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A Technological Approach to Late Pleistocene and Early Holocene Aquatic Adaptations in the Far West of North America

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A Technological Approach to Late Pleistocene and Early Holocene Aquatic Adaptations in the Far West of North America:

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Abstract

A growing body of data suggests that the Western Stemmed Tradition and Island Paleocoastal Tradition likely originated from a Pacific Coastal migration from northeast Asia in the late Pleistocene. These two traditions are often considered as linked due to overlaps in crescent and stemmed point typology. While interior groups of the Western Stemmed Tradition did take large terrestrial game including artiodactyls, their subsistence pattern largely mirrors the broad spectrum aquatic diet of the Island Paleocoastal Tradition. Increasing evidence shows that both Island Paleocoastal Tradition peoples and interior Western Stemmed Tradition peoples made use of upland environments and resources, however their dominant settlement pattern was oriented near large bodies of water: the sea and inland pluvial lakes. Due attention has been given to technological systems associated with lithic reduction of the Western Stemmed Tradition in the Intermountain West, yet little technological analysis has been conducted on the California Channel Islands (largely due to the fact that late Pleistocene and early Holocene occupations were only relatively recently discovered). This dissertation focuses on a detailed technological analysis surrounding the organization of production of flaked stone tools across three of the best preserved sites associated with the Island Paleocoastal Tradition on California's Channel Islands. Details of this technological system are then compared more broadly with mainland Western Stemmed Tradition finds. Additionally, as watercraft clearly played a significant role in the colonization and subsistence system of the earliest known islanders, replicative studies are used to evaluate the production dynamics associated with simple boating technology (the tule balsa) to address when and why people invest in boating. This study shows that even the simplest boats represent significant startup costs and therefore specific circumstances are needed to justify their manufacture and use. Additionally, parallels in the chaine operatoire/reduction sequence behind flaked stone tool production on the California Channel Islands and mainland Intermountain West suggest that the Island Paleocoastal Tradition should be considered a coastal variant of the broader Western Stemmed Tradition.

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Contents

Chapter One

INTRODUCTION

In this dissertation I use three lithic assemblages from late Pleistocene and early Holocene archaeological sites on the southern California Channel Islands coupled with actualistic/experimentally derived data to examine technological organization associated with the peopling of the Far West of North America. This investigation seeks to answer two analytical questions: from a technological standpoint, should early maritime Paleoindian populations of the southern California Channel Islands be considered distinct, or intrinsically linked, to the broader mainland manifestation of the Western Stemmed Tradition (WST)? And, did the makers of the WST manufacture and use simple watercraft around massive Pluvial Lakes in the late Pleistocene and early Holocene Intermountain West? More broadly, this dissertation addresses why hunter gatherers initially invest in watercraft, and why subtle details in lithic operational sequences of both island and western mainland Pleistocene assemblages consistently seem to overlap.

A Brief History of the Peopling of the Americas

A Flat Past

Aleš Hrdlička is credited for developing the original model of the initial peopling of the Americas via the Bering Strait. As a physical anthropologist, he noted clear similarities in skeletal morphology between Northeast Asian populations and Native Americans. It led him to speculate that since the Bering Strait represented the closest geographic proximity between North America and Asia, it was the most parsimonious point of entry for the initial peopling event (Hrdlicka 1915). However, Hrdlička maintained that this initial migration occurred no earlier than the late Holocene, and therefore Indigenous occupation of the New World reflected a relatively short duration. Any claims that an archaeological find representing human occupation predating this relative "flat past" were systematically refuted by Hrdlička and colleagues. As founder and editor of the *American Journal of Physical Anthropology* and curator of Physical Anthropology at the US National Museum (now the Smithsonian Institution), of which he was also a founder, Hrdlička set the stage for fierce debates surrounding the peopling of the Americas that have lasted more than a century (Clewlow 1970). Through such early debates, Hrdlička and colleagues such as William Henry Holmes, had also established a precedent that any proposed site associated with early colonization would be subject to strict criteria and intense scrutiny before being seriously considered. While some saw this move as an establishment of standards nearly impossible to fulfill, it certainly advanced the science of Pleistocene archaeology in the Americas by forcing detailed demonstration of site integrity, accurate dating, and interpretation.

Ice Age Hunters

In 1926 Jesse D. Figgins and Harold J. Cook announced the discovery of stone projectile points of unique morphology and undoubted antiquity from excavations they had conducted near Folsom, New Mexico. One point was found still embedded between the bones of extinct Pleistocene fauna; a confirmation of its early age (Meltzer et al. 2002, Thomas 2000:149). Initially Hrdlička, Holmes, and other critics were not convinced of the authenticity of the association, citing stratigraphic mixing and poor excavation techniques (Thomas 2000:149). However, when another fluted point was discovered *in situ* between the ribs of *Bison antiquus* the following year, the evidence seemed clear (Figgins 1927; Wormington 1957). Hrdlička was eventually convinced of the association, but not of the antiquity. However, many other prominent scholars of the time, including Nels Nelson, Barnum Brown, and A.V. Kidder (among others) were convinced of the association and Pleistocene age of the find which gradually led to general acceptance in the archaeological community.

The Clovis type was first recognized as a distinct projectile point type at Blackwater Draw in eastern New Mexico (Howard 1935; Sellards 1952). Here, these distinct projectile points and associated technologies were found within archaeological deposits predating Folsom. Even so, these finds were routinely met with ardent opposition from the general archaeological community until ample evidence suggested secure chronological integrity (MacNeish 1973; Meltzer 1989). In the end, these finds, provided support for an even earlier late Pleistocene peopling event. The general absence of artifactual remains in strata below Clovis occupations suggested that the earliest American inhabitants were in fact the makers of Clovis. Under this model, these Pleistocene hunter-gatherers migrated via the Beringian land-ice bridge which connected north Asia and North America when sea levels were lower. Relying largely on a terrestrial large game hunting subsistence strategy, they followed herds of ice age fauna as the animals migrated south through a gap in the Laurentide and Cordilleran ice masses as the climate ameliorated and Arctic-steppe vegetation replaced formerly impenetrable glaciers (Haynes 1964). These big game hunting specialists soon spread across North America carrying with them the diagnostic fluted projectile point technologies that had been found at sites like Clovis and Folsom far to the south (Mason 1962). This Clovis-first theory quickly dominated archaeological discourse to form the longest standing paradigm surrounding Paleoindian migrations into the New World.

The Meeting of Two Cultures

Currently, fluted point technologies such as seen in Clovis and Folsom represent some of the earliest securely dated artifacts in much of North America. In the American Far West however, fluted projectile points are often found in surficial contexts making chronological associations problematic (Davis et al. 1996; Rondeau et al. 2007). These points are often found near the margins of relict Ice Age pluvial lakes indicating an early chronological association in the region (e.g., Davis 1975). Unlike many parts of North America, in the Far West, fluted points are occasionally found in association with stemmed projectile points and lithic crescents suggesting that these technologies overlap chronologically. The association of fluted points, stemmed points, and crescents with pluvial lakes in the region led Bedwell (1970) to classify these technologies as belonging to a western Paleoindian subsistence strategy that he referred to as the Western Pluvial Lakes Tradition (WPLT). The WPLT designation has largely been replaced by discussions of the Western Stemmed Tradition (WST) (Willig and Aikens 1988; see also Bryan 1980) in more recent years as the latter classification does not suggest an inherent tie to a single specific environment. The current use of the WST also implies that Western Fluted points may represent the movement of peoples disparate to the WST (Beck and Jones 2010; Davis et al. 2012; Bryan 1978, 1988; Bryan and Tuohy 1999). Additionally, Beck and Jones (2010) suggest that some of these Western Fluted points may represent a copying error where WST peoples borrowed the fluted point design with imperfect knowledge of certain design characteristics more common of fluted points to the east i.e. overshot bifacial thinning and large single channel flake removals.

Early Burials and Genetic Data

Due to preservation bias, Paleo-Indian human remains are rare in the archaeological record of North America. However, the remains of an infant associated with Clovis material culture was unearthed at the Anzick site in Montana (Owsley and Hunt 2001) yielding a date of approximately 12,600 cal BP. Other finds of younger Paleo-Indian remains include Buhl Woman, found in Buhl Idaho and radiocarbon dated to 10,675+/- 95 cal BP (Green et al. 1998), Spirit Cave Man, radiocarbon dated to approximately 9,400 cal BP (Kirner et al. 1996; Tuohy and Dansie 1997), and human bone from On Your Knees Cave circa 10,300 cal BP (Kemp et al. 2007). Between 1959 and 1960, Phil Orr led excavations on Santa Rosa Island off the coast of southern California at the Arlington Springs site. There, Orr uncovered human skeletal remains which were later radiocarbon dated by Johnson and colleagues (2002) with a reported age of 13,000 cal BP. Considering the lack of fluted points and preponderance of stemmed points and crescents on the islands, Arlington Man may reflect an early presence on the California coast supporting Pleistocene maritime adaptations and the Pacific Coastal Migration model (Erlandson et al. 2007; Erlandson and Braje 2011).

Recent genetic studies indicate that founding populations of Native Americans derived from two Asian populations which had contributed to a broader Beringian ancestral population some time near the Last Glacial Maximum (LGM). Raghavan and coauthors (2014, 2015) maintain that the more major contribution stemmed from eastern Asia with smaller contributions from the Siberian interior. According to Moreno-Mayer and coauthors (2018), two related populations then emerged from this late Pleistocene Beringian group, one of which contributed to the Native American populations south of the Laurentide and Cordilleran ice masses while the other "Ancient Beringian" population was tied archaeologically to the Denali Complex. Under this genetic model, the ancestors of the first major groups to make their way into the Americas, represented by the Clovis and Western Stemmed Tradition more broadly (including Island Paleocoastal peoples), shared ancestry with this Beringian group which indicates that this source population exhibited some shared Clovis and WST technologies (Pratt et al. 2020). However, it is also feasible that some of these Beringian groups maintained unique ancestral technologies, or even developed these tools in Beringia, and that more coastal-oriented and interior-focused groups coexisted and interacted regardless of potential differences in maritime and terrestrial subsistence focuses. Since the distributions of early East Asian populations before ~30,000 BP, and their potential relationship with the earliest Native American populations is yet unclear, Davis and Madsen (2020:3-4) suggest that the earliest Native American populations developed from a merger of two source populations. In their model, one group of East Asian descent entered the Japan/Paleo-Sakhalin-Hokkaido-Kuril region from Korea and Taiwan to the south, and another group related to the Mal'ta child traveled down the Amur River valley where they met, not in Beringia, but in the Japan/Paleo-Sakhalin-Hokkaido-Kuril area, before migrating into Beringia and then eventually into the Americas.

A Pacific Coastal Migration

In 1979 Knut Fladmark (1979:55) wrote "(T)he possibility of a coastal migration route has not been seriously considered by New World specialists, who can accept that coastal adaptations developed from prior interior bases but are reluctant to consider the opposite alternative." While the dominant paradigm concerning the earliest colonization of North America centered on terrestrial routes and the adaptive strategies of groups interior from the coast, Fladmark (1979) proposed that the Pacific Coast was also a viable alternative path for early hunter-gatherer dispersals from Asia into the Americas (Braje et al. 2019). Largely dismissed at the time, new data indicates that a Pacific Coastal Migration in fact played a significant role in these early colonization events (Braje et al. 2019; Erlandson et al. 2007). After dozens of late Pleistocene and early Holocene sites (now more than 100) were documented on the Southern California Channel Islands, researchers shifted focus once again to Fladmark's theory and to discussions concerning the nature of early maritime migrations and settlement of North America's west coast. Erlandson and coauthors (2007) noted that productive marine ecology in the form of kelp bed ecosystems found around the Pacific Rim alleviated some environmental pressures otherwise impacting latitudinal movements of peoples if they migrated by boat north from Northeast Asia and then east along Beringia or perhaps even the Aleutian Islands, and finally south again along the west coast of North America. This "Kelp Highway Hypothesis" as it came to be known, was later supported by Braje and Erlandson (2011) who mapped the distribution of stemmed projectile points (albeit of different types) along the same coastal path. Most recently this Pacific Coastal Migration Theory was formalized by Davis and Madsen (2020) who formulated a number of testable hypotheses related to this colonization model.

Discoveries of stemmed points (and coprolites containing aDNA) with reported pre-Clovis dates from Oregon's Paisley Caves (Gilbert et al. 2008; Jenkins et al. 2012) and more stemmed points with associated pre-Clovis dates from Cooper's Ferry in Idaho, began to connect the dots between potential coastal migrants bearing stemmed projectile points and early WST settlement of the Intermountain West, bordered on the east by the Rocky Mountains and the Cascade/Sierra Nevada Mountains on the west. Beck and Jones (2010) for instance, suggested that a Pacific Coastal migration led to groups traveling inland from the coast along major river systems such as the Columbia River. Following analogous resources such as anadromous fish runs, waterfowl, freshwater shellfish, and terrestrial game, such a migration led these hunter gatherers to the Salmon River (Cooper's Ferry) in the Columbia Plateau, the Snake River Plain, and eventually on to the Great Basin (Paisley Caves). Other major river courses including the Klamath and Sacramento River may have also facilitated inland migrations from the coast. Such links between the coast and the interior explain overlaps in projectile point hafting strategies, the presence of lithic crescents in both areas, and significant overlaps in subsistence and settlement patterns largely (though not exclusively) focusing on aquatic environments. It should be noted that new finds at Debra L. Friedken and Gault sites in Texas have also recently yielded unfluted and stemmed projectile points and other artifacts underlying Clovis layers further supporting the idea that Clovis was not the first culture to occupy the west (Waters et al. 2018; Williams et al. 2018).

Mainland WST and Island Paleocoastal Technologies

Davis and coauthors (2012) used a *chaine operatoire* approach to distinguish specific features of stone tool manufacture and concluded that WST and Clovis reduction strategies were indeed distinct and likely reflective of two migrations or techno-complexes. Typological overlaps (Moss and Erlandson 2013), and techno-typological studies (Pratt et al. 2020) routinely allude to connections between stemmed point- and crescent-bearing islanders and mainlanders. While interior WST lithic reduction has received warranted attention over the past few decades (Beck and Jones 2009, 2010; Beck et al. 2002), to date no fully comprehensive technological analysis of early Northern Channel Islands lithic assemblages has been completed. While Pratt and coauthors (2020) did illustrate previously documented lithic artifact attributes from the islands, and they concentrated on a coastal migration model as one potential technological antecedent for island and mainland stemmed point bearing peoples, they followed suite and referred to the islanders and mainlanders as somewhat disparate groups. Building upon these investigations, this dissertation research seeks to further explore potential overlaps and differences between Paleocoastal island dwellers and the broader WST from a technological approach.

I apply here a technological approach to late Pleistocene and early Holocene assemblages that to disentangle formerly disparate or not-yet-described artifact forms and link them to their associated shared and learned systems of production. While typological approaches are essential to understanding patterns of human behavior, including regional culture histories, a technological approach concerning the processes by which artifacts are manufactured allows for a more nuanced comparison. The technological approach is rooted in the concept of an operational sequence. Through convergence, this concept was developed by both French (*chaine operatoire*) and American (*reduction sequence*) schools as an effective way to disentangle technological manufacturing stages (Holms 1891, 1894; Sellet 1993; Shott 2003). The reduction sequence approach begins with the artifacts themselves, which were deposited in the archaeological record in a condition that we can essentially consider the final stage of their use-life. An analytical reconstruction of the stages of manufacture (from material procurement to discard and even recycling) are then evaluated (Schiffer 1972). Conchoidal fracture produces both positive and negative byproducts. The positive byproduct of this process of flaking is, in the case of core reduction, the blank itself. The negative byproduct is the remnant flake scar (referred to as a negative). Since subsequent removals erase and overlay portions of previous flake scars, a general sequence of events can be assessed through qualitative and quantitative means. In a sense, the analyst can reconstruct a general progression of removals based on the size, shape, and direction of early and late negatives. These lithic attributes form the basis of interpretation regarding technical options that the knapper employed when faced with specific material constraints. These same analyses are thus applicable beyond core reduction, blank production, and retouch (Peligrin et al. 1988).

The operational sequence approach can be applied to numerous artifact forms. Continuing with a flaked stone tool example, establishing an understanding of a chaine operatoire can go much further than simply understanding the organization of artifact production at a single site. If, for instance, broadly contemporaneous sites across a region display multiple disparate core reduction and artifact manufacturing strategies but similar point types (end products), we might conclude that the points were manufactured through a process of convergent evolution. If, however, the reduction methods were very similar across these assemblages, especially if they are similar across complex stages, and the projectile points are also typologically similar, we might conclude that this pattern reflects a broader population. Essentially these groups could be considered representative of a broader archaeological culture. Finally, it is also possible, as has been proposed in the Far West of North America (Beck and Jones 2010; Davis et al. 2012), that two or more broadly contemporaneous point styles, each produced through consistent (yet distinct) manufacturing sequences, may reflect multiple groups occupying the same landscape.

This thesis provides site-specific information regarding all stages of lithic technological organization at a hunting camp at CA-SRI-512 on Santa Rosa Island, and quarry workshops from CA-SMI-678 and CA-SMI-679 at Cardwell Bluffs, San Miguel Island. I then compare these data more broadly with mainland WST lithic reduction signatures, subsistence-settlement patterns, and broader features of material culture. In addition, if watercraft were an important technology in the Pacific Coastal peopling of the Americas as expected, we explore the idea that simple boating technology may not have exclusively been used by the coastal and island dwellers of the WST, but that it may have also been an important tool used by WST occupants of the massive pluvial lakes of the Great Basin. We explore the hypothesis proposed by Schulz et al. (2016) that if such watercraft were used in the relative absence of large timber necessary for dugout canoes, and in the presence of extensive wetlands, then perhaps simple tule boats made from pliable and buoyant wetland plants may have been employed. We use actualistic/experimental data derived from the construction of a tule canoe to examine production dynamics, the stone tools needed in their construction, and the costs and benefits of this technological investment to add to discussions of why hunter-gatherers invest in watercraft at all?

Experimental Archaeology and Technological Intensification/Investment

Experimental archaeology first gained popularity during the 1960's-1980's as a method of generating analogous data to address gaps in our interpretation of the archaeological record. Like investigations into taphonomy (Lyman 1994), site formation processes (Schiffer 1983), and ethno-archaeology (Binford 1978), this approach was intrinsically linked to the development of Middle Range Theory (Bettinger 1987; Binford 1983). Middle Range Theory helps to bridge the gap between low level inquiry and high level theory to make meaningful interpretations more broadly in terms of human behavior. The definition of *experimental archaeology* has changed considerably since its incipient development as a field (Fergusson 2010; Callahan 1999; Coles 1978). Experimental archaeology, in a broad sense, includes *actualistic* in-field investigations and controlled experiments more typically undertaken in laboratory settings. Both types of archaeological experimentation have merit, the former more closely approximating human behavior in response to natural conditions such as those encountered in the ancient past but with obviously less control of specific variables, and the latter (conducted within laboratory settings) more systematically controlling variables to eliminate bias and maximize replicability. One component of this dissertation concentrates on the manufacture of a tule canoe using an actualistic in-field experimental approach. By systematically documenting manufacturing times as well as the toolkit necessary for simple reed bundle boat production, we produce a dataset that we model to provide insights into hunter gatherer investment in early watercraft technology.

Human Behavioral Ecology (HBE) uses evolutionary theory and concepts of optimization and adaptation within ecological contexts to understand human behavior and cultural diversity within a broader evolutionary framework. Originally developed by Ugan and coauthors (2003) and later modified (Bettinger et al. 2006) and fully developed by Bettinger's (2009, 2021) models of technological investment/intensification provide an HBE mathematical structure for evaluating rational time investment in simple and complex tool production, especially as it relates to subsistence resource returns, which can directly translate to broader issues of patch choice, intensification, diet breadth, and mobility.

This model essentially explains how rational individuals would manufacture the best performing tools possible with the least necessary time invested "where tool performance is measured by the rate at which resources are procured or processed when using it" (Bettinger 2009). Here, we can apply the model of technological investment to predict when the critical switch point should occur and hunter gatherers should invest in the front-loaded production of watercraft over less costly foot-based travel. Of course, to use this model to examine the issue of why hunter gatherers would initially invest in boating, it is first necessary to define specific parameters. While general estimates of walking or paddling (km/hr) are known, one aspect in need of quantification is how long specific boats take to produce using only period appropriate materials and tools. Here, we use analogous data generated from the manufacture of a tule reed bundle canoe (not unlike those used throughout California and the Western Great Basin in ethnographic times) as a baseline to quantify the costs of simple watercraft. The term ‘simple’ is typically is applied to technologies consisting of less components such as self-arrows and self-bows when compared to their composite forms. The term *simple watercraft* therefore is used throughout this manuscript not as a judgmental evaluation of tule boats as "primitive" or inefficient, but merely that they required less complex toolkits in their manufacture and less specialized knowledge in production when compared to other known western Native American boat types (e.g., Northwest Coast dugout canoes and the sewn-plank canoes of the Southern California bight). The replication of this tule boat using only period appropriate tools and materials was essential in generating data on production dynamics of an otherwise perishable technology. Without such experimentally derived data, it would be challenging at best to accurately model and predict early watercraft investment. While these models provide a quantitative basis for understanding the costs and benefits of technological investment in relation to specific set of parameters, human behavior rarely fits a model perfectly and we are left with new avenues to explore. This dissertation uses the multi-faceted theoretical and methodological approaches described above to investigate several research questions pertinent to the peopling of the Americas. The subsequent description of thesis organization by chapter, provides the reader with a framework that we used to address some of these issues.

Summary and Research Questions

To date, numerous studies centered on the role of the Pacific Coast in early migrations and the peopling of the Americas leave many questions unanswered. Here, I list a few basic issues that I propose to address in this dissertation. It should contribute to a better understanding of how stone tools from island and mainland settings are produced, and how specific technologies such as projectiles, or watercraft, allowed some of the earliest Americans to articulate with their environment and extract needed resources. These questions are listed by order of appearance in the following chapters:

1) From a technological standpoint, what is the nature of the organization of flaked stone tool production at the scale of a site?
2) What can an inter-site comparative technological analysis tell us about the organization of Island Paleocoastal flaked stone tool manufacture more broadly?

    a) Do the Island Paleocoastal Tradition and mainland Western Stemmed Tradition share enough similarities to indicate recent common ancestry?

3) Why did hunter-gatherers first invest in simple watercraft?
    a) What are the tools needed and startup costs associated with simple reed-bundle boat manufacture?
    b) Broadly, under what circumstances would technological investment in simple tule boat technology be favored?
    c) Under what specific circumstances might Western Stemmed Tradition peoples have invested in such boats?

Chapter Two: As explained above, there is a shortage of technological studies on the early material in California's Channel Islands. One of the main reasons for this is the lack of stratified deposits representative of the early Paleocoastal occupations on the islands. Here, I present a detailed study of the material from CA-SRI-512. The goal is to characterize the organization of flaked stone tool production at the local level, from a dated California Channel Islands site. CA-SRI-512 is located just west of the mouth of Arlington Canyon (where the ~13,000 cal BP remains of Arlington Man were recovered in 1959) on western Santa Rosa Island. While currently situated on the edge of a bluff directly above the extant shoreline, the site would have been some 5-7 km interior from the late Pleistocene sea shores (Erlandson et al. 2011). The site has yielded both excavated and surface collections indicative of Island Paleocoastal occupations with no evidence for middle or late Holocene intrusion. Bird bone and charcoal associated with flakes stone tools provided AMS ^{14}C dates that range from ~12,000 to 11,350 cal BP, with a most likely date range of ~11,800 to 11,500 (Erlandson et al. 2011). Abundant faunal remains from seasonal migratory birds, shellfish, fish, and sea mammals paired with abundant island chert artifacts including stemmed projectile points and lithic crescents and debitage tell a story of early maritime-adapted peoples at what we interpret as a logistically oriented seasonal interior hunting camp.

We are left asking if such patterns reflect site specific artifact manufacture, or are they typical of the Island Paleocoastal in general? We also question whether trends observed in the small assemblage of early stage artifacts will hold or differ from comparisons across sites containing higher densities of early stage materials?

Chapter Three: After describing the technological organization of the lithic production at CA-SRI-512, we are left wondering if it reflects site-specific artifact manufacture, or if it points toward a pattern that characterized several Island Paleocoastal assemblages. More specifically, the trends observed could be restricted to small assemblages, lacking early stages of production, with an emphasis on recycling by-products. Hence, chapter 3 revisits Island Paleocoastal lithic reduction strategies through an inter-site comparison between CA-SRI-512 and two additional sites from the Cardwell Bluffs area of San Miguel Island (CA-SMI-678 and CA-SMI-679). These latter two deflated Paleocoastal sites appear to have been capped by dune sands after the sites were abandoned and, like CA-SRI-512, have produced no artifacts diagnostic of middle or late Holocene occupations. The Cardwell Bluffs site complex area is currently located approximately 1-2 km from the late Pleistocene shoreline and was first recognized due to the presence of over 400 bifaces and temporally diagnostic artifacts associated with late Pleistocene and early Holocene occupations of the islands (Erlandson et al. 2011). In addition to flaked stone tools in all stages of reduction, these sites also contain several intact shell midden deposits that have produced radiocarbon dates between~12,250 to 11,200 cal BP at CA-SMI-678, whereas four dates from CA-SMI-679 average ~11,850 cal BP (Braje et al. 2013; Erlandson et al. 2011). These sites are situated atop an uplifted Pleistocene conglomerate cobble beach deposit that contains chert cobbles that seem to have attracted early mariners away from the coast for acquisition of high-quality tool-stone. As such, the occupants of CA-SMI-678 and CA-SMI-679 engaged in substantial stone tool production including early cobble testing, core reduction, and biface production; stages that were minimally represented at the seasonal hunting camp CA-SRI-512.

Chapter Four: The typological overlap between artifact forms such as lithic crescents and stemmed projectile points in the Island Paleocoastal assemblages and mainland Western Stemmed Tradition has led some (Beck and Jones 2010, 2013; Braje et al. 2019; Erlandson et al. 2020; Moss and Erlandson 2013) to propose that these island and mainland groups derived from the same Pacific Coastal Migration. As Erlandson and coauthors (2007, 2011) and Braje and coauthors (2019) have noted, even during the Last Glacial Maximum some 19,000 years ago, when sea levels were up to 120 meters lower than today, the Northern Channel Islands would have been separated from the mainland. In the terminal Pleistocene when these maritime Paleoindian populations first made their way along ancient coastlines and settled the region, the current northern island chain (comprised of Anacapa, Santa Cruz, Santa Rosa, and San Miguel) would have been one larger super island, known as Santarosae. And yet, Santarosae was still separated by at least 6 km from the mainland coast requiring some form of watercraft to successfully colonize this productive offshore environment. There are, however, no watercraft preserved for these early periods. The WST peoples who lived in the Great Basin largely settled and organized subsistence efforts around massive pluvial lakes. Typological artifact similarities and subsistence strategies suggest that Island Paleocoastal peoples and mainland Western Stemmed Tradition peoples occupying the Great Basin may have originated from the same mariner ancestry, yet, only Schulz et al. (2016) have discussed the potential role that boats may have played in the subsistence economies of WST peoples in the Great Basin.

Heizer and Massey (1953) hypothesized that tule reed bundle boats may be the oldest form of watercraft on the California coast due to their extensive distribution, a theory seconded by Gamble who pushed back the proposed use of tule watercraft to potentially the early Holocene in the California Channel Islands (2002:305). Subsequent finds of terminal Pleistocene occupations on the islands push the potential use of the tule balsa (or at least some kind of watercraft) back even earlier (Erlandson et al. 2011). Because of the lack of available data, I rely here on experimental archaeology to better understand watercraft technology and the costs of producing a simple tule boat. This chapter examines the hypothesis that boating technology provides advantages to hunter gatherers who consistently organize their settlement and subsistence strategies around large bodies of water. Building from the Paleo-Maritime Hypothesis (Schulz et al. 2016), I use the experimental construction of a tule canoe, using all stone tools, to generate actualistic data surrounding production dynamics in order to model the costs and benefits of investment in reed bundle boating technology. The chapter will examine technological investment and intensification, and compare what we know from ethnographic tule boat using cultures with the archaeological signatures of interior WST peoples to evaluate whether boat investment would have been a priority to populations living near pluvial lakes as it certainly was to populations on the coast and islands. More broadly, I ask why hunter gatherers first invest in boating technologies, and what factors may have led to decisions of such an investment?

Chapter Five: The research questions investigated in this dissertations are revisited in the end. I place special emphasis on discussing the general trends in artifact manufacturing strategies across the three Island Paleocoastal Tradition assemblages, new technological questions and implications derived from these studies as well as new insights into subsistence strategies and island-mainland connections. I also reexamine the use of watercraft as a subsistence technology not only on the islands and Pacific Coast, but also within the great Basin Pluvial Lakes. Finally, I conclude that the Island Paleocoastal Tradition should be viewed as a coastal variant of the broader Western Stemmed Tradition.

Chapter Two

PALEOCOASTAL LITHIC TECHNOLOGICAL ORGANIZATION AT CA-SRI-512, SANTA ROSA ISLAND, CALIFORNIA

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Abstract

More than 100 archaeological sites dating to the terminal Pleistocene and early Holocene have been identified on the southern California Channel Islands placing this island chain at the forefront of research regarding early maritime migrations and adaptations. CA-SRI-512 is a well-preserved Island Paleocoastal site located on the northwest coast of Santa Rosa Island and dates to approximately 11,700 cal BP. Zooarchaeological remains indicate a broad-spectrum diet including fish, sea mammals, migratory birds, and shellfish while associated stone tools include finely crafted stemmed projectile points and lithic crescents, hallmarks of the Western Stemmed Tradition. Here, for the first time, we describe the organization of Island Paleocoastal flaked stone tool production, including a distinct projectile point reduction sequence where early establishment of hafting elements on projectile points precedes the finishing of point-blade morphology. The chaine operatoire, including several point types, is overwhelmingly bifacial in nature, but also exhibits unique unifacial flake-tools.

Introduction

Some of the earliest evidence for human occupation in the Far West of North America derives from archaeological assemblages grouped under the name of ‘Western Stemmed Tradition’ (WST). Unlike western fluted (Clovis) Paleoindian assemblages, the WST is typified by stemmed projectile points, lithic crescents, and an associated Paleoarchaic subsistence system (Beck and Jones 2010). Whether these differences represent a local variation of the Clovis phenomenon is unclear but in 2010, Beck and Jones followed Erlandson and coauthors (2007) in proposing that the WST represents archaeological evidence of a distinct population movement. This group would have entered the Intermountain West (comprised of the Columbia Plateau, Snake River Plain, and the Great Basin) by following major river courses as offshoots of a maritime colonization event associated with the Pacific Coast, building upon notions originally proposed by Fladmark (1979:64).

While typological distinctions between projectile points and associated tools used by these groups have long been recognized, it is the subtle differences, especially associated with complex manufacturing decisions, that provide clues that can be used to distinguish technological traditions (Davis et al. 2012; Kuhn and Zwyns 2014). Artifacts can be produced in different ways, and the repetition of specific pathways (especially in complex production schema) may sometimes reflect systems of shared and learned manufacturing organization. Alternatively, similar artifact types or technologies can be independently invented by distinct groups (convergence) either by chance, or when faced with similar environmental pressures (Kuhn and Zwyns 2014:35, 2018:133; O'Brien et al. 2018). Such tool types can even cross existing social networks disassociated from their original inventors (Eerkens and Lipo 2005).

Beyond specific tool types, the WST assemblages are said to have a unique way of producing stone artifacts (reduction sequence) in common, and it was suggested that WST and Clovis groups represent (at least) two distinct populations who met while initially colonizing western North America towards the end of the last Ice Age (Beck and Jones 2010; Davis et al. 2012). Because WST assemblages are also defined based on similarities in subsistence strategies, a possible convergence cannot be ruled out. In the latter scenario, archaeological differences would not necessarily correspond to distinct human groups. Instead, it could also reflect the relative flexibility of a single group adapting its technology to the available resource.

So far, there are too few detailed technological studies beyond the Paleoindian and Paleoarchaic mainland record to fully evaluate proposed connections with early maritime migrations and potential antecedents. While a broader theoretical goal of this research aims to evaluate similarities and differences between Pleistocene islanders and mainlanders in the Far West, such an endeavor necessarily begins with a complete technological analysis at the local level. Here, we report the findings from the analysis of cores, bifaces, preforms, conventional points, crescents, flake tools, and debitage from CA-SRI-512 on Santa Rosa Island as a basis for the first detailed technological characterization of Island Paleocoastal Tradition (IPT) lithic technologies.

Regional Background

Some of the most compelling archaeological evidence for the late Pleistocene Pacific Coastal Migration Theory (CMT) for the maritime colonization of North America come from the southern California Channel Islands (Davis and Madsen 2020; Erlandson et al. 2007, 2011, 2015). It is difficult to associate the archaeology of the region to the Clovis phenomenon because to date, no fluted points or associated technologies have ever been recovered from the island chain. Instead, more than 100 sites dating to the terminal Pleistocene and early Holocene have now been documented, many of them containing flaked stone crescents and stemmed ultra-thin Channel Islands Barbed (CIB) points and Channel Island Amol (CIA) points (Gusick and Erlandson 2019). Although they differ from mainland projectile points in size and morphology, the presence of stemmed hafting elements on the island points, their association with crescents, and the total lack of fluted points in any Channel Islands context has led researchers to conclude that the earliest maritime hunter-gatherers in North America must be intrinsically linked to the broader WST (Beck and Jones 2009, 2010, 2015; Davis et al. 2012; Erlandson et al. 2011, 2020).

Since the general antiquity of the early island assemblages has only recently become widely known, archaeological investigations to date have necessarily centered on radiocarbon dating (Johnson et al. 2002; Erlandson et al. 2011), settlement patterns and site distribution (Gusick and Erlandson 2019; Sanchez et al. 2016; Braje et al. 2013), subsistence strategies (Erlandson et al. 2011; Gill 2016; Gill et al. 2019, 2019a, 2020), and the broader picture of the early maritime peopling of the Americas (Erlandson et al. 2007, 2015; Erlandson and Braje 2011; Braje et al. 2019). Studies of Island Paleocoastal lithics have concentrated on establishing typologies (Glassow et al. 2013; Erlandson 2013), understanding resource procurement and material qualities (Jew and Erlandson 2014; Jew et al. 2013), heat treatment (Jew and Erlandson 2013), and deciphering potential artifact function(s) (Glassow et al. 2013:193; Moss and Erlandson 2013). While our understanding of early island settlement has vastly improved over the past few decades, the organization of Island Paleocoastal lithic tool production is not yet fully understood. Technological analyses of diagnostic stone tools and all artifact forms associated with potential reduction systems, in a site specific approach similar to what has been done in mainland contexts (Morrow 1995; Beck and Jones 2009), would be beneficial to more accurately evaluate the potential ties between the earliest island assemblages and the broader WST.

Materials and Methods

CA-SRI-512 is located on an uplifted marine terrace east of the mouth of Arlington Canyon on Santa Rosa Island (**Figure 1**). It is located near where the remains of Arlington Man, ^{14}C dated to ~13,000 cal BP, were found in 1959 (Johnson et al. 2002). The site was excavated between 2009 and 2012 by a team led by Jon Erlandson and Torben Rick and funded by the National Science Foundation. Diagnostic material was collected from the slopes below an exposed paleosol, while1x1 meter units were excavated from within the paleosol itself using trowels, brushes, and scoops. Excavation proceeded in arbitrary 10 cm levels, and all earth (except for bulk samples) was dry-screened using standard 1/8" mesh. Site stratigraphy includes six paleosols formed since the terminal Pleistocene. Due to a lack of burrowing animals on the California Channel Islands, CA-SRI-512 exhibits little to no stratigraphic mixing between the lithological units, and cultural materials were capped by sterile alluvium varying from a few centimeters to over two meters thick (Erlandson et al. 2011). The assemblage includes well preserved bird, fish, and marine mammal bones, poorly preserved shellfish remains, associated lithics, bone tools, and red ochre. The far eastern portion of the site contains a small late Holocene shell midden eroding from a higher (A2) soil, but no waterfowl remains or typical Paleocoastal artifacts been recovered from this late Holocene portion of the deposit. Additionally, a diffuse lithic scatter overlies portions of the Paleocoastal component but it is separated from it by approximately 1.5 meters of sterile deposit.

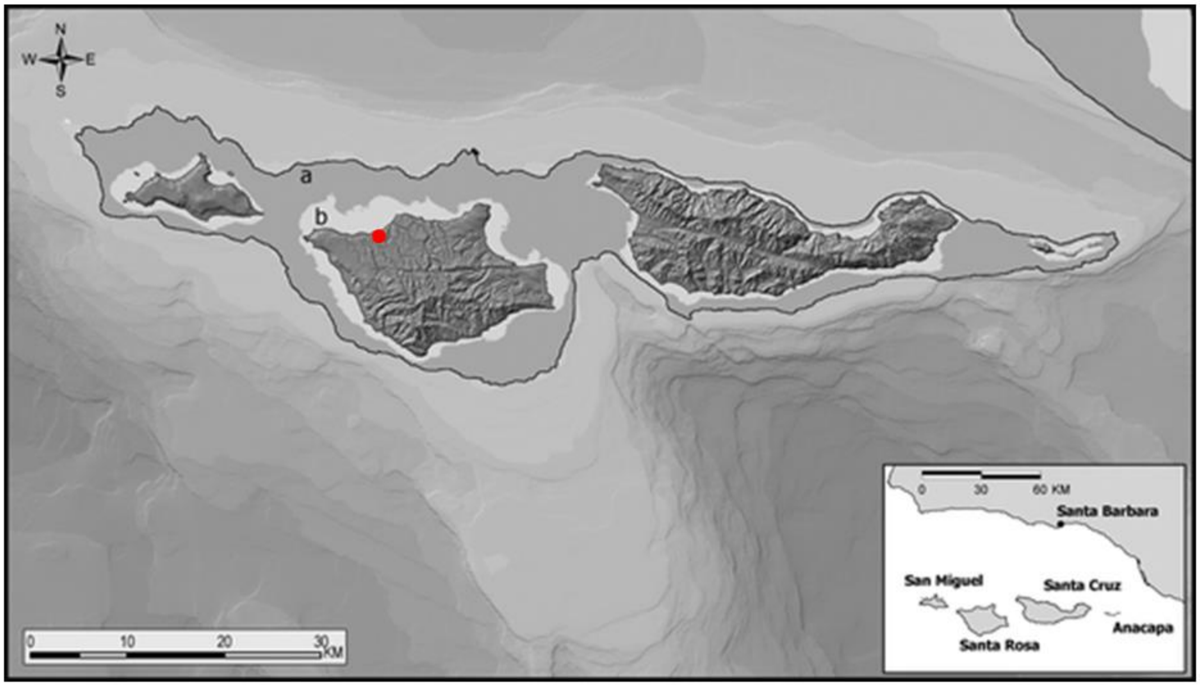

Figure 1. Map of CA-SRI-512 (red dot) in relation to paleo-shorelines at a) 13,000 cal BP and b) 9,000 cal BP (adapted from Watts et al. 2011).

The faunal assemblage from CA-SRI-512 is dominated by thousands of migratory waterfowl and sea-bird bones. Species include albatross (*Phoebastria albatrus*), cormorant, (*Phalacrocorax* spp.), snow geese (*Chen caerulescens*), Canada geese (Branta canadensis) in addition to smaller numbers of fish and sea mammals. It has been hypothesized that some CIB types could have been used in hunting these migratory birds (Glassow et al. 2013: 193). In the absence of well-preserved marine shell, charcoal from *Ceanothus* sp., a short lived species, and collagen and mineral carbonate from goose bone were selected for radiocarbon dating in the paleosol associated with the Paleocoastal occupation. The dates suggest that the site was occupied between ~11,800-11,500 cal BP (**Table 1**). Flaked stone tools recovered during surface collection and excavations include cores, flake tools, bifaces, debitage, stemmed projectile points, and crescents (Erlandson et al. 2011).

Table 1: AMS ^{14}C dates from CA-SRI-512. All dates are for single bone or charcoal fragments, measured via accelerator mass spectrometry (AMS); calendar age ranges, expressed at 1σ, were calculated in CALIB 6.0, using a Δ*R* of 225 ± 35 for marine samples. UF, ultrafiltration (adapted from Erlandson et al. 2011).

CA-SRI-512	Material Dated	Lab Number	Measured Age	Calibrated age range (cal BP)
A6 paleosol	Goose bone (XAD extract)	UCIAMS-59871	10,000 ± 30	11,600-11,355
A6 paleosol	Goose bone (XAD extract)	UCIAMS-59872	10,045 ± 40	11,700-11,405
Burned stump on slope below A6 paleosol	*Ceanothus* charcoal	Beta-261353	10,090 ± 50	11,820-11,410
A6 paleosol	Goose bone (UF)	OS-68030	10,150 ± 40	11,970-11,730
A6 paleosol	Charred twig	UCIAMS-60751	10,155 ± 30	11,960-11,760
Below A6	*Ceanothus* charcoal	OS-75147	10,200 ± 45	12,010-11,820

Formal lithic artifacts (n=179) coming from eight units excavated over two field seasons at CA-SRI-512, but also a systematic surface collection that targeted the recovery of all bifaces, formal tools, cores, and diagnostic artifacts (**Table 2**), were analyzed at the University of Oregon's Island and Coastal Archaeology Laboratory. The sample includes all bifaces, formal tools, and diagnostic artifacts from excavated units and surface collections, and a debitage-specific analysis conducted on an assemblage of approximately 1,900 flakes, fragments, shatter, and potlids recovered from the two most artifact-rich units; units 4 and 8.

Table 2: Frequency of Formal Artifacts Recovered from CA-SRI-512.

CA-SRI-512					
	Surface		**Excavated**		
Artifact	**n**	**%**	**n**	**%**	**Total**
Cores	7	6%	8	13%	15, 8%
Production Bifaces	23	20%	13	20%	36, 20%
CIB's	32	28%	7	11%	39, 22%
CIB Preforms	15	13%	5	8%	20, 11%
Late Bifaces & Misc. Points	3	3%	3	5%	6, 3%
Crescents	10	9%	4	6%	14, 8%
Crescent Preforms	4	4%	3	5%	7, 4%
Flake Tools	21	18%	21	33%	42, 24%
Total	**115**	100.0%	**64**	100.0%	**179,** 100.0%

Lithic Analysis

Qualitative and quantitative lithic artifact analyses were non-destructive in nature and adapted from Amick (1999), Andrefsky (2005), Inizan et al. (1999), and Beck and Jones (2015). These analyses included an inventory of all lithic artifacts, qualitative assessments of specific features, and quantification of various attributes. When applicable, artifacts were evaluated on their condition of preservation, biface stages of reduction, flake scar orientation, flake scar morphology, platform preparation, cross-section and profile shape, and associated lithic reduction methods and techniques. Early and middle-stage bifaces were separated from late-stage bifaces based on criteria adapted from Beck and Jones (2015) and Andrefsky (2005). Late-stage bifaces exhibiting morphology closely resembling point or crescent shape, but also clear sinuous edges, un-flaked platforms, step-fractures, and knapping flaws were analyzed separately as potential preforms on a production trajectory towards diagnostic known flaked stone tool types. Diagnostic typological assignments were derived from Glassow et al. (2013), Erlandson (2013), Hopkins and Fennenga (2010), Tadlock (1966), and Justice (2002). Length was measured along the longest access of complete bifaces, preforms, and points. Width measurements were taken at the widest point perpendicular to length and thickness was taken at the thickest point (**Figure 2**). Length, width, and thickness of fragments were measured the same way. For example, if the longest measure of a biface end fragment was at the width of a formerly complete biface, this measure was still considered the width and the length was taken along the axis perpendicular to that with a note that it was fragmented. Fracture types were assigned to crescent and crescent preforms according to standards outlined by Amick (1999:163). While a gloss-meter was not used, evidence for heat exposure was analyzed by adapting methods from Jew and Erlandson (2013), including using a 10x jewelers loop to evaluate which items clearly had evidence for heat spalling and crazing. Analysis of cobble tools, ochre, and manuports was also non-destructive in nature, and methods were adapted from Adams (2002). These analyses included basic quantitative measurements of artifact metrics and qualitative assessments of potential wear patterns such as battering and abrasion that may have resulted from artifact use.

