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Abstract

Creating and Transcending Territorial Boundaries in Late Holocene Pacific Coast Communities

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Chair of Supervisory Committee:
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Anthropology

In this research, I investigate precontact territorial behavior in the San Juan Islands, Washington and San Nicolas Island, California. Drawing on economic defensibility models, I generate hypotheses for change over time in boundary defense and permeability in the context of Late Holocene climate and settlement pattern change. Defensive characteristics of archaeological sites and lithic procurement patterns should reflect increased boundary defense and smaller territories when resources are adequate to the needs of the community. Extra-local materials should increase in abundance during times of resource scarcity.

For the San Juan Islands case study, data on visibility, elevation, and distance to lookouts do not indicate significant changes through time in site location consistent with changes in boundary defense. Dissimilarities between artifacts from the Watmough Bay site (45-SJ-280) on Lopez Island and and nearby beach cobble toolstone suggests lithic procurement beyond the local beach at 1600-1000 cal BP, consistent with predictions for minimal boundary defense due to resource scarcity at that time. I do not find increased use of nearby beach cobbles or slate at 600 cal BP-Contact during a period of predicted increased boundary defense. Data on the spatial and temporal distribution of extra-local materials are insufficient to evaluate hypotheses regarding boundary permeability.

For the San Nicolas Island case study, data on elevation and distance to lookouts do not indicate significant changes through time in site location consistent with changes in boundary defense. For the lithic procurement study using data from Tule Creek Village (CA-SNI-25) Mound B and CA-SNI-106, I found few changes through time in material type or artifact dimensions at either site that would indicate shifts in cobble procurement locations. Increases in abundance of chert are correlated with increases in sample size.

For both study areas, results indicate potential sample size issues that must be resolved to further investigate my predictions. People may have engaged in boundary defense at a larger scale than the village; community boundaries may have always been permeable to interactions between kin and friends. This study has implications for social complexity studies and research on human adaptations to resource abundance and scarcity.

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Chapter 1: Introduction

When Europeans arrived on the Pacific Coast of North America in the 1500s, they found large villages connected through exchange, intermarriage, kinships, friendships, and rivalries. My dissertation research investigates the development of territoriality in the context of complex and interconnected coastal communities and Late Holocene climate change. I focus in particular on peoples of the San Juan Islands, Washington and San Nicolas Island in the southern Channel Islands, California (Figure 1.1, 1.2). The San Juan Islands and southern Channel Islands study areas are well-suited to an investigation of the emergence of territoriality because territorial behaviors are recorded in the ethnographic literature, paleoenvironmental reconstructions are detailed, and settlement patterns are thoroughly documented. A comparison of the Northwest and California coasts facilitates archaeological investigations of the unique behaviors of coastal peoples (e.g., Ames 2005b; Coupland 2004; Erlandson 2001; Fitzhugh and Kennett 2010; Lightfoot 1993) and more rigorously tests the predictions of territoriality models. Territorial behavior is a critical dimension of the emergence of sociopolitical complexity among complex hunter-gatherers, defined here as horizontal differentiation into groups such as households or domestic units, and/or vertical division into ranks associated with different levels of prestige or access to resources (Fitzhugh 2003). This research does not focus on evaluating social complexity models but provides new insights that will be useful in addressing how and why social and political systems in both study areas changed over time.

To test hypotheses and predictions regarding the emergence of territoriality in the San Juan Islands and southern Channel Islands, I investigate the relationships between boundary defense, boundary permeability, and resource procurement. I examine settlement patterns and temporal and spatial patterns in the acquisition and conservation of local and extra-local toolstone throughout the Late Holocene. This research project required excavation, settlement pattern analysis, toolstone surveys, and lithic analysis. Lithic assemblages analyzed include the Watmough Bay site (45-SJ-280), Lopez Island, San Juan Islands, Washington and Tule Creek Village (CA-SNI-25) Mound B and CA-SNI-106, San Nicolas Island, southern Channel Islands, California. Where possible I have attempted to parallel the analyses for each study area; however, different components of the research took different trajectories and required more or less investigation and explanation.

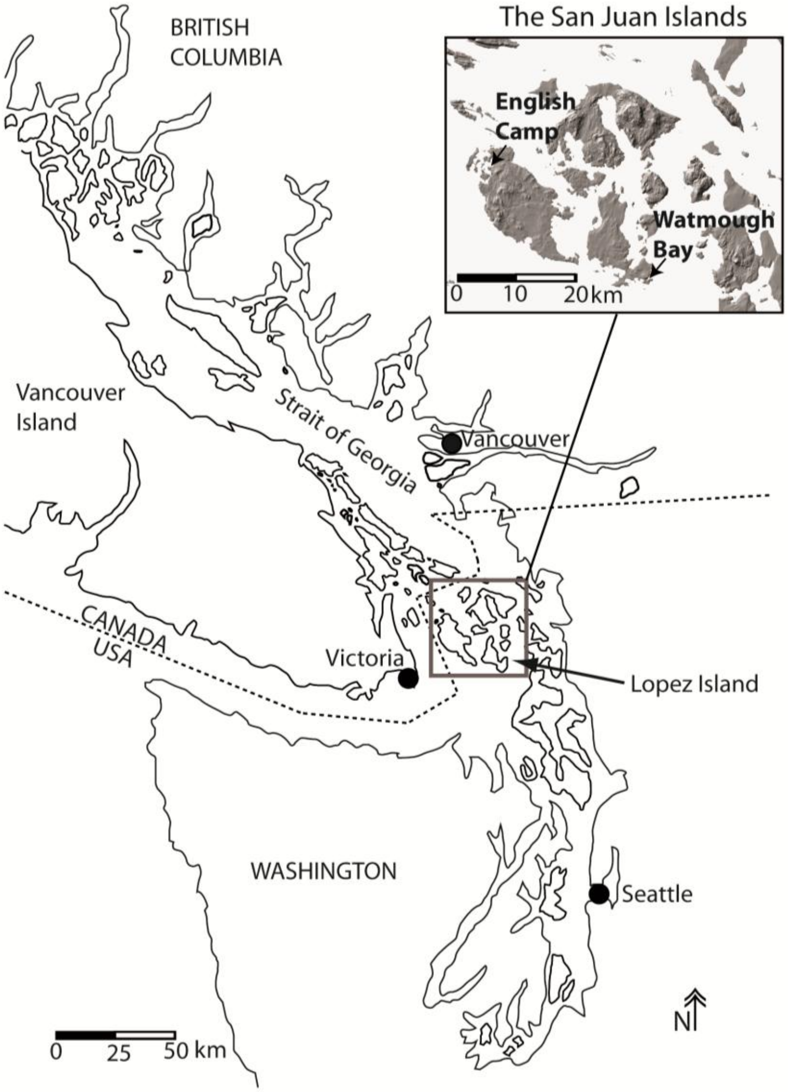


Figure 1.1. Map of the San Juan Islands and Gulf of Georgia.

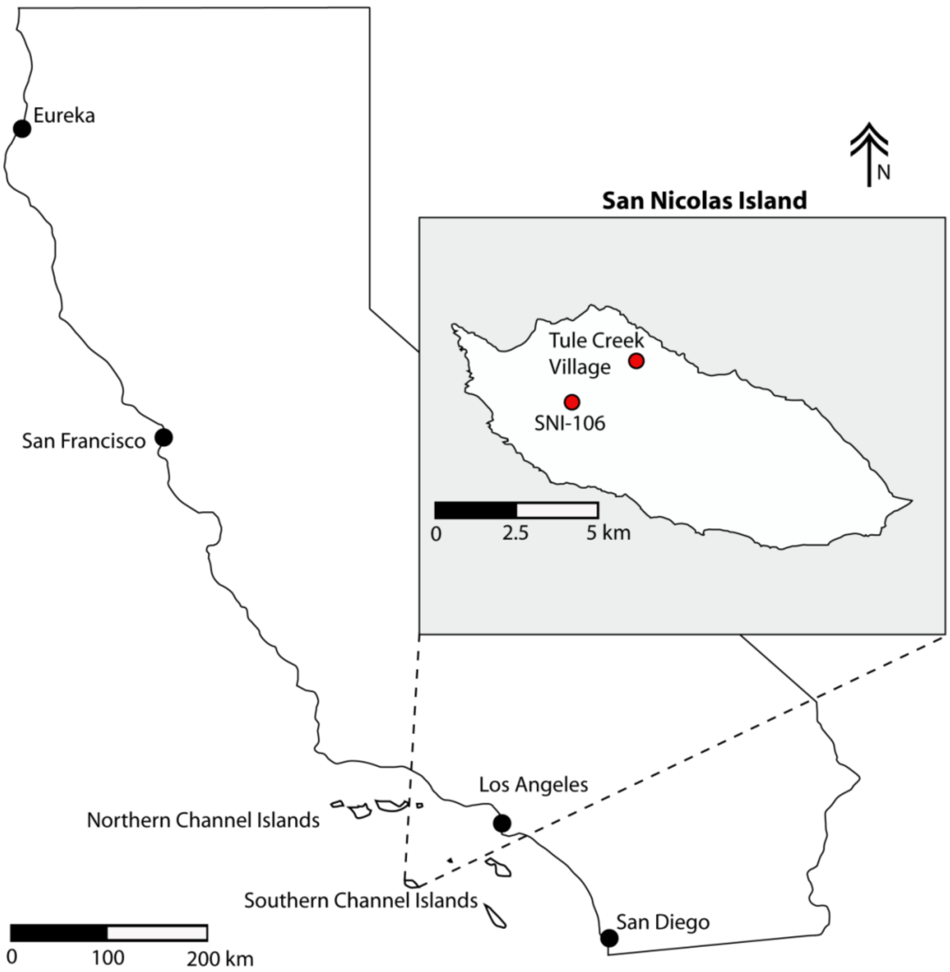


Figure 1.2. Map of San Nicolas Island and southern California.

Territoriality in Coastal Settings

Territory size, shape, degree of boundary defense, and degree of boundary permeability are all elements of human territoriality, a complex set of behaviors that restrict access and resource use within a defined spatial area (Cashdan 1983; Dyson-Hudson and Smith 1978). I define a territory as an area that a group defends and identifies as a community-owned space. Land ownership systems range from exclusive control of land and resources to common pool systems where land and resources are accessible to community members based on rules and traditions (e.g., Ostrom 1990) or expectation of future reciprocation (e.g., Eerkens 1999:298).

Like other aspects of human adaptation, people change their territorial strategies in response to increases and decreases in resources, population density, and other social and environmental variables. The boundaries that demarcate territories can be built out of wood, earth, or stone; they can also be natural physical boundaries or social boundaries that leave no physical trace (Tringham 1972).

Territoriality is a topic of particular interest on parts of the Pacific Coast where resource density and economic modes of production supported high population aggregations and sedentism. Yesner (1980:739) notes that maritime foraging of densely packed and patchy resources often works best from a single location. Use of boats facilitates resource gathering from geographically distant resource patches, thus villages are often located at a point on the landscape where people can easily access a few different resources. These settlements tend to be near resources that are easy to collect and process such as shellfish, seabird colonies, marine mammal rookeries, and fishing grounds. People use storage to maintain resource surpluses at the habitation site (Renouf 1984:21). In such contexts, staying in one spot allows communities to maintain exclusive access to nearby abundant and predictable resources, and conversely, sedentism is impossible if resources are insufficient to support the group. Rosenberg (1998) proposes that sedentism is desirable in contexts of high population pressure because it allows more exclusive access to the most productive parts of a territory. In "cheating at musical chairs", some groups of people stop moving on their seasonal round and instead establish a more permanent settlement in the most resource-productive area they can find.

For both case studies, the communities that I investigate may not have been fully sedentary; ethnographic examples indicate that people occupied different parts of the landscape during different seasons. Several researchers describe this type of semi-sedentism on the continuum of between sedentism and mobility (Kelly 1991, 1992; Rocek and Bar-Yosef 1998). Here, I use Binford's (1980:13) definition of semi-sedentary groups as those who "shift from one to another fixed settlement at different seasons or who occupy more or less permanently a single settlement from which a substantial proportion of the population departs seasonally to occupy shifting camps."

Since the 1970s, several ethnographic studies have focused on complex semi-sedentary hunter-gatherer-fishers in marine environments (e.g., Acheson 1988, 2003; Acheson and Gardner 2004; Ackerman and Ackerman 1973; Angelbeck 2009; Aswani 2002; Barber 2003; Begossi 1995; Durrenberger and Pálsson 1987; McCay 1978; Richardson 1982; Schaepe 2006, 2009). These studies suggest modifications to traditional territoriality models for complex hunter-gatherer fishers. For example, habitation sites may be at a distance from the most productive resources on the landscape, yet people still establish exclusive access to these areas through social of physical boundary defense. Establishing and maintaining boundaries on the open water involves different costs and benefits than maintaining boundaries on land. As well, with high population density, rapid boat transport, and complex social structures, communities are highly inter-connected within and across territorial boundaries. Ethnographic analysis of territoriality and community in both study areas provides further context for this research.

Ethnographic Research on Territoriality in the San Juan Islands

The ethnographic record of the central Northwest Coast provides a rich resource on the ways that people established, maintained, and crossed group boundaries. I focus specifically on Coast Salish communities, defined by Suttles (1960b[1987:29]) as the groups that lived in the area around the Georgia Strait, Strait of Juan de Fuca, Puget Sound, and on the open coast between the Olympic Peninsula and Willipa Bay. The native peoples of the San Juan Islands are identified by ethnographers as Central Coast Salish and Straits Salish speakers (Carlson 2001:23; Suttles 1990). The land tenure system of the Coast Salish in the San Juan Islands is characterized by communities that establish and maintain ownership to territories on land and sea based on descent from an ancestor who fell from the sky in the distant past in the time of the Transformers (Suttles 1987:9, 1960a; Thom 2005:292). Families trace their line and rights to property, knowledge, and resources to the First Ancestors (Barnett 1955:141, 291; Thom 2005:84-85).

Evidence of boundary defense among the Coast Salish comes from a variety of sources. European colonizers painted images and composed letters and ship logs that attested to violent interactions between tribes and Spanish and English explorers (Angelbeck 2009:1, 69-129), and conflict between groups. Ethnographers wrote of skirmishes, land seizing, and slave-raiding between the Coast Salish and southern Kwakw̱aḵa’wakw communities in the 1700s that ended with a marriage alliance in the 1800s (Thom 2005:361). Weapons included slate or metal knives, stone, wood, or bone clubs, bow and arrows, spears, slings, and buckskin armor (Angelbeck (2009:102-108). Angelbeck notes that warfare and construction of defensive sites among the Coast Salish increased after European colonization began, perhaps due to the effects of social disruptions caused by a smallpox epidemic, uneven distribution of firearms, and conflicts between Coast Salish groups, traders, and colonists. The Stó:lō of the lower Fraser Valley and other groups have place names and stories associated with conflict and defense (Schaepe 2006, 2009).

Defensive sites recorded by ethnographers and archaeologists also attest to boundary defense. The Coast Salish built palisaded forts on bluff-tops, trenches, embankments, rock-wall fortifications, refuges in defensive areas, lookouts in high areas, and skulls on posts and other symbolic displays (Angelbeck 2009:108; Schaepe 2006, 2009). Many rock wall fortification systems are still visible today. Some built and some natural, these structures were designed by shape and location to operate over a large area within a system of social cooperation of kin groups under a central political leadership. The walls protected people and communicated power (Carlson 2010; Schaepe 2006). In general, river travel and resource access was more restricted than ocean travel and marine resource access (Carlson 2010:53).

Based on ethnographic accounts, different territorial strategies operate simultaneously at different scales of community for the Coast Salish. Suttles 1964[1987:209] discusses six community tiers: (1) families that live together in a section of a plank house and participate in a common domestic economy; (2) several related families in a plank house who co-host ceremonies; (3) groups of houses on a beach that share a common group name and ceremonial rights; (4) several groups of houses on a long stretch of shoreline that share a common language, subsistence methods, and ritual; (5) kin groups that hold rights to resource patches; and (6) all of the people who participate in subsistence activities and ceremonies that may or may not parallel residential units (see also Thom 2005:280; Robinson 1963:27).

Both residence and descent groups were dynamic social structures that varied through time and space (Thom 2005:285). There have been particularly pronounced changes since the beginning of the 20th century when smaller groups were pushed into larger villages. Groups split, reunited, and relocated based on resource availability. They maintained salmon camps in the spring, traveled to high-elevation berry patches in the summer, held potlatch ceremonies and hunting trips in the fall, and fished for sturgeon and held large gatherings in the winter (Carlson 2001:62; Elmendorf 1971:357; Suttles 1960a[1987:23).

The concept of community most commonly discussed by ethnographers in narratives of territoriality is the village, which consists of multiple groups of houses on a beach who united for group defense (Angelbeck 2009:226; Suttles 1951:277). Outsiders were actively excluded unless they had permission to trespass (Richardson 1982; Suttles 1960a[1987:16]). Angelbeck (2009:257) describes a decentralized cooperative strategy with different “nodes” of defense that communicated using scouts, lookouts, messengers, and signal stations. Among some groups such as the Stō:ló, multiple villages might band together for defense against an outside threat by coordinating defensive structures and aggressive strategies (Schaepe 2006, 2009).

Boundary defense also took place at the level of the kinship group but centered on productive resources rather than village territories. During the postcontact period, productive resource areas were controlled by the more powerful extended families (Carlson 2010; Richardson 1982; Robinson 1963; Suttles 1960a,c[1987]); Thom 2005:283). Standing in a family group demonstrated through public gifting during feasts and potlatches secured access to family resources (Thom 2005). A host family or village invited members of other communities to acquire food, blankets, shell ornaments, baskets, clothing, stone tools, canoes, and slaves (Suttles 1960a[1987:19-21]). Suttles (1951:68-69; 1960a[1987:20]) records family ownership of camas, fern, wapato, and shellfish collecting areas as well as reef net locations. Stern (1934:47) records clam gardens created and maintained by the Lummi in the 1920s on descent group-owned beaches. The same was true for waterfowl, deer, mountain goat, and seal hunting areas, and sturgeon traps (Barnett 1955:251; Robinson 1963). Salmon weirs and traps were sometimes controlled by a village rather than a family (Thom 2005:320). Resources that were extremely abundant, such as salal berries and shellfish, were rarely restricted (Richardson 1982; Carlson 2010:47). Knowledge about exploiting resources was passed down from generation to generation

(Suttles 1987:8). Trespass by non-kin could result in violent confrontation or an obligation to provide reparations (Thom 2005:377).

