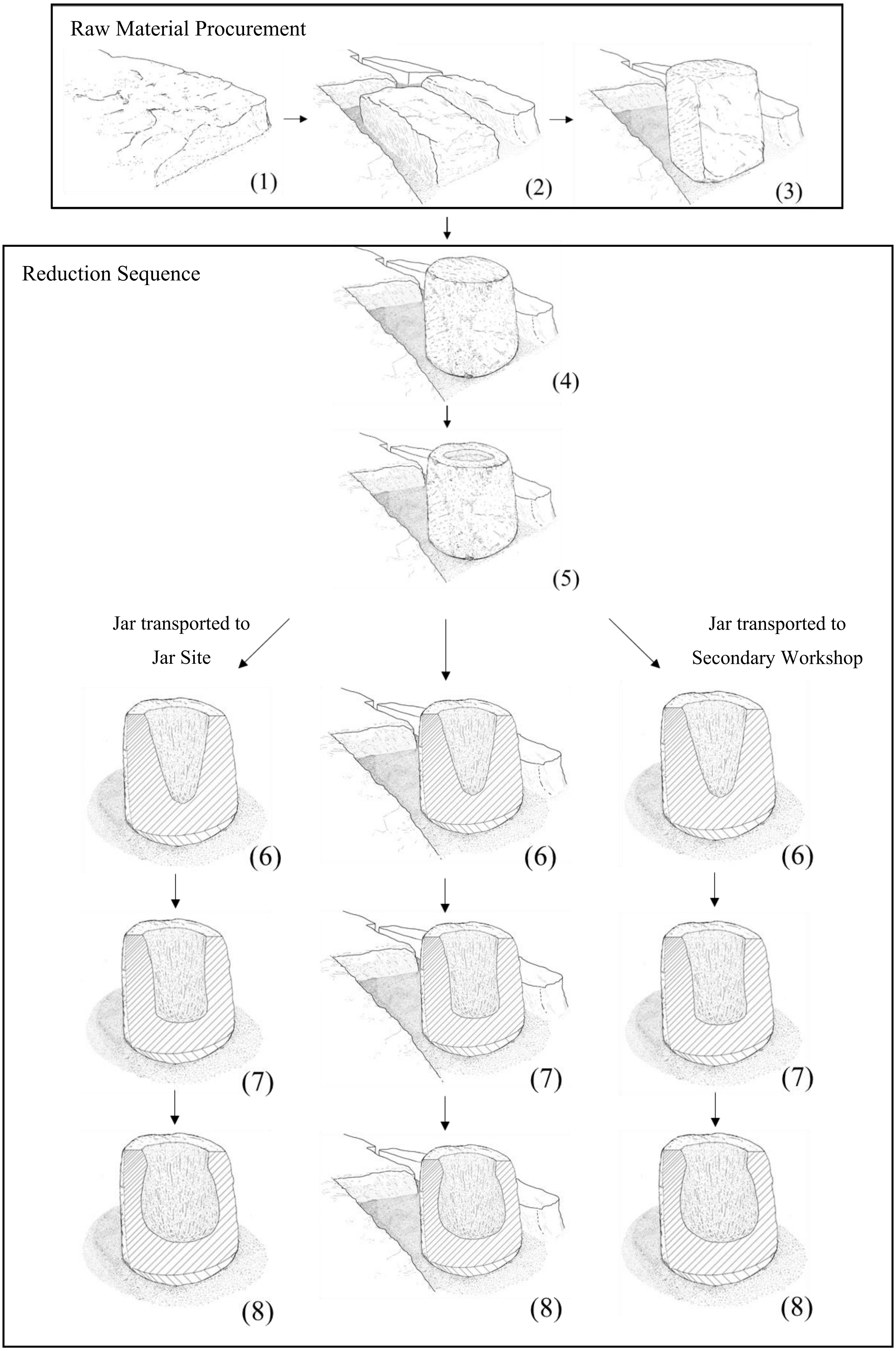


Figure 44. Jar carving procedure following the potential past production practices, this procedure is employ throughout the experimental work.

The jars were then employed within their central practice, that of mortuary vessels for either primary deposition or cremation. Within this *chaîne opératoire* there is one subsection of particular importance to this thesis, that of reduction. The process and outcomes achieved within the production section are the main focus of this research with all questions connecting directly to this element. The procedure identified appears to have a consistent flow from start to finish. Firstly, the outer surface of the jar is roughed in, producing a cylindrical shape. Secondly the lip and an internal trough is carved, situating the jars' opening and beginning the work of the internal carving. The internal carving proceeds with the internal cavity of the jar being lowered, before the cavity is widened, producing an internal shape that more closely mirrors the external shape. The lip is then internally undercut before the final cleaning and smoothing of the lip and external surface is completed. Throughout the experimental work this procedure is employed, allowing for consistency across each carving. The recording of weights is also divided across internal and external work (where applicable) to allow for a greater understanding of each element's impact on the jar's transformation and debitage production[3].

[3] The carving work itself was undertaken by myself, located at an outdoor workshop on the James Cook University campus. The jars were protected from environmental factors by a tin roof, however some heavy rain events impacted some of the collection of debitage, discussed on page 139.

Complete *chaîne opératoire* of jar production



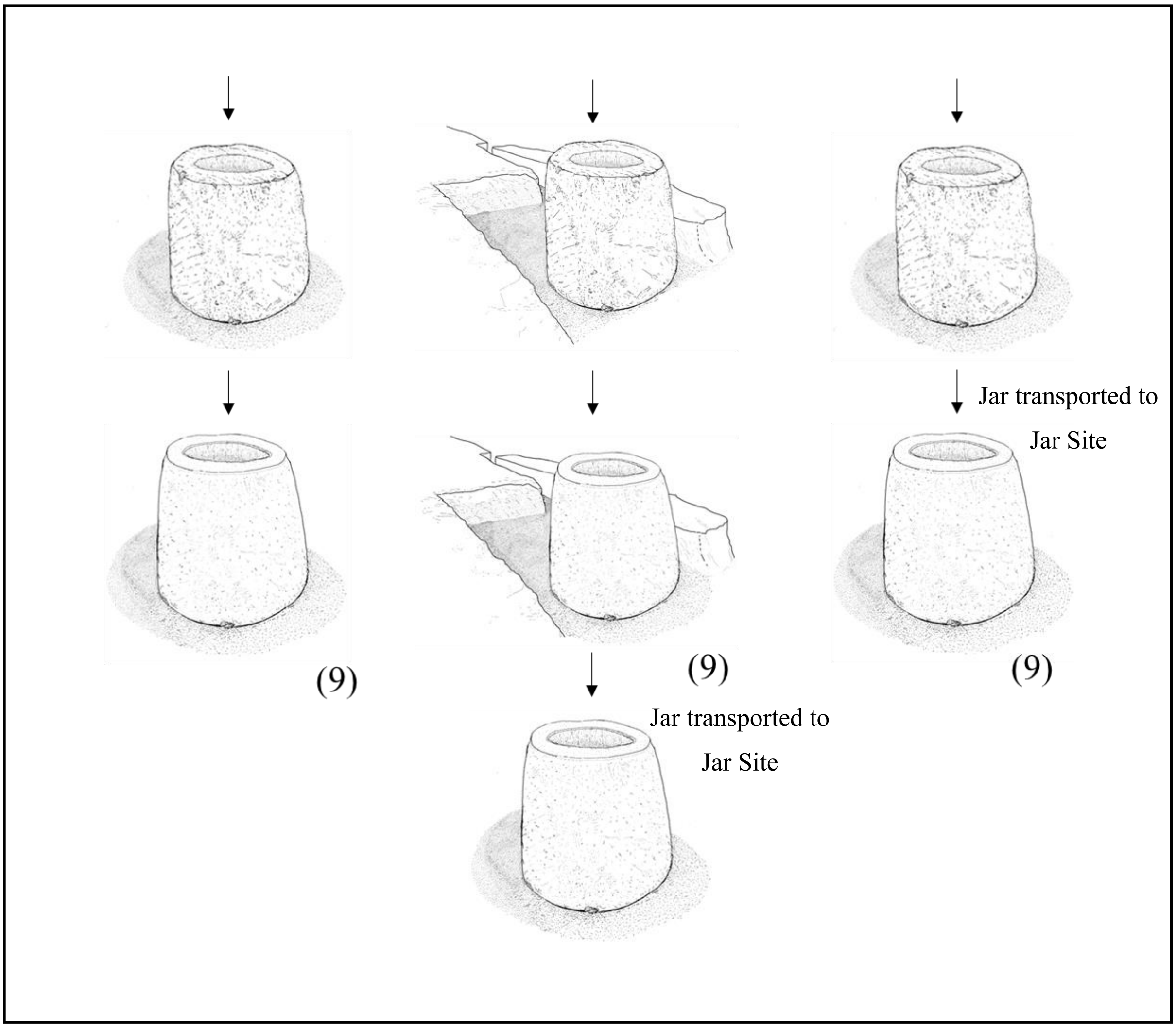


Figure 45. Complete jar production sequence; including three theories for jar production locations and transportation. Throughout these differing theories, the raw material extraction and rough external shaping remains the same.

Left branch: Jar production undertaken entirely within jar site locations, after initial rough out but before any major internal carving occurs.

Centre branch: Jar production undertaken completely at quarry sites before being carefully transported to their final placement at jar sites.

Right branch: Dr Sayavongkhamdy's secondary workshop theory, Jar production is undertaken at quarry sites and secondary workshop locations. Initial outer carving and setting up the start of the internal work is completed before the jar is transported to a secondary workshop location where the jar is complete. The jar is then transported to final placement at jar site.

4.5 Tool materials

Understanding the stone and procedure for production are amongst the most important variables to be considered for this experiment. Just as important is the production and verification of the tools employed within the carving. While this project is, at face level, an analysis of megalith production and the time investment required, it is also an analysis of tool's capabilities. Details of each tool type employed including material composition, working procedure and discussion of analogous accuracy are provided.

Aside from the materials employed there will also be a discussion of the tool styles employed. The carvers employ a range of plain chisels, point chisels and tooth chisels. These three tools are present within modern sets of masonry hand tools, each serving a particular purpose. Examples of both tooth chisels and a potential point chisel have been identified within the Plain of Jars context, where plain chisels have not (Colani 1935b: 50; Tener 2020). Plain chisels can be characterised by their straight steep blades. The tool's point has a wide angle of around 45˚, as opposed to a shallow angle of 17-20˚ which is employed for knives and other cutting tools. This results in a higher strength blade which can be subjected to higher force without breaking, this wide angle also reduces the tool's sharpness, resulting in a blunt but strong striking point.

Secondly is the point chisel which consists of a tapering point with a similar 45˚ tip. This tool is predominantly employed for initial rough working where it is most capable of removing large quantities of material quickly.

The last chisel employed within the carving work was the tooth chisel. While the tooth chisel appears more complex in design it remains the only chisel identified within the Plain of Jars region. The chisel resembles a plain chisel with 5 small teeth separated by equally sized spaces. Each tooth would function as a small blade allowing for a more controlled and consistent refining of prior tool marks. The tooth chisel is for refining work in the later stages of carving.

Complete toolkits including each chisel type were employed throughout carvings using iron, bronze and copper tools. Jar 1 was completed with only plain chisels as these were the only commercially available modern steel tool.

It should be noted for clarity that all of the tools used within the experiment work, aside from the modern steel tools, were produced by myself. While not a trained blacksmith myself, there was consultation with a local smith as well as extensive research surrounding the practice and the tools being produced. Each of the tool forms produced were archaeologically available examples, with both the point chisel and tooth chisel forms being uncovered within the context of the Plain of Jars (Colani 1935b: 50; Tener 2020).

Steel

The steel tools employed within jar carving 1 was comprised of a range of modern steel plain tools. These tools were composed of either vanadium, chromium or carbon harden steels. Each chisel was a plain chisel of varying size with the smaller chisels being vanadium hardened and the larger being carbon hardened.

Although these tool types were not available at the time of the jar's production it serves as a baseline test to see how greatly the process differs when undertaken with modern tools and carvings with non-industrial tools.

Iron

The iron tools used in the carving of jars 2, 6 and 9 were forged from segments of a wrought iron wagon wheel. The closest analogous material available to cast iron was wrought iron, produced throughout the casting and forge welding on numerous iron billets. Traditionally wrought iron is produced by repeatedly heating and reworking cast iron, giving the material a far higher tensile strength while also providing greater ductility. The processes involved within production of wrought iron include the lamination and reworking on numerous cast iron billets with different compositions (Lorenzis, Stratford & Halloway 2008). Although containing less carbon than cast iron, wrought iron also contains less carbon than what are considered carbon steels, 0.1% for wrought iron, ~0.1 to about 1.5wt% in steel (Ohring 1995). The lamination of wrought iron not only results in a slight lamination patterning visible in the material cross-section but also in a variance in material characteristics throughout an individual wrought iron piece (fig 46).

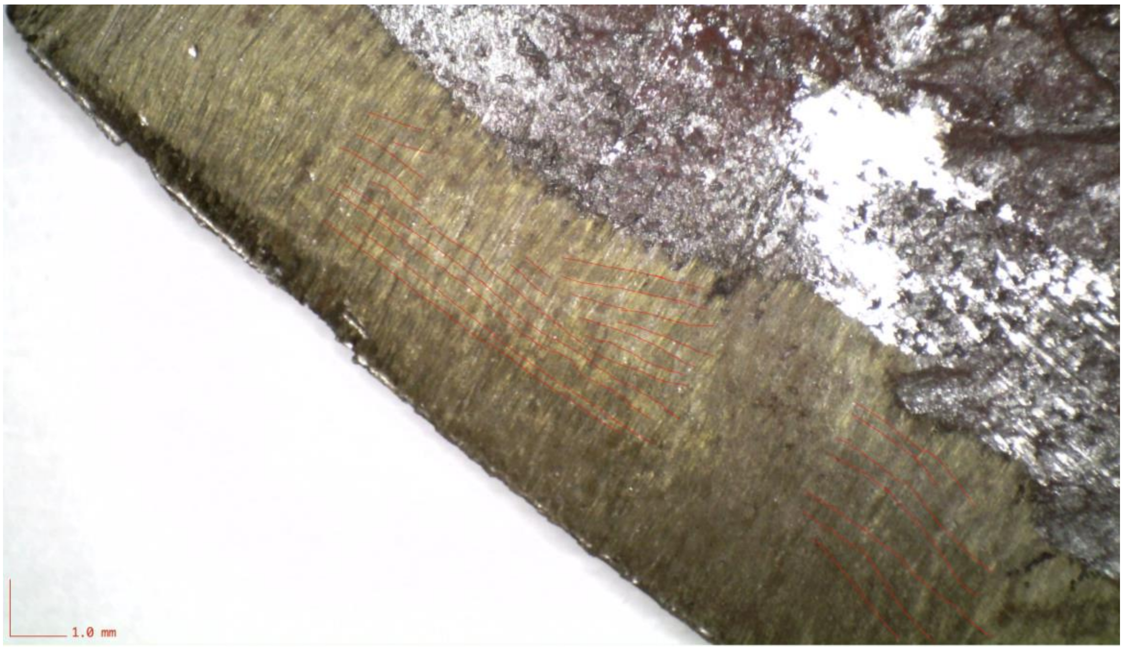


Figure 46. Image of iron plain chisel blade, potential signs of lamination highlighted in red.

The wrought iron used for the production of iron tools consisted of a small piece of a wrought iron wagon wheel. The piece was cut into strips approximately 230 mm long, 25 mm wide and 8 mm thick. The first set of tools these were forged into working ends, either blades or points depending upon the tool form desired. The pieces also had a tang forged on the back end and were internally set into a wooden handle. These particular tools were employed throughout carvings 2 and 4. These tools were also used for the initial work during carving 9 but eventually snapped at the shoulder. This breakage was attributed to the tools being too thin and repeatedly bending, resulting in gradual work hardening, increased stress and eventual breakage. Tool ware and breakage is discussed in greater detail within the discussion chapter.

The replacements were cut from the same stock, sharing the same dimensions as the original tools. The pieces were then forged using a propane furnace where they were shaped. Before producing the chisel form the pieces were upset (forged with the thinnest face of the material perpendicular to the anvil, compressing the material to thicken it) resulting in more preferable dimensions of 230 mm long, 14 mm and 13 mm. The wrought iron was then forged to either a point or a blade depending on the chisel form sought. These tools were also forged into a tang and internally set in a wooden handle. The second set of tools displayed higher strength and lower impact from multidirectional pressure experienced throughout the carving.

The iron tools were forged in a propane forge with no heat treatment, tempering or cold working undertaken. Avoiding material conditioning practices was purposefully undertaken as the high carbon content of cast iron tools would have prevented such practices from being effective. While not identical in material composition or production process, these tools represent a reliable analogue for early iron tools. The tools produced boast slightly higher structural strength than cast tools were likely to have had yet the tools remain acceptably analogous.

The wooden handles that accompanied the iron tools required the setting of a bronze loop or ring to prevent splitting of the wood. This technique is employed by modern woodworkers with many tool types being handled in this manner. Although this was time consuming to accomplish it greatly increased the strength and endurance of the wooden handles produced. It is likely this, or similar, techniques, such as binding, would have been employed in past contexts.

Bronze

Producing reliable analogues for bronze tools was more achievable but no less complex. The bronze alloy identified for use within the project was a mix of 12% tin to 88% copper. This mid tin bronze boasts high structural strength while also remaining ductile. Tin alloy bronzes between 10 and 12 wt% have been employed within Bronze Age Southeast Asia, predominantly for tools and weapons. While other bronze alloys were employed throughout the Southeast Asia Bronze Age, this particular mixture was most heavily employed for practical items with higher tin bronzes (up to 23 wt %) being used for jewellery, decorative bowls, and other trade goods (Reay & Chang 1998; Forbes 1964; Seeley & Rajpitak 1984, Higham 1996).

The bronze alloy was first melted from the raw constituents, firstly 264g of copper was melted nearly completely before the addition of 36g of pure tin pellets was added. The molten material was stirred with a copper stirring rod to avoid contamination by other materials, the rod was slightly heated to avoid rapid cooling and attachment to the rod. Once the molten material was well mixed it was sand cast into 100g ingots. The ingots were lightly smoothed with abrasives to remove inclusions of the casting medium and minor build-up of carbon.

Figure 47. Bronze tool kit including three chisel forms

For the chisel casting a two-piece sandstone cast mould was prepared which would produce the desired chisel design (fig 48). The chisel design was a socketed chisel with a short thick stem and head approximately 25 mm long, 25 mm wide and 10mm thick. The socket measures approximately 70 mm long and 25 mm in diameter at thickest. The overall length of the bronze chisel (from point to base of socket) was 90 mm. The design was identified within Madeleine Colani's second volume of *Mégaliths Du Haut-Laos* (1935b: 50). Currently the chisel is the only reported chisel uncovered within the Plain of Jars region. The chisel appears to be a socketed bronze tooth chisel. During casting a heated steel drift was suspended within the two-piece cast mould, creating the socket. The socket required some further working with both additional width and depth being achieved through modern power tools. Of note however is the ease of producing the socket chisel using only casting methods, without the need for modern tools.

The casting was accompanied by minor reworking after annealing was completed, making the material more receptive to cold work. Finally, the chisel was given a 45˚ blade or point and slightly cold worked to increase the chisel edge hardness before being smoothed and the edge sharpened. Three chisels of this style were produced, a point chisel, a plain chisel and a tooth chisel. The bronze point chisel slightly diverged in design from other such examples. The point chisel incorporated a slightly wider profile, making a small pointed blade approximately 10 mm wide formed into a wide v shape rather than a steep point as previously employed. The impacts of this change are notable when analysing the tool marks produced and are explored in the discussion chapter.

Figure 48. & Figure 49. Bronze chisel two-piece cast mould made from sandstone and finished bronze chisel

A secondary design of bronze chisel was produced, employing a tang embedded in a wooden handle in a similar style to the iron chisels produced. This chisel proved ineffective due to the thin cross section of the chisel and likely would have been similarly as effective as the iron tang chisels.

The wooden handle used for the bronze tools were socketed into the base of the chisel head and held in place with friction. While there were some minor breakages experienced with the wooden handles used, replacement and repair of the bronze tools was a far simpler task than remaking the iron tools after their breakage. Throughout the series of carvings, no socketed bronze chisel heads broke, with only one bronze tool breakage, that being the internal tang chisel. The wooden handles used were easily produced, requiring hand tools only with most of the work being dedicated to providing a smooth finish to the handle.

Copper

The copper chisels were produced from sections of a pure copper plate. The plate was cut into pieces 200 mm long, 50 mm wide and 20 mm thick for the point and tooth chisels and a piece that was slightly wider (70 mm) for the plain chisel. The pieces were forged in a propane forge, where they were upset (as previously defined) to increase multidirectional strength and rigidity. The back or striking end of the tool was also slightly upset to increase the striking platform, offering a larger surface area to aid in dissipation of forces to both the chisel and wooden mallets used.

Each chisel point was cold forged, both forming the chisel blades or points while also work hardening the working end of the tool. Cold working the points and blades increased the hardness of the tool making it more closely resemble the rigidity of the iron and bronze tools. Three chisels were produced for the carving of Jar 4, those being a copper plain chisel, copper point chisel and a copper tooth chisel. While these tools were left without wooden handles, the wider striking platforms achievable with the material greatly aided in the upkeep of the wooden hammers and mallets used throughout the experimental work.

Stone

The last toolkit employed within the experimental work were stone tools. The stone tools employed were relatively simple in form and function with only minor reduction necessary to shape the required forms. Three main tools were used throughout the carving of jars 5 and 8, a basalt hand axe/adze, a small basalt adze-like chisel and lastly a granite hammer stone. The tools were crude in design with only minor working undertaken on the profile and tools working edge. While these tools were not heavily shaped through knapping, they were still highly efficient.

The small hand chisel was produced from small basalt river stone approximately 100 mm long and 50 mm wide. The stone was struck across the width of the blade, dislodging a single flake which produced the main carving edge. While this method is crude and the working edge is not perfect, the tool was adequate for the carving practice.

The larger basalt hand axe was employed with both chopping and chiselling motions to clean the outer surface of the jar and begin the internal carving of each of the jars. The large basalt hand axe required slightly more working, with more flakes being removed from a larger core. The flaking method employed was fairly similar to that employed with the smaller tool. The original stone was also a basalt river stone, measuring 140 mm long and 90 mm wide. The stone appeared to have two minor fractures running nearly perpendicular to one another through the stone about 30 mm into the stones length. There fractures created an x shape on the edge of the stone and once struck the small sections were dislodged, producing a v shaped point which was smoothed into the final working edge of the tool.