In addition to analyses carried out on formal flaked stone tools, debitage recovered from excavated units (unit 4 and unit 8) were chosen for more detailed analyses due to high lithic artifact density. Debitage was sorted into size groups of 1", 1/2", 1/4", and 1/8" using US geological standard graduated screens. In the 1" or greater category, intact flakes (with platforms) and those exhibiting more than 50% of their original length (but missing a platform) were subjected to individual analysis as potential tool blanks for the production of formal artifacts (such as projectile points). More general lithic attributes recorded for smaller size fractions including material type, presence of cortex, frequency of thermal affects, platform preservation, and general associated reduction methods and techniques. Debitage in the size classes below 1" were also divided into flakes, shatter, and flake fragments, and when possible were subdivided and classified as associated with core reduction, biface reduction, or retouch. For the screened material, no attempt to distinguish between pressure or percussion retouch flakes was made. Debitage artifacts were organized into core reduction flakes, biface reduction flakes, retouch flakes, flake fragments, shatter, and potlids.

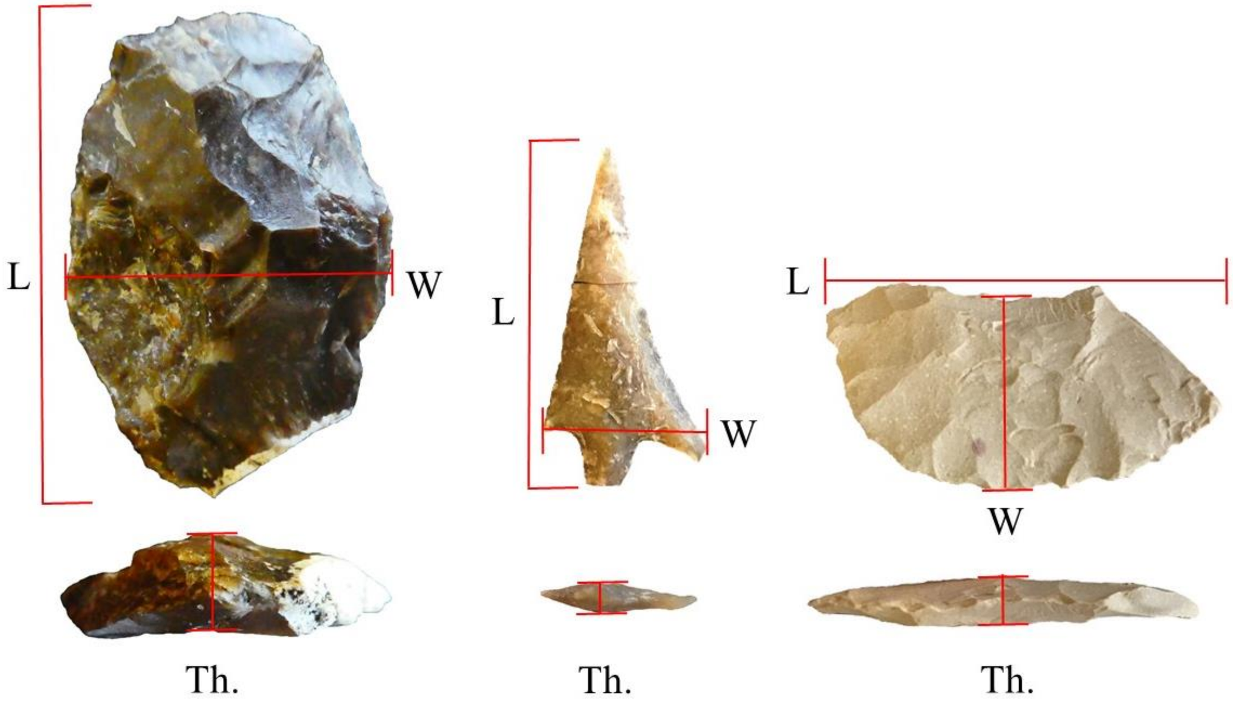

Figure 2. Location of measurements taken on major artifact categories. (Artifacts not to scale).

Wear-Pattern Analysis

A sample of ten lithic flake tools were selected at random from the broader assemblage of 42 used and retouched flakes and were subjected to specific wear pattern analysis. Micro-wear was performed using a 10-70x stereo-microscope (Bausch & Lomb Stereo zoom 7) to analyze these artifacts for macro and micro-wear patterns. Tools were first analyzed with the naked eye and 10x hand lens for macro-flaking patterns. Next, the artifacts were analyzed for micro-wear under 50-70x power microscopy to determine potential contact materials, number of utilized edges, and invasiveness of polish on ventral and dorsal surfaces.

Results

The CA-SRI-512 assemblage is dominated by eight major artifact classes including cores, bifaces, Channel Islands Barbed (CIB) preforms, CIB points, miscellaneous points, crescent preforms, crescents, and modified flake tools. The following section summarizes the results of qualitative and quantitative analyses of these artifact classes, a sample of debitage, and a few miscellaneous lithic artifacts. I propose a parsimonious reduction sequence model in the discussion and I briefly discuss the strength, weaknesses and implications of the model.

Cores (Tabular Pebble and Bifacial):

Artifacts considered to be potential cores and core fragments were those lithics exhibiting prominent cortex and yet lacking a ventral face (indicative of a cortical flake), with unprepared platforms or thick prepared but un-flaked platforms, with at least one remnant negative from a flake removal. While some cores can occur in a state with no cortex present, especially when field-processed, only one bifacial piece (described later) was of sufficient size to be considered as such. Fifteen small tested tabular pebbles, pebble core fragments, and a single bifacial core (measured separately) were identified within the assemblage (**Table 3**). Tested water-worn (neo-cortical) flattened tablets dominate the collection (n=11; 73%) suggesting that site occupants may have selected pebbles with specific flattened morphology. An additional three (20%) fragments bear evidence of flattened neocortex on a single face and seem to have also been reduced from water worn tabular pebbles. Out of the 15 tested pebbles, pebble cores, and fragments, all exhibited neocortex indicative of Tuqan chert (an island variant of Monterey Chert typified by a white weathered rind) (Erlandson et al. 2008) (**Figure 3**). Neocortex indicates water tumbling and tool stone acquisition from a source distant from primary outcrops. On San Miguel Island and Santa Rosa Island, Tuqan chert is most often found in raised beaches on uplifted ancient marine terraces or in alluvium derived from their reworking (Jew et al. 2013:53-54). In addition to chert cores/core fragments likely associated with the broader production of formal flaked stone artifacts on site, a single meta-volcanic and a single quartzite cobble core-tool were also present. These artifacts are inferred to have functioned not as cores for flake production, but instead as core tools/choppers due to the presence of fine unifacial retouch along the working edges of both artifacts.

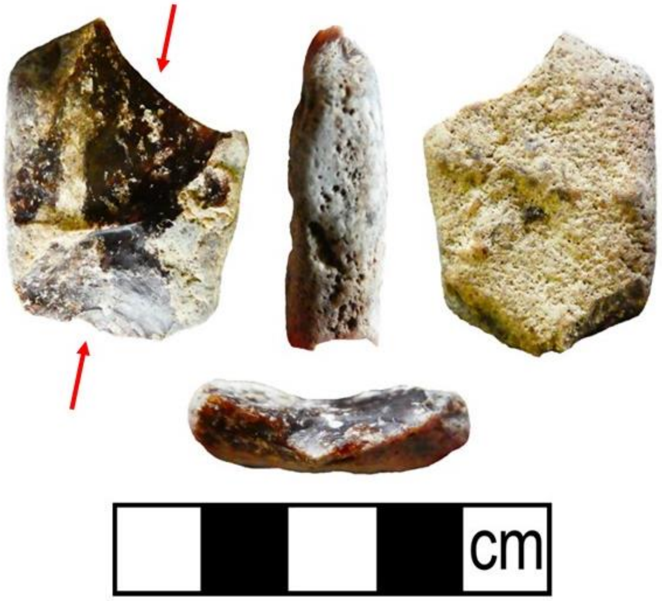

Figure 3. Tuqan/Monterey tested pebble-core. Note the bi-directional removals indicated by red arrows on one face and the neo-cortical white weathered rind.

Though the core assemblage here was largely comprised of tested cobbles and cobble fragments, a single specimen shows how difficult it can be to differentiate bifacial tools from bifacial core preforms. This Tuqan chert artifact is typologically a biface (and described as such later in this study) although it lacks morpho-functional details such as marginal retouch. Hence technologically, it can be characterized as a bifacial core. From such a small sample (n=1), it is not possible to evaluate the significance of this artifact form, but it is interesting to note a few features that set this artifact apart from other bifaces in the assemblage. The presence of a single large end-struck negative (measuring 45.24 x 27.32 mm) on one face (**Figure 4a**), and a similar negative on the opposite face indicating that one function of this artifact could have also been the production of small flake-blanks. Interestingly, the second negative described above could not be measured as the flake scar has been largely obscured by a subsequent removal exhibiting extensive crazing within the negative (**Figure 4b**). The relatively large removals on a small artifact are rare, and with the exception of this biface/bifacial core, the cores and core fragments exhibit no observable diagnostic features associated with heat-induced changes. It could indicate a relative flexibility in the use of tools, which can also be (re-)knapped to produce flakes.

Figure 4. Tuqan chert biface/core exhibiting a) large end-struck removal, and b) removal with heat-induced crazing.

In general, tabular pebble cores are so fragmented, or were discarded so early in reduction due to internal flaws, that they are less informative on subsequent stages of reduction than examples found in quarry contexts. In most cases, chert pebbles appear to either have been tested through the removal of one or more cortical or secondary core reduction flakes along flat faces (often the same face), with no platform preparation: i.e., cortical in nature. A few specimens also exhibit clear evidence of alternate flaking along margins, and in some cases, longer negatives indicate that flakes were struck from bifacial platforms converging closer to the profile mid-line, or slightly above the midline from a previous marginal preparation removal (essentially functioning as a non-cortical plain striking platform). Keeping in mind the small sample size and generally small size and fragmented nature of these pebble cores, three do bear evidence of the removal of slightly larger flakes (22-27mm long and ~25mm long) from flattened faces (possibly for later use as smaller tool blanks). Some of these pebbles were so thin to begin with (~6-8mm), that they appear to have been tested with the likely goal of near-immediate biface reduction rather than prolonged use as flake cores. Two such specimens appear to have been rapidly abandoned after testing due to a heterogeneous interior stone structure. All in all, there is little evidence for a systematic blank production independent from the early stages of bifacial reduction.

Bifaces:

A total of 36 bifaces recovered from surface and excavated contexts was analyzed (**Table 3)**. While thin late-stage bifaces likely reflect tool preforms or foliate points and were analyzed separately, the thicker and more generic bifaces and biface fragments analyzed here largely represent early and intermediate stages of production. As only the minority of the assemblage (n=4; 11%) exhibited any cortex, evaluating the frequency of the Tuqan chert material type (identifiable by its cortex) was not possible. Still, 3 (8%) of the four artifacts with cortex did exhibit traits consistent with local Tuqan chert. The remaining bifaces were made from Monterey chert (n=30, 83%), Wima chert (n=1; 3%) and Cico chert (n=1; 3%). Wima cherts have previously been identified on Santa Rosa Island, and are characterized as opaque and cherty-shales ranging widely in color (Erlandson et al. 2012). Cico cherts are chalcedonic, cloudy to semi-translucent, island variants found in outcrops and raised beach deposits on several of the Northern Channel Islands (Erlandson et al. 1997; Jew et al. 2013:53-54). Flaking patterns that could be distinguished on bifaces and fragments are dominated by irregular flaking (n=22; 61%), followed by parallel-collateral flaking (n=10; 28%) and broad collateral flaking (n=3; 8%). Seven (19%) appeared solely percussion flaked, while eight (22%) exhibited a pressure-over-percussion signature, and 21 (58%) appeared pressure flaked (Inizan et al. 1999:146). Only four (22%) bifaces appear to have been made on flakes, and one on a pebble (3%), while the majority of the assemblage (n=31, 86%), was too reduced to determine. Finally, eight (22%) of the bifaces exhibit some diagnostic features of burning (including potlidding and/or crazing). Overall, the biface assemblage is comprised of middle-stage reduction. Many late-stage bifaces were analyzed separately and considered as finished tools or preforms based on overall morphology. Specimens, clearly distinct in shape, with attributes more indicative of preforms, (i.e., un-flaked platforms, sinuous edges, and overall asymmetry) are described as such in the sections that follow.

Table 3: Summary of Quantitative Data for Cores and Bifaces.

Variable	Statistic	Class	
		Bifaces	**Cores/Fragments**
Total Length (mm)	n	2	2
	Range	41.6-61.3	38-41.5
	Mean	51.4	39.8
	SD	9.9	2.5
Maximum Width (mm)	n	12	6
	Range	11-41.7	25.3-37.3
	Mean	24.7	29.6
	SD	9.3	4.8
Maximum Thickness (mm)	n	25	15
	Range	2.8-13.7	6-14.1
	Mean	6.4	9.9
	SD	2.9	2.1
Actual Weight (g)	n	36	15
	Range	0.2-38.8	3.8-17.3
	Mean	4.9	10.1
	SD	7.1	4.5

Crescents:

Seven crescent preforms, or possible crescent preforms, were identified within the CA-SRI-512 assemblage (**Table 4**). Crescent preforms were identified based on qualitative and morphological variables including overall size and shape, the presence of sinuous edges and prepared but un-flaked platforms, patterns of edge grinding, and a degree of bilateral asymmetry (**Figure 5a and 5b**). While one or two of these attributes on their own may not have been enough to conclude that the artifact was an unfinished crescent in production rather than a finished artifact, taken as a whole, these traits seem to represent crescents abandoned or lost before they were finished. Crescent preforms were overwhelmingly produced on Monterey chert (n=6; 86%) with only a single specimen (14%) manufactured on Wima chert. The dominant flake scar pattern in the assemblage was parallel-collateral (n=5; 71%), and two (29%) exhibiting more irregular flake negatives.

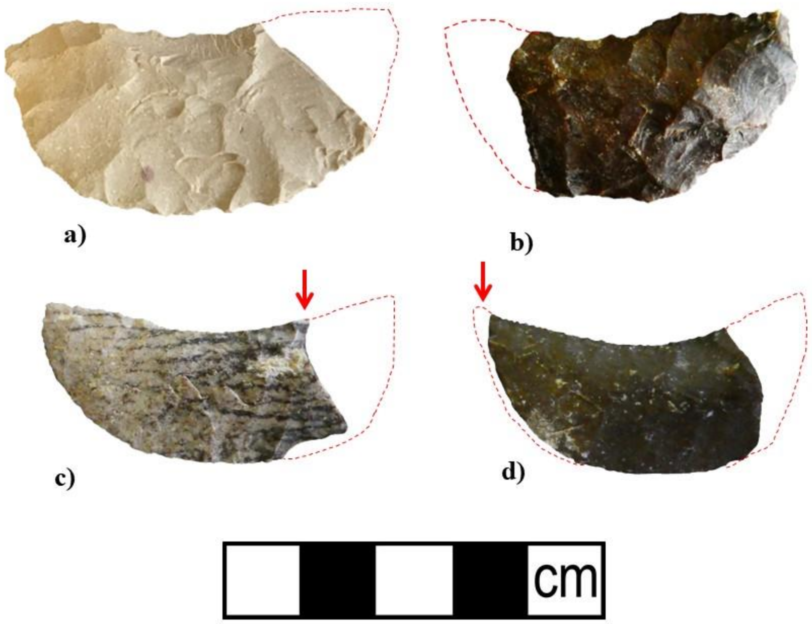

Figure 5. a) Wima chert crescent preform, b) Monterey chert crescent preform, c) crescent with "rotation-burination" indicated by arrow, d) crescent with burination indicated by arrow. Dotted line reconstructions based on known typology.

Abrasion patterns were also evaluated, with edge grinding being found on four (57%) preforms, but concentrated to un-flaked platforms in two (29%). Another specimen exhibited grinding around all edges, while the remaining artifact appeared abraded in the center proximal and distal edges similar to patterns observed on many finished crescents (Amick 1999; Tadlock 1966). Two preforms (29%) were complete, while the remaining five (71%) were missing a single wing/end.

One preform, may not have been functional as it was a very peculiar piece made on light and extremely fragile Monterey calcareous material. This particular preform sustained an undetermined break. The remaining four crescent preforms exhibiting breakage, sustained fractures indicative of bending (n=2; 29%) and snapping (n=2; 29%). No evidence for retooling was observed; however, one preform did bear clear evidence of thermal alteration. Finally, while preforms do not always perfectly conform to diagnostic typologies, it should be noted that three of these specimens loosely fit within Tadlock's type 1 "quarter moon" crescent category and another appears close in morphology to Tadlocks type 3 "winged" crescent.

Fourteen crescents were identified within the CA-SRI-512 assemblage (**Table 4)**. Finished crescents were identified based on qualitative and morphological variables including overall size and shape, the absence of sinuous edges and prepared but un-flaked platforms, patterns of edge grinding, and a degree of bilateral symmetry, setting them apart from crescent preforms. Although size and shape are subject to categorical bias, it is worth noting that while differences in width (U = 31, p = 0.3749) and thickness (U = 35.5, p = 0.6119) are only subtle, these variables are more standardized in crescents than preforms. It is particularly the case with the thickness with coefficient of variations of 16.3 and 31.6 respectively (one-tailed Flingner-Killeen test; T=8.792, p=0.0356). All 14 crescents were made on Monterey chert, 12 (86%) were produced using a parallel-collateral flaking method, while two (14%) were manufactured using a more irregular flaking pattern. Thirteen (93%) were fully bifacial, while a single specimen (7%) exhibited covering retouch on one face and marginal-to-invasive retouch on the other, a type Amick (1999) refers to as being made on "edged flakes."

Edge grinding was present on 12 (86%) crescents, but only one (7%) exhibited grinding solely on striking/pressure platforms. Three crescents (21%) were complete, two (14%) were wing fragments, two (14%) were mid sections, while the rest (n=7; 50%) were missing one wing. Since several fractures were present on the same crescent in some instances, percentages here are reported from a total of 17 observed breaks on the 14 crescents. Fracture types were assigned to crescents based on Amick (1999:163, Fig 14.I.); however, Amick's use of the general term "burination" as a designation for several types of crescent margin spalls was expanded. Here, the term "rotational-burination" was used in addition to "burination" (**Figure 5c**) to distinguish a subset of burin-like breakage patterns with distinct morphology. Such fractures can be identified by features including a generally straight break originating from the distal edge, followed by a change in the fracture direction, resulting in a burination of the proximal edge as illustrated in (Figure 4d**)**. The rotational-burination appears to be is the result of a rotational force applied to the crescent body as the wing is violently detached. In total, fractures included classic burinations (**Figure 5d**) (n=5; 29%), rotational-burinations (n= 2; 12%), bending fractures (n=6; 35%), snaps (n=3; 18%), and a single edge bite (6%) that occurred on the proximal edge at the interface with a calcareous inclusion.

Only a single crescent (6%) from the assemblage exhibited clear thermal alteration, and two (12%) exhibited retooling. Finally, seven (54%) could reliably be fit into Tadlock's (1966) type 1"quarter moon" category, three (21%) fit Tadlock's type 2 "half-moon" category, and one (6%) best fit as a concave base lunate that somewhat resembled Tadlock's type 3 "winged" crescent category, although it is more elongated.

Table 4: Summary of Quantitative Data for Crescents and Crescent Preforms.

Variable	Statistic	Class	
		Crescent	**Crescent Preform**
Total Length (mm)	n	3	2
	Range	43.9-48.1	42.9-44.8
	Mean	46.5	43.8
	SD	2.4	1.3
Maximum Width (mm)	n	12	7
	Range	14.3-24.2	13.4-23.9
	Mean	18.4	20.2
	SD	3.4	5
Maximum Thickness (mm)	n	12	7
	Range	3.8-6.1	4.1-8.2
	Mean	4.9	5.6
	SD	0.8	1.8
Actual Weight (g)	n	14	7
	Range	1.5-3.9	2.4-9.9
	Mean	2.8	5.1
	SD	1	2.5

Channel Islands Barbed Points:

Channel Islands Barbed (CIB) point preforms were identified by general size and shape, the presence of unflaked sinuous edges, asymmetry, lack of established barbs, and general thickness (**Figure 6**). When considering both surface and buried material, preforms (n=24) are thicker than points (n=38) (U = 206, p = <0.01) and slightly less standardized in thickness (coefficient of variation of 29.971, and 23.008 respectively). The median width is similar between the two categories, with coefficient of variations of 16.3 and 31.6 respectively but this variable is far more standardized among points (n=40) (coefficient of variation of 29.84, and 12.897 respectively; two-tailed Flingner-Killeen test; T=42.653, p=<0.01). Twenty Channel Island Barbed (CIB) point preforms were identified within this assemblage in a condition complete enough for analyses (**Table 5)**. Of the 20 point preforms, 11 (55%) appear complete or nearly complete, 1 (5%) is a mesial fragment, 7 (35%) are mesio-proximal fragments, and 1 (5%) is a proximal fragment. Three (15%) bear clear evidence of fire affects, while the remaining 17 (85%) show no distinct features of burning. The assemblage is dominated (n=14; 70%) by a chevron flake scar pattern, while a minor portion (n=3; 15%) were parallel collateral and irregular. Almost all CIB preforms (n=18; 90%) appear to have been produced through pressure flaking, although two (10%) show evidence of pressure following percussion flaking. Just over half of the assemblage (n=11; 55%) consist of complete or nearly complete preforms, while the rest are comprised of mesio-proximal fragments (n=7; 35%), a mesial fragment (5%) and one fragment (5%) that could not be determined.

Figure 6. Channel Islands Barbed point preforms (top row) and Channel Islands Barbed points (bottom row). Note the unique shape of the preforms already exhibiting incipient barbs and stems before the points were finished. Dotted line reconstructions based on known typology.

Thirty-nine Channel Islands Barbed (CIB) points were identified within this assemblage in a condition complete enough for analyses (**Figure 6**). In addition, 37 potential point and point preform fragments were also identified here but were excluded from most analyses due to small size or extremely fragmented condition. However, it should be noted that 20 of these fragments share morphology with CIB tips or barb-tips. Of the population of 39 CIB's described here, 13 (33%) were complete or nearly complete, 11 (28%) were mesial fragments, 6 (15%) were mesio-distal fragments, 6 (15%) were mesio-proximal fragments, and three (8%) were proximal fragments. Twelve (31%) were clearly fire affected, while the remaining 27 (69%) did not show clear signs of burning. Thirty-two (82%) were manufactured on Monterey chert, while four (10%) were made on "island" chert, two (5%) were Cico chert, and a single example (3%) was identified as Tuqan chert. All 39 points were produced through pressure flaking, while 35 (90%)

exhibit a chevron flake scar pattern, two (5%) were parallel-collateral, one (3%) was irregular, and one (3%) could not be determined.

Table 5: Summary of Quantitative Data for Channel Islands Barbed Points and Preforms.

		Class	
Variable	**Statistic**	**CIB**	**CIB Preform**
Total Length (mm)	n	2	9
	Range	28.8-36.4	30.6-47
	Mean	32.6	34.6
	SD	5.4	6.2
Maximum Width (mm)	n	15	13
	Range	16.4-24.2	10.6-26.9
	Mean	20.9	20.1
	SD	2	5.4
Maximum Thickness (mm)	n	35	19
	Range	1.8-4.8	1.2-6.9
	Mean	3.0	4
	SD	0.7	1.3
Actual Weight (g)	n	39	20
	Range	0.4-2	1.2-6.9
	Mean	0.9	4
	SD	0.3	1.3

Miscellaneous Points:

In addition to the CIB's and associated preforms, six less standardized points were also identified, some exhibiting a general foliate morphology (**Figure 7**). These late-stage bifacially-worked artifacts exhibit a general foliate or shouldered morphology and are typically thicker than CIB's and CIB preforms (**Table 6)**. Four (67 %) of these artifacts were manufactured on Monterey chert, while a single specimen was made from Cico chert (17 %), and one from island chert (17%). The parallel collateral flake scar pattern seems to dominate these bifacial artifacts (n=3; 67%) while the remainder are divided between chevron (n=2; 33%) and irregular (n=1; 17%) flake scar patterning. All of these items appear to have been produced exclusively through bifacial covering pressure flaking, although the single Cico chert specimen is predominantly flaked on one face with only long-to-invasive flaking on the other. Five (83%) are complete or nearly complete, while a single artifact (17%) is a mesial fragment. A burin spall along the margin of one specimen is likely from impact; however, it is possible that some of these foliate and shouldered artifacts were used as knife blades in addition to or instead of as points.

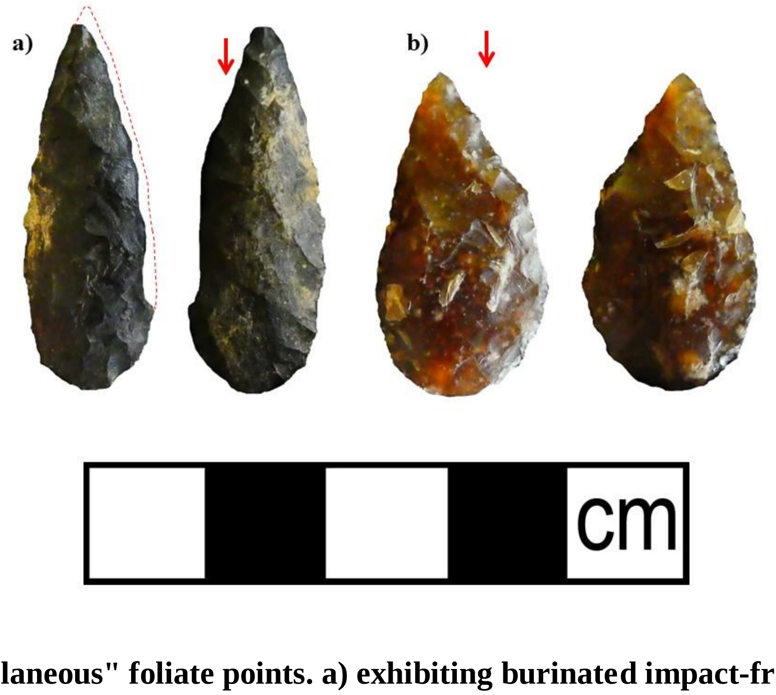

Figure 7. "Miscellaneous" foliate points. a) exhibiting burinated impact-fracture from use as a projectile point, and b) exhibiting off-axis retouch possibly indicative as use as a knife blade.

Scrapers and Flake Tools:

Forty-two flake tools and scrapers were also present within the assemblage (**Figure 8**) ranging in size and shape (**Table 6)**. Sixteen (38%) of these artifacts exhibited neo-cortex, two (5%) had possible primary cortex, and the remaining 24 (57%) exhibited no cortex. As cortex was visible on at least some specimens, 11 (26%) were successfully identified as Tuqan chert. The remaining population was comprised of Monterey chert (n=25, 60%), Cico chert (n=2; 5%), undetermined chert (n=3; 7%) and Wima chert (n=1; 2%). The flake blanks on which these tools were produced ranged from secondary core reduction flakes (n=15; 36%), to decortication flakes (n=12; 29%), to early biface reduction flakes (n=10; 24%), with four blanks (10%) being unidentifiable, and a single specimen (2%) was not made on a flake at all. While 16 (38%) were made on complete flakes, the remainder of the population was distributed between seven (17%) mesial flake fragments, six (14%) proximal fragments, five (12%) distal fragments, four (10%) mesio-distal fragments, three (7%) mesio-proximal fragments, and one (2%) undetermined fragment. Platforms were not present on 19 (45%) specimens however, of those with platforms, 12 (29%) were facetted, seven (17%) were cortical, and four (10%) were plain. Interestingly, 19 (45%) exhibited direct retouch, while only one (2%) exhibited bifacial retouch. In addition, 40 (95%) exhibited either direct retouch overlaid with smaller removals from use (also originating from the ventral and climbing on to the dorsal surfaces), and only one (2%) exhibited small removals from use along the ventral edge (originating from the dorsal plane) similar to inverse retouch from use. It is also worth noting that only four (10%) of these artifacts appear burned. Interestingly, convex scrapers are rare in comparison to concave scraping tools within the assemblage.

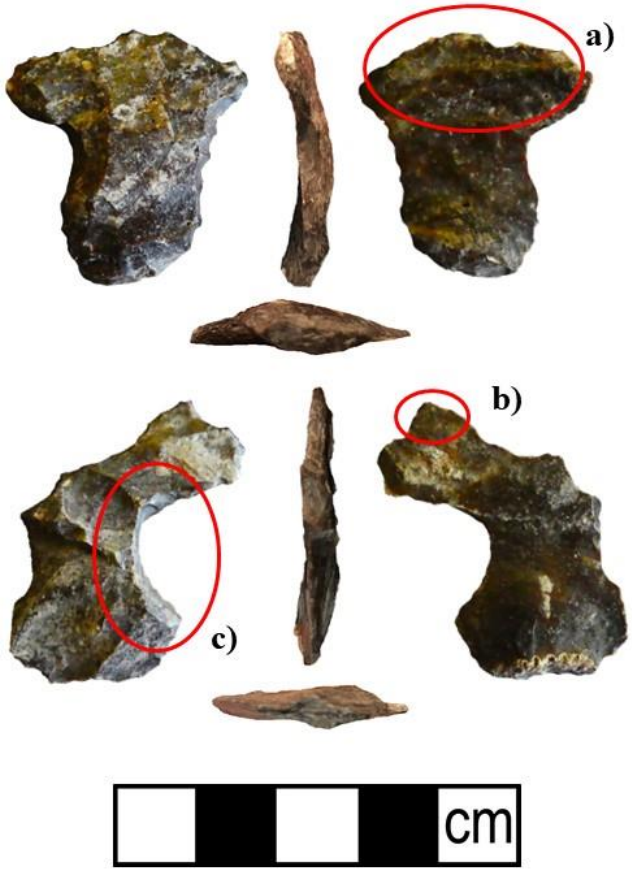

Figure 8. Modified flake tools exhibiting morphology consistent with multiple functions. a) convex scraper edge, b) concave "spokeshave" scraper edge, and c) pointed graver tip.

Table 6: Summary of Quantitative Data for Flake Tools and Miscellaneous Points

		Class	
Variable	Statistic	Scrapers & Flake Tools	Misc. Points
Total Length (mm)	n	40	4
	Range	17.6-59.3	26-50.4
	Mean	31.2	36.3
	SD	9.2	10.2
Maximum Width (mm)	n	42	4
	Range	27.4-50.2	12.4-18.8
	Mean	25.9	14.8
	SD	6.3	2.8
Maximum Thickness (mm)	n	42	6
	Range	6.8-11.6	2.7-4.8
	Mean	7.3	4.2
	SD	3.0	0.8
Actual Weight (g)	n	42	6
	Range	5.6-32.4	0.8-3.6
	Mean	6.4	1.9
	SD	5.6	1.0

Use Wear Patterns of flake tools

We identified a total of fifteen utilized edges out of 36 edges analyzed on the ten flake tools sampled for wear-patterns. A variety of uses on tool-edges include scraping, cutting/sawing, and graving. Polish types associated with certain uses are consistent with processing materials classified as hard, medium, and hard-medium according to standards outlined by Stevens and coauthors (2010). Eight tools exhibit wear patterns consistent with predominant use on hard contact surfaces (hard woods, bone, antler, etc.) identified by high frequencies of micro-chipping, micro-stepping, and snaps along working edges. Polish consistent with hard contact materials tends to exhibit low, invasive polish along micro-chipping flake scar arrises and high spots associated with stepped and snapped margins along used tool edges. The second most prevalent polish type in the sample is consistent with hard-medium contact materials and increases in invasive polish along utilized tool margins, as well as reduced snapping and stepping along the edge. Six edges on four tools (cat # 130, 418a, 683, 706) exhibit patterns identified by invasive polish along utilized edges, often occurring further into micro-chipping flake scars, and overlaying retouch flakes that have occurred along the edges as well. One tool edge exhibited wear-patterns most typical of medium contact material edge-utilization, which was identified by the presence of micro-chipping, low amounts of stepping, and no snapping along the utilized edge. This type of wear-patterning is indicative of use on many different contact materials which can include soft woods and raw hide. Out of the tools analyzed, four were retouched, five were use-modified tools, and one was a reworked tool form.

Miscellaneous Lithic Artifacts:

In addition to the major artifact classes outlined in previous sections, several peculiar lithic artifacts were also present. Two cobble choppers, one of meta-volcanic measuring 87.06mm x 65.89mm x 38.85mm, and weighing 280.87g, and another of quartzite measuring 79.65mm x 49.74mm x 31.61mm, and weighing 125.83g, were observed. Both of these artifacts exhibit a single unifacially percussion flaked margin with fine unifacial retouch overlying initial flake removals. A single amorphous piece of incised red ochre, and a single fragment of soft silicious shale with several parallel incisions were also noted. Finally, one chalky calcareous cobble hammer stone exhibiting flattened faces from use, was also observed.

Debitage:

Debitage from the two richest units (Unit 4 and Unit 8) were selected for analysis. Stone tool debris were classified by flake type, as flake fragments, shatter, or potlids (heat spalls). A total of 886 such artifacts were analyzed from unit 4 and an additional 1075 were analyzed from unit 8. Material selection strategies between unit 4 and unit 8 are essentially the same (X^2 (2, n = 1958) = 1.129, p =0.5686) with a clear preference for Monterey chert (likely Tuqan chert) with significantly less emphasis on Wima, Cico, and other material types (**Table 7**). It is unclear if the preferential use of Monterey/Tuqan cherts over other material types reflects distance to potential sources or some other desired quality such as homogeneous raw material structure. Erlandson has noted a broader preference for Monterey/Tuqan chert, however, as a strong pattern among Paleocoastal sites on San Miguel and Santa Rosa Islands.

When debitage categories are broken down by flake type (**Table 8)** including flake fragments, shatter, and potlids, it becomes evident that fragmented flakes represent one of the highest frequencies in the debitage assemblage. This high fragmentation rate is somewhat deceiving until one takes into account the thin and fragile nature of the assemblage that is overwhelmingly dominated by retouch and to a lesser degree by biface reduction flakes. Since late-stage bifacial reduction includes thin and long flakes (including pressure-thinning flakes) it should come as little surprise that ca. 35% of are fragmented in Unit 4 and Unit 8. While some fragmentation surely occurred in post-depositional contexts, many long and thin flakes are also prone to fragmentation at the time they are detached from middle and late stage bifaces, preforms, crescents and conventional points. When only flakes exhibiting platforms are examined, a clear parallel between the units emerges. Both units are dominated by retouch flakes (pressure and percussion), followed by biface reduction flakes and to a much lesser extent, core reduction flakes.

Table 7 Debitage type breakdown

CA-SRI-512, Unit 4 Debitage

	Monterey		Cico		Other		Total	
	N	%	N	%	N	%	N	%
Core Reduction	9	1.1	-	-	4	6.6	13	1.5
BF Reduction	126	15.7	1	5	13	21.3	140	15.8
Retouch	318	39.5	9	45	17	27.9	344	38.8
Burin Spall	4	0.5	-	-	-	-	4	0.5
Flake Fragment	284	35.3	7	35	20	32.8	311	35.1
Shatter	27	3.4	1	5	5	8.2	33	3.7
Potlid	37	4.6	2	10	2	3.3	41	4.6
Total	805	100%	20	100%	61	100%	886	100%

Table 8: Debitage type breakdown

CA-SRI-512, Unit 8 Debitage

	Monterey		Cico		Other		Total	
	N	%	N	%	N	%	N	%
Core Reduction	18	1.8	-	-	4	6.5	22	2.0
BF Reduction	199	20	-	-	6	9.7	205	19.1
Retouch	287	28.8	5	29.4	21	33.9	313	29.1
Burin Spall	-	-	-	-	-	-	-	-
Flake Fragment	364	36.5	12	70.6	15	24.2	391	36.4
Shatter	32	3.21	-	-	10	16.1	42	3.9
Potlid	96	9.6	-	-	6	9.7	102	9.5
Total	996	100%	17	100%	62	100%	1075	100%

Discussion

The following section outlines artifact-specific observations and interpretations as well as more broad discussion concerning the organization of lithic artifact manufacture at CA-SRI-512. Based on the data described above, we propose a simple model for the minimum number of reduction sequences used at CA-SRI-512. Second, we discuss the issue of the flaking techniques used. Finally, we briefly describe some of the broad implications of our results.

Chaine Operatoire/Reduction Sequence

Raw Material Procurement

The presence of cortex on 21% (n=101) and 18% (n=89) of the debitage (with platforms intact) from units 4 and 8 respectively, coupled with a small number of tested cobbles, support the conclusion that at least some early-stage cobble and core reduction occurred on site. Surprisingly, no evidence of raw material quarried from primary deposits was observed. Instead, features such as naturally battered and rounded weathered surfaces on all raw materials exhibiting cortex indicate selection from secondary deposits (as nodules) which may have been late Pleistocene beaches and/or uplifted cobble conglomerate benches (Erlandson et al. 2008:26; Jew et al. 2013:53-54). With the exception of the two cobble choppers, the flaked stone tools are dominated by local chert from the Monterey formation possibly coming from the west end of Santa Rosa Island (Jew and Erlandson 2013). While diagnostic artifacts are largely devoid of cortex, many Monterey chert artifacts exhibited features such as thick white cortical rinds indicative of local Tuqan chert. Cico chert and Wima chert were also present in the assemblage, but at significantly lower frequencies, perhaps indicating infrequent procurement from sources more distant to CA-SRI-512 than more local and predictable sources of Tuqan/Monterey chert. It should also be noted that a single obsidian flake from the Coso source was recovered from this Paleocoastal component, indicating a very early participation in long-distance exchange networks involving WST peoples of the interior (Erlandson et al. 2011).

Core Reduction

Pebble Cores

Evidence for early stages of lithic reduction at CA-SRI-512 occurs in low frequency. As previously outlined, 16 small tested pebbles and pebble fragments were recovered. Physical attributes indicate selection of neo-cortical flattened chert pebbles, with the best preserved examples showing a preference for flaking one surface over the other. The few tested pebbles and fragments from the current analysis described as "bi-directional" are quite small and therefore may have only permitted an opposed platform reduction method or, more likely, were broken and/or discarded early in testing. Some bipolar flaking is possible on such pebbles but no diagnostic features of such a strategy were identified. Again, the slightly larger nodules with several removals suggest a turning system of flake removals, centripetal in nature, with a hierarchical preference for one surface over the other. Some flattened pebbles also exhibit bifacial and alternate removals along one or more margins suggesting that bifacial rather than bidirectional or centripetal reduction occurred in the early stages of reduction to some extent.

A Biface/Core

While the cores and core fragments in the assemblage were dominated by tested cobbles and cores in very early stages of reduction, one artifact stands apart. This item, for all intents and purposes, is a simple early stage biface, but large removals on both faces indicate that it may have facilitated the production of large flake blanks in addition to functioning as a potential tool blank itself. This artifact did not initially stand out as a potential bifacial core until two larger flake negatives were closely examined. These larger removals appear to have been end-struck (orthogonal removal), perpendicular to the general flake pattern of this biface, similar in orientation to a channel flake, which leads us to consider this artifact as both bifacial and end-struck core (**Figure 4a**). Additionally, the presence of two large removals originating from the biface's end lends support to the hypothesis that this may have been systematic and intentional rather than a one-off haphazard example. This artifact is by no means a perfect match to the Levallois-like cores described by Davis and coauthors (2012:50-52) and Davis and Willis (2018), as no clear hierarchy between flaking surfaces was observed. Yet, the end-struck flakes removed perpendicular to the most prevalent biface thinning negatives took advantage of one of the convex flaking surfaces, conditioned by the scars of the previous removals allowing the exploitation of this surface for a larger invasive removal, similar to a preferential Levallois concept. The general lack of platform preparation, and strong bifacial character, also sets this biface/core apart from more conventional Levallois reduction methods (Although see Boeda 1994); yet again, this peculiar strategy warrants discussion. While some limited reduction of cores and early stage bifaces is supported, platform preparation (i.e., abrading, trimming, hammering) are uncommon features on both artifact classes.

Early Stage Reduction Techniques

Although it is often difficult to identify the flaking technique in individual artifacts, early core reduction appears to have been conducted through the application of a direct percussion flaking technique. A single recovered hammerstone made on a calcareous limestone-like material provides some insight into this process and perhaps reflects selection of stones with ‘mineral soft hammer’ qualities analogous to antler. Unfortunately, with no blanks over the 1" (25mm) cutoff to measure individually for quantitative attributes associated with hard hammer reduction (i.e., 4 mm platform thickness) (Pelegrin 1995:67-68), the hypothetical use of hard hammer percussion involved in core reduction is inferred solely based on qualitative observations on the tested nodules themselves (i.e., broad flake negatives).

In a previous study Jew and Erlandson (2013) noted that the presence of potlidding, crazing, and high gloss in lithic assemblages from several Island Paleocoastal sites (including CA-SRI-512) suggesting that intentional lithic annealing (heat treatment) may have been an important technique used by these early mariners. Heat treatment alters the physical properties of lithic raw materials including chert, and can allow for greater control and ease of flaking during the flintknapping process (Jew and Erlandson 2013). In the current study, only artifacts exhibiting visible potlidding, crazing, or other thermal damage were noted as possibly being fire affected. As gloss was not evaluated here, it is possible that numerous artifacts recorded as "unburned" were successfully heated without spalling or fracturing. In addition to formal artifacts 41 (5%) and 102 (10%) potlids (heat spalls) were recovered from the assemblage of flakes, fragments, and shatter analyzed from units 4 and 8 respectively. Some artifacts from the CA-SRI-512 assemblage show crazed cross sections inconsistent with the overall texture of these artifacts, and heat spall removals with inter-negative secondary patina indicative of heat-induced removals long after manufacture and discard of the original artifact. Besides potential controlled heating of lithic raw material, accidental/post-depositional burning should be considered. We note, however, that certain artifacts such as tabular cores and flake tools are largely unburned, while evidence of burning is much higher on formal tools.

Blank Production and Flake Tools

A small frequency of tested chert tabular pebble cores, a bifacial core, a few core reduction flakes, and the core reduction modified flakes discussed below indicate that at least some blank production must have occurred on site. However, the complete lack of any debitage in the analyzed sample over 25mm (1") also leads us to seriously consider the likelihood that many of the flake-blanks necessary for point production, as well as the finished bifaces and preforms described hereafter, may have been imported to the site in a semi-finished form. While some of the primary and secondary core reduction flakes removed from tabular pebbles may have been retouched and used as tools, we consider it unlikely that it is the case for every single flake above 1". Instead, we suggest that a significant number of the large artifacts were imported to the site in a middle-to-late stage of reduction. Such a scenario is consistent with the lack of flake cores and associated debitage and the lack of recycling of rare large flakes or broken tools into expedient tools. Because early stages of production are missing, we can only speculate based on the limited signatures of CA-SRI-512's early reduction that blanks suitable for the manufacture of small CIB points and less common "miscellaneous" points (including foliates) were flakes removed elsewhere from prepared bifacial or hierarchical-centripetal cores.