Village boundaries were sometimes aggressively defended, but they were also permeable to certain inter-group interactions between kin or families allied through marriage or friendship (Elmendorf 1971:358; Suttles 1963). Kinship was bilateral with lineages reckoned through male lines. Residence was usually patrilocal (Suttles 1960a[1987:9]). Kin and marriage alliances enabled resource sharing, which balanced out temporal and spatial fluctuations in subsistence resources (Carlson 2010; Miller 1989; Suttles 1960a,b[1987]). Elmendorf (1971:359) notes frequent "reciprocal visiting" and exchange of food resources between kin in different Coast Salish communities. Carlson (2001:27; 2010:49) records visits from kin from the Gulf Islands and Vancouver Island to the Fraser Valley to harvest resources. High status families retained intensive knowledge of their geneology and low status families or "worthless people" were those who had forgotten who they were and where they came from.

If an inter-village relationship was established through marriage, the two families could exchange goods and property as long as the marriage lasted. This involved a series of exchanges that in some cases became competitive. If one family had a surplus of herring they could bring it to parents-in-law, receive a blanket in exchange, and later use that blanket to thank the parents-in-law for gifts of camus bulbs and dried sturgeon (Suttles 1960a[1987:17]). Traditions of intermarriage between certain communities led to alliances and reciprocal access between descent or residence groups (Onat 1984; Thom 2005:298).

Ethnographic Research on Territoriality in the Southern Channel Islands

The people who lived on the southern Channel Islands during the post-Contact period are known as the Island Gabrielino or the Tongva. They are Uto-Aztecan speakers whose traditional tribal territory includes Santa Catalina Island, San Clemente Island, San Nicolas Island, and Santa Barbara Island and the central coast and interior south of the Chumash territory to Newport Bay and east from the coast to the San Gabriel and Santa Ana Mountain (McCawley 1996, 2002). Little is known specifically of the Nicoleño because they were removed to missions on the mainland by 1835 prior to any visits by ethnographers. One woman was left behind on San Nicolas Island and died soon after she was brought to the mainland in 1853 (Meighan 1954).

Texts from early Spanish explorers beginning the 1500s suggest that the Tongva approached the newcomers with friendly behavior and eager participation in exchange of clothing, beads, and other items (Bean and Smith 1978:547; McCawley 1996:4-9, 25,90-91). However, when attempts were made to colonize Tongva territory on the mainland in the late 1700s, they were met with violent and organized resistance under the principal chief of Porciuncula (Castillo 1999:48).

Similar to the Coast Salish, the Tongva had complex communities. For mainland groups, the settlement round was characterized by dispersed family units at certain times during the year and larger settlements at other times depending on resource distribution. Primary settlements controlled political and spiritual life, secondary settlements served as trade loci, and small special purpose sites were used for hunting, fishing, shellfish harvesting, and processing of various materials (McCawly 1996:27-29). Villages were organized into one or more lineage groups (several related families). Each village was headed by a *tomyaar*, an inherited position of political, spiritual, and economic power usually served by men. In some cases, *tomyaars* had authority over several communities. Lineage groups included related families descended from an ancestor through the paternal line who shared access to hunting areas, acorn and seed gathering locales, and shellfish beds. Families contributed a share of their food to a reserve managed by a tomyaar and hoarding had consequences (McCawley 1996:111). Each lineage group had an elite class that held ceremonial rights and political sway over the chief, a middle class of craftspeople and skilled laborers, poorer people, and slaves (McCawley 1996:104-105; 2002).

The ethnographic record indicates violent conflict between Tongva groups due to trespassing, particularly between the coast and inland; however, food and other resources could be shared across group boundaries during formal gatherings. Lineages were grouped into wildcat and coyote moieties that owned specific ritual knowledge and objects. During inter-group gatherings, families representing both moieties were needed to complete ceremonies through ritual and paraphernalia. Groups in different village would take turns hosting ceremonies (Harrington 1942; McCawley 1996:89). Goods exchanged at these meetings included plant foods, seal, sea otter skins, red ochre, shell beads, plant foods, steatite, soapstone bowls and pipes, and other manufactured items and raw materials (McCawly 1996:112-113).

Resource access beyond the village territory could also be obtained through inter-community marriage alliances. Tomyaars created intra and inter-community alliances through marriages, sometimes even outside of the language boundaries of the Tongva territory with the Cahuilla, Chumash, Serrano, and Luiseño (Bean and Smith 1978:547). The elite class tended to favor marriage partners from other communities for political and economic gain (McCawley 1996:104). If the leadership declared war, allies through marriage ties from other communities might be given gifts in exchange for assistance (McCawly 1996:106-107).

Boundary permeability was also negotiated through professional guilds that cross-cut lineage groups such as shaman guilds, plank canoe guilds and artisan guilds (McCawley 1996:10). One way that the Tongva restricted movement across the region was through access to the *te'aat*, a plank canoe. Only those individuals who were part of a guild had access to knowledge about how to build and use watercraft. Gamble (2008) notes that among the neighboring Chumash, canoes were only owned by families that had inherited wealth and power (Arnold 1992, 1993, 1995a; Gamble 2008).

Theoretical Perspectives on Territoriality

In my research, I endeavor to synthesize ethnographic data, ideas about territoriality from anthropological theory, and data from both study areas to understand how and why shifts in territorial strategies occurred in both the Gulf of Georgia and the southern Channel Islands. The ethnographic record provides an important place to start in understanding how territorial behavior—both boundary defense (Dillian 2003) and boundary permeability—manifested itself among complex hunter-gatherer-fishers of the Pacific Coast. Along with long-term continuities between the ethnographic record and the deeper past, there are also significant discontinuities (Moss 2011:24). The ethnographic record thus provides inspiration for developing hypotheses that can be integrated with anthropological theories and tested using the archaeological record. Below I review theoretical perspectives on the relationships between human territoriality and the natural and social environment. I outline my approach to investigating this behavior among coastal hunter-gatherer fishers by drawing on models from human behavioral ecology, archaeological studies, and ethnographic research. Finally, I create a set of basic predictions to evaluate my approach that focus on lithic procurement strategies on the Pacific Coast of North America.

A variety of theoretical perspectives are successfully used to explore human territoriality and conflict. Anthropologists apply concepts from boundary theory (Kooyman 2006), Marxist-based modes of power, Bourdieu’s (1977, 1990) practice theory, anarchy theory (Angelbeck 2009), materialist theories (McCauley 1990; Haas 1990), theories about innate human capacity for aggression (Maschner and Reedy-Maschner 1998), and evolutionary or human behavioral ecology (e.g., Krebs and Davies 1997; Smith and Winterhalder 1992; Winterhalder and Smith 2000). To develop hypotheses on territoriality, I draw mainly on human behavioral ecology, an approach that is grounded on the concept that humans evolved through natural selection to be flexible in our ability to adapt to the environment. We are capable of adjusting our extended phenotype to achieve an optimal adaptation to survive and reproduce, thus our fitness-enhancing behavior is predictable (Boone and Smith 1998: 144; Stephens and Krebs 1986).

The goal of human behavioral ecology is to explore “the differential persistence of variability in behavior over time” (Kelly 2000:64). Several human behavioral ecologists investigate the relationships between humans and their environment through the lens of human territoriality (Axelrod 1997; Boone 1983, 1992; Cashdan 1983, 1990, 1992; Durham 1976; Dyson-Hudson and Smith 1978; Smith 1981, 1983; Smith and Winterhalder 1992). The simple, abstract, and deductive models provided by human behavior ecology are useful tools for disentangling relationships between environment and behavior (Broughton and O’Connell 1999; Kennett 2005:12; Smith 1988:225). Expectations derived from human behavioral ecology models can be articulated with one another and used to generate testable predictions for each study area (Fitzhugh 2003).

The goals of this research are to better understand the emergence and nature of territoriality in the San Juan Islands and southern Channel Islands and to use those case studies to investigate the processes of emergence of territoriality in complex hunter-gatherer societies. The use of two study areas helps to more rigorously test the same hypotheses in more than one environmental and social context. Determining how the same hypotheses play out in more than one study areas provides more information about the strengths and weaknesses of those hypotheses, but I do not intend to use the study areas to prove the validity of abstract human behavioral ecology models. Rather, the models that I draw on are conceptual tools for developing hypotheses and articulating assumptions in a formal way.

Human Behavioral Ecology Studies of Boundary Defense

Several recent archaeology studies use concepts from human behavioral ecology to explore territorial behavior in coastal and island settings. Many of these studies draw on an economic defendability model originated by Brown (1964) that assumes that organisms defend boundaries if the benefits of controlling access to resources outweigh the costs of actively defending boundary. Dyson-Hudson and Smith (1978:26) build on this concept and present a model that predicts different territorial strategies given different degrees of resource density and predictability (Figure 1.3). If resource supply is *far greater* than demand, costs of defending territorial boundaries—energy spent on boundary maintenance and defense, risk of injury, confinement to a smaller area for resource access—outweigh the benefits of exclusive access to land and resources. The benefits are low because everyone on the landscape has more than enough food and water. If resources are *scarce and unpredictable*, territorial behavior is costly because people must move within a larger area to obtain sufficient resources and larger areas are more difficult to defend. In situations of resource superabundance or scarcity/unpredictability, Dyson-Hudson and Smith (1978) predict that people will not create geographically stable territorial systems. They suggest that where resources are abundant and predictable but just *adequate* to meet a group's needs, the benefits associated with defending a discrete area will likely outweigh the costs. Because resources are abundant, people can remain in a small area that is easy to defend. If they let others access their food and water, they would not have enough for the community to subsist on. Although Dyson-Hudson and Smith do not explicitly state that this scenario assumes that a population is at the carrying capacity of the local environment, their model assumes a threat of intruders who do not have enough resources of their own due to spatial and temporal fluctuations in productivity levels. This would occur to certain communities if the larger population of the region was at or near carrying capacity.

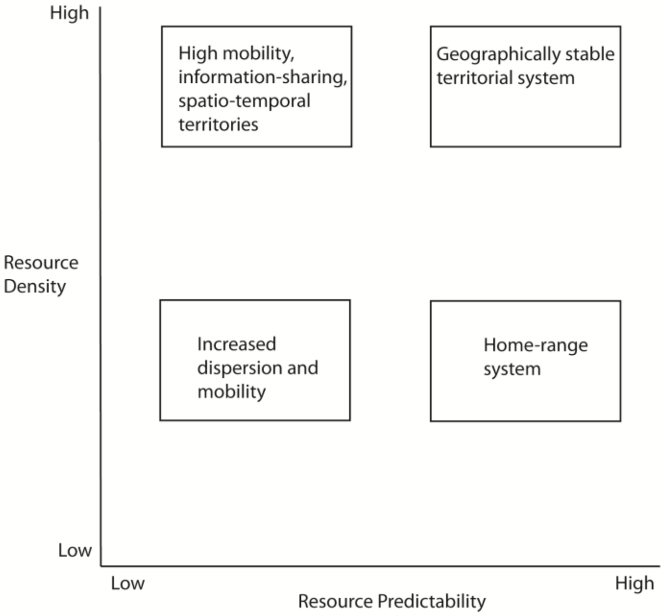


Figure 1.3. Predictions of the economic defendability model reproduced from Dyson-Hudson and Smith (1978:26).

Some recent human behavioral ecology studies on territoriality in coastal settings also draw on social science models of competition (e.g., Carneiro 1970; Cohen 1977; Haas 1990) triggered by subsistence stress due to increased population density or decreased resource abundance (Bawden and Reycraft 2000; Boone 1992; Ember and Ember 1992; Jones et al. 1999; Lambert and Walker 1991). These studies emphasize that people also engage in alliances and other types of cooperative behaviors during periods of conflict (Gumerman 1986), which I will discuss in further detail below. Kennett and Kennett (2000) propose that on the Northern Channel Islands, the origins of a variety of competitive and cooperative responses such as violence and production of trade goods occurred at 1500-650 cal BP during a period of climatic instability and associated increased risk of resource shortfall. Their review of settlement pattern analysis indicates sites with more defensive characteristics during this period, and osteological data shows an increase in violence. Kennett and Kennet propose that increased fishing may be consistent with more intra-group cooperation. Evidence for exchange of food, beads, and microdrills also increases at this time.

Kennett and his colleagues do not use the economic defendability model, but they use other human behavioral ecology models to further explore territorial behavior in the Channel Islands (e.g.,Kennett 2005; Kennett and Clifford 2004; Kennett et al 2009). Kennett and Clifford (2004) propose that during the Middle Holocene, Northern Channel Islands peoples moved between large semi-permanent coastal villages (prime locations for accessing shellfish on the rocky coast and freshwater) and inland hilltop villages (prime location for accessing plant resources and defensive sites) based in part on the presence or absence of other groups. They may have followed a bourgeois game theory strategy where players fight for resources that they currently own (play the hawk) but do not challenge ownership of resources that they do not own (play the dove) if other options are available.

Kennet (2005) traces the shift from an ideal free to an ideal despotic distribution in the Northern Channel Islands (see also Winterhalder et al. 2010). He suggests that people select locations for central places to achieve an optimal balance between accessing high-ranked resources and minimizing costs of travel and transport of resources. In an ideal free distribution where people are free to select any resource patch to exploit, they should aggregate near patches with the highest return rates, in this case areas on the coast near the mouths of large drainages. When the per capita yield of the patch decreases due to an increase in population density, at least some of the group should move to the next best patch near smaller drainages. Territorial behavior occurs when some groups protect the best resource patches and leave secondary resource patches to groups that are less competitive. This results in an ideal despotic distribution. Based on an increase in primary villages in less desirable places (from a central place foraging standpoint) at 1500 BP, Kennett suggests that there is a shift from an ideal free to ideal despotic distribution on the Northern Channel Islands during the Late Holocene due to increased population density resulting in territorial behavior.

In her dissertation research and subsequent articles on land tenure on the Fiji Islands, Field (2003, 2004, 2005; Field and Lape 2010) integrates an economic defendability model with a social scientific approach to competition (e.g., Kennett and Kennett 2000; Lambert 1993; Lambert and Walker 1991; Raab and Larson 1997). She hypothesizes that people use competitive strategies when resources are abundant and predictable (Dyson-Hudson and Smith 1978) but both competition and conflict increase rather than decrease when resources are temporally unpredictable. She hypothesizes further that cooperative behaviors also increase at times of resource unpredictability and scarcity. In Fiji, Field's GIS-based spatial analysis of human activities and resource distribution indicates that climatic fluctuations associated with the El Niño Southern Oscillation (ENSO) caused drops in agricultural productivity. She tests her hypotheses using the distribution of fortified and unfortified sites, the distribution of buildings with religious architecture, and the distribution of objects used in exchange such as pottery. Field (2003) finds that in the area of the Sigatoka Valley that was most vulnerable to ENSO fluctuations due to a severe dry season, competitive behavior was most intense but cooperation was also present. In areas of the upper Sigatoka Valley where the environment was more stable, there is less evidence for violent conflict. Religious structures indicate inter-group cooperation.

Boundary Permeability

The research described above focuses on boundary defense suggests that both boundary defense and cooperative strategies that allow people to transcend boundaries are related components of a territorial adaptation. In contexts in which resources tend to be scarce or unpredictable, groups buffer against resource variance in many ways (see review in Gamble 2005:100-101). One important strategy is to share information and exchange resources with other individuals or groups (Boone 1992; Cashdan 1990; Dyson-Hudson and Smith 1978; Gumerman 1986; Halstead and O'Shea 1989). I define *boundary permeability* as the ability of individuals or families to strategically transcend territorial boundaries, often based on the strength of inter-village relationships between kin or friends. People transcend boundaries through reciprocal access agreements, ceremonial gatherings, marriage ties, and exchange (Fitzhugh et al. 2011:87; Malinowski 1922; McCoy et al. 2010; Rautman 1993; Smith 1988:241; Wiessner 1982). Just as boundary defense varies based on the costs and benefits of investing in boundary maintenance, the degree and nature of boundary permeability can be investigated using a cost/benefit analysis.

Boundary permeability and reciprocity arrangements occur in many contexts including kin, marriage, and friendship relationships and political alliances. Studies from anthropology (Wiessner 1977), biology (Hamilton 1964), sociobiology (Palmer 1991), evolutionary psychology (Dunbar and Kenyatta 2008; Dunbar et al. 1995; Kruger 2003), and human behavioral ecology (Boone 1992) all present evidence for frequent and mutually beneficial interactions between kin. On the Pacific Coast, dense populations and frequent interactions between groups facilitated by boat travel likely encouraged strong ties between groups. Marriage ties and friendships may have been as important or even more important than genetic ties. Marriage ties often involve the transfer of resources from one family to another through the initial transfer of bridewealth from the new husband and his family to the family of the new wife. This may lead to lasting relationship and exchange of resources between the two families (Apostolou 2008). The ethnographic literature for the Gulf of Georgia and the Channel Islands attests to the strength and complexity of these relationships. Hill et al. (2009:188) note "extraordinary cooperation" involving economic transactions, political alliances, religious ceremonies, and other interactions between non-kin in many communities. They note than in many experiments, people choose to cooperate rather than compete despite minimal evidence of immediate rewards or benefits to their behavior. Thus boundary permeability is an essential part of territoriality models because it both structures and is structured by choices about boundary defense.