Lastly, the granite hammer stone was a long semi-rectangular column approximately 200 mm long initially this tool was used unmodified to slowly produce the depths of the internal carving through repeated bashing and scraping, in a motion akin to the motion of a pestle striking a mortar. While this process was sufficient to carve jar 5, further refining was necessary to increase the tools effectiveness for jar 8. The smallest profile end of the column was knapped on each of the four faces resulting in numerous small flakes being removed. This slowly brought the tools profile from a rounded end to a more pointed end with a rough point slightly wider than 45˚. This newly shaped form was employed throughout the majority of the carving for Jar 8 and allowed for a greater depth to be carved than was possible with the rounded end. The impacts of this change will be explored within the results chapter. While these tools are crude in design and simple in production, they serve to show the effectiveness of even unworked stones when carving soft stones such as limestone and sandstones. While each of the other tool materials relied upon cutting edges to undertake the major portion of the work the stone tools were capable of carving using primarily percussion and pecking.

Figure 50. Basalt hand adze employed in carving of jars 5 and 8.

Chapter 5:

Results

Throughout the experimental work the parameters previously mentioned were maintained. Each phase of the experiment is discussed below with necessary data and descriptions of individual experimental works. Each phase employed the same working procedure and rigorous data collection regiment.

5.1 Phase 1

Phase 1 of the experimental work incorporated steel, iron, bronze, copper and stone tools for the carving of small jars. Carving jars at this small scale was logical for a number of reasons. The smaller scale allowed the exploration of parameters otherwise troublesome to collect due to cumbersome size of the final jars. Weight and volume were not easily assessable with full scale jars but could be calculated using data collected at the small and medium scale. The small jars also served to show how size effected carving capabilities, providing a key data point for calculation of the relationship between jar size and carving time. While these jars are much smaller than the full-size jars located within Laos, the carving of these jars was accompanied by numerous insights and troubles avoided at a larger size.

Table 6. Phase 1 general data

Phase 1	*Tool*	*Time*	*Start Weight*	*End Weight*	*Start Volume*	*End Volume*	*Internal Volume*
J1	Steel	11 hours 36 mins	21 kg	14 kg	9900 cm3	6300 cm3	620 ml
J2	Iron	5 hours 51 mins	23 kg	13 kg	10000 cm3	6500 cm3	500 ml
J3	Bronze	5 hours 21 mins	25 kg	17 kg	11160 cm3	7,600 cm3	675 ml
J4	Copper	7 hours 33 mins	21 kg	10.5 kg	10050 cm3	5800 cm3	500 ml
J5	Stone	5 hours 27 mins	22.5 kg	15 kg	10600 cm3	7750 cm3	600 ml

Each jar was carved from a block ranging in weight from 21–25 kg. Following the preferred jar design, the jars have a base which accounts for between 30% and 50% of the total jar height. This thicker base still allows an internal volume of between 500 ml and 650 l. Each of the jars have been lightly smoothed using sandstone abrasion to reduce the appearance of tool marks, there is no direct evidence that this step was undertaken within the actual carving of the jars of Laos. However, the time committed to surface smoothing was deducted from calculations of blows per minute and would likely have rounded out the finishing of the jars. Time investment within phase 1 (Table 6 and Fig 51) shows the large variance across each of the carving times. The quickest carving was undertaken with bronze tools taking 5 hours and 21 minutes while the longest carving was undertaken with steel tools, taking a total 11 hours and 36 minutes. While the complexity of the steel tools may be higher, a number of factors likely contribute to the extended time requirement for the carving of jar 1. Burgeoning masonry skills alongside a smaller tools set, containing only plain chisels, likely prompted this extended production time.

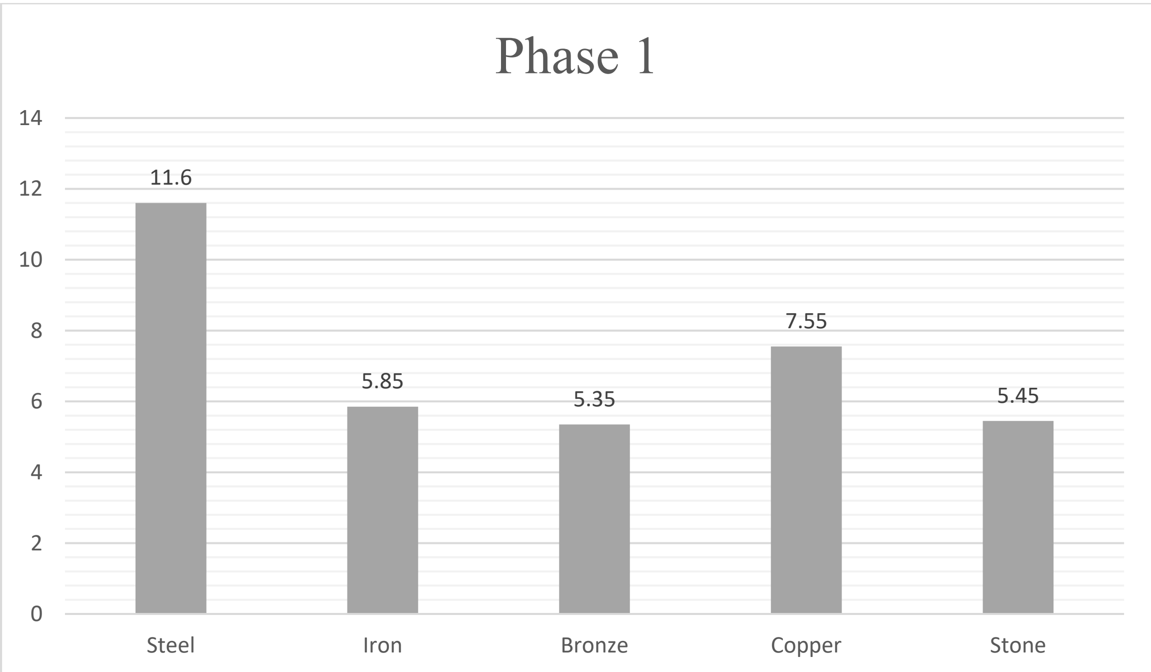


Figure 51. Phase 1 time investment

Nonetheless, each of the tool materials was effective and efficient when carving the sandstone. Each tool material was not only capable of carving the sandstone but was also highly effective, completing the task within a short window. While there appears some variance throughout the time investment, it is clear that iron, bronze and stone tools all displayed a similar capability with each of these tools being completed within 30 minutes of one another.

Debitage

The debitage collected for the Phase 1 experiments was a collection of dust and flakes from the worktable surface approximating an area of 1 m x 1.5 m as well as the collection of large flakes from the workshop floor within a 2 m radius. Only a small percentage of the weight removed was visible within the debitage collected, this is likely due to the collection method as well as the prevalence of fine dust among the debitage which is highly transient material and may not be easily collectable.

Table 7. Phase 1 debitage data

Phase 1	*Weight removed*	*Debitage weight*	*Potential Debitage collected*	*Debitage Dust Percentage*
J1	7 kg	4724 g	67.49%	80.2%
J2	10 kg	6511 g	65.11%	66.5%
J3	9 kg	5232 g	58.13%	54.97%
J4	10.5 kg	6813 g	64.89%	64%
J5	7.5 kg	5490 g	73.2%	79%

The division of debitage (Table 7) is determined by flake size, with flakes smaller than 2 cm in diameter being categorised together with dust and all flakes larger than 2 cm being categorised as large flakes. Between 55% and 75% of total produced debitage was collected, with a range of 50% to 81% consisting of dust. While a mixture of dust and flakes was present within the debitage, it was also clear that different stages of carving produced markedly different debris. The external carving provided the majority of the large flakes while internal carving was mostly categorised by fine dust. Although some cross over was notable, the majority of the debitage throughout this experimental phase mirrored this observation.

Jar 1

The first jar carving was undertaken with steel tools; chromium, vanadium and carbon alloyed steel. Although none of the tools are comparable to past technology uncovered in the Plain of Jars context, this carving served to display modern carving capability for comparison against prehistoric tools.

The external shaping of Jar 1 (Fig 53) was performed over 5 hours and 23 minutes which removed 3 kg of material from the jar. Of this material only 645 g was large flakes with a further 1864 g of dust and small flakes produced. The internal carving of the jar was performed over a further 3 hours and 28 minutes with the removal of 4 kg from the jars weight. This work produced 212 g of large flakes and 559 g of dust and small flakes. The finishing work of the jar, both internally and externally, was performed over another 3 hours and 4 minutes. This finishing work removed a further 1 kg from the jar and produced 74 g of notable debitage and 1370 g of dust and flakes. Time investment for Jar 1 totals 11 hours and 36 minutes.

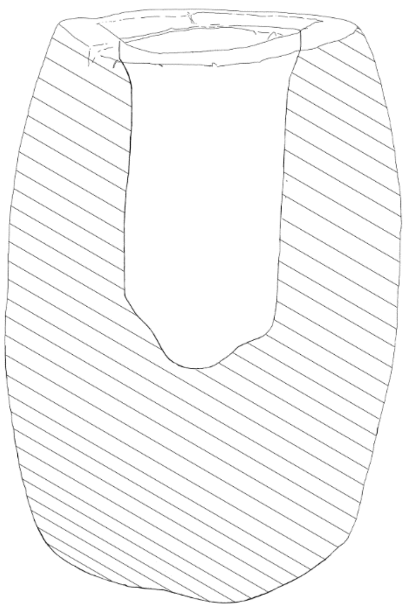


Figure 52 & Figure 53. Jar 1 cross section and Jar 1 complete

The jar itself remains somewhat square in cross-section yet mostly shaped. The jar base measured 12 cm, accounting for 41% of the jar’s height, the internal cavity had parallel walls with a diameter of 75 cm. The internal volume of the jar was 630 ml (Fig 52). With the completion of the full range of experimental carvings it became apparent that Jar 1 is an outlier regarding the time required, the modern tools employed, and the incomplete development of carving skills.

This carving was undertaken as a first introduction to the processes, feeling of jar carving and variable recording system. It has also, unintentionally, demonstrated that high quality modern tools do not provide any notable advantage within the carving process.

Jar 2

The carving of Jar 2 (Fig 55) was undertaken with the first set of iron tools, the toolkit included a point chisel, a plain chisel and a tooth chisel. While sharpening was necessary throughout this carving, there was no major need for reworking or tool repair.

The external shaping of Jar 2 was performed over 3 hours and 9 minutes which saw a total of 8 kg of material being removed from the jar. This work produced 2184 g of large flakes and approximately 3,013 g of dust and small flakes. The internal carving of the jar was performed over a further 2 hours and 43 minutes which included the removal of 2 kg from the jars weight. This carving work produced large flakes but approximately 1317 g of dust and small flakes. Both the external and internal finishing was also performed within this latter period. Time investment for Jar 2 totals 5 hours and 51 minutes.

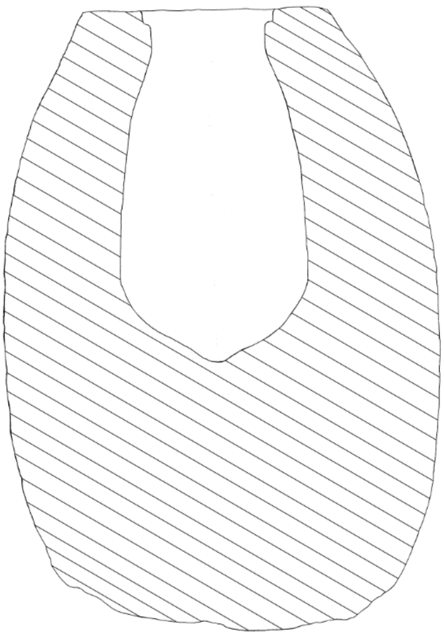


Figure 54 & Figure 55. Jar 2 cross section and Jar 2 complete

The final jar shape differs from that of the Jar 1 with a thinner top and more accentuated curvature. Initially a structural failure was expected to occur upon the upper lip of the jar during the internal carving period. This was due to a fracture line which cause the breakage of a large piece of the previous jar's upper lip. The source stone was flipped in the early stages of working, relocating the fracture to the lower portion of the jar which had higher structural strength (due to the thick base). This can be noted through the presence of an inclusion of grey sandstone running through the jar's upper reaches, whereas this same inclusion ran through the lower reaches of the previous jar. As such the fracture line never caused a structural failure.

The jar was carved to an internal depth of 16 cm leaving a base of 12 cm (42%). This jar is consistent with the thick based design desired. The internal volume of the completed jar was 550 ml, slightly less than that of the prior jar (Fig 54).

Jar 3

The carving of Jar 3 (Fig 57) was undertaken with a complete bronze toolset including a plain chisel, point chisel and a tooth chisel. While these tools were available, the tooth chisel was employed less than in other experiments as the tool marks produced by the point chisel were easier to smooth than in other carvings. This lack of deep tool marks from the point chisels can likely be attributed to the slightly wider profile of the tool's point as previously discussed. This wider profile produced tool marks reminiscent of procession or pecking – slight smooth separate indents which were easily smoothed – rather than the deep channels observed in other carvings. This will be discussed in greater depth in the discussion chapter.

The external shaping of Jar 3 was undertaken over 2 hours and 48 minutes with the removal of 6.2 kg of material. This initial work produced 2356 g of large flakes and 1307 g of dust and small flakes. The internal carving was undertaken over a further 2 hours and 33 minutes with approximately 1569 g of dust and flakes being produced but no large flakes. The smoothing and finishing of both the jar's internal and external surfaces were also completed during this period. Time investment for Jar 3 totals 5 hours and 21 minutes, the shortest time throughout phase 1.

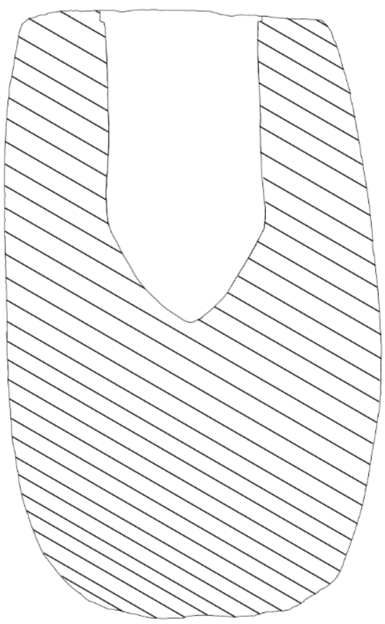


Figure 56. & Figure 57. Jar 3 cross section and Jar 3 complete

The design of Jar 3 is reminiscent of some of the parallel walled jars present within Jar Sites 2 and 3. These jars display less curvature in the vertical profile, maintaining straight parallel walls with slight rounding at base and top of the jar. While this design does not conform to the phase 1 design detailed in the methods chapter, the jar still represents a form commonly found within the Plain of Jars region.

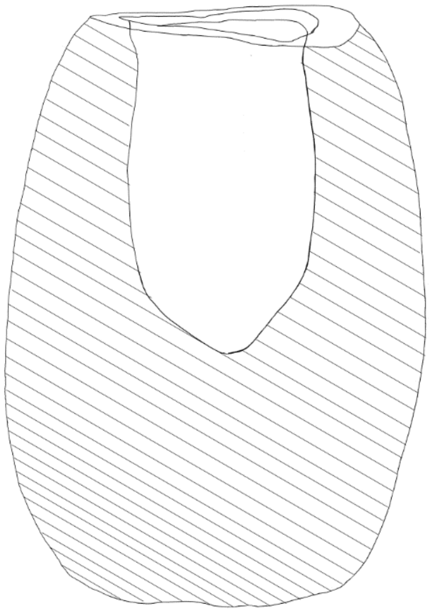
This jar represents the quickest carving within the first experimental phase, although both Jar 2 (iron) and Jar 5 (stone) were completed within an additional 30 minutes. The differences in time between these three examples is minimal and not consistent across other experimental phases.

The jar was carved to an internal depth of 16 cm, displaying a base of 15.5 cm (49%). Although, slightly thicker than previous examples this jar was taller than the other examples measuring 31.5 cm tall (Fig 56). The internal volume of the jar measured 675 ml, making this the largest internal volume of the phase 1 jars.

Jar 4

Jar 4 (Fig 59) was carved using the forged copper plain, point, and tooth chisels. The copper chisels proved capable of carving the sandstone, producing less prominent tool marks but working at a slower pace. This may be attributed to the inherent softness and malleability of the material when compared with the other tools employed.

The external shaping of Jar 4 was performed over 3 hours and 34 minutes with a total of 8 kg of material being removed from the jar. This work produced 2398 g of large flakes and 2828 g of dust and small flakes. The internal carving of the jar was performed over a further 4 hours which removed 3.5 kg from the jars weight. The final work produced 52 g of large flakes and 1535 g of dust and small flakes. The finishing of each surface was completed within their respective segments (external finishing was completed before the internal work began). The total time investment for Jar 4 was 7 hours and 33 minutes.



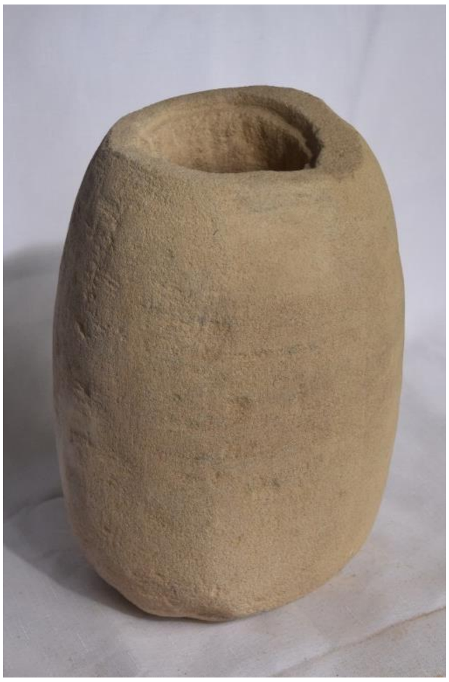


Figure 58 & Figure 59. Jar 4 cross section and Jar 4 complete

Some considerations were taken due to the ending shape of the Jars 1 and 3. The external carving was more extensive upon this jar and focused upon producing a jar with further curved features and a shape that closer resembled the phase 1 design. Rather than just rounding the corners, this carving greatly reshaped the stone to make it far more jar like in appearance. Although the upper and middle shaping of the jar is of greater design, the lower reaches undercut the jar too severely. While this undercutting is acceptable on the smaller scale jars, undercutting of this severity would make placement and carving of the large jars precarious. This observation guided the design of the large jars with a wider base and a lower degree of undercutting.

The internal cavity of the jar was 15.5 cm deep, leaving an 11.5 cm thick base (42%). While this jar required more extensive external carving the internal cavity remained comparable to that of Jar 2, with the internal volume measuring 550 ml (Fig 58).

Jar 5

The carving of Jar 5 (Fig 61) was completed using the basalt hand axe, the basalt chisel and the granite hammer stone prior to its reworking. The tools were extremely effective at carving the outer surface of the jar, relying on the removal of small chips and flakes rather than the removal of large pieces. This resulted in a more controlled removal of material and finer tool marks, requiring less reworking. The internal carving was more troublesome, this portion was slowed by the clunky nature of the tools employed. The hammer stone was capable of completing the task, but this carving would likely have been quicker if a more developed toolset had been employed.

The external carving of Jar 5 was performed over 2 hours and 47 minutes removing 5 kg from the jars weight. The external carving produced 1130 g of large flakes and 2546 g of dust and small flakes. The internal carving was undertaken over an additional 2 hours and 41 minutes and removed 2.5 kg. This carving produced a further 1814 g of dust and small flakes but no large flakes. Time investment for Jar 5 totals 5 hours and 27 minutes.

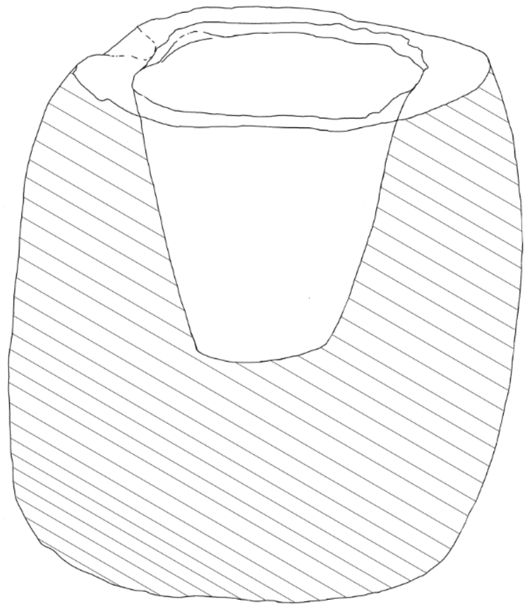


Figure 60 & Figure 61. Jar 5 cross section and Jar 5 complete

This carving has a wider mouth than pervious jars as the tools used for the internal carving were larger in dimensions than those used in previous carvings. The pounder produced a wide initial carving of the jar's internal cavity but was incapable of following the *chaîne opératoire* completely, as undercutting the lip was not achievable with these tools. The internal cavity was carved to a depth of 12.5 cm with a base of 12.5 cm (50%). This shallow cavity was due predominantly to tool limitations but did result in a slightly larger internal cavity. The internal cavity had a volume of 650 ml, slightly higher than the previous jar's which is mostly due to the wider opening (Fig 60).

5.2 Phase 2

Phase 2 of the experimental work reduced the range of tool types to better reflect the research focus on iron and bronze tools. This phase also continued the experimentation of stone tools, due to the known usage of stone tools in other megalithic examples. The previous experimental phase proved that all tool materials were capable of carving the sandstone, this next phase aimed to identify differences in finish quality and time investment at a larger scale. The second size also built towards the calculation of modelling the relationship between jar size and time investment. The jars are all carved from similar blank stock measuring 40 cm x 30 cm x 20 cm. This stock produced a slightly ovoid shape in the horizontal plane. Other morphological elements are notable across the range of jars, each being caused in part by the elongated starting block. The long sides of the jars all display a flat face due to the length of the material, while some have a more accentuated face (mainly the jar carved using iron tools) other examples provide a smoother transition from jar straights to curves.

Table 8. Phase 2 general data

Phase 2	*Tool*	*Time*	*Start Weight*	*End Weight*	*Internal Volume*
J6	Iron	8 hours 12 mins	36.5 kg	24.5 kg	1300 ml
J7	Bronze	8 hours 19 mins	40 kg	29.5 kg	1350 ml
J8	Stone	7 hours 45 mins	38 kg	29 kg	1050 ml

Each jar was carved from a block weighing between 35–40 kg and was carved to a nominal depth, with a base thickness of between 30 % and 50% of the jar's overall height. Once again, the production time for each of the jars showed marginal differences yet were all close together in total time investment. While variance is present it is much smaller with only a difference of minutes rather than hours witnessed during phase 1 (Table 8 and Fig 62). The carving capability of each tool observed in phase 1 continued into the second experimental phase, although some minor retouching of stone tools was necessary.