Similar to raw material frequencies, the percentage of debitage classes match the overall artifact assemblage well. The lack of core reduction flakes (even in smaller size categories) is consistent with the near absence of cores on site. These two lines of evidence suggest that flake production was not the main priority of lithic reduction at CA-SRI-512, save for occasional usable biface reduction flakes from shaping of bifacial pieces. The overall signature seems consistent with the Field Processing Model (Beck et al. 2002; Shott 2015): if the site was located some distance from the source, we should expect blanks and preforms to have been imported in a semi-refined state rather than as raw cobbles or large cores; activities centered about primary reduction would be minimal (though see Ames 2002). As such, tabular pebbles may have been reduced bifacially after only a few centripetal /bidirectional removals. In other words, core reduction at CA-SRI-

512 was infrequent, and with few exceptions was largely bifacial in nature after only a few initial "core reduction" removals. Essentially, these cores may have functioned primarily as preforms for bifacial pieces.

It should be noted that in total, four burin spalls were identified within the debitage as well. One of these was found in unit 4 level 3 and three were found in unit 4 level 4. While other Paleocoastal assemblages have yielded what are referred to as “burin cores,” burinated bifaces, and burin spalls in early Holocene contexts (Cassidy et al. 2004, Lebow et al. 2015), the extremely small number from CA-SRI-512 and the lack of burin cores in this assemblage suggest that these were accidental knapping byproducts rather than intentional tools at this site.

Crescents and their associated preforms are easily distinguished from CIB's and their associated preforms by a number of features including overall shape, length and width. Yet, in terms of blank selection, the thickness of these artifact classes may be most informative. Because preforms are defined partly based on size and shape, we grouped them with finished products to account for possible classification biases (for more detailed info, see descriptions above). With a median thickness of 5.2 mm, crescents and crescent preforms are consistently thicker than CIB's and their associated preforms, which are evaluated here at 3.1 mm using a Mann-Whitney test ($U = 98.5, p = <0.01$) (**Figure 9**). Since thickness was not used *a priori* to categorize these artifacts in our analysis, it may indicate a difference in the manufacture of these two distinct artifact types. This may indicate a difference in the manufacture of these two distinct artifact types. CIB's seem to have been made on small and thin flakes consistent with the byproducts of bifacial reduction, while the objects used for crescent manufacture were routinely thicker and longer. While some crescents may have been produced on larger flakes, we find no evidence for their production at the site. Hence, we suggest that crescents were likely to derive from bifacial preforms (perhaps used first as flake-cores). Based on a single biface/bifacial core in the CA-SRI-512 assemblage, it is difficult to test this hypothesis. If it is validated by the study of Paleocoastal quarry-workshops, it would indicate a difference in the conception of the two categories of objects. The CIB points would rely on a flake production to produce blanks, later thinned by retouch. The crescents would not necessarily depend on the production of suitable flakes and could be produced by bifacial shaping and thinning of a nodule, before being retouched. We note that the two processes can coexist in a system that does not require the production of large flakes.

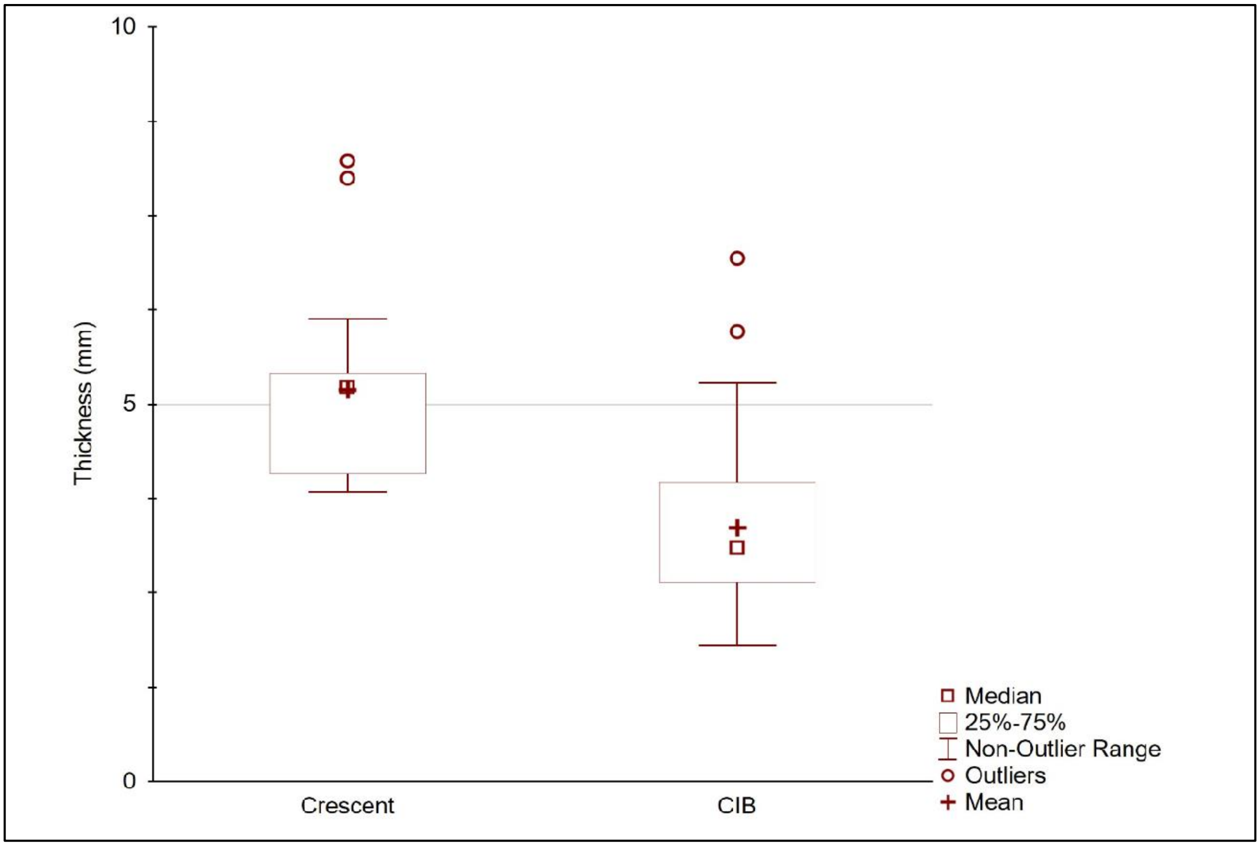

Figure 9. Box plot representing a comparison between the thickness of crescents (and associated preforms) with the Channel Islands Barbed Points (and their associated preforms).

Recognized as tools, a small assemblage of flakes over the 1" size category, and several others below this cutoff were analyzed separately due to unique morphology and retouch signatures. This is the first descriptive analyses of flake tools (including scraping tools such as spokeshaves and gravers) from Northern Channel Island Paleocoastal contexts. An examination of flake platform preparation and the flake types used to produce these tools indicates that there is little effort made for the production of standardized blanks. Instead, it appears that the main metric governing such flake tools was sufficient thickness (~7-12mm). It is notable that the largest flakes would have been of nearly large enough size to make at least small CIB's. Although some other features of these items may have made them less desirable for point manufacture. Inconsistent with trampling patterns of edge damage (McPherron et al. 2014), activities such as scraping/graving of hard and medium-hard materials (possibly hard wood or bone) inferred from the use wear analysis were also an important aspect of the raw material economy at CA-SRI-512 and in numerous contemporaneous mainland assemblages associated with the WST (Beck and Jones 2009:109-126, 2015:179-193; Graff 2001; Goebel and Buvit 1997; Pratt et al. 2020).

Shaping Formal Tools

Bifaces

In some ways the biface assemblage here seems analogous to the Great Basin WST biface manufacturing model described by Beck and coauthors (2002) and Beck and Jones (2009:88-89). For instance, reduction of larger early stage bifaces into long and thin artifacts, may have been guided by the need for larger finished bifacially flaked stone tools. This biface assemblage is dominated by fragmented and discarded artifacts exhibiting largely lenticular cross-sections and broad collateral to irregular flake scar patterning indicative of hard and possibly soft hammer percussion thinning. Since the largest population of sizable (and yet thinned and refined) bifaces in Paleocoastal contexts described to date are in fact crescents, it is also possible that at least some of this biface assemblage represents fractured and abandoned bifaces in a stage between primary roles as flake producing bifacial cores and crescent preforms.

Crescent Preforms and Crescents

Several crescent preforms and preform fragments identified in this analysis suggest that bifaces were further refined and thinned into distinct crescent types. In the later stages of crescent manufacture, the preform mid-width (which we presume is the hafting element if used as a transverse projectile point) appears to have been established even before the "wings" are fully flaked and refined. Finished crescents are set apart from crescent performs (**Figure 5)** in this assemblage by general patterns of symmetry in plan and profile, marginal abrasion of one or both edges of the mid-section, in some cases fine serrated "teeth" near the wing tips on the distal edge, fine pressure-retouch, and a general lack of remaining step-fractures and un-flaked platforms. As noted previously, many of these artifacts have also been fractured in use and discarded or retooled and discarded. Burin fractures were common and seem consistent with those described by Amick (1999) and Lenzi (2015) associated with use as transverse projectile points.

Channel Islands Barbed Points

Channel Islands Barbed (CIB) points were produced by establishing incipient barbs and stems before the point blade was fully finished (**Figure 6**). Originally described by Glassow et al (2013:192), the preforms were then reduced through percussion flaking (if necessary) and subsequently (or exclusively) through pressure-thinning. The next stage of CIB production (**Figure 6**) involved carefully pressure flaking the thin contracting stem, and deep notches to establish the proximal edges of the point barbs. After the hafting element was largely refined, the point blade is relatively thin and symmetrical in section, but often appeared highly asymmetrical and irregular in plan-view. The last stage focused on the latter part of the artifact and in some cases, on fine serrated teeth established on both margins, about mid-way between the tip and barb tip. Abrasion of the stem is observable macroscopically on only a few specimens, perhaps due to the extremely thin nature of these points.

Miscellaneous Points

While these did make up only a small portion of the overall assemblage, untyped projectile points (likely including some late-stage point preforms or knives) varied in shape from single shouldered and stemmed forms to foliate. They lack the standardization of other Paleocoastal artifacts in terms of overall form, but also in thickness and size. While their manufacture likely derived from flake blanks, some may have also been produced from the full thinning and reduction of a thicker biface, or bifacial core similar to the process described earlier for crescent manufacture. Some of these artifacts may have been discarded during the production of other objects (late stage foliate-like preforms) but the presence of a pronounced impact-burination of one artifact (**Figure 7a**) leaves open the possibility of occasional use as a projectile point.

The lack of standardization of these points not only sets them apart from the CIB's described above, but also from Channel Island Amol (CIA) points identified in some Northern Channel Islands Paleocoastal assemblages (Erlandson 2013). CIA's typically exhibit shoulders, contracting stems, longer overall dimensions than CIB's, and many (though not all) exhibit distinct and deeply pressure flaked serrated margins. While none of the artifacts described here exhibit the pronounced serrated margins typical of CIA's, it should be noted that half do have shoulders (n=3; 50%). Finally, two of the potential points described here closely resemble crescents. Furthermore, a burinated foliate suggests use as a point rather than a knife blade while others exhibit off-angle retooling that may be indicative of use as knives (**Figure 7b**). Overall, these exceptions are a reminder that the flexible approach to the use of stone tools by hunter-gatherers does not necessarily fit the assignment of a single function to a specific tool type.

Percussion Thinning and Pressure Flaking

In terms of techniques used, based on flake negative size and shape, it appears that percussion flaking (using hard and/or soft hammer) was followed by pressure flaking to reduce and refine bifaces into conventional points and crescents. When bifaces, preforms, crescents, and conventional points are combined as a single population (n=116), seven (6%) seem to exhibit negatives indicative of percussion flaking exclusively, thirteen (11%) exhibit negatives seemingly associated with pressure over percussion, and ninety-six (83%) exhibit negatives likely reflecting pressure exclusively. To some, this trend may imply that many flake blanks were reduced exclusively through pressure flaking (which is a possibility); but our observations suggest that pressure technique occurs relatively late in the manufacturing sequence and it may overprint negatives of direct percussion flaking. The complementary role of percussion thinning and pressure thinning/retouch is also reflected in the debitage samples from units 4 and 8 which are dominated by biface reduction and retouch flakes (which likely reflects a mix of percussion and pressure).

Summary

The assemblage of CA-SRI-512 is characterized by six main categories of lithic objects: bifacial cores/preforms, bifaces, crescents, CIBs, retouched flakes, and unmodified debitage. Here we outline a simple model for the production of these objects that is consistent with the empirical data (**Figure 10**). Atypical points and fragments are informative on the intermediate steps of the reduction.

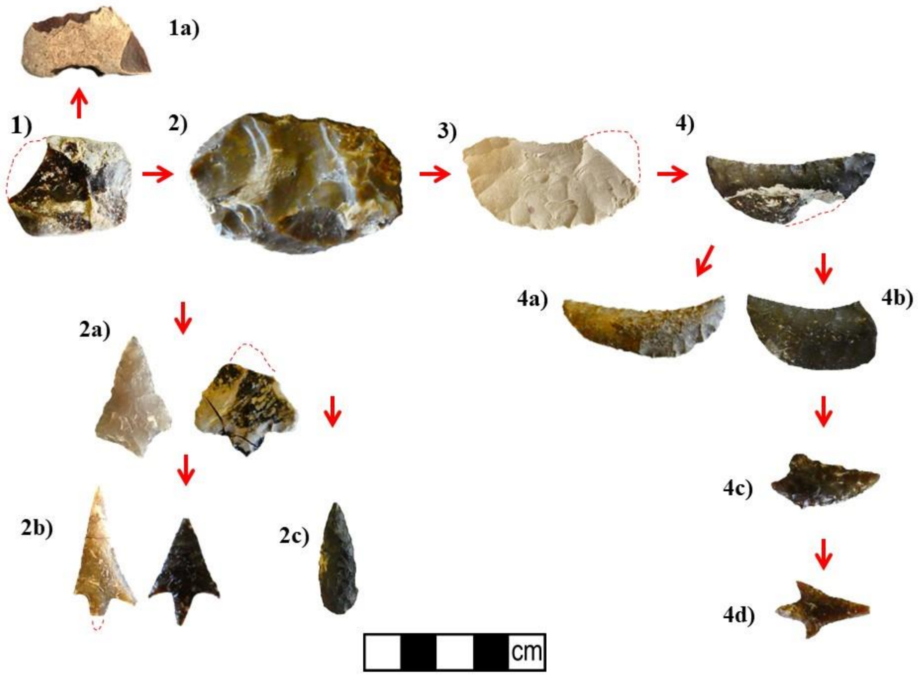

Figure 10. CA-SRI-512 Chaine Operatoire. Step 1) Flake-blanks are removed from one dominant face of neo-cortical chert pebbles with flattened morphology. 1a) Flakes can then be modified for use as scrapers and gravers, or as tool blanks. Step 2) Pebble cores are worked bifacially with some large end-struck flake removals. 2a) Flake-blanks are reduced in size and shape into unique stemmed preforms with incipient barbs. 2b) Channel Islands Barbed points are refined from their respective performs. 2c) a few foliate-shaped points are also finished through pressure thinning. Step 3) Bifacial cores, if unbroken, are further reduced and begin taking on characteristic crescent morphology as crescent preforms. Step 4) Preforms are further refined into crescents. 4a) crescents burinated during use are retooled, 4b) or discarded if too heavily fragmented. 4c) some crescent wing-fragments are recycled as CIB preforms and 4) further refined into CIB's.

1. Collection of water-worn chert tablets.
2. Tablets are tested and reduced following a centripetal or bi-directional flake removal sequence, focusing first on one face. Import of semi-finished bifacial preforms. The former are represented by a few unifacial preforms that can also be considered as cores, given that they produce usable flakes, the latter is suspected given the lack of primary reduction flakes.
    a. Flakes are used unmodified, retouched into simple tool forms (scrapers, spoke shaves, and gravers),
    b. Flakes are thinned and refined as CIB points using percussion and then pressure flaking.
        i. CIBs are first shaped starting from the stem, and then the retouch extends toward the tip and the edges.
        ii. Pressure removals of the triangular barbs, contracting stem, and finally the triangular blade body produce an ultra-thin finished CIB with a characteristic chevron flaking pattern.
3. Once core/preforms become too flat to produce tool blanks, flakes are struck from the opposing face of the tabular core producing an early stage biface. Some flakes detached during the process may be used as tool blanks.
4. The oval shaped preform is then turned into a crescent using percussion and pressure flaking techniques.
    a. They are first shaped at mid-section.
    b. The wings are formed.
5. Crescent are often broken before discard.
    a. Occasionally, fragments may be recycled into CIB's.

The model described here is hypothetical because it is based on the occurrence of certain traits, but also on the absence of others. Overall, the sample is somewhat small (though large by Paleoindian standards) and may group several seasonal occupations that took place during a relatively short time, or may reflect one longer wet-season occupation. For these reasons, there are limitations to what can be tested solely based on CA-SRI-512. Diagnostic Paleocoastal artifacts were mostly known from surface contexts, however and CA-SRI-512 provides a rare opportunity to look at the larger assemblage associated with diagnostic tools to better understand the details of their production. The model outlined above offers clear predictions regarding the size and the intermediate forms that a more complete assemblage would yield, and it can be tested using additional assemblages (e.g., in a production workshop, or on a quarry site).

We note that this reduction model does not require a strong investment in the production of predetermined flake/blade blanks (or *debitage*). Instead, it is constructed around bifacial shaping (or *faconnage*) and a relative efficiency in the use of flakes it generates. It is difficult to talk in terms of byproducts, or final products, because objects may change shape and/or function several times along the lines of an intricate process. We also note that discrete features, such as the emphasis on the CIB stem or the crescent mid-section, may indicate a careful preparation for hafting prior to the investing into the refinement of the tool, and therefore be relevant for discussing the function of these tools.

Implications for the Function of Crescents and CIBs

The analyses described here offer a first technological look at two artifact types for which the function is still debated. Below, we discuss the relevance of some of our observations regarding the function of these objects, their role for hunter-gatherer subsistence strategies, and their cultural meaning.

The function of crescents has long been debated based on morphological features that some interpret as reflecting knives and scraping implements, while others interpret them as transverse points (Amsden 1937:51; Cressman et al. 1942; Clewlow 1968; Daugherty 1956; Davis 1973; Gifford and Schenck 1926; Tadlock 1966; Wardle 1913:656). Further, breakage, wear patterns, residues, and recycling have complicated interpretations of the primary function(s) of crescents. The general bilateral symmetry of many crescents has been implicated as a potentially important factor in necessary arrow dynamics supporting their use as projectile tips (Moss and Erlandson 2013; Tadlock 1966). Taken as a whole, features such as abrasion patterns and impact fractures, and the emphasis on the mid-section of the tool during manufacture are consistent with hafting and use as transverse projectile points. The close geographic association of crescents with lake, marsh, estuary, and marine habitats has led some to believe they may have been used to hunt waterfowl and other birds (e.g., Erlandson et al. 2011; Moss and Erlandson 2013; Sanchez et al. 2017).

At CA-SRI-512, only two finished crescent wing fragments are present in the recovered assemblage. Instead, crescent mid-sections or crescents missing one wing are far more common. While several snap and bending fractures are present, and could have occurred through a number of factors including post-depositional processes, the dominance of burinations, rotation burinations, and the single edge bite, are all consistent with projectile point use reported by Amick (1999) and experiments conducted by Lenzi (2015). It should also be noted that Cat # 750, bears distinct alternate pressure retooling of nearly half of the proximal edge, terminating just short of completely obliterating a remnant 90 degree angle we believe was caused by a long burination. If this is the case, the remainder of this burination that was not retooled, which is situated in the proximal center of the artifact, may have been obscured while still in the haft if the artifact was resharpened in the field after sustaining the burin fracture. These data, in conjunction with the presence of medial abrasion patterns that might have facilitated hafting as suggested by Tadlock (1966) and supported by experiments conducted by Lenzi (2015), all suggest that the crescents at CA-SRI-512 were likely used as transverse projectile points. Use as transverse points for hunting waterfowl is supported by the associated faunal assemblage, which is dominated by migratory avifauna including ducks and geese (Erlandson et al. 2011).

The ultra-thin and bi-plano/nearly flat cross section of delicate Channel Islands Barbed points has led researchers to hypothesize that they may have functioned primarily in aquatic environments and specifically to take fish, birds, or in the case of slightly larger sub-types, sea mammals (Glassow et al. 2013). Thomas (1989) noted that residential sites typically contain higher frequencies of projectile point bases than tips (which should be lost in the field during hunting activities). The high number of "tip fragments" found in addition to the main assemblage of points analyzed here should be treated with a degree of caution however, as many are likely not the distal fragments of projectile points, but barb-tips which bear nearly identical morphology and flake negative signatures to the distal most end of CIB's. While features related to impact were easily observable on the slightly thicker crescents within the assemblage, the ultra-thin nature of CIB's makes rates of snap-fragmentation extremely high, and therefore it is quite difficult to evaluate what fractures were due to impact and which were manufacturing breaks when compared to other point types. As a result of this conundrum we are left echoing the conclusions that Glassow and coauthors (2013) have already proposed, that these points may have been predominantly used in aquatic environments for fish and birds due to their ultra-thin nature. The presence of fish and sea mammals in the assemblage may indicate that some CIB's were manufactured at this site for use on the coast. Their abundance at the site, however, suggests that some CIBs may also have been used to hunt birds, the remains of which are more common than those of fish or marine mammals at the site (see Erlandson et al. 2011).

Broader Implications

In summary, the reduction sequence/chaine operatoire at CA-SRI-512 reflects economic decisions governed by the manufacture of conventional projectile points and lithic crescents from local island cherts. It should be reiterated that the largest formal flaked stone implements known within the CA-SRI-512 Paleocoastal assemblages to date are not stemmed points, but crescents. They seem to have different raw material requirement than CIB points. In the absence of a systematic production of massive flakes, we posit that crescents were probably flaked out of large nodules of high quality chert. Consequently, crescents are relatively costly and their numbers are low in comparison to conventional projectile points in most assemblages. Blanks for CIB points can be found in the debitage of the crescent production. If we assume that the lithic assemblage at CA-SRI-512 reflects economic decisions governed by the costs of lithic transport (Beck and Jones 2009), the difference between crescent and CIB points could also explain the imbalance in their frequency or the extent of their curation. We can expect the frequency of crescents to decrease faster than the CIB as one moves away from the raw material source and the recycling or curation to increase.

By examining the preform assemblage through a technological approach, we find unusual trends in the CIB reduction sequence. Some of the most widely used and cited North American bifacial point reduction sequences (Andrefsky 2005:32, 190; Callahan 1979; Whittaker 1994; Woldorf 1979:20), and even the original concept of the reduction sequence proposed to American archaeologists by Holmes (1894), all share a common thread. Although there are variations in the number of different stages, each of these sequences describes the reduction of a point from a blank, through subsequent bifacial thinning, to general shaping, and final finishing with the establishment of any number of diagnostic hafting elements (i.e., stems, notches, etc.) as the last stage. The CIB preform assemblage from CA-SRI-512, however, deviates from these standard models. Originally noted by Glassow and coauthors (2013:192), the CIB's at CA-SRI-512 seem to have been produced from preforms that were shaped to have the stem, incipient barbs, and general hafting elements established *before* the blade body was fully flaked (**Figure 5**). Interestingly, this peculiar reduction strategy does not appear to be governed by necessity. In fact, the stem and barbs of a CIB could easily be knapped in the last stage of reduction as is so commonly described and illustrated in regards to other point forms. Whether it reflects a site-specific or a more widespread behavior is still unclear but it may be informative on how this technology was transmitted between individuals or groups (Sackett 1982, 1985).

With the exception of multi-purpose flake tools and expedient modified flake tools, the toolkit represented at this site is also conspicuously lacking in formal scrapers typical of mainland WST assemblages. Because of the change in coastline during the Holocene, however, it is unclear if the artifact type-list described here is representative of "typical" Paleocoastal behaviors. In fact, the presence/absence of certain tool types could also reflect the range of activities performed specifically at interior seasonal hunting camps away from seaside residences. Through an investigation of middle and late Holocene occupations on Santa Cruz Island, Perry and Glassow (2015) suggest that subsistence resources and artifacts found in deep interior contexts still reflect the overall maritime economy of that time. Unfortunately, since islanders likely established residential bases (at least seasonally) on coastlines that are now submerged, our current understanding of late Pleistocene hunter-gatherer adaptive strategies on the islands (and thereby the differences in scraper frequencies) remains somewhat skewed.

Conclusion

Here, we described CA-SRI-512, one of the rare excavated lithic assemblages that yielded crescents and CIBs in a stratified context on the Northern Channel Islands. We used a technological approach to investigate the manufacture of such tools that we summarize in a simple model. Our results suggest that the production of crescents is central to the technical system and is mainly produced by shaping a nodule of raw material. CIBs can be produced on flakes coming from bifacial core/preforms and are therefore less costly in raw material, easier to transport, and in general more numerous than crescents. Our analysis shows that the mid-section of the crescent and the stem of the CIBs are subjects of special attention. Both are shaped before the wings and the tip blades (respectively). Gravers, spokeshaves, and scrapers are produced on flake blanks or as byproducts of the bifacial reduction, and allow for a more holistic understanding of Island Paleocoastal behavior. As of now, CA-SRI-512 core reduction, biface manufacture, and stemmed-point and crescent production are all activities consistent with the broader Western Stemmed Tradition. Looking forward, comparing the model described here with similar assemblages found in quarry context should be informative on regional connections, and on the technological flexibility within what it is broadly described as the WST.

Chapter Three

CHARACTERIZING THE ISLAND PALEOCOASTAL TRADITION, A VARIANT OF THE BROADER WESTERN STEMMED TRADITION: NEW INSIGHTS FROM CA-SRI-512, CA-SMI-678, AND CA-SMI-679, ON CALIFORNIA’S CHANNEL ISLANDS.

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Abstract

Stemmed projectile points and flaked stone crescents associated with the Western Stemmed Tradition (WST) have recently been linked with early population migrations, including the peopling of the Americas. Although the WST may originate from a maritime dispersal along the Pacific Coast, research regarding this tradition has largely focused on assemblages from the Intermountain West. In the last few decades, over 100 terminal Pleistocene and early Holocene sites have been documented on California’s Channel Islands. These sites are often associated with stemmed points and crescents rather than fluted point technologies suggesting that Island Paleocoastal peoples were related to the broader WST. However, to date only limited research has been published regarding the manufacture of these tool types, and assemblages from buried and stratified contexts are rare. Here, we describe and compare the organization of flaked stone tool manufacture across three well preserved Island Paleocoastal sites (CA-SRI-512, CA-SMI-678 and CA-SMI-679) from Santa Rosa and San Miguel islands. Although we observe variation between islands, all three sites share a consistent technological pattern that informs on the variations in composition of the assemblages. Considered as a whole, the repeated use of the same production system is difficult to explain by mechanical constraints alone and indicates a cultural connection between the hunter-gatherer groups that occupied the three sites. Because the same general pattern seems to extend beyond the Channel Islands, it supports the idea that the Island Paleocoastal Tradition (IPT) is a maritime variant of the broader WST. Overall, the pattern emerging behind the manufacture of crescents and stemmed points on the islands offers a promising avenue for technological studies of the WST more broadly.

Introduction

Environments adjacent to lakes and rivers have clearly attracted our hominin ancestors for millions of years as evidenced by sites like Lomekwi 3 near the west shores of lake Turkana, Kenya, dated to approximately 3.3 million years ago (Harmand et al. 2015), and OGS-6 and OGS-7, located near the confluence of the Kada and Ounda Gona rivers in the middle Awash, Afar, Ethiopia, and dated to 2.6 million years old (Semaw et al. 2003). Middle Stone Age (MSA) sites of South Africa contain abundant shellfish (Jerardino and Marean 2010; Klein and Steele 2013) as well as the oldest clear evidence for symbolic objects, which for some indicate an MSA origin of 'behavioral modernity' (McBrearty and Brooks 2000). To consider that adaptation to aquatic environments may have been decisive in the origin and worldwide dispersal of our species is not an exaggeration. MSA diet-breadth expansions, which included marine shellfish, are also coeval with the development of innovative lithic technologies (heat treatment, large bifacial pieces and projectiles) (Henshilwood 2012; Schmidt et al. 2020). Further diversification, and even specialization, of stone tool kits occurred alongside some of the first successful modern human maritime expansions out of Africa as early as 60 thousand years ago allowing the peopling of Australia (Clarkson 2017) and subsequent seafaring dispersals later in time (Allen et al. 1989; O'Connell and Allen 2012; O'Connor et al. 2011; Wickler and Spriggs 1988).

But some technologies do not solely reflect strong functional constraints imposed by environmental pressures. They may (but do not necessarily) exhibit practical choices informed by way of teaching and learning (Sackett, 1982) when the repetition of structured manufacturing processes is associated with a relative degree of hierarchical complexity (Byrne 2007; Zwyns et al. 2019; Zwyns 2020). Hence, similarities in technological systems or tool types may reflect convergence, diffusion, or other intricate systems of shared and learned behavior (Byrne 2007; Bettinger and Eerkens 1999; Eerkens and Lipo 2005; Eerkens et al. 2013; Kuhn and Zwyns 2014; Zwyns et al. 2019). To identify and understand why there are visible overlaps between archaeological finds from different layers and/or sites is crucial because it is often used to recognize *archaeological cultures* (McKern 1939), also referred to as *traditions*, *industries*, or *techno-complexes* (Clarke 1978). Among other features, notable variations between lithic assemblages have been instrumental in the definition of two such units associated with the initial peopling of the Far West of North America: the Paleoindian (Western Fluted) Tradition and the Western Stemmed Tradition (Davis et al. 2012).

Considerable attention has centered on the nature, timing, and distribution of the WF and WST (Davis et al. 2012), although much of these efforts has concentrated on the Intermountain West, comprised of the Great Basin, Snake River Plain, and Columbia Plateau (Beck and Jones 2010, 2013; Connolly et al. 2016; Smith et al. 2020). Currently, there are two main models for the initial peopling of western North America. Based on a Clovis-first paradigm, the terrestrial model maintains that the earliest populations entered North America via Beringia and the Ice Free Corridor (IFC). Subsequently, Pleistocene hunter-gatherers in pursuit of top-ranked large game animals and armed with fluted projectile points rapidly expanded into the Far West (Haynes 1964).

The alternative model, first fully described by Fladmark (1979), maintains that early Pleistocene population were mariners coming from Northeast Asia (perhaps Japan or the Beringian coast). They then migrated along coastlines and islands which connected North America and Asia in the late Pleistocene, when sea levels were significantly lower. The Pacific Coast Model (PCM) posits that people reached the North American Far West by following productive marine kelp forest habitats. These populations would have traveled by foot and boat while practicing a broad-spectrum mixed-marine diet, and carrying (or soon developing) stemmed projectile points and other technologies distinct from Clovis. This ancestral population led to the development of the Island Paleocoastal Tradition (IPT) and Western Stemmed Tradition (WST), as these groups split, with one group continuing south along coastlines and island chains (Braje et al. 2019; Erlandson and Braje 2011; Erlandson et al. 2007; Fladmark 1979; Rick et al. 2005), and the other group traveling inland along rivers. Particularly productive of food resources, major rivers such as the Columbia River, Klamath, and Sacramento were dispersal corridors, that eventually led people to settle interior environments of the Intermountain West (Beck and Jones 2010; Davis et al. 2012).

Over the past 40 years, as a number of early coastal and island sites were discovered along the Pacific Rim and down the coast of North and South America, the PCM has gained momentum (Braje et al. 2019; Erlandson and Braje 2011; Dillehay et al. 2008; Erlandson et al. 2011;

Fladmark 1979). To date, over 100 terminal Pleistocene and early Holocene archaeological sites are documented on southern California's Channel Islands, which play a pivotal role in the discussions of early maritime dispersals and adaptations. Yet, there are few descriptive studies concentrating specifically on lithic technology, and fewer still detailed comparisons between tool manufacturing processes. In chapter 2, we proposed a model describing the organization of lithic tool production at the Paleocoastal occupation at CA-SRI-512 on Santa Rosa Island. While this analysis yielded insights into the structure of lithic tool production at a local level, the model remained hypothetical.

The early stages of manufacture were largely absent from the CA-SRI-512 assemblage which left us with new questions pertaining to core preparation and blank production as well as whether the unique aspects of the manufacturing sequence at CA-SRI-512 were typical of the broader IPT or simply unique to that site. Therefore, in many ways we were left with more questions than answers. It is possible that some of the subtle and unique stages of lithic tool manufacture at CA-SRI-512 were simply unique to that assemblage. If this were the case, we should expect that even though similar formal artifact types such as crescents and stemmed points have been found in numerous IPT sites, the manufacturing trajectory from core, to blank, to finished artifact should vary. Alternatively, if the unique reduction sequence observed at CA-SRI-512 was found to be consistent with other well-preserved IPT assemblages, and especially if the more unique manufacturing stages were found to be consistent across artifact types, we might then conclude that these features are typical of a shared and learned IPT manufacturing system.

Here, we build upon our previous analysis by comparing lithic technological organization from CA-SRI-512 to additional Island Paleocoastal sites (CA-SMI-678 and CA-SMI-679) from Cardwell Bluffs on San Miguel Island. These two sites also yielded buried material and chronological data important for contextualizing reduction strategies of the IPT. Close to a raw material sources, they contain abundant lithic artifacts in early stages of manufacture allowing us to construct a more detailed understanding of the early manufacturing strategies. This should be a step forward allowing a broader discussion on the connections between sites as well as bridging the islands and mainland WST phenomena.

Background

Clovis First

Fluted points were first recognized as distinct projectile point types when Folsom types were discovered associated with Pleistocene *Bison antiquus* at Blackwater No. 1 in eastern New Mexico in the 1920's (Figgans 1927). Subsequently, older Clovis point types were found in deeper strata at this site (Howard 1935) and the general absence of artifacts in strata below Clovis occupations suggested at the time that these artifacts were left behind by the earliest American inhabitants. The “Clovis-first” theory quickly dominated normative archaeological discourse surrounding the peopling of the continent (Haynes 1964). In a description of Clovis and associated technologies in Eastern North America, Mason (1962:228-229) went so far as to assert that if it were ever found, an "ideal column" (sequence) in the Far West of North America would clearly show that fluted points were at the bottom, and that these tools would occur alongside traits including "... no plant processing or groundstone, narrow spectrum diet focused on the highest ranked big game hunting, high residential mobility, and only much later a replacement of this suite of characteristics by narrow collateral flaked points".

In the Far West of North America, fluted points are rarely found in datable contexts. When they are, they often chronologically overlap with, or even post-date stemmed points. Such observations have led some to suspect whether Clovis indeed represents the earliest techno-complex in the Americas (Beck and Jones 2010, 2013; Smith et al. 2020). Stemmed points, fluted points, and lithic crescents in the Far West are often found in highest concentrations near relict Pluvial lakes shores. Surficial contexts at similar elevations around ancient lake margins suggests the use of similar environments and possible co-habitation of stemmed and fluted point bearing peoples (Smith et al. 2015). The environmental association between fluted points, stemmed points, crescents, and ancient pluvial lake shores led to the definition of the Western Pluvial Lakes Tradition (WPLT) by Bedwell (1970). The use of Western Pluvial Lakes Tradition has now been largely replaced with the Western Stemmed Tradition (WST), which does not suggest an inherent tie to a single specific environment. WST is then compared with the Western Fluted Tradition, which includes Clovis and Folsom-like points.

The Western Stemmed Tradition

The Clovis techno-complex has received due attention since its association with extinct Pleistocene fauna was confirmed. Discussions concerning the antiquity of stemmed projectile points, lithic crescents, and the WST, however, have only recently regained popularity in archaeological literature (though see Bryan 1991). In 1977, Tom Dillahey began excavations at Monte Verde, Chile, which yielded direct radiocarbon dates circa 14,800 cal BP with no fluted points present (Taylor et al. 1999). More recently, AMS dates on seaweeds found in saturated deposits at Monte Verde suggest that the site was occupied about 14,000 years ago, nearly a millennium older than Clovis (Dillehay et al. 2007). Stemmed projectile points were also recovered from buried deposits at Cooper's Ferry, a site located along the shores of the Salmon River in Idaho, and reportedly dating to approximately 16,000 cal BP (Davis et al. 2019) and at two Texas sites (Gault and Friedkin) dated between ~14,000 and 17,000 years ago (Waters et al. 2018; Williams et al. 2018). Stemmed points, human coprolites, and a bullrush textile fragment documented at Paisley Caves, in southeast Oregon also provide a dated context suggesting that the WST is contemporaneous with, or possibly even predates, the Clovis tradition (Braje et al. 2013; Davis et al. 2016; Jenkins et al. 2012; Smith et al. 2020). Numerous sites on the California Channel Islands have also yielded terminal Pleistocene dates associated, not with fluted points, but with stemmed varieties (Braje et al. 2013; Erlandson and Braje 2011; Erlandson et al. 2020). In fact, while not a single fluted point has ever been found on this island chain, several distinct stemmed point forms and lithic crescent types are routinely identified in early contexts dating between 12,200 and 11,000 years ago (Erlandson et al. 2011; Rick et al. 2013).

Coastal Migration Scenarios

Genetic studies suggest that founding populations of Native Americans derived from two Asian populations contributing to a broader Beringian ancestral population as early as the Last Glacial Maximum (LGM). Raghavan and coauthors (2014, 2015) maintain that a major contribution originates from eastern Asia with smaller contributions from the Siberian interior. According to Moreno-Mayer and coauthors (2018), two related populations then emerged from this late Pleistocene Beringian group, one of which contributed to the Native American populations south of the Laurentide and Cordilleran ice masses. The implication is that the makers of the Clovis, the Western Stemmed and Island Paleocoastal traditions shared ancestry with this Beringian group. For Pratt et al. (2020), one could expect that lithic assemblages associated with the source population could therefore exhibit unique or even shared Clovis and WST traits. Alternatively, Beringian groups could have maintained ancestral typo-technological traits, while coastal-oriented and interior-focused groups developed their new traits after moving out of Beringia.

Skoglund and colleagues (2015) sequenced the genome of a Clovis-associated individual (dated to approx. 12,600 cal BP) and compared these data with populations from North, Central, and South America. Their study provided genome-wide data indicating that some Amazonian groups descend from a Native American founding population. Because ancestral contributions are more closely related to Australians, New Guineans, and Andaman Islanders than any Eurasian or Native American groups, the authors suggest that at least two genetically dissimilar waves of Paleo-Indian populations moved into North America, potentially around the same time.

Archaeologically, the PCM is based largely on early dates from island and coastal sites often containing rich marine faunal assemblages. Broad similarities between terminal Pleistocene stemmed and leaf-shaped projectile points are found along the Pacific Rim from Japan to the west coast of North America and South America (Braje et al. 2011; Pratt et al. 2020). The PCM model follows what Erlandson and coauthors (2007) refer to as the “Kelp Highway Hypothesis”; namely that a migration of maritime hunter-gatherers, technologically distinct from Clovis, followed productive marine environments from northeast Asia to the west coast of north America, and down into South America (Erlandson et al. 2011). Pleistocene mariners, already well acquainted with aquatic subsistence strategies, then followed large estuaries into river passes (such as along the Columbia River). They navigated their way from the coast to the pluvial lakes of the Great Basin possibly lured by anadromous fish runs (Beck and Jones 2010, 2013; Fladmark 1979:64). Overall, the model explains the existence of sites in the west occupied by the bearers of a technologically distinct ‘pre-Clovis’ tradition. It also addresses why early sites are routinely found adjacent to coasts, rivers, ancient lakes, and why associated faunal assemblages are often (though not exclusively) dominated by aquatic resources such as waterfowl, fish, and shellfish.

Traditions, Human Groups, and Migrations

The traits that characterize the mainland Clovis, WST, and Island Paleocoastal assemblages can be interpreted as behavioral variations within a population, or as evidence of the co-existence of different groups. In the context of the debate on the peopling of the Americas, to document typo-technological variance is not a trivial issue. Depending on the results, it means to support a single, or several, Pleistocene peopling events. With a lack of buried sites, specific tool types have played disproportionate roles as '*fossil directeurs*' to identify and outline the distribution of specific traditions. The assumption is that the distribution of distinct tool types reflects the distribution of distinct groups, or populations. Although there are problems with such an approach, it offers a starting point for developing testable hypotheses.

For example, flaked stone crescents are some of the most iconic artifacts of the WST. They are occasionally found with fluted points, but are far more frequently found in association with stemmed points and span the terminal Pleistocene and early Holocene (~13,000-8,000 cal BP) in the Far West (Hopkins and Fenenga 2010). Crescents vary in overall morphology from lunate to winged and eccentric shapes (Justice 2002: 116-123). Numerous new finds in western North America have linked flaked stone crescents with waterfowl remains and the Pacific Flyway (Moss and Erlandson 2013). Additionally, a Geographic Information Systems (GIS)-based Euclidian distance analysis of over 100 crescents from the Far West suggests a direct association between crescents and wetlands; approximately 99% of the crescents mapped in this study were found within 10km of paleo-shorelines, and 95% within 1 km of major waterways (Sanchez et al. 2016). Over the past decade Erlandson and colleagues have uncovered dozens of these artifacts in direct association with stemmed projectile points and waterfowl remains on the California Channel Islands (Erlandson et al. 2007, 2011). Associated radiocarbon dates consistently cluster with the terminal Pleistocene and early Holocene suggesting that these crescents, stemmed points, and waterfowl played important roles in the lives of earliest Paleo-maritime inhabitants of the region (Moss and Erlandson 2013).

While routinely treated as being linked, the Paleocoastal and WST are often described separately, and even as separate traditions sharing a common ancestry (Pratt et al. 2020). Because tools can be exchanged, recycled or copied by members of other groups, it is difficult to outline the distribution of a tradition using typology alone. But to compare where and how the objects in question are produced would help evaluating whether the distribution of tools and their production matches, and how consistent people are in the methods and techniques they use to produce them. In the present case, a clear marine subsistence signature and coastal/insular settlement in Paleocoastal contexts sets these peoples apart from interior WST groups. However, the settlement and subsistence pattern of WST in the Great Basin focused largely on pluvial lake shores and, at least in part, lacustrine resources analogous to those of the sea. The overlap of specific tool types and the propensity for lowland WST peoples in the Intermountain West to settle near, and largely subsist from, aquatic environments, begs the question: are these in fact distinct cultural units (Pratt et al. 2020) or for all intents and purposes, do they belong to one larger cultural group that colonized the Far West?

Early Occupations of the Northern Channel Islands

Discoveries of stemmed points (and coprolites containing aDNA) with reported pre-Clovis dates from Oregon's Paisley Caves (Gilbert et al. 2008; Jenkins et al. 2012) and more stemmed points with associated pre-Clovis dates from Cooper's Ferry in Idaho (Davis et al. 2019) has led to considerable discussion concerning the nature of early settlement of the Intermountain West, and who the first inhabitants of the Americas really were. The discovery of an archaeological component dated between~14,000 and 14,600 cal BP at the Monte Verde II site in Chile, significantly predates Clovis in the Americas, while the abundance of various species of seaweed at this inland location supports the theory that the first South Americans were also exploiting coastal resources (Dillehay et al. 2008; Erlandson et al. 2008; Meltzer et al. 1997). If, as Beck and Jones (2010) suggest, the mainland WST originated from an early Pacific Coastal migration and colonization event, then detailed analysis of the earliest coastal stone tool assemblages is clearly needed to evaluate the degree of similarity or differences in the organization of production with contemporaneous technological systems of the Intermountain West.