The primary costs of boundary permeability include travel (both on land and over water), conflict with other groups, loss of resources through gifting or exchange, and potential for failure of future reciprocation (Aldenderfer 1998; Cashdan 1990, 1992; Halstead and O’Shea 1982; Fitzhugh et al. 2011; Kennett and Kennett 2000; Smith 1988). Travel costs are determined not only by the difficulty of the landscape but also by the degree to which boundaries that must be crossed are defended. If boundary defense is low it should not be difficult for families who belong to different groups to meet and even form temporary communities. If boundary defense is high, the arrangements that allow people to transcend boundaries must become more formalized within the sociopolitical framework of the group. In this context, people will not be able to cross a boundary without giving something back in return. They must spend time and energy in maintaining the inter-group relationship. Thus, the relative costs of boundary permeability should be higher at times when boundary defense is more intense. The benefits are also lower at this time because resource availability is adequate.

The benefits of boundary permeability include information exchange, marriage partners, acquisition of objects that may elevate individual and family status in the community, access to rare or essential resources beyond territorial boundaries, and “buffering” against potential resource shortfall (Aldenderfer 1998; Arnold 1990a; Cashdan 1990, 1992; Fitzhugh et al. 2011; Halstead and O’Shea 1982; Janetski 2002; Kennett and Kennett 2000). Sharing between groups is particularly important because more information decreases uncertainty about resource distribution and abundance. Studies of reduction in unpredictable shortfall (sometimes referred to as risk reduction or risk minimization) indicate that people often make choices to minimize the possibility that they will fail at procuring a desired amount of resources (Halstead and O’Shea 1989; Hiscock 1994; Wiessner 1982). The chance that two groups will experience the same resource fluctuations decreases with distance (Mackie 2001; Smith 1988; Wiessner 1982). In choosing alliance partners, people must weigh the costs of transport and travel against the possibility that an alliance partner may also be experiencing resource shortfall due to climate change or natural disaster (Cashdan 1985; Kennett and Kennett 2000; Rautman 1993; Rensink et al. 1991; Whallon 1989, 2006). Based on these considerations, boundary permeability should increase in contexts of resource scarcity or uncertainty when people perceive a greater benefit to exchange, sharing resources, and sharing information.

The benefits of inter-group relationships have been addressed using a variety of models. In human behavioral ecology models used to predict pooling or sharing behavior, the relationship between resource abundance (harvest size) and value of the resource to the forager is expressed as a sigmoid-shaped utility function. The value of the resource increases quickly when resources are scarce but eventually that value levels off and increases more slowly (diminishing marginal utility) as harvest size increases. Thus, during times when resource availability far exceeds the needs of the community, extra food provides less value to the group so that the benefits (insurance against potential future shortfall, relationship-building, marriage partners) provided by sharing are greater than the costs incurred by losing the resource. This finding parallels the tolerated theft model (Blurton Jones 1984). During times of resource scarcity, resources have a relatively higher value to the group so the benefits of sharing are less likely to outweigh the loss of the resource (Figure 1.4; Smith 1988; Kohler and Van West 1996; Winterhalder, Lu and Tucker 1999). Based on this model, groups with extremely abundant resources should be willing to share or allow raccess to groups that have less, particularly if they know it could be their turn for shortfall in the near future. Groups with adequate resource may be less likely to share. This model does not distinguish between adequate and extremely scarce or unpredictable resources. Given low boundary defense and higher benefits of sharing information and subsistence resources (Fitzhugh et al. 2011), groups with scarce or unpredictable resources may be more likely to engage in inter-group relationships.

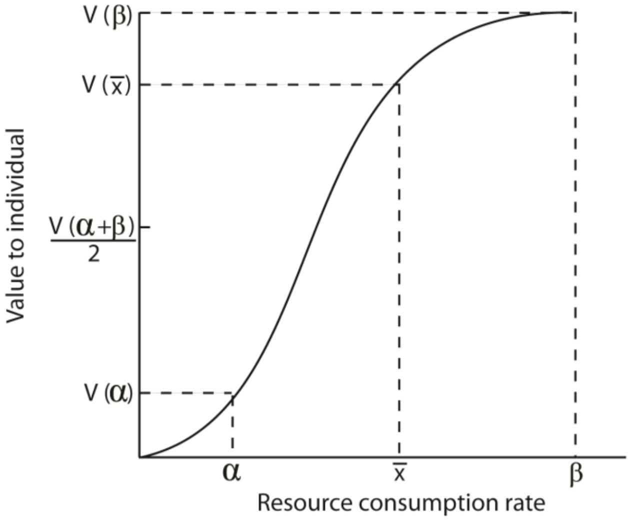


Figure 1.4. Reproduced from Smith's (1988:235) risk reduction model of resource sharing. Individuals who share resources gain higher value from their resources [V($\overline{x}$)] than individuals who do not share resource [V (α + β/2)].

A cost-benefit analysis of social networking by Fitzhugh et al. (2011) explores the issue of inter-group relationships in times of scarcity using a broad view of boundary permeability that incorporates not only environmental variability also interaction cost variability. They suggest that when environmental productivity/predictability and networking costs are low, people should pursue more connections at various scales from local to supraregional. If networking costs are high and resources are unproductive/unpredictable, people should rely more on individual traders rather than full-scale group interactions. When networking costs are high and resources are productive/predictable and, people should become more insular. If networking costs are low and resources are productive/predictable, people should interact in a competitive way. The most tightly interconnected communities are expected when resources are unproductive/unpredictable and networking costs are low (Figure 1.5) Fitzhugh et al. (2011) apply this model using ceramic and lithic artifacts from the Kuril Islands between Japan and Siberia (see also Phillips 2011). I follow their basic model in integrating boundary defense and boundary permeability predictions to create a set of hypotheses for territoriality on the Pacific Coast of North America; however, I differentiate between formal and informal interactions across boundaries. Formal interactions are defined as community-sanctioned events, meetings, gifting, and trader-led exchange. Informal interactions encompass reciprocal access of common use areas, temporary groupings of family groups, and unplanned encounters.

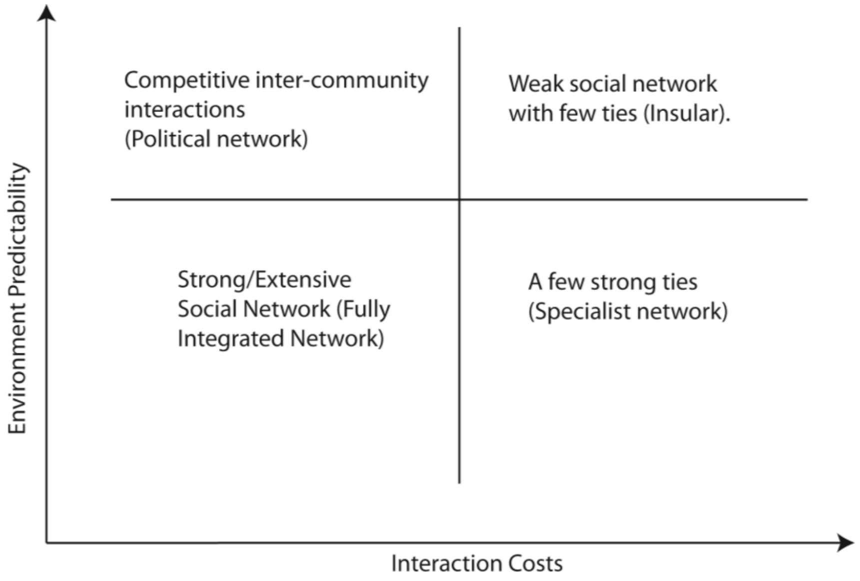


Figure 1.5. Reproduced from Fitzhugh et al. (2011:97), preditions for social networks given different levels of environmental predictability and networking costs.

Hypotheses for Precontact Territoriality on the Pacific Coast of North America

My hypotheses integrate an economic defendability model with expectations for boundary permeability based on the costs and benefits of inter-village relationships on the Pacific Coast. In constructing hypotheses for economic defendability, I consider resource adequacy relative to population levels. If population density is low, food and water resources are more likely to exceed the needs of the population. I also design these hypotheses with the assumption that the distribution of terrestrial, marine, and freshwater resources in coastal areas is patchy. Shellfish occur on certain beaches, fish are abundant in kelp beds or along certain routes, and plant resources are found only in certain environments (Kennett 2005:29). Patchniness encourages territorial behavior because aggregated resources are less costly to defend (Cashden 1983).

In general, if food and water resources adjacent to a community far exceed its needs either due to low population density or extremely abundant and spatially and temporally predictable resources, I predict minimal boundary defense. Since the value of the resource is higher to outside groups than to the group adjacent to the resource, they should tolerate "theft" (e.g., Blurton Jones 1984). At times when resources are extremely abundant in one patch, they may also be abundant in multiple patches on the landscape and other groups may not need to trespass unless population grows rapidly. Although boundaries should be permeable, benefits of interactions should be low and therefore infrequent. There may be other less resource-driven reasons for interactions across boundaries such as obtaining marriage partners and prestige items.

Where resources are scarce and/or unpredictable, territories are large and poorly defined and boundary defense should be minimal. If a community does not have a valuable patch to defend, they will not spend time and energy protecting their resources against outsiders. Unhindered travel and greater value of information in buffering against shortfall will encourage more frequent and informal interactions across boundaries.

Finally, when villages are located near abundant and predictable resources that adequately satisfy the requirements of the community, people should engage in aggressive boundary defense. The benefits of defending the resource will outweigh the costs. Aggressive boundary defense is associated with smaller territories because they are easier to defend given sufficient resources (Cashdan 1992). If population density is at or near carrying capacity, temporal and spatial perturbations in food and water resources will cause some people or groups to attempt to trespass on others' territories, resulting in aggressive boundary defense. In this context, boundary permeability should be low due to more restricted movement across the landscape. Interactions should be formal (Table 1.1).

Table 1.1. General predictions for boundary defense and permeability for a community.

	Boundary	
Resources	**Defense**	**Permeability**
Unproductive/Unpredictable	Low	High, informal
Adequate	High	Low, formal
Highly productive/Predictable	Low	Low, formal

This basic model must be further adjusted for coastal groups because marine and terrestrial resource productivity often shift independently of one another, which alters cost/benefit calculations for boundary defense and permeability. I generate the following scenarios for territoriality strategies in a coastal context (Table 1.2):

In environments with long-term marine resource abundance adequate to the needs of the group but poor or unpredictable terrestrial resources, people should move more freely on land and focus on boundary defense at villages on the coast adjacent to fishing or shellfishing areas. Inter-group interaction on land should be frequent and informal. Over water or on the coast, interactions should be limited and formal.

In environments with long-term terrestrial resource abundance adequate to the needs of the group but poor or unpredictable marine resources, boundary defense should focus on inland resources and freshwater sources. Interactions on land should be limited and formal. Interactions on water or on beaches should be more frequent and more informal.

Table 1.2. Expectations for boundary defense and permeability in a coastal environment.

		Boundary			
Resources		Defense		Permeability	
Marine	Terrestrial	Water	Land	Water	Land
-	-	Low	Low	High, informal	High, informal
+	-	High	Low	Low, formal	High, informal
-	+	Low	High	High, informal	Low, formal
+	+	High	High	Low, formal	Low, formal

Finally, the alternative hypothesis to the above is that although some degree of defense took place at the level of the village, kin and marriage relationships may have rendered boundaries permeable to certain people or families regardless of the marine or terrestrial productivity. Cashdan (1983) suggests that even when people do not engage in active boundary defense, they tend to participate in systems of reciprocal altruism in which they control access to social groups. This is particularly effective with sparse and unpredictable resources in which information exchange is vital to increasing foraging efficiency. In other words, the benefits of frequent interactions may always have outweighed the costs. If this is the case, people should defend areas beyond a single village and they should access resources outside that area as well. As Kennett (2005) notes, complex group formations often occur in coastal areas because many foraging expeditions depends on cooperation between group members. This alternative hypothesis is more consistent with descriptions of interconnected communities in the ethnographic record for both study areas.

Predictions

To test the hypotheses presented above, I analyze settlement pattern data and lithic procurement. To determine if high boundary defense occurs when marine and terrestrial resources are adequately productive and predictable, I test whether there are significant differences in defensive characteristics of sites occupied during different climatic at demographic regimes.

The bulk of the analysis focuses on toolstone procurement patterns. Unlike fish, birds, and other subsistence resources, rocks do not shift with changing environmental conditions. If the area over which people could access resources decreased during periods productive/predictable resources due to increased boundary defense, the lithic assemblage should reflect the toolstone that was available nearby. If the area over whch people accessed resources increased during period of unproductive/unpredictable resources due to decreased boundary defense, the lithic assemblage should reflect a variety of toolstone sources and/or the most attractive toolstone areas on the landscape. Alternatively, if boundaries always remained permeable to kin or friends, different areas of the site should show significant differences in toolstone sources corresponding with different resource access that is based on inter-group family connections rather than village connections. In both study areas, most toolstone comes in the form of local beach cobbles. I use cobble size, shape, and cortex appearance to match lithic artifacts at habitation sites to sources on the landscape. I also consider degree of processing and conservation as an indicator of easier or more difficult access to high quality toolstone. None of these lines of evidence are sufficient on their own to demonstrate change over time in toolstone access, but separate lines of evidence can be "triangulated" to establish convergence in support of a hypothesis (Wylie 2002).

I examine boundary permeability mainly through analysis of the abundance and distribution of items that would have marked exchange relationships between groups such as extra-local toolstone, beads, and other ornamental objects. Although food and everyday materials were also likely exchanged between groups, more unique objects and materials can be recognized as status markers. They serve as a visible means to maintain a relationship. Frequent and informal intergroup interaction should result in a more dispersed pattern of exchange items while infrequent and formal intergroup interaction should results of concentrations of rare or ornamental objects in certain households.

Dissertation Organization

In Chapter 2, I discuss current research on Late Holocene climate change in both study areas, current settlement pattern research, and other relevant background information on precontact lifeways and previous research in each study area. I present a quantitative analysis of the defensive characteristics of sites for both the San Juan Islands and San Nicolas Island. In Chapter 3, I provide detailed information on the archaeological sites from which I analyze lithic assemblages to test my predictions. I describe spatial and temporal analytic units based on dating and stratigraphy at each site. For the Watmough Bay site, excavations were completed in 1968 and 2004. Extensive dating efforts by previous researchers made creating analytic units relatively straightforward. For the Tule Creek Village Mound B site, sediment analysis and detailed stratigraphic analysis were required to create temporal units.

Chapters 4-6 focus on the lithic analysis used to test the hypotheses presented in Chapter 1. In Chapter 4, I discuss the results of field surveys in both study areas to determine the distribution, extent, and accessibility of high quality toolstone. For the San Juan Islands study area, this required geochemical analyses to determine the source provenance of the toolstone. For San Nicolas Island, toolstone surveys were sufficient since the provenance of the material was identified in previous studies. Chapter 5 provides background information on the flake tool technology, formal tool technology, and reduction sequences for each site based on the lithic analysis. In Chapter 6, I discuss my predictions for the lithic assemblages at each site and the results of analyses designed to test these predictions to investigate changes in lithic procurement. In Chapter 7, I summarize the results of the research in the context of larger theoretical, methodological, and topical issues for each study area. I also identify areas for future research.

Chapter 2: Pacific Coast Paleoenvironments and Settlement Patterns

General similarities in the San Juan Islands and southern Channel Islands, such as an island setting, reliance on marine resources, boat transport, and large multi-house villages, allows the application of the same hypotheses in both places. Differences between the study areas in distance from the mainland, distance between islands, paleoenvironment, and settlement pattern facilitates a more rigorous test of hypotheses about territoriality in coastal hunter-gatherer-fisher communities. Exploring questions from a broader coastal archaeology framework rather than from one study area also helps me to challenge some of the assumptions associated with the culture histories and research traditions of the Gulf of Georgia and Southern California Bight.

In this chapter, I review information about the culture histories, environments, and settlement patterns of each study area. Since the hypotheses discussed in the previous chapter consider territoriality in the context of resource availability, detailed examination of paleoenvironmental data are essential to predicting shifts in boundary defense and boundary permeability strategies in the Late Holocene. Settlement pattern data are an essential component of an investigation into territoriality for several reasons. Demographic data are important because population density affects relative resource abundance. Calculating actual population levels using archaeological data is beyond the scope of this research, but site size and abundance provides insights on the size of precontact communities. The location of sites on the landscape are also important to understanding which resources people chose to settle near and defend. Finally, I also examine the distribution and characteristics of defensive sites in both regions to test predictions about active defense of village sites.

The San Juan Islands Study Area

Less than ten kilometers offshore, the San Juan Islands are part of an archipelago of 450 islands north of the Puget Sound between Vancouver Island and the Washington and British Columbia coasts. Along with the Gulf Islands, the Lower Fraser River, the Strait of Georgia, northern Puget Sound, and southeastern Vancouver Island, they form part of the Gulf of Georgia culture area (Stein 2000; Suttles 1990). Most of the San Juan Islands are held by private landowners (approximately 85%) with the exception of San Juan Island National Historical Park, Washington State Parks, San Juan County Parks, areas protected by federal agencies, land trusts and other organizations, and land held by the University of Washington. The coastal landscape is characterized by rocky and sandy beaches. Inland areas are characterized by open prairies, farmland, and mixed coniferous forest.

Today, several Coast Salish speaking native communities include the San Juan Islands within their traditional territories. These include the Lummi Nation, the Samish Indian Nation, the Swinomish Indian Tribal Community, the Songhees Nation, and the Saanich Nation The coastal archaeological record is dominated by shell midden sites. Inland sites are scarce due to poor preservation of organic material in acidic soil and limited research. These sites are characterized by isolated finds of lithic artifacts. Kenady et al. (2008) also report a surface lithic scatter on a high bedrock outcrop on San Juan Island.