Each tool type was effective and efficient when carving the sandstone. There was little difference visible between the finish quality of both the jars produced with iron and bronze tools, with some minor differences visible in the jar produced with stone tools. The tool marks produced by the stone tools were once again finer than those of the iron and bronze tools. In a similar fashion to Jar 3, the bronze point chisel tool marks also appeared to be slightly shallower than those of the iron point chisel.

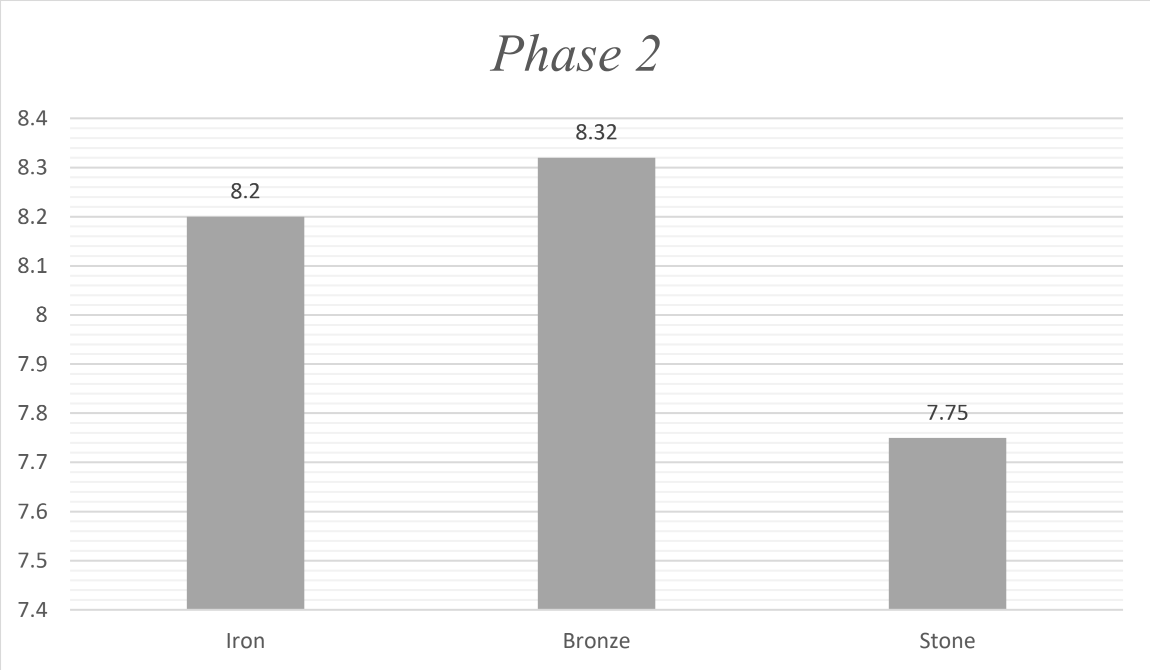


Figure 62. Phase 2 time investment

Debitage

The debitage collection area for the Phase 2 was larger, encompassing a rectangle of approximately 2.6 m x 1.9 m. All debitage was left *in situ* throughout the carving of the requisite jar, this was done to allow for a complete view of the working floor and to show the gradual breakdown of medium size flakes when exposed to a working environment for the duration of jar carving. There is a notable increase in both percentage of debitage collected and percentage of dust within this debitage at the larger scale with a range of 70-90% and 75-85% for collection percentage and dust percentage respectively (Table 9).

Table 9. Phase 2 debitage data

Phase 2	*Weight removed*	*Debitage weight*	*Total Debitage Collected*	*Debitage Dust Percentage*
J6	12 kg	10742 g	89.52%	81%
J7	10.5 kg	7403 g	70.5%	76.2%
J8	9 kg	4094 g	45.49%	95.82%

When considering workshop identification, the divergence from collecting debitage periodically provides insight into a working floor if debitage was left *in situ* either throughout the carving or long after the carving was completed. While it is unclear if this was the practice employed within the Plain of Jars the variation between phase 1 and the second and third phases will provide a comprehensive view of the potential working floors produced by jar production.

Jar 6

Jar 6 (Fig 64) was carved using the first set of iron tools produced, just as Jar 2 was previously. This set of tools included an iron plain chisel, point chisel and a tooth chisel. During this carving the first signs of structural strain the tools were undergoing became apparent. The tool repeatedly bent at the shoulder where it connected with the wooden handle, requiring the tool to be bent back into shape. While this strain was visible and their effects were becoming apparent the tools did not break before the carving was completed.

The external shaping of Jar 6 was performed over 4 hours and 47 minutes with a total of 9.5 kg of material being removed from the jar. The internal carving of the jar was performed over a further 3 hours and 24 minutes which removed 2.5 kg from the jars weight. Only 2002 g of large flakes were produced with 8740 g being small flakes and dust. The time investment for Jar 6 totals 8 hours and 12 minutes.

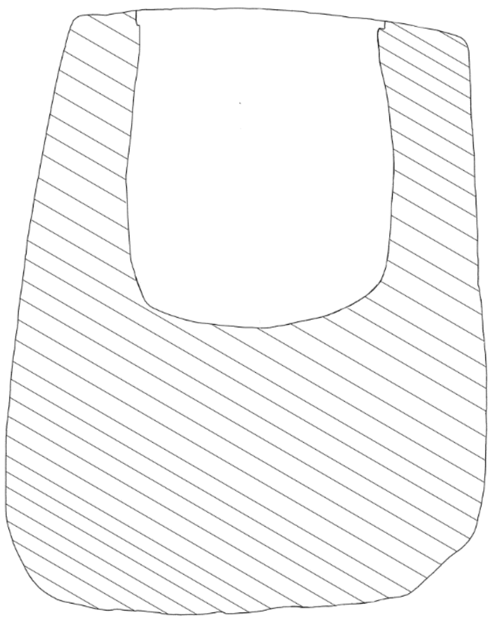


Figure 63 & Figure 64. Jar 6 cross section and Jar 6 complete

The impact of the wide starting material is immediately clear with the jar having an ovoid shape in the horizontal plane. This feature is shared throughout the Phase 2 jars. The jar conforms closely to the desired Phase 2 design, displaying a slight undercutting as well as a gradual slope from the mid to upper reaches. This produces a wide based jar with a thinner top and opening. The internal carving of the jar was finished to a depth of 17.5 cm leaving 15.5 cm for the base (46.97%). The internal cavity has a volume of 1300 ml (Fig 63), more than doubling the volume of (most of) the jars in phase 1. While the jar has been rounded along the corners there is a notable flat along the jar's sides due to the longer profile of the starting material.

Jar 7

The carving of Jar 7 (Fig 66) was undertaken with the set of bronze tools including the point, plain and tooth chisels. For the early stages of this carving a further tool was employed, this was the bronze plain chisel attached with a tang. Following the style used for the iron tools the chisel was handled via an internally set bronze tang with a copper loop maintaining the wood's structural strength. Where the thin iron tools lasted multiple carvings, the thin bronze tool did not. Within the first hour of carving this particular chisel was broken beyond repair. The other bronze tools employed fared much better, showing no sign of damage throughout the carving.

The external shaping of Jar 7 was undertaken over 4 hours and 47 minutes, removing 8 kg from the jar. A further 3 hours and 32 minutes were invested into the internal carving removing a further 2.5 kg from the jar. Of the debitage weight collected only 1759 g was large flakes with the remaining 5644 g being comprised of dust and small flakes. The time investment of Jar 7 totals 8 hours and 19 minutes.

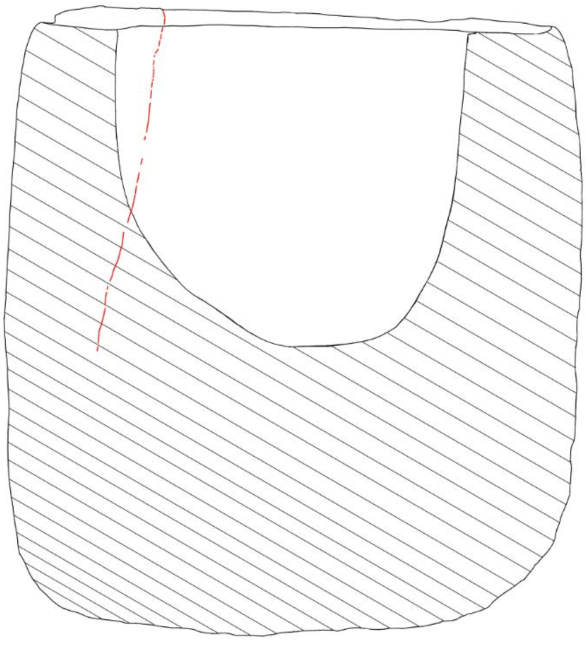


Figure 65 & Figure 66. Jar 7 cross section and Jar 7 complete

The internal carving of Jar 7 was completed to a depth of 17 cm, resulting in a base 15 cm thick (46.87%). The internal cavity of the jar had a volume of 1050 ml, this is in part due to the higher base on the side which experienced a fracture (highlighted in red, Fig. 65).

Jar 7 was the only jar which experienced a large-scale structural failure throughout the experimental work. During the initial internal carving of the jar, a large fracture line became apparent with the potential for a third of the jars upper lip to be fractured off. The remainder of the carving for Jar 7 required a delicate touch with less internal depth being reach in the corner transected by the fracture. This also resulted in the jars upper reaches being slightly wider than the other examples, as it was feared additional working close to the fracture would worsen the structural strength of the jar.

Jar 8

Jar 8 (Fig 68) was carved using the prior stone tool kit with some minor modifications. While both the basalt hand axe and the basalt adze/chisel remained in use in the same form the granite hammer stone was reshaped part way through the carving. As the internal carving work began, it became clear that the granite hammer stone was working both slowly and clumsily, resulting in inefficient strikes. This prompted some minor retouch of the granite column, refining the thinner end from a hammer type rounded end into a more pointed end. While the pointed end was still quite wide, with a point angle wider than 45˚, the tools efficiency increased markedly.

The carving process for Jar 8 was arduous, causing higher physical strain than previous carvings. The external shaping of Jar 8 was performed over 3 hours and 10 minutes, removing 4.5 kg from the jar's outer surface. A further 4 hours and 35 minutes where the final 4.5 kg was removed. Of the debitage weight collected only 171 g was large flakes with the remaining 3923 g being comprised of small flakes and dust. The time investment for Jar 8 totalled 7 hours and 45 minutes, making Jar 8 the quickest carving within phase 2.

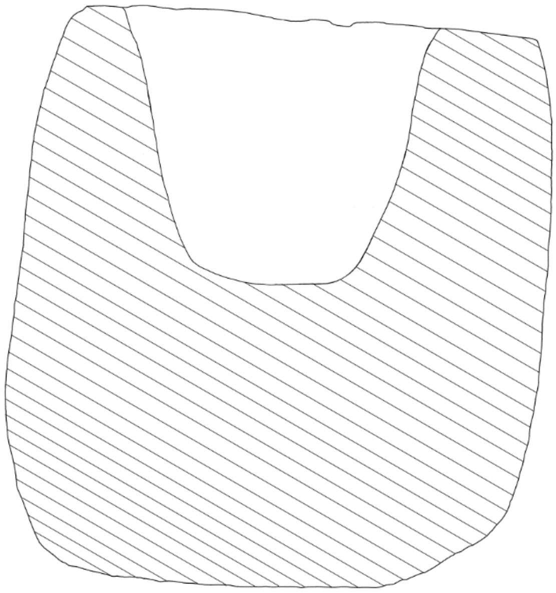
 

Figure 67 & Figure 68. Jar 8 cross section and Jar 8 complete

The internal carving of Jar 8 was completed to a depth of 14.5 cm, resulting in a base 17.5 cm thick (54.68%). This base is thicker than the other examples of phase 2, which is parallel to the stone tools' ability within Phase 1. Due to the small aperture on the jars and lack of tool manoeuvrability (as the stone tools is quite large and cumbersome) reaching similar depth to previous examples is troublesome. Resulting from the shallower depth, the jar has an internal volume of only 1050 ml (Fig 67).

5.3 Phase 3

Phase 3, being the last phase of main carving, was undertaken on the largest sandstone stock accessible within the project's timeframe. The material for the final two jars was originally a singular block of sandstone which was 120 x 50 x 50 cm in size and weighed approximately 651 kg. Once cut into two equal blocks they measure 60 x 50 x 50 cm and weigh approximately 325.5 kg each. Due to the size of the jar and rough nature of the outer surfaces the exact volume and weight were not measurable. At this size the jars are comparable in size to those present in the periphery site of Jar Site 52. This final phase of carving aimed to further explore the capabilities of the iron and bronze tools, solidifying interpretations of their working capabilities and comparisons between them. As such, only two carvings were completed at this size, the first with iron and the second with bronze. These final carvings also completed the data set needed to determine the relationship between jar size and time investment. These carvings are of the most direct importance due to their comparable size, as such their carving will be described in greater detail.

Table 10. Phase 3 general data

Phase 3	*Tool*	*Time*	*Start Weight*	*End Weight*	*Debitage Weight*	*Dust Percentage*	*Internal Volume*
J9	Iron	22 hours 4 mins	325.5kg	178.42 kg to 219.42 kg	95600 g	75.2 %	Approximately 23.5 l
J10	Bronze	21 hours 33 mins	325.5kg	215.34 kg to 245.94 kg	72602 g	71.53%	Approximately 20 l

Time investment (Table 10) for these two jars continued to be relatively similar to those observed in the previous experiments. While there is a minor difference in time investment, the carving process was fairly consistent across each carving. Bronze tools completed the carving marginally quicker than iron tools, as seen during phase 1. Although the task was quicker with bronze tools it was still within the 30-minute window of difference displayed by the iron and bronze tools in phase 1. The tools appeared to display similar mechanical capability with similar hardness and consistent edge retention across both tools. The overall finish quality and carving capability of each tool was similar with neither having any clearly defined tool marks. These two carvings are the cornerstone of the experiment, representing the only directly applicable examples of actual jar (re)construction. Both the iron and bronze produced jars are nearly identical to the jars present within the Plain of Jars with the only difference between the experimental jars and the jars of Laos being surface finish. This difference is likely due to weathering occurring throughout the years following the jar's placement.

Jar 9

Jar 9 (Fig 70) was carved using iron tools. The carving used two sets of tools as the tools employed for the initial half of the experiment broke. During the initial stages of the jar's internal carving the strain and tension observed within the tools during the previous carving were amplified. This eventually led to the breakage of both the point and plain chisels within the first hour of internal carving. This breakage was likely due to the minor straightening and reshaping necessary throughout the previous carving. This reworking likely work hardened the shoulder of the chisel before an eventual breakage as the tools became brittle. The thin profile of the tools likely exacerbated this process, resulting in the tools snapping at the tang neck much quicker than a thicker tool would have.

The remainder of the carving proceeded without further complication. This was due to the use of the second iron toolkit which took the cause of the breakage into consideration. The tools were forged into thicker stock before being completely shaped and were handled in the same fashion as the previous set.

Jar 9 stands approximately 60 cm tall with a width and depth of both 50 cm. Due to the blocks overall size the weight was not directly collectable. This weight for the blank and potential weights for the jars can be calculated. The starting weight is assumed to be approximately 325.5 kg – considering the stones density. The estimated completed jar weight is approximately between 178.42 kg and 219.42 kg.

The carving took a total of 22 hours and 4 minutes. The outer carving of the jar produced the few large flakes of stone present within the debitage. While the jar's size allowed large flakes to be dislodged regularly from the outer surface the remainder of the carving practice resulted in fine dust and small flakes. Of the 95.6 kg of debitage 75.2% was comprised of fine dust and small flakes, with much of the large debitage being isolated into a small number of very large flakes.

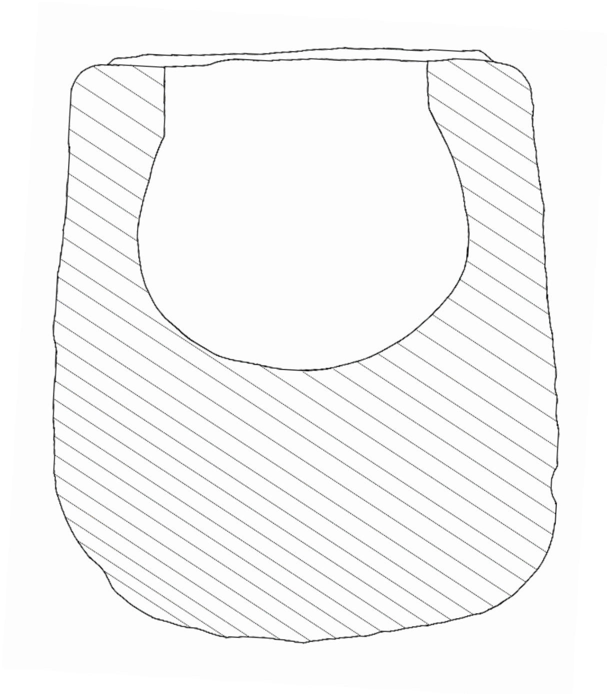


Figure 69 & Figure 70. Jar 9 cross seciton and Jar 9 complete

Jar 9 displays continuing trends present within the prior experimental phases. The relationship between weight of jar blank and time investment continued to develop in a non-linear fashion. While the jar weights increase by a factor of ten between phases 1 and 3, the time investment only increased by a factor of four. This relationship will be discussed in greater detail within the discussion portion of the thesis. Tool marks and tool wear also continue to remain consistent from previous carvings. The debitage floor covered a circle 2 m in diameter centring on the jar. The first metre closest to the centre constituted a ring of dense fine dust, while a mix of larger fragments and dust were situated in the remaining metre. The area of fine dust is likely due to continuous treading across the work floor slowly breaking down the debitage. While the outer reaches of the work floor appeared safe during the experiment, increased travel or additional workers would likely result in the further breakdown of large fragments.

The jar was carved to a depth of 31.5 cm, resulting in a base 27 cm thick (46.15%). Due to the jar's size the internal cavity could not be determined through the means employed for prior carvings, the volume can be roughly calculated however. An estimated volume of the internal cavity is approximately 23.5 l (Fig 69).

Jar 10

Jar 10 (Fig 72) represents the final carving of the experimental work. The jar was completed using a complete bronze toolkit including socketed plain, socketed point and socketed tooth chisels. Each of these chisels performed with little complication although the tooth chisel was not considered necessary for the majority of the carving work. This is due to the shallower tool marks produced by the point chisel, which were easily cleaned using only the plain chisel.

The tools required infrequent and minor resharpening with minor handle breakages being the only point of note. Each of the wooden handles fractured at the connection between the chisel shoulder and internal wooden pin. While this breakage occurred in a similar fashion to the iron chisel breakage – at the shoulder between chisel head and handle – the replacement process for the bronze chisels was less costly in regards to both time and supplies. While reforging the iron tools was a multi-day task requiring forging and the production of complex wooden handles, the production of wooden handles for the bronzes tools was much quicker (only taking two hours each).

The carving as a whole proceeded with few complications. Some minor difficulties arose due to the carving being undertaken on a wooden pallet. The carving was undertaken upon the pallet to facilitate movement – once the jar was completed – as the jar's weight made movement both hard and potentially dangerous to those involved. As such the jar was completed upon a wooden pallet to allow easy transportation using a pallet jack. While this made transporting easier than Jar 9, it also made jar repositioning throughout the carving more troublesome for an individual craftsperson. Consequently, the jar base is squarer in shape than the jar made using iron tools.

The carving of Jar 10 took a total of 21 hours and 33 minutes, making this the fastest of the two carvings undertaken in phase 3. The carving produced 72.6 kg of debitage, with 71.53% of that being dust and small flakes.

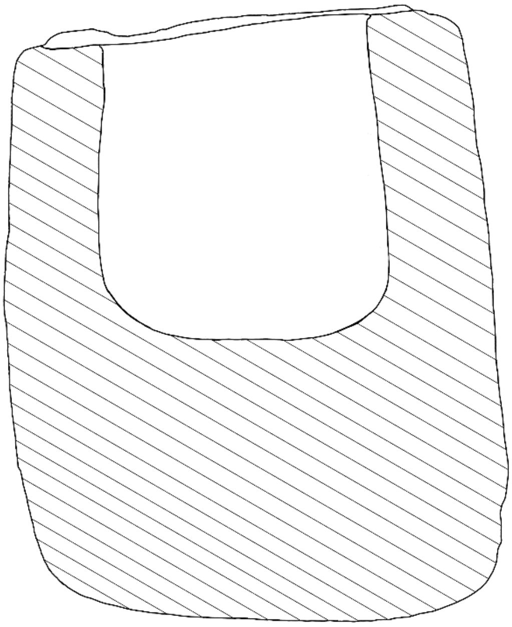
 

Figure 71 & Figure 72. Jar 10 cross section and Jar 10 complete

Once again, the jar was approximately 60 cm tall with a width and depth of 50 cm each. The blank block weight is also estimated at 325.5 kg with the completed jar at an estimated weight between 215 kg to 249 kg. The carving took a total of 21 hours and 33 mins, making it marginally faster than Jar 9. Bronze tools proved to be both capable and adept at carving with a block of this size. Similarly, to Jar 9, the outer shaping produced a number of large stone flakes. As carving progressed the frequency of large flakes of this form being dislodged reduced. This trend continued throughout carving with the late-stage internal carving producing only fine dust.

While the debitage from Jar 10 was left *in situ* as was previously done with Jars 6 through 9, the presence of the pallet upon the work floor may have impacted the distribution of debitage. There is likely to be a higher percentage of large flakes found within close proximity to the jar, the pallet may have further impacted the resultant debitage. Due to the protection provided for some of the debitage, it may be possible that distribution between large and small flakes may be skewed in the final results, lending to a slightly higher percentage of large flakes than observed in the debitage of Jar 9. The jar was carved to a depth of 32.5 cm, leaving a base of 27.5 cm (45%). The internal volume can be calculated at approximately 20 l (Fig 71).

Phase 3 summary

While phase 3 represented the only directly applicable comparison to actual jars, the size of material made data collection less achievable. As such the complete range of data collected in earlier experiments was not possible for Jars 9 and 10. While this data may be extrapolated from the smaller scale jars it likely represents a less accurate data range. Nonetheless, the data collected from phase 3 confirmed the trends from the previous carvings. This included similar time investment for both iron and bronze tool produced jars. Secondly, the relationship between raw material size and time investment continued to develop in a non-linear fashion, this relationship will be explored further in the coming chapter. The debitage produced within each of the final experimental carvings continued to consist of predominately dust with a higher dust to large flake ratio. Although the percentage did not exceed those observed in phase 2, the dust percentage continued to be above 75%. The slight decline seen from phase 2 is likely due to the ability to remove large flakes easily from the jars outer surface in phase 3. The largest fragments dislodged weighed upwards of 3 kg. While phase 3 alone offers some significant data and insight into the jar production process, the complete dataset provided by the experiment work adds further opportunities for analysis.