The southern California Channel Islands play a pivotal role in our understanding of the early maritime settlement of the region. During the late Pleistocene, the northern chain of the southern California Channel Islands once connected Anacapa Island, Santa Cruz Island, Santa Rosa Island, and San Miguel Island as one larger landmass known as *Santarosae*. Even during the Last Glacial Maximum some 18,000-23,000 BP, Santarosae was separated from the mainland coast by at least 6-8 km requiring watercraft to reach. Due to an influx of glacial melt water, Holocene sea levels rapidly rose up to 110 meters by approximately 9,000 cal BP, separating Santarosae into the current northern island chain, eroding and/or covering seaside habitation sites and approximately 75% of Santarosae (Reeder-Meyers et al. 2015) (**Figure 11**). Even still, more than 100 Paleocoastal sites, exhibiting diagnostic flaked stone tools and a consistent radiocarbon chronology, have been identified (Erlandson et al. 2020). Additionally, the Arlington Man burial, originally recovered by Orr (1960) at CA-SRI-173 and later dated by Johnson and coauthors (2002) to approximately 13,000 cal BP, is among the earliest human fossils in the Americas (though see Erlandson et al. 2020:9). Although it may document early maritime migrations, such a body of evidence suggests that the terminal Pleistocene-early Holocene human occupation of California's Channel Islands was far from ephemeral.

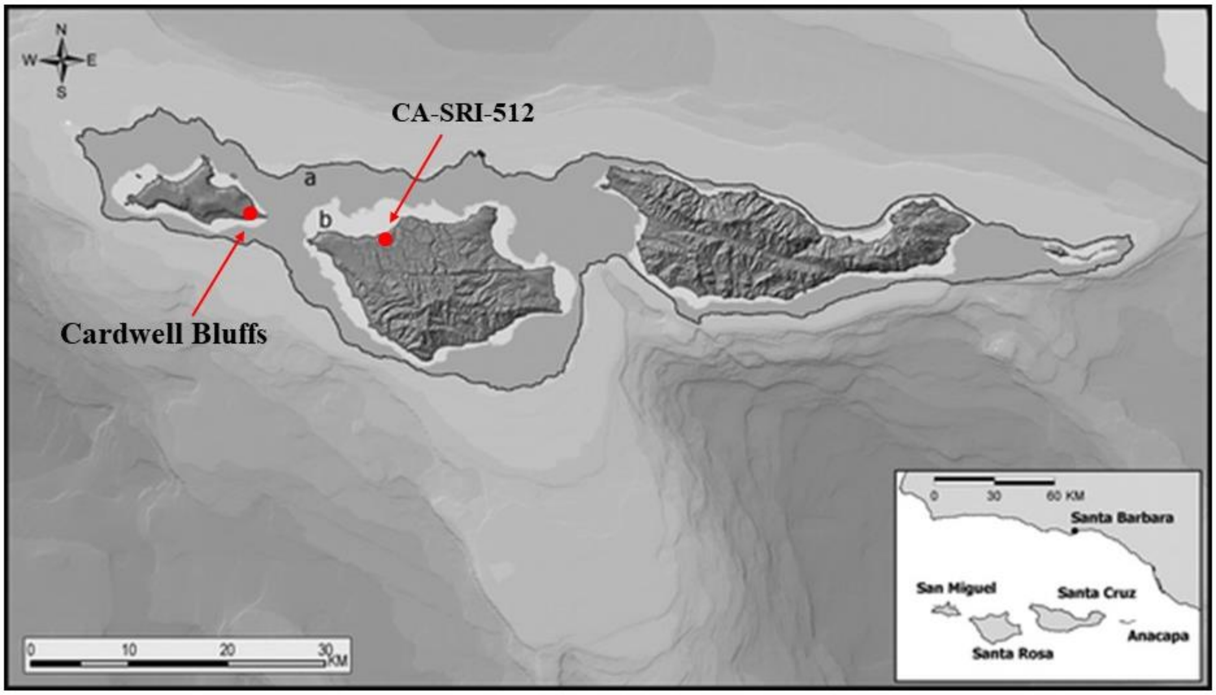

Figure 11. Site locations in relation to Santarosae paleo-shorelines a) 13,000 BP and b) 9,000 BP (Adapted from Watts et al. 2011)

Who Were the Earliest Channel Island Hunter-Gatherers?

To summarize, the understanding of Channel Islands archaeology has improved over the last few decades, and the material reviewed above is relevant for the current debates on the early peopling of the New World. It also shows that there are many questions left unanswered on the cultural affinities, and overall subsistence of the hunter-gatherer populations who inhabited the islands. Below we highlight two questions (among many) that a technological study may help to address:

- *Do Island Paleocoastal and mainland WST technologies share enough similarities to suggest shared ancestry?* In over 200 years of antiquarian collecting and archaeological research, not a single fluted projectile point associated with Clovis or their descendent populations has ever been recovered on any southern California Channel Island. Instead, stemmed projectile points and lithic crescents are common diagnostic artifacts associated with the earliest human presence yet known on these islands. Still, the nature of the relation between the earliest Channel Islanders and the mainland WST is still unclear.
- *Where did Island Paloecoastal groups come from?* To discuss potential technological antecedents of these early American populations, Pratt and coauthors (2020) conducted a broad typo-technological comparison between the published data on Paleocoastal assemblages from the California Channel Islands, mainland WST assemblages, and lithic assemblages from Siberia and the broader Pacific Rim. Our own analyses of flaked stone tool production in Paleocoastal contexts (Chapter 2) suggest that there are still undetected technological systems in the California Channel Islands relevant to this issue. Although it is notoriously difficult to find the origins of the so-called 'archaeological cultures', it seems essential to determine how much variation there is (or the lack thereof) behind the production of the very tools defining the WST in this quest for antecedents.

There are currently too few technological analyses of lithic artifacts from the terminal Pleistocene and early Holocene on California's Channel Islands, and further, stratified Island Paleocoastal Tradition sites are rare. Without detailed technological studies, it is unclear whether stone tool production studies can help address these questions. Hence, we first need to evaluate if technological data are a suitable proxy for identifying a common cultural background, or if it shows variations that are sensitive to variables such as raw material access, site function or other practical constraints. We assume that both pragmatic constraints and cultural background are recorded in the technological systems, but can we expect technology to inform on the identity of a group?

To address this issue, we follow a three-step approach:

- First, we examine the stone tools from three distinct Paleocoastal assemblages on the southern California's Northern Channel Islands. For each site, we used empirical observations to reconstruct parsimonious technological models that best describe the manufacture of the toolkits.
- Second, we compare the technological models obtained to highlight the main commonalities and differences and discuss the meaning of the variations observed. We expect that if there is such a thing as a technological signature in the Channel Islands material, the three sites analyzed should show relative consistency in the production of diagnostic tool types despite differences in raw material access, settlement patterns, or other practical constraints. The absence of clear patterns in the production would point toward flexible technological solutions and a system driven by equifinality. In this scenario, technological procedures would be more likely to inform on adaptive processes faced by human groups than on cultural affinities.
- Third, we extend the comparison to what is known from the WST assemblages on the mainland. If there is a cultural connection between the Channel Islands and the mainland WST, we expect that some technological redundancy will be discernable beyond the constraints of an insular context. It is understood that the lack of a technological pattern would not invalidate a possible connection between the islands and mainland, but it would certainly inform on the limits of using technology as a proxy to establish such a connection.

Material

Site Descriptions

CA-SRI-512 is located on an uplifted marine terrace east of the mouth of Arlington Canyon on Santa Rosa Island (**Figure 11**), not far from where the remains of Arlington Man, ^{14}C dated to ~13,000 cal BP, were found in 1959 (Johnson et al. 2002). Securely dated between ~11,800-11,500 cal BP, CA-SRI-512 contained a dense artifact assemblage associated with thousands of faunal remains, including well preserved bird, fish, and marine mammal bones recovered from a discrete and deeply buried paleosol. Surface collection and excavated units yielded an artifact assemblage dominated by stemmed projectile points, crescents, associated preforms, flake tools, debitage, and a few cores and tested pebbles. Additionally, a few bone tools, incised minerals including red ochre, and a single hammerstone, were recovered (for more detailed description, see Erlandson et al. 2011).

CA-SMI-678 and CA-SMI-679 are two dense lithic scatters associated with intact shell midden deposits on San Miguel Island. They are securely dated to the terminal Pleistocene, between ~12,200 and 11,200 cal BP (Erlandson et al. 2011). Situated on the bluffs near Cardwell Point, approximately 1-2 km from the late Pleistocene shoreline (**Figure 11**), the two sites were first recognized as belonging to the Island Paleocoastal Tradition due to numerous temporally diagnostic artifacts including CIB points, Channel Island Amol (CIA) points, and lithic crescents (Braje et al. 2013; Erlandson et al. 2011). Cardwell Bluffs may have attracted early island inhabitants due to a commanding view of the coastline below, coupled with an abundance of lithic raw material occurring as chert nodules in this uplifted ancient marine terrace. Collectively, the Cardwell Bluffs site complex spans an area of approximately 300 x 500 meters and has yielded nearly 400 bifaces in multiple stages of production in addition to the diagnostic artifacts described above (Erlandson et al. 2011). While the assemblages are largely surficial due to soil deflation, several intact midden deposits within the two sites were also located providing important chronological context as well as information on early coastal foraging strategies and environment. Twelve test pits were excavated within the intact midden deposits yielding thousands of flaked stone artifacts and almost 10kg of marine shell. It should also be noted that soil profiles from both sites suggest that the cultural materials were long covered by dune sands and only recently exposed which may be one of the reasons the site complex was not heavily looted by early antiquarians.

Four midden deposits located at CA-SMI-678 yielded AMS ^{14}C dates from well preserved marine shell situating occupations of this site between~12,250 to 11,200 cal BP Erlandson et al. 2011). Shellfish remains included red abalone (*Haliotis rufescens*), giant chiton (*Cryptochiton stelleri*), California mussel (*Mytilus californianus*), various crabs, and black turban snail (*Tegula funebralis*), a species with relatively low comparative meat yields. Perhaps as a result of the schlep effect, or a combination of sun exposure, sand blasting (of surface materials), soil composition, and differential faunal preservation, no osseous materials were observed.

Four ^{14}C dates on marine shell from a single basin shaped midden deposit located at CA-SMI-679 provided four ^{14}C dates on marine shell, which averaged of 11,850 cal BP (Erlandson et al. 2011). Although a charred twig was also dated to~13,000 cal BP, which may reflect an earlier occupation of the site contemporaneous with reported ^{14}C dates from Arlington Man (Johnson et al. 2002). Erlandson et al. (2011) put little credence in the presence of an earlier cultural component, however. The basin-shaped midden deposit was dominated by black turban snails adjacent to the earliest recorded pitted stones on the islands, an artifact that has been associated with *Tegula* marine snail processing for some time (Cook et al. 2017; Studwick 1995; Webb and Jones 2018). Significantly, no artifacts more typical of middle Holocene and late Holocene occupations were found at these two sites.

In addition to flaked stone tools, several lithic artifacts associated with cooking and processing activities were also recovered from both Cardwell Bluffs sites and CA-SRI 512. Fire Affected Rock (FAR) including a cooking stone exhibiting substantial residue, and pitted stones were among the processing and cooking related implements from the Cardwell Bluffs sites. CA-SRI-512 exhibited several pieces of incised soft mineral including shale and red ochre, and a soft mineral hammerstone as well as two unifacial cobble choppers of quartzite and meta-volcanic rock. While these artifacts make up a small portion of the three assemblages, they provide evidence for activities across these sites that included cooking with heated stones (possible stone-boiling or pit-roasting) and possibly woodworking or heavy hide-working with the cobble tools.

To summarize, we compare sites that differ in terms of context. CA-SRI-512 has yielded both buried and surface material for what represents a relatively small assemblage likely corresponding one or more short-term occupations. CA-SMI-678 and CA-SMI-679 are larger, buried and surface lithic assemblages that appear to represent a palimpsest of several terminal Pleistocene and early Holocene occupations spanning a millennium or more. The taxa identified at the sites also differ although they are part of the variations expected for the subsistence of hunter-gatherers in the Paleocoastal environment. Although subject to time-average accumulations to a degree, these are among the best documented sites providing contextual information for crescents, CIB points, and CIA points, without concern for possible mixing with middle and late Holocene cultural materials.

Sampling Method

As we stressed above, there are few stratified sites documenting the distribution of the Paleocoastal technology in question. The focus on excavated data comes at the expense of the sample size considered. Here, we compare excavated data with the associated surface assemblage to reconstruct time-averaged sequences. Pending the analysis of larger excavated assemblages, it provides a first look at the technological context surrounding the occurrence of diagnostic tool types such as crescents, Channel Islands Barb points, and CIA points.

Materials analyzed as part of this broader inter-site comparison were comprised of 465 formal lithic artifacts recovered from the Cardwell Bluffs Paleocoastal occupations at CA-SMI-678 and CA-SMI-679 and the 183 previously reported (Chapter 2) flaked stone tools (**Table 9**) and 1,894 pieces of debitage recovered from CA-SRI-512.

Since the surface materials from these sites were largely deflated due to post depositional erosion, systematic surface collection targeted the recovery of all bifaces, formal tools, cores, and diagnostic artifacts, which were numerous and comprised the majority of the assemblages. Flake tools were collected from surface contexts only when overall morphology was obviously indicative of human modification. Additionally, at CA-SMI-678 and CA-SMI-679, twelve 1x1 meter test units were excavated using trowels, brushes, and scoops, in arbitrary 5cm levels to determine the depth of remaining deposits and potential stratigraphic integrity. All excavated sediment from these units was dry-screened over standard 1/8" mesh. The shell midden deposits, unfortunately relatively shallow in nature, did produce a small number of Paleocoastal artifacts in situ consistent with those from overlying surface contexts and from previously described buried Paleocoastal assemblages (Erlandson et al. 2011; Gill et al. 2021).

Lithic analysis was conducted on all surface collected and excavated bifaces, formal tools, and diagnostic artifacts at the University of Oregon's Island and Coastal Archaeology Laboratory. In addition to analyses of all formal flaked stone tools, debitage-specific analysis was conducted on a small assemblage recovered from Locus D, Unit 1 and Unit 2 (two of the most artifact-rich units) from CA-SMI-678. Numerous flake tools were recognized and separated from the CA-SRI-512 and CA-SMI-678 assemblages during debitage analysis, but a comparable sample from CA-SMI-679 has yet to be completed. Hence, the frequencies of flake-tools from CA-SMI-679 listed here should be understood as minimum frequencies.

Table 9: Summary of formal lithic artifacts in the sample

	Surface						**Excavated**					
	CA-SMI-678		*CA-SMI-679*		*CA-SRI-512*		*CA-SMI-678*		*CA-SMI-679*		*CA-SRI-512*	
	n	**%**	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**
Cores	-	-	5	1.5	7	6	2	14	-	-	9	14
Prod. Bifaces	60	48.8	213	65.9	23	19.7	5	36	2	40	13	20
CIA's	11	8.9	15	4.6	-	-	1	7	-	-	-	-
CIA Preforms	6	4.9	7	2.2	-	-	-	-	-	-	-	-
CIB's	5	4.1	15	4.6	32	27.4	-	-	-	-	7	11
CIB Preforms	3	2.4	6	1.9	15	12.8	-	-	-	-	5	8
Misc. Points/Pref.	20	16.3	29	9	4	3.4	2	14	-	-	3	5
Crescents	4	3.3	19	5.9	9	7.7	-	-	-	-	4	6
Cresc. Preforms	4	3.3	8	2.5	6	5.1	1	7	1	20	3	5
Flake Tools	10	8.1	6	1.9	21	17.9	3	21	2	40	21	32
Total	**123**	**100**	**323**	**100**	**117**	**100**	**14**	**100**	**5**	**100**	**65**	**100**

Methods

The analytical approach used in this inter-assemblage comparison relies on a descriptive analysis of qualitative features and quantitative metric attributes to evaluate manufacturing trajectories within specific artifact classes. The classes include tested raw materials and cores, bifaces, preforms, crescents, conventional points, flake tools and scrapers. These observations are then used to reconstruct models of operational sequences (*chaine operatoire*). Since the specific focus of this technological analysis is concerned with comparing the organization of production across sites and assemblages, we are presenting the main attributes that may reflect specific decisions made by groups of knappers regarding raw material procurement, core manipulation, blank production, and tool refinement.

Qualitative and quantitative lithic artifact analyses were non-destructive in nature and adapted from Amick (1999), Andrefsky (2005), Inizan et al. (1999), and Beck and Jones (2015). When applicable, artifacts were evaluated on their condition of preservation, biface stages of reduction, flake scar orientation, flake scar morphology, platform preparation, cross-section and profile shape, and associated lithic reduction methods and techniques. Late-stage bifaces exhibiting thin bi-convex to flattened cross-sections, straight (or nearly straight) profiles, a general size and shape reflective of diagnostic artifacts, but with some degree of un-flaked platforms, sinuous edges, and/or plan asymmetry, and in some cases morphology closely resembling diagnostics (but with clearly unfinished blade edges, stems, wings, etc.) were designated as point and/or crescent “preforms” and were analyzed separately from production bifaces. Diagnostic bifacial artifacts (conventional points and crescents) were also analyzed separately from production bifaces. Diagnostic typological assignments were derived from Glassow et al. (2013), Erlandson (2013), Hopkins and Fenenga (2010), Tadlock (1966), and Justice (2002). Analysis of cobble tools, ochre, and manuports was also non-destructive in nature, and methods were adapted from Adams (2002). These analyses included basic quantitative measurements of artifact metrics, and qualitative assessments of potential wear patterns such as battering and abrasion that may have resulted from artifact use. In addition to formal flaked stone artifacts, a sample of the debitage from CA-SRI-512 and CA-SMI-678 was also analyzed. Flakes ≥1” (25mm) were measured independently as potential tool-blanks while all debitage below this size fraction were analyzed and organized by material type, flake type, preservation, and/or heat spalls and shatter. Any debitage under 1/16” were left unanalyzed as they were smaller than the smallest size screen used in the excavation of these materials.

The following section summarizes key features of flaked stone tool production across these three Paleocoastal assemblages. Special attention concentrates on describing specific steps in the reduction process including core reduction, and the production of bifaces, preforms, conventional points, crescents, and flake tools. Here, the overall reduction sequence/*chaine operatoire* is emphasized, including material procurement, artifact functions, and patterns of discard. It should be noted that *methods* and *techniques* are treated as complementary but distinct categories for evaluating manufacturing behaviors. Here, we follow Inizan and coauthors (1999:30) where the term *methods* refers to a chain of events or system of reduction leading to artifact production, whereas the term *techniques* refers to tools or technical means used in artifact manufacture (e.g., pressure flakers, percussion flaking, and heat treatment). Site functionality, and how Island Paleocoastal patterns of manufacture overlap with and/or differ from the broader Western Stemmed Tradition will be addressed in the subsequent discussion.

Results

Raw Material Procurement

At CA-SRI-512, lithic raw materials were dominated by local variants of Monterey chert (100% of the early and middle stage bifaces). No clear evidence of raw materials quarried from primary outcrops was observed. Instead, all cortex identified exhibited characteristic features (rounded and sub-rounded water-tumbled edges and micro-hertzian cones) typical of neocortex, indicating that raw materials seem to have been pebbles derived from secondary deposits including late Pleistocene shorelines and/or uplifted conglomerate benches (Erlandson et al. 2008:26, Jew et al. 2013:53-54). Flaked stone tools in this assemblage are overwhelmingly dominated by local chert; specifically, Tuqan/Monterey chert (see **Figure 12a**). Cico chert (a chalcedonic semi-translucent local chert variety) and Wima chert (island opaque chert and cherty-shale ranging in color) (Erlandson et al. 2012) were also present in the assemblage, but at significantly lower frequencies, indicating infrequent procurement from sources more distant from CA-SRI-512 than predictable local sources of Tuqan/Monterey chert, or curation of those kinds of artifacts over longer periods if people were moving across islands in seasonal rounds.

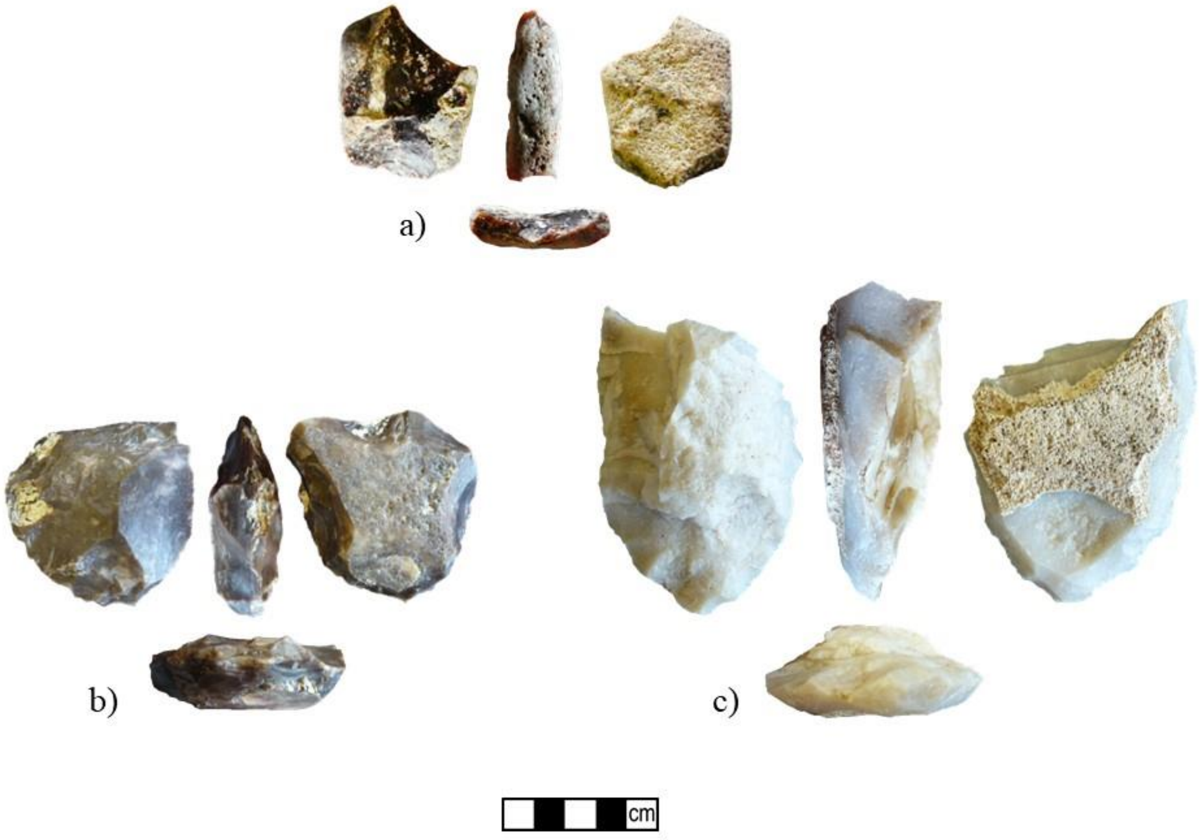

Figure 12. a) Bi-directional neocortical Tuqan chert pebble core/tested pebble exhibiting white weathered rind from CA-SRI-512, b) Monterey chert discoidal/hierarchical centripetal core from CA-SMI-679, c) Cico chert Hierachical bifacial core from CA-SMI-678.

CA-SMI-678 and CA-SMI-679 also exhibit high frequencies of Monterey variant cherts (**Figure 12b**). Cico chert, (**Figure 12c**) is found in outcrops and raised beach deposits on several of the Northern Channel Islands including the Cardwell Bluffs area (Erlandson et al. 1997; Jew et al. 2013:53-54), and is more prevalent at both Cardwell Bluffs sites than at CA-SRI-512, which may reflect the use of a Cico chert source located closer to the Cardwell Bluffs area. For instance, among the middle and late stage bifaces, ten (17%) at CA-SMI-678 and sixteen (8%) from CA-SMI-679 were made on Cico chert with the rest made on Monterey/Tuqan chert. Another difference is that unlike the assemblage at CA-SRI-512, Wima chert is absent (Erlandson et al. 2012). Also unlike CA-SRI-512, where much of the material appears to have been imported as later stage bifaces, conventional points, and crescent preforms, the Cardwell assemblages exhibit early production stages on site. While CA-SRI-512 provided high frequencies of diagnostics and tools in the later stages of manufacture, artifacts in early reduction stages were rare. In contrast (X^2 (6, n = 366) = 68.717, p =<0.01), both Cardwell Bluffs sites exhibit all production stages of biface reduction, with a higher frequency of early stages, providing an opportunity to expand interpretations of a complete manufacturing trajectory (**Table 10**). However, Cardwell Bluffs sites differ with one another in terms of Early and Late stage frequencies (X^2 (3, n = 366) = 10.092, p =0.012).

Table 10: Summary of biface reduction stages across the three sites

	CA-SRI-512		CA-SMI-678		CA-SMI-679	
	n	%	n	%	n	%
Early	8	11	43	44	157	58.6
Middle	13	17	16	16	46	17.2
Late/Preform	47	63	35	36	52	19.4
Indet	7	9	4	4	13	4.9
	75	100	98	100	268	100

Consistent with our observations from CA-SRI-512, formal tools from the Cardwell Bluffs sites exhibiting residual cortex are dominated by the presence of rounded to sub-rounded and battered neocortex indicative of cobble rather than outcrop exploitation. At CA-SRI-512, tested pebbles and pebble core fragments indicate that chert pebbles with flattened morphology were selected for transport to the site where they appeared to have been tested using various centripetal, bi-directional, and bifacial reduction strategies. Because they produced flakes similar in size and shape compared to those used as tools, such tested cobbles could technically be considered as cores, and/or initial flaking of bifacial preforms. Raw material selection, in terms of overall pebble/cobble morphology, seems to be more variable at Cardwell Bluffs. In general, bifaces and cores are larger in size here than those recovered from CA-SRI-512, and while flattened pebbles do not necessarily dominate the early stages of these assemblages, some centripetal, discoidal and bifacial early stage reduction occur on pieces with similar flattened morphology.

Early Reduction Methods (Cores and Bifacial Cores)

Early stage cobble-core reduction, blank production, and biface manufacture appear to have been largely accomplished through direct percussion, though some bipolar percussion is also possible. Cobbles, cores, and even early stage bifaces from CA-SMI-678 and CA-SMI-679 exhibit interesting parallels with the early stages of lithic reduction from CA-SRI-512, especially a preference for reduction of one flaking surface over another. Flattened cores, which in some cases appear to have been made on large and thick flakes, or the result of thoroughly reduced thicker nodules, exhibit this clear pattern of bifacial-hierarchical-centripetal reduction (de la Torre et al. 2003), which has also been described as a flattened discoidal method (Terradas 2003). At the Cardwell Bluffs sites, cores exhibit perimeter flakes removed largely (and often solely) to establish and maintain striking platforms on the preparation surface, while the opposed face functioned as the primary flaking surface for flake-blank production (Terradas 2003) (**Figure 12b)**. While the relatively thin and flattened morphology observed in these assemblages remains distinct, the flaking pattern is reminiscent of cobble cores described as "centripetal" by Des Lauriers (2010:106-107) from early Holocene sites on Isla Cedros off the Pacific Coast of Baja California. The clear preference for one dominant flaking surface over another is most easily observed by comparing the cross section to the plan view of both faces on such artifacts. Bifacial-hierarchical-centripetal cores are somewhat rounded in plan-view, but in some cases this hierarchical reduction occurs on ovate forms. Ovate bifacial-hierarchical cores generally lack the centripetal pattern of removals on the flaking surface, likely due to their overall ovate shape (**Figure 12c**). Instead, they display irregular or broad collateral and irregular patterns of reduction with occasional removals crossing the midline of the flaking surface.

These latter forms, which for all intents and purposes are large bifaces, likely served (at least in part) as cores for the production of flake-blanks removed from the main flaking surface. It seems as though knappers chose to reduce the more convex face of bifaces, and in some cases completely ignored the opposed flat face until later in reduction. This pattern will be further described in the section below concerning middle and late stage biface thinning.

Bifaces, Preforms, Crescents, and Conventional Points

A strong emphasis on biface manufacture is exhibited across both Cardwell Bluffs sites. While CA-SRI-512 exhibited 36 (20%) early and middle stage bifaces (almost all fragmented), CA-SMI-678 and CA-SMI-679 contained 59 (60%) and 203 (76%) respectively. In all three cases, bifaces were largely recovered in fragmented form likely discarded after end shock or bending fractures split them into a number of pieces during percussion thinning. Early and middle stage biface fragments exhibit irregular and broad collateral flake scar patterning, occasionally crossing the midline but often terminating at the mid line. Most interestingly, early and middle stage bifaces also often exhibit a plano-convex cross-section similar to those recognized as bifacial cores based on their size, and smaller artifacts described by Skinner and Ainsworth (1991) which they refer to as "unifacial bifaces."

It seems that again diverging from conventional idealized biface reduction sequences, the islanders, at least on occasion, prepared platforms by marginal flaking around the perimeter in preparation for larger flakes to be struck from the opposite surface. In this sense, they reduced bifaces one face before the other. The marginal inverse removals, and a few larger removals opposite the dominant flaking surface, suggests that these artifacts are part of a bifacial rather than truly unifacial reduction continuum (**Figure 12**). By concentrating thinning flakes first on the dorsal surface of flake blanks, the knappers eventually thin and match the flat face of the ventral plain. Finally, once significantly thinned, the ventral plane is also thinned with long, invasive, and finally covering removals. It is notable that the small samples of debitage examined from Locus D, units 1 and 2 at CA-SMI-678 are dominated by biface reduction flakes, a broader category which includes more commonly cited "biface thinning flakes" (Beck and Jones 2009:126). Some of these bifaces were likely on a trajectory to be used as crescent preforms and crescents, though some may have also been used to produce some other not well defined foliate or shouldered point forms.

Overall, while the manufacture of projectile points and crescents across all three assemblages exhibits some variation in terms of typology, the technology underlying flaked stone tool production is remarkably standardized. Techniques include percussion thinning often overlaid, or even erased, by subsequent pressure flaking. Similar to the lithic assemblage from CA-SRI-512, numerous Channel Islands Barbed (CIB) points and associated preforms were recovered from both Cardwell Bluffs assemblages, although from strictly surface contexts. Five CIB's (4%) and three CIB preforms (2%) were recovered from CA-SMI-678 while, 15 CIB's (5%) and six CIB preforms (2%) were recovered from CA-SMI-679. In contrast, 39 (22%) CIB's and 20 (11%) CIB preforms were recovered from CA-SRI-512. At the Cardwell Bluffs sites, CIB's exhibit some morphological variation in size and shape; however, contracting stems and prominent barbs are traits that are broadly shared between these assemblages and those from CA-SRI-512. Most notable however is that the unique stemmed CIB preforms previously described at CA-SRI-512 (Chapter 2) also occur across the two Cardwell Bluffs assemblages. Such CIB preforms exhibit distinct hafting element morphology, where barbs and stems or at least incipient barbs and stems, were produced before the point-blade was finished (**Figure 13**). This unique reduction sequence drastically differs from those most commonly cited (Andrefsky 2005; Callahan 1979) in North American archaeological literature in that the preform hafting element is established so early on in the chaine operatoire.

Figure 13. Channel Islands Barbed (CIB) point preforms (bottom row), and finished CIB's (top row). Left column CA-SRI-512, middle column CA-SMI-678, right column CA-SMI-679. Note the finished hafting-element on the CIB preform (bottom right) even though the point-blade is unfinished.

In contrast to CA-SRI-512, both Cardwell Bluff's sites yielded a number of finely crafted Channel Island Amol (CIA) points as well. Twelve CIA's (9%) and six CIA preforms (4%) were recovered from CA-SMI-678 with 15 CIA's (5%) and seven CIA preforms (2%) were recovered from CA-SMI-679. Across the two Cardwell Bluffs sites, CIA's also exhibit some morphological variation in size and shape, but contracting stems, shoulders, and in some cases fine serrated margins are traits that are broadly shared between both assemblages. Similar to the CIB preforms found in all three sites described above, CIA point preforms across the two Cardwell assemblages also exhibit distinct hafting element morphology, where shoulders and stems appear to have been produced before the point-blade was finished (**Figure 14**), again starkly contrasting the most commonly cited point reduction models (Andrefsky 2005; Callahan 1979).

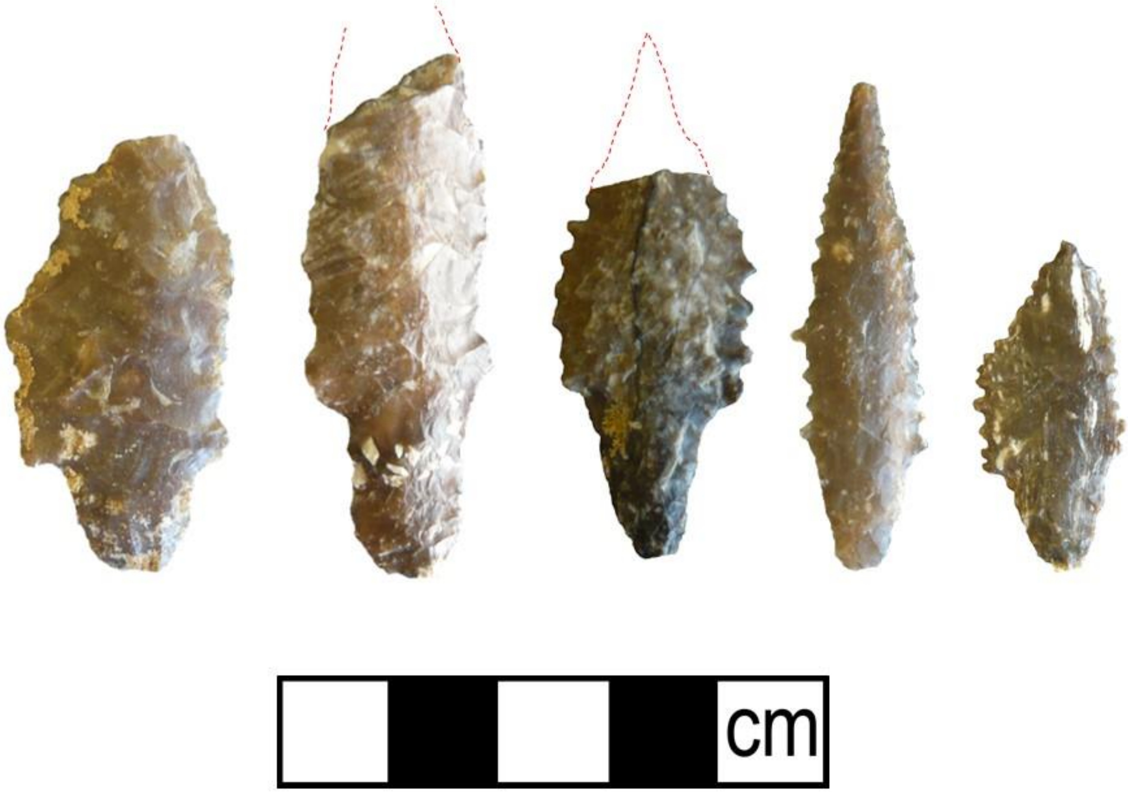

Figure 14. Left to right: Channel Island Amol (CIA) point preform from CA-SMI-678, CIA preform from CA-SMI-679, CIA from CA-SMI-678, and two CIA's from CA-SMI-679. Note the established hafting elements on the preforms even before the blades are finished and the serrated retouch along the distal left margin of the far-right specimen possibly indicative of reworking of a broken point for use as a knife.

Lithic crescents and associated preforms, similar to artifacts found in abundance at CA-SRI-512, were recovered from both Cardwell Bluffs sites. In contrast to the crescents from CA-SRI-512 which were dominated by lunate forms, several known lunate, winged, and eccentric crescent types (Hopkins and Fenenga 2010; Fenenga 1984) were recovered from the Cardwell Bluffs sites. Four crescents (3%) and five crescent preforms (4%) were recovered from CA-SMI-678, while 19 crescents (6%) and nine crescent preforms (3%) were recovered from CA-SMI-679.

Across the Cardwell Bluffs sites, variation in crescent sub-types and overall crescent size was present. However, more broadly, certain specific eccentric and lunate forms were shared between the Cardwell Bluffs assemblages, and the lunates from these contexts overlap typologically with those recovered from CA-SRI-512.

Similar to the stemmed point preforms described above, crescent preforms across these three assemblages also exhibit distinct morphology reflective of type-specific shapes early in their reduction, and at least occasionally exhibit the establishment of hafting element morphology (if hafted as transverse projectile points), similar to finished forms (but before crescent wings are fully finished) (**Figure 15)**.

Figure 15. Left column: crescent (top) crescent preform (bottom) from CA-SRI-512. Middle column: crescent (top) and crescent preform fragment (bottom) from CA-SMI-678. Right column: crescent (top) and crescent preform (bottom) from CA-SMI-679. Note how the unique shape of crescent preforms often reflects specific finished crescent types.

Miscellaneous Points and Flake Tools

The term "miscellaneous points" is used here to describe late stage bifaces that may be finished or nearly finished points but do not yet fit known island typologies. It groups artifacts that could have functioned as points, knife blades, or even point preforms (**Figure 16)**. Similar to the six (3%) non-diagnostics recovered from CA-SRI-512, twenty-two miscellaneous points/point preforms (16%) were recovered from CA-SMI-678, and 29 miscellaneous points/point preforms (9%) were recovered from CA-SMI-679. Across the two Cardwell Bluffs sites, these late-stage bifacial pieces exhibit some variation in morphology, yet foliate and shouldered forms broadly overlap between these two assemblages and CA-SRI-512. While miscellaneous foliate and shouldered forms of non-diagnostic points occur in relatively high frequencies when compared to diagnostic point types, the former category likely includes some unrecognized preforms of the latter.

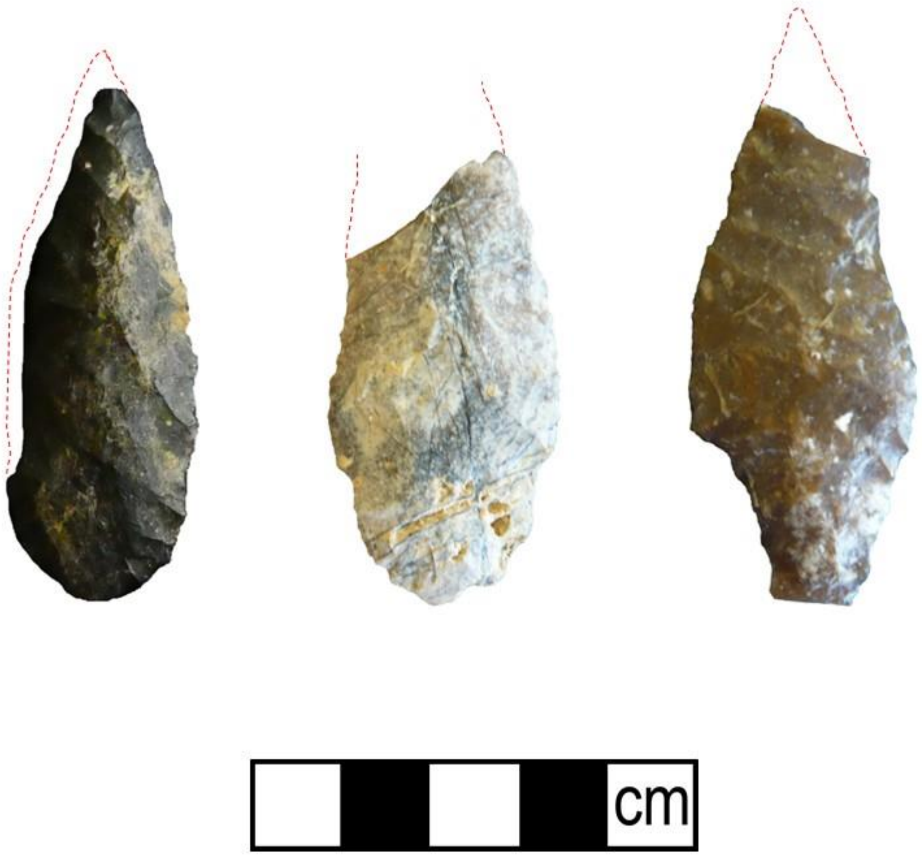

Figure 16. Miscellaneous points. Left: foliate with impact-burination from CA-SRI-512. Middle: Stemmed point proximal fragment from CA-SMI-678. Right: Single-shouldered stemmed point missing tip from CA-SMI-679.

All three assemblages exhibit simple flake tools which likely functioned as scrapers, gravers, spokeshaves, and cutting tools (**Figure 17**). These artifacts were collected from surface contexts only when overall morphology was obviously indicative of human modification and therefore reflects only the minimum number of possible utilized flakes. Thirteen (10%) modified flake tools were recovered from CA-SMI-678, while eight (2%) were recovered from CA-SMI-679. These tools exhibited some variation in morphology, but are dominated by small removals from use and retouch overwhelmingly concentrated on dorsal planes. Across these two assemblages, multiple used edges suggest multi-functionality including use as spokeshaves, gravers, and scrapers. These tools are consistent with the 42 flake tools recovered from CA-SRI-512, a sample of which, when submitted to micro-wear analysis, was most likely associated with the processing of hard and medium-hard materials, such as dense wood and bone (Chapter 2).

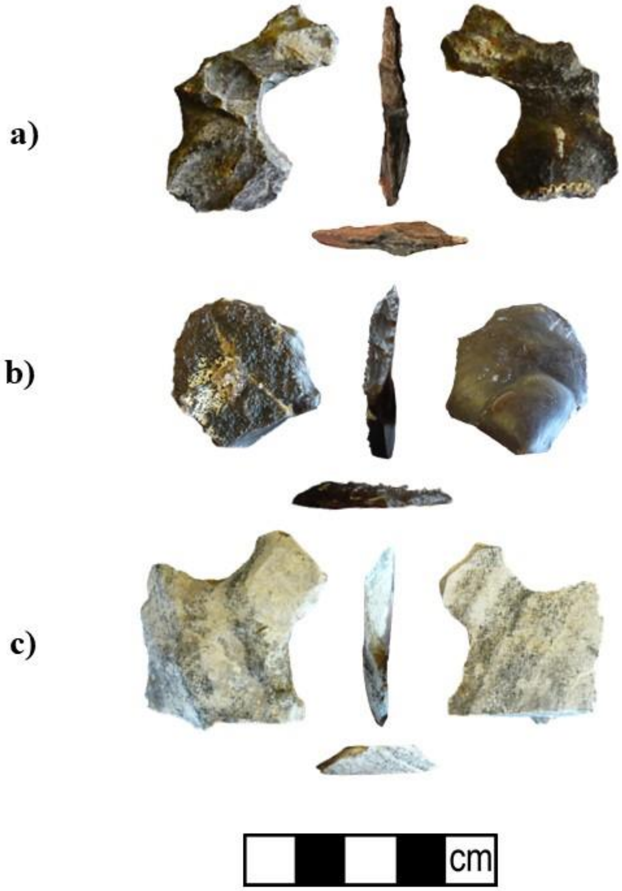

Figure 17. Flake tools: a) concave "spokeshave" scraper from CA-SRI-512, b) convex end scraper/graver from CA-SMI-678, c) dual concave "spokeshave" scraper from CA-SMI-679.

Debitage

A sample of debitage was analyzed from two 1x1 meter units (1&2) with the highest lithic artifact densities at CA-SMI-678's Locus D, dated to ~12,000 cal BP. Considering that the depth of the deposit at this CA-SMI-678 locus is relatively shallow (~12-20cm) compared to our previous debitage analysis of the two richest units at CA-SRI-512 which yielded nearly 2,000 pieces of debitage, artifact densities here are relatively low. **Table 11 - Table 14** provide a summary of flake types and material frequency among the debitage from CA-SMI-678.