The culture history of the Gulf of Georgia area presents a narrative of a terrestrial-oriented initial colonization (Cascade Phase, 9000-4500 cal BP), followed by increased use of marine resources and related fishing technology. Shell middens appear in the Locarno Beach Phase at 4500-2500 cal BP, although shell-bearing deposits are found earlier elsewhere on the Northwest Coast (Stein 2000). Gulf of Georgia researchers propose an increase in population density and sedentism at ca. 2500-1500 cal BP during the Marpole phase (Croes and Hackenberger 1988; Matson 1983, 1985; Matson and Coupland 1995). The appearance of larger houses and villages during the Marpole is thought to reflect increased social stratification and changes in the ways that resources were controlled (Ames 1994, 1995; Ames and Maschner 1999; Grier 2003). Researchers also cite evidence for intensified salmon fishing and associated tools (Burley 1980; Croes and Hackenberger 1988; Matson 1983, 1992; Mitchel 1971), ornamental and artistic objects, wood and bone craft specialization (Burley 1980; Matson and Coupland 1995), large houses, multihouse settlements (Ames 1994; Grier 2001, 2003), and increased regional exchange of obsidian and other materials (Carlson 1994; Grier 2003).

The roots of sociopolitical structures observed in the historic period are thought by some to lie in the Marpole phase (Burley 1980; Carlson 1960; Matson and Coupland 1995; Mitchell 1971). Lepofsky et al. (2005) suggest that some sociopolitical developments are associated with a warmer and drier Gulf of Georgia during the Marpole that led to resource scarcity that was most acute outside the Fraser River region. This may have encouraged exchange relationships between the Fraser Valley and other Gulf of Georgia communities. People with kin relationships in the Fraser would have developed higher status. Similarities in artifact assemblages, artistic and status-marking items such as labrets and other decorative objects, and the distribution of materials considered trade items throughout the Gulf of Georgia region provides evidence for increased or stabilized social and economic relationships throughout the region (Burley 1981; Grier 2003).

The period following the Marpole, known as the “Late Phase” or “San Juan Phase” (1500 cal BP-Contact), is associated with a continuation of many of the cultural trends that appeared during the Marpole but a decrease in abundance and variety of “elaborate goods”, possibly due to a change in burial practices and/or a shift in social organization (Lepofsky et al. 2005:273), a decrease in chipped stone, and an increase in bone and antler tools. In general, the San Juan Phase is poorly studied and this research will contribute to a greater understanding of this time period.

Gulf of Georgia Paleoenvironment

Today, the Northwest Coast climate is classified as "mild maritime" with cool summers and wet and mild winters. Due to the rain shadow effect of the Olympic Mountain Range, San Juan Islands summers are drier than mainland summers. Dominant tree species include douglas fir (*Pseudostuga mensiesii*), Pacific madrone (*Arbutus menziesii*), white oak (*Quercus garryana*) big leaf maple (*Acer macrophyllum*), grand fir (*Abies grandis*), lodge pole pine (*Pinus contorta*), Pacific yew (*Taxus brevifolia*), western hemlock (*Tsuga heterophylla*), western red cedar (*Thuja plicata*) and red alder (*Alnus rubra*). Understory species include ocean spray (*Holodiscus discolors*), snowberry (*Symphoricarpus albus*), nootka rose (*Rosa nootkanensis*), and salal (*Gaultheria shallon)* (Mitchell 1971; Wessen 1986).

Due to mixing of cold and highly saline ocean waters with brackish surface waters, the diverse marine environment of the Gulf of Georgia is characterized by rich kelp forests and eelgrass beds. Freshwater is more limited on the San Juan Islands than on the adjacent mainland. Below I review both marine and terrestrial climate change in the Salish Sea from the beginning of the late Holocene at 4500 cal BP. Since change over time in sea surface temperature and upwelling both have important implications for the productivity of marine flora and fauna (Daniels 2009; Kozloff 1990, 1993), both are considered in this review of marine climate change. My discussion of terrestrial climate change focuses on temperature and precipitation.

Marine Paleoenvironment in the Gulf of Georgia

Following a relatively stable and productive Middle Holocene, the Late Holocene (4500 cal BP-Contact) Gulf of Georgia marine environment was characterized by changes in upwelling and sea surface temperature, both of which affect the productivity of the marine resources upon which native communities relied (Figure 2.1). Climate researchers use increases and decreases in fauna and oxygen isotopes to pinpoint shifts in upwelling and sea surface temperature, which do not always change in tandem in the Gulf of Georgia (Daniels 2009). The period from 4000-2800 cal BP is characterized by cooler sea surface temperature based on analysis of diatoms, silicoflagellates and biogenic silica in Effingham Inlet, Vancouver Island (Hay et al. 2007). According to Daniels' (2009) sea surface temperature study using stable isotope data from *Protothaca staminea* (littleneck clam) from the English Camp site on San Juan Island, ocean waters warmed at ca. 700-1400 cal BP, cooled at ca. 1400-1000 cal BP, and warmed again at ca. 1000-300 cal BP. Preliminary data suggest possible warming at 300-100 cal BP, but Daniels (2009:80-82) was unable to rule out sampling issues.

Regarding upwelling, the period from 4000-2800 cal BP was characterized by decreased upwelling based on analysis of diatoms, silicoflagellates and biogenic silica in Effingham Inlet, Vancouver Island (Hay et al. 2007). Changing proportions of fish taxa in the same area indicate increased upwelling afterwards at 2800-1500 cal BP (Wright et al. 2005). Daniels establishes upwelling history by building on a local marine reservoir chronology created by Deo et al. (2004) using paired shell and charcoal dates. Since increased local upwelling causes an increase in C^{14} depleted carbon in surface waters, changes in marine reservoir between local and global surface water (ΔR) can be used as a proxy for increased upwelling (Daniels 2009:51). Daniels also considers stable carbon and oxygen isotope data from shell samples from the English Camp and Watmough Bay sites on the San Juan Islands. Like Wright (see also Tunnicliffe 2001), she finds an increase in upwelling at 3000-1400 cal BP. She also notes a decrease in upwelling at 1000-600 cal BP followed by an increase in upwelling 600 cal BP to modern times (Daniels 2009:70).

Terrestrial Paleoenvironment in the Gulf of Georgia

On land, a decrease in temperature and increase in precipitation at 3000-2400 BP are consistent with a brief neoglacial advance (Brown and Hebda 2003; Hallett et al. 2003; Hebda 1995; Long et al. 1998; Pellatt et al. 2001). At about 3000 years ago, increased precipitation and decreased temperature led to closing of the canopy in western hemlock and cypress-family forests, an increase in wetlands (Brown and Hebda 2003), and more cedar, western helmlock, spruce, and douglas fir (Pellatt et al. 2001). Glacial advances are documented throughout British Columbia at this time (Koch et al. 2007; Luckman 1994). At 2400-1200 cal BP, the Gulf of Georgia region experienced a warmer and drier climate associated with anomalies in the mid-troposphere caused by climate forcing (Hallett 2001; Lepofsky et al. 2005). Glacial retreats (Koch et al. 2007) and increases in soil charcoal in upper Fraser lake sediments associated with increased fire caused by drier wood and increased electrical storms (Hallett 2001; Hallett et al. 2003; Lertzman et al. 2002) establish the Fraser Valley Fire Period in southwestern British Columbia.

Paleoecologists in the San Juan Islands (Fujikawa 2002; Sugimura et al. 2008) identify a similar climatic shift in the San Juan Islands. The findings are based on both an increase in charcoal and an increase in fire-adapted alder (*Alnus*) pollen in sediment cores from bogs on Mt. Constitution on Orcas Island. Brown and Hebda (2003) also propose an increase in fires on Vancouver Island after 1940 cal BP based on charcoal records from lake sediments. It is possible that anthropogenic burning played a role in increased fire frequency in the Gulf of Georgia region, but the weight of the evidence and contemporaneous droughts in western North America (Gavin et al. 2003; Hallett et al. 2003; Meyer and Pierce 2003) support a warmer and drier climate at 2400-1200 cal BP (Fujikawa 2002; Hallett et al. 2003; Lepofsky et al. 2005:277-278).

Paleoecological research in the Olympic Mountains (Gavin and Brubaker 1999) and southwestern British Columbia (Hallett et al. 2003) suggests that after a brief period of increased precipitation after the Fraser Valley Fire Period, the climate returned to warmer and drier conditions in the islands at 1050-600 cal BP (Gavin and Brubaker 1999). At 300-100 BP, the climate cooled again. Evidence for this cooling event has been found in pollen data on western Vancouver Island (Gavin and Brubaker 1999) and the Olympic Peninsula (Greenwald and Brubaker 2001), tree ring data from Mount Rainier (Graumlich and Brubaker 1986), glacial sediment in the British Columbia Coast Mountains (Koch et al. 2004; 2007; Larocque and Smith 2003; Ryder 1987, 1989; Smith and Desloges 2000; Walker and Pellat 2003), and increased charcoal in Upper Fraser lake sediment (Hallett et al. 2003).

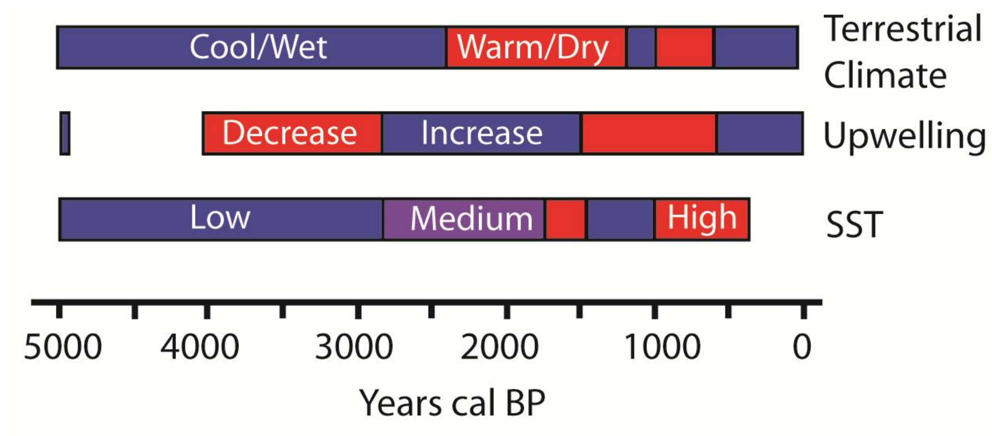


Figure 2.1. A summary of terrestrial climate, upwelling, and sea surface temperature for the Late Holocene Gulf of Georgia.

Gulf of Georgia Marine Resources

To address hypotheses regarding shifts in human territoriality in the context of climate shifts, I consider the impact of paleoenvironmental changes on the resources upon which precontact Gulf of Georgia communities depended. Shell middens are typically dominated by littleneck clam (*Protothaca staminea*), butter clam (*Saxidomus giganteus*), and blue mussel (*Mytilus trossulus*). People also gathered cockle (Cardiidae), horse clam (*Tresus* spp.), snail (Gastropoda), limpet (*Littorina* spp.), dogwinkle (*Nucella* spp.), periwinkle (Lottidae), barnacle (*Balanus* spp.), bentnose clam (*Macoma* spp.) and sea urchin (*Strongylocentrotus* spp.) (Wessen 1986). The San Juan Islands offer a fishing advantage in that salmon (*Oncorhynchus* spp.) returning to the Fraser River to spawn must pass through narrow passages between the islands (Mitchell 1971). People also fished for steelhead (*Salmo gairdneri*), eulachon (*Thaleichthys pacificus*), smelt (*Spirinchus* spp. and other genera), sturgeon (*Acipenser* spp.), Pacific lamprey (*Lampetra tridentata*), halibut (*Hippoglossus stenolepis*), Pacific herring (*Clupea harengus*), cod (various genera), dogfish (*Squalus acanthias),* perch (various genera), sculpins (Cottidae), and flatfish (Pleuronectidae) (Suttles 1990). Native communities exploited Waterfowl such as cormorants (*Phalacrocorax auritus, penicillatus,* and *pelagicus*), sea ducks (Merigini) and pochard ducks (Aythyini) (Bovy 2005). A variety of marine mammals were available for hunting including northern elephant seal (*Mirounga angustirostris*), California sea lion (*Zalophus californianus*), northern sea lion (*Eumetopia jubatus*), Dall's porpoise (*Phocoenoides dalli*), and harbor seal (*Phoca vitulina*).

The Gulf of Georgia environment is characterized by rich marine resources but because productivity varies over both space and time based on precipitation, altitude, salinity, and shoreline (Suttles 1960b [1987:26-27]), depictions of this area as a “Garden of Eden” (Erlandson 1994) are misleading. Higher sea surface temperature diminishes microscopic marine plants and kelp forests, resulting in diminished fish and shellfish populations. Warmer sea surface temperatures are also associated with the algal species that cause paralytic shellfish poisoning (Horner et al. 1997). Late summer droughts cause fires and increase erosion which increases silt and streams and diminishes spawning. In places like the lower Fraser River where all five species of Pacific salmon thrive, people may not have been adversely impacted (Lepofsky et al. 2005). On the San Juan Islands, however, a decline in fish populations could have caused a shortfall in subsistence resources. Bovy (2005, 2007) notes that warm water events like El Niño can diminish some seabird populations on the Northwest Coast. Thus, during periods of warmer sea surface temperature and decreased upwelling, many marine resources would have become less abundant and/or more spatially unpredictable. Based on the hypotheses outlined in the previous chapter, I predict that this would have resulted in more boundary defense surrounding more abundant and predictable marine resource patches (unless they far exceeded the needs of the group), and decreased defense of boundaries surrounding less abundant/predictable resource patches. I also predict increased permeability to informal inter-group interactions.

Gulf of Georgia Terrestrial Resources

Regarding the terrestrial environment, people gathered plants such as camas (*Camassia quamash*), wapato (*Sagittaria latifolia*), and a variety of berries (Barnett 1955; Stein 2000; Suttles 1990; Wessen 1986). They hunted terrestrial mmamals including river otter (*Lontra canadensis*), Columbia black-tailed deer (*Odocoileus hemionus*), bear (*Ursus* spp.), and elk (*Cervus elaphas*) (Wessen 1986; Jim Kenagy pers. comm).

During the drier Fraser Valley Fire Period and Medieval Warm Period, the islands would have been more adversely impacted than the neighboring mainland for several reasons, First, they are less ecologically diverse with only 2 of 13 Gulf of Georgia biogeoclimatic variants (Lepofsky et al. 2005). Lepofsky et al. (2005:278) note that some mammals such as mule deer, elk, marmot, and snowshoe hare would have flourished in more open forests following large fires, but other taxa would have declined. Increased open meadows would have negatively affected some plant resources although berries and camas may have thrived in a more open environment.

Despite an increase in some subsistence resources, a shortage of freshwater on the San Juan Islands may have been problematic for people and for certain animals during times of drought. The islands are drier than the surrounding area due to the rain shadow effect of the Olympic Mountains; there are only six perennial streams to choose from. Most streams on the islands have no flow between June and November (Dietrich 1975:68; Wixom and Snow 2004). The higher elevation areas on eastern Orcas Island receive more rainfall than other areas with approximately 76-114 centimeters per year while southern San Juan Island and Lopez Island are drier, receiving 51-64 inches per year (Detrich 1975:60) (Figure 2.2; Table 2.1).

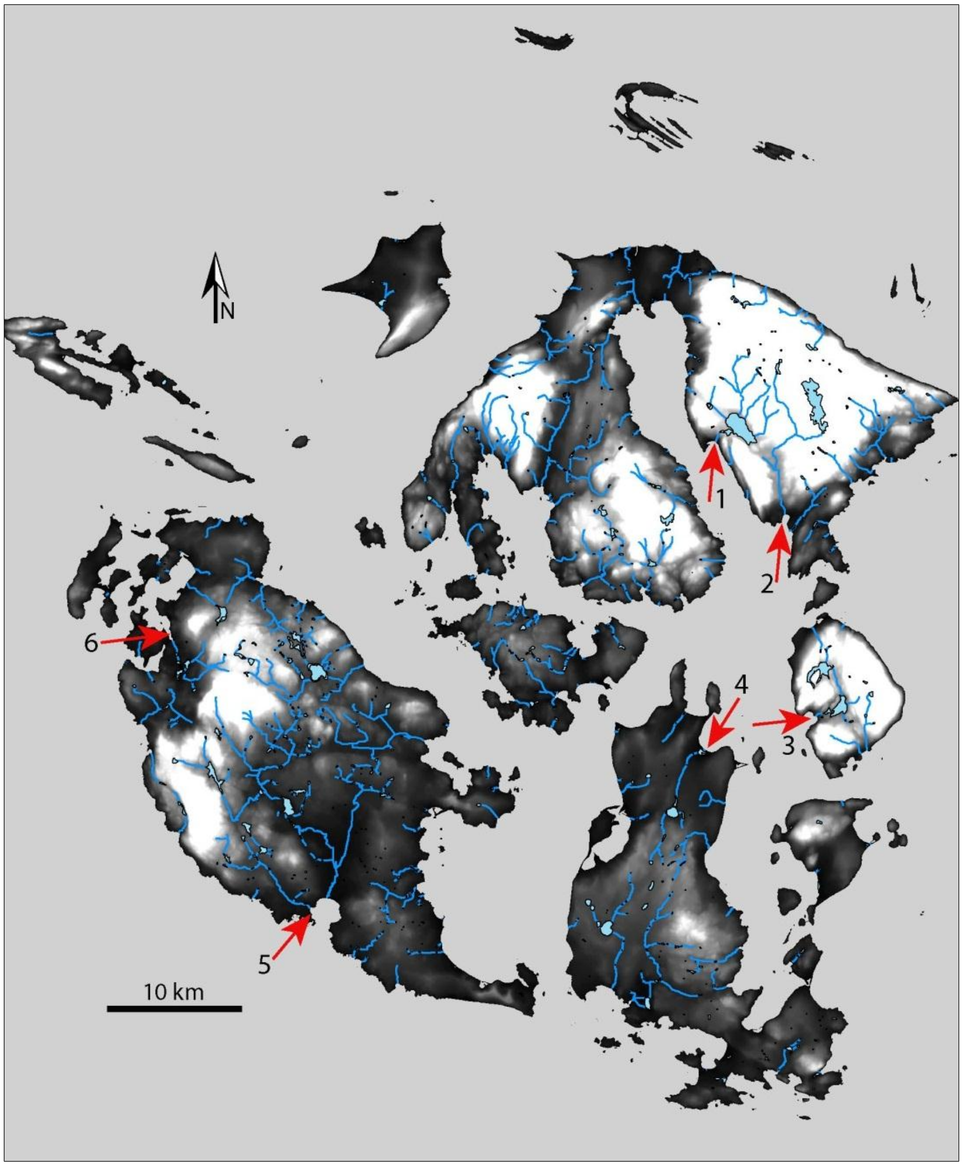


Figure 2.2. Map showing streams that were perennial freshwater sources (arrows with numbers refer to Table 2.1 below) on the San Juan Islands modified from Taylor et al. 2011.