It is at this point that previously mentioned limitations are addressed. The large and heavy nature of the stone employed within phase 3 made some aspects of data collection unachievable. Although the details of original weight and final weight cannot be always directly measured there are ways to estimate some of this absent data. Such calculations will be undertaken here before the overall dataset is discussed in detail.

Phase 3 weight calculations

While a direct measurement of the jar's initial weight and end weight was not achievable it can be estimated using known variables. For the starting block, the weight can be calculated using the density and volume of the sandstone. Potential final weights for the jars can be calculated using debitage and debitage collection percentages extrapolated from the observed values for smaller jars, providing a range of weights the jars potentially fall within.

Starting block weight

The starting blocks can be calculated using the volume and the average density of the sandstone used which is 2.17 g/cm³.

$$Volume = (Length \times Width \times Height)$$

$$60cm \times 50cm \times 50cm = 150{,}000\ cm^3$$

Taking this volume of 150,000 cm³ it is simple to calculate the jar weight using the density of 2.17 g/cm³.

$Mass = volume \times density$

$$150{,}000 \times 2.17 = 325{,}500g$$

Assuming the stone density is consistent, the original stone weight for the Phase 3 jars is approximately 325,500 g or 325.5 kg. As each block has the same original dimensions it is possible to assume this is an approximate start weight for both blank blocks.

Completed jar weights

Jar 9

Firstly, the completed jar weight can be calculated using the data regarding debitage percentage collected. If one assumes that the percentage of collected debitage remains consistent, between 65% and 90%, we can produce a range of potential weights for the completed jars.

The calculation will modify the prior calculations used to determine debitage percentage which was $Debitage\ percentage = \frac{debitage\ weight}{total\ weight\ loss} \times 100$ with total weight loss referring to the weight difference between the starting block and final jar weight. Reworking this calculation provides us with the necessary calculation to determine the potential range of ending weights for each jar. The calculation is $Total\ weight\ loss = \frac{debitage\ weight}{Debitage\ percentage} \times 100$ applying this calculation twice, firstly for the lowest displayed percentage collection of 65% and secondly for the highest percentage of 90%, a potential range of total weight removal can be determined.

$$Maximum\ total\ weight\ loss = \frac{debitage\ weight}{lowest\ debitage\ percentage} \times 100$$

$$\frac{95.6}{65} \times 100 = 147.08\ kg$$

$$Lowest\ total\ weight\ loss = \frac{debitage\ weight}{highest\ debitage\ collection} \times 100$$

$$\frac{95.6}{90} \times 100 = 106.2\ kg$$

As such, the potential weight removal from Jar 9 was between 106.08 kg and 147.08 kg. The potential final weight of Jar 9 therefore ranges from 219.42 kg at heaviest to 178.42 kg at lightest. Determining where within this range Jar 9 actually resides requires additional work (and access to heavy duty scales).

Jar 10

The calculation once again assumes the debitage collected represents between 65% and 90% of the total weight removed.

$$Maximum\ total\ weight\ loss = \frac{debitage\ weight}{lowest\ debitage\ percentage} \times 100$$

$$\frac{71.602}{65} \times 100 = 110.16\ kg$$

$$Lowest\ total\ weight\ loss = \frac{debitage\ weight}{highest\ debitage\ collection} \times 100$$

$$\frac{71.602}{90} \times 100 = 79.56\ kg$$

The calculations indicate the potential weight removal from Jar 10 was between 79.56 kg and 110.16 kg. Thus, the potential final weight range for Jar 10 is from 245.94 kg at heaviest to 215.34 kg at lightest.

5.4 Complete Data set

Taking each phase into consideration separately can show us the minor differences between the data but when taken as a collective the data can offer much greater insights. Each carving undertaken was accompanied by unique challenges and each offers a piece to the overall picture. Each jar provided a necessary insight into the processes of jar production and each addressed the research aims in purposeful ways. The complex nature of these insights will be explored further in the approaching discussion chapter, but not before a complete accounting of the data (Table 11).

While the range of carvings undertaken was not comprehensive it does allow for a view of the impacts of each variable.

Tool material showed minimal impact upon the time investment of jar production. At each size, iron and bronze time investment varied by 30 minutes at most. There were also no consistently faster tools, bronze appeared fast for phase 1 and 3 while iron was faster for phase 2. Furthermore, the other tools explored also displayed similar time investment – aside from steel for previously explained reasons. What is of greater consequence and impact was the tool forms themselves.

Tool type or shape had a notable impact upon both tool marks and overall time investment. The lack of a complete toolkit for Jar 1 is likely the primary reason for the jar's longer production time. The complete toolkit is also key in producing the notable tool marks present upon the jars. This element is discussed in greater detail within the following chapter.

Of considerable interest is how similar bronze and iron tools were across each of the experiment phases, as well as stone tools' capabilities when compared to each of the main metallic examples. While variance is present within the jars produced by these experiments, this variance is minor in nature. The range of variance displays a similar range of jar shape and form to those present within the Plain of Jars itself. Lastly, the experimental range provides an extensive view of the material remains produced by the experiments. Small stone flakes and fine dust were the most prominent element of debitage produced throughout the each carving. While larger flakes were noted more often as the jar scale increased, the percentage of these large flakes was still consistently dwarfed by the large quantity of dust and fine flakes.

The data produced by this experimental work can be analysed in a number of ways, exploring each of the focal questions presented in the initial phases of this thesis. The following discussion explores the data from a variety of perspectives, providing opportunities for the data to be extrapolated and inferences made. While this data not only works to offer insight into the research questions alone, the data can act as a baseline investigation into jar carving and megalithic production practice as a whole.

Table 11. Complete experiment dataset

Jar	*Time*	*Number of Blows*	*Average per minute*	*Weight of debitage*	*Dust percentage*	*Debitage percentage*	*Start weight*	*End weight*	*Rate of material removal*	*Internal volume*
Jar 1	11 hours 36 mins	45307	65	4724 g	80.20%	67.49%	21 kg	14 kg	603.45 g/h	620 ml
Jar 2	5 hours 51 mins	26641	75.9	6511 g	66.50%	65.11%	23 kg	13 kg	1709.4 g/h	550 ml
Jar 3	5 hours 21 mins	20975	68.2	5323 g	54.97%	66.53%	25 kg	17 kg	1682.24 g/h	675 ml
Jar 4	7 hours 33 mins	34207	75.34	6813 g	64%	64.89%	21 kg	10.5 kg	13907.28 g/h	550 ml
Jar 5	5 hours 27 mins	27804	98.36	5490 g	79%	73.2%	22.5 kg	15 kg	1376.15 g/h	600 ml
Jar 6	8 hours 12 mins	36103	80.23	10742 g	81%	89.52%	36.5 kg	24.5 kg	1634.41 g/h	1300 ml
Jar 7	8 hours 19 mins	27699	66.47	7403 g	76.2%	70.5%	40 kg	29.5 kg	1262.02 g/h	1350 ml
Jar 8	7 hours 45 mins	29473	63.38	4094 g	95.82%	45.49%	38 kg	29 kg	1161.29 g/h	1050 ml

Jar 9[4]	22 hours 4 mins	78062	64	95600 g	75.2%	Assumed between 65% and 90%	325.5 kg	178.42 kg to 219.42 kg	4814.14 g/h to 6667.27 g/h	Approximately 23.5 l
Jar 10[5]	21 hours 33 mins	79527	63.52	72602 g	71.53%	Assumed between 65% and 90%	325.5 kg	215.34 kg to 245.94 kg	3691.88 g/h to 5111.83 g/h	Approximately 20 l

[4] Jar 9 calculations are found within the discussion chapter. End weight and material removal are calculated from debitage weight from Jar 9 alongside debitage collection percentages displayed by other carvings throughout the experimental works.

[5] Jar 10 calculations are found within the discussion chapter. End weight and material removal are calculated from debitage weight from Jar 10 alongside debitage collection percentages displayed by other carvings throughout the experimental works.

Chapter 6.

Discussion

This experimental archaeology research project was designed to address three focal ideas, each addressed by the data above. To reiterate the focus points and their aims;

(1) What are the mechanics of jar production?
(2) Considering production time, how where the jars valued by the culture who produced them?
(3) What debris is created by the jar production process?

Each of these aims, accompanied by a range of supplementary questions, was built into the experimental practice with different experiment phases providing insight into specific foci. The discussion will concentrate on each of these foci in-turn, with a component dedicated to each question, their available data and the interpretations of the results.

6.1 Question 1: Intricacies of Jar production

This portion of the research focus was predominantly concerned with the carving capabilities of different tool materials, with an emphasis on the capabilities of iron and bronze. The research was designed to incorporate a full range of tools including those which were less likely to have been employed; steel and copper. The inclusion of these tools was to produce a thoroughly explored data set to show the broadest range of impact of different tool mechanical properties upon the final jars produced. This element of the research sought to explore the overall ability to carve the material but also sought to explore the differences in quality of finish produced and the differences in time investment across the range of tool materials. As steel tools were definitely not employed within the Plain of Jars context only one, small-scale, jar was carved using this modern tool, saving material and time. While copper may have been in use within the context of the Plain of Jars, the predominant focus on distinguishing between bronze and iron meant that only a single carving was produced using the copper toolkit. The data provided by a full range of copper and steel carvings would have been interesting but this was outside of the scope of this research project and remains to be investigated in greater detail in future work. While the relative efficacy of bronze and iron are the main focus of the research, initial experiments with stone tools also made it clear they were a possible tool here – potentially more effective and/or efficient than iron – leading to their inclusion in phase 2.

The production of small-scale jars during phase 1 was focused upon exploring the minor differences in the time and finish with each tool material. Phase 2 continued to explore the differences at a slightly larger scale and focused upon the more applicable tool materials; iron, bronze, and stone. Lastly, phase 3 examined the carving capabilities of the two tool materials of highest significance to the research focus, and more particularly, at a scale equivalent to actual examples of stone jars in Laos, albeit at the smaller end of the scale.

To explore the capability of each tool explored there were two main measures, firstly the overall time investment and secondly the rate of material removal. To analyse the finish quality of each of the tools a preliminary tool mark analysis is also employed at the macroscopic level.

Time investment

Time investment can be modelled by considering both the time spent working on the jars themselves and the time spent reworking the tools (Table 14). Tool reworking predominantly refers to sharpening or straightening when working with metal tools and retouch when referring to stone tools.

Table 12. Time investment and tool maintenance data

Phase 1	*Time*	*Reworking/ sharpening*	*Reworking/ sharpening time*	*Tool breakage*	*Time remaking tools*
Jar 1 (Steel)	11 hours 36 mins	Yes	4 mins total	-	-
Jar 2 (Iron)	5 hours 51 mins	No	-	Wooden mallet	4 hours total
Jar 3 (Bronze)	5 hours 21 mins	Yes	5 mins total	Chisel handle	2 hours total
Jar 4 (Copper)	7 hours 33 mins	Yes	18 mins total	-	-
Jar 5 (Stone)	5 hours 27 mins	No	-	-	-
Phase 2					
Jar 6 (Iron)	8 hours 12 mins	Yes	10 mins total	-	-

Jar 7 (Bronze)	8 hours 19 mins	Yes	4 mins total	Chisel blade	Not remade
Jar 8 (Stone)	7 hours 45 mins	Yes	10 mins	-	-
Phase 3					
Jar 9 (Iron)	22 hours 4 mins	No	-	2 chisel blades	9 hours total
Jar 10 (Bronze)	21 hours 33 mins	yes	10 mins total	1 chisel handle 1 wooden mallet	5 hours total

Of all tool types tested the only materials to avoid complete chisel breakage were steel, copper and stone, with stone requiring the least reworking (table 12). Iron tools experienced the most breakage due to the thin profile of the first toolkit and the strain being isolated to the shoulder where the internal tang met the blade portion. Replacing the two iron chisels which broke during the carving of Jar 9 was the longest time investment outside of jar carving. The time spent reproducing the iron chisels took approximately five hours to forge and a further four hours for chisel handling. Fortunately, breakages of this severity were uncommon with only three chisels breaking entirely, two of which were iron and the third was bronze. These breakages were due in part to the final form of the tang shoulder being too thin to endure the strenuous forces throughout the carvings. This issue was rectified with the remade chisels produced with thicker dimensions. The thicker cross section of the tools increased their resilience greatly, with no further breakage and no indication of breakage in the future. Replacing hammers required approximately four or five hours of work and rehandling both bronze chisels cost a similar amount of time, around two hours each.

The time investment necessary to produce the tools is not the only thing of note when comparing the tools but the cost of materials was also of importance. The ease with which the bronze tools were cast made the production much quicker and more economic in regards to material wastage. Being able to recast the tool and reuse broken tools and offcuts was highly valuable and cannot be understated.

When taking into consideration the time investment of tool reworking, the slow nature of the iron working increased the total time investment for jars made with iron tools greatly. It also appeared that the iron tools' edges were more susceptible to flattening than the bronze chisels were. The bronze chisels required little sharpening with the plain chisel receiving no reworking throughout the experimental work.

While there were few notable differences between iron and bronze throughout each experimental phase (bronze was 30 minutes faster in phases 1 and 3, while iron was 7 minutes faster during phase 2), there are some minor differences when considering overall time. If tool production and upkeep is important when considering time investment, bronze tools were less costly in regards to initial production and upkeep. The ease of replacing the bronze tools' socketed wooden handles compared to reproducing entire iron chisels upon their breakage was clear. The immediate reusability of the bronze was also highly valuable as recasting the tools was a quick task requiring much lower heats (around 970˚ c for bronze, compared with the 1127-1204˚ c for melting iron for casting) than recasting iron would have required. If forging was the preferred method of production, then the task may have been even more time consuming, taking around five hours and numerous heat cycles for each tool to be forged.

As a short side note, the copper tools provided some interesting information regarding softer materials. While the copper tools were softer in nature and became deformed at a quicker rate throughout the working, the points were also the easiest to repair. While all other tool types required abrasive stones to sharpen – engendering loss of tool material – or access to a forge, the copper tools could easily be cold-worked back to shape. This greatly increased the speed of repair and meant the tools could be fixed would any additional tools, requiring only a hammer and hard surface to use as an anvil.

Rate of material removal

The general efficiency for each tool was easily determined by dividing the overall weight removed by the number of hours carved. This provided a measure of removal of grams per hour (g/h) which clearly demonstrates the tools carving abilities at each size explored (Table 13).

Table 13.Rate of material removal in grams per hour (g/h)

Phase 1	*Time*	*Material removed*	*Rate of material removal (g/h)*
Jar 1 (Steel)	11 hours 36 mins	7 kg	603.45 g/h
Jar 2 (Iron)	5 hours 51 mins	10 kg	1709.4 g/h
Jar 3 (Bronze)	5 hours 21 mins	9 kg	1682. 24 g/h
Jar 4 (Copper)	7 hours 33 mins	10.5 kg	1390.7 28 g/h
Jar 5 (Stone)	5 hours 27 mins	7.5 kg	1376.15 g/h
Phase 2			

Jar 6 (Iron)	8 hours 12 mins	12 kg	1463. 41 g/h
Jar7 (Bronze)	8 hours 19 mins	10.5 kg	1262.02 g/h
Jar 8 (Stone)	7 hours 45 mins	9 kg	1161.29 g/h
Phase 3			
Jar 9 (Iron)	22 hours 4 mins	106.2 kg to 147. 08 kg	4814.14 g/h to 6667.27 g/h
Jar 10 (Bronze)	21 hours 33 mins	79.56 kg to 110.16 kg	3691.88 g/h to 5111.83 g/h

Throughout the experimental work there were slight fluctuations within each experimental phase regarding removal rate. Removal rates ranged from 603.45 g/h to 1709.4 g/h during phase 1, while in phase 2 there appeared to be a lower degree of spread. However, once the outlier Jar 1 is removed from consideration the range of g/h values for phase 1 narrow to 1376.15 g/h to 1709.4 g/h.

Across the set of experiments each tool type appears to experience a 200-500g/h reduction between phase 1 and 2. Iron tools reduced from 1709.4 g/h to 1463.41 g/h, a reduction of 245.99 g/h or 14.39%. A similar reduction was seen with the bronze and stone tools, losing 420.22g/h (24.98%) and 214.86 g/h (15.6%) respectively. This reduction may be due in part to the increase to the jar's internal cavity. While the internal carving of the jar almost doubled in terms of amount of material removed and time required, the work required for external shaping changed little from phase 1 to phase 2. With the internal carving being a notably slower process, this reduction in speed of overall material removal is expected.

During phase 3 there appears to be a notable increase in removal rates, considering both the low and high range of potential weight removal. The removal rate appears to almost double from the prior phase which may be attributed to the ability to remove extremely large outer flakes in a short period of time. This high removal rate also correlated with the developing relationship between starting block and time investment. This data suggests that larger jars may be formed at an increasingly faster rate (as the size increases) than their smaller counterparts. This relationship and how it is reflected in the jars produced, will be discussed more below.

Consistently throughout each carving phase, iron tools appear to display the fastest material removal rates with bronze following closely behind. Copper appears marginally faster than stone within the first phase of experiments with steel tools clearly being the slowest. Once again, this is likely due to a number of factors and may not be an accurate indicator of the capabilities of steel tools.

Tool mark comparisons

The last element to consider when assessing carving capabilities is tool marks. While an assumption that iron tools employed for jar carving did exist within Colani's work (1935b: 123), her main reason for this appears to be that the tool marks present upon the jars indicated iron tools (1935a: 134, 144). Throughout different stages of jar carving a collection of images were taken to capture the tool marks for macro analysis, to be at least approximately comparable with Colani's own observations. The following begins with a discussion of tool mark differences noted throughout the experimental work before comparisons are drawn between the experimental jars and some notable tool marks from the Plain of Jars. When undertaking the carving it became clear that particular tool types produced distinctly identifiable marks. Tool marks varied slightly throughout the carving process with different marks being notable at different stages of carving. While different marks were notable it became apparent that these differences were due to tool *type* and not tool *material*. The only exception to this being stone tools which differ from the other tool marks. All metallic tools appear to produce similar markings, but different tool types – point, plain and tooth – each produce distinctly different tool marks. Tool marks produced by plain chisels appeared as horizontal cuts – normally the width of the tool – that repeatedly crossed the jars surface, with approximately 5 mm between each marking. As the plain chisels were used for removing high spots and flattening deep troughs in the prior carving, this chisel was often employed from the top to bottom of the jars, slowly removing highs and lows to create a uniform level surface (fig 73 & 74).

Figure 73 & Figure 74. Jar 2 showing iron plain chisel tool marks and Jar 3 showing bronze plain chisel tool marks.

Point chisels produced markedly different tool marks than plain chisels. Both iron and copper point chisels produced troughs and channels which crossed the jar erratically. These markings cut horizontally in some instances, vertically in others and also diagonally (fig 75 & 76). This is likely due to their sharp, steep-pointed nature tending towards channelling strips of material. This channelling action produced deep trenches which transect the jar surface at various angles. The only point chisel that differed from this was the bronze point chisel. This particular tool produced shallower cuts which did not turn into channels. The tool did, however, produce a working surface reminiscent of pecking or chipping, with isolated hollows and only occasional channelled grooves. This is likely due to the chisel's slightly wider profile, with the tool point coming to a v-shaped blade 10 mm wide rather than a fine point.

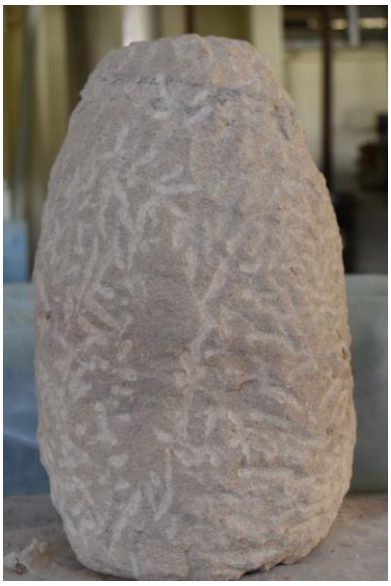



Figure 75 & Figure 76. Jar 2 showing iron point chisel tool marks and Jar 3 showing bronze point chisel tool marks.

The tool marks on the internal surface of Jar 9 and Jar 10 both show similar channel-like grooves running from the jar's lip into the transition from wall to base (Fig 77 & 78). The tool marks are more exaggerated across the phase 3 examples but similar markings were present throughout each phase.

Figure 77 & Figure 78. Jar 10 internal tool marks and Jar 9 internal tool marks

Lastly, the tooth chisels produced consistent parallel channels which covered the entire jar from top to bottom. The tooth chisels were employed as a second stage within the carving, used mostly to remove highs and lows produced by the point chisels. As such the tooth chisels were used to carve from one end of the jar to the other, levelling the surface. The tooth chisels had the most distinct tool marks which are noted by close strips of parallel lines running across the jars' surface (Fig 79). Each of the tooth chisels employed produced remarkably similar markings.

Figure 79. Jar 4 showing copper tooth chisel tool marks

While each of the metallic tools discussed are nearly indistinguishable from one another in terms of the marks they produce, the marks produced by stone tools were quite different. The stone tools relied heavily on pecking for material removal with the tool marks displaying this. Numerous shallow dips where small chips were dislodged litter the jar's surface. Many of these hollows are only 2-5 mm wide, with some being slightly larger. Most of these hollows have a rough stone texture where the small chips and flakes were broken from the jar (fig 80). There are some similarities between these tool marks and those produced by the bronze point chisel yet the marks produced by stone tools appear to be shallower. The stone adze produced a small scattering of cut marks also, but these were less prominently than the chip marks.

Figure 80. Jar 8 with minor pecking marks visible on left side.

Overall, the range of metallic tools produced remarkably similar tool marks throughout. There may prove to be differences between these marks when more detailed analysis is undertaken yet to the naked eye there are no clear differences. Any notable differences between tool marks would become even less visible when taking weathering into consideration. Colani's observations that the visible tool marks were those of iron tools (Colani 1935a; 134, 144) was likely determined by macro analysis, rather than microscopic analysis. As such, with the similarity in tool marks across the metallic tools, it is possible that any of the metallic tools were responsible for some of the more prominent tool marks present within the jar assemblages. There is every possibility that the tools marks visible on the jars were produced by stone tools which were hafted, allowing the tools to exert greater pressure upon the jar and dislodge larger flakes. Hafted stone tools were not a part of this experimental project. It will be interesting to test these in future work. Although this is a possibility, the tool marks visible at Jar site 42 are most reminiscent of the markings produced by the bronze point chisel. The pitting and shallow hollows visible across the jars surface appear to be consistent with those produced during the carving of jars 3, 7 and 10 which employed bronze tools. This could be due to the jar's broken state resulting in the outer surface remaining unsmoothed. These tool marks are some of the few noted by the author during field observations at numerous jar sites.[6]

Tool marks are more prominent on the inner surfaces of the jars, likely due to the slight protection from weathering offered by the jars' overhanging lip. The tool marks noted upon the inner surface of the jars appear to be similar to the marks produced by experimental metallic point chisels. The clearest similarity is between experimental Jars 9 and 10 and some of the jars I have observed at Jar Site 1 and 52 (See fig 81 & 82), with Colani claiming jars at Jar Site 1 appear to display iron tools marks in particular (Colani 1935a: 134).