Table 11: Debitage summary CA-SMI-678, Locus D, Unit 1.

	Monterey		Cico		Other		Total	
	n	%	n	%	n	%	n	%
Core Reduction	8	6.5	3	9.7	2	40	13	8.2
Biface Reduction	16	13	6	19.4	-	-	22	13.8
Retouch	19	15.4	3	9.7	-	-	22	13.8
Burin Spall	1	0.8	-	-	-	-	1	0.6
Flake Fragment	32	26	13	41.9	1	20	46	28.9
Shatter	35	28.5	4	12.9	2	40	41	25.8
Potlid	12	9.8	2	6.5	-	-	14	8.8
Total	123	100%	31	100%	5	100%	159	100%

Table 12: Debitage summary CA-SMI-678, Locus D, Unit 2.

	Monterey		Cico		Other		Total	
	n	%	n	%	n	%	n	%
Core Reduction	13	6.7	-	-	1	20	14	5.8
Biface Reduction	23	11.8	5	12.2	-	-	28	11.7
Retouch	19	9.7	9	22	-	-	28	11.7
Flake Fragment	84	43.1	16	39	1	20	100	41.7
Shatter	42	21.5	6	14.6	2	40	50	20.8
Potlid	14	7.2	5	12.2	1	20	20	8.3
Total	195	100%	41	100%	5	100%	240	100%

The debitage signature from the two richest units (Unit 4 and Unit 8) at CA-SRI-512 are both dominated by retouch flakes (38% and 29% respectively) followed by biface reduction at 16% (Unit 4) and 19% (Unit 8). Monterey is the most utilized material type.

Table 13 : CA-SRI-512, Unit 4 Debitage

	Monterey		**Cico**		**Other**		**Total**	
	N	%	N	%	N	%	N	%
Core Reduction	9	1.1	-	-	4	6.6	13	1.5
Biface Reduction	126	15.7	1	5	13	21.3	140	15.8
Retouch	318	39.5	9	45	17	27.9	344	38.8
Burin Spall	4	0.5	-	-	-	-	4	0.5
Flake Fragment	284	35.3	7	35	20	32.8	311	35.1
Shatter	27	3.4	1	5	5	8.2	33	3.7
Potlid	37	4.6	2	10	2	3.3	41	4.6
Total	805	100%	20	100%	61	100%	886	100%

Table 14 : CA-SRI-512, Unit 8 Debitage

	Monterey		Cico		Other		Total	
	N	%	N	%	N	%	N	%
Core Reduction	18	1.8	-	-	4	6.5	22	2.0
Biface Reduction	199	20	-	-	6	9.7	205	19.1
Retouch	287	28.8	5	29.4	21	33.9	313	29.1
Burin Spall	-	-	-	-	-	-	-	-
Flake Fragment	364	36.5	12	70.6	15	24.2	391	36.4
Shatter	32	3.21	-	-	10	16.1	42	3.9
Potlid	96	9.6	-	-	6	9.7	102	9.5
Total	996	100%	17	100%	62	100%	1075	100%

While significant early reduction appears to have been a dominant activity at the Cardwell Bluffs sites, especially evidenced by the high density of early-stage bifaces, the debitage signature at the two richest units (1 and 2) at CA-SMI-678 are evenly split between biface reduction and retouch. When focusing on these two categories and the core reduction, the assemblages from the two sites share the same frequencies (X^2 (3, n = 399) = 2.121, p =0.5476). By comparison, retouch and bifacial flake frequencies are much higher in Unit 4 (the same applies to Unit 8) at CA-SRI-512 while core reduction remains relatively low (X^2 (6, n = 1285) = 123.307, p =<0.01).

In both units, Monterey chert dominates the assemblages and overall the frequencies of raw material are the same (X^2 (2, n = 400) = 0.919, p =0.6315). In Unit1, Monterey chert retouch flakes (15%) are only slightly more dominant than biface reduction flakes (13%) while the

Monterey chert debitage from Unit 2 has slightly higher frequencies (12%) of biface reduction than retouch (10%).

A single burin spall was also identified from Unit 1, Level 1. While no burinated artifacts were observed at CA-SRI-512, two burinated bifaces were found at CA-SMI-678 and nine were recovered from CA-SMI-679 (which we will revisit later in this paper). However, the presence of a single spall may be simply an unintentional byproduct of flintknapping activities, or strictly accidental due to an artifact dropping on a hard surface. Finally, while some flakes ≤1” (25mm) were observed on both Cardwell Bluffs sites, none were recovered from Unit 1 or Unit 2 at CA-SMI-678.

Summary: Paleocoastal Lithic Technological Organization

All three Paleocoastal assemblages share a basic reduction sequence (**Figure 18, Table 15**). First, there is an emphasis on raw material from secondary sources. Chert nodules in the form of beach-tumbled neocortical pebbles or small cobbles were collected from late Pleistocene shorelines or uplifted conglomerate beds. Cobbles and pebbles were then tested and reduced by removing flakes from one of the broad surfaces, while the other surface shows little to no preparation (hierarchical approach) except for peripheral platform preparations. The reduction patterns are centripetal or discoidal. The plano-convex nodule was then reduced from the opposite face to reach a roughly symmetrical cross-section, which was then thinned into a bifacial preform.

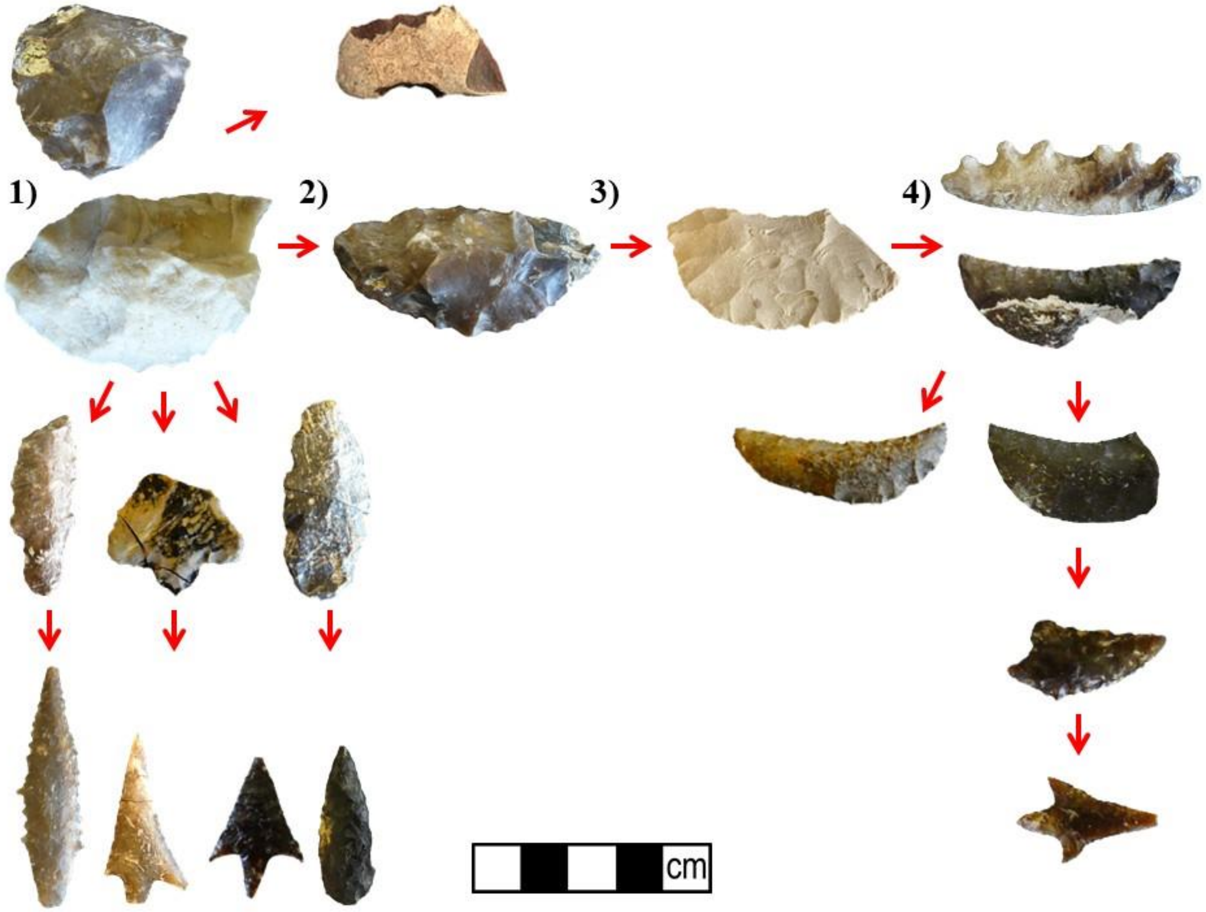

Figure 18. Island Paleocoastal Tradition General Chaîne Opératorie: Stage 1: bifacial core or discoidal core is used to produce flakes for the manufacture of flake-tools (top right) or stemmed points (bottom left). Step 2: bifacial cores are further reduced and may start taking on crescent-shape if unbroken. Step 3: crescent preforms take shape reflecting finished-crescent morphology. Step 4: crescents are refined and finished. Lower right: crescents are then either burinated and retooled, heavily fragmented and discarded, or fragments are recycled into CIB's (far right bottom).

Meanwhile, flakes were produced in the process and could be used as potential tool blanks. Some flakes were then selected for use as simple edge-modified tools including scrapers, gravers, and spokeshaves. Thinner and flatter flakes were selected for the manufacture of CIB and CIA points. Some larger flakes may have been used to produce crescents as well but so far, there is little evidence for the systematic production of large flakes.

Bifacial cores, subsequently thinned after flake-blank production, were used as preforms for crescents, but they also may have served as preforms for foliate, shouldered, or other unknown point types possibly exported from these sites. CIB points, CIA points, and crescents of several types across all three sites share a peculiar reduction sequence where hafting element morphology was nearly finished (or in some cases completely finished) before point blades and crescent wings were fully refined (**Figure 19**).

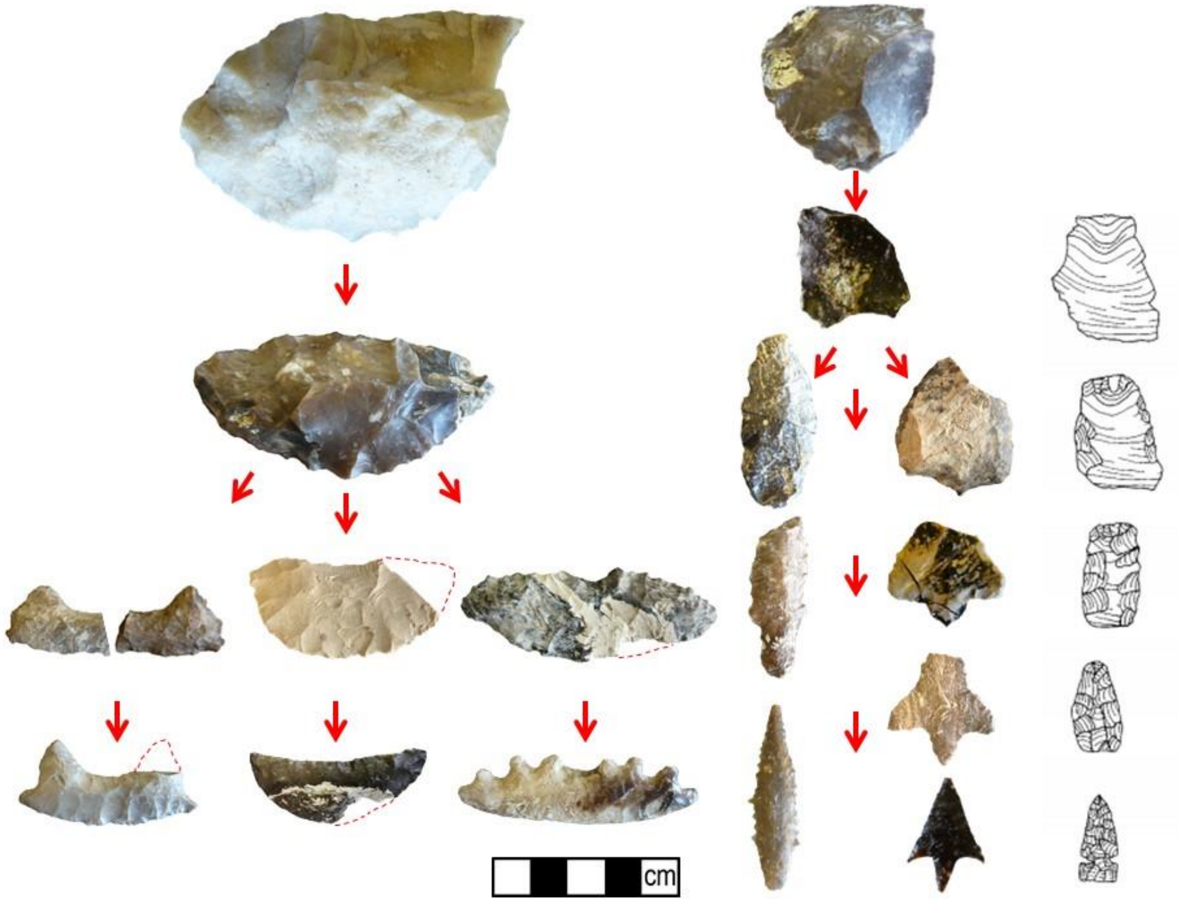

Figure 19. Specifics of crescent chaine operatoire (left) and stemmed points (right) compared to idealized reduction sequence (far right) adapted from Andrefsky (2005:32). Note how Island Paleocoastal point and crescent reduction deviates from the idealized sequence with hafting elements and/or stemmed preforms taking shape before the blade or wings take final shape. Also note: top left is a bifacial hierarchical core, top right is a discoidal core, but most reduction across these assemblages seems to derive from a bifacial origin.

Table 15: comparative table summarizing the reduction sequences. Main differences are shaded

	CA-SMI-678 CA-SMI-679	**CA-SRI-512**
Raw material	Mostly local, cobbles, flat cobbles, Tuqan/Monterey + Cico Chert	Mostly local, cobbles, flat pebbles, Tuqan/Monterey + Cico and Wima chert
Flake production	Unifacial cores, surface reduction with centripetal pattern (possibly tested cobbles for bifacial reduction)	Poorly represented, tested flat cobbles with unifacial cores, surface reduction with centripetal pattern
Bifacial Preform	Bifacial (& occasionally unifacial plano-convex preforms, prepared on site	Bifacial and unifacial plano-convex preforms, mostly imported (?); Early stages missing
Bifacial thinning	Mostly reduced from the convex face, then adjusted on the flat face	Mostly reduced from the convex face, then adjusted on the flat face
Biface	Abundant, mostly fragmented, late stage show transitional forms toward crescents or foliates	Show transitional forms toward crescents or foliates, occasionally used as core
Crescent	On elongated bifaces, specific types discernable on preforms, occasionally mid-section produced first	On elongated bifaces, mid-section produced first, mostly lunates, mostly fragmented, occasionally reshaped as CIB
CIA	On flakes from bifacial reduction, stem produced first	Absent
CIB	On flakes from bifacial reduction, stem produced first	On flakes from bifacial reduction, stem produced first
Other Points	Variable, may include preforms of known types	Variable, may include preforms of known types
Flake tools	Flakes from centripetal cores or bifacial thinning, retouched into scrapers, spokeshave or graver	Flakes from bifacial thinning, retouched into scraper, spokeshave or graver

Differences exist between the assemblages (highlighted in Table 5), but we note that they are mostly observed between the two localities, Cardwell Bluffs and CA-SRI-512. Essentially, they have to do with the lack of core reduction and early stages of bifacial reduction at CA-SRI-512. We also note that the Cardwell assemblages show typological variations not observed at CA-SRI-512, with the occurrence of the CIA points but also with more diverse crescent types. As we discuss in the following section, most of these differences can be explained when considering site functions in a dynamic settlement pattern.

Discussion

Our previous analysis of the flaked stone tool chaine operatoire at CA-SRI-512 (Chapter 2) left us wondering if some of the unique behaviors associated with the organization of stone tool production in that assemblage were simply idiosyncratic, site-specific or if they were part of broader pattern across Paleocostal sites. Here we compared three sites coming from two localities. While some artifacts vary in frequency or form between sites (e.g., specific crescent types or presence/absence of CIA's), overall, the methods used to produce the various tool types show remarkable structural similarities. Below we address the possible behavioral meaning of the similarities/differences observed by discussing the artifact and the site functions, and by building on comparisons with other Paleocostal and mainland sites.

Artifact Functions

Burinated crescent wing-tips and several other fracture types occur at high rates in numerous crescent assemblages (Amick 1999; Smith 2015) including CA-SRI-512 (Chapter 2). Experimentation shows that these artifact breakage patterns are most consistent with impact-fractures derived from crescents used as transverse projectile points (Lenzi 2015; Smith 2015), a hypothesis originally proposed by Tadlock (1966), which Moss and Erlandson (2013) have concluded were likely aimed at bird exploitation. The abundance of waterfowl and other bird bones at CA-SRI-512 supports this idea. The unique barbed shape of the Channel Islands Barbed points implies a likely function in some type of spearfishing and/or sea mammal hunting activity where their barbed morphology provided advantages to hunters in retaining aquatic fish and game that could otherwise escape after being wounded, as originally proposed by Glassow and coauthors (2013). The ultrathin and delicate nature of most CIA and CIB points supports a function in aquatic hunting or fishing, as well, as they would have broken exceptionally frequently if used in terrestrial settings. The Channel Islands have virtually no terrestrial mammals worth hunting, of course, and the faunal remains from all three assemblages indicate a broad spectrum diet including exploitation of birds, sea mammals, shellfish, and fish (Erlandson et al. 2011). Except for shellfish, these flaked stone tools appear ideally suited towards targeting these species.

Some CIB's exhibit fine serrated margins, but few are as ornately denticulated as many Channel Island Amol (CIA) points. CIA's likely functioned as atlatl dart or spear points, but it is also possible that some functioned as knife blades. The intricate and deep pressure-serrated margins of these artifacts would increase the surface area of the cutting edge which may have been a strong functional advantage to this unique modification. Erlandson (personal communication) has also suggested that some specimens are so ornately serrated that they may represent some type of social signaling.

As previously stated, the less standardized shouldered, stemmed, and foliate "miscellaneous points" may arbitrarily group artifacts that served different functions. While these artifacts may have functioned as projectile or thrusting spear points, they may have also served (at least at times) as knives. At the first glance, the constraints of using the tools in question for hunting a specific kind of game do little to explain why we observe the repetition of the specific production pathway outlined above. Indirectly though, it is informative on the range of activities we might expect at the sites, on the formation of the assemblage and the frequencies of certain tool types.

Site Functions

CA-SRI-512 is interpreted as a seasonal hunting camp based on the abundance of migratory waterfowl remains suggesting occupation in late fall to early spring (Erlandson et al. 2011). The inland site location may have also served as a staging area between lithic raw materials sources and coastal foraging grounds. Site occupants had access to abundant resources such as birds to hunt in the lower reaches of Arlington canyon and potentially at adjacent "Orr’s Pond." When not actively pursuing subsistence resources, they further reduced bifaces, cores, and preforms into CIB's for transport and later use as harpoon tips in coastal logistical forays. Although the exact sources for stone materials remain unknown, the absence of early stage production is consistent with a lithic Field Processing Model (Beck and Jones 2002; Shott 2015) where raw material was collected and early reduction occurred some distance away from the site.

Located in the vicinity of a raised beach conglomerate bed containing abundant unmodified chert cobbles, CA-SMI-678 and CA-SMI-679 have been described as quarry workshops due to the abundance of chert cobbles and early and middle stage biface reduction. Based on the range of radiocarbon dates, these sites were likely used multiple times over several centuries, with several localized shell midden deposits also indicating short-term camping on site (Erlandson et al. 2011). Consistent with the large numbers of bifaces in numerous stages of reduction, the main documented activities at the site suggest that it was primarily used for raw material collection and the production of tools and blanks for use elsewhere. Some retooling of hunting equipment may also have taken place on site, given the number of broken crescents and CIA/CIB points that appear to have been finished artifacts. Some of these broken points were undoubtedly reworked on site, but others were discarded once their utility was exhausted.

No bipointed bone fish gorges have been recovered from any of these sites, but do appear in the Paleocoastal toolkit by at least 10,000 cal BP at Daisy Cave (Erlandson et al. 1996). A lack of single piece shell fishhooks is consistent with the AMS radiocarbon chronology in the southern California Bight (Rick et al. 2002), though it should be noted that such hooks are present in Island Paleocoastal assemblages in the early Holocene strata at Espiritu Santo Island (Fujita 2014) and Terminal Pleistocene contexts on Isla Cedros (Des Lauriers et al. 2017), Baja California. The presence of schooling fish such as those in the sardine family at CA-SRI-512 (Erlandson et al. 2011:1183) supports the idea that nets may have been an important Paleocoastal technology in addition to CIB's used as fishing spear tips (Erlandson and Braje 2008; Rick et al. 2005:194; Vellanoweth et al. 2003). Finally, the presence of pitted anvil stones associated with a concentration of black turban (*Chlorostoma funebralis*) snails at CA-SMI-679 indicates some processing of small intertidal gastropods through a hammer and anvil technique (Strudwick 1995; Webb and Jones 2018), while burned rocks (including one specimen with extensive residue) may indicate pit roasting or cooking activities using heated stones.

CA-SRI-512 is situated 5-7 km distant from the paleoshoreline near the limit of a daily foraging radius, while Cardwell Bluffs are some 1-2 km distant from the shoreline of the time. Both localities are situated relatively high above sea level, at approximately 75 masl and 125 masl respectively (Erlandson et al 2011:1182-1184). While bird hunting at interior freshwater sources such as Arlington Canyon and Orr's Pond is strongly supported by a faunal assemblage of thousands of migratory bird remains at CA-SRI-512, quarrying of raw material at Cardwell was certainly a draw to this location, the commanding view from the Cardwell Bluffs overlook may have also allowed strategic observation of prey species (Erlandson et al 2011:1184). Since charred blue dicks corms have now been found in several well-dated Island Paleocoastal contexts dating as early as 11.500 cal BP (Gill 2014, 2015, 2016; Gill et al. 2021; Reddy and Erlandson 2012) plant food harvesting in plateau/interior environments was also likely a factor in such logistical interior moves. In addition to important plant foods, gathering of essential materials which may have included willow saplings for atlatl dart shafts, and dense slow-growing species such as *Heteromeles arbutifolia* for dart foreshafts and digging sticks, might have also required interior logistical movements where such species grow in greater abundance.

Overall, the two localities may illustrate examples of different site functions in a system that is yet to be fully understood. Assuming that both sites reflect interior movements of primarily maritime-adapted peoples, the site-structure of Island Paleocoastal occupations may significantly differ from what would be a seaside habitation now underwater. With this in mind, the differences between the reduction sequences observed here are in the range of what is expected for human groups that engage in residential and logistical movements. We also note that the differences in site function do not seem to affect the structural elements of the reduction sequence, except for frequency of their representation in the assemblage and the presence/absence of specific tool types.

Islanders and Mainlanders

Some of the distinctive aspects of the IPT technology identified here have been noted in other insular sites, and on the mainland. For example, the intriguing pattern of bifacial reduction, focusing on only one face during the first half of the reduction process, has been reported at Daisy Cave (Erlandson and Jew 2009). Davis and Willis (2018) also note hierarchical cores that they refer to as "Levallois-like" from Cooper's Ferry associated with foliate and Lind Coulee style points, while Muto (1976) reported similar hierarchical "cascade cores" associated with foliate points and Windust components in Washington at the early Holocene and terminal Pleistocene sites of Wexpusnime (45GA61) and Granite Point (45WT41). Muto (1976:2) also noted that similar cores represented a widespread of early reduction strategy across the Columbia Plateau, Snake River Plane, and into the Northern Great Basin. Finally, Des Lauriers (2010) reported core reduction illustrated as centripetal and hierarchical from terminal Pleistocene and early Holocene occupations of Isla Cedros off the coast of Baja California.

A strong reliance on bifaces such as described in the Cardwell Bluffs locality is also known in WST mainland quarry contexts. It includes a high rate of fragmented and discarded bifaces in production and high frequencies of biface reduction flakes, though some of these boast up to 80% of debitage as biface reduction (Beck and Jones 2002, 2009). The use of bifaces as cores is reported on the adjacent mainland coast. At Vandenberg, the Sudden Flats site dated to ~10,700-cal BP has yielded numerous artifacts including a crescent and bifaces used as cores to produce flake tools (Lebow et al. 2015). These bifacial cores could have subsequently served as bifacial blanks of sufficient dimensions for the production of stemmed points, an example of which was found at the site after Lebow and coauthors (2015) described the assemblage. Specific kinds of breakage identified as burinations (Chapter 2) were also reported on burinated bifaces from the Sudden Flats site (Lebow et al. 2015). This system certainly overlaps with trends observed in the lithic assemblage from CA-SRI-512; but the Cardwell Bluffs site complex provides sample sizes large enough to generate a more comprehensive understanding of these various reduction strategies than was previously possible.

At least in some cases it appears that early establishment of complete or nearly complete hafting elements on crescents (before the wings were fully flaked) (Amick 2015:13) and stemming of WST point preforms (Amick 2004; Beck and Jones 2009:90; Glam and Gough 2008) were also practiced among Great Basin and Columbia Plateau WST peoples (**Figure 20**). Notable is the proposed biface reduction sequence illustrated by Beck and Jones (2009, 2015) for large points (Lake Mohave, Cougar Mountain, and Parman types) that clearly shows the establishment of the hafting element (stem) early in the reduction process. The stemmed preforms associated with Parman points described by Amick (2004) in the McNine Cache and Haskett points from Sentinal Gap (Galm and Gough 2008) also support the idea that WST point manufacturing sequences sometime established hafting elements on large bifacial preforms long before the blade took final shape, at least in some contexts. At least two broken Lind Coulee style artifacts from the Cooper's Ferry point cache reported by Davis et al. (2014) (Cat #'s 73-636 and 73-642) reflect stemmed preforms broken in production, but closer comparisons of flake scar and edge morphology are needed to test this hypothesis. If the atypical asymmetry of crescent preforms described by Amick (2015) are not as he believed (recycled from larger Black Rock Concave Base points), but instead simply crescents in production with center hafting elements already established (before the wings were finished), this trend would also appear to overlap between the islands and mainland.

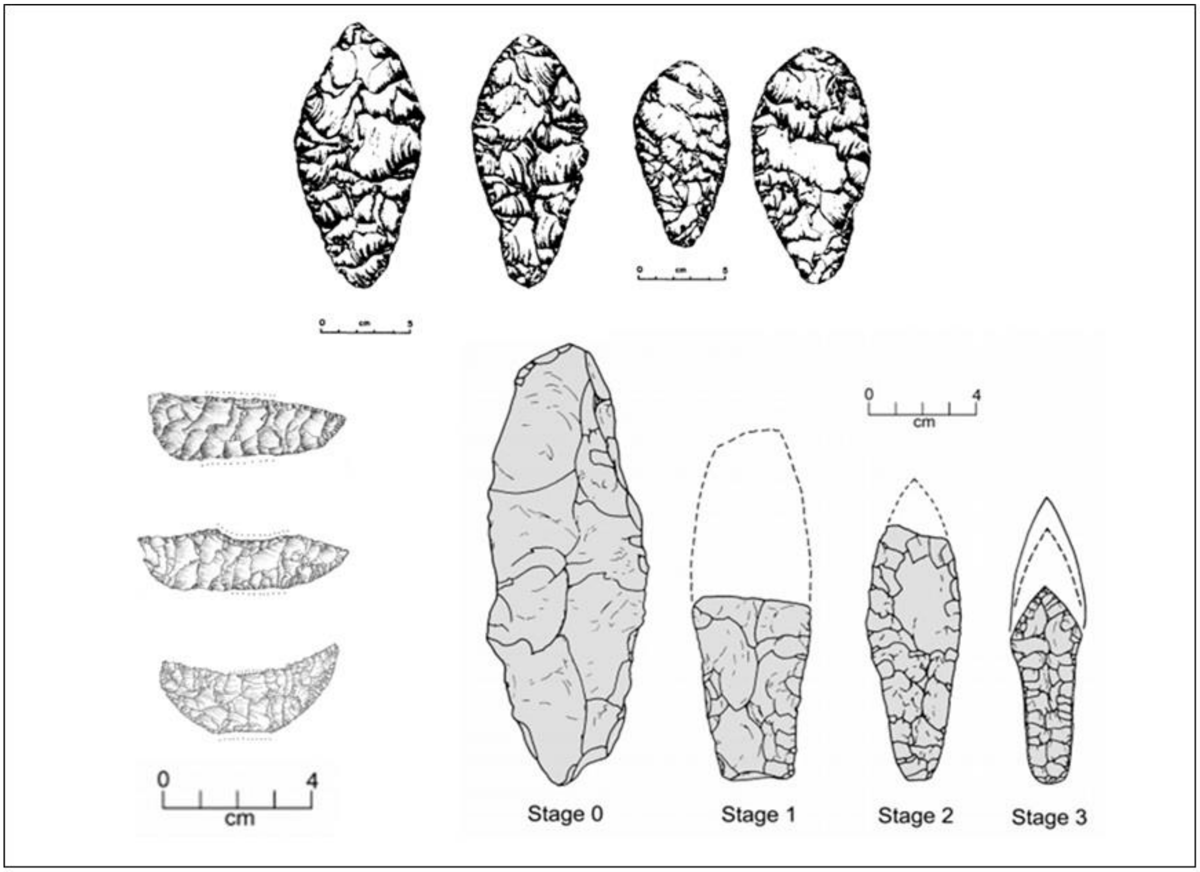

Figure 20. WST artifacts in multiple production stages. Top row: Parman stemmed preforms from the McNine Cache. Bottom Row left: Possible crescent preforms with finished hafting elements but unfinished wings and one finished lunate crescent. Bottom row right: Great Basin Stemmed point reduction sequence showing early establishment of stemmed hafting element. (Adapted from Amick 2004, 2015 and Beck and Jones 2015).

Single shouldered points (Amick 2004; Davis et al. 2014) and foliates (Daugherty 1956; Ezell 1977) are also found in many IPT and mainland WST assemblages. Hierarchical cores have been described in numerous WST contexts and include bifacial hierachical flake cores that Amick (2004:136) refered to as "ovoid bifacial blanks." Similar artifacts were also recovered from the early Holocene paleo-shorelines of Lake Mojave (Knell 2014:50), the C.W. Harris site (Warren

1967; Knell and Becker 2017) and other sites associated with the San Dieguito Complex. The latter includes foliates similar in morphology to those described at CA-SRI-512 (Chapter 2), and have been reported from the C.W. Harris site with proximal hafting residues (Ezell 1977). In conjunction with the impact-fracture noted on one specimen from CA-SRI-512, this suggests that at least some of the less standardized bifacial artifacts in Island Paleocoastal assemblages were finished and functional points or knives rather than preforms.

While the comparisons above concentrate on a technological approach, some discussion regarding typological overlap deserves further attention. Half-moon, quarter-moon, winged (Tadlock 1966), and several eccentric crescent types (Hopkins and Fenenga 2010; Fenenga 1984; Jertberg 1986) have now been found in late Pleistocene and early Holocene assemblages on California's Channel Islands (Erlandson and Braje 2008; Erlandson et al. 2011, 2016). The minute details of such specific types remain consistent across expanses of the Far West more than 1,000 km apart. Such mainland examples in California include San Dieguito and Lake Mojave Complexes in the south (Warren 1967), occupations at Tulare Lake in the Central Valley (Hopkins and Fenenga 2010), Scotts Valley on the Central Coast (Carteir 1989:199), and Borax Lake in northern California (Harrington 1948: 93-95). However identical crescent forms also occur at sites including Lind Coulee in Washington (Daugherty 1956), as well as numerous additional localities along major rivers and ancient lake shores across California and the Intermountain West (Sanchez et al. 2017).

Overall, our observations on the IPT lithic assemblages seem corroborated by previous work on the mainland, but the issue warrants a more systematic review of the material at a broader scale. In fact, the similarities noted with the mainland do not stop at lithic technology; patterns of subsistence, settlement, and broader signatures of material culture also overlap. Fiber technologies including cordage, mats, basketry, and sandals (Connolly et al. 2016), as well as specific shell bead forms, were all components of the IPT and broader WST material culture. Each of these aforementioned technological and subsistence categories, in addition to stemmed points and crescents, are also shared with the earliest California islanders, although material use of aquatic plants differs by local species (i.e. *Phylospadix* sp. on the islands) and bone beads are yet unknown in the early island sites (though *Olivella* sp. spire lopped beads are present) (Vellanoweth et al. 2003).

Technological Pattern and Cultural Transmission

Detailed inter-island and intra-island comparisons between Paleocoastal sites are still in its infancy, but some salient trends are emerging (Erlandson et al. 2020). Tool types such as flaked stone crescents and stemmed projectile points have long suggested ties between early island sites and the broader WST. While the co-occurrence of similar artifact forms in a comparable environmental setting naturally leads to discussions concerning the possibility of convergent technological evolution, the latter scenario is less compelling when the co-occurrence of the same numerous subtle, yet specific, stages of manufacture surround the formal tools. In the previous sections, we established that there is a relative consistency between three insular assemblages, we reviewed possible factors influencing variations (or the lack thereof), and found some points of comparisons between the islands and mainland. If one accepts the recognition of a structured system beneath the production of iconic tool types, it opens up alternative ways to interpret assemblage compositions, variations in tool size or frequencies, and ultimately to revisit the idea of a possible connection between early island and the mainland peoples. Although it would be difficult to formally invalidate all possibilities of convergence, convergence is unlikely to explain the whole sets of similarities described here. It also leads to complicated scenarios in which one big question remains: if the islanders are not coming from the mainland, where are they from? Hence, it seems legitimate to discuss cultural transmission mechanisms that could explain the technological pattern that we see emerging.

Noting that human evolution occurs "not by genes alone," Boyd and Richerson (1985) and Richarson and Boyd (2005) introduced Dual Inheritance Theory, an evolutionary perspective concerning how systems of shared and learned behavior are transmitted in human societies. As a cultural analog to biological processes, in their model, ideas and their material manifestations are most commonly passed from individuals to others through modes including unbiased transmission, guided variation, and biased transmission. The system of unbiased transmission is most analogous to biology, and assumes that pupils (children) simply copy the model and behaviors of their direct parents. Such a vertical transmission system may have occurred among some hunter-gatherer groups, but considering that even small bands would have included potential models such as grandparents, aunts, and uncles, this system seems unlikely to have been the only one. Alternative systems surrounding the transmission of ideas and technologies are considerably more complex, realistic, and interesting. Guided variation, typified by learning through trial and error, implies that individuals choose from a variety of ideas (or technologies) and subsequently experiment and innovate independently with these. This system necessarily relies on diverse models and a prolonged process of evaluation that can be expensive in terms of cultural adaptation (MacDonald 2010). Finally, in biased transmission, individuals choose to copy models within the group who they deem most successful at that particular task. It is often considered as one of the most common modes of transmission illustrated in the archaeological record, although it is often difficult to demonstrate (Mesoudi and O'Brien 2008). Further, a system of indirect bias may also occur, where individuals copy many or even all traits associated with the teacher's "success". These "indicator traits" may prove to be useful, neutral, and even deleterious, yet since they are perceived as successful traits by pupils, they are still adopted as part of "the good hunter package."

The reduction system we described here, where point preforms are stemmed in early stages, strongly diverges from some of the most commonly used reduction sequence models in North American archaeology (Andrefsky 2005:32; Callahan 1979). We suggest that part of it might be interpreted as an example of what Sackett (1982, 1985) refers to as *isochrestic variation*, where complex similarities in manufacturing sequences may be interpreted as culturally taught and learned, and subject to a mechanism of biased transmission, indirect or not. Again, stemmed points and crescents could have been made every bit as successfully if hafting elements were established as the final stage of manufacture, consistent with commonly cited idealized reduction sequences (Andrefsky 2005:32; Callahan 1979; Waldorf 1979:20; Whittaker 1995) (**see Figure 19**), yet they were not. Alternatively, there could be other reasons why manufacture would focus on the stem first and that specific trait warrants further investigations. The bottom line is that the repetition of the reduction sequence described here adds to the list of features that support a cultural link between Island Paleocostal Tradition sites, that seemingly extends to the mainland WST.

While technologies and systems requiring numerous complex stages of manufacture are less likely to be reinvented due to convergence, simple tools can easily and independently emerge over and over again. The presence of retouched flake tools (scrapers, gravers, and spokeshaves) in Paleocoastal assemblages from the islands is important to document, tools of nearly identical morphology are found not only within the mainland WST, but also in Clovis assemblages. While antecedent populations may have made and used them, their shape might solely reflect functional constraints and they are simple enough to have been reinvented through convergence. The same applies to cobble tools found in early island contexts (Chapter 2) and mainland WST assemblages (Sappington and Schuknecht-McDaniel 2001). Alone, such traits are weak arguments to establish a cultural connection between assemblages.

Getting Beyond the Point

Recent studies (Davis et al. 2019; Pratt et al. 2020) have relied on techno-typological features of Paleocoastal lithics comparing these with artifacts typical of the WST and those from complexes originating from Siberia and the broader Pacific Rim in a well-rounded discussion concerning potential antecedent populations to a Pacific Coastal Migration colonization event. While the authors, like several before them (Beck and Jones 2010; Erlandson and Braje 2011), treated the earliest island populations as potentially linked to the broader WST, their comparisons between these islander and mainlander signatures were based on the published data that was available to them at the time. However, now that a more nuanced perspective of the early maritime settlement of the California Channel Islands is available, it is time to revisit these potential links (Beck and Jones 2010, 2013; Erlandson et al. 2020; Pratt et al. 2020).

If these two groups are in fact tied to the same ancestral population which colonized North America via a Pacific Coastal Migration (Beck and Jones 2010, 2013; Braje et al. 2019; Davis and Madsen 2020; Erlandson and Braje 2011; Erlandson et al. 2007), we should expect significant similarities in material culture (beyond projectile points), and technological organization, which may even include subsistence and settlement pattern overlaps. Yet, if islanders and mainlanders did split from the same source population, some variation (derived features) is also expected. We have extensively discussed the production of projectile points and crescents, but attention to broader traits of islander and mainlander populations are in order. Connolly and coauthors (2016) provided interesting insights into an array of perishable WST material culture, while trait comparisons developed by Pratt and coauthors (2020) examined Island Paleocoastal and WST technologies more broadly to address potential technological antecedents.

The mainland manifestation of the WST includes a settlement-subsistence pattern largely (though not exclusively) reliant on aquatic environments where a broad-spectrum diet included migratory waterfowl, fish, freshwater shellfish, small game, and plant foods in addition to upland species and high-ranked terrestrial fauna. Twined-fiber technologies made from terrestrial plants (*Artamisia* spp.) and aquatic plants (*Scirpus or Schoenoplectus* spp.*)* included cordage, mats, basketry and sandals (Connolly et al. 2016). Shell beads (signifying long distance exchange with the coast), occasional bone beads, and bone tools have also been at least occasionally found in mainland WST contexts. In addition, lithic artifact production included discoidal/centripetal, hierarchical core reduction, and intensive biface manufacture throughout the region. Broadly, each of these technological and subsistence categories, in addition to local stemmed point variants and typologically identical crescent forms, are also found in Island Paleocoastal contexts.

The first California islanders maintained a textile tradition including twining of aquatic plants for cordage (Vellanoweth et al. 2003), sandals (Connolly et al. 1995), and nets (implied by sardine capture at CA-SRI-512), although material use of aquatic plants differed by locally available species (i.e. *Phylospadix* sp. on the islands). While bone beads are yet unknown in late Pleistocene and early Holocene island sites, *Olivella* spire lopped beads are present. In addition, a small obsidian flake from CA-SRI-512 not included in the present analysis was sourced to the West Sugarloaf flow of the Coso Volcanic Field attesting to long distance exchange with the mainland interior (Erlandson et al. 2011; Gill et al. 2019b). While absent in the interior sites documented so far on the Northern Channel Islands, Paleocoastal peoples on the islands off of Baja California developed and used single piece shell fishhooks made on California mussel shell (*Mytilus californianus)* on Isla Cedros and Pearl oyster shell (*Pinctada mazatlanica*) on Espiritu Santos Island (Des Lauriers 2017; Fujita 2014). In addition to the artifact forms described above, cobble choppers, incised minerals, pitted anvil stones, cooking stones, hammer stones, the use of percussion and pressure biface production, heat treatment, and the unique chaine operatoire involving hafting-element production in the middle stages of point and crescent manufacture are all traits that were present on the islands in the late Pleistocene and early Holocene. The Paleocoastal mariners also targeted high-ranked sea mammals in the absence of large terrestrial game, reef-fish, schooling-fish, shellfish, avifauna, and geophytes as part of a broad-spectrum subsistence adaptation.

Boating technology, strongly associated with maritime subsistence adaptations and population movements, would have been necessary for colonizing offshore islands even when Terminal Pleistocene sea levels were significantly lower and the nearest shoreline of Santarosae was a mere 6-8 km from the mainland coast. Watercraft as a technology may have been lost the further inland WST peoples moved if we believe that these groups stemmed from the same Pacific Coastal migration. However, building on the Paleo-Maritime Hypothesis (Schulz et al. 2011), maintain that easily-made tule balsas provided significant advantages to WST peoples living along Great Basin Pluvial lakeshores in some contexts, especially in the movement and exchange of raw materials, subsistence items, and in improving encounter rates and retrieval rates with waterfowl which provided a large component of the WST subsistence base (Chapter 2). Simple watercraft therefore may have been maintained, or even reinvented, as part of the interior WST toolkit.

To summarize, the material culture and adaptive strategies of the earliest island populations and mainland WST closely overlap. One sub-group exhibits a maritime signature centered on saltwater coastlines and islands and the other sub-group exhibits a largely lacustrine signature centered about rivers and massive freshwater pluvial lakes. Following this idea, the adaptive strategies of this broad population are essentially the same (Davis et al. 1969; Moratto 1984:104-109). Since Bedwell (1970) proposed the concept of the Western Pluvial Lakes Tradition (WPLT), this term has largely been replaced by the WST, as the latter does not imply sole adaptation to lake environments. While we agree that seasonal, and in some cases permanent, occupations in upland and riverine environments in the Intermountain West reflect a more diverse strategy than sole subsistence and settlement along ancient lake shores, by and large WST sites do concentrate near freshwater habitats. However, our results support the idea that stemmed point and crescent-bearing hunter-gatherers found a niche on the California coast and islands. In other words, WST peoples were probably well-equipped and flexible enough to thrive in insular environments beyond the productive lakeshores of the late Pleistocene and early Holocene Intermountain West. Our analysis supports the idea that the Island Paleocoastal Tradition (IPT) as a maritime variant of the broader WST.

Conclusion

We have described the technological organization behind the production of formal tools at three Paleocoastal sites on California's Channel Islands. We find that tool types such as lunate, winged, and eccentric crescents, Channel Islands Barbed points, Channel Island Amol points, foliate points, and other less standardized point forms were produced using a recurrent system. The latter relies on bifacial reduction and the flakes it produces are used as blanks for formal tools. Early bifacial and core reduction (discoidal and bifacial-hierarchical cores) are not represented in all assemblages, but they are well represented at quarry workshop sites. Along with subtle details in the flaking patterns and preparation of the stemmed points, this comparison suggests overall a shared and coherent IPT lithic reduction system. While comparisons with a well stratified mainland WST lithic assemblage are certainly needed, a cursory literature search suggests that such technological analyses are also relevant to address potential connections between the islands and the mainland manufacturing systems.