Table 2.1. Descriptions of primary freshwater sources in the San Juan Islands based on Dietrich 1975; Wixom and Snow 2004. Reproduced from Taylor et al. (2011).

Map #	Freshwater Source Area	Description
1	Cascade Bay, Orcas Island	Cascade Bay provides access to an unnamed creek 400 m SW of Cascade Lake (volume 4,600 acre-ft.). This is a high precipitation area surrounding Mt. Constitution with a large spring that feeds Cold Creek, a high-flow perennial stream that runs into Cascade Lake.
2	Buck Bay, Orcas Island	Buck Bay provides access to the mouth of Cascade Creek, a high discharge stream fed by Mountain Lake (volume 8,800 acre-ft.) located in the high precipitation area surrounding Mt. Constitution.
3	Unnamed Bay, Blakely Island	The large bay on western Blakely Island provides access to an unnamed creek and is 200 m from Spencer Lake (volume 5,400 acre-ft.).
4	Swifts Bay, Lopez Island	The Swifts Bay watershed is fed by Hummel Lake (volume 272 acre-ft.). An unnamed stream runs from the lake to the bay.
5	False Bay, San Juan Island	The False Bay watershed is fed by streams running from Trout Lake (volume 1,400 acre-ft.) on Mt. Dallas and Zylstra Lake (volume 350 acre-ft.). San Juan Valley Creek begins at Trout Lake and runs year round.
6	Garrison Bay, San Juan Island	The source of freshwater to Garrison Bay is a year-round creek with its head on the north side of Mt. Cady, a high precipitation area on northern San Juan Island.

San Juan Islands Settlement Patterns

Prior to this research, settlement pattern data on the San Juan Islands consisted of dates from only a handful of the largest shell midden sites. The goal of the San Juan Islands Archaeological Project (2005-2009) was to date additional “big” shell midden sites (larger than 3,000 square meters) and “small” shell midden sites (smaller than 3,000 square meters) (Taylor et al. 2011). Definitions of site size for different time periods for multi-component sites was based on augering and spatial data from previous excavations. I conducted this project with Dr. Julie Stein (Principal Investigator), and Stephanie Jolivette (University of Washington Graduate

Student). We sampled shell middens throughout the islands by augering and collecting shell from the eroding bank. The results of this project are reported in scholarly articles and unpublished reports at the Burke Museum and the Washington State Department of Archaeology and Historic Preservation (Taylor and Stein 2006, 2007; Taylor et al. 2009a, 2011).

From 2005-2009 the SJIAP obtained a total of 84 dates from 41 sites (Taylor et al. 2011:293-296) and combined these data with 145 previously published dates (Bovy 2005; Daniels 2009; Deo et al. 2004; Stein et al. 2003; Walker 2003) from a total of 50 sites in the San Juan Islands. Based on work by Deo et al. (2004) and refined by Daniels (2009), the regional marine reservoir correction value (ΔR) is 400 years at 0-600 cal BP and 1000-3000 cal BP and 0 years at 600-1000 cal BP due to decreased upwelling.

The data show small numbers of sites on the islands beginning at 4000 cal BP, an increase in sites at approximately 2500 cal BP, and the highest frequency of dates at 650-300 cal BP (Figure 2.3-2.11). The scarcity of older sites is likely due to sea level change and erosion. Sea level history in this region is complex due to influences of isostatic depression and rebound, eustatic sea level change, and tectonic processes (Clague and James 2002; Fedje et al. 2009; Hutchinson 1992; James et al. 2005; Mosher and Hewitt 2004) . In the Cascadia region, as the glaciers melted and isostatic rebound began, relative sea level fell from 75 meters above sea level to modern levels by 11,700 ± 170 RCYBP (James et al. 2005; Mosher and Hewitt 2004:25). The land continued to emerge and sea level may have been over 10 meters below its present level at 9000 RCYBP (see also Clague 1981; Dethier et al. 1996). At 5000 RCYBP, relative sea level rose to within two meters of modern sea level because eustatic sea level change outpaced tectonic uplift (Clague and James 2002; Mazzoti et al. 2008). Sea level rose to within a meter of its present position within the last 2000 years (Fedje et al. 2009; Grier et al. 2009; Whittaker and

Stein 1992). Underwater excavation for early sites has been attempted in the Gulf Islands (Easton and Moore 1991) and may hold potential in the San Juan Islands. Megafauna finds (Kenady et al. 2007, 2011; Wilson et al. 2009) suggest a potential Terminal Pleistocene/Early Holocene human occupation on the islands. Efforts to find inland lithic manufacture, hunting, and habitation sites are ongoing.

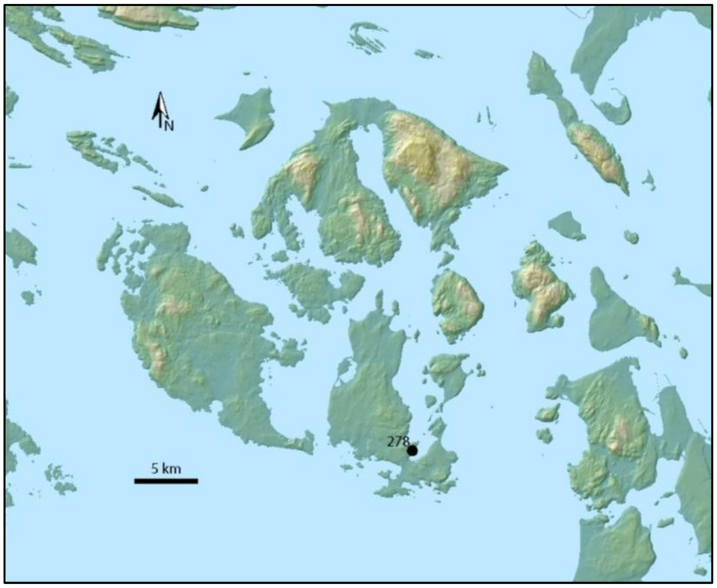


Figure 2.3. Settlement pattern map for the San Juan Islands at 4000-3500 cal BP. Numbers indicate site numbers recorded in the Department of Archeology and Historic Preservation site database. Black circles indicate big sites.

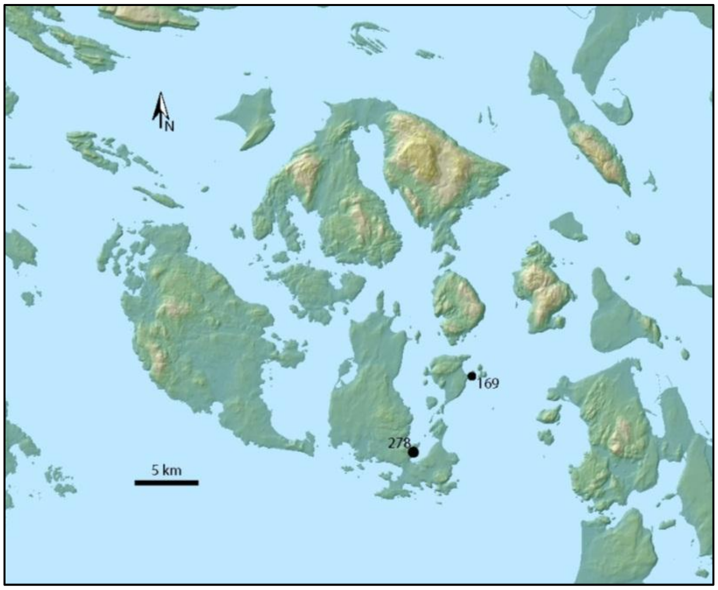


Figure 2.4. Settlement pattern map for the San Juan Islands at 3500-3000 cal BP. Numbers indicate site numbers recorded in the Department of Archeology and Historic Preservation site database. Black circles indicate big sites.

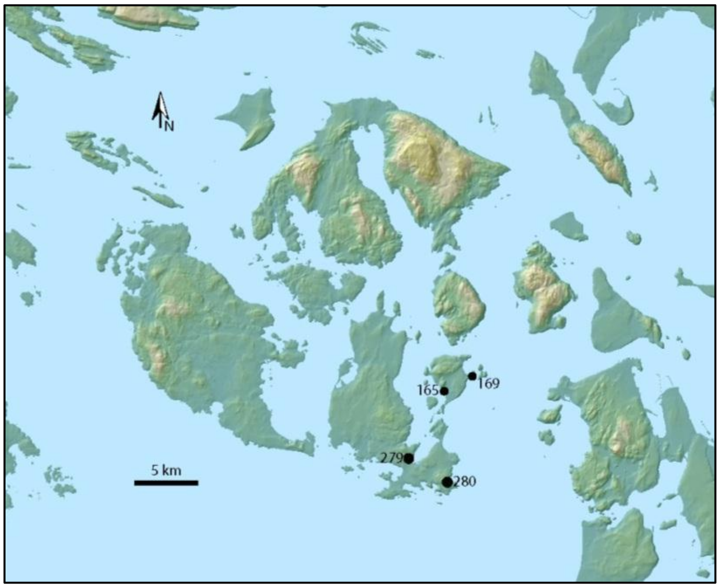


Figure 2.5. Settlement pattern map for the San Juan Islands at 3000-2500 cal BP. Numbers indicate site numbers recorded in the Department of Archeology and Historic Preservation site database. Black circles indicate big sites.

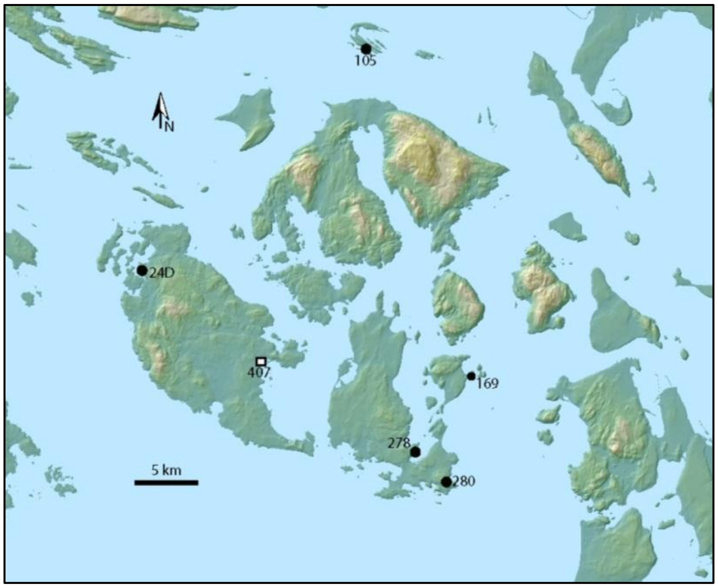


Figure 2.6. Settlement pattern map for the San Juan Islands at 2500-2000 cal BP. Numbers indicate site numbers recorded in the Department of Archeology and Historic Preservation site database. Black circles indicate big sites and white squares indicate small sites.

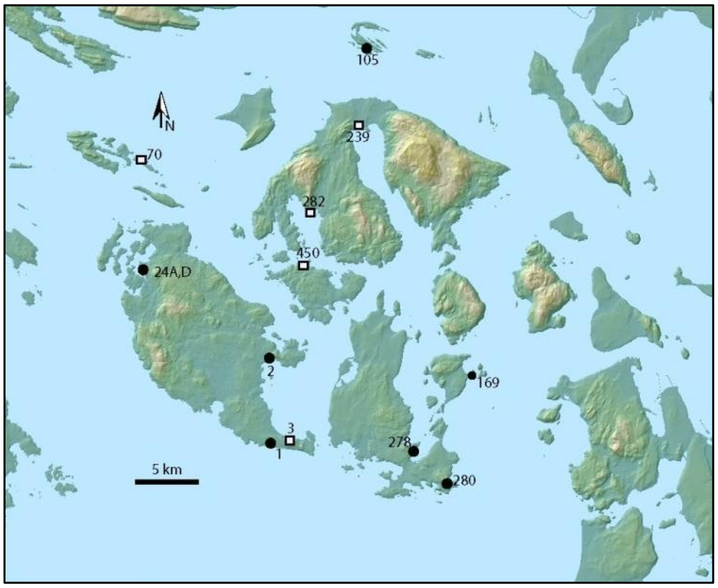


Figure 2.7. Settlement pattern map for the San Juan Islands at 2000-1500 cal BP. Numbers indicate site numbers recorded in the Department of Archeology and Historic Preservation site database. Black circles indicate big sites and white squares indicate small sites.

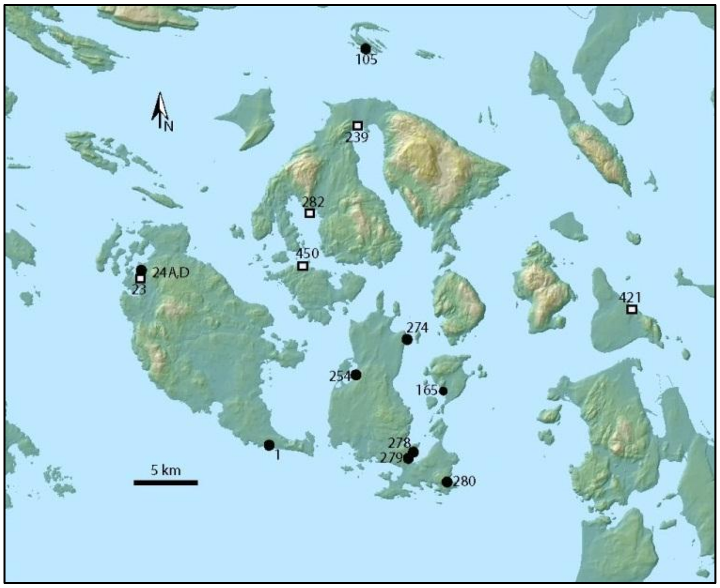


Figure 2.8. Settlement pattern map for the San Juan Islands at 1500-1000 cal BP. Numbers indicate site numbers recorded in the Department of Archeology and Historic Preservation site database. Black circles indicate big sites and white squares indicate small sites.

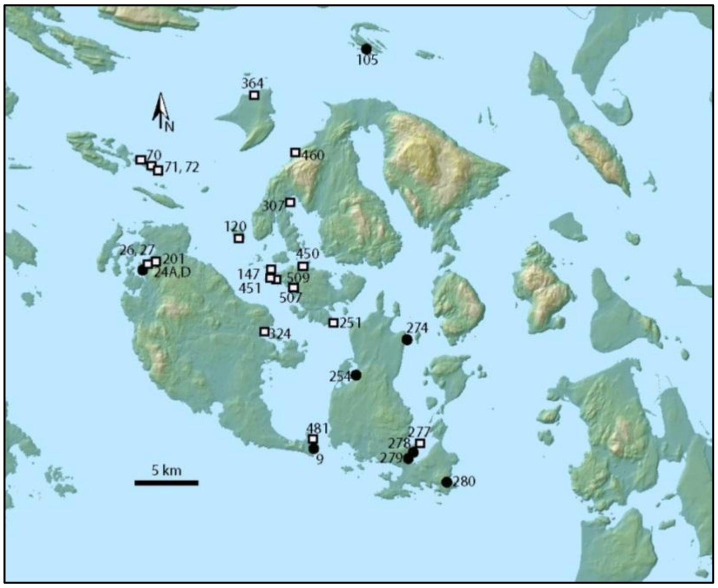


Figure 2.9. Settlement pattern map for the San Juan Islands at 1000-500 cal BP. Numbers indicate site numbers recorded in the Department of Archeology and Historic Preservation site database. Black circles indicate big sites and white squares indicate small sites.

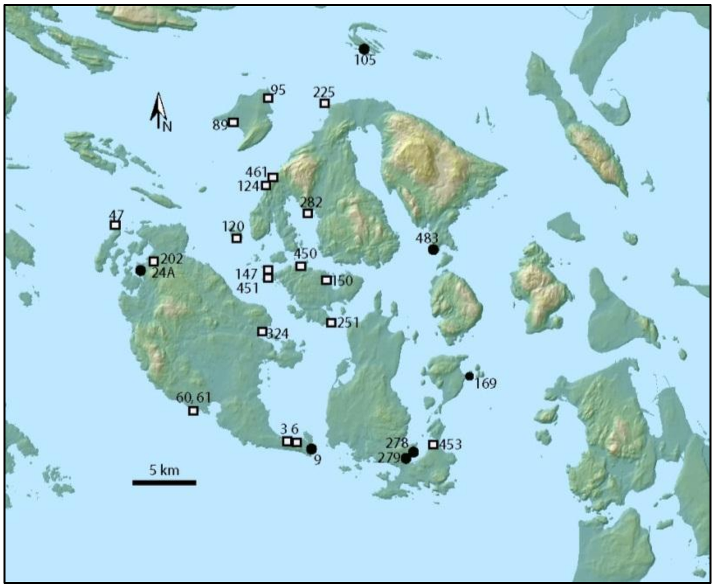


Figure 2.10. Settlement pattern map for the San Juan Islands at 500-0 cal BP. Numbers indicate site numbers recorded in the Department of Archeology and Historic Preservation site database. Black circles indicate big sites and white squares indicate small sites.