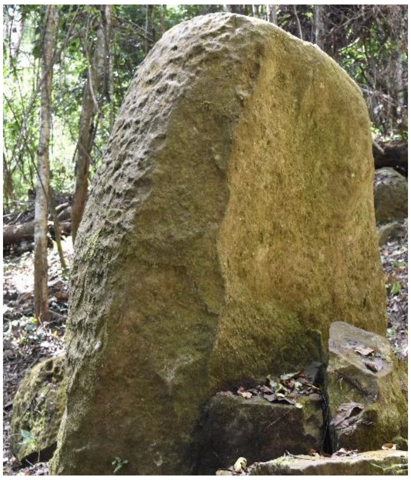


Figure 81 & Figure 82. Tool marks on external surface of jar at Jar Site 42 and Internal tool mark present on jar from Jar Site 52.

Summary

This experimental work indicates that jar production could reliably be performed using iron, bronze or stone tools. Each of these tool materials displays similar time investment and finish qualities with bronze tools being the quickest tool for phase 1 and phase 3, while stone tools were the quickest for phase 2. Iron tools display the highest material removal rate but require additional work to smooth the rough marks produced by iron point chisels, resulting in bronze tools being more efficient overall. Not only are each of these tools similar in time investment, but tool marks also. Tool marks produced by stone tools differ slightly from those of iron and bronze. Stone tool marks can be categorised as slight pitting and pecking marks, produced by the removal of small stone chips and flakes throughout the carving process. Some cuts can also be seen on the jars' outer surface but these are relatively rare. Iron and bronze tools both display extremely similar tool marks across the range of tool types. The markings

[6] While microscopic analysis is preferrable, access to the Plain of Jars necessary to perform this analysis was not achievable due to Covid-19 travel restrictions. Future work will seek to include microscopic analysis.

produced by each of these tools are indistinguishable to the human eye, with consistency throughout each experimental phase.

When considering the tool marks seen in the Plain of Jars context, the tool marks witnessed are only visible in isolated instances. From the few available tool mark instances, mostly on the internal surface of the jars, the tool marks appear reminiscent of the channels produced by iron and bronze point chisels. While the markings on the Plain of Jars examples are less prominent, the markings on the experimental examples display similar form and flow. The external surfaces differ slightly however, as external markings in the Plain of Jars context appear to display pits and hollows reminiscent of stone tool marks. Further work is required to examine these markings in greater detail and access to the Plain of Jars is necessary for comprehensive comparisons to be undertaken.

6.2 Question 2: Considering time investment

The second research question focuses on time investment. Although covered somewhat in the previous section, this subchapter will explore the concept deeper. There are a number of insights provided by exploring this key element of the jars' production. Time investment can be an indicator of the socio-economic value based on the investment the jars require, offering insights into their importance within the Plain of Jars culture. Economic investigation of this nature, employing elements of Labour theory of Value to estimate the economic importance of objects based on material and time investment. While exploring the jars in this fashion were amongst the initial aims for the research, results proved more complex with other elements needing greater consideration. Below the thesis discusses elements of further importance, cautioning against a strictly economic view and opting for a more socially discursive view of jar production while providing a small accounting of the time investment. Future work will seek to explore the economic value of jars when more extensive data is available.

The initial expectations for time investment were exceptionally high; rather than a number of hours it was expected to take a number of days. Once the experimental work was underway, however, those expectations quickly shifted. The softness of the stone and ease of carving it resulted in a smooth process taking less than 24 hours in the case of the phase 3 jars. The removal rate ranging from around 600 g/h in the early phases to potentially over 6 kg/h in phase 3 allowed for a quick shaping and refining of the jars. The data suggests there is a notable difference between time investments on external and internal shaping, but for this portion the investment will be discussed as a collective. With the data produced by the experimental work it became apparent that small scale jars, like those present at part of Jar Site 52, could be easily completed over a few working days by a single craftsperson, certainly less than a week.

One major reason for exploring time was to determine if the jars represented a specialised craft or a seasonal or everyday activity undertaken by general members of the community. The initial impression is that the scope and scale of jar production suggests a specialised craft, with at least the transportation of the jars being a costly activity requiring numerous participants. However, although the jars may need to be quarried and moved by multiple people, it appears they can easily be carved by an individual craftsperson. Furthermore, the lower than expected time investment required for the jars' production questions the necessity of specialised craftspeople altogether. It is possible to complete a small jar within a month with only an hours' worth of carving a day. It should be noted that the data produced in this study only concerns small jars and some of the larger archaeological jars are up to 80 times the size of phase 3 experimental jars (The King's Cup with a height of 3 meters and diameter of 2 meters compared to smaller Jar Site 52 jars measuring approximately 60 cm x 50 cm). Exploring the relationship between jar size and time requirement allows for the development of a metric for quantifying the relationship.

To examine the relationship and its development with the increase of both parameters a logarithmic function can be employed to track this relationship (Fig 83). This has been done independently for jars made with iron tools and jars made with bronze tools. It should be noted this model is built entirely from the author's work and the calculations are consistent with the author's individual working speed. Although built from a small data set this model functions as a baseline investigation, with clearly defined parameters and variables. This allows for future work to refine this function and potentially improve its accuracy. The logarithmic function is expressed as;

$$y = log_b(x) - a$$

$y = time\ in\ minutes$

$x = size\ starting\ block\ in\ kg$

Assuming the function is both accurate and the density of the sandstone present within the Plain of Jars is similar to those used in this study, the function can predict the time necessary to carve a jar of any size.

Firstly, using iron tools;

$$y = log_{1.00264}(x) - 855.221$$

And secondly using bronze tools;

$$y = log_{1.00264}(x) - 898.081$$

For example, taking the King's Cup, the largest recorded jar, which has a height of 3 meters and a diameter of 2 meters the proposed weight of the initial block can be determined as 2323g/m³ with a volume of approximately 12 m³ (3m x 2m x 2m) resulting in a starting block weighing 27,876 kg. From this, it is possible to determine the time required working at the same pace as the author.

The function predicts that it would take approximately 3028 minutes to complete the carving (or 50 hours and 28 minutes). If using bronze tools, the production time is predicted to be 2984 minutes (or 49 hours and 43 minutes). To verify the accuracy of this model further testing is required. Nonetheless, the model offers a predictive view of potential production time of large jars. The model displays the continued prevalence of bronze tools due to the data used to produce the model. Iron tools may be faster than bronze at different sizes (as witnessed in phase 2) yet the model cannot predict this potential shift in trends. Although iron tools boast a faster material removal rate overall, the additional work necessary to smooth the rough tool marks produced by iron point chisels makes the overall carving task longer.

If the ancient jar production followed these predicted trends, then it is possible that none of the jars from the Plain of Jars required any more than 50 hours for a single craftsperson. For a further example, a more averaged-sized jar with a height of 1.5 meters and a diameter of 1 meter would require approximately 36 hours for bronze tools and 37 hours for iron tools to produce (fig 83). This short time requirement prompts a number of questions about the need for specialised craftspeople and when the jars would have been completed, a discussion of these can be found in the interpretations section of this chapter.

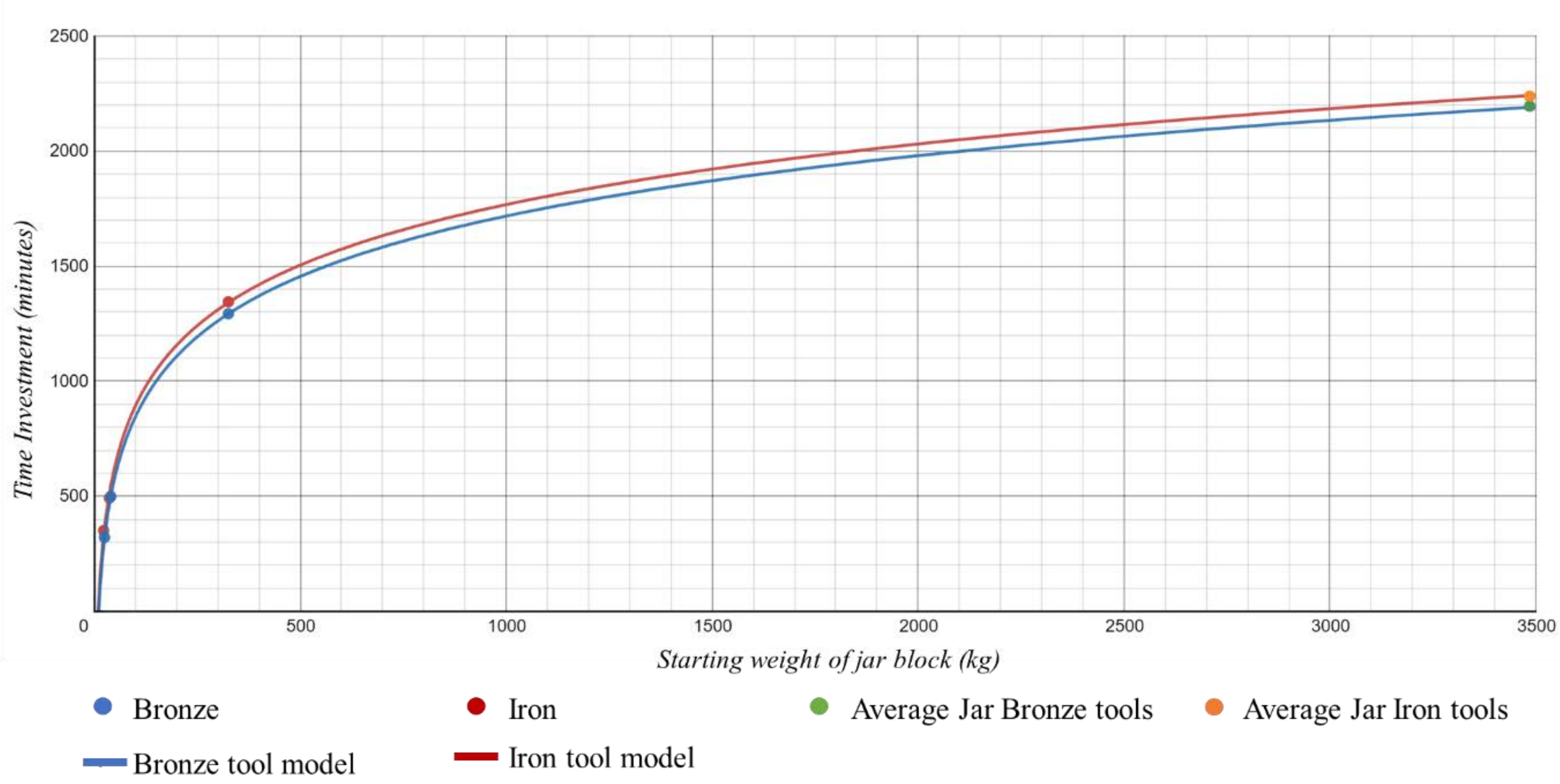


Figure 83. Relationship between Starting block weight and Time investment

Interpretations of jar production

Firstly, it appears that specialist craftspeople are not technically a necessity for the carving of a jar. If the demand for jars is low then it would be possible to carve a jar as a low season activity. Furthermore, the carving of a jar is a quick task, requiring a single participant for the carving portion of the work. A number of alternative production systems may have been in place within the Plain of Jars, technical complexity of the task means it is quick and easily done by anyone.

Depending upon the way jars are used, it could be a possibility that jar carving was a low season activity. The production of jars could be performed by craftspeople who have other specialisation, or it could be a cultural community practice, seeing a period of intense jar production and community-wide burial activity. Further possibilities arise from this interpretation. If jars were used by a connected family lineage or clan, rather than a singular individual, the need for jars would be greatly reduced. With a higher use rate and lower jar numbers it may be a cultural community practice undertaken by members of an individual family or clan to produce a jar for use in mortuary practice. The intricacies of this interpretation produce a range of further questions; what was considered a clan or family? Was it likely that over 2000 distinct extended families existed throughout the Plain of Jars at some stage (as there are over 2000 jars presently recorded)? Or is it more likely that a clan or an extended family associated with a cluster of similarly positioned and shaped jars? Was jar production undertaken by an entire family or only select members? Were the jars only used for mortuary practices? Or were they associated with a range of other ritual practices? Alternatively, jar production could be associated with another cultural or ritual event such as a coming of age or other rite of passage.

The experimental work has demonstrated that it is perfectly possible that the jars could have been produced by laypeople without the particular skillset associated with carving stone. This possibility may also go some way towards explaining the variations seen in jar shape and size throughout the region, including within individual sites. Although the task can be performed by unskilled workers, the tools required for the task are fairly particular and would have likely been costly. Both iron and bronze could have required metallurgical knowledge or a specialist metallurgist to produce, although there is some debate about the extent of craft specialisation in the Southeast Asian context (see White & Pigott 1996; Cawte 2008). Stone tools differ here, however, as minimal stone knapping skills were necessary for the production of adequate tools.

Discounting economic limitations stopping laypeople from producing the jars, there may have been social or cultural limitations placed upon the craft also. While it is physically possible for anybody to produce a jar, it may have been a ritualised craft with only specific craftspeople being allowed to participate in. One such practice which displays this is the production of Moai on Rapa Nui. The quarry and carving of Moai was a ritualised task, undertaken by a particular class of specialist craftsmen known as *tangata maori anga moai maea* according to ethno-historic analogy (Métraux 1940:137). Production of Moai was limited to these members of the community who were exclusively men and had their own gods and class (Van Tilburg & Ralston 2005:23). The task was of high ritual importance with carving work falling not only under community expectations but also the gaze of the ancestors. As the quarry of Rano Raraku was approached the frequency of Moai increased, it was believed that through the Moai ancestors watched over Moai production (Richards *et al.* 2011:196). With the inherent ritual nature of the jars (which is of course an assumption in itself) it is possible that this craft was undertaken by a particular sect of craftspeople. The cultural importance and investment that most researchers assume to be associated with the jars would support the interpretation that the jars are built into a wider ritual practice. This perception of associated importance would also support the possibility of particular craftspeople for the jars. The jars may purely represent the material consequence of ritual practice occurring within the Plain of Jars. While these ritual elements exist and may impose ritual restriction upon the activity, the demonstrated relative ease of the task suggest a different, more 'everyday' interpretation is also possible.

The example of Moai production is not an isolated occurrence. Another such example of ritual taboos and culturally prescribed restrictions can be witnessed through the ethnography of Sub-Saharan African iron smelting. Iron smelting in numerous regions of Africa is governed by ritual restrictions and practices, employed to make the practice safe for the participants and for the community as a whole. Within the context of the Venda, iron smelters are required to sexually abstain due to metaphorical links with gestation and procreation. The practice of abstinence is to separate smelting practice from menstruating women which can have disastrous consequences to smelting and farm practices.

As well as sexual abstinence, numerous rituals and medicines are employed before and throughout smelting to guard against evil forces (Mathoho *et al*. 2016:237). While these restrictions differ from those witnessed in Moai production, they result in similar outcomes. Firstly, iron smelting practice is restricted to male participants, distancing menstruating women from the practice. Secondly, the task was performed isolated from population centres, in the area of Vuu – referred to as the masters of iron smelting technology within the Venda lands – iron smelting was undertaken in the mountains at a remove from community centres (Mathoho *et al.* 2016:238). Within the context of the Vuu, class implications are also connected with iron smelting practice. Iron smelting was dominated by the ruling lineage of the region who maintained overall control of the society due to the technology being embedded with political leadership (Matholo 2012 in Matholo et al 2016: 238). Different magico-religious interactions can be viewed in other parts of Africa, such as those witness in pre-colonial Igboland, Nigeria. Once again only men were permitted to be smiths and smelters. Men born into iron-working lineages were permitted to learn the craft and join the profession as the knowledge of safe iron handling was inherited by blood, but more intensive restrictions were placed upon those outside these lineages. Some areas prevented those outside the lineages from becoming smiths (Agbaja Udi and Nsukka peoples), while other communities allowed those outsides to be apprenticed into the craft after extensive consideration and ritual (Awka, Abirba and Nkwere peoples) (Njoku 1991: 196). In these instances, apprenticeship was rigorous, long, and tortuous. Once completed the apprentice underwent a ceremony, forming a ritual kinship between the graduating apprentice and the smith, incorporating him into the lineage (Njoku 1991: 200). Restrictions also surrounded the principal tools of the craft such as hammers and anvils preventing non-smiths from wielding the tools. In some instances, the practices of smelting and smithing became separated – due to material availability, monopoly development, or lineage distinction – resulting in a status quo being fixed through mythical charters, ritual sanctions and taboos prevent a family from both smelting and smithing (Njoku 1991:201-202). The rituals practiced by metal smelters and smiths throughout Sub-Saharan Africa is enmeshed in a ritual practice, acting as mediation between craftsmen and the gods or spirits.

While much of the ethnographic exploration of ritualised iron production has been concerned with Iron production in the African context (e.g. Njoku 1991; Mathoho 2012; Mathoho et al. 2016), examples of ritually enmeshed practices can be seen within the Asian context also. Iron production in the Arun valley in Eastern Nepal have been described ritually mediated activities, involving the practice of multiple sacrifices for the prevention of misfortune related to the task (Haaland et al. 2002). Kris production in the Indonesian context is a similarly mediated task which sees miners, smelters and smiths all interfering with cosmic processes of birth death and decay, resulting in the subjection of ritual regulations upon all involved in the craft (O'Conner 1975). A story regarding the production of a famous sword made by the renowned sword smith Kan Chiang, offers another example of ritual enmeshed within the weapons production. 'He chose the right time and place, with the Yin and Yang in bright harmony, and the hundred spirits assembled to watch…' (Needham 1980: 516). The tale offers another instance were ritual practice becomes a key consideration for practice. Anna Källén explores these and other practices when discussing the practice of iron production in the context of Lao Pako, a proto-historic (around 500CE) settlement in Vientiane province of Laos. Källén suggests from these examples that it is more probable that iron production in the Lao Pako context likely had a metaphorical structure for experiencing and explaining iron production related to gender, age, and human procreation, rather than one based on industry and capitalism (Källén 2004:194). These ethnographic examples provide a cautionary tale for exploring past activities through a purely economic lens, emphasising the role ritual played in many ethnographic contexts.

While attributing any specific ritual restrictions to the production of jars in Laos can only be speculation, these examples act as a reminder that more than simple technical requirements should be considered when attempting to reconstruct past practice. These examples offer ethnographic analogues for ritual restrictions, taboos, and limitations on production practices. Each example discusses a process that transforms the original material into something else, sculpting the Moai, iron smelting or smithing, which are often central to social identity. The relationship between socio-religious impacts and political impacts is also noted throughout these examples with class and social rank being connected to these practices. Considering these examples, the production of jars in Laos could be a similarly mediated activity. While the experimental carving suggests the possibility for untrained people to produce the jar, socio-religious restrictions may limit participants. Similar restrictions as those witnessed in the Igboland context may also restrict access of specialist tools to carvers in the context of the Plain of Jars. Thus, it is possible that this craft was undertaken by a particular sect of craftspeople. The technical ease of jar production may be overshadowed by ritual expectations and limitations in production of tools and the carving practice itself, resulting in a ritually constrained, prescribed, and mediated task. While remaining entirely speculation, these will be important aspects to consider in future excavation and experimental work. The key points raised by these ethnographic examples is that while the experimental work can provide the parameters for time and effort, it still does not necessarily account for the layers of culture practice and processes potentially enmeshed with production of megaliths.

Aside from raising questions regarding the status of craft specialisation the short production window also raises questions around mortuary practice. If we surmise that the jars were employed in mortuary practices, as commonly suggested, would the jars have been produced *en masse* before they were needed and essentially stockpiled? Or, were they produced individually after or around the time of death? With the short production window, even for a single craftsperson, it would be possible to complete an *in situ* jar within a week of the jar being required. Depending further on the time required to move the jar, it may be a possibility that the carving of the jar was a part of the mortuary practice itself involving a portion of the community rather than an isolated craftsperson. Some informed estimations can be made from experimental and ethnographic work. In the context of megalithic sarcophagi building in West Sumba, teams of 5-10 men were needed to quarry the stone used for the production. The ethnography also shows that megalith movement is undertaken by a team of between 300 and 1000 participants, most commonly moving the stones between 500 m and 5000 m (Adams & Kusumawati 2010: 23-24). While these distances are shorter than those witnessed at Jar Site 1, many other sites in the region would fall within 5000m of their quarry locations. One example in particular represents the larger end of the movement, requiring the participation of over 400 people and taking over two years for the organisation, carving, and movement of the 16-ton stone, as well as the performance of connected ceremonies (Steimer-Herbet 2018:54). Once again, this example shows that megalith production not only has physical and technical requirements, but ritual ones also.

Rather than representing a mortuary vessel alone, the carving of the jar may constitute a distinct and important potion of the overall mourning and mortuary practice of the Plain of Jars area. Whether the jars were produced by the kin of the deceased or by a specialist craftsperson, potentially a central figure in the ritual as a whole, the production could represent a step in the transition from life to death (Van Gennep 1960). Although jar production can be a relatively quick activity, the alternative interpretation that jar carving was a seasonal activity also exists, as discussed above. This interpretation would see the deceased buried leading up to the jar production season before being placed within the vessel as a secondary burial stage. Multi-phase burials may already be identified at the jar sites (O'Reilly *et al*. 2019) – with burial within the jar considered the first stage of mortuary practice – could jar burials actually represent a secondary deposition? This interpretation may provide context for the few examples of primary burials found surrounding the jars in the context of Jar Site 1(O'Reilly *et al.* 2019:980). This interpretation may also explain the high number of capstones throughout the sites, potentially indicating burial in pits (such as those excavated by Nitta in 1996: 16) as a temporary occurrence while waiting for jar production to be complete.