Our results suggest that in addition to artifact typological overlaps, stemmed hafting elements, settlement patterns, long distance exchange networks, and diet breadth, the unique manufacturing patterns observed across these island sites are at least present in some mainland WST assemblages. While future comparisons with mainland WST lithic assemblages from excavated contexts are needed, for now, it appears that the Island Paleocoastal Tradition (IPT) has more in common than it differs from the broader mainland Western Stemmed Tradition. However, some variations in artifact style and even the presence of a few disparate artifact types should be expected as islanders and mainlanders adapted to specific (albeit largely aquatic) environments in the Far West. Isochrestic variation (Sacket 1982, 1985) in lithic reduction strategies and the overwhelming similarities of complex subsistence bases and overall material culture suggest that these geographically distinct groups are instead two manifestations of a single technocomplex. As Pratt and coauthors (2020) caution, we should not necessarily expect to find a single antecedent archaeological population exhibiting all aspects of material culture within the broader WST (in its island and mainland manifestations). However, we hope that the information gained from this technological comparison across three Paleocoastal archaeological sites on the islands provides enough new details to spark further discussions regarding technological and other cultural connections between early islanders and mainlanders, as well as the role of the Pacific Coast in the peopling of the Americas.

Chapter Four

USING REPLICATIVE STUDIES TO ADDRESS THE PRODUCTION DYNAMICS OF EARLY NORTH AMERICAN TULE BOATS

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Abstract

The technological development of watercraft transformed environmental barriers such as rivers, lakes, and oceans into foraging conduits and navigable extensions of early human dispersals throughout the world. In California and portions of the Great Basin, bundled Tule (*Schoenoplectus* spp.) reed boats were extensively used in ethnographic times to expand catchment areas and facilitate long distance trade. The extent to which such boat technologies figured into prehistoric California economies is unclear. We generate data from the replication of a tule canoe to address questions of archaeological visibility and economic viability. Based on our observation, we discuss the potential role that tule watercraft may have played in early subsistence, settlement, and social systems in the Far West of North America. We find that tule canoe investment would have been viable in western pluvial lake environments only under specific circumstances tied to travel, transport costs, and/or logistical inter-patch subsistence intensification.

Introduction

Watercraft played a major role in facilitating early modern human migrations and developing maritime economies throughout the world. By at least 50,000 cal BP our species began expanding into formerly inaccessible regions as the use of boats transformed aquatic environmental barriers into navigable and interconnected pathways (Clarkson et al. 2017; Erlandson 2001; Gaffney 2020; O'Connell et al. 2010). In conjunction with developments such as new and effective fishing technologies, the use of watercraft allowed for the widespread expansion of marine subsistence systems of societies living in coastal and island contexts.

Boating also allowed hunter-gatherers to travel along rivers and lakes and to transport more and heavier goods than foot travel alone would allow. In coastal and interior areas with complex and convoluted shorelines, moreover, boats could significantly reduce travel times for many destinations.

Some of the first cultural traditions in the Americas—if not *the* first—made use of boating technology. In the last 25 years, the theory that maritime peoples from Northeast Asia followed Pacific Rim coastlines into the Americas has gone from marginal to mainstream, replacing the longstanding terrestrial alternative that Clovis big game hunters were the First Americans. Towards the end of the Pleistocene, hunter-gatherers spread across the Far West of North America, with at least some populations concentrating around aquatic environments such as coastlines, rivers, and lake shores. Some of these early occupants, armed with stemmed projectile points and lithic crescents, have come to be known as the Western Stemmed Tradition (WST). While much research on WST is associated with occupations of the Great Basin and broader Intermountain West (Beck and Jones 1997, 2010; Connolly et al. 2016; Goebel et al. 2007, 2011; Jenkins et al. 2012), the WST also appears to have included a coastal manifestation as evident in the California Channel Islands known as the Island Paleocoastal Tradition (Erlandson 2020; Erlandson and Braje 2011, 2015; Glassow et al. 2013; Moss and Erlandson 2013). Supported by more than 100 Paleocoastal sites on California's Channel Islands and beyond, a model of Pacific Coastal migration for the peopling of the Americas maintains that some of the earliest peoples to make it to western North America arrived in boats via the Pacific Rim. It has been proposed that northeast Asian populations ventured by foot and boat along rich island and mainland coastlines practicing a broad spectrum diet largely derived from abundant kelp forest ecosystems and coastal landscapes (Davis and Madsen 2020; Erlandson and Braje 2011; Erlandson et al. 2007, 2011; McLaren et al. 2019). The Pacific Coastal Migration model maintains that the coast was passable before an interior "ice free corridor" opened between the Laurentide and Cordilleran ice masses.

According to Beck and Jones (2010: 42) maritime hunter-gatherers associated with the WST might have been drawn not only down the Pacific Coast but also inland possibly following large rivers such as the Columbia, Klamath, and Sacramento. Through these river corridors, early WST peoples could have first entered the Great Basin. While the nature and timing of the arrival of the WST in the Great Basin is still debated, we do know that by the time of their arrival, these peoples encountered not the arid and warm dry high-desert environments we see today, but mixed environments with enormous pluvial lakes and wetlands in lowland basins, while pine, juniper, sage, and cacti occupied more xeric upland settings (Howard 2016; Reheis et al. 2014). At their most recent highstands approximately 15,000 cal BP extensive aquatic environments covered approximately one-third of the Great Basin (Grayson 1993:86; Madsen 2002). Massive pluvial Lake Lahontan, for instance, reached its highstand in the Jessup embayment between 13,070±60 cal BP and 13,280±110 cal BP (Adams and Wesnousky 1998). Such rich and convoluted aquatic landscapes may have encouraged the use of watercraft, especially if WST peoples descended from maritime peoples. On the other, it is possible that early interior populations did not invest in boating technologies given that incentives were ostensibly less than in coastal environments. The extent to which early interior populations utilized boating technology remains unclear.

Based on the abundance of Paleocoastal sites on the California's Channel Islands, which were not connected to the mainland during the late Pleistocene, early occupants of the Far West almost certainly had boats. Lacking any material remains or artistic depictions of Paleoindian boats, it is not known what type of boats the earliest people might have used to traverse the convoluted coasts of Beringia and the Pacific Northwest. Erlandson and Braje (2007) speculated that relatively seaworthy skin-on-frame watercraft similar to umiaks used by contemporary Aleuts may have been used, but simpler boats might also have been used. For California, Heizer and Massey (1953) argued that the tule balsa may be the oldest watercraft, and Gamble (2002:305) suggested that tule bundle boats might have been used in the initial settlement of the California Channel Islands. Unfortunately, no boats have been found in archaeological contexts on the California coast or Channel Islands that predate the late Holocene, probably due to the perishable nature of watercraft and sea level rise (Rick et al. 2003; Gamble 2002). Boat technology could have been an important component in early human population dispersal, subsistence, and mobility, but it would also come at a cost. The economics of hunter-gatherer boating technology, including material and labor costs, as well as potential returns on such investments, remain poorly understood. This study seeks to contribute to our understanding of watercraft costs and benefits through the construction of a simple bundle-boat using only period-appropriate tools. Additionally, our study addresses the broader question of whether or not WST peoples occupying Great Basin pluvial lakeshores in the late Pleistocene and early Holocene would have invested in watercraft.

Background

Before discussing our examination of tule boat production dynamics from an experimental perspective, we provide context for early boat use, tule use, tule ecology, and our actualistic/experimental approach. The following section presents archaeological evidence for early boat use on both a broad and regional scale, the ecology and distribution of tule reeds and suitable tule habitats in the Terminal Pleistocene and early Holocene Far West, and the earliest evidence of tule in material culture in the region. Additionally, ethnographic and ethnohistoric studies are presented to illustrate potential connections between lakeside settlements, lacustrine subsistence strategies, tule material culture, and bundle boat technology. Finally, we provide an overview of the application and debates surrounding experimental archaeology and use wear studies to help frame our research approach to understanding tule boat manufacturing strategies and the signatures such activities might leave behind in the archaeological record.

The Archaeology of Watercraft Use

Beginning at least 50,000 years ago, humans dispersed to numerous remote locations including Australia, New Guinea, Okinawa and the other Ryuku Islands, and Near Oceana (New Ireland, New Brittan and the Solomon Islands) would have only been possible with sophisticated boating technologies (Allen et al. 1989; O'Connell and Allen 2012; O'Connor et al. 2011; Wickler and Sprigs 1988). However, due to the organic nature of early boats, watercraft are entirely absent from archaeological contexts for at least the first 40,000 years of their existence. To date, the Pesse canoe, a Mesolithic wooden dugout from the Netherlands dated between approximately 10,000 and 9500 cal B.P. is the oldest boat recovered from archaeological contexts in the world (Courant 2001; van Zeist 1957). The Dufuna Canoe, discovered in Nigeria in 1987, represents yet another very early dugout canoe from extinct Mega Lake Chad dating to approximately 8,000-8,500 B.P. (Adewumi 2021). Both of these examples were made of wood, a perishable material that withstands decay in anaerobic wetlands significantly longer than soft plants such as reeds. Depictions of watercraft made from bundles of buoyant reeds date to at least 7,000-5,000 BP in pre-dynastic Egypt. Such watercraft were used along the Nile River, constructed of locally abundant reeds of papyrus (*Cyperus papyrus*) and ranged in size from single person boats to cargo vessels that were even equipped with sails. In the highlands of Ethiopia on Lake Tana, similar papyrus reed watercraft continue to be made and used today (**Figure 21a**). In some cases, prehistoric papyrus bundle boats had a hull coating of bitumen, as was the case of a fragment recovered from archaeological contexts in Kuwait, dated to approximately 7,000 BP (Carter 2002).

Figure 21. a) Papyrus boat and fisherman, Lake Tana, Ethiopia, b) Aymara building tule boat, Lake Titicaca, Bolivia, c) Pomo paddling tule boat, d) Ohlone or Bay Miwok using a tule boat in San Francisco Bay illustrated by Louis Choris 1816. (Adapted from (a) Mengistu et al. 2017 (b) Ryan 2012) (c) Curtis 1924, (d) https://www.nps.gov/articles/000/alcatraz-is-indian-land.htm).

In North America, the archaeological evidence for early colonization of islands reachable only by boat predates the earliest confirmed watercraft by thousands of years. Often, archaeological signatures such as tools potentially associated with watercraft production (Cassidy et al. 2004; Gamble 2002; Lambert and Loebel 2015:286-287) or the presence of human populations on otherwise inaccessible regions (Allen et al. 1989; Braje et al. 2019; Erlandson et al. 2007, 2011; O'Connell and Allen 2012; O'Connor et al. 2011; Rick et al. 2005; Wickler and Sprigs 1988) are cited by archaeologists to support early boat use. However, the oldest boat recovered from archaeological contexts in North America, a bald cypress dugout canoe from DeLeon Springs in Florida, dates to approximately 7,030-6,740 B.P (Wheeler et al. 2003). In California, the oldest directly dated watercraft remains all cluster within the late Holocene (Gamble 2002) even though the California Channel Islands exhibit an extraordinary abundance of early maritime sites. Clearly, a significant preservation bias limits what can be said concerning early watercraft development and use. Except for terminal Pleistocene archaeological sites in island contexts, much of the archaeological evidence associated with California prehistoric boating technology, including woodworking kits (Gamble 2002; Arnold 2001; Cassidy et al. 2004) and canoe effigies (Gamble 2002; Rick et al. 2003), is also limited to the Late Holocene (though see Cassidy et al. 2004). Furthermore, much of the research surrounding early prehistoric boat use and production in the Far West has focused on coastal and insular contexts. Far less attention has been given to the potential Pleistocene use of boats in inland environments (though see Engelbright and Seyfert 1994; Jodry 2005; Lambert and Loebel 2015:286-287; Schultz et al. 2011:35-40).

Watercraft and Bundle Boats in American Ethnography

In the Americas, the most widely known examples of reed-bundle boats are those of the Uros and Aymara of Lake Titicaca and the Trujillos of the Peruvian coast who still manufacture and use boats constructed of bullrush (*Schoenoplectus californicus* ssp. *tatora*) **(Figure 21b).** Along the coast, these boats are now used regularly for commercial fishing, but in the highlands they are now primarily built for tourism. In North America, in ethnographic times, watercraft styles ranged from Algonquin composite birch bark canoes, to Mandan bull boats made by stretching animal skins over simple rounded frames of bone or saplings (Wood and Irwin 2001). Some boats, such as the large dugouts of the Pacific Northwest coast, were ornately carved, painted, and otherwise adorned (Suttles 1990). Others, such as the ocean kayaks of Arctic Aleuts, exhibited some of the greatest technological complexity of any hunter-gatherer boats globally (Damas 1984). In northwest California, large expertly crafted redwood dugout canoes were used for riverine transport and other subsistence activities (Pilling 1978). In southern California, poplar (cottonwood) or willow log dugouts and balsas were used, but these have received far less attention in the literature than more technologically complex seaworthy sewn plank canoes used by the seafaring Gabrielino and Chumash (Arnold 2001; Gamble 2002; Hudson 1978; Hudson and Blackburn 1979; Timbrook 2007)

Among the hunter-gatherer cultures of coastal and interior California bundled tule boats (also known as *balsas*) were used by at least some: Eastern Pomo (**Figure 21c**), Klamath, Modoc, Achumawi, and Paiute to the north and east, the Patwin, Coast Miwok, Valley Miwok, Nisenan, Yokuts, Ohlone, and Coastanoans in Central California, and the Chumash, Gabrielino, Luiseno, Diegueno, and coastal Taipi-Ipai in southern California (Driver 1937; Drucker 1937; Harrington 1942; Heizer 1978). Bundle boat use was so common that it was often described and illustrated in early historic accounts of Alta California (**Figure 21d**). The tule canoe was also the most common watercraft for the cultures occupying both the Pacific and Gulf coasts of the Baja peninsula (Heizer and Massey 1953) and was also found in the Colorado River area among the Cocopa, Maricopa, and Mohave (Drucker 1941). Of the Great Basin tribes, tule watercraft were noted among the Shoshone, Ute, Southern Paiute, Owns Lake Paiute, Northern Paiute, and Washoe (D'Azevedo 1986; Steward 1941; Stewart 1941). Many of these cultures had vast territories with varying terrain, elevation, and ecology so that tule boating might have only been used by part of the overall group or even on a seasonal basis. However, most groups in California (Heizer and Massey 1953) and the Great Basin (Wheat 1967) whose territory encompassed large wetlands, lakes, and tule sources, made extensive use of the tule balsa.

Ethnographically, tule watercraft varied in shape, size, binding materials, and geographic distribution. In southern California, several tule canoe styles were described by early ethnographers such as Jon P. Harrington (Hudson and Blackburn 1979:331-336). According to Chumash consultants and elders Maria Solares and Fernando Librado (Kitsepawit) some tule canoes were made in three, five, or even ten bundle construction styles. In this culture area, the hulls of ocean-going balsas were described as occasionally being coated with a layer of petroleum tar (a.k.a., asphaltum or bitumen) as a sealant for watercraft longevity, much like the ancient Old World designs described earlier. Tule boats in this area were lashed together using dogbane (*Apocynum cannabinum*) cordage, also known as Indian hemp or *Tok* by the Chumash, and had either elevated bows or both elevated bows and sterns (Hudson and Blackburn 1979:331-337). Around Tulare Lake, the Tachi Yokuts consultant and elder Bob Bautista described tule watercraft as being lashed together using willow (*Salix* sp.) wefts with sizes ranging from small canoes used by a single individual to boats 25 feet long and capable of transporting numerous individuals with all of their possessions (Campbell 2000:395). In the latter case, these large boats were equipped with a mud or clay platform on which cooking fires were built and a hole through the hull, which when not covered by a tule mat was used to spear fish while the watercraft transported passengers on multi-day journeys (Campbell 2000:394-395).

In the western Great Basin, according to Northern Paiute consultants and elders Jimmy and Wuzzie George, tule boats were typically manufactured of two bundles lashed with expedient twisted cattail leaf cordage and equipped with a shallow U-shaped cattail gunwale which, functioning similar to a basket, allowed the boat to more securely transport fowl, fish, and eggs. These watercraft ranged from those capable of transporting one person to several individuals and typically exhibited a square stern and elevated bow (Wheat 1967). Among the Eastern Pomo, square-stern tule boats were often lashed together using wild grape vines (and likely wild grape roots) as an alternative to flexible willow wefts, dogbane cordage, or cattail cordage. These watercraft also ranged in size from a single person to multiple person boats and at least some of the time were constructed in the five-bundle style (Heizer and Massey 1953). An historic account of Bodega Bay Coast Miwok also described tule canoes as having elevated bows and sterns and five bundle construction (Priestly 1937). Due to the craft's wide coastal distribution, and strong association with double-bladed paddles, Heizer and Massey (1953) believed the combination of bundle boats and double-bladed paddles were likely the oldest watercraft system on the Pacific Coast south of Bodega Bay. However, since the distribution of tule boats was not strictly limited to the coast, but included interior rivers and lakes in California and the western Great Basin, it is also likely that reed bundle boats may be of great antiquity in relatively landlocked western settings.

Tule Ecology and Archaeological Antiquity in the Far West

Understanding tule boat economics requires an understanding of the broader role of tule in prehistoric economies. For the Indigenous peoples who occupied much of the California Coast and interior, tule (*Scirpus* sp.) (**Figure 22**) was arguably one of the most versatile wetland species on par with cattail (*Typha* sp.) (**Figure 22**), providing both food and building materials. Tule rhizomes contain edible carbohydrates, the young shoots are edible, and some species of tule also provided seeds which were gathered for food (Gilliland 1985; Simms 1984:207). In terms of tule as a raw material, the pliable and buoyant properties of tule stalks were ideally suited for the production of many aspects of Native American material culture including basketry, footwear, roof thatching, sleeping mats, carrying bags, pitch-coated water bottles, waterfowl decoys, and boats (D' Azevedo 1986; Heizer 1978). At the time of European contact, the use of this plant for the aforementioned purposes crossed over a dozen cultural boundaries in California and the western Great Basin. Discussed in further detail below, basketry, footwear and mats manufactured from several wetland plants including tule (*Scirpus* sp.) have also been recovered from numerous well preserved Paleoarchaic contexts in the northern Great Basin testifying to longstanding traditional use in the material culture of the region (Connolly et al. 2016) (**Figure 22**). Paleo-environmental reconstructions show that the now arid Great Basin was once a mixed habitat with lush wetlands adjacent to large pluvial lakes in the terminal Pleistocene and early Holocene (Reheis et al. 2014). Comparing the distribution of extant lakes with extinct lakeshores of the Far West, a picture of the vast potential of suitable habitats for the construction and use of tule boats becomes clear (**Figure 23**). From several well-preserved dry cave and rock shelter sites located near paleo-lake shorelines in the Great Basin, preservation of organic materials is exceptional and we gain a glimpse into the antiquity of tule use in the region. Elsewhere, being extremely perishable in nature, artifacts made from tule rarely survive in the archaeological record. Therefore, as is the case with most organic material culture, determining the true antiquity of tule use in the region is elusive.

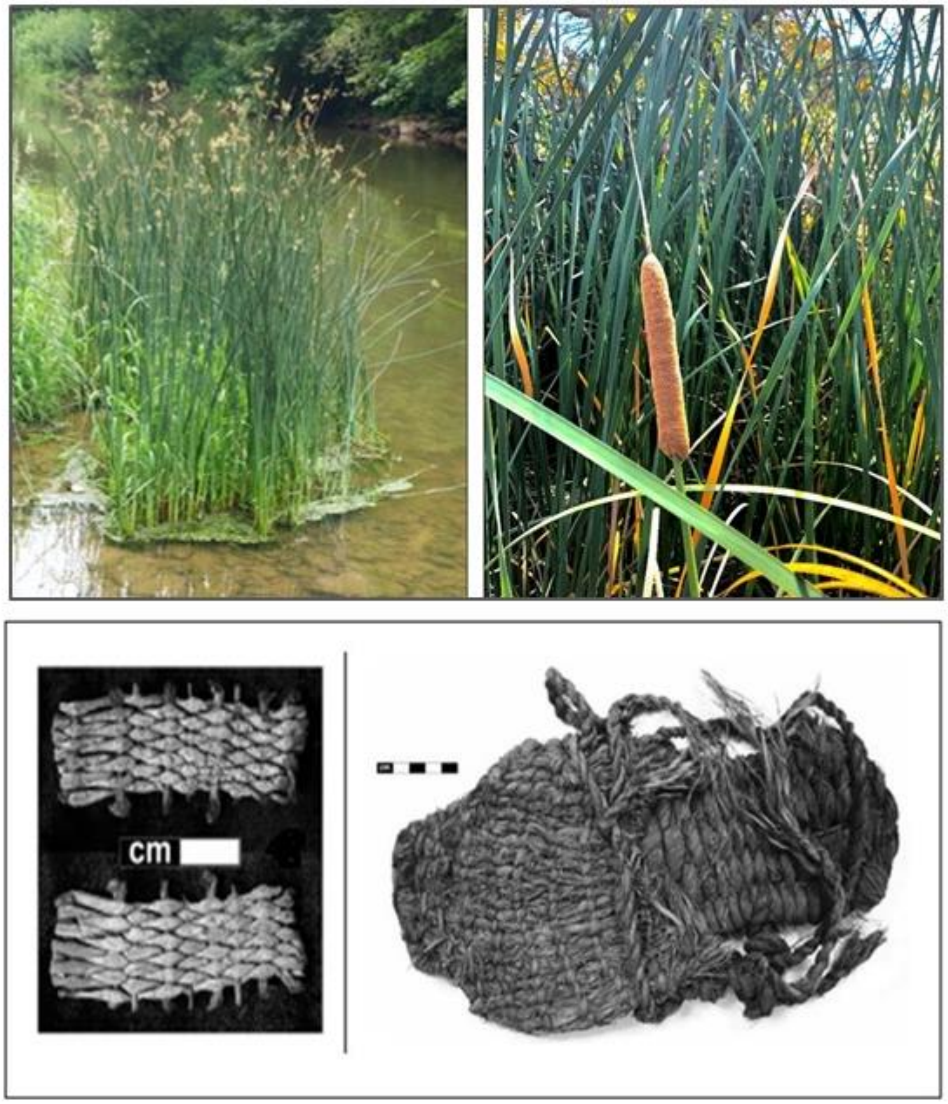

Figure 22. Top Row: Species used in boat construction. Left) Tule (*Scirpus* sp.) in wetland. Right) Cattail (*Typha* sp.) in wetland. Bottom Row: Western Stemmed Tradition Textiles commonly made from *Artemisia* and *Scirpus* sp. Left) Warp-Face Plain Weave basketry (11,000-9,600 cal BP). Right) Fort Rock Sandal (10,585 – 9,040 cal BP) (adapted from Connolly et al. 2016).

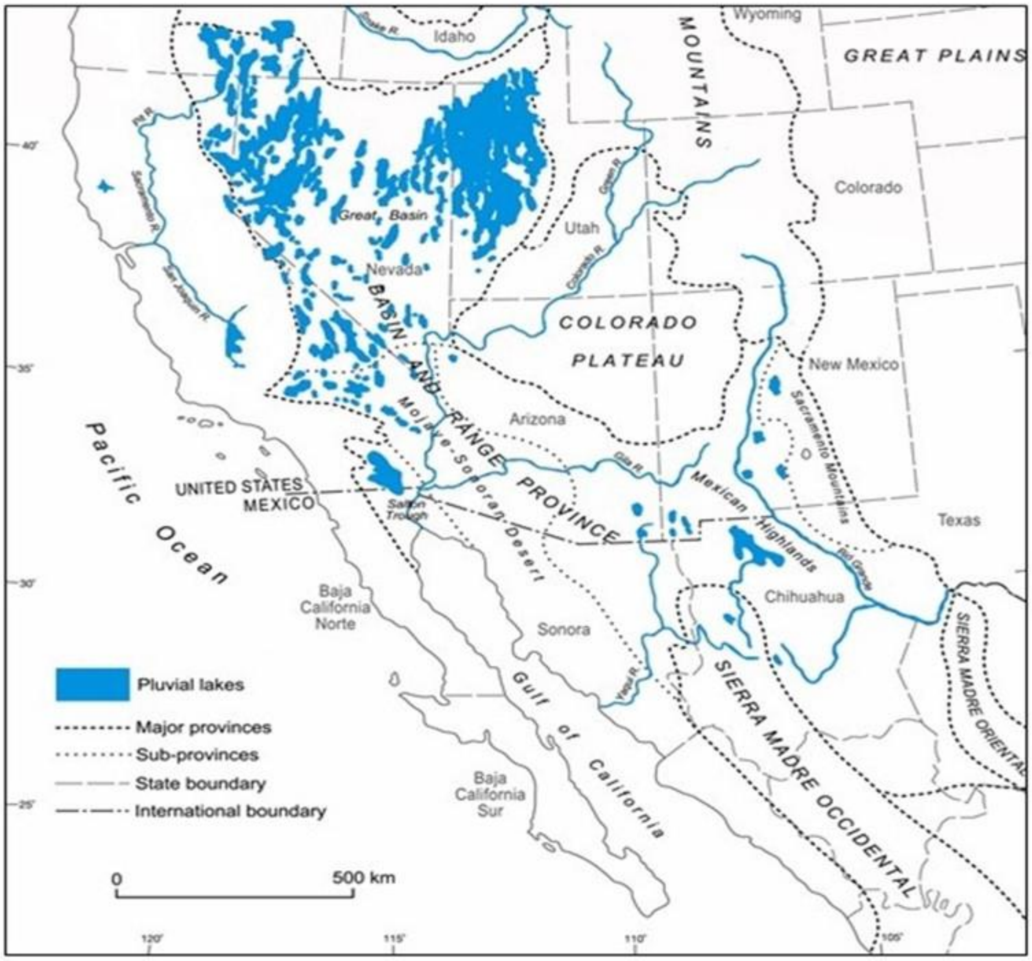

Figure 23. Distribution of pluvial lakes and large fresh water bodies of California, the Great Basin, and the Southwest during the late Pleistocene and early Holocene. (adapted from Orme 2008:53).

Adovasio (1986) described early textiles recovered from numerous dry rockshelter and cave sites in the northern, western, and eastern Great Basin, which were dominated by materials including the bark of sage (*Artemisia* sp.) and fibers from water loving plants such as dogbane, willow (*Salix* sp.), and tule. Connolly and others (2016) reexamined these collections and additional perishable artifacts recovered from the region, providing a rare and detailed radiocarbon chronology of plant-based material culture. Based on these analyses, the authors discussed the implications of perishable woven artifact styles and methods of manufacture including warp-faced plain weave and catlow twined types whose earliest presence in the archaeological record is strongly associated with the WST. Radiocarbon dates from perishable material culture indicate that WST peoples made extensive use of several local plant species by at least 12,205 cal B.P. (Jenkins et al 2013). Tule use, as evidenced by sandals, bags, baskets and mats from several of these sites, dates firmly to the terminal Pleistocene and early Holocene (**Figure 22**) (Connolly et al. 2016). In fact, some of the oldest warp-faced plain weave textiles yielded direct dates ranging from 11,000-9,600 cal B.P. (Connolly et al. 2016) and a recently reported twisted bulrush fragment (tule?) interpreted as a possible textile weft from Paisley Caves yielded a date of 12,273 ± 56 14C yr B.P. (Shillito et al. 2020:Figure S3). Spirit Cave yielded numerous examples of warp-face plain weave bags and mats with split tule used as the warp and dogbane as the weft, including mats associated with the Spirit Cave Man burial and one example which was dated between 10,540-10,340 cal B.P. (Connolly et al. 2016:502-503; Tuohy and Dansie 1997).

Acknowledging the limitations of ethnographic analogy (Wobst 1978), it is worth noting that every ethnographic group described previously who used tule balsas, also resided near lake shores, rivers, estuaries, or marshes, and relied at least in part on an aquatic subsistence system. Each of these Indigenous groups also wove some form of mats and/or basketry from tule stalks, similar to the WST artifacts described above. Although, the earliest people of the Great Basin would never again see pluvial lakes of the same magnitude, a general trend of desiccation may have improved the environment temporarily as shrinking lakes caused wetlands to expand for a time in new shallows, providing greater foraging opportunities (Bedwell 1970, 1973). During the early Holocene, however, significant loss of smaller wetlands may have concentrated human activities in a more logistically-oriented strategy within remaining patches, at least on a sub-regional level (Duke 2011). With a clear and intimate knowledge of the many material uses for tule, WST peoples were certainly aware of its buoyant properties. Since WST subsistence strategies largely focused on the aquatic environments where they often settled, it is reasonable to hypothesize, that during more temperate climatic conditions, in a region known for extensive pluvial lakes, they invested in the manufacture and use of tule watercraft. On the other hand, no tule boat has ever been recovered from any archaeological context in North America, likely due to a preservation bias we will revisit later. The interior Great Basin is also intrinsically more terrestrial than the coast, potentially affording more opportunities for foot travel especially with low population densities assumed for the late Pleistocene and early Holocene. An alternative hypothesis is that Great Basin boat technology was a relatively late development that emerged only when population growth compelled greater relative sedentism, making boat technology more economically viable. Our goal is to gain insight into the economic tradeoffs that early Great Basin populations may have faced in deciding how to move through changing environmental and social landscapes.

Experimental Archaeology and Actualistic Reproductions

Experimental archaeology first gained popularity during the 1960's to 1980's as a method of generating analogous data to address gaps in our interpretation of the archaeological record. Like investigations into taphonomy (Lyman 1994), site formation processes (Schiffer 1983), and ethno-archaeology (Binford 1978), this approach was intrinsically linked to the development of Middle Range Theory (Binford 1983). Middle Range Theory helps to bridge the gap between low level inquiry and high level theory to make meaningful interpretations more broadly in terms of human behavior. The definition of *experimental archaeology* has changed considerably since its incipient development as a subfield (Ferguson 2010; Callahan 1999; Coles 1978). Experimental archaeology, in a broad sense, includes *actualistic* in-field investigations, reproductions, and controlled experiments more typically undertaken in laboratory settings. Both in-field and in-lab types of archaeological experimentation have merit. The former more closely approximates human behavior in response to natural conditions such as those encountered in the ancient past but with obviously less control of specific variables. The latter, conducted within laboratory settings, more systematically control variables to eliminate bias and maximize replicability. Consistent with Lin and coauthors (2018) we acknowledge that our bundle boat reproduction is a “pilot experiment,” and that further hypothesis testing is needed. However, to our knowledge, our bundle boat pilot experiment provides a baseline of actualistic data on traditional tule watercraft manufacture conducted with only period-appropriate supplies and methods. By systematically documenting production times as well as the toolkit necessary for reed bundle boat production, we derive a dataset that we model to provide insights into hunter-gatherer investment in early watercraft technology.

Methods

Our replicative study and analyses proceeded in three steps. First, we reconstructed a bundle boat starting from material procurement to launching in an effort to understand baseline manufacturing costs. All stages of tule canoe construction were documented with photography and video. All cutting tasks were performed with stone flakes. The production times and quantity of materials used were recorded in the field as a basic measure of the cost for the technology. Second, we examined the experimental flake tools for use wear to address the issue of archaeological visibility of this technology. Third, we applied a model of technological investment to examine the cost of boating versus walking as a means of travel and transport. Finally, we discuss the role of watercraft as a subsistence technology comparing residential and logistical mobility to further examine the potential role of boating in early hunter-gatherer societies in the Far West.

Material Procurement and Watercraft Construction

The construction of our tule boat were adapted from procedures outlined in ethnographic and ethno-historic accounts (Campbell 1999; Colnett 1940:175; Hudson et al. 1978; Hudson and Blackburn 1979; Wheat 1977). We used a five-bundle construction method with a willow sapling pole frame support inside the main bundle. For the purpose of this experiment, we tried to keep the production steps as simple as possible to reduce manufacturing time.

We used stone tools to harvest and process the entire boat replica. Fine grained volcanic (FGV) rock, procured in Grass Valley, Nevada, was used to produce simple (un-retouched) flake tools characteristic of many WST archaeological assemblages found along the shores of Great Basin lakebeds (**Figure 24**). All materials used in the construction of this boat, including willow poles, were harvested using only two FGV core reduction flakes.

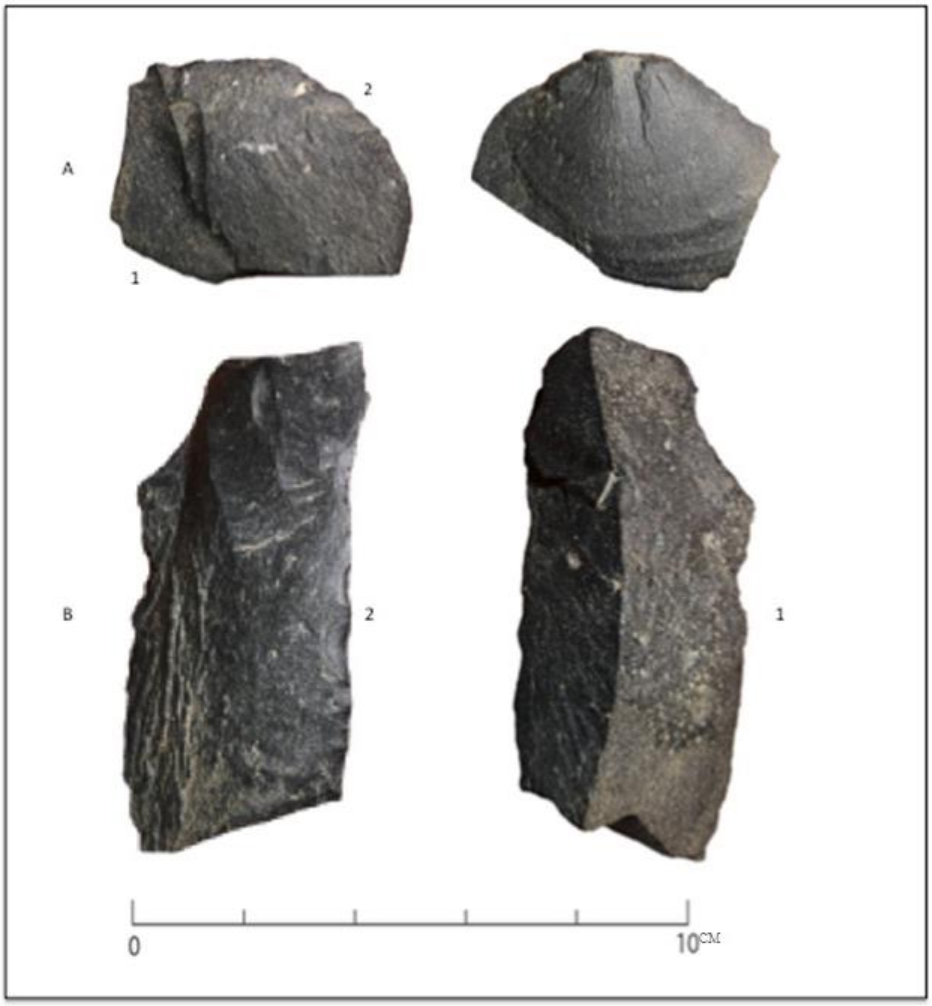

Figure 24. Lithic tools after use in boat construction. Tool A and B with represented utilized edges 1 and 2.

To maximize buoyancy of the finished watercraft, tule reeds were dried in direct sunlight as described in ethnographic accounts (Campbell 1999; Gayton 1948:21; Hudson and Blackburn 1979). While fully dried after a few days, we waited for approximately two weeks to resume boat construction. Cattail leaves were also harvested using the same two flake tools and were dried until achieving a tan color before being rehydrated and woven into the cordage necessary for lashing the tules into pontoon-like bundles, and those bundles into the completed boat. The previously unutilized edge (edge 2) of flake tool B was exclusively used to fell two small diameter willow poles (~3 cm) through chopping and groove-and-snap methods. Based on ethnographic and ethno-historic accounts (Hudson and Blackburn 1979), these willow saplings provided inner support for the main tule bundle. Directly after felling these poles, the willow supports were staked to the ground to season in the sun for two weeks to take on the characteristic shape that would later translate to an elevated boat bow and stern. Cattail cordage was produced through a three-ply braiding method (for final bow and stern lashing) and two-ply overhand twining methods for the main boat body as an alternative to more expedient twisted leaf cordage. This more curated and twined cattail cordage production was based on a combined ethnographic accounts of dogbane (*Apocnyum* sp.) cordage in southern California (Hudson and Blackburn 1979) and twisted cattail in the Great Basin (Wheat 1967). The two large main supporting bundles were added to the sides of a main bundle, and finally two smaller diameter bundles were lashed to these to function as gunwales. Last, using the same stone flakes, the bow and stern were trimmed to shape, as were any tag ends of cordage or tule ends not streamlined with the hull of the boat (**Figure 25**).

Figure 25. Tule canoe in process of construction. a) Bound tules ready for drying, b) Cattail leaf braid and twined cattail cordage, c) Three tule bundles, d) Replica in construction.

Use Wear Analysis

High and low power wear pattern analysis has been shown to be successful in understanding general categories of tool use (Keeley 1980; Odell and Odell-Vereecken 1980). Distinguishing between use on particular soft materials, such as plants and animal hide, is difficult. However, distinguishing between use and no use and tools used on hard versus soft materials, as well as directionality of tool use is readily visible using low power microscopy (Bamforth 2010; Keeley 1980; Odell and Odell-Vereecken 1980; Stevens 2010). Although the two FGV flakes used in this study were not blind tested, wear patterns were analyzed using the naked eye for any potential macro wear-patterns that might be easily identifiable in the field if similar tools were recovered from archaeological contexts. These two expedient stone flakes were analyzed with a 10-70x stereo-microscope (Bausch & Lomb Stereozoom 7). The 10x scale represents what might be available to field archaeologists equipped with a jeweler's loop. The higher 50-70x magnification for polish and fine edge damage represents what is typically available in an archaeology lab. Edge rounding, polish, micro fractures along working contact and invasiveness of polish were recorded when present, on both ventral and dorsal surfaces. Polish and wear patterning were compared with experimental use wear reference samples at the Archaeological Research Center (ARC) at Sacramento State University to evaluate consistency or inconsistency with plant and wood processing activities.

Technological Investment Computation

Building on the data recorded during watercraft manufacture, we use the technological intensification/investment model (Bettinger 2009, 2021; Bettinger et al. 2006) to estimate when boat production and use is "worth the trouble" (Ugan et al. 2003). Our estimate of tule boat construction time makes it possible to model when an individual should invest in boat construction or opt for some other technological alternative. One of the most basic functions of a watercraft is transportation between resource patches, whether economic or social resources. We can contrast boating with the most basic form of transportation—walking. Fundamentally, boating offers a direct line of travel between two points when two-dimensional bodies of water separate them. Especially in areas of Complex and convoluted shorelines, including many locations within extensive pluvial lakes of the Great Basin typical of the terminal Pleistocene, a boat has the potential to reduce resource acquisition times significantly enhancing resource utility.

Walking inherently requires longer travel times around water bodies than boating directly across them. For travel purposes alone, one or more individuals might swim across a narrow lake, but returning with heavy subsistence resources or toolstone across the same body of water would be impossible. However, a boat is not free as one has to invest time in making the boat. In contrast, walking *is* virtually free. Humans are well-known to walk without foot-wear, and even when footwear is needed, manufacturing/production costs can be minimal, just 20 minutes by one estimate (Geib 2000; Jolie and McBrinn 2010:156-158). Thus there is a fundamental tradeoff between travel time and technological startup cost when considering travel by foot or boat. Many modern boat owners will tell you that their definition of a boat is a hole in the water that you throw money into. For our purposes, the question then is, *when is it worth the effort to invest in a boat?*

To answer this question, we start by considering a simple thought experiment in which a forager has established camp on a lakeshore and wishes to access some resource on the opposite side of the lake. The forager could walk around the lake to access the resource, swim across the lake, or build a tule boat to make a bee-line to the resource. Intuitively, the decision depends on the size and shape of the lake. If the lake is small—say a pond 20 meters in diameter—then it would make no sense to go to build a boat when one could walk to the resource in minutes. However, when the lake is large, it might make sense to invest in a boat. If so, the switch point must lie somewhere between those extremes. In other words, we wish to know how big of a lake it would take to justify boat building such that investment costs are recouped in travel-time savings. The simple answer, if travel time is the sole measure of payoff, is that people should invest in boats when walking time is greater than paddling time plus boat construction time.

Results

Watercraft Construction: Material Procurement and Costs

Our completed and fully functional tule canoe replica was 3.3 meters in long, 77 cm wide, and 50 cm high (**Figure 26**). The main bundle was approximately 35 cm in diameter at the widest point, with the two smaller supporting bundles measuring 25 cm in greatest diameter, and gunwales measuring 9 cm in greatest diameter. The boat could have been produced by a single person, but because two builders KNS and MK were involved, recorded times were doubled to reflect the total person-hours (the time one person would have taken to manufacture the craft) invested. No tasks in the process seemed to require two participants. Tule reeds ranging in diameter from approximately 1-3 cm were used in the construction of the boat. These tules were harvested in 14 hours using the two FGV expedient flakes. As the tule reeds dried in approximately 30 cm diameter bundles in direct sunlight for two weeks, the same flake tools were used to gather cattails for cordage production. The simple flake tools were effective and retained sharp edges throughout the cattail harvest with no need for retouch. Cattail leaves with no significant creases or tears that might affect structural integrity in cordage manufacture, as consistent with ethnographic accounts (Wheat 1967), were specifically targeted for harvest. After two weeks of drying in direct sunlight the once green (and now tan) cattail leaves were then rehydrated in fresh water for approximately 30 minutes with periodic dipping if they began drying out during cordage production. In 19 person hours, approximately 74.2 meters of twined two ply and three-ply braided cordage was manufactured. Finally, two willow poles with a maximum diameter of 3 cm were felled using the previously unused second edge of flake tool B in 3.5 minutes. In total, start to finish, including harvest time, cordage production, and assembly, the boat took approximately 59 person hours to complete (**Figure 27**). Cure-times (the times needed to let materials sit and dry unattended) were not included in overall construction/work time, but required three days that temporarily halted construction.

Figure 26. Martijn Kuypers testing the tule boat in Davis, California.

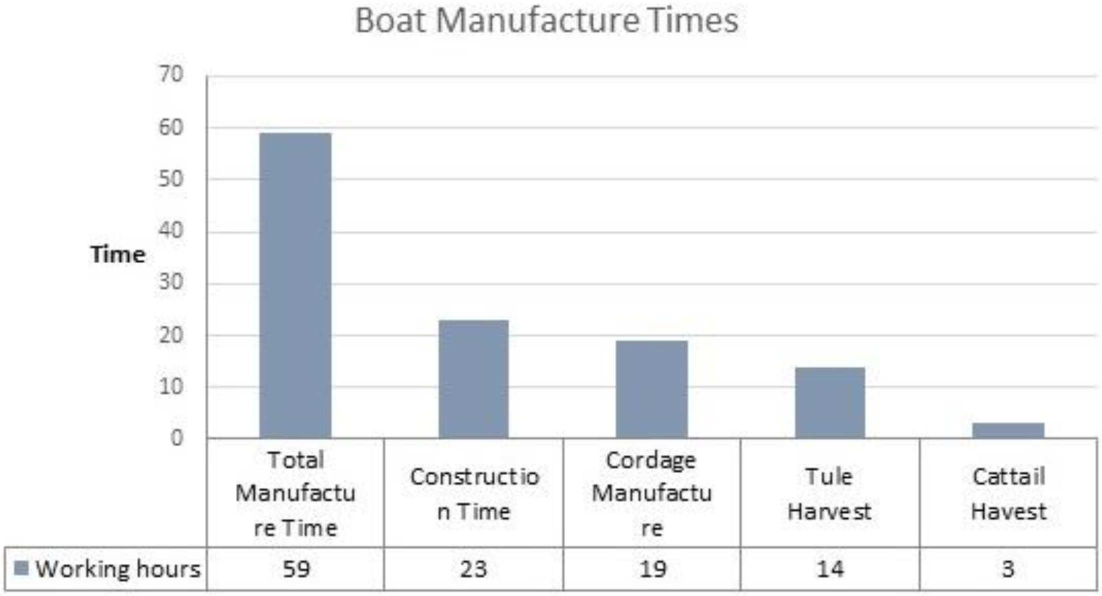

Figure 27. Times (person hours) invested in various stages of tule boat production.