The slight increase in sites on the San Juan Islands at 2500 cal BP is similar to findings for the Canadian Gulf of Georgia (Lepofsky et al. 2005); however, a more dramatic increase in sites at 650-300 cal BP only occurs in the San Juan Islands (Figure 2.11, 2.12). Site size differs significantly before and after 650 cal BP ($\chi^2 = 16.931$, 1 df, $p < 0.001$), with more big sites prior to 650 cal BP and more small sites afterwards. One possible explanation for the discrepancy between the two records concerns climate change. The Fraser Valley area provided more resources than the Gulf Islands and San Juan Islands at 2400-1200 cal BP during the Fraser Valley Fire Period. Lepofsky et al. (2005) note that the Fraser region had large volume of freshwater, ecological diversity, a large salmon run, and high waterfowl populations. Their summed probability plot that shows an increase in sites and/or a dispersion of people across the landscape supports the hypothesis that people clustered in a productive area of the Gulf of Georgia. Perhaps after the climate became cooler and wetter after the Medieval Warm Period at 600 cal BP, part of the larger Fraser Valley population relocated to the San Juan Islands.

Research on site vulnerability to erosion based on fetch, bathymetry, vegetation, and landform by Taylor et al. (2011) indicates that erosion is also probably a factor in the smaller number of sites at 2500-15000 cal BP but is not enough to explain this pattern.

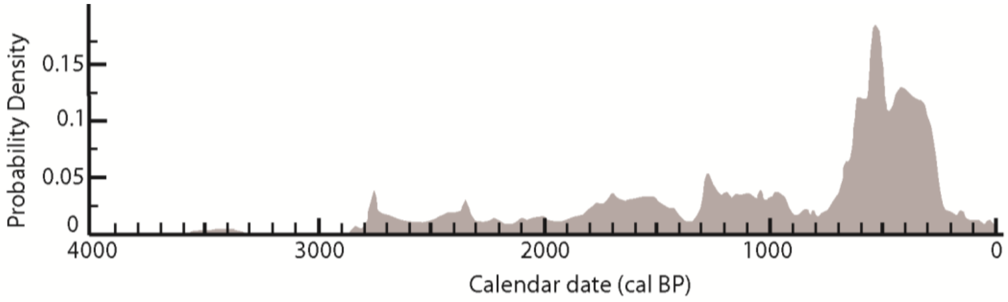


Figure 2.11. Summed probability plot for San Juan Islands dates reproduced from Taylor et al. 2011. Following the same protocol as Lepofsky et al. (2005), this plot incorporates only one date per site per 200-year interval to ensure that the better-dated large sites do not bias the chronology.

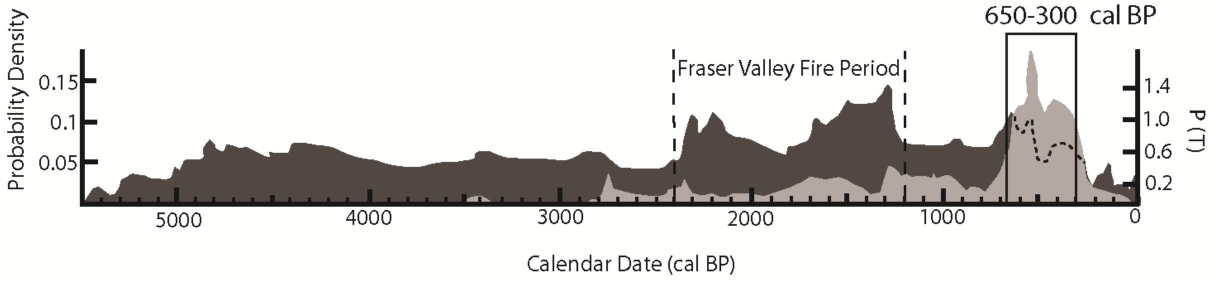


Figure 2.12. Summed probability plot for San Juan Islands based on SJIAP data and for the Canadian Gulf of Georgia reproduced from Lepofsky et al. (2005). Both plots incorporate only one date per site per 200-year interval.

Territoriality Predictions for the San Juan Islands

To create more specific expectations for boundary defense and permeability in the Late Holocene San Juan Islands I apply the boundary defense/permeability concepts outlined in the previous chapter to the specific environment and settlement patterns of the San Juan Islands record. The arbitrary time periods chosen for both settlement pattern and lithic analysis are based on both paleoenvironmental shifts and the dating of the assemblages from the Watmough Bay site.

During the period from 3500-2500 cal BP, a cool wet terrestrial climate and a shift towards increased upwelling would have provided a resource supply that far exceeded the demands of a relatively low population. I predict minimal boundary defense and moderate boundary permeability reflecting longer-distance travel and the need to maintain large social networks to find marriage partners. Population may have risen slightly during the 2500-1600 cal BP period when terrestrial productivity was low and marine productivity was high. I propose that marine resources were still so abundant that people would not have defended boundaries around their villages. I predict minimal boundary defense and moderate boundary permeability reflecting longer-distance travel and the need to maintain large social networks to find marriage partners. During the 1600-1000 cal BP period, low terrestrial and marine productivity should be associated with minimal boundary defense on most of the landscape and high permeability on both land and water due to resource unpredictability. During the 600 cal BP-Contact period, with both high terrestrial and marine productivity and a higher population, communities located near adequately productive resource patches should defend boundaries against intruders more intensely and participate in more formal but less frequent boundary crossings (Table 2.2).

Table 2.2. Expectations for Late Holocene boundary defense and permeability for the San Juan Islands based on paleoenvironmental and demographic shifts.

				Boundary			
		Resources		**Defense**		**Permeability**	
San Juan Islands	**Population**	**Marine**	**Terrestrial**	**Water**	**Land**	**Water**	**Land**
600 cal BP-Contact	High	+	+	High	High	Low, formal	Low, formal
1600-1000 cal BP	Medium	-	-	Low	Low	High, informal	High, informal
2500-1600 cal BP	Medium	+	-	Low	Low	Moderate, informal	Moderate, informal
3500-2500 cal BP	Low	-	+	Low	Low	Moderate, informal	Moderate, informal

San Juan Islands Defensive Sites

Quantifying the abundance and distribution of defensive sites after 650 cal BP in the San Juan Islands provides information on the amount of effort people put towards the active defense of boundaries. Previous research on central Northwest Coast settlement patterns suggests an upsurge in defensive sites at approximately 900-1000 cal BP (Keddie 1984, 1996; Moss and Erlandson 1992). Angelbeck's (2009) archaeological, ethnographic, and ethnohistoric dissertation research on the Coast Salish indicates an increase in fortified defensive sites at 1600-500 BP and again during Euroamerican colonization. Radiocarbon dating on trench embankment sites for the Coast Salish shows an increase in sites at approximately 400 cal BP (Angelbeck 2009:262). Schaepe (2006, 2009) describes multi-village corporate family group defensive systems using built and natural structures on the Fraser River. Considering the San Juan Islands record alone, however, indicates minimal evidence of built defensive sites. Suttles (1949:70) notes defensive structures built by the Lummi and Anglebeck reports four trench-embankment fortifications on the southern islands. He also reports a rock-wall fortification on Hunter Bay on southern Lopez Island. Angelbeck (2009:224-225) notes that although some archaeologists have assumed that the Coast Salish were defending their territory against people who lived to the North, there is no concentration of defensive sites of any type at that border, rather they are relatively evenly dispersed throughout the region.

To determine if people in the San Juan Islands aggressively defended their boundaries during certain time periods, I look beyond built earthworks that can be affected by post-depositional processes and modern disturbances. I rely on natural site location and context to investigate the defensive potential of a site by using Martindale and Supernant's (2009) defensibility measures. Martindale and Supernant propose simple quantitative measures of visibility, site elevation, accessibility, and area that can be calculated for almost any site based on site forms and reports.

For this study, I focus on visibility and elevation measures because these can be calculated most accurately and they are more appropriate to the San Juan Islands sites that often have completely accessible approaches. Visibility is calculated as the degrees of visibility beyond 100 meters divided by the total degrees of approach around the site. Higher visibility is assumed to make a site more defendable than lower visibility because people would have more time to prepare for a potential attack. Elevation is measured as the slope measured from a point inside the site to a point just outside the site. A higher slope gives an advantage to defenders because it is more difficult for attackers to access the site and forces the attackers to congregate at an area near the defenders as they attempt to gain access, making them more vulnerable to a counter-attack (Martindale and Supernant 2009:195). I measure elevation change towards the water assuming that enemies are coming from water rather than land. The elevation measure is expressed as the ARCTAN of the elevation difference from the inside to the outside of the site divided by the site radius. Radians are converted into degrees and divided by 90 to provide a ratio between 0-1. I also calculate distance from site to a lookout point (point on the landscape with greater than 200 degrees of visibility over water) with the expectation that increased defensiveness should correspond with decreased distance to a lookout (Appendix A).

In comparing defensive characteristics of sites, I consider two sets of data. For the first dataset, I assign each site to the earliest time period to which it dates. For the second dataset, all multi-component sites are assigned to every time period to which they date. The first dataset emphasizes the period when the site location was first chosen since people may pick a site due to its defensive capabilities but continue to use it due to community tradition or for other less strategic reasons. The second dataset emphasizes each set of sites on the landscape used during each time period.

If boundary defense in the San Juan Islands was more intense at 600 cal BP-Contact, I expect a significantly higher value for visibility and elevation measures and lower measures for distance to lookout during this time period. Although only certain sites would be located near resource patches that would be worth the effort of defending, overall, higher values for these sites should increase the overall mean for sites dating to the 600 cal BP-Contact time period. I use one-way ANOVA tests to determine if differences in mean visibility, elevation, and distance to lookout measures for each time period are significantly greater than differences that might be produced by random sampling. The results of this analysis indicate no significant difference in defensibility measures between time periods for either the first or second dataset (Table 2.3, 2.4).

Table 2.3. Results of an ANOVA for visibility, elevation, and distance to lookout measures for sites in the San Juan Islands. Sites are assigned to the first time period in which they appear.

Time Per. (cal BP)	*n*	$\bar{x}$ Visibility	F	Sig.	$\bar{x}$ Elevation	F	Sig.	$\bar{x}$ Distance to lookout (m)	F	Sig.
600-Contact	32	0.44	0.191	0.477	0.24	0.477	0.7	358.13	0.68	0.569
1600-1000	8	0.49			0.19			400		
2500-1600	7	0.44			0.22			407.14		
3500-2500	4	0.41			0.18			750		

Table 2.4. Results of an ANOVA for visibility, elevation, and distance to lookout measures for sites in the San Juan Islands. Sites are assigned to every time period in which they are inhabited.

Time Per. (cal BP)	*n*	$\bar{x}$ Visibility	F	Sig.	$\bar{x}$ Elevation	F	Sig.	$\bar{x}$ Distance to lookout	F	Sig.
600-Contact	43	0.46	0.147	0.931	0.22	0.306	0.82	387.44	0.806	0.495
1600-1000	13	0.44			0.19			476.92		
2500-1600	10	0.43			0.2			485		
3500-2500	4	0.41			0.18			750		

I also used Student *t*-tests to compared mean defensibility values before 600 cal BP and after 600 cal BP, combining time periods prior to 600 cal BP when boundary defense is predicted to be least intense, and comparing that sample to sites dating to after 600 cal BP when boundary defense is expected to be least intense. Results of this analysis indicate no significant difference in mean visibility, elevation, or distance to lookout before and after 600 cal BP for either the first or second dataset (Table 2.5, 2.6). Potentially, the large sites that date to the 600 cal BP-Contact period could be considered sites near high-value resource patches that would be more likely to be defended. Considering all time periods, there is also no significant difference in mean visibility, elevation, or distance to lookout between big sites and small sites (Table 2.5). Considering only sites that date to 600 cal BP-Contact (using the dataset in which sites are included in every time period in which they appear), there is also no significant difference in mean visibility, elevation, or distance to lookout between big sites and small sites (Table 2.6).

Table 2.5. Results of *t*-tests comparing means for defensive measures for sites before and after 600 cal BP, equal variances not assumed. Dataset 1 = Sites are assigned to the period in which they first appear. Datset 2 = Sites are assigned to every time period in which they are inhabited.

Dataset 1	*n*	x̄ Visibilit	F	t	*p* (2-tailed)	x̄ Elev.	F	t	*p* (2-tailed)	x̄ Distance to lookout (m)	F	t	*p* (2-tailed)
Before 600 cal BP	19	0.45	1.83	0.22	0.83	0.2	0.89	-1.1	0.28	476.32	0.33	0.79	0.43
After 600 cal BP	32	0.44				0.24				358.13			
Dataset 2													
Before 600 cal BP	27	0.43	1.09	-0.614	0.541	0.19	2.21	-0.954	0.344	520.37	1.03	1.3	0.199
After 600 cal BP	43	0.46				0.22				387.44			

Table 2.6. Results of *t*-tests comparing means for defensive measures for big sites and small sites dating to all time periods. Results of *t*-tests comparing means for defensive measures for big sites and small sites dating to after 600 cal BP, equal variances not assumed.

All time period	*n*	x̄ Visibilit	F	t	*p* (2-tailed)	x̄ Elev.	F	t	*p* (2-tailed)	x̄ Distance to lookout (m)	F	t	*p* (2-tailed)
Big	14	0.42	6.87	-0.57	0.57	0.16	6.15	-1.87	0.067	567.86	0.486	1.44	0.157
Small	37	0.46				0.25				339.46			
600 cal BP-Contact													
Dataset 2													
Big	17	0.43	0.85	-0.92	0.36	0.2	0.01	-0.67	0.51	417.65	1.8	0.34	0.74
Small	26	0.48				0.23				367.69			

Overall, quantitative analysis comparing defensibility sites between time periods is not consistent with the prediction that people more actively defended their boundaries at 600 cal BP-Contact when resources at sites near productive resource areas were adequate to communities' needs. The dearth of evidence for trenches, fortifications, and other human-made modifications based on Angelbeck's (2009) research also suggests that violent conflict may not have presented a threat to people on the San Juan Islands during the Late Holocene.

Given the lack of change through time in defensive characteristics of sites, I also consider the sensitivity of the analyses to changes in territorial behavior. It is possible that the elevation and visibility indices used do not fully capture the ways that people defended sites against outsiders. Locations on the landscape that people considered acceptable for establishing communities may also have happened to have comparable defensive characteristics. Finally, it is also possible that the scale of active boundary defense against outside threats was greater than the village or even the San Juan Islands. If villages interconnected by kinship, marriage, and alliance defended themselves against outside threats from the north or the south, sites with higher defensive indices might exist at those boundaries.

The Southern Channel Island Study Area and San Nicolas Island

The Channel Islands of the Southern California Bight stretch from Point Conception to the border between the United States and Mexico. The northern group of islands in the Santa Barbara Channel region include Anacapa, Santa Cruz, Santa Rosa and San Miguel. They are associated with the Island Chumash band of the Chumash Nation. Channel Islands to the south include Santa Catalina, Santa Barbara, San Clemente and San Nicolas Island. These islands are within the traditional territory of the Tongva people (Johnston 1962). That the Tongva are Uto-

Aztecan speakers like the Western Shoshone to the east while the Chumash are Hokan speakers suggests a possible incursion of peoples from the east into the southern Channel Islands during the Late Holocene. Researchers use evidence from linguistic data (Kroeber 1976), bead styles (Howard and Raab 1993; Vellanoweth 2001a), and human osteology (Reinman and Townsend 1960) to determine when a possible incursion occurred but different evidence points towards different dates. The communities that lived on San Nicolas Island are referred to as the Nicoleño. The most isolated of the Channel Islands, San Nicolas Island is located 98 kilometers from the mainland and is approximately 5.6 kilometers long and 13 kilometers wide (Vellanoweth et al. 2002). The land is now owned and managed by the United State Navy. The modern coastal landscape is characterized by both rocky and sandy beaches and the interior is a large plateau covered in sand dunes. The archaeological record in both coastal and inland areas is dominated by shell-bearing sites, many of which are located on sand dunes (Afifi 2000).

The southern Channel Islands culture history begins with short term seasonal occupations during the Terminal Pleistocene (13,000-10,000 cal BP) and Early Holocene (10,000 cal BP-7500 cal BP). Based on assemblages from early sites, particularly the well-documented Eel Point site (SCLI-43) on San Clemente Island, people relied on marine resources from the first human settlement of the islands (Erlandson 1994; Erlandson et al. 2009, 2011; Rick et al. 2005a). Early sites on the northern Channel Islands indicate a marine-oriented adaptation, emphasis on rocky shore shellfish, and secondary reliance on fish and birds (Rick et al. 2001). Formal chipped stone tools are rare, but leaf-shaped bifaces, crescents, and small contracting stem points have been found. The first appearance of *Olivella biplicata* shell beads associated with exchange networks occur at several sites. Ornaments are rare (Cannon 2006; Rick et al. 2005a).

During the Middle Holocene (7500-4500 cal BP), more people moved to the Channel Islands and lived there year-round. They continued to focus on marine resources, particularly kelp bed environments, and incorporated a greater variety of fish and shellfish in their diet. An increase in the number of inland site and artifacts associated with plant resources such as mortars and pestles (Basgall 1987) suggests an increase in use of inland areas. Technology remains similar to the Early Holocene except for the appearance of side-notched and contracting stemmed points and increased diversity in stone, bone, and shell tools (Cannon 2006; Rick et al. 2005a). Throughout the Channel Islands, evidence of social complexity—increased sedentism, permanent houses, exchange, and social hierarchy—first appears during the Middle Holocene and intensifies during the late Holocene after approximately 3500 years ago (Glassow 2004; Rick et al. 2005a). Based on AMS dating of ornamental shell beads, long distance exchange networks between the southern Channel Islands and the mainland date back at least 5000 years (Vellanoweth 2001a) and there is an increase in variety of bead styles throughout the Middle Holocene (Rick et al. 2005a).