Consequently, several alternative models for craft organisation can be proposed. These can be summarised as:

(1) Jar production undertaken as a portion of mortuary practice, either by craft specialists or lay people;
(2) Jar production undertaken as a highly ritualised practice, only preferred under very particular circumstances, increasing the 'inherent' ritual or cultural value of the jars;
(3) Jar production undertaken as a construction craft alone, with ritual only effecting the jars' use;
(4) Jar production undertaken as a seasonal activity, essentially stockpiling jars for use as required;

Each of these potential interpretations remains a possibility within the technical context of the jar production process. Exploring the exact practices undertaken in the region is not within the parameters of this project, but the experimental data would suggest each of these interpretations are a possibility. Furthermore, the lack of notable technical limitations on jar production do not remove the potential for ritual and social restrictions. Considering the ritual practice of other production activities previously discussed, the task may be restricted to a sect of specialist craftspeople, selected and trained for both the physical task and ritual practice enmeshed within. While this remains speculation, it is an interesting topic as it allows for a potentially deeper exploration of the lived experience of past stone carvers within the Plain of Jars context. Future archaeological excavators at the Plain of Jars quarry sites should keep this in mind and consider how ritual activity might be reflected in the field.

Summary

Each of these concepts furthers our limited understanding of the culture present within the Plain of Jars. Exploring concepts of community practice, craft specialisation, and the role of clans and family units offers new avenues for exploring the Plain of Jar's past. While none of these concepts are new to the world of archaeology and they are speculative, they do allow the construction of new models and theories that can be tested by future archaeological work. While many of the previously mentioned interpretations of jar production and use remain speculative, the work does provide a range of clear empirical understandings of jar production. Firstly, jars can be produced by specialists and laypeople alike; however, specialist craftspeople would likely be more accustomed to the task making their work faster and finish quality superior. Secondly, the time requirement for a somewhat average jar (approximately 1.5 m x 1 m) is approximately 36-37 hours (depending on tool material used). The largest known example, the King's Cup, is predicted to have required only 50 hours, making the construction possible within a week of work (assuming 8-hour work days; of course, the organisation of past peoples working days remain mere speculation). Considering the previously discussed value of specialised tools it may be reasonable assumption (though still an assumption) is probably likely that a jar carving specialist did exist in some capacity; whether as an isolated carver or as an overseer guiding the work. This idea can at least be proposed as a hypothesis that future archaeological and experimental work can be designed to test. Considering the ritual nature of the jars themselves it may be possible that the carving practice was enmeshed within ritual practice. This could either occur through ritual restrictions on craftspeople and tool use, or potentially through the jar carvings incorporation into the mortuary ritual itself.

Overall, the data offers new insights into the time investment and working capabilities of the tools explored. The data provides a model for use in future experimental work and potential (after its accuracy is further verified) within the Plain of Jars context itself. The data provided through the experimental work offers new avenues for exploring practice and community within the Plain of Jars region. While much of this remains speculative at present, additional work in the Plain of Jars region as well as continued experimental work will continue to offer a greater depth of clarity to practice within the Plain of Jars.

6.3 Question 3: Exploring debitage and identifying workshops?

While each of the prior research foci has been concerned with the jars themselves, this last question aims to aid in future exploration and excavation. Assessing the debitage and *in situ* work floor produced by the carving activity this work can provide archaeologists a tool for future identification of workshop sites in the field. Determining the production location for the jars may elucidate some of the processes and procedures involved in jar production, providing further insights to previously discussed concepts such as craft specialisation and potentially site dating. To provide a proxy for workshop identification a number of key elements are explored; debitage distribution, debitage make-up and other, more general, characteristics of an *in situ* working floor.

Debitage analysis

Debitage was collected throughout the experiment work, with each carving being isolated and considered separately. Some observations can be made regarding the debitage which are relatively consistent throughout the data collected. The data (Table 14) indicated that with each of the smaller jars the majority of the debitage is fine dust and small chips rather than large flakes. As the jar size increased so did the number of large stone flakes, yet there appeared to still be a majority of small flakes and fine dust.

Table 14. Debitage collection dataset

Phase 1	*Weight of Debitage collected*	*% of total Debitage collected*	*Debitage % comprised of dust*
Jar 1	4724 g	67.49%	80.2%
Jar 2	6511 g	65.11%	66.5%
Jar 3	5325 g	66.53%	54.97%
Jar 4	6813 g	64.89%	64%
Jar 5	5490 g	73.2%	79%
Phase 2			
Jar 6	10742 g	89.52%	81%
Jar 7	7403 g	70.5%	76.2%
Jar 8	4094 g	45.49%	95.82%
Phase 3			
Jar 9	95600 g	N.A.	75.2%
Jar 10	726602 g	N.A.	71.53%

Dust accounted for no less than 64% of the debitage collected across each of the carvings' working floors. The total weight of debitage collected accounts for between 64% and 90% of the total material removed from each jar during carving. Data from Jar 6 suggests that much of the missing debitage was also dust. Jar 6 has the highest percent of debitage collected (89.52% of the total weight removed). Jar 6 also represents the highest percentage of dust with 81% of the debitage collected being categorised as small flakes and dust. Considering this data, and general observations within the workshop, it is likely that fine dust represents a large portion of the absent debitage due to its highly transient nature. While there appears to be fluctuations in debitage percentages there appears to be no one prevalent cause for these variations. It may be that the greater amount of internal working for phase 2 jars increased the dust percentage as creating the cavity in the jars produced a higher percentage of dust than outer shaping. Interestingly, it appears that the tools employed have little effect upon the debitage distribution. The stones soft nature likely contributes to the predominance of dust and small flakes, as small flakes are more likely to be dislodged from the jar, but larger flakes are also susceptible to breakage.

Both Jar 9 and Jar 10 offer further evidence of the breakdown of small and medium stone flakes as displayed by a 1-meter circle surrounding the jars consisting predominantly of dust and small flakes (fig 84 & 85). This is due to the gradual breakdown of the small-medium flakes as they are repeatedly trodden throughout the carving process. It is likely that debitage left *in situ* would undergo a gradual breakdown, producing a work floor of fine dust accompanied by larger flakes on the peripheries of the working space (a circle around the 2–3-meters in diameter centred upon the jar). Recent excavations at Jar Site 52 potentially corroborate this theory as excavations surrounding the jar revealed a large amount of fine sand in the immediate vicinity of the jars (Shewan *et al.* 2021).

Figure 84. Jar 9 and its associated work floor

Aside from a predominance of small flakes and dust there are other observations that can be made regarding the debitage. Essentially, the outer carving of the jar produced the majority of the large flakes while the internal carving produced a higher proportion of dust and small flakes.

This becomes of interest when attempting to identify potential indicators of production sites when flakes of stone would likely be most archaeologists' initial expectations. While large flakes are produced by this carving work, they represent a smaller percentage of the visible debris. Further complicating workshop identification is the segmented construction method that has been proposed for the Plain of Jars. Thongsa Sayavongkhamdy's secondary workshop theory (in Chang 2017; Chang 2018) argues that jar production began at the quarry sites with the rough outer shaping. Since the majority of the large flakes are dislodged within the outer shaping component of jar production, it is likely that the majority of the large flakes would be located within the quarry site. Sayavongkhamdy then suggests that the partially worked jars were transported to the Ban Ang airport Site near the present Xiang Khouang Airport approximately 2 km from Jar Site 1. He argues that final working was completed here before moving the finished objects to Jar Site 1. If the secondary workshop theory is accepted then the next working location is the secondary workshop, where the external refining and internal carving are undertaken. During this second phase of the carving process the majority of the fine dust and small flakes would be dislodged, resulting in a work floor characterised by this fine dust and sand. So, fine dust and sand should be considered an indicator of a jar working site, whether the original quarry, a possible secondary working site, or the final resting place of the jars. To date, quarry sites are the only clearly identified location where jars were worked. While this is a large element of the jar production process, it is only one part of the overall process with the remainder of the work occurring elsewhere.

Stepping beyond the data, a set of criteria for identifying each of these work areas can be achieved. Firstly, quarries and adjacent workshop locations can be characterised by the presence of large stone flakes within a matrix of progressively smaller flakes and sand. If material is left *in situ* large flakes will be absent in sections of the work floor, mostly in circles, surrounded by a higher intensity of large flakes on the peripheries. As much of the work occurring at quarry sites is concerned with outer shaping, the majority of the large flakes produced by the carving would be located there. Secondary workshops may differ significantly as they may be characterised by the presence of high quantities of fine dust and a small scattering of flakes. While much of this dust is likely to be located within a circle 3 meters in diameter, there is potential for the working surface to be more widely spread. Further, considering the secondary workshop theory proposed by Sayavongkhamdy, the material produced by the internal carving and final finishing would further be split between the workshop and the final jar placement site. In such a case, the visibility of work floors would be low. Finally, there may be further evidence of final working at or near to the final resting place of the jars. This may include fine sand or dust material, likely without the presence of larger flakes.

The working floors may undergo extensive weathering or compacting depending upon the workshop's topography. While undertaking the experimental carving of Jar 10 the impact of weathering on debitage was noted. During Jar 10's production a period of intense downpour lasting four days occurred. This rain event wet a portion of the debitage (visible in Fig 85) resulting in a compacted sand layer approximately 2 cm thick. While the debitage was mostly protected from the downpour (as the jar was under a corrugated iron roof) the material affected was fairly heavily compacted and it appears some of the fine debitage was washed away.

Figure 85. Jar 10 and its associated work floor

Chaîne opératoire

Within the wider *chaîne opératoire*, the carving process is likely the most visible within the archaeological record. The *chaîne opératoire*, detailed within the methods chapter, lays out the procedure for jar production into three separate components; material procurement, reduction, and lastly use. Throughout this process debitage will likely be produced in both the procurement and reduction stages of the craft. Furthermore, the reduction stage can be further divided by the procedure inferred from the jar assemblages.

The production of the jars can be divided between two or three distinct locales. Firstly, the quarry sites represent the start of production; the quarrying and outer carving. A secondary workshop location may account for the further refining and internal working of the jars before the jars are moved to their final placement in the context of Jar Site 1. Alternatively, this work may occur entirely at the jar's final placement site or, the whole jar could have been made at the quarry and transported as a completed object. Between each of these stages material transportation would need to occur, in some instances over distances as large as 8 km. These production locales may be punctuated by working floors dense with various debris, likely distinct depending upon the locale and the carving work being undertaken. Although this element of practice is likely the most visible element throughout this production, it may be less visible than initially thought. The friable nature of the stone and the transient nature of the light dust may result in a work floor with low visibility within some contexts. That is not to say there are no material indicators of carving practice. Detritus is produced and notable amounts could be deposited within the landscape surrounding jar working, however the density of these deposits may be less than initially thought.

It is clear that the distribution of material between dust and flakes does not conform to initial expectations and density likely follows suit. Further work is required with both experiments and excavations offering further data and building understandings of the material consequences of jar production.

Building onto the *chaîne opératoire*, the carving of the jars requires a relatively low investment of both time and participants. The relative ease of the carving work results in a fast process that is easily achievable by a single participant. The carving of the jar would fit within the reduction portion of a traditional *chaîne opératoire*, which ordinarily represents most of the work involved within an artefact's transformation. In the context of megalith production, however, the transportation may actually represent the most time-consuming and costly component. The central use of *chaîne opératoire* being the exploration of lithic production of smaller dimensions, such as stone tools, results in transportation not receiving particular consideration within traditional application. Although this component is not explored within this research, transportation should be emphasised a key, distinct component within the *chaîne opératoire*. As such I propose that future use of *chaîne opératoire* within the context of megaliths can be refined to incorporate a clearly defined component dedicated to transportation. In the context of the Plain of Jars, the transportation should be considered as several instances within the reduction phase of the experiment, with transportation likely occurring before, within or upon completion of this stage within most megalithic contexts.

Further exploration of the entire *chaîne opératoire* of jar production would offer further insights into the overall investment of time and participants into the production of the jars. Considering the production as distinct periods of reduction interspersed between transportation stages is important within this context, and likely others, to provide an accurate representation of potential work floors and material consequences of jar production throughout the entire process.

6.4 Plain of Jars and the wider world

While the research set out to further understandings of the Plain of Jars region, in part through comparisons with a wider megalithic range, the research can also add to our understandings of megaliths more widely. The research offers data for megalithic jar carving, providing insight into tool capabilities and the way the megalithic design directs carving activity.

The experimental work offers further support for the use of different tools, particular stone, within megalith production. In Chapter 2 it is noted that stone was widely used as a tool material in production of megaliths worldwide. And, although the knowledge that stone tools are capable of producing megalithic structures is not new, this research emphasises the efficiency of stone tools in comparison with other materials explored. Stone tools proved to be highly effective, producing a surface that required less final finishing work (smoothing). The tools also proved to be the most resilient, requiring the least reworking throughout the experimental work.

The research also offered a comparative example for time investment in megalith production. The only analysis of time investment identified within the literature was the calculations of William Routledge regarding the quarrying and carving of Moai. While this research explored a particular element of the overall production process it offers further evidence that megalith production can be a relatively quick task. Routledge estimated a total time investment of 15.5 days for the production of a 30 ft Moai if undertaken by a team of 30 workers. While this differs greatly from the three to four days for the production of a somewhat average jar by a single craftsperson, the size difference, carving style and stone hardness of these megaliths likely has extensive impacts upon time investment. Furthermore, the inclusion of quarrying within Routledge's estimate also provides a more complete picture of the production process. Further work is necessary to see how time investment differs between quarrying and carving.

On a broader level, the research also offers a potential system for future exploration of megaliths within the global context. While experimental archaeology has been used to investigate elements of megalith production, there is a notable lack of work exploring carving practices in other megalithic traditions, in regards to both forming a three-dimensional object (as in the example of the jars, or the Olmec heads of Central America) or iconographic carvings (such as relief carvings on T-pillars at Göbekli Tepe). This project offers insights into a potentially overlooked aspect of megalith production that can be explored in other regional and temporal contexts.

While offering insights into the wider range of megaliths, the research also provides a deeper look at the potential connections between megalithic traditions. Potential connections between the megalithic traditions of the Plain of Jars, Assam and jar traditions of Island Southeast Asia have appeared in the literature since the sites were first identified (see Colani 1935, Thakuria 2014, Kaudern 1938, Genovese 2019b, and Sukendar 1987). Although these connections are treated with interest by some, most research has avoided this particular topic. This research also followed that trend, in a way, focusing intently upon the Plain of Jars alone. Although the research did not set out to explore these other megaliths, the experimental work offered some minor insights into these other regions. Firstly, in the case of Assam, the research shows that if the jars are produced from similarly soft stone to those of Laos then the jars could have been made with all manner of tools – be they stone, copper, bronze or iron. Furthermore, in the event the jars are produced from similar material, as has been suggested (see Thakuria 2014; Colani 1935), then this experimental would could effectively be applied to some of the jars of Assam. The production process of the jars of Assam is also assumed to involve the use of iron tools (Thakuria 2014:208-209) likely due to the perceived connection between these regions. However, as this project has revealed, this is an assumption that should be examined more closely in the Assam context. The situation is different when considering the jars of ISEA as their primary material differs greatly. It is stated these jars are made of granite (Kauldern 1938:85) and further research on working the harder granite of the Island Southeast Asia assemblages, and some isolated examples within Laos, could benefit from employing a similar experimental framework.

The last direct potential connection between megalithic traditions is within Laos, between the Plain of Jars and the Menhirs of Hin Tang. The Plain of Jars and Hin Tang megaliths differ greatly in construction, appearance, and material employed. Drawing connections between these distinct megaliths is hard with the data provided by the experimental work but personal observations of materiality may offer some insights. The stone employed within megaliths not only influences the structures resilience to weathering and the materials working requirements, it may also influence the achievable form of the megalith itself, as explored by Colani (1935a; 1935b). The carving of the sandstone jars has now been shown to be a relatively easy task, mostly due to the characteristics of the stone itself. The soft nature of the stone is a key element to this but just as importantly is the materials' natural structure. The compression of quartz, feldspar, and rock pieces within a silicate rich matrix produces a material with somewhat consistent strength qualities. Although layered, the material shows similar strength and concretion on multiple axis. When working sandstone, the material breaks small chips from the stone regardless of the direction of the material bedding. Shale and slate differ greatly from this as they form in distinct layers that greatly impact the overall strength of the material. Shale naturally separates into thin sheets, displaying weaker degrees of concretion between layers, making the carving of a jar in slate or shale a potentially impossible task. The material is less likely to be receptive to working as a whole due to its tendency to separate into thin layers.

While this does not directly indicate the megaliths of the Plain of Jars and Hin Tang are connected by a shared megalithic practice, there remains a possibility that the practices are connected; the idea of placing megaliths in clusters in ritual contexts may be what connects the two traditions. Interestingly, capstones are present on the ground among the standing stones of Hin Tang, working as groundcovers of chambers carved from the bedrock below (Colani 1935a: 30-36). These are remarkably similar in appearance to those found at the jar sites, especially Jar Site 1. These provide a more obvious link between the two types of megalithic sites that could be explored in future research.

6.5 Experiential observations

Experiential observation is a valuable tool when exploring landscape and human interaction in the past. Decentralising economic models and modern mapping, allows archaeologists to perceive the world around themselves in terms more appropriate to people of the past. While most heavily employed as an offshoot of landscape archaeology, phenomenology allows archaeologists to attempt to understand the visual perception and interconnectedness of sites within landscape. While this research is not particularly concerned with site locale and distribution, the experiential systems employed within phenomenology offer a further tool for viewing the lives of past jar producers and their interactions with the material of their world.

While the jar production can be explored in economic terms of value and investment, the nature of the craft also lends itself to experiential exploration. Jar carving is a process rooted in transformation, reshaping the material world around oneself. Transformation does not occur in a singular direction however, as shaping the stone also shapes the sculptor. Taking an ontological and phenomenological approach to the jars' placement and production provides the ability to perceive the past through practice. Practice is deeply enmeshed in ontological thought, so intertwined as to be inextricably linked, with ontology shaping the very understandings of one's reality and everything found within (Alberti 2016: 164-165). Jar production, material selection, placement, and production are all important practices, governed by physical constraints, but also, and perhaps more potently, by ritual ones.

While jar production has been viewed thus far as a physical production activity, there is value to stepping beyond this view and seeing jar production as a performance. Monuments as performance can be viewed as continuous action, punctuated by intensity during key points (Jones 2012: 168-169) – such as jar production and placement – within a wider transformation of landscape. With this in mind, the Plain of Jars' long period of use, and periods of intense jar production, can be discussed. Jar production and maintenance as performance leads to the interpretation of the Plain of Jars as a complex palimpsest. In this interpretation, the Plain of Jars experiences a long development over a number of different periods, with continued interaction at a range of intensities.

The social performance of construction may be deeply enmeshed with the carving of jars. Jar crafters, whether they be specialist or layperson, are performing a ritual. The transformation of the stone; the preparation of burial vessel, is likely a ritual act, or a ritual transaction, creating something from nothing. Ritual performance can be seen in the production of Moai. Rano Raraku is surrounded by concentric rings of Moai with increased frequency as the quarry is approached. The experience of Moai carving is not only overseen by other craftsmen and the community, but falls under the gaze of the ancestors themselves (Richards *et al.* 2011:196). Jar carving likely shares similar social and ritual expectations. In such a model, the carving and use of jars is deeply connected to rites of passage and passing, which are themselves rites of transformation. As with humans transforming from living to dead, from physical to spirit, the stone of the jars also undertakes a transformation but in this case from nothing to something (or possibly from nature to culture?).

The carving of the jars is a physical production activity, but is closely associated with ritual practice. Similar ritually enmeshed production can be seen through the Venda and Igobland ethnography previously discussed (Mathoho 2012; Mathoho *et al.* 2016 & Njoku 1991). Ritual practice and performance is found throughout iron working in these regions, with metal workers not only participating in a production activity, but mediating with between spirits, the gods and supernatural forces (see Mathoho 2012; Mathoho *et al.* 2016; & Njoku 1991). Jar carvers may serve a similar role, mediating between the living and the dead through the crafting of mortuary vessels themselves. Performative elements of jar carving may be of as much importance as the use of the jars.

Aside from the production processes themselves, the striking locales of the megalithic jar sites offer another point of ontological and phenomenological reference. The high placement and distant views of the majority of the Plain of Jars sites emphasises the contrast between the flood plains and the turbulent mountain chains which surround them. The jar's placement predominantly favours mountain ridges, slopes and saddles surrounding the plains below (Shewan *et al.* 2021: 1-2), watching over the landscape where communities enact the flow of everyday life. As Moai represent ancestors gazing across the quarry and the roadside Moai are spirits traversing *ara* to reach the sea, the ancestors of the Plain of Jars may continue to watch over the land from their mountain peaks. The contrasting nature of the plains and their mountain surroundings may make the jars' placement significant, with the ancestors of the plains traversing the mountains to reach their eventual sanctuary. In this way, our way of perceiving the Plain of Jars is being transformed, in part, from an examination of monuments in a landscape into a discussion of 'elements of landscape engagement' as coined by Lesley McFadyen (2008: 313). Envisioning and exploring the jars as an element within a wider interaction with landscape pushes interpretations beyond the quarrying, carving, and placement of jars into an active, perpetual processes of transformation.

Selection criteria for materials can also overemphasise the economic value as opposed to the ritual. Was the stone selected based simply on the availability or were the quarry sites places of significance for these communities? Thus, the jar's origin from a place of cultural importance could represent a significant part of their value. This may also explain why many jar sites are located in close proximity to their quarries. It is clear that transportation of jars was possible over large distances making megalith placement around quarries a potentially important aspect. Following this vein, one could say Jar Site 1 represents a divergence from the majority of sites, located 11 km from the quarry on a small rise in the centre of the largest plain. The local of Jar Site 1 could be seen as important to the people of the plains in a different way than other jar sites are, prompting this shift in tradition. The interpretations of ritual importance placed upon the jars is speculative, although it draws emphasis to the ways ritual and cultural factors are just as impactful as technological ones.

Physical transformations of the sculptor

As ritual observations and community importance can run parallel to the carving of the jar, so too can observations on the individual doing the work. Exploring the experience of the individual, draws on my own physical experience and personal observations throughout the experimental work. The physical impacts of the work will be briefly detailed first. The carving practice lent itself to physiological development; the highly repetitive nature of hammer strikes improved particular physical markers. As the task progressed so too did the physical developments identified. Firstly, throughout Phase 1 there was a notable increase in strikes per minute(s/m), gradually increasing from 65s/m to a maximum of 98s/m. This was due to an increase in endurance allowing for more infrequent breaks and higher strike speed. Throughout this experimental phase general strength also improved, principally notable in forearms, shoulder and back strength. This phase was also accompanied by the highest occurrence of mis-strikes. In later phases mis-strikes were much less frequent.

Interestingly phase 2 saw the strike rate decreased from 80s/m down to 63s/m. While this may appear to be a regression it was in actual fact a development, just of a different kind. While strike rate reduced, strike strength and effectiveness improved. This is due to continuation in strength development as well as greater carving aptitude resulting in more efficiency from each strike. This development may also be witnessed anecdotally in metal working practice as some workers prefer heavier hammers, which move material further with lower strike count. Similarly, a good carpenter strikes in a nail with one or two heavy (but accurate) blows, whereas someone less accustomed may require 15 smaller blows. Strength continued to increase throughout this phase in the previously mentioned areas, while general fitness also saw improvement, potentially due to longer work periods.