Use Wear on Manufacturing Tools

The two FGV cutting tools was surprisingly effective during the entire production, which included cutting tule, cattail, and the willow support poles (**Figure 27**). We did not detect any dulling of the flakes and they remained effective throughout the process. Edge 2 of tool B (along one margin of the ventral plane) exhibited macro-flaking visible with the naked eye and under 10x microscopy after use in heavy duty woodworking, while edge 1 of tool B exhibited no significant macro-wear. Under 50-70x magnification (**Figure 28**), two utilized edges were identified on tool A, both exhibiting edge rounding and silica polish on all high points. Tool B also exhibited two utilized edges. Edge 1 showed significant edge rounding and silica polish, while edge 2 was characterized by patterns of micro-chipping and wear more consistent with woodworking. Invasiveness of polish was also noted on both the ventral and dorsal surfaces of each tool. Visible polish was consistent with what is expected of processing silica-rich plants and is characterized as a glossy rounding on high points along working edge margins.

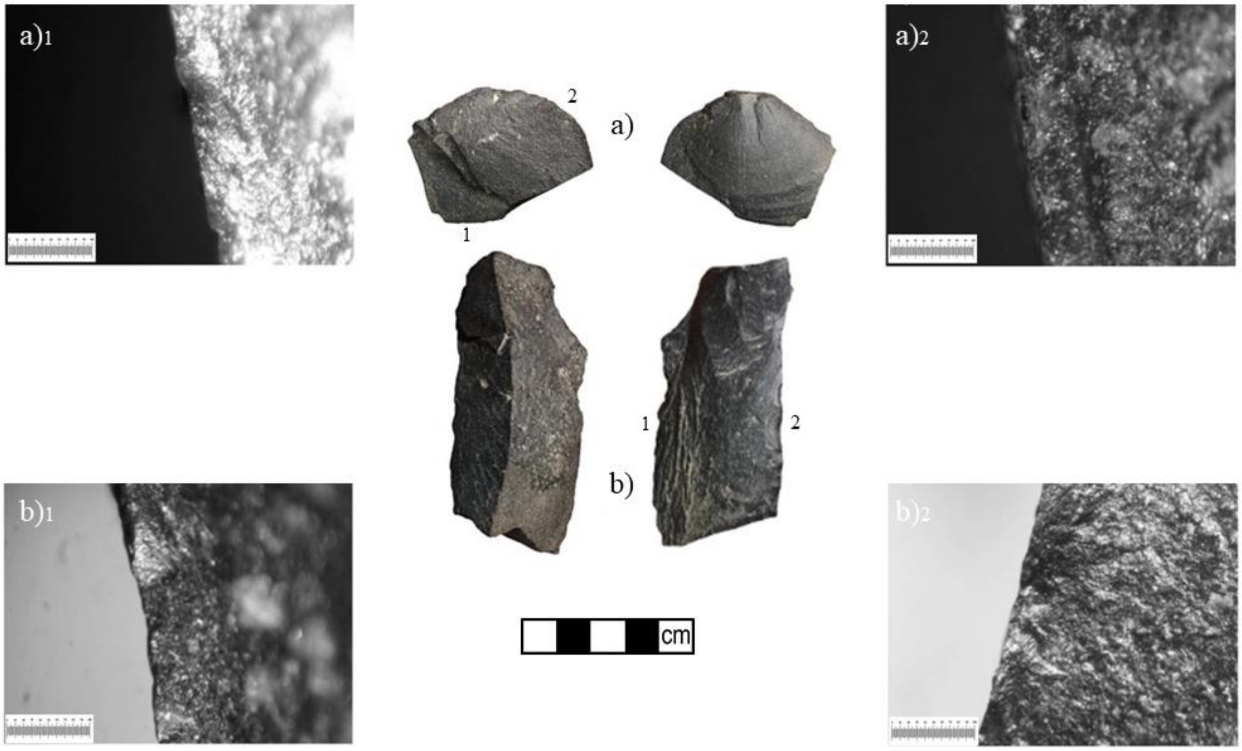

Figure 28. Micro-wear edge images. Top row, Tool A) edges 1 & 2, silica polish from cattail and tule harvest. Bottom Row, Tool B) edge 1 silica polish from cattail and tule harvest, edge 2 microchipping and edge damage from willow harvest. Center shows flake tools used in the experiment with used edges labeled.

Is a Tule Boat Worth the Effort?

Knowing boat construction time and making a few simplifying assumptions, we can make estimate the time threshold at which a forager should construct a tule boat. We eliminated overhand twining times for curated cordage as most ethnographic bundle boat makers use simpler split grape vine/root, willow withies, or simple twisted cattail leaf bindings. Building on the work of Brandy and Byrd (2018), we apply Bettinger's (2009; 2021) Technological Investment Model to our experimental baseline derivation of 40 person-hours (cordage twining excluded) to construct a single-person tule boat. As a first approximation, we consider a one-off situation in which a forager targets some resource on the opposite side of a water body. The forager must decide whether to walk around the water body or build a boat to make a bee-line. For simplicity, we assume a round body of water--a pond, lake or perhaps a bay that is semicircular in shape--lies between the forager and resource.

We begin with the simple premise that one could be expected to invest in a boat when the round-trip walking time (w) to the resource exceeds the sum of round-trip paddling time (p) and boat-construction time (b), or

$$w > p + b \ (1).$$

To find this technological switch point, we first set eq. 1 as an equality such that

$$w = p + b \ (2).$$

This indicates that the switch point occurs when round-trip walking time is equal to round-trip paddling time plus boat construction time. To solve for w, we have to know the values of p and b. We have estimated the value of b at 40 hours based on our replication. Furthermore, we can approximate the relationship between walking and paddling times making two simplifying assumptions. First, we can assume that walking and paddling rates are equivalent given that they are comparable, both around 5 km/hr (Ames 2002). Second, if we assume a round body of water, we can model distance relationships given circular geometry where round-trip walking time is the circumference of the circle, or

$$w = c \ (3)$$

and round-trip paddling time is twice the diameter of the circle, or

$$p = 2d \ (4).$$

The relationship between the circumference and diameter of a circle is

$$d = \frac{c}{\pi} \ (5).$$

Substituting w for c per eq. 3 and inserting this equation into eq. 4 gives a paddling time of two times the walking time divided by π, or

$$p = \frac{2w}{\pi} (6).$$

Inserting eq. 6 into eq. 2 gives

$$w = \frac{2w}{\pi} + b \text{ (7).}$$

Rearranging to solve for *w* gives the switch point in walking times beyond which it pays to invest in tule boat construction,

$$w_{switch} = \frac{\pi b}{\pi - 2} \text{ (8).}$$

This round-trip walking time reflects the walking time at which it becomes profitable to invest in boat technology assuming a round body of water. With our estimate of boat-construction time, *b*, (40 hours), we can estimate a switch point of 110 hours, or a lake with a circumference of 550 km (approximately 175 km in diameter). This solution is shown graphically in (**Figure 29)**. Thus, under a certain set of conditions, we should only expect a forager to invest in boat production in a one-off scenario when walking time around a body of water to a desired resource takes 110 hours or more. Beyond that point, it pays to invest in a boat. Until that point, one could more efficiently acquire the resource on foot.

This thought experiment is admittedly simple, but it reveals surprisingly high opportunity costs when investing in even simple boat technology. The 110-hour walking distance threshold translates to a round-trip walking distance of 550 km, assuming a 5km/hr walking speed. Such distances are drastically higher than logistical forays documented among most hunter-gatherers, which are more typically 3-7 km (Kelly 2013) if temporary camps are not erected. If the target resource was a primary subsistence resource, one would do better to simply walk 55 hours (one way) and establish a new residence, which Morgan et al. (2018) experimentally estimate to require under 8 hours for a typical family, a total investment time of 63 hours for moving a house. This is considerably less than 110 hours required for boat construction and roundtrip transport of the resource. It therefore seems that a forager is unlikely to invest in even the simplest boat technology in one-off resource acquisition events when residential mobility is an option and time allocation is a major concern. Some other set of conditions must be met to justify boat construction.

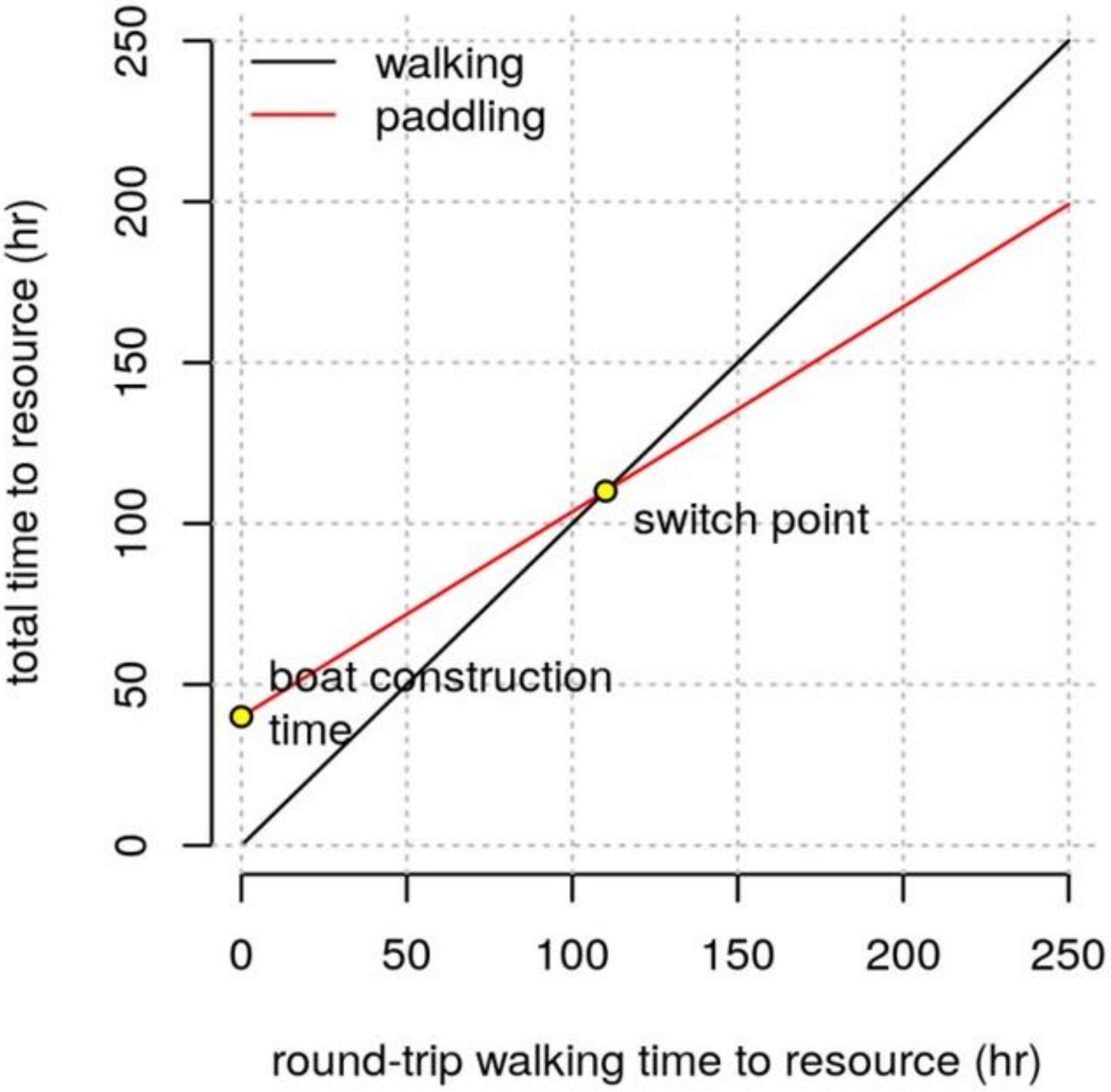

Figure 29. Graphical representation of model using experimentally derived boat construction data. The model indicates that boat manufacture and travel will replace foot travel to a fixed resource in a one-off scenario when foot travel exceeds 110 hours (round trip).

While it may not pay to invest in a boat for a one-off trip, it may be worthwhile if the forager knew that they would reuse the boat or had to transport large loads. Ames (2002) suggested that boats acted essentially like floating baskets, freeing people to transport larger loads greater distances with less field processing needed in comparison to terrestrial traveling costs. Schneider and La Porta (2008:31) described the ease by which a reed bundle boat transported up to 300 lbs of ground stone tool blanks in experiments conducted in the Levant, while Vranich (2005) showed that a large tule boat was capable of transporting a stone weighing nine tons on Lake Titicaca. We could imagine that a forager having to transport a large load might benefit from boat technology when it would reduce the number of trips required by foot. The working model can be extended to account for such scenarios of multiple trips by adding a repetition term, *r*, to eq. 1 as follows:

$$w * r > p + b \text{ (9)},$$

which can be rearranged to solve for *w* as follows:

$$w > \frac{p+b}{r} \text{ (10)}.$$

Substituting eq. 8 for $p + b$ to account for lake geometry gives

$$w_{switch} = \frac{\pi b}{r(\pi - 2)} \text{ (11)}$$

This simply says that boating should be preferred when paddling plus boat construction time is less than walking time multiplied by the number of trips, or repetitions, required. Suppose that a forager knows of a herd of elk on the opposite side of the hypothetical lake. With atlatl or bow, they can take an animal from the herd. Targeting one of the larger animals and butchering it, they could expect to produce over 100kg of meat. If a typical forager can carry a 50kg load, transporting this load would require two walking trips. An elk hunt, with these parameters and a tule boat construction time of 40 hours, predicts a switch point of 55 hours of round-trip foot travel to the elk. Beyond 55 hours of foot travel, investment in a boat would save the forager time. However, the alternative strategy of moving camp to the resource is still more economical, requiring 30 hours of time—22 hours of one-way foot travel plus 8 hours to establish camp (Morgan et al. 2018). It seems that even the biggest subsistence resource in the Great Basin would be unlikely to compel a forager to invest in a boat.

These results suggest that some other set of conditions must be met to compel boat production. Other possible explanations include population packing, which compels sedentism and thus makes residential moves to resources impossible. Another possible explanation is some major resource that cannot be taken near shore, but requires access to deep water areas. Yet another possibility is access to resources on islands or in marshes where foot travel simply is impossible. Another is some other mass resource that requires more than two trips. We note that the theoretical switch point for four trips is 28 hours, which is greater than the theoretical house-relocation time which would require 22 hours in this circumstance—14 hours one-way travel plus 8 hours of camp construction.

When Tule Boats Are Advantageous: Residential Mobility.

An interesting tradeoff to consider is when hunter-gatherers who subsist from and live along shorelines should invest in residential mobility (to more productive patches) or stay at their current residence and practicing more logistically oriented subsistence pursuits. While moving a residence and foraging terrestrial resources on land and aquatic resources from shore can be done by foot, mobility facilitated through boat-use can allow new access to potential resources that would otherwise necessarily be ignored. In the late Holocene, ethnographic hunter-gatherers living in such environments in California and the Great Basin invested in tule boats more often than not. However, it is possible that the startup costs of boats (40-hours), may not have been worth the trouble until human population packing required a degree of sedentism. If lakeside occupants did not have the option to simply move their residence to the next productive lakeshore patch, the ethnographic trend of tule boat-use could be viewed as analogous to ethnographic ground stone use and seed processing. In other words, boat investment might have arisen only when intensification of lower ranked resources was required as frequent residential mobility was not possible.

When WST people first entered the Great Basin, it is likely that population densities were so low that these hunter-gatherers would have been unencumbered in terms of where to settle in order to maximize proximity to the most productive resources (Ideal Free Distribution). WST sites largely cluster around Great Basin pluvial lakeshores which were highly productive wetland patches where large game, small game, waterfowl, fish, and plant food densities were high. If we consider wetlands around lakeshores as relatively consistent in the abundancies of these resources, then residential and logistical mobility patterns would have concentrated on lake margins with occasional task-oriented movements further away from lakes to upland and mountain environments. Under these circumstances, would the investment in boats ever be favored when a highly mobile WST group could simply move twice the distance of their foraging radius and establish a new residence on the lakeshore?

Considering that freshwater shellfish, fish, waterfowl, and (likely) bird eggs were all part of the WST diet, and that all of these resources can be taken offshore in wetland patches most easily by boat, a comparison of two competing mobility and subsistence scenarios for lakeside foragers is in order. Neither the construction of a dwelling nor the construction of a boat are free, yet, as noted above, for hunter-gatherers with lakeshore residential bases, boating provides access to a complete foraging radius around the camp while groups without boats are largely anchored to the terrestrial half of a foraging radius. In other words, those that invest in boats could essentially double the amount of foraging territory per residential move when compared to those who do not. Consistent with the Marginal Value Theorem, mobile hunter-gatherers occupying lakeshores should move their base camp along the shoreline to exploit new foraging radii when the productivity of the patch covered by the foraging radii surrounding their old residential base depreciates to a given point (Law of Diminishing Returns). The costs of residential moves are fundamental considerations to any hunter-gatherer group when deciding when to abandon one patch for another. Essentially a Central Place Foraging problem, we envision two competing mobility strategies and patch exploitation configurations which loosely mirror the ‘half radius continuous pattern’ and ‘full radius leapfrog pattern’ described by Binford (1982:10) (**Figure 30**) with a few important modifications specific to coastlines where access to water is possible.

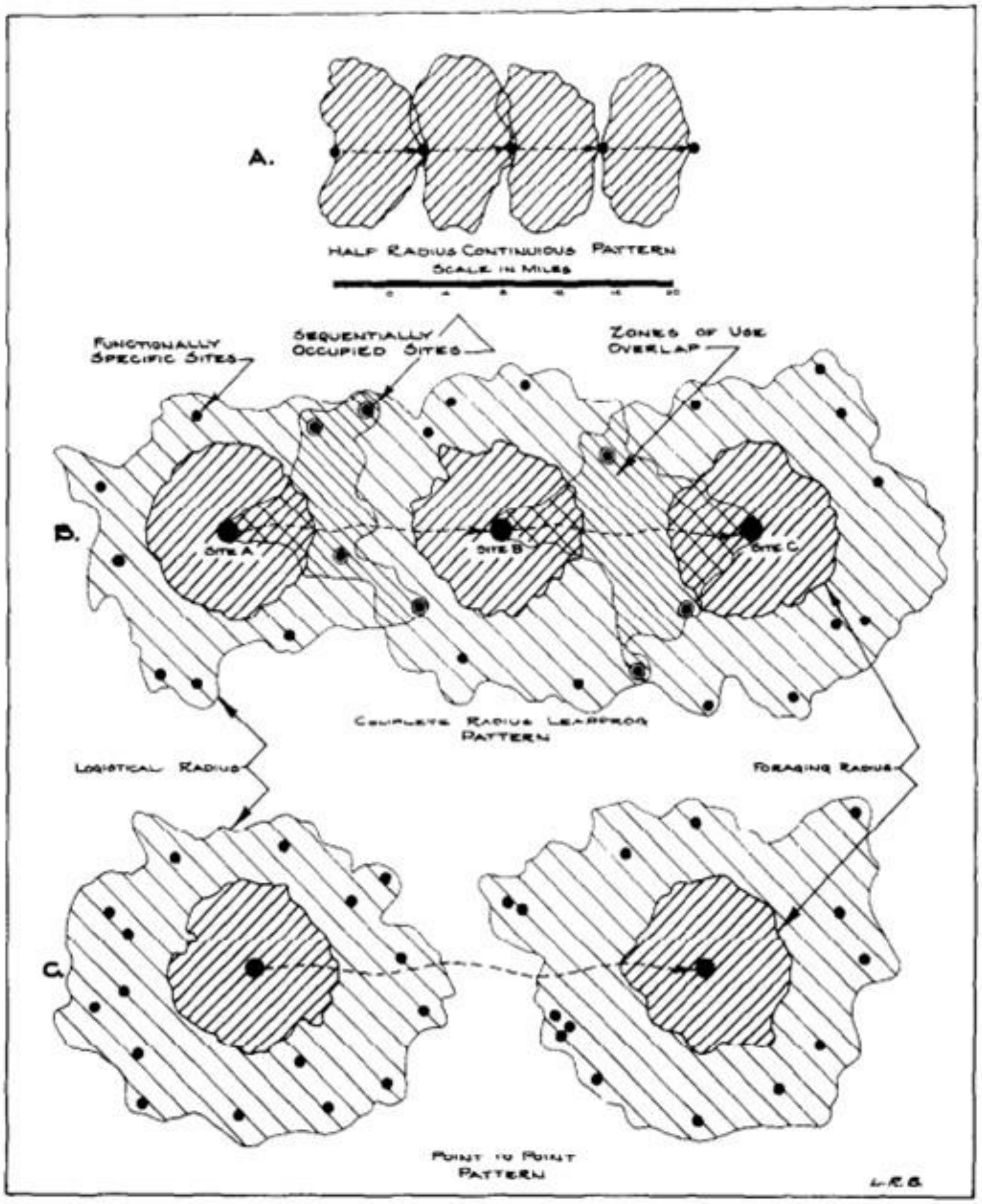

Figure 30: Idealized patterns of residential camp movement with overlap or spacing of foraging or logistical zones around residences (adapted from Binford 1982:10).

Morgan and coauthors (2018) quantified the production of common Great Basin style shelters and provided comparative data to further evaluate when one might invest in residential mobility considering residence construction costs. The authors completed a cattail thatched ‘wickiup’, measuring approximately three meters in diameter and two meters in height, in a mere 14.63

person-hours (Morgan et al. 2018). Even when we eliminate cordage production time from our boat-build (as reflected in our application of the technological investment model) in favor of expedient lashings as described in many ethnographic accounts, our tule canoe would still have taken approximately 40 hours to construct. Therefore, the cattail wickiup constructed by Morgan and coauthors (2018) is a less costly technology than our tule boat. Comparing these startup costs, it would seem that logical foragers would simply move their residential base camp to a new lakeshore location to exploit another productive patch unencumbered by boat investment. However, when we consider that the use-life of a tule boat of similar dimensions in a freshwater environment is six months (Hidalgo-Cordero and Garcia-Navarro 2018), and we consider how boat-use expands the available territory in a patch that can be exploited before residential moves are required, this scenario becomes increasingly complex.

Below, (**Figure 31**) provides a graphical representation of two competing mobility strategies. Here, nuclear families (Group A and Group B) both place residences on lakeshores and focus subsistence activities around their camps. If foraging radii are constant between groups, then Group A (boat users) have access to double the patch size and resources when compared to Group B who do not invest in boating. If we rely on the estimate for production of a cattail dwelling at 14. 5 hours (Morgan et al. 2018), then Group A has invested this time and the 40-hour startup cost to build a tule boat (54.5 hours) while Group B has merely invested 14.5 hours for their residence construction. Yet, since group A can exploit a full foraging radius, they can practice a complete foraging radius leapfrog pattern (Binford 1982:10) while Group B must practice a modified half radius leapfrog pattern as aquatic resources are only available to them from shore. In other words, Group B must make residential moves twice as often as Group A. Considering that the tule boat constructed by Group A has a use-life of six months in fresh water (Hidalgo-Cordero and Garcia-Navarro 2018), then boat-building would only occur twice a year. Therefore, by the time Group B has moved six times and invested in constructing six residences (14.5 x 6 = 87 hours), Group A has only moved three times and invested in one boat build and the construction of three residences (40 + (14.5 x 3) = 83.5 hours. In this case, the construction of the tule boat by group A would be favored over not building a boat by their third residential move.

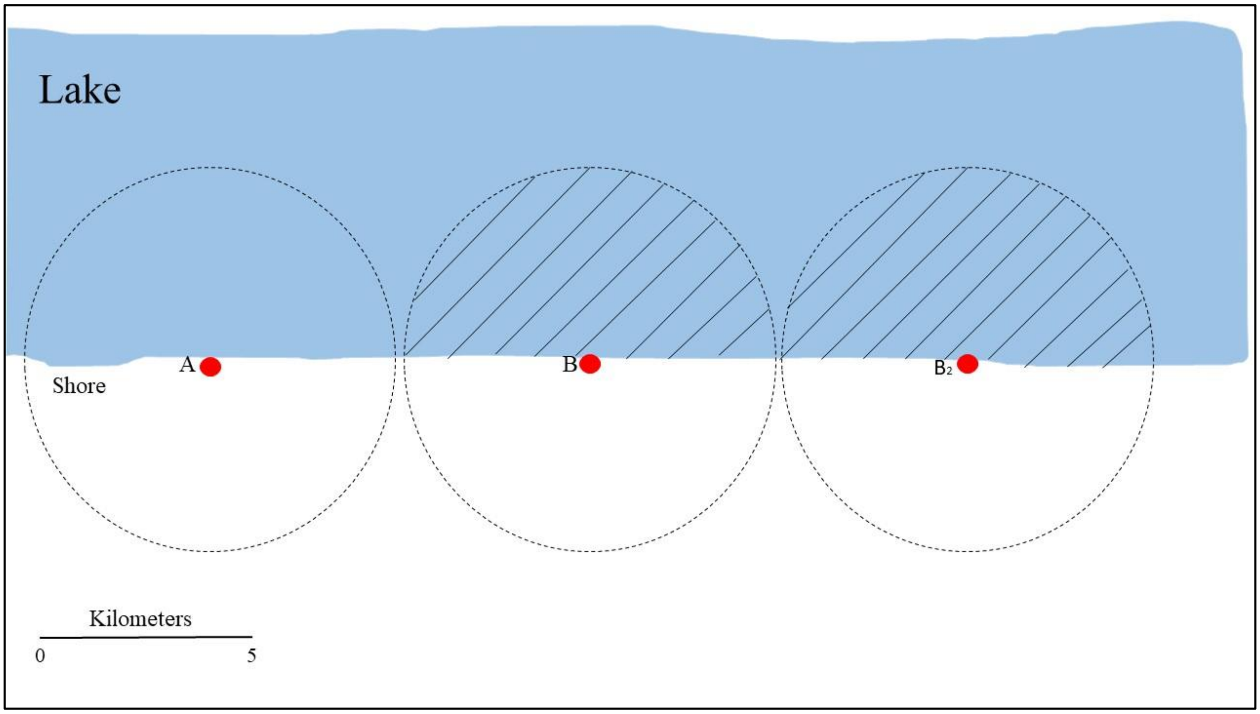

Figure 31: Graphical representation of two competing foraging radii. Group A (boat users) have full access to their foraging radius while Group B does not.

However, if the same scenario is applied to the convoluted shorelines typical of Great Basin pluvial lakes, and we consider an additional ‘lean-to style wickiup’ as a logistically oriented task specific camp, which Morgan and coauthors (2018) estimate to take 6.5 hours to erect, the model becomes slightly more complicated. Here, (**Figure 32**) the far shore is 5 km across a lake finger from the residential base camps of both groups, yet it is only reachable at the edge of the 5 km foraging radius by Group A who has invested in the tule boat. In this scenario, Group A now has not only the ability to exploit the full foraging radius around their residential base, but can now invest a mere 6.5 hours to establish a task specific logistical camp on the far shore (location a). Group B must move and construct three residences in the time it takes group A to move one residence and construct a boat and one temporarily camp. In other words, by the time Group B has moved six times and invested in construction of six residences (87 hours), Group A has made one boat (40 hours), two residential moves (29 hours), and two logistical camps (13 hours). Or 40 + 29 + 13 = 82 hours.

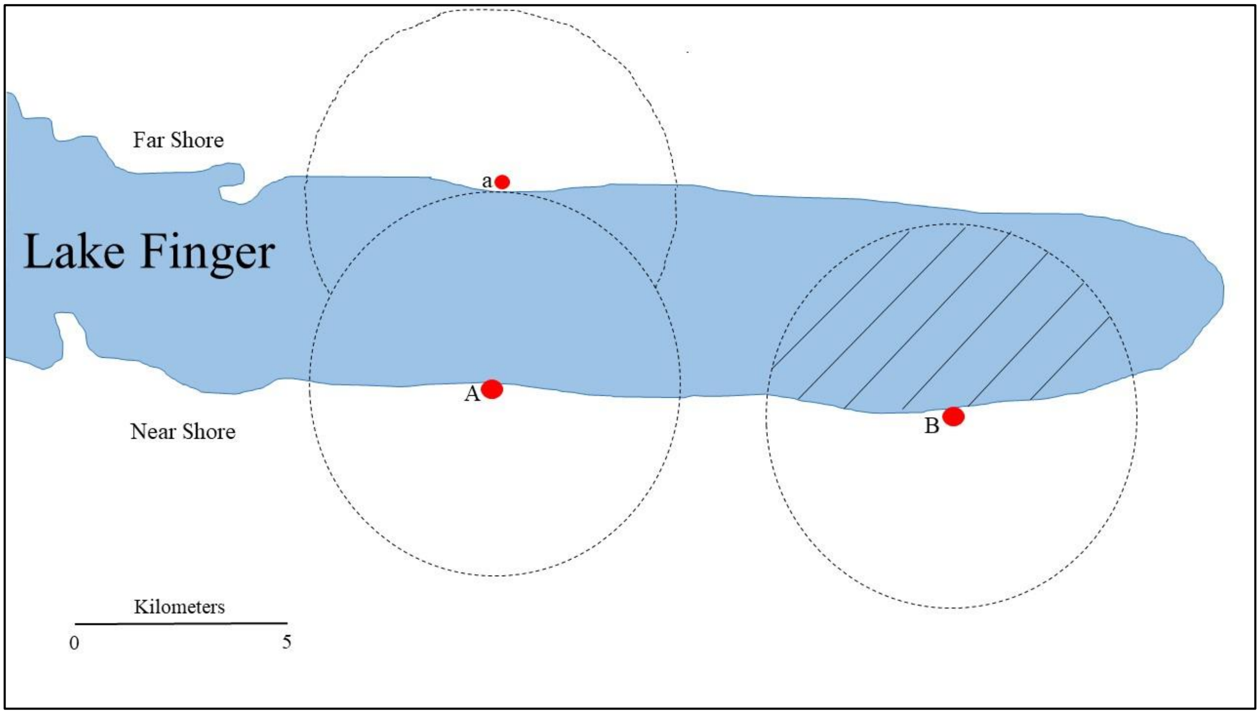

Figure 32: Graphical representation of the same competing strategies but with the now added advantage of access by Group A to a task oriented logistical camp (a) on the far-shore of a lake finger not reachable by group B unless they walk around the lake.

Up to this point we have relied on Morgan et al. (2018) as estimates of residential and logistical camp investment times. However, most ethnographic accounts detailing the construction of residences in lakeshore environments with lakeshore resources (tule and cattail thatching) also make numerous specific references to thatching in such a way that the roof is waterproof (Fowler 1990; Wheat 1967). A waterproof roof on a residential dwelling would have been important especially in more temperate climates of the terminal Pleistocene and early Holocene. Since Morgan and coauthors (2018) do not note whether their ‘cattail wickiup’ was waterproof, we applied their 14.5-hour construction time to the same scenario as outlined above, but this time treating their ‘cattail wickiup’ as the temporary camp. Production times gathered from numerous sources show that waterproof dwelling thatched with tule, reeds, and grass of similar dimensions to that produced by Morgan and coauthors (2018) range from 190 hours at the low end (Dino LaBiste, personal communication 2021) to over 500 hours at the high end (Yannick de Raff, personal communication 2021) (**Figure 33**). Even if we divide the lowest estimate of 190 hours for a residence construction in half, *and* we add back the 19 hours spent on curated twined cattail cordage for an investment of 59 hours to build a boat, after just a single residential move by group B (who do not make boats), boat-building is favored by group A. In other words, Group A invests 95 + 59 = 154 hours in the time that Group B invests 2(95) = 190 hours. Additionally, in a sinuous lake finger where the opposite shore is reachable by boat at the edge of the daily foraging radius, when Group A has invested in a residence (95 hours), a boat (59 hours), and a logistical camp on the far shore (14.5 hours), for a total of 168.5 hours, Group B has invested in three residential moves at 95 hours each, for a total cost of 285 hours!

Figure 33: Waterproof Pomo-style tule thatched dwelling by Dino LaBiste (left), and ‘cattail wickiup’ (right) adapted from Morgan et al. 2018.

To sum up, by comparing the costs of residence construction and boat-building, if the ‘Cattail wickiup’ times generated by Morgan et al. (2018) are used, then boat investment is rapidly favored over occupying the lakeshore but ignoring boats. Additionally, even if we were to cut the lowest estimate for the construction of a waterproof dwelling in half, and add the cost of curated cordage back to boat construction (accurately reflecting the exact process we used to build our tule canoe), boat investment is justified before our hypothetical Group A has to make even a single residential move! Perhaps, the different dwelling construction times, and how this scenario plays out as a result, could also be used to help model the time invested in residence construction and mobility during cold-wet seasons and warm-dry seasons depending on whether waterproof roofing was needed. It is now apparent however, that in both cases, watercraft-building and use is justified even among highly mobile hunter-gatherers as long as their settlement and subsistence pattern predominantly focuses on shorelines. In other words, if WST peoples did occupy lake shores targeting productive terrestrial and aquatic environments as the archaeological evidence indicates, the advantages of investing in tule boats among the Great Basin pluvial lakes would have far outweighed their cost.

Discussion

Tule Boat Replication: New Perspectives

Technological analyses of archaeological materials provide important insights into ancient human behavior. Due to preservation biases, however, our understanding of non-perishable artifacts is far more comprehensive than that of organic technologies. Ethnographic and ethno-historic accounts attest to many ways that indigenous peoples made use of perishable materials as intrinsic components of their everyday lives. While artifact analysis and ethnographic studies have provided vital information about many of these technologies, few researchers have aimed at replicating ancient perishable items using period-appropriate methods and materials to address questions regarding production dynamics from pre-contact western North America.

In 1979, a team led by Michael Macko and Jon Erlandson manufactured a 5.3-meter-long two person tule canoe following ethnographic accounts for a traditional seven bundle Chumash construction style. Tule reeds were harvested with stone tools and dried for two weeks. Modern cordage was used to assemble this boat and, as described in some southern California accounts, the hull was coated with asphaltum obtained from an oil seep near Carpenteria, California (Hudson and Blackburn 1979). This two-person tule canoe was manufactured in approximately 89 hours with 30.5 hours in willow and tule collection, 46.5 hours in boat construction, and 12 hours in coating the hull with asphaltum. Upon completion of this larger asphaltum-coated tule balsa, Erlandson and Macko navigated the watercraft for about 20 km along the kelp forests of the Santa Barbara Coast (Michael Macko and Jon Erlandson, personal communication 2018; Hudson and Blackburn 1979:332-333). Although modern cordage was used, this recreation, and the more expedient smaller single-person replica made by Northern Paiute elders Wuzzie and Jimmy George (Wheat 1969:40-47) are some of the most comprehensive and detailed reproductions of traditional tule boats that have been documented in published literature. Since some of the most detailed and comprehensive ethnographic and ethnohistoric descriptions of tule boat building (Campbell 2009; Wheat 1969) mention the use of traditional tools, but detail tule boat construction relying on metal implements, examining construction dynamics through the exclusive use of stone tools, and their associated wear patterns, is a necessary step to build on such studies and establish a more comprehensive understanding of reed watercraft production. This approach also allowed us to detail tool efficiency and provide a comparative assemblage of wear patterns that might survive and be identified in archaeological contexts.

The Paleo-Maritime Hypothesis (Schulz et al. 2011) proposed that the water-rich Great Basin landscape of the late Pleistocene and early Holocene would have favored the use of watercraft. Further, abundant cattails and tules were thought to have been the most logical choice of materials for the production of boats in this environment (Jodry 2005). While it is still uncertain whether boating technology in the pluvial lake environments of the Far West was worth the investment, as a logistical subsistence technology it may have benefited lakeside WST peoples tremendously as we discuss later in this paper. If WST people did in fact invest in building boats, we also agree that wetland plants such as tules and cattails were logical materials of choice for their production. Our study also provides data which can be compared to other early boating technologies to further our understanding of what conditions might facilitate investment in more complex watercraft such as dugouts and plank canoes.

One observation that we made during this process was that tules, cattails, and willows are short lived but ubiquitous and rapidly replenishing resources. However, tules and cattails are not present in significant numbers and suitable size year-round. Depending on the geographic location, tules and cattails die off and succumb to breakage in the wind during late Fall-Early Spring. While this annual die off varies geographically, the pattern of a seasonal material shortage is ubiquitous. As a result, tule canoes can only be made during certain seasons when adequate numbers and quality of materials are present. As such, boat building, and associated bundle boat construction sites likely include a seasonal dimension. Additionally, unlike dugout boats or plank canoes, minimal specialized knowledge is required for tule boat production. While Schultz and coauthors (2011) hypothesized that WST flaked stone tool technologies like crescents (which they referred to as "crescent knives") may have been specialized tools for tule boat production, our experiments indicate that no specialized tools are needed. Our observation implies that crescents serve a function other than wetland plant harvesting within the WST toolkit. Further, tule boats, in their simplest form, may have allowed for some level of individual or nuclear family autonomy as their manufacture was contingent on ubiquitous wetland resources with minimal prior knowledge and a toolkit made up of one of the most basic tools invented by humans: the flake. Finally, this study also serves as a cautionary note. Without micro-wear analysis of simple flake tools, we must ask ourselves if technologies associated with bundle boat construction will ever be recognized in the archaeological record? Flake tools with the high silica polish and distinctive wear described in this paper may have been tule-harvesting tools, but we cannot say definitively that they were used in boat construction. However, if found spatially associated with features that are ethnographically linked to boat building, maintenance, and launching sites, then arguments for potential tule boat manufacture may hold more weight. The following section proposes certain landscape features that, through targeted survey, might yield such evidence for boat manufacture and use in the Great Basin if bundle boats were used on pluvial lakes.

Implications for the Western Stemmed Tradition and Maritime Adaptations

When WST peoples initially settled in the Great Basin, they made use of tule as a material resource evidenced by numerous examples of material culture (mats, basketry, sandals, etc.) from dry cave and rockshelter assemblages. WST peoples also relied on a subsistence strategy that was at least partly focused on lacustrine resources and environments. Almost every Native American ethnographic group in California and the western Great Basin with similar subsistence strategies, living in similar wetland contexts, and using tules as a material resource in similar ways, routinely made and used tule canoes. While construction of tule watercraft may not have been justified for a one–off trip as we showed through our initial application of Bettinger's (2009) technological investment model, a boat with a use-life of six months can give significant advantages as a subsistence technology to lakeside dwelling hunter-gatherers. Comparing the economics of logistical boat use against more frequent and costlier residential moves required of lake-shore inhabitants who ignore boating, we see that boating is quickly favored. It therefore seems reasonable that WST peoples living on lake margins would have had incentives to invest in tule boating technology. Once such an investment takes place, bundle boats offer significant advantages for ease of travel, transportation of heavy loads far beyond those of burden baskets, potential increased encounter rates and retrieval of wetland fauna, and access to new and productive foraging environments such as islands and offshore fishing waters that would be otherwise inaccessible by foot, ideas further explored below. The reasons why WST people might have invested in such technologies are numerous.

Further Advantages

The costs associated with watercraft include the time spent in material procurement, the labor invested in production, and the labor necessary for tool manufacture and (in some cases) maintenance. These tasks could take away time that could otherwise be allotted to fulfill alternative subsistence pursuits, social networking and information sharing, courting, and parenting. Keeping this in mind, in some situations building even simple tule boats is relatively costly when walking is an alternative. Ethnographically, however, many California and western Great Basin peoples invested in tule boats. The coupling of experimental and ethnographic observations leads us to consider the conditions that might subsidize boat construction costs. Here, we consider five additional factors: carrying load, re-use, errors in our replicative study, non-anchored resources, and the costs of residential mobility.

Carrying Load and Reuse. Pertaining to California tule balsas, Brandy and Byrd (2018) combined ethnographic, archaeological, and GIS least cost analyses to model the energy expenditure and potential utility of travel between known sites via terrestrial trails and by tule canoe in the San Francisco Bay Area. Their results indicate a significant advantage in the use of tule canoes for transporting people and goods especially in navigating around the sinuous shorelines of the bay. Further, their study indicates an additional advantage of tule canoes as boats allowed hunter-gatherers access to new fishing grounds that were otherwise outside of a catchment area based on foot traffic alone. A related point concerning non-anchored subsistence resources will be further evaluated later in this discussion.

Simple boats have been used to transport impressive weights of various commodities throughout the world (Campbell 2009; Fitzpatrick and Hazell 2006; Schneider and LaPorta 2008; Vranich et al. 2005). If a boat-based forager could return from a single trip carrying four times the weight of the foot-based forager due to the boat's storage space and buoyancy, then the switch point for walking versus boat investment shifts significantly. We imagine that this would become particularly important when dealing with heavy or voluminous resources such as lithic material, large game, multiple travelers, or mass captures of fish or fowl. The boat investment model can be extended for such savings in two ways. First, boats can be reused such that an initial construction cost can subsidizes future use. It then becomes important to understand the life span of the boat when evaluating investment dynamics. This variable can be captured with the same term added for carrying loads. Long term replicative studies may be needed to fully evaluate boat lifespan, which was unfortunately impossible in this study as our boat was auctioned off at the Society for California Archaeology annual meetings just a few weeks after its maiden voyage. Macko and Erlandson's boat was unfortunately destroyed by vandals after its second voyage. However, tule reed boats of similar dimensions to our construction made and used on Lake Titicaca, Peru, have a use-life of six months according to a recent study by Hidalgo-Cordero and Garcia-Navarro (2018). If only used for two hours daily, a boat's life span would then equate to 365 hours before replacement became necessary.

Replicative Studies and Potential Errors. While the replication of our tule canoe was conducted by two archaeologists/technologists with over twenty years of combined experience in experimental archaeology, there is no doubt that our boat production times would reduce if we were to repeat the experiment. The effects of the learning curve on datasets concerned with efficiency of production or use are correlated to the complexity of the operation or technology under replication and the familiarity of the technologist with that technology or process. While material harvest and twined cattail cordage production seem unlikely to change as both KNS and MK had years of experience in related activities prior to this project, one place in the boat manufacturing process that both agreed could be streamlined is boat assembly. The lashing and re-tightening of bundles, consolidating and assembling bundles into the hull and gunwales, and re-tightening of all lashings to complete a "seaworthy" craft took twenty-three person hours. With previous boat build experience, KNS and MK feel that boat assembly could be significantly reduced in a future replicative study or by working with or observing more experienced Indigenous tule boat builders.

As previously stated, cordage production is unlikely to change if a similar overhand twined cattail leaf strategy were employed. However, if a more expedient wild grape vine/root, willow withie, or single-twist cattail leaf rope were used as is reflected among some Paiute, Eastern

Pomo, or Yokut boat builders, the 19 hours spent twining cordage might be reduced, yet added to our 40-hour estimate for an even more detailed production time. If assembly time was streamlined and expedient rather than curated cordage was used, these updated manufacturing times could also affect the switch point between boating and walking. However, if our twined cattail leaf cordage time is included to reflect the overall time spent manufacturing this boat, a total of 59 hours was invested. Interestingly the only ethnographic account describing intensive investment in curated cordage (made from dogbane in that case) and additional investment in asphaltum-coating of tule boat hulls are from the coastal Chumash (Hudson et al. 1978; Hudson and Blackburn 1979). These maritime people also had some of the greatest distances to travel (to and from the southern California Channel Islands) and therefore, as predicted by the technological investment model, would be the one group that might benefit most from higher investment in construction that could increase watercraft longevity. The coating of the exterior of Chumash tule balsas may have been another strategy for extending the use-life of such craft. Ethnographic tule boat users often propelled their craft in freshwater using poles which can be used as paddles in open water or pushed off the bottom to propel the craft in the shallows. Such poles could be felled in a matter of minutes using the same flake tool we used to cut poles of similar length and diameter for the support in the main boat bundle. To estimate the lowest cost boat possible for this paper, we considered this as the main way such a boat would be propelled. However, costlier curated double bladed paddles were commonly used on the coast with tule boats and would significantly increase the startup cost of such a boat build and may have even required a more specialized toolkit. As it stands, our current bundle boat production times represent a baseline for understanding initial investment in simple reed watercraft (when cordage time is omitted), but long term replicative studies are warranted.