By the Late Holocene (4500 cal BP-Contact), there is evidence on both the northern and the southern Channel Islands for increased complexity with larger and more sedentary villages, more exchange, sophisticated craftwork, evidence of social stratification, and complex ritual practices (e.g., Arnold 2001, 2004; Bartelle et al. 2010; Vellanoweth et al. 2008). Lambert (1993, 1994) proposes that analyses of human remains from the northern Channel Islands provide evidence of increased population density, circumscription, and inter-group violence. During this period, new tools appear including the single-piece fishhook, toggling harpoon, and small projectile points. On the northern Channel Islands, chert microblade technology flourished. Stone tool technology is mainly characterized by expedient stone and bone tools and small projectile points. People focused on marine resources but pursued more deep water fish, decreased their reliance on shellfish, and increased the variety of shellfish that they gathered (Rick et al. 2005a).

Southern Channel Islands Paleoenvironment

Today, the southern Channel Islands climate is characterized as a "Mediterranean" climate with mild temperatures during both the dry summers and wet winters. Dominant plant taxa include the giant coreopsis (*Coreopsis gigantea*), rattlesnake weed (*Daucus pusillus*), silver beach weed (*Ambrosia* chamissonis), and coyote brush (*Baccharis pilularis*). A large percentage of the annual precipitation comes in the form of fog; the island receives only 16.5 centimeters of rainfall annually (Vellanoweth et al. 2002:83). Freshwater is mainly located in the northwest part of the island where there are 12 perennial springs and seeps (Burnham et al. 1963; Vellanoweth et al. 2002:83). San Nicolas Island lacks richness and diversity in terrestrial flora and fauna but marine upwelling and mixing creates a productive marine environment (Rick et al. 2005a).

To use the San Nicolas Island archaeological dataset to test a set of hypotheses on the relationship between territorial strategies and resource distribution requires a review of the paleoclimate record. It also requires a consideration of the impact of climate change on the abundance, predictability, and distribution of marine and terrestrial subsistence resources and freshwater.

Marine Paleoclimate in the Channel Islands

Below, I review paleoclimatic reconstructions of ocean upwelling, sea surface temperature, and terrestrial temperature and precipitation to establish a chronology of resource availability for San Nicolas Island. Sea surface temperature fluctuated significantly in the

Channel Islands during the Late Holocene, affecting the productivity of marine resources. Marine paleoclimate research has centered mainly on the Northern Channel Islands. A 25-year resolution oxygen isotope analysis of sediment cores from the Santa Barbara Basin indicate cool sea surface temperatures between approximately 3800-2900 BP, warm sea surface temperatures between 2900-1500 BP, coolest sea surface temperatures between 1500-500 BP, and a return to warm sea surface temperatures between 500-Contact (Kennett and Kennett 2000; Kennett 2005). Oxygen isotope data on a large sample of California mussel shells from the Northern Channel Islands also suggests colder sea surface temperature at 1400-400 cal BP and possibly at 250 cal BP (Kennett and Kennett 2000). These findings contradict previous work by Pisias (1978, 1979) who analyzed changes in radiolarian assemblages in a Santa Barbara Basin sediment core, potentially due to problems with the stratigraphic integrity of the core (Kennett and Kennett 2000:382). Future work may further clarify change over time in sea surface temperature in the Santa Barbara Basin, but for the purposes of this study I follow Kennet and Kennett's interpretation.

Sea surface temperature alone is not enough to determine marine productivity in the Southern California Bight. Researchers use a marine productivity index based on temperature differences between surface ocean water and deep ocean water. This index demonstrates degree of upwelling and other features of ocean circulation. Temperatures at the surface and in deeper water are determined using oxygen isotope data on planktonic foraminifera that live in those environments (Kennett 2005:67; Kennett and Kennet 2000:383-384; Kennett et al. 1995, 2007:352-353; Pak et al. 1997; Pak and Kennett 2002). Marine productivity index results demonstrate high productivity at 3800-2800 cal BP and 1000-500 cal BP. Despite cold temperatures at 1500-1000 cal BP, upwelling did not increase in intensity (Kennett 2005; Kennett and Kennett 2000; Kennett and Ingram 2005).

Regarding the terrestrial record, Kennett and Kennett (2000) suggest that during the Late Holocene, terrestrial drought correlates relatively well with times of cold sea surface temperature. Larson and Michaelson's (1989) tree-ring data from the southern California Bight and Stine's (1994) lake level data from the Sierra Nevadas indicate droughts at 1450-1150 and 970-700 cal BP. Gamble (2005:96) argues that these data are not convincing because Michaelson and Larson's data has not been published and Stine's data is from outside the region. However, pollen data from the Twin Rivers Marsh, San Nicolas Island indicates that between 1375-1250 and 920-420 BP, conditions were warmer and drier with cooler and wetter periods in between (Davis et al. 2003) (Figure 2.5). People also experienced substantial environmental variability at a decadal scale due to El Niño/Southern Oscillations (ENSO) events (Gamble 2005:98; see also Sandweiss et al. 1996 for analysis of ENSO events in Peru).

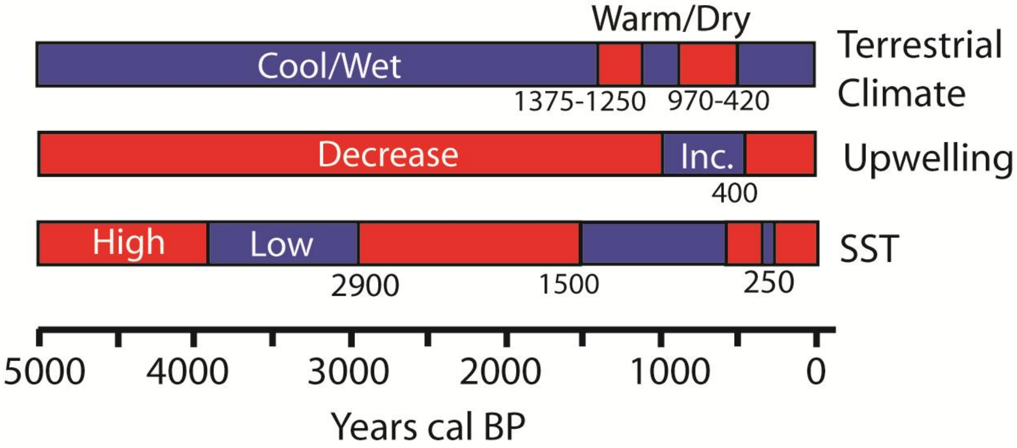


Figure 2.13. Climate change expressed through precipitation, upwelling, and sea surface temperature for the Middle and Late Holocene, San Nicolas Island.

Marine Resources and Climate Change in the Channel Islands

The paleoclimate record tells part of the story of human interaction with the environment, but it also important to consider more specifically how the resources that people depended on were affected by climate change. Regarding marine resources, people mainly focused on the intertidal and nearshore areas. Shellfish were a consistent staple of Channel Islanders' diet (Glassow 1980; Kennett 1998). Common taxa include five species of abalone (*Haliotis* spp.), California mussel (*Mytilus californianus*), wavy topshell (*Astraea undosa*), limpet (*Lottia gigantean, Megathura cenulata, Fissurella volcano*), chiton (*Mopalia ciliate, Cryptochiton stelleri*), norris top shell (*Norrisia norrisi*), and turbans (*Tegula* spp.) (Vellanoweth et al. 2002:84; Cannon 2006). People also caught fish from a variety of trophic levels including cabezon (*Scorpaenichthys marmoratus*), California sheephead (*Semicosyphus pulcher*), lingcod (*Ophiodon lingatus*), rockfish (*Sebastes spp.*), surfperch (*Embiotocidae*), swordfish and marlin (*Xiphiida*), *and* tunas (*Scombridae*) (Erlandson et al. 2009:715). They hunted sea mammals including sea otters (*Enhydra lutris*), California sea lions (*Zalophus californianus*), northern elephant seals (*Mirounga angustirostris*), and Pacific harbor seals (*Phoca vitulina*). The archaeological record also demonstrates use of marine birds such as cormorants (*Phalacorcorax* spp.) and gulls (Laridae) (Erlandson et al. 2009:715; Vellanoweth et al. 2002:84-85).

The main impact of marine climate change on the Nicoleño's marine food source would have been declines in fish and shellfish communities caused by damage to plant communities of the nearshore and intertidal zone during times of warmer sea surface temperature. Kelp (*Macrocystis* spp.) forests that grow along a submarine shelf extending four kilometers offshore (Cannon 2006:46; Engle 1994:18) decline when sea surface temperature is high. They are particularly vulnerable if nutrient availability is low, as is often the case in southern California

(Dayton et al. 1999; Edwards 2004; Tegner et al. 2001; Gerard 1997; Steneck et al. 2002). Long term sea surface temperature above 20 degrees celcius destroys kelp forests and reduces marine productivity. This is observed during ENSO events every several years (Kennett and Kennett 2000:381). Taxa that rely on the kelp forest ecosystems of southern California include sea urchins, abalone (*Haliotis* spp.), sheephead fish (*Semicossyphus pulcher*), spiny lobster (*Panulirus interuptus*), sea snail (*Tegula* spp.), halfmoon fish (*Medialuna californiesis*), greenfish (*Girella nigricanus*), and sea otter (*Enhydra lutris*), (Steneck et al. 2001:440). A recent study on abalones indicates that they rely on drift kelp to feed, and that warm temperatures also hinder their larval dispersal (Tegner et al. 2001). Abalones were a major source of food and tools for native communities and were also a food source for sea otters (*Enhydra lutris*).

Terrestrial Resource and Climate Change in the Channel Islands

Important terrestrial resources in the region include silver lupine (*Lupinus albifrons*), malva rosa (*Lavatera assurgentiflora*), Morman tea (*Ephedra* sp.), prickly pear cacti (*Opuntia* littoralis), and sage (*Penstemom speciosus*) (Thomas 1995; Yatsko and Raab 2009). At SNI-35, soil samples were analyzed for macrobotanical remains and included wild cucumber (*Marah* sp.), red maids (*Calandrinia* sp.), legume family (Fabaceae), manzanita (*Arctostaphylos* sp.), and blueberry/huckleberry (*Vaccinium* sp.) Pollen found on ground stone indicates processing of cheno-am, and sagebrush and sea grass may have been used to make containers (Thomas 1995:27). Fuel wood like silver lupine may have been depleted on the island by the Late Holocene (Vellanoweth 2001b:205). Domestic dog (*Canis familiaris*) and island fox (*Urocyon littoralis*) were the largest native land animals. Smaller animals such as the island night lizard

(*Xantusia riversiana*), side-blotched lizard (*Uta stansburiana*), white-footed deer mouse (*Peromyscus* maniculatus), and land snail (*Micrarionta* spp.) would not have been a significant food source due to their small size (Vellanoweth 1998; Vellanoweth et al. 2002).

Regarding the terrestrial environment of San Nicolas Island, droughts would have been a significant problem because surface water is limited in the summer months (Rick et al. 2005a: 173). Yatsko (2000a, 2003) tests the hypothesis that human settlement on San Clemente Island was significantly affected by drought conditions during the Medieval Warm Period and finds that water would have been limited under the best conditions. People relied to a greater degree on plentiful marine food resources (Vellanoweth et al. 2002:84), but plants in particular were likely an important source of carbohydrates and nutrients.

Settlement Pattern Data for San Nicolas Island

Settlement pattern data for San Nicolas Island provides important insights into demographic data, distribution of communities relative to resources, and active defense of village boundaries. Much of the settlement pattern research on San Nicolas Island was conducted by California State University Los Angeles (CSULA) archaeologists in the 1990s who surveyed sites and excavated index units from a variety of environmental zones including the inland plateau, the slope, and the coastal plain (Martz and Rosenthal 2001; Martz 2002, 2008). The CSULA project recorded a total of 535 sites and obtained 68 radiocarbon dates from 41 sites. Site sampling has also been conducted as part of cultural resources management projects by Petra Resources and Statistical Research (Vellanoweth et al 2002) and through other archaeological investigations bringing the total number of dated sites on San Nicolas Island to 61 sites. Many sites have components dating to more than one period. Afifi's (2000) research on site location preference suggests that people may have preferred dune sites for habitation site locations and non-dune areas for special purpose sites. Village sites also tend to be closer to the ocean that special purpose sites, although preferences for locations of special purpose sites changed through time.

Site destruction caused by modern activities presents a challenge to settlement pattern analysis on San Nicolas Island. The landscape has undergone dramatic changes in the last hundred years due to erosion, which has been accelerated by denudation of the landscape caused by sheep grazing from 1857 through the 1950s (Martz et al. 2005:67). Modern disturbance caused by construction of roads, buildings and other Navy activities has also impacted some sites. Lastly, much of the Terminal Pleistocene/Early Holocene record of the Southern California Coast has been inundated by ocean waters that lay 90 meters below present levels at 14,000 BP and rose to 30 meters below present by 10,000 BP. Relative sea level continued to rise gradually through the Holocene. At 8000 RCYBP the shoreline was 10 meters below its present level, at 6000 RCYBP it was 5 meters below present, and by 5000 RCYBP it reached modern levels (Inman 1983; Masters and Aiello 2007). Lack of commercial and private development has preserved the archaeological record on San Nicolas Island, as has the lack ground squirrels and other burrowing animals.

The oldest site on San Nicolas Island is CA-SNI-339. It is located on the southeast coast and dates to nearly 8000 cal BP (Schwartz and Martz 1992). The number of sites on the island (and possibly population density) increases in the Middle Holocene after about 6500 cal BP, especially along the northwest coast of San Nicolas Island. A total of 22 sites date to this period. Site types include habitation sites, lithic sites, and shellfish processing sites (Martz 2005). During the Late Holocene, an increase in the number of sites to 42 and an increase in dispersion of sites across the island parallels an increase in population and multifamily sedentary villages in the southern Channel Islands and Los Angeles Basin (Koerper and Drover 1983; Rick et al. 2005a; Vellanoweth et al. 2002).

By plotting the sites on a map in 500 year intervals, it is possible to see finer-grained patterns in the distribution of site types (Figure 2.14-2.24). Dates are calibrated using CALIB 6.0 (Suiver et al. 2010). For marine shell, I applied a Marine09 calibration (Reimer et al. 2004) and ΔR value of 225 ± 35 (Kennett et al. 1997; Prior et al. 1999; Rick et al. 2005b; Vellanoweth 2001a). Prior to 5000 cal BP until 3000 cal BP, most sites are residential and are concentrated on the northwest coast of the island. A few camps and lithic sites are also apparent at 5000-4000 cal BP. At 3000-2500 cal BP there is an increase in sites on the plateau. There is an increase in non-habitation sites at 2500-2000 cal BP. Site frequency appears to decrease at 2000-1500 cal BP but increases afterwards. A summed probability plot using 159 radiocarbon dates from 61 sites across the island indicates possible peaks in population just after 3000 cal BP and later at 1000-500 cal BP (Figure 2.25). Ethnographic research on the proto-historic period suggests that the pre-contact population may have been between 600-1,200 individuals on San Nicolas Island. The total number of Tongva on the islands and the mainland is estimated at approximately 5000 (Bean and Smith 1978:539-540; McCawley 1996).

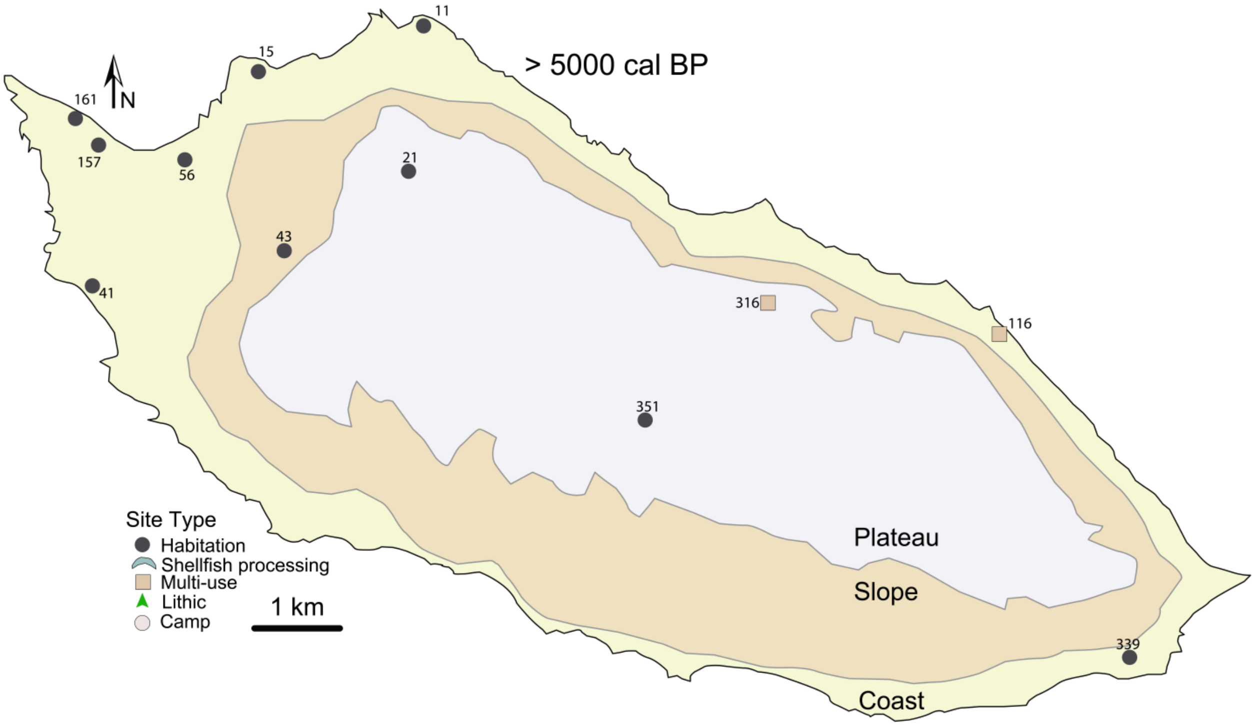


Figure 2.14. Site distribution on San Nicolas Island prior to 5000 cal BP. Numbers indicate site numbers recorded in the California Office of Historic Preservation site database.