Phase 3 further continued the trends previously identified. Strike rate plateaued at around 63s/m, but with material removal rates potentially doubling from prior carvings. It should be noted that the repetition of hammer strikes accompanied by the tools' low weight (between 1 and 3 kg) resulted in the building of lean muscle in identified areas. Overall body mass remained relatively consistent throughout the experiments but physical strength greatly improved. Detailed measurements were not taken and so these observations remain anecdotal and somewhat individual in nature. However, these may be interesting to explore further in the future with more tightly designed experiments.

6.6 Summary

This experimental work sought to explore jar carving practices and the insights they could provide. Exploring this key element of jar production provided a critical review of the Plain of Jars production narrative. Assessing the capabilities of a range of tool materials showed that prior understandings of jar production may differ from actual practice. The research offered a comparative view of megaliths around the world while situating Laos and the Plain of Jars within its individual context.

Madeline Colani's 1935 publication of *Mégaliths Du Haut-Laos* set the groundwork for current understandings of the Plain of Jars archaeological complex. The work provided the initial dating of the site to the regional Iron Age, based upon the artefactual remains found surrounding the jars. The artefacts, alongside Colani's interpretation of iron tool usage (1935a: 134, 144; 1935b: 123), provided the basis for the Iron Age dating. Although work has increased within the region, few offer clear refence to her work, but continue to rely on these prior suggestions of Iron Age production (O'Reilly et al. 2019: 986; Sayavongkhamdy & Bellwood 2000: 105). While the wider literature regarding megaliths suggested iron was not necessary for carving stone, the narrative of production in Laos continued to reiterate the assumption.

The experimental work focused on examining these assumptions, while also offering a greater depth of understanding regarding jar production practices. The research poses three key questions to explore the production process in a technical and empirical fashion. The questions themselves were;

(1) What are the mechanics of jar production?
(2) Considering production time, how where the jars valued by the culture who produced them?
(3) What debris is created by the jar production process?

The research answered each of these questions in turn and offered insight into further questions surrounding these three.

The first question emphasised the carving capabilities of a range of tools but focused most heavily on iron and bronze tools. The research showed that iron tools were not necessary for the carving of sandstone jars. The jars can be carved with steel, iron, bronze, copper and stone, with each showing similar capabilities to one another. While iron and bronze appeared more effective than copper and the steel tools employed, stone tools showed an increased efficiency which rivalled that of iron and bronze. The second phase of the experimental work showed stone tools working quicker than iron and bronze but overall these tools performed in a closely comparable fashion. However, there is a key difference in the ease of reworking or replacing damaged or broken tools. Bronze was much easier in this regrd, with iron requiring considerable added time and effort to recover from breakages. Furthermore, the research provided an analysis of tool mark variations between the tool materials. While there were some variations seen with stone tools, each of the metallic tools produced consistently similar tool marks.

The research clearly demonstrated that tool type has more impact on tool marks than the material the tools are made from. While it may be possible to differentiate the marks of stone tools from those of metal, the same cannot be said for differentiating iron and bronze. Further research is necessary to determine if the similarity in tool marks is consistent at the microscopic level.

Considering the second question, the research proves that small jars, the size of those located at one part of Jar Site 52, can be completed within 22 hours using either iron or bronze tools. The data provided by the entire experimental range allows for the production of a model, tracking the relationship between starting block size and time investment. If the modelled trend continues in the predicted pattern, then an 'average' jar of 1.5 m tall and 1 m in diameter could be produced by a single craftsperson within 36 hours using bronze tools or 37 hours using iron tools. Furthermore, the model suggests the King's Cup, the largest identified jar at 3 m tall and 2 m in diameter, could be produced in approximately 49 hours with bronze tools and 50 hours using iron tools. Thus, a jar could be produced within a week by a single craftsperson. The accuracy of this model can be tested and improved with further data from experimental carvings, resulting in a reliable model for determining potential time investment for the jars in the Plain of Jars itself. Furthermore, the data showed that a specialist craftsperson was not needed to undertake the carving work. No technical limitations exist preventing laypeople from participating in jar carving practice. This is not to say the restrictions did not exist at all, however. The discussion of the nature of craft specialisation incorporated a range of analogous ethnographic examples of production practices being mediated by ritual expectation and limitations. The ethnographic examples of Moai production and Sub-Sahara African metalworking practices emphasise the potential for production activities to be highly entangled in ritual practice. Although there is no way to determine the applicability of these concepts to the Plain of Jars, it is important to note that while technical limitations are absent, ritual limitations may not have been.

Exploration of the third question showed that material consequences of the jar carving process may be hard to identify in some archaeological contexts. The carving process can be divided into two components, the external carving and the internal carving. The external carving produces the jar's cup shape while the internal carving creates the jar's internal cavity. These two components displayed markedly different debris production with the majority of large stone flakes being dislodged during external carving and the internal carving producing predominantly dust and small flakes. It should be noted that these two elements of carving may well have been separate in regards to location. The *chaîne opératoire* of jar production sees quarrying and external shaping occurring before the jar is transported to either a secondary workshop location or a jar site. The next proposed stage would begin with the carving of the internal cavity. As such these two elements may produce geographically distant working surfaces, the first characterised by a scatter of large stone flakes within a thin matrix of dust and sand material. The second working surface would likely be characterised by a collection of small flakes in a thick matrix of fine dusts, potentially compacted depending on the workshop's protection from environmental factors, an element that can be explored with further research.

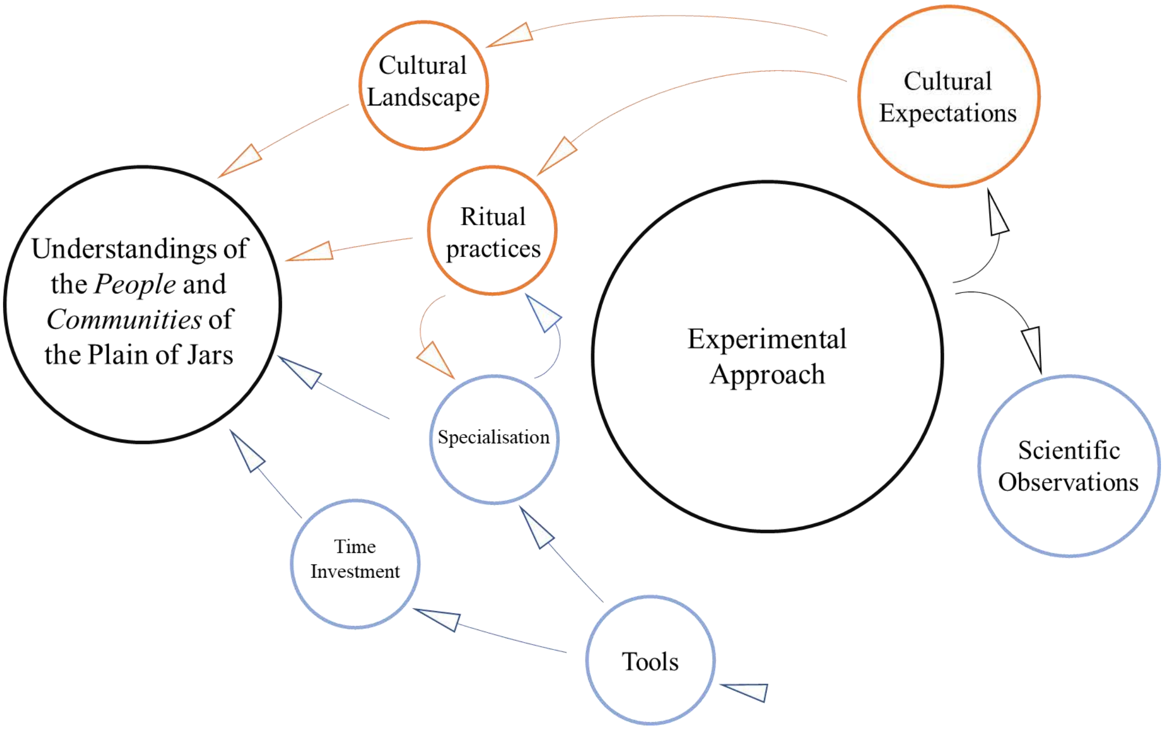


Figure 86. The flow of ideas and influence throughout this research

The research also offered opportunity for experiential observations and assessment of physical impacts upon the individual craftsperson. The jars likely encompass a part of a ritualised landscape, with jar production being both a social and ritual performance. The Plain of Jars context lends itself to a landscape of ritual practice and performance which sees fluctuating periods of intensity. The mortuary practices the jars are employed within are transformative practices as is the production of jars themselves. The jars potentially served a role beyond that of mortuary vessel, being incorporated into the flow of mortuary practice, other ritual and social activities, as well as landscape transformation. The scientific observations produced by the experimental work intertwine with experiential aspects to build a wider picture of practice and purpose within the jar producing community as illustrated in figure 86.

A multi-facetted approach to the research questions offered a wide breadth of interpretive capability, drawing on scientific data, personal experience, and ethnographic data to view the practice as a whole. The jar carving practice was likely more than the sum of its parts, representing a large element of cultural tradition imbued with ritual importance. While in empirical terms it can be described as a production activity, the task was likely accompanied by ritual practice and importance. The jar's potential involvement within transformative rites, such a rite of passage between life and death (Van

Gennep 1960), build the structures into more than their physical components. The jar production was likely a key part of ritual practice enmeshed within ritual, building a production activity into a ritual one. The role of jars sculptors may have involved mediation between the living and the dead or the gods, as seen in other contexts (see Mathoho 2012; Mathoho *et al.* 2016 and Njoku 1991) and the task may have been one observed by the spirits of ancestors (see Richards *et al.* 2011 and Van Tilburg & Ralston 2005). While considering technical and scientific factors surrounding jar production, exploring ritual importance and practice is key to the complete understanding of past lives and practice within the Plain of Jars. This work attempts to incorporate each of these key aspects of life, drawing on their interrelated nature to explore the past and the narrative within. It is the author's opinion that multi-facetted approaches such as this are key to the practice of future work and the potential insights provided through this broad approach cannot be overstated.

Chapter 7.

Future work and Conclusion

7.1 Conclusion

Our knowledge of the prehistory of Lao PDR, has developed greatly over the last 20 years. Along with its neighbours, Laos has seen an increase in archaeological interest, deepening understandings of the past world and the people who lived within it. The Plain of Jars has not been ignored by this rise in interest, yet the region remains shrouded in mystery. The large megalithic jars which scatter the mountain sides remain an enigmatic reminder of human ingenuity. The region has garnered increased international attention, culminating in the awarding of World Heritage Status in 2019. While international and archaeological interest in the region has never been higher, the new work in the region has provided few insights into the regions past and people. While new research is being undertaken and a small collection of new data is being provided every year, the narrative of the Plain of Jars production and use is mostly built from past insights. The work of Madeleine Colani remains influential in understandings of the region's past.

The narrative built from Colani's work is partially based in interpretation; retold and reiterated until it was seen as fact. This phenomenon is a common occurrence throughout archaeology and academia as a whole, and revision of the narrative and assessment of its origins is necessary to provide empirical support for observations such as these. Colani suggested the jars were produced with iron tools, with the tool marks present on the jars indicting such (Colani 1935a 134, 144). The reiteration and retelling through decades of archaeological work has obscured the grounding of these assumptions, further complicating the narrative. The emphasis of dating that fits within the pre-existing narrative continues to shape interpretations and the development of future work (as can be witnessed in O'Reilly *et al.* 2019: 986). The assumption that iron was employed for jar production has continued to direct the narrative of the regions past, originating from Colani's speculative discussion of tool marks in sites 1 and 2 (1935a: 134, 144). Furthermore, the overarching claim that the jar culture fits within the regional Iron Age continues to build an interpretation of the jars as a product of the Iron Age within her work (Colani 1935b: 123). Throughout most of her work Colani remains cautious to make assumptions and large claims such as these, emphasising that they are predominantly speculative in nature and cautioning directly against general claims (Colani 1935a: 92, 152). While some data supports this idea, as seen at Jar Site 1, numerous other examples exist where data is discounted for falling outside the existing narrative (see discussion of Sayavongkhamdy & Bellwood 2000 in O'Reilly *et al.* 2019: 986). While these ideas have been taken as fact, they remain untested. This research sought to verify the accuracy of these ideas and explore the intricacies of jar production.

The assessment of this narrative and its foundation employing both analogous examples of global megalith production as well as (re)constructions of jars providing insights into an element of the production process. As discussed in the last chapter, key focal questions of this research were;

(1) What are the mechanics of jar production?
(2) Considering production time, how where the jars valued by the culture who produced them?
(3) What debris is created by the jar production process?

The experiments undertaken were developed to explore each of these focal questions and a range of sub-questions which accompanied them. The experiments provided insight into the jar production process as a whole, while also exploring each of these questions in depth. To summarise the experimental results; the experiment demonstrated that the carving of sandstone jars can be performed using a full range of tool materials, including steel, iron, bronze, copper and stone. Each of these tool materials is not only capable of carving sandstone, but is highly efficient.

The research explores the variation between the tool marks, time investment and finish quality achieved with both bronze and iron tools. The internal tool marks visible on Jar 9 and Jar 10 are reminiscent of the internal tool marks visible in the Plain of Jars context. While there are no clear features that differentiate these tool materials, each of the tools appear similar in form to tool marks observed within the Plain of Jars. The external tool markings on actual Plain of Jars vessels differ somewhat from the markings produced experimentally by iron and bronze tools as they are more reminiscent of the markings produced by the pecking and percussion of stone tools. A minor overlap between the external tool marks of stone and bronze tools does exist as bronze tools can also sometimes produce marks similar to the pecking observed with stone tools. While some minor examples of tools marks are visible within the Plain of jars, the impacts of extensive weather over time have heavily obscured these markings.

Exploration of time investment provided a direct example of how long jar production could take. The research highlighted the quick nature of sandstone carving and provided a range of jar sizes each with short time investment. The Phase 3 carvings, while comparable in size to jars at Jar Site 52, took less than 24 hours each to complete. The research provided further insights into jar production times through the production of a predictive model. Mapping the relationship between jar starting block size and time investment a model was produced which can provide estimates for jar production time for any sized jar. Application of the model suggested the 'average' jar of 1.5 m height and 1 meter diameter could be carved by a single craftsperson in approximately 37-38 hours dependent upon tool material used. Furthermore, the carving of the largest jar identified, the King's Cup (3 m tall by 2 m diameter), could be produced within approximately 50 hours. As such jar production could be completed, by a single craftsperson, within a week. As a caveat, it should be noted that this estimate is independent of quarrying, transport, and tool maintenance.

The last focal question of the research sought to explore the debris produced by the carving activity. The research strived to produce a proxy for workshop identification. A directly applicable proxy could provide archaeologists a method for workshop identification within the field, allowing insight into jar production locations and potential transport routes. The data suggested the majority of the debitage produced by the carving process was fine sand or dust. The friable nature of the material also added to the build-up of this dust as large flakes which remained within the working floor experienced further breakage. The carving and debitage can be divided into two distinct elements, firstly the external carving can be categorised by the removal of large stone flakes form the jars outer surface, resulting in a drastic weight reduction over a short period.

This removal of large flakes would be accompanied by a high distribution of large flakes within a four-meter diameter centred on the jar. The majority of the large flakes observed within the experimental debitage was produced during this initial phase of the carving process. The secondary phase is the jar's internal carving. Theories suggest the jars were likely moved prior to internal carving being undertaken, resulting in a separation of the debitage across numerous sites (Sayavongkhamdy in Chang 2017; 2018). The internal carving can be categorised by the removal of small flakes and fine dust as the jars internal cavity is produced. Much of the material produced during this phase is sand, small stone chips and transient dust. As such the working floor would consist of a scatter of small flakes within a compact layer of fine sand and dust.

The research strived to explore the ideas proposed during the initial exploration of the Plain of Jars, undertaking a critical review of the ideas using analogous data. The work not only disproved these ideas but provided support for a range of other ideas. The interpretations of this research suggest the Plain of Jars represents a complex palimpsest, with different sites being used at different periods. This interpretation would support the wide variance of dates found throughout the region. Supporting this idea is the identification of iron, bronze, and stone as viable tool materials for jar production, meaning the jars could reliably be produced within the local Neolithic period through to the Iron Age. While this interpretation would require further supporting evidence to be considered reliable, the research shows that jar production was a technical possibility in any of these major time periods. The research offers an overview of a particular element of jar production, carving, providing a baseline study to be built upon in future research. Future exploration with the concepts of craft specialisation, material diversity, and larger scale production can offer archaeologists a greater understanding of the complexity of jar production, the competency of past jar carvers, and some insights into the type of community and wider culture there were a part of.

Empirical exploration aside, the research also offered an experiential glimpse at the life of those who lived and worked around the jars. While the sculptor shaped the stone, the stone shaped the sculptor in turn. The research offers a glimpse into a practice potentially shrouded in both mystery and ritual importance. The carving of the stone represents a key element to the Plain of Jars' past and the jar's enduring presence upon the landscape continue to influence the lives of locals and archaeologists alike.

7.2 Future work

While this research offers new insights into practices and technical elements of jar production much of the overall production process remains a mystery. While carving is a key element of the jars' production *chaîne opératoire*, quarrying and transportation are just as important to understanding the complexity and investment required to produce a jar. Further, the production and maintenance of carving tools is clearly another important aspect. Experimental work building from this research could provide valuable insights into the remaining elements of jar production, offering a complete and detailed *chaîne opératoire* of the production from start to finish. Understanding the investment required for the entire process would not only improve the validity of value-based analysis but also solidify data regarding material necessities. Exploring transportation could also provide insight into participant numbers which has not been explored through jar carving. While exploring the entire production process is insightful, widening the scope in regards to jar material could also be valuable.

While sandstone represents the most commonly used jar material within the Plain of Jars, other materials were sometimes employed. Both granite and breccia were used in isolated instances with each being the main jar material at their respective sites. Was this due to material availability? Or was there a technical reason for using these stones? Exploring the use of each of these materials could provide a comprehensive view of the Plain of Jars megalithic assemblages while potentially offering comparative insights into other megalithic jar traditions. This avenue of work would provide further opportunity to explore the connections between the Plain of Jars and the megalithic jar traditions of Island Southeast Asia.

Further adding to this research, it is possible to test the accuracy of the time investment model through larger scale experimental work. Refining and verifying the model would allow a potential system for calculating the overall time investment into individual jars in the Plain of Jars itself. While not acting as a direct comparator, the model could inform theories regarding value and differences of time investment between different jar forms and different sites. For the model to be as accurate and reliable as possible, it would need to undergo testing and potential refinement. In particular, much larger jars should be produced experimentally, with attention paid to quarrying and transportation processes, as well as carving.

Discussion of time investment also raises a number of key questions surrounding craft specialisation. While craft specialists were potentially unnecessary, the task may have been expedited by the involvement of a specialist in some capacity. A number of questions can be posed which explore this element, such as;

1. Were specialist crafts necessary when carving full scale jars?
2. Could specialist craftspeople effectively direct a team of untrained workers?
3. Or would all participants need to be craftspeople?

Future work may provide insight into these questions that have been raised based on the findings of this research project. The short production window demonstrated here also raises questions of when the jars were made. As the jars can be produced quickly it is possible their production is incorporated into the mortuary rituals they are involved within. Alternatively, the jars may have been produced seasonally. This interpretation offers explanation for the few examples of primary burials surrounding the jars, with the jars actually being a secondary stage of the mortuary practice in some instances. Greater depth of exploration into the value of jars employing economic models, such as a Labour theory of value, to provide a greater understanding of the potential value of the jars in strictly economic terms. Running parallel to this investigation further research into the ritualised nature of the jars and their production may provide a more nuanced understanding of the procedure and cultural value of the jars, as opposed to the economic value.

While the research offers a glimpse into the production of megalithic jars and the lives of past jar carvers, further work is needed to deepen these newfound insights. Each future research avenue can be explored using similar experimental approach developed by this project, building on this baseline research into the jars of Laos. The merits of a multi-facetted approached must also be expressed as this research has benefitted greatly from a comprehensive holistic approach to the final discussion of interpretations. Exploring the physical production while also discussing the individual and community elements is key to providing insights to the lived experience of jar carvers rather than the materiality of the task alone.

Appendix

Ahu – Platform for Moai placement, often located along coastal bluffs of Rapa Nui

Ara – Moai roads, associated with spiritual pathway to Hawiki, or Hiva in the Rapa Nui context

***Chaîne Opératoire* –** An archaeological analytical tool employed with lithic analysis; this method emphasises the processes involved in artefact production.

Extracted – Extraction of stone from columnar or pillar outcrops.

Gorytos – Leather bow case, worn on the hip.

Hawaiki – The place of origin in Eastern Polynesia belief, often given local name depending on location (see; Hiva)

Hiva – The Place of origin within Rapa Nui belief.

Jar – A megalithic sub-form which consists of a jar or cup shape, these jars can range from cylindrical to more conical in shape depending on site.

Kalamba – Unique sub-form of jar burial unique to the Island of Sulawesi.

Khirigsuurs – A burial tradition of the Mongolian Steppe region, ever Khirigsuur has associated deer stone monument within close vicinity.

Megalith – Large stone structure, often attributed cultural or religious value.

Menhir – A megalithic sub-form which consists of a vertical stone protruding from the group, can also be referred to as Standing Stones.

Microlith – Small stone structure or purposely positioned stone.

Moai – The megalithic form unique to the island of Rapa Nui, often referred to as Easter Island, the megaliths depict anthropomorphic human figures.

Preslite – Unique spotted Dolerite stone, located within an outcrop at Presli Hills, United Kingdom.

Pukao – Megalithic hats which adorn numerous coastal Moai upon Rapa Nui.

Rano Raraku – Volcanic crater located on the eastern side of Rapa Nui, used as a quarry, supplying stone for the production of Moai

Rapa Nui – Currently referred to as Easter Island, Rapa Nui is am eastern Polynesian island off the coast of Chile.

Tanga maori anga moai maea – Title given to the carvers of Moai within Rapa Nui.

***Terminus Post Quem* –** A term used to indicate the final placement of an object, in this thesis it is used to determine the later placement of a jar within Jar site 1 and Jar site 52.

ToeToena – Megalithic sub-form which acts as a lid for the Kalamba.