Non-anchored Resources. If boats were not used by people who settled and subsisted from lake shores and adjacent wetlands, the only portions of the lacustrine environment that could be exploited efficiently would be the lake margins. As noted by Brandy and Byrd (2018), one of the major advantages in boat use beyond transporting people and heavy goods is the ability to exploit resources that are otherwise difficult or impossible to reach by foot. From dry land, or by wading, lake margin subsistence on foot would allow hunter-gatherers to encounter and take large, medium, and small game, as well as waterfowl species including geese, swans, and dabbling ducks. Stationary blinds located on lake shores could also be used to ambush waterfowl that might pass overhead. Dabbling ducks such as teal (*Anas* spp.), mallard (*Anas platyrhynchos*), American wigeon (*Mareca americana*), northern pintail (*Anas acuta*), northern shoveler (*Spatula clypeata*), and gadwall (*Mareca strepera*) subsist largely on invertebrates, seeds, and aquatic vegetation and use wetland plants on lake margins as camouflage to avoid predation. However, diver duck species including canvasback (*Aythya valisineria*), redhead (*Aythya americana*), ring-necked duck (*Aythya collaris*), scaup (*Aythya spp.*), mergansers (*Mergus* sp.), goldeneyes (*Chordata* sp.), buffelheads (*Bucephala albeola*), and ruddy ducks (*Oxyura jamaicensis*), as well as numerous other species of sea ducks native to Western North America, are adapted to open-water habitats and use a strategy of diving to avoid predation and to access their primary food resources including fish, shellfish, and a variety of other foods found near the bottom. Surface-feeding dabblers such as gadwalls and American wigeons are also known to regularly venture far from shore to feed in the same open water habitats as diving ducks and rails such as American coots (*Fulica americana*). If a foot-based lakeshore hunting strategy was solely employed, the majority of the diver duck population and off-shore dabblers on a given body of water would be ignored. Once the waterfowl species that occupy near-shore environments had received enough hunting pressure to make their capture difficult around the entire lake margin, hunter-gatherers would be faced with a simple patch choice decision. Is the distance to the next productive lake a short enough walk to justify ignoring the still-abundant diving duck population in the current lake? Or should 40 person hours be invested in boat production to intensify resource exploitation and target diver ducks in open water in the current patch?

The answer to the above questions are not straightforward. Several additional factors may have had significant effects on seemingly simple decisions of when and how to move. Knowing that WST peoples relied heavily on waterfowl for subsistence, we briefly explore migratory bird ecology and hunting effectiveness and strategies that may have influenced prehistoric boat investment. Earlier we modeled a comparison for foot travel around vs. boat travel across a round water body between two fixed points (e.g., a village and a lithic outcrop). However, unlike stones and even plants, we know that many subsistence resources are not anchored to points on the landscape, and thus associated hunting strategies have adapted for specific environments and species to optimize effectiveness. As previously highlighted, diver ducks that use open water offshore habitats to forage and to avoid predation are most easily targeted by boat (Denson 1964) and could have been an enticing incentive for early boat investment in the Far West.

Denson (1964) studied land-based and water-based hunting strategy and success rates on Humboldt Bay in northern California. His study indicated that boat-based hunters routinely took more birds than any other shore-based hunting strategy (including the use of stationary blinds, offshore blinds, and decoys). Of course, these were sculling boats, a particularly low profile craft that conceal the movements of a paddler. Perhaps of equal importance, however, shore-based hunters in the study were up to 50% less likely to retrieve wounded birds than boat-based hunters. While these data are based on hunting with modern shotguns, one could easily imagine the added benefit of using watercraft to quickly retrieve atlatl darts or arrows without a need to wade or swim. Similar to sculling, outfitting the balsa with stacked loose tules as a mobile-blind and propelling through a hole cut in the hull of the boat (usually used to spear fish) was a known method to approach birds on the water in California (Campbell 999:395). An additional effective method for hunting waterfowl involves group cooperation and the use of boats to drive birds towards stationary blinds. By employing watercraft in this scenario, not only can boat-based hunters get shots at fowl on the water, but shore-based hunters do not have to simply sit, wait for, and/or call to birds that they may have already spooked into deeper water. The combined approach of boating and blinds works as a waterfowl drive. Driving game such as antelope and hares (Egan 1917:235-241; Thomas et al.1986:267-268) was of such great importance among Great Basin cultures in the late Holocene that specific shaman and rites guided driving the former, and nets associated with the latter (at least among some Paiute) were of the few items passed on rather than being burned after the owner died (Wheat 1967:59). It therefore seems likely that a people heavily reliant on migratory birds (as WST people were) would have developed a drive-hunting strategy for waterfowl in the deep past especially if open water species could be driven towards shore blinds by only a few boats. Finally, zooarchaeological studies of WST associated assemblages have noted diver species in sites from the California Channel Islands and Great Basin contexts (Moss and Erlandson 2013:179-185) further supporting the idea that boats may have played a fundamental role in open-water subsistence strategies in the terminal Pleistocene and early Holocene Far West.

Future Directions: Archaeological Visibility

The lack of complexity in tools needed to produce tule watercraft would likely result in a relatively ephemeral site signature in the archaeological record. Only two simple (expedient) flakes were used in this study and neither required retouch even though they were used continually (curated) for over 40 hours. Use-wear appears to be relatively insignificant to the naked eye on both tools. However, under microscopy, the silica sheen and distinct rounding and micro-fracturing of used edges are notable. Further, while KNS and MK used two flakes to produce the boat for this project, we are confident that this entire watercraft could have been manufactured by one individual with no more than a single unmodified flake. This begs the question, without collecting such artifacts and conducting micro-wear analysis, would we even recognize a potential tule boat construction site if we found them in the field?

Ethnographically, tule boats were not covered to protect them from weather (as was the case with sewn-plank canoes), and they were left moored in the water or merely dragged on shore to dry while not in use. This is a common practice among recent Ethiopian bundle boat users (Hudson and Blackburn 1979; Wheat 1967). While sandals, baskets, mats, bird decoys, cordage and other highly portable perishable artifacts may be found in Great Basin dry cave/rockshelter sites where they were presumably cached, it is unlikely that early boats would be stored there, unless caves and rockshelters were located directly on the lake shore. A detailed examination of simple flake tool use-wear patterns may be an essential strategy to investigate the hypothesis that WST peoples were making and using tule boats. However, just because a tool has silica polish does not mean it was used to build boats. Additionally, it would be impractical to conduct use wear studies on all WST associated flakes. We have already established that a tule textile tradition spans more than 10,000 years in the region, so wear-patterns consistent with tule cutting could be associated with a variety of activities. Instead, future research should try to predict and target the location of landscape features, both geological and cultural, that might be associated with boat building, use, and maintenance activities. In such contexts, use-wear studies may be applied to further evaluate potential prehistoric evidence for the manufacture of boats in pluvial lake environments.

Field surveys along current dry lake shores associated with "black mats" leftover from pluvial lake wetlands may provide archaeologists with opportunities to test for the presence of tule boating. On cobble shorelines boat builders and users routinely move stones out of the way to establish a flat cobble-free surface often shaped like a long U or V patch of bare earth in an otherwise rocky terrain. Ground clearing and cobble stacking activities associated with boat production and launch/landing sites result in features similar in appearance to North American rock rings that have long been associated with prehistoric house floors (La Pierre 2010), canoe runs/skids on the Pacific Northwest Coast (MacDonald 2006), canoe houses on the Hawaiian Islands (Magnusun 1998:64), and semi-circular stone fish weirs (Mehringer 1986:36-37; Phukan 2019; Wilke 1976 ; White and Roth 2009) although they may vary in size and shape compared to these examples. If such features are present along pluvial lake shores in the Far West, they could easily be miss-categorized as associated with fishing activities or as disturbed "sleeping circles." Such contexts may have been precisely the types of locations where hunter-gatherers might lose or discard tools while manufacturing or repairing tule watercraft. Use-wear studies on simple flake tools in such contexts may prove to be uniquely informative if multiple lines of evidence point to the possibility of boat use. Finally, if WST peoples were making and using boats, GIS modeling of former pluvial lakes should target elevated landforms that would have been disconnected from former shorelines for archaeological signatures, as these landforms would have once acted as offshore islands most easily accessible by boat (Schultz et al. 2011:36-40).

Conclusion

This study adds to a growing body of work that draws attention beyond coastlines to subsistence systems and settlement patterns focused on inland aquatic environments. While watercraft and their use in such inland contexts may not be "maritime" per se, boating technology and water-adapted-peoples in inland contexts share many commonalities and connections with coastal communities. Whether directly discussing the technological and subsistence links between the WST variant found on California’s Channel Islands and the Great Basin, or even links between inland and coastal hunter-gatherers beyond North America, water-adapted transportation in deep prehistory is relevant. It may seem logical that people would invest in simple boat construction to ease travel to and from a given resource. By applying our replicative dataset to Bettinger's (2009, 2021) technological investment model, however, we have shown that a single round-trip would almost never justify investment in watercraft. Yet hunter-gatherers across space and time made such an investment. By comparing the quantitative data generated from our replicative studies to the costs of residential mobility and the advantage of logistical foraging by boat, we are left with new avenues to explore that may have had fundamental influences on the adoption of early watercraft even in the Great Basin pluvial lakes.

While most discussions surrounding the earliest use of boating technology concentrate on rafts or dugouts, both of these watercraft styles would likely require more complex toolkits and longer production times than what we have shown is needed for the manufacture of tule canoes. Our study has generated quantitative data and new observations concerning the manufacture of what may be one of the oldest forms of watercraft in western North America. Additionally, we have shown how production dynamics generated from this replication may be used to model decisions of when early hunter-gatherers should invest in simple watercraft. Beyond the implications of the role that watercraft likely played in WST subsistence and mobility, we hope this study shows how replicative studies can be used to address broader questions regarding prehistoric aquatic adaptations, and that our work helps spur new and insightful research surrounding watercraft, perishable material culture, and the use of replicative studies in California, the Great Basin, and beyond.

Chapter Five

DISCUSSION AND CONCLUSIONS

The research questions addressed in this dissertation surrounded characterizing the lithic technological organization at a single Island Paleocoastal site (CA-SRI-512), comparisons of that assemblage with two additional broadly contemporaneous site (CA-SMI-678 and CA-SMI-679) assemblages and with the broader Western Stemmed Tradition (WST). Since a formal model of the origins for the Island Paleocoastal Tradition (IPT) and the WST is associated with a Pacific Coastal Migration facilitated at least in part by the use of watercraft (Davis and Madsen 2020), understanding Indigenous boating technology from a technological perspective is key to this broader discussion. The role of reed-bundle boats as part of a hunter-gatherer toolkit was evaluated here as a representation of some of the simplest and low-cost boating technologies used by Native Americans of the Far West.

Lithic analysis conducted as part of this study led to new discoveries surrounding core reduction, biface manufacture, projectile point production, associated tool forms, and activities. CA-SRI-512 appears to have functioned as an interior seasonal hunting camp ca. 11,700 cal BP, where abundant migratory birds were targeted at nearby wetland habitats. The site also allowed for logistical use of coastal resources including shellfish, sea mammals, sea birds, and fish. Lithic tool production concentrated on middle-to-late-stage manufacture of conventional points and crescents. CIB points were likely used for fish and sea mammals, while crescents likely served as transverse points for bird hunting. The local structure of stone tool production reflects, on the one hand, site-use as a seasonal hunting camp, and on the other hand, the costs of lithic reduction and transport in terrestrial environments (Beck and Jones 2009; Bettinger et al. 1997:888).

However, since *some* examples of *most* stages of reduction are present within this assemblage, a somewhat fragmentary picture of the organization of IPT stone tool production emerged and my broader interpretations of the production system were somewhat limited. The analyses of the CA-SMI-678 and CA-SMI-679 "quarry-workshop" assemblages from Cardwell Bluffs, on San Miguel Island, provided further details regarding these early stages of stone tool organization. Analysis of these assemblages, deposited during multiple occupations ca. 12,200 and 11,300 cal BP, helped to establish which features of lithic reduction were site-specific while revealing a broader pattern of lithic technological organization among the Island Paleocoastal Tradition (IPT). Such consistency of the technological pathways across several distinct bifacial artifact forms is remarkable and it suggests close cultural affinities between late Pleistocene and early Holocene islanders.

While some hypotheses have been tested, numerous questions remain unanswered. Some have to do with specific details in lithic technology on the islands, while others derive from our attempts to integrate stone tools into the realm of subsistence strategies, or to broader discussions on the peopling of North America. Aside from the stone tools themselves, there is a need to discuss technology in less abstract terms and at a more ‘human scale’. Here, I selected a few issues that I consider essential, progressively moving away from the details of these lithic assemblages toward broader considerations of the archaeological record:

1. *New technological questions and implications*: I address the distinction between cores and tools and how it affects our understanding of assemblage formation and artifact transport. Then, I look at stemmed point production and the meaning of a specific variant identified in our analysis and reexamine the issue of heat treatment as a technique used by islanders to improve the knapping qualities of the chert.
2. *Islander subsistence strategies*: I try to integrate our results with what is known about hunter-gatherer subsistence, in hopes of exploring the interplay between production dynamics, technology, and artifact functions. I consider that the function of conventional points and crescents is (at least partly) use as projectiles, and I address the use of watercraft. By summarizing the contextual data in the three sites studied, I discuss how they can be informative on the acquisition of resources, and site settlement patterns.
3. *Island-Mainland connections and broader implications:* I discuss the broader implications of our results for understanding the WST, and its relevance for the peopling of the Americas.

New Technological Questions and Implications

Cores, Tools, or Both?

While describing the *chaine operatoire* across these three sites, I experienced some difficulties in using arbitrary categories such as “cores” or “tools”. Because some of the CA-SRI-512 tested cobbles have yielded flakes that fall into the morphological range of the flakes that are used as tools, it seems legitimate to consider them as ‘cores’. The relevance of such a category was further confirmed by my observations at CA-SMI-678 and CA-SMI-679, where flake production is clearly represented. Some cores and bifacial preforms, however, share similarities that lead us to consider that the distinction is not always self-evident. As I suggest below, a distinction between the methods of reduction is more likely to be helpful than to force objects into categories that are not mutually exclusive.

The flaking process at CA-SRI-512 began with the acquisition of flat water-worn chert tablets. The latter are reduced following a centripetal or bi-directional flake removal sequence often favoring one face over the other, with the latter showing only minimal preparations. This initial phase produced cortical and secondary flakes suitable for further bifacial thinning, on a trajectory towards CIB manufacture. Alternatively, irregular flake-blanks are turned into expedient flake-tools first and/or eventually through near-exclusive direct-retouch, used as scrapers, spokeshaves, and gravers. This shows two important points: large-medium flakes are actually used, and the reduction of the core/preform is typically focused on one face.

The treatment of the second broad face, opposed to the first one, changes when the pebble becomes flatter. It marks the beginning of the bifacial shaping and the pebble can be categorized as an early stage biface. Smaller and thinner flakes are detached until the contour of the biface is ovate. By then, the bifacial reduction is advanced but the distinction between “tool-preform” and “core” is still not clear. Granted that the thinning stage is not always completed, some bifaces could then be further shaped (sometimes in crescent-shaped preforms) using percussion and pressure. Yet again, the flakes that are still suitable for CIB production would have been thinned through percussion or (more commonly) through a pressure-over-percussion technique. At the final stage, the crescents (or other larger bifacial tools) are adjusted by pressure flaking only. The debitage from this activity is much smaller and therefore less likely to produce suitable tool-blanks. The process described above is almost identical on both islands, except that the early stages of reduction are better documented at Cardwell Bluffs.

Essentially, some of the earliest stages of flaking may be serving a dual purpose: to obtain a bifacial preform and to produce flakes that are transformed into tools. Hence, it would be justified to consider the blurred distinction between tool-preforms and cores as artificial. In addition to the difficulties inherent to the classification of objects, the benefit of using arbitrary categories is questionable. Instead, a basic technological distinction between methods might prove more informative in the present case. Shaping (*faconnage*) is a method that consists of 'sculpting' a bifacial tool out of a nodule, tablet or large flake. It differs from a method that relies on the production and selection of blanks (*debitage*) which are further transformed in smaller tools. Such a distinction is standard in the French literature (e.g. Inizan et al. 1999) but it is notable that the principle has also been known since Holmes (1894). Far from trivial, the differences between the two methods are expressed in the composition and the structure of lithic assemblages observed. Because the system illustrated here includes a recycling of the bifacial 'byproducts', several embedded *chaines opératoires* (*ramification* sensu Bourguignon et al. 2004) branch away from the larger biface reduction.

Beyond the jargon and the semantic discussions, there are implications for raw material procurement strategies and for the circulation of artifacts. For instance, the fact that CIAs/CIBs are produced on flakes provides direct insight on their frequency. By default, flake-blanks are expected to be more numerous than the cores/preforms they come from. Therefore, it is not a surprise that when they co-occur in these assemblages; the small points routinely outnumber the crescents. However, crescents may have also had a longer use-life than such thin points adding to this dynamic. Other implications have to do with the mode of transport. As Kuhn (1994) suggested, transporting nodules of raw material/cores and transporting usable flakes come at different risks and costs. From a functional point of view, flakes are likely to be useful just for their cutting edge. Nodules, cores, and preforms cost more in transport and can potentially be turned into tools but with an increased risk of failure. Overall, this suggests that larger bifacial production (shaping only) and smaller ones (on flakes) are subject to different constraints in raw material procurement and transport. Finally, it suggests that the CIAs/CIBs might depend on the production of suitably sized blanks (see below). Such hypotheses should be further investigated to better understand some of the distinctive features of the islander technology – namely the emphasis on unifacial flaking during the early stages of reduction.

Stem First

In the previous chapters, I described a pathway to produce hafted points that diverges from most conventional lithic reduction models (Andrefsky 2005; Callahan 1979). Incipient stems and shoulders and a general CIB or CIA point body plan were often established before the points were finished and not at the end of the process. From here, subsequent pressure removals of the triangular barbs (in the case of the CIB), contracting stem, and finally the triangular blade-body produced an ultra-thin finished CIB point with a characteristic chevron flaking pattern or a more elongated CIA point with parallel collateral flaking pattern. Crescent preforms, broken in production, were also occasionally reworked into CIB or CIA preforms. But why produce the stem first? Is there any practical advantage to such a method? While the technical benefits of producing the stem first are still unclear, addressing the motivations behind the technological choices observed is essential to better understand the meaning of variations in the reduction sequences.

To produce a stem means that one has to narrow the width of a blank down to the desired size. Touzé (2018) described an Early Upper Paleolithic assemblage at Maisières-Canal (Belgium) where various stemmed point types (*pointe de Maisières*, *pointe pedonculée*, and *pointes à cran*) coexist with a production of relatively massive, poorly standardized flint blades. In that case the size of the blank seems to condition the techniques which in turn impact the rate of success in producing a stem. When using direct percussion on flint, technical challenges arise if the width is too large to start with. First, flat and invasive retouch mostly visible on the mesio-distal end are removed to narrow down the blank before the stem is shaped by semi-abrupt or abrupt retouch. Stepped removals accumulate once the angle of flaking reaches 90°, and overall, abrupt retouch by direct percussion does not allow for much reduction of the stem. While it might be sufficient to produce a stem when the original blank is narrow, as observed later in the Gravettian (Touzé, 2018), starting from a broad blank requires first a reduction by flat retouch and tangential percussion. Overall, the (lack of) selection among the blanks partly explains why there is broad morphological variability among points. A stem is produced last (after thinning by flat retouch) when the blank selected is too large for direct, marginal percussion (that would step).

Going back to the CIAs/CIBs, carefully choosing the flake may help to increase the standardization of the final product while minimizing effort. There is little evidence for standardized production of such flakes across the three island assemblages, except the bifacial thinning flakes themselves. Although both techniques are used in combination, the use of pressure technique may relax some of the constraints linked with direct percussion. If it is the case, the stem should be almost exclusively shaped using pressure flaking. Finally, producing the stem first may be part of a process to select viable blanks that are worth investing in. Being a delicate and yet essential part of the tool, it might be shaped near the place of raw material extraction while the mesio-distal portion is adjusted later, perhaps after being exported. In sum, it is not easy to find a direct benefit in producing the stem first and for now, I consider the possibility that this trait is neutral enough (*sensu* Dunnell 1978) that combined with other technological features, it may help identify a shared tradition. It is also clear that additional efforts to understand the potential function of a 'stem first' method would strengthen the argument.

Heat Treatment

In a previous study Jew and Erlandson (2013) noted that the presence of potlidding, crazing, and high gloss in lithic assemblages from several Island Paleocoastal sites (including CA-SRI-512, CA-SMI-678 and CA-SMI-679) indicating that intentional lithic annealing (heat treatment) may have been an important technique used by these early mariners. The desired outcome of controlled heat treatment is to improve the flaking characteristics of silica-rich stone, though sometimes internal flaws, high moisture content, or imperfections in the heating and cooling process lead to lithic annealing failures. In the current study, gloss values were not taken with a gloss-meter. Instead, I used a conservative system to identify artifacts exhibiting visible potlidding, crazing, or other thermal damage. Hence, it is possible that I underestimate the number of artifacts exposed to heat by recording extreme examples that show visible damage only.

At CA-SRI-512, 41 (4.7%) and 102 (9.9%) potlids (heat spalls) were recovered from the assemblage of debitage in addition to formal artifacts, fragments, and shatter analyzed from units 4 and 8 respectively. At CA-SMI-678, Locus D, Unit 1, 14 (8.8%) potlids and 20 (8.3%) from Unit 2 were also recovered from the debitage sample. The numbers suggest that in addition to a potential controlled heating of lithic raw material (e.g. to improve flaking characteristics), there are also a fair number of objects that were damaged by heat. These artifacts occasionally show crazed cross sections inconsistent with the overall texture of these artifacts, and heat spall removals with inter-negative secondary patina indicative of heat-induced removals long after manufacture and discard of the original artifact. Overall, these patterns suggest that heat exposure on some artifacts may have been accidental. On individual objects, the identification of controlled use of heating as part of the flaking techniques is not easy. For example, the single large flake removal exhibiting crazing within the negative on the one biface/bifacial-core from CA-SRI-512 was exposed to heat late in the flaking process (after the removal of the end-struck large flakes), and the internal quality of the stone was visibly compromised (**Figure 3b**). Although this suggests that part of the assemblage was probably burned accidentally, Paleocoastal heat treatment (Jew and Erlandson 2013) is not excluded. Very long pressure flake negatives and visible luster on some artifacts observed previously support this possibility. In our data, one of the strongest arguments in favor of the use of thermal annealing is that heat damage does not appear to be distributed equally across all artifact categories. Tabular cores and flake tools are largely unburned, while evidence of burning is much higher in artifacts typical of later stages of reduction.

IPT Subsistence Strategies

Projectiles and Targets

It has been hypothesized that some CIB types could have been used in hunting migratory birds (Glassow et al. 2013:193). However, it should be noted that modern bow hunters often prefer field tips or blunt tipped arrows to "broadhead" style points for large migratory birds as the latter (similar, but not identical to CIB's) often pass through the body of the bird without killing it. As a result, projectiles tipped with such sharp points are often lost in migratory birds that fly away with the point still embedded in them. This may be more of an issue with smaller and lighter projectiles like contemporary arrows rather than atlatl darts, but is still worth noting. While CIB's and CIA's represent the most abundant diagnostic flaked stone tools across these sites, crescents are also more common in these island assemblages than most significantly larger WST assemblages on the mainland (Beck and Jones 2015:173). The proposed use of crescents as transverse projectile points for bird hunting (Tadlock 1966) has recently regained attention (Erlandson et al. 2011, 2020; Lenzi 2015; Moss and Erlandson 2013; Sanchez et al. 2016). The association here between migratory bird remains and crescents exhibiting high numbers of distinct breakage patterns associated with their use as transverse projectile points (Amick 1999; Lenzi 2015; Smith 2015) further supports the idea that migratory bird hunting with crescents was a focus at CA-SRI-512, and perhaps a significant influence on site location. Future surface survey of the adjacent plateau pond landforms may provide insight into this hypothesis if crescents, and especially crescents fragmented in use, are recovered.

According to the Ideal Free Distribution (IFD) model for early colonization, CA-SRI-512 would have been an advantageous location until the middle Holocene (Jazwa and Rosencrance 2019; Jazwa et al. 2016; Winterhalder et al. 2010). Along the edge of the elevated coastal plain/plateau and adjacent to major drainages such as Arlington Canyon (on the northwestern end of what is now Santa Rosa Island) human groups may have benefited of temperate episodes and associated wildlife. Because sea levels have risen substantially since the site was occupied, the distribution of nearby rocky reef and kelp forests is largely speculative, but the faunal assemblage is consistent with bird exploitation from interior fresh water sources and fish procurement from rocky reef and open water marine environments. At CA-SRI-512, faunal remains are overwhelmingly dominated by thousands of migratory and sea-bird bone fragments. Species include albatross (*Phoebastria albatrus*), cormorant, (P*halacrocorax* spp.), snow geese (*Anser caerulescens*), Canada geese (*Branta canadensis*) in addition to smaller numbers of fish and sea mammals.

While it has been proposed that the site was occupied in the winter due to the presence of migratory fowl, it is also possible that a general wet weather occupation could have included the Autumn when migratory birds first arrived. Gill and coauthors (2021) note that blue dick corms are best harvested in the Spring, Summer, and Fall, and that these starchy corms have now been recovered from numerous sites on the islands dating back to the terminal Pleistocene.

Additionally, they note that experimental return rates place island blue dicks at a higher rank than those reported from mainland contexts due to their significantly larger size which seems to have attracted early maritime peoples to target these starchy underground storage organs. It is therefore feasible that the occupants of CA-SRI-512 may have also chosen this interior site location in part as a base from which logistical collecting geophytes could be conducted while they awaited annual migrations of waterfowl; in a sense, potentially offsetting risk of scheduling errors. Therefore, in addition to proposed functions as bone tool carving implements, or even hardwood foreshaft working tools, an additional potential function of the flake-tools exhibiting hard to medium-hard wear-patterns, may have been the manufacture and maintenance of digging sticks similar to tools described in mainland contexts by McGuire and Stevens (2017).

The presence of sea mammals and fish remains indicates exchange with, or travel to the coast. If Glassow and coauthors (2013) are correct, and the delicate nature of CIB's indicates their use in spearfishing, then perhaps this could also help explain the production of CIB's at this interior site. Interestingly, the presence of smaller pelagic fish species such as sardines (in addition to the larger perch and rockfish that could be taken by spear) indicates the use of netting technologies which rarely persist in the archaeological record due to their perishable nature. It has long been hypothesized that nets were a part of the early maritime toolkit of the islands based on ichthyofauna from a number of early sites and a few notable early Holocene plant fiber cordage and textile artifacts (Connolly et al. 1995; Erlandson and Braje 2008; Rick et al. 2006; Vellanoweth et al. 2003). Nets, are also described in the acquisition of migratory birds in the Arctic, and their role in Paleocoastal bird hunting as a supplement to crescents is certainly possible. However, beyond the ichthyofauna, no artifacts associated with netting technology (e.g., weights, gauges, netting needles) were recovered from CA-SRI-512.

Fresh Water Ponds

At CA-SRI-512, as opposed to the Cardwell Bluffs, the lithic assemblage does not support intensive raw material collection as a governing factor influencing a move to the interior. Although it is difficult to evaluate, population pressure is assumed to be low during the Late Pleistocene. Still, why would a maritime-adapted people establish a camp, even a seasonal camp, 5-7 km away from sea shores and the coastal resources (Erlandson et al. 2011:1182)? As part of the archaeological surveys of Santa Rosa Island in the mid 1960's, Phil Orr noted that during wet seasons, natural bowls in the otherwise flat topography of the "highlands" (plateau) near Arlington Canon would fill with, and hold, fresh water as small "ponds" (Orr 1968:182). Jazwa and Rosencrance (2019:235) suggested that these pools may have attracted people to the interior when other fresh water supplies may have been limited during more arid climatic periods in the middle and late Holocene. I suggest that such fresh water pools would likely have been larger, more common, and longer lasting during more temperate phases such as the late Pleistocene and early Holocene. A combination of "Orr's ponds", associated vegetation for feed, and wetlands within Arlington Canyon may have provided an attractive landing for certain species of seasonally migrating waterfowl. If CA-SRI-512 was occupied during the wet season (Erlandson et al. 2011) as part of an annual round, then the location of the site would have been just far enough from the pond described by Orr (1968) and the potential wetlands of Arlington Canyon (Erlandson et al. 2011) to not unnecessarily disturb landing and feeding birds, and yet close enough to plan strategic approaches for ambush hunting.

Investigating a Maritime Culture from Interior Island Sites

The distribution and structure of known sites associated with the IPT may ultimately not be representative of the "typical" Paleocoastal behaviors which I believe would have been focused along the coastline. While the suite of behaviors described above likely represent some of the diversity in site organization, the sites not inundated by Holocene sea level rise seem to reflect the activities of interior logistical organization. We must then ponder what components of a broader maritime adaptive strategy and associated toolkit may yet be uncovered? However, as Perry and Glassow (2015) have shown through an investigation of middle and late Holocene occupations on Santa Cruz Island, many similar subsistence resources and artifacts found in deep-interior contexts still reflect the overall maritime economy exhibited in coastal contexts. If, as I suspect, IPT peoples focused residential bases primarily on the coastline that are now submerged, then our current understanding of Pleistocene hunter-gatherer adaptive strategies on the islands may be skewed. The degree to which IPT site structure away from the coast may overlap or differ from potential coastal village organization is still yet to be determined.

While Holocene sea level rise has obscured much of what can be said in terms of early shoreline sites in island contexts, the exact opposite pattern occurred in the Great Basin where pluvial lakes shrank. Here of course, shoreline sites subjected to aeolian erosional processes may be subject to deflation creating a palimpsest effect, mixing with later occupation material culture. Surveys for potential offshore archaeological sites are currently under way using submarines, remote sensing, and targeted seafloor coring off the coastline of the Northern Channel Islands, but the best analogy we have at present for understanding the nature and organization of IPT shoreline habitation sites may in fact be found in the Great Basin where WST peoples settled adjacent to ancient lakeshores. Especially if such shoreline sites were influenced, as they likely were on the islands (Ames 2002), by the use of watercraft.

Watercraft

The potential for a Pacific Coastal maritime ancestral origin of the WST has recently regained attention (Beck and Jones 2010, 2013; Davis et al. 2020; Erlandson et al. 2020), and is supported by the regional distribution of WST and IPT sites along major waterways from Cooper's Ferry to the California Channel Islands. If people entered the Far West of North America with an adaptive strategy which already emphasized a broad-spectrum aquatic-based settlement pattern and diet, we should expect watercraft to be part of their technology. As proposed by Beck and Jones (2010, 2013) following Erlandson and coauthors (2007), if WST peoples followed large freshwater rivers as off-ramps from the proposed "kelp highway," then populations could have colonized the Columbia Plateau and Great Basin following large coastal rivers such as the Columbia, Klamath, and Sacramento deep into the interior. I propose that some such populations could then have followed the Snake River inland and turned south, potentially along the Owyhee River drainage, linking the Columbia Plateau with the northern Great Basin. Though associated with drainages flowing into the Pacific, rather than south into the Great Basin, the Owyhee uplands, in ethnographic times, were more closely linked with the Great Basin cultural area than that of the Plateau possibly due to ease of travel (Aikens 1982:139). In this area, near the ethnographic Northern Paiute - Shoshone boarder, Indigenous peoples were commonly bilingual (Miller 1986), further supporting a strong connection between these two culture areas at least late in human history. In the late Pleistocene, in this transition zone between riverine and pluvial lakes environments (especially if travelers heading upstream were faced with rapid and shallow headwaters), it is possible that the boating technology these people used on the coast would have been eventually abandoned or lost. However, considering that approximately one-third of the Great Basin was covered with Pluvial Lakes, wetlands, and streams circa 15,000 cal BP

(Grayson 1993:86; Madsen 2002), boat investment for movement of goods and people, and as a hunting technology, may have been retained or even reemerged in the material culture more than once.

Our replicative studies are among the first in the region aimed at understanding production costs associated with Indigenous watercraft and set the stage for future work with early boating technology from this part of the world. Our experimental boat construction provides direct quantitative data surrounding the manufacturing dynamics required for a simple tule bundle-boat, helps us to evaluate why people invest in early boating technology, and allows us to test if conditions were conducive to such investments when WST peoples first entered the Great Basin. If boats were used in the Great Basin at this time, they would have likely been constructed from tule, a ubiquitous wetland plant which was routinely used for this purpose in similar environments during the late Holocene (Schultz et al. 2011). While we do not know if such boats were used in the late Pleistocene and early Holocene Intermountain West, our research, relying on the technological investment/intensification model developed by Bettinger and coauthors (2006) and Bettinger (2009, 2021), evaluates several scenarios in which boating could have provided advantages.

With more than 40 pluvial lakes in the Great Basin reaching their last high stands ca. 15,000 cal BP, our comparisons of foot-based and boat-based travel seem justified. However, the startup costs associated with boat manufacture may not have been favored over residential moves in an environment that was more productive at that time than it has been ever since. Yet, if hunter-gatherer populations flourished in the late Pleistocene and early Holocene (Elston and Zeanah 2002:107), conditions favoring diet breadth expansion and possibly inter-patch (lake and wetland) intensification (see Duke 2011) may have favored such an investment in boating. In this context, a special case of supply and demand in the face of desiccating lakes and temporary expansion of larger wetlands does seem to have led to the eventual widespread adoption of milling stone technology used to process lower ranking seed resources, or in other words wetland intensification. If late Pleistocene hunter-gatherers of the WST were already equipped with crescents, which we believe were specialized bird-hunting implements, then they were at least seasonally invested in a somewhat intensified wetland exploitation, at least when compared to

Clovis populations. In such a context, boat-based waterfowl hunting strategies, supported by crescents, may have been favored.

Using tule boats as mobile blinds, similar to ethnographic descriptions from the San Joaquin Valley (Campbell 999:395), WST peoples could have increased encounter rates with otherwise inaccessible diving birds, and even surrounded and driven abundant fowl (both migratory and resident) rendered flightless during the molt as it was done among the ethnographic Paiute (Wheat 1967:11). While most waterfowl molt in the Arctic today, large populations of year-round resident waterfowl also molt in more southerly wetlands such as the Klamath Basin on the California-Oregon border (Fleskes et al. 2010). Pluvial lakes would have certainly boasted large populations of year-round resident waterfowl in the late Pleistocene and early Holocene as well. However, confirming whether or not WST peoples used boats in Great Basin pluvial lakes (as the earliest islanders did on the coast) is not possible if this hypothesis is not at least considered. GIS lake-level modeling may help target potential shorelines and elevated landforms that might have been islands during the Pleistocene-Holocene transition. Targeted surveys, excavations, and lithic use-wear studies are necessary to follow up and further field-test this Paleo-Maritime Hypothesis originally proposed by Schulz and coauthors (2011).

Optimal Foraging Theory predicts that higher ranked resources will always be pursued upon encounter. However, the highest ranked resources are not necessarily daily dietary staples. If high ranked game is scarce, it will always be taken when encountered, but local lower ranked foods may make up the majority of the subsistence base. Bettinger and Baumhoff's (1982) examination of the replacement of pre-Numic high-cost "travelers" by low-cost Numic "processors" is a case in point. Not only does this example illustrate that high-cost broad spectrum diets can out compete low-cost diets focused on high ranked resources, but it also provides an example of how unique population history influences the organization of a subsistence strategy. WST peoples in island and mainland contexts consumed a wide array of plant and animal foods. In the Intermountain West mammals including black bear, beaver, bison, horses, camels, and artiodactyls were taken, yet WST peoples also regularly consumed fish, shellfish, waterfowl, and geophytes including tule and cattail rhizomes (McGuire and Stevens 2017). Islanders took several species of high-ranked sea mammals, but also regularly consumed fish, shellfish, waterfowl, and geophytes (Erlandson et al. 2011; Gill et al. 2020; Gusick and

Erlandson 2019). Therefore, if the IPT and WST are derived from the same antecedent populations, then the broad-spectrum diet they each practiced throughout the Far West may have had deeper roots in the Upper Paleolithic where similar diet-breadth had proven an effective subsistence strategy (Fujita et al. 2016) even when faced with known Pleistocene climate fluctuations and environmental uncertainty (Richerson et al. 2001). These subsistence parallels provide yet another link between these islanders and mainlanders, and add to the technological discussion below, providing new research avenues concerning the origins of the IPT and WST.

Island-Mainland Connections and Broader Implications

The lithic technology described in all three IPT site assemblages I analyzed may deviate from standard technological models (Andrefsky 2005; Callahan 1979), but comparable material suggest that it extends to mainland WST contexts. Large stemmed points, including Lake Mohave, Cougar Mountain, and Parman types, clearly show the establishment of the hafting element (stem) by stage 1 (Beck and Jones 2010, 2015). Amick's (2004) description of the McNine Cache clearly shows stemmed preforms associated with Parman points, while Galm and Gough (2008) report a stemmed Haskett point preform from Sentinel Gap. At least two broken Lind Coulee-style artifacts from the Cooper's Ferry point cache (Davis et al. 2014; Cat #'s 73-636 and 73-642) may also be stemmed preforms broken in production, but closer comparisons of flake scar and edge morphology are needed to fully evaluate this hypothesis. Amick (2016) described the atypical asymmetry of crescent preforms as the recycling of larger Black Rock Concave Base points. Alternatively, they could be a stage in crescent production described herein - with center hafting elements already established before the wings were finished. Far from trivial, such difference would mean that the reduction sequence that crosses over multiple artifact types in the IPT assemblages is seen in mainland assemblages as well. This possibility should also cause caution when examining under-rated ‘crude’ stemmed points as they may in fact be point-preforms, that could help further establish a link between insular and continental technologies.

Typological similarities include essentially identical eccentric, lunate, and winged crescent forms on the islands (Erlandson 2005; Erlandson et al. 2011, 2016) and mainland (Daugherty 1956; Harrington 1948; Hopkins 2010; Jertberg 1978, 1986; Rogers 1939; Tadlock 1966; Warren 1967) spanning more than 1,000 km in some cases. Single-shouldered points (Amick 2004; Davis et al. 2014) and foliates (Daugherty 1956; Ezell 1977) are also found in island and mainland WST assemblages. Hierarchical cores and bifacial hierarchical pieces similar to the forms described here in island assemblages, have been described in numerous mainland WST contexts as well (Amick 2004:136; Davis and Willis 2018; Knell 2014:50; Knell and Becker 2017; Muto 1976; Warren 1967). Additionally, Des Lauriers (2010) reported centripetal core reduction illustrated as clearly hierarchical from terminal Pleistocene and early Holocene occupations of Isla Cedros off Baja California's Pacific Coast. Considering the presence of specific typological overlap, and numerous technological similarities in core reduction and biface manufacturing patterns, the most parsimonious explanation is that the earliest known island sites are in line with a system of shared and learned manufacturing behaviors consistent with the broader WST.

Faunal collections across assemblages are consistent with a broad-spectrum diet on the mainland and on the islands. Larger seaside habitations are currently obscured due to Holocene sea level rise in the latter context, but a general settlement pattern largely tied to aquatic ecosystems, and yet by no means ignoring upland interior resources and terrestrial environments, seems consistent with the distribution and constituents of over 100 IPT sites. The earliest California islanders harvested geophytes (Gill et al. 2020), made shell beads (Vellanoweth et al. 2003), and maintained a textile tradition including twining of aquatic plants into items such as cordage, sandals (Connolly et al. 1995), nets (implied by sardine capture) (Erlandson et al. 2011:Table S3), and use of watercraft. Occasional use of shell fishhooks in the islands far to the south (Des Lauriers 2017; Fujita 2014) appear to be derived technologies. The overlaps in subsistence and settlement patterns, lithic reduction strategies, fiber technologies, personal ornamentation, and identical flaked stone tool types (e.g., winged, lunate, and eccentric crescent forms) on the islands and mainland in a regional expanse ranging over 1,000 km suggests broad-scale population connections more consistent with a united techno-complex than can be explained by sub-regional diffusion or convergence.

Island Paleocoastal Tradition: A Maritime Variant of the Broader Western Stemmed Tradition

Watercraft were important technologies for the islanders and almost certainly played a prominent role in the Pacific Coastal Migration. Above, I argued that as a hunting technology, or even as a transport technology, simple watercraft may have been reinvented when WST peoples finally made it to the Great Basin pluvial lakes. Yet, a terrestrial residentially mobile system may have been favored except under specific circumstances. If WST peoples did indeed follow large river systems such as the Columbia, the Klamath and the Sacramento into the interior, they may have maintained boating technology for some time. Consistent with Bettinger and Baumhoff's (1982:489-490) example of Numic and pre-Numic *adaptive peaks*, it is possible that the makers of the WST arrived in the Intermountain West with, and maintained, watercraft as a key component of a time-proven toolkit and subsistence strategy, rather than adopting a predominantly terrestrial approach, at least initially.

Davis et al. (2012) maintained that from a technological standpoint, key features in late Pleistocene stone tool assemblages linked with the peopling of the Americas, are present in at least two distinct techno-complexes: Clovis and the Western Stemmed Tradition (WST). Though recent finds at Gault and the Debra L Friedkin Sites in Texas suggest a pre-Clovis technological antecedent there which warrants further study (Waters et al. 2018; Williams et al. 2018). Here emphasis was placed on hierarchical core reduction (referred to as "Levallois-like") and stemmed projectile point manufacture from flake-blanks among the WST, in contrast to bifacially overshot flaked and fluted projectile points, blades, and volumetric blade cores manufactured by Clovis peoples. Since 1970 when Bedwell proposed the concept of the Western Pluvial Lakes Tradition (WPLT), this term has largely been replaced by the WST, as the latter does not imply sole adaptation to pluvial lake environments. While I agree that seasonal, and in some cases permanent, occupations in upland and riverine environments in the Intermountain West reflect a more diverse strategy than sole subsistence and settlement of ancient lakeshores and lacustrine resources, most Great Basin WST sites concentrate on the latter environment. However, the fact that stemmed point and crescent bearing peoples found a niche in coastal and insular California is consistent with the use of WST over WPLT. It supports the idea that WST peoples were flexible and able to thrive in environments beyond the productive lakeshores of the late Pleistocene and early Holocene Intermountain West. Therefore, the Island Paleocoastal Tradition is essentially a maritime variant of the broader Western Stemmed Tradition.

As Pratt and coauthors (2020) caution, we should not necessarily expect to find a single antecedent archaeological population exhibiting all aspects of material culture within the broader WST (in its island and mainland manifestations). While we continue to search for the origins of the Western Stemmed Tradition, I hope that the information gained from this technological comparison across late Pleistocene and early Holocene sites, and our experimentally-derived evaluation of bundle boat technology, provides new details to spark further discussions regarding islanders, mainlanders, and the role of the Pacific Coast in the peopling of the Americas.

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