Abbreviations

PPNA – Pre Pottery Neolithic A

PPNB – Pre Pottery Neolithic B

DSK – Deer stone-Khirgsuur complex

ISEA – Island Southeast Asia

OSL – Optically Stimulated Luminescence

POJ – Plain of Jars

MoH – Measure of Hardness

References

Adams, R. 2019 Household Ethnoarchaeology and Social Action in a Megalith- Building Society in West Sumba, Indonesia. *Asian Perspective* 58(2): 331-365.

Adams, R., & B, Kusumawati. 2010 The Social Life of Tombs in West Sumba, Indonesia. *Archaeological Papers of the American Anthropological Association* 20(1): 17-32.

Agan, C. 2016 A preliminary study on the conservation and polishing performance of Sanliurfa limestones as a traditional building material. *Bulletin of Engineering Geology and Environment* 75(1): 13-25.

Allard, F. & D, Erdenebaatar. 2005 Khirigsuurs, ritual and mobility in the Bronze Age of Mongolia. *Antiquity* 79(305): 547- 563.

Baldock, J., & J, Van Den Bergh. 2009 Geological mysteries of the Plain of Jars begin to unravel. *Geology Today* 25(4): 145-150.

Barbier, J. 1987 Megaliths of the Toba- Batak Country. In Carle, R (ed.), *Cultures and Societies of North Sumatra*. Berlin: Deitrich Reimer Publishing.

Bender, B 1992 Theorising Landscapes, and the Prehistoric Landscape of Stonehenge. *Man* 27(4): 735-755.

Bourdieu, P. 1977 *Outline of theory of Practice*. Cambridge: Cambridge University Press.

Box, P. 2003 Safeguarding the Plain of Jars: megaliths and unexploded ordnance in the Lao People's Democratic Republic. Journal of GIS in Archaeology, 1: 90-102.

Broderick, L., Seitsonen, O., Bayarsaikhan, J., & J. Houle. 2016 Lambs to the Slaughter: A Zooarchaeological Investigation of Stone Circles in Mongolia. *International Journal of Osteoarchaeology* 26: 537-543.

Buonasera, T.Y. 2015 Modelling the costs and benefits of manufacturing expedient milling tools. *Journal of Archaeological Science* 57: 335-344.

Busacca, G. 2017 Places of Encounter: Relational Ontologies, Animal Depiction and Ritual Performance at Göbekli Tepe. *Cambridge Archaeological Journal* 27(2): 313-330.

Cawte, H. 2008 Smith and Society in Bronze Age Thailand. Ph.D. dissertation, Department of Anthropology, University of Otago, Dunedin, New Zealand. Available at https://ourarchive.otago.ac.nz/handle/10523/10135

Chang, N. 2017 Preliminary report: Archaeological Excavation of the Ban Ang-Airport (BAA) Archaeological Site, Xieng Khouang Province, Lao PDR. Unpublished report prepared for Plain of Jars research project.

Chang, N. 2018 Report: Second Archaeological Excavation of the Ban Ang-Airport (BAA) Archaeological Site, Xieng Khouang Province, Lao PDR. Unpublished report prepared for Plain of Jars research project.

Childe, G. 1950 The Urban Revolution. *The Town Planning Review* 21(1): 3-17.

Clare, L., Dietrich, O., Notroff, J., and D, Sönmez 2018 Establishing Identities in the Proto-Neolithic: "History Making" at Göbekli Tepe from the Late Tenth Millenium cal BCE. In Hodder, I (ed), *Religion, History, and Place in the Origin of Settled Life*. Colorado: University Press of Colorado.

Clewlow, C. 1974 *A Stylistic and Chronological Study of Olmec Monumental Sculpture*. Berkeley: University of California.

Coe, M., & R, Diehl. 1980 *In the Land of the Olmec: The Archaeology of San Lorenzo Tenochtitlan*. Austin: University of Texas Press.

Colani, M. 1935a *Mégalithes Du Haut-Laos*. Paris: *Les éditions d'art et d'historie*.

Colani, M. 1935b *Mégalithes Du Haut-Laos* vol 2. Paris: *Les éditions d'art et d'historie*.

Cusack, C. 2012 Charmed Circles: Stonehenge, Contemporary Paganism, and Alternative Archaeology. *Numen* 59 (2): 138-155.

Daniel, G. 1963 *The Megalith Builders of Western Europe*. London: Hutchinson & co.

David, B. & J, Thomas. 2008 *Handbook of Landscape Archaeology*. Left Coast Press: Walnut Creek, California.

Diamond, J. 2005 *Collapse: how societies choose to fail or succeed*. New York: Penguin.

Dietrich, O., Dietrich, L., & J. Notroff. 2019 Anthropomorphic Imagery at Göbekli Tepe. In Becker, J., Beuger, C., & B. Muller-Neuhof. *Human Iconography and Symbolic Meaning in Near Eastern Prehistory*. 151-166. Vienna: Austrian Academy of Sciences Press.

Dietrich, O., Heun, M., Notroff, J., Schmidt, K., & M. Zarnkow. 2012 The role of cult feasting in the emergence of Neolithic communities. New evidence from Göbekli Tepe, south-eastern Turkey. *Antiquity* 86(333): 674- 695.

Dua, H., & A, Singh. 2008 Watchful Eyes: Moai Mata. *Br J Ophthalmol* 98(12): 1572.

Fagan, B. 1998 *From Black Land to fifth sun: the science of sacred sites*. New York: Basic Books.

Fitzhugh, W. 2009 Stone Shamans and Flying Deer of Northern Mongolia: Deer Goddess of Siberia or Chimera of the Steppe? *Artic Archaeology* 26(1): 72-88.

Fitzhugh, W. 2017 Mongolian Deer Stones, European Menhirs, and Canadian Artic Inuksuit: Collective Memory and the Function of Northern Monument Traditions. *Archaeological Method and Theory* 24: 149- 187.

Fleming, A. 2006 Post-processual landscape archaeology: a critique. *Cambridge Archaeological Journal* 16:267-180.

Frobes, R. 1964 Studies in Ancient Technology 9.

Genovese, L. 2006 *The Plain of Jars: Mysterious and Imperilled*.

Genovese, L. 2019a Widening the Geographical Reach of the Plain of Jars, Laos. *The Journal of Lao Studies* 7(1): 55-74.

Genovese, L. 2019b Spirits of the Stone, From Landlocked Laos to Sabah, Insular Malaysia. *Journal of the Archaeology of Malaysia* 32(1):53 – 76.

Gheorgiu, D., & G, Children. 2011 Experiments with past materialities. *British archaeological Reports International series 2302*. Oxford: Archaeopress.

Giddens, A. 1979 *Agency, Structure in Central Problems in Social Theory: Action, Structuration, and Contradiction in Social Analysis*. London: Macmillan. 45-95.

Gillings, M., and J, Pollard 2016 Making Megaliths: Shifting and Unstable Stones in the Neolithic of the Avebury Landscape. *Cambridge Archaeology Journal* 26(4): 537-559.

Gioncada, A., Gonzalez-Ferran, O., Lezzerini, M., Mazzuoli, R., Bisson, M., & S, Rapu. 2010 The Volcanic rocks of Easter Island (Chile) and their use for the Moai sculptures. *European Journal of Mineral* 22: 855-867.

Grove, D. 1997 Olmec Archaoelogy: A Half Century of Research and Its Accomplishments. *Journal or World Prehistory*, 11(1): 51-101.

Grove, D. 2014 *Discovering the Olmecs: An unconventional History*. Austin: University of Texas Press.

Haaland, G., Haaland, R., & S Rijal. 2002 The Social Life of Iron: A Cross-Cultural Study of Technological, Symbolic, and Social Aspects of Iron Making. *Anthropos* 97: 35-54.

Hanks, B, & K, Linduff. 2009 *Social Complexity in Prehistoric Eurasia: Monuments, Metals and Mobility*. New York Cambridge University Press.

Harris, B. 2018 Roll me a great stone: a brief historiography of megalithic construction and the genesis of the roller hypothesis. *Oxford journal of Archaeology* 37(3): 267-281.

Harker, R., Mahar, C. &Wilkes, C. 1990 *An introduction to the work of Pierre Bourdieu*. London: Macmillian.

Hasanuddin, N. 2016 Social and Religi Values in Megalithic Tradition in South Sulawesi. *Kapata Arkeologi*, 12(2): 191-198.

Hazell, L & G. Brodie. 2012 Applying GIS tools to define prehistoric megalith transport route corridors: Olmec megalith transport routes: a case study. *Journal of Archaeological Science* 39: 3475- 3479.

Hazell, L. 2013 An Analysis of Log Raft Open Water Performance and Crew Capability to Move Megaliths Preclassic Olmec Used for Colossal Head Sculptures. *Journal of Maritime Archaeology* 8: 139-152.

Heine-Geldern, R. 1928 Die Megalithen Südostasiens und ihre Bedeutung für Klärung der Megalithenfrage in Europa und Polynesien. *Anthropos* 23: 276-315.

Heyerhal, T., & E, Ferdon. 1961 *Reports of the Norwegian Archaeological expedition to Easter Island and the East Pacific*. Stockholm: George Allen & Unwin.

Heyerdahl, T., Skjolsvold, A., & P, Pavel. 1989 The 'walking' Maoi of Easter Island. In Kon Tiki *Museum Occasional Papers 1*. Oslo: Kon Tiki Museum.

Higham, C. 1996 The Bronze Age of Southeast Asia. Cambridge: Cambridge University Press.

Hixon, S., Lipo, C., McMorran, B., & T, Hunt. 2018 The colossal hats (*pukao*) of monumental statues on Rapa Nui (Easter Island, Chile): Analyses of *pukao* variability, transport, and emplacement. *Journal of Archaeological Science* 100: 148-157.

Hung, H., Nguyen, K., Bellwood, P., & M, Carson. 2013 Coastal Connectivity: Long-Term Trading Networks Across the South China Sea. *The Journal of Island and Coastal Archaeology* 8(3): 384-404.

Hunt, T., & C, Lipo. 2006 Late Colonization of Easter Island. *Science* 311(5767): 1603-1606.

Hunt, T. 2007 Rethinking Easter Island's ecological catastrophe. *Journal of Archaeological Science* 34: 485-502.

Jaime-Riverón, O. 2010 Olmec Greenstone in Early Formative Mesoamerica: Exhnage and process of production. *Ancient Mesoamerica* 21(1): 123-133.

Johnson, M. 2011 *Archaeological Theory: An Introduction*. Chichester: John Wiley & Sons.

Johnson, M. 2012. Phenomenological approaches in landscape archaeology. *Annual Review of Anthropology* 41:269-284.

Jones, A. 2012 *Prehistoric Materialities: Becoming material in Prehistoric Britain and Ireland*. Oxford: Oxford University Press.

Källén, A. 2004 And Through Flows the River: Archaeology and the Pasts of the Lao Pako. *Studies in Global Archaeology* 6. Uppsala: Uppsala University.

Källén, A. 2015 *Stones Standing: Archaeology, Colonialism, and Ecotourism in Northern Laos*. New York: Routledge.

Kaudern, W. 1938 *Ethnographical studies in Celebes: Results of Author's expedition to Celebs 1917-30, vol. 5: megalithic finds in Central Celebes*. Götenborg: Elanders Boktryckeri Aktiebolag.

Kirleis, W., Muller, J., Kortemeier, C., Behling, H., & S. Soeghondo. 2012 The Megalithic Landscape of central Sulawesi, Indonesia: Combing Archaeological and Palynological Investigations. In Tjoa-Bonatz, M., Reinecke, A., & D. Bonatz, eds *Selected Papers from the 13th International Conference of the European Association of Southeast Asian Archaeologists*. 199-218. Singapore: NUS Press.

Ladeforged, T., Stevenson, C., Haoa, S., Mulroonye, M., Puleston, C., Vitousek, P., & O, Chadwick. 2010 Soil nutrient analysis of Rapa Nui gardening. *Archaeology in Oceania* 45(2): 80-85.

Lavachery, H. 1935 *L'lle de Paques*. France: Editions Bernard Grasset.

Lipo, C., Hunt, T., and S, Rapu Haoa 2013 The 'walking' megalithic statues (moai) of Easter Island. *Journal of Archaeological Science* 40(6): 2859-2866

Malmer, M. 1997 On Objectivity and Actualism in Archaeology. *Current Swedish Archaeology*, 5.

Mathieu, J. 2002 Experimental archaeology: replicating past objects, behaviours, and processes. *British Archaeological reports international series 1035*. Oxford: Archaeopress.

McFadyen, L. 2008 Building and architecture as landscape practice. In David, B., & J, Thomas (eds), *Handbook of Landscape Archaeology*. Walnut Creek: Left Coast Press.

Mens, E. 2008 Refitting megaliths in western France. *Antiquity* 83(315): 25-36.

Métraux, A. 1940 Ethnology of Easter Island. *Bernice P. Bishop Museum Bulletin* 160.

Michell, J. 1999 *Megalithomania: Artists, antiquarians and archaeologists at the old stone monuments*. London: Thames and Hudson.

Mills, J., & J, Hutton 1929 Ancient monoliths of north Cachar. *Journal and Proceedings of the Asiatic Society of Bengal* 25(1): 285-287

Millson, D. 2010 *Experimentation and Interpretation: The Use of Experimental archaeology in the Study of the Past*. Oxford: Oxbow books.

Mohen, J. 1999 *Standing Stones: Stonehenge, Carnac and the World of Megaliths*. London: Thames and Hudson.

Moorti, U. 2008 Megaliths. *Elsevier*

Needham, J. 1980 The Evolution of Iron and Steel Technology in East and Southeast Asia. In Wertime, T.A & J.D. Murphy (eds) *The Coming of the Age of Iron*, pp. 507-541. New Haven: Yale University Press.

Nitta, E. 1996 Comparative study on the burial traditions in Vietnam, Thailand and Laos. *Historical Science Reports at Kagoshima University* 43: 1-19.

North, J. 1997 *Stonehenge: Neolthic Man and the Cosmos*. London: Harper Collins.

O'Reilly, D. Shewan, L. Van Den Bergh, J. Luangaphay, S. and T. Luangkhoth. 2018 Megalithic Jars Sites of Laos: A comprehensive overview and new discoveries. *Journal of Indo-Pacific Archaeology* 42(1): 1-31.

O'Conner, S.J.1975 Iron working as Spiritual Inquiry in the Indonesian Archipelago. *History of Religions: an International Journal for Comparative Historical Studies*, vol. 14(3): 173-190.

O'Reilly, D., Shewan, L., Domett, K., Halcros, S., and T, Luangkhoth 2019 Excavating among the megaliths: recent research at the 'Plain of Jars' site 1 in Laos. *Antiquity* 93 (370): 970-989.

O'Reilly, D., Shewan, L., Khamphouvong, M., & A. Butphachit. 2020 Research at megalithic jar site 52 and the discovery of new jar sites in Xiang Khouang Province, Laos. *Asian Perspectives* 3: 21-33.

Paardekooper, R. 2019 Experimental archaeology: Who does it, what is the use? *EXARC Journal*.

Parker Pearson, M., Bevins, R., Ixer, R., Pollard, J., Richards, C., Welham, K., Chan, B., Edinbrough, K., Hamilton, D., Macphail, R., Schlee, D., Schwenninger, J., Simmons, E., and M, Smith 2015 Craig Rhos-y-felin: a Welsh bluestone megalith quarry for Stonehenge. *Antiquity* 89 (348): 1331-1352.

Parker Pearson, M., Chamberlain, A., Jay, M., Marshall, P., Pollard, J., Richards, C., Thomas, J., Tilley, C., & K, Welham. 2009 Who was buried at Stonehenge? *Antiquity* 83(319): 23- 39.

Parker Pearson, M., Pollard, J., Richards, C., Welham, K., Casswell, C., French, C., Schlee, D., Shaw, D., Simmons, E., Stanford, A., Bevins, R., and R, Ixer 2019 Megalith quarries for Stonehenge's bluestones. *Antiquity* 93 (367): 45-62.

Parker Pearson, M. 2013 Researching Stonehenge: Theories Past and Present. *Archaeology International* 16: 72-83.

Pauketat, T.R. 2001 Practice and history in archaeology: An emerging paradigm. *Anthropological Theory* 1:73-98.

Prasetyo, B. 2012 Stone Jars in Sumbawa: Distribution, Type, and Technology. *Journal of Penelitian Dan Pengembangan Arkeolog* 30(1).

Reay, A., & N, Chang. 1998 The Metal Artifacts. In Higham, C., & R, Thorarat (eds), The Excavation of Nong Nor: A prehistoric site in Central Thailand. *University of Otago Studies in Prehistoric Anthropology* 18: 305-314.

Renfrew, C. 1983 The Social Archaeology of Megalithic Monuments. *Scientific American* 249(3): 152-163.

Renfrew, C. 2000 Megaliths: perspective improves; central mystery remains. *Antiquity* 74(285): 726-728.

Richards, C., Croucher, K., Paoa, T., Parish, T., Tucki, E., & K, Welham. 2011 Road my body goes: re-creating ancestors from stone at the great moai quarry of Rano Raraku, Rapa Nui. *World Archaeology* 43(2): 191-210.

Sayavongkhamdy, T and P. Bellwood. 2000 Recent Archaeological Research in Laos. *Bulletin of Indo-Pacific Prehistory* 19(1):101 – 110.

Schmidt, K. 2000 Gobelki Tepe, Southern Turkey: A Preliminary Report on the 1995-1999 Excavations. *Paleorient* 26(1): 45-54.

Schmidt, K. 2010 Göbekli Tepe – the Stone Age Sanctuaries. New results of ongoing excavations with a specific focus on sculptures and high reliefs. *Documenta Praehistorica* 37(633): 239-256.

Selley, N., & W, Rajpitak. 1984 The bronze technology. In, Higham, C., & A, Kijngam (eds), Prehistoric Investigations in Northeast Thailand. *British Archaeological Reports* (International series) 231(1-3).

Sellet, F. 1993 Chaine Operatoire: The concept and its applications. *Lithic Technology* 18(1): 106-112.

Sengupta, G. & S. Sharma 1946. Archaeology in North-East India: The Post-Independence Scenario. *Ancient India* 1: 353-368.

Sherwood, S., Van Tilburg, J., Barrier, C., Horrocks, M., Dunn, R., & J, Ramírez-Aliaga. 2019 New excavations in Easter Island’s statue quarry: Soil fertility, site formation and chronology. *Journal of Archaeological Science* 111: 1-22.

Shewan, L., O'Reilly, D., Luangkhoth, T., Armstrong, R., Beavan, N., Toms, P., Halcrow, S., Dommett, K., Van Den Bergh, J., & N, Chang. 2021 Dating the Megalithic Culture of Laos: Radiocarbon, Optically Stimulated Luminescence and U/Pb Zircon Results. *PloS one* 16(3)

Sherratt, A. 1990 The Genesis of megaliths: Monumentailty, Ethnicity and Social complexity in Neolithic Northwest Europe. *World Archaeology* 22(2): 147-167.

Shillito, L. 2019 Building Stonehenge? An alternative interpretation of lipid residues in Neolithic Grooved Ware from Durrington Walls. *Antiquity* 93(370): 1052-1060.

Souyoudzoglou-Haywood, C., & A, O'Sullivan. 2019 *Experimental archaeology: Making, Understanding, Story-Telling*. Oxford: Archaeopress.

Squitieri, A., & D, Eitam. 2016 An experimental approach to ground stone tool manufacture. *Journal of Lithic Studies* 3(3): 553-564.

Steimer-Herbet, T. 2018 *Indonesian Megaliths: A forgotten cultural heritage*. Oxford: Archaeopress.

Stocks, D. 1986 Tools of ancient craftsman. Popular Archaeology 7(6): 25-29

Stocks, D. 1999 Stone Sarcophagi manufacture in ancient Egypt. *Antiquity* 73(282): 918-922.

Stocks, D. 2003 The development of stone sarcophagus manufacture. In Stocks, D. *Experiments in Egyptian Archaeology: Stoneworking Technology in Ancient Egypt*. London: Routledge

Sukendar, H. 1987 Description on the megalithic tradition of Indonesia. *Berkala Arkeolgi* 8(1): 1-30.

Tener, S. 2020 Visual and statistical analysis of tool scars on the Plain of Jars, Lao PDR: A chaîne opératoire of megaliths. Unpublished Honours theses, College of Arts and Social Science, Australian National University, Canberra.

Tilley, C. & W, Bennett. 2016 *Body and Image: Explorations in Landscape Phenomenology 2*. Left Coast Press: Walnut Creek, California.

Tishkin, A. 2020 Advancing Archaeological research of the Mongolian Altai through the Scientific Study of Deer Stones: New Discoveries from Buyant Valley. *Asian Perspectives* 59(2):453-477.

Thakuria, T. 2014 Hollowed Monoliths of North Chachar, Assam: Prospects for Archaeology and Ethno-history. In T. Jamir & M. Hazarika (eds), *50 Years after Daojali-Hading: emerging perspectives in the archaeology of Northeast India*, pp. 243-249. New Delhi: Research India Press

Tsoniv, L. 2019 Megaliths and Physics. *AIP Conference Proceedings* 2075.

UNESCO. 2019 Megalithic Jars Sites in XiengKhuang – Plain of Jars World Heritage Nominations Volume 1.

Wendt, C. 2005 Excavations at El Remolino: Household Archaeology in the San Lorenzo Olmec Region. *Journal of Field Archaeology* 30(2): 163-180.

White, J., & V, Pigott. 1996 From Community Craft to Regional Specialization: Intensification of Copper Production in Pre-State Thailand. In Wailes, B (ed), Craft Specialization and Social Evolution. University Museum Monograph 93: 151-175.

Williams, H., & R, Heizer. 1965 Sources of Stones used in Prehistoric Mesoamerican Sites. *Contributions of the University of California Archaeology Research Facility*. Berkley: Department of Anthropology.

Wright, J. 2014 Landscapes of Inequality? A critique of Monumental Hierarchy in the Mongolian Bronze Age. *Asian Perspectives* 51(2): 139-163.

Wright, J. 2017 The honest labour of stone mounds: monuments of Bronze Age and Iron Age Mongolia. *World Archaeology* 49(4): 547-567.

Wylie, A. 1985 The reaction against analogy. *Advances in Archaeological Method and Theory* 8:63-111.

Wylie, A. 2002 Archaeological cables and tacking: Beyond objectivism and relativism. In Wylie, A. *Thinking from Things*, pp.161-167. Berkeley: University of California Press.

Van der Hoop, M. 1932 *Megalithic Remains in South-Sumatra*. Zutphen: W.J. Thieme & Co.

Van Tilburg, J., & T, Ralston 2005 Megaliths and Mariners: Experimental archaeology on Easter Island. In Johnson, K (ed), *Onward and upward! Papers in hour of Clement W. Meigan.* Chico: Stansbury Publications.

Volkov, V. 2002 *Olennye kamni Mongolii (Deer Stones of Mongolia)*. Moscow: Nauchnyy Mir.