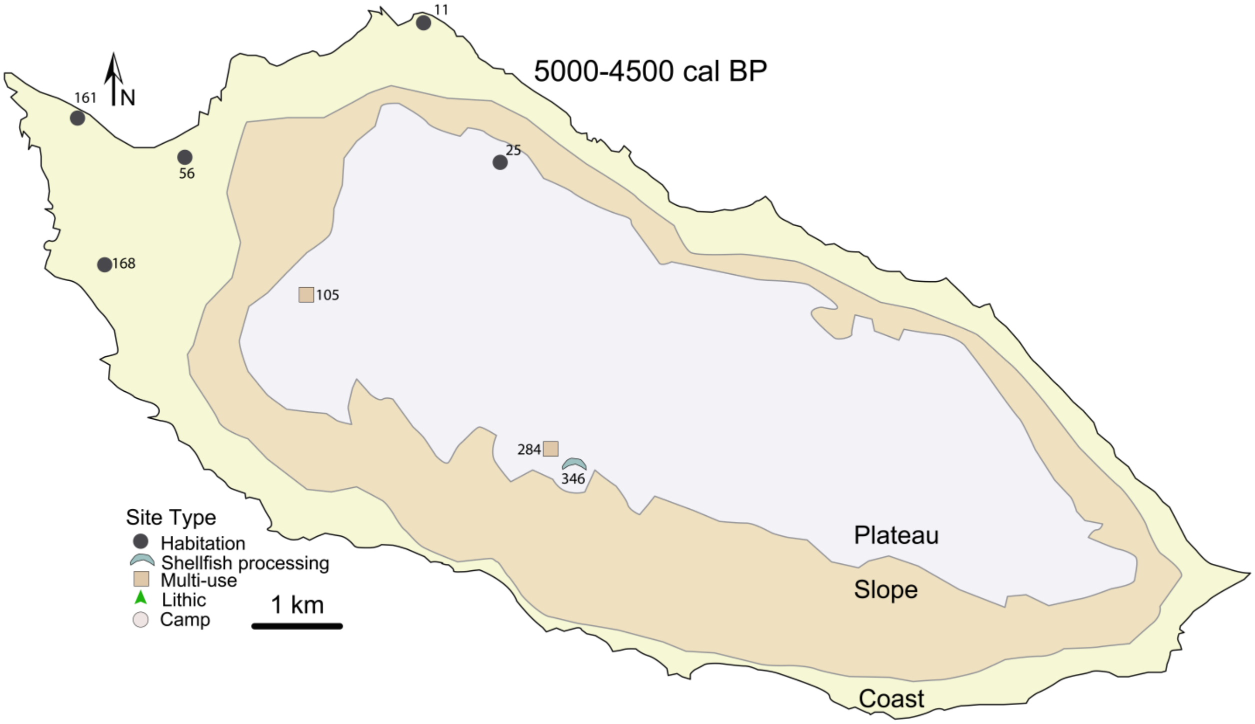


Figure 2.15. Site distribution on San Nicolas Island at 5000-4500 cal BP. Numbers indicate site numbers recorded in the California Office of Historic Preservation site database.

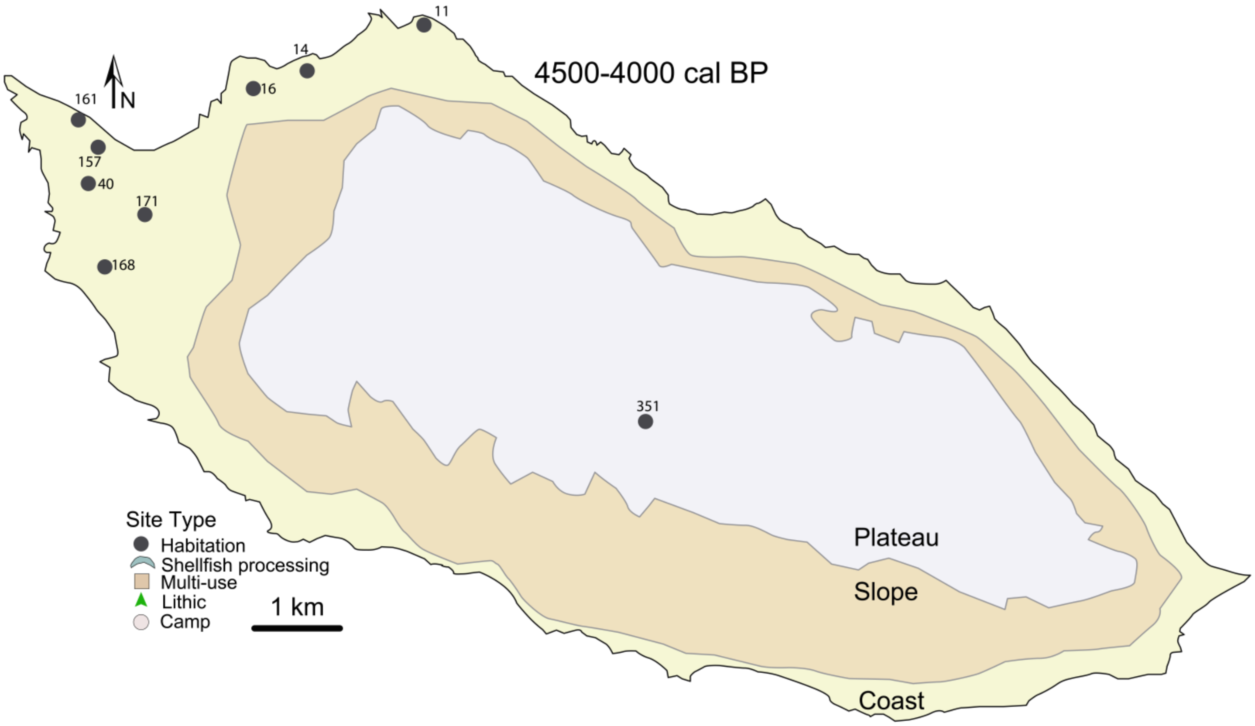


Figure 2.16. Site distribution on San Nicolas Island at 4500-4000 cal BP. Numbers indicate site numbers recorded in the California Office of Historic Preservation site database.

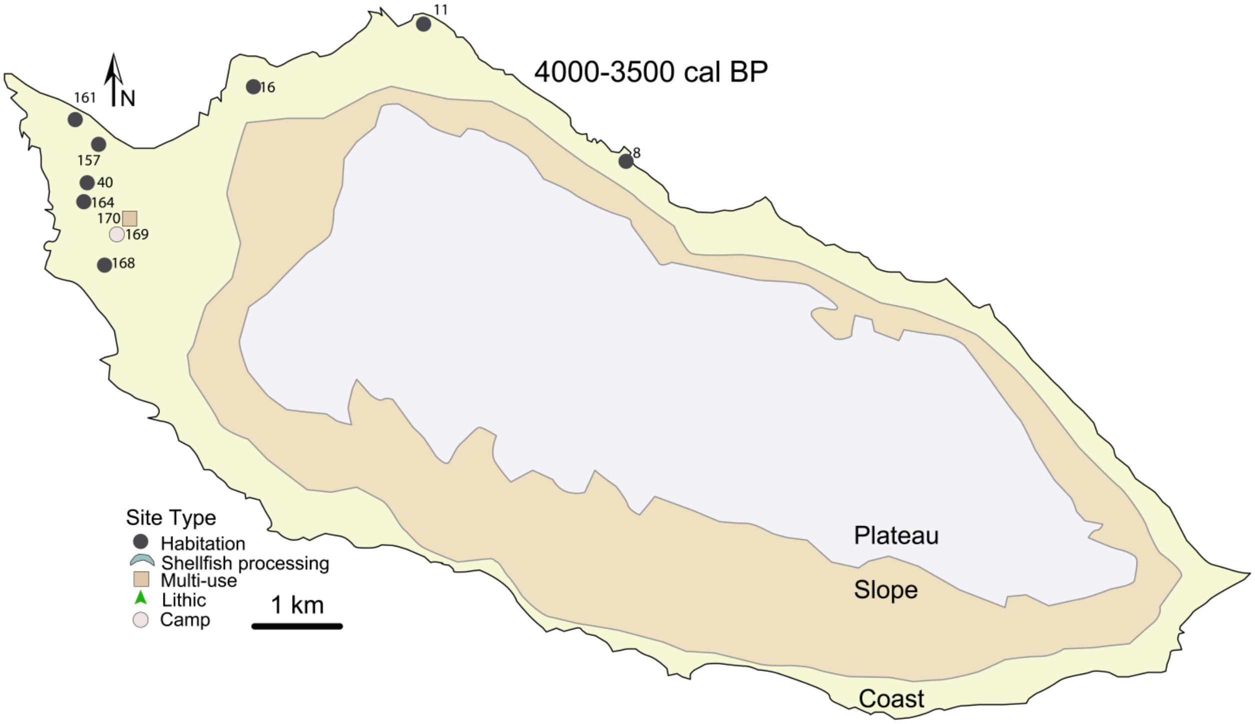


Figure 2.17. Site distribution on San Nicolas Island at 4000-3500 cal BP. Numbers indicate site numbers recorded in the California Office of Historic Preservation site database.

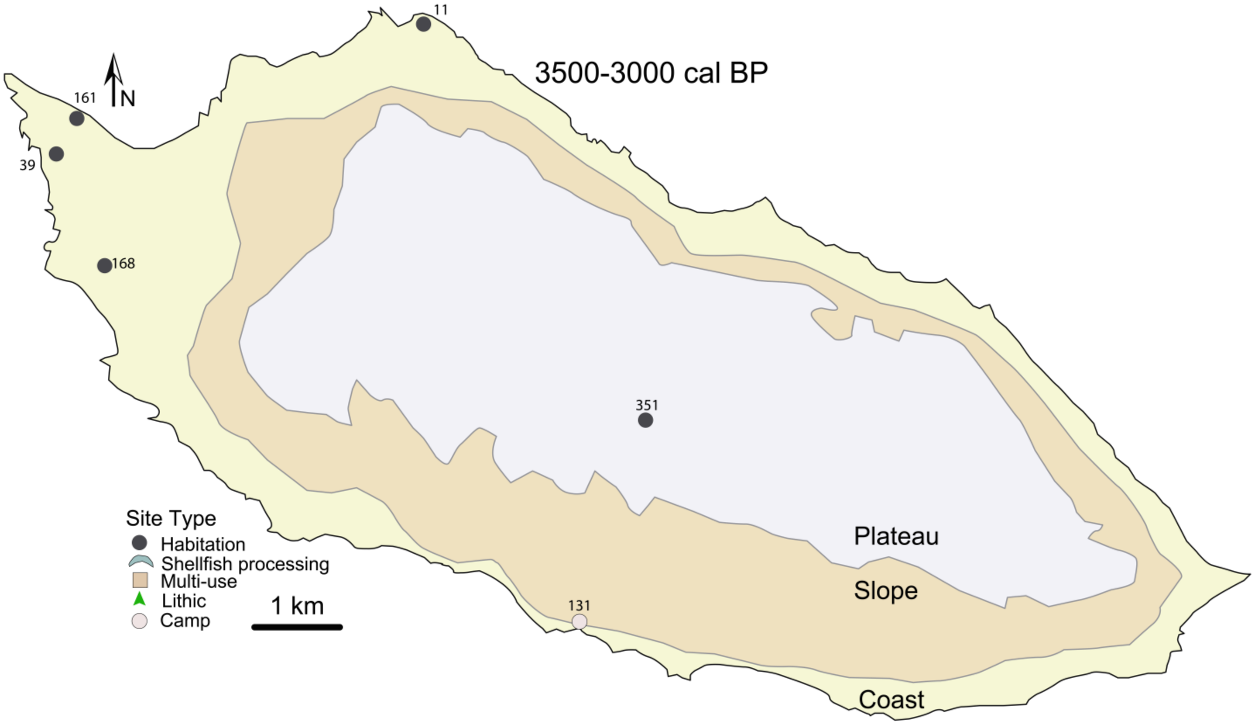


Figure 2.18. Site distribution on San Nicolas Island at 3500-3000 cal BP. Numbers indicate site numbers recorded in the California Office of Historic Preservation site database.

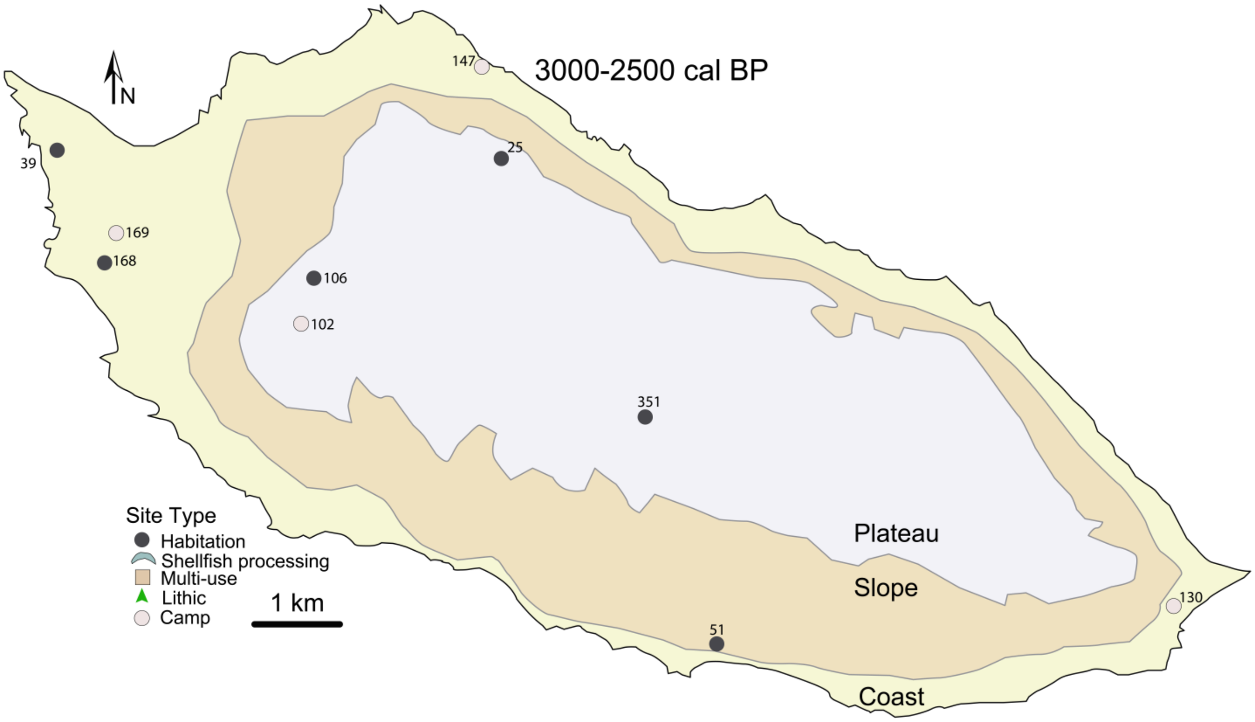


Figure 2.19. Site distribution on San Nicolas Island at 3000-2500 cal BP. Numbers indicate site numbers recorded in the California Office of Historic Preservation site database.

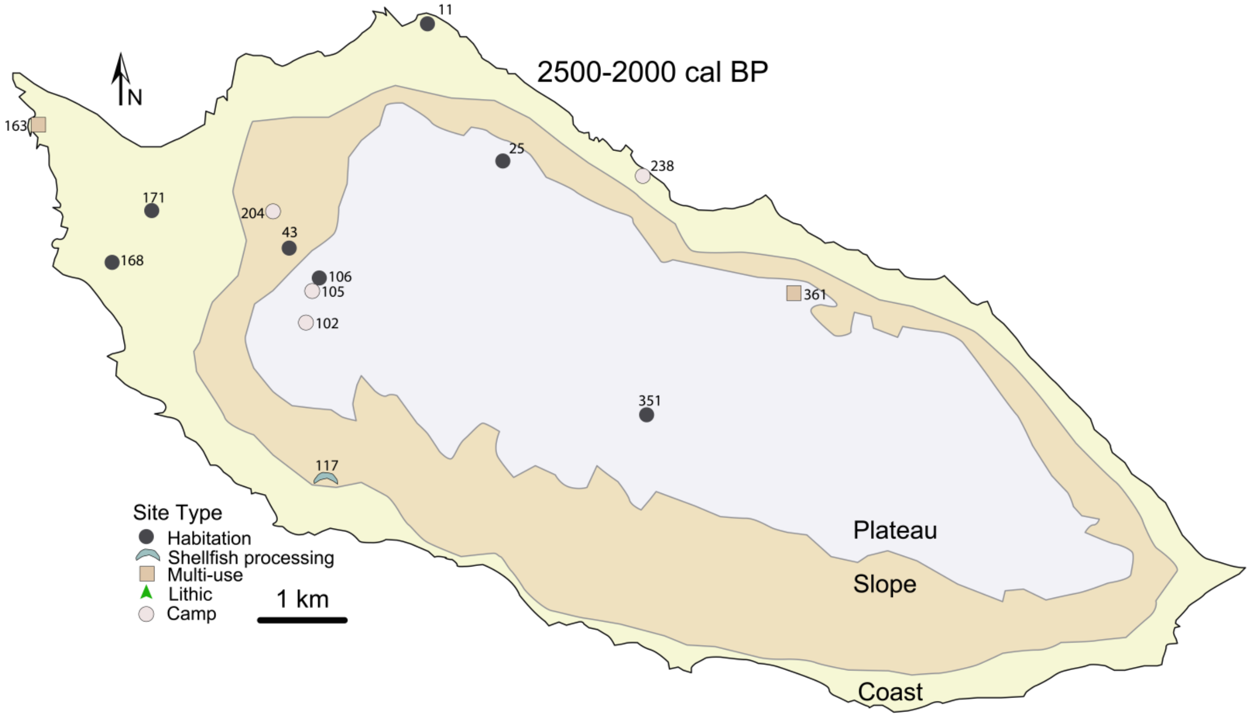


Figure 2.20. Site distribution on San Nicolas Island at 2500-2000 cal BP. Numbers indicate site numbers recorded in the California Office of Historic Preservation site database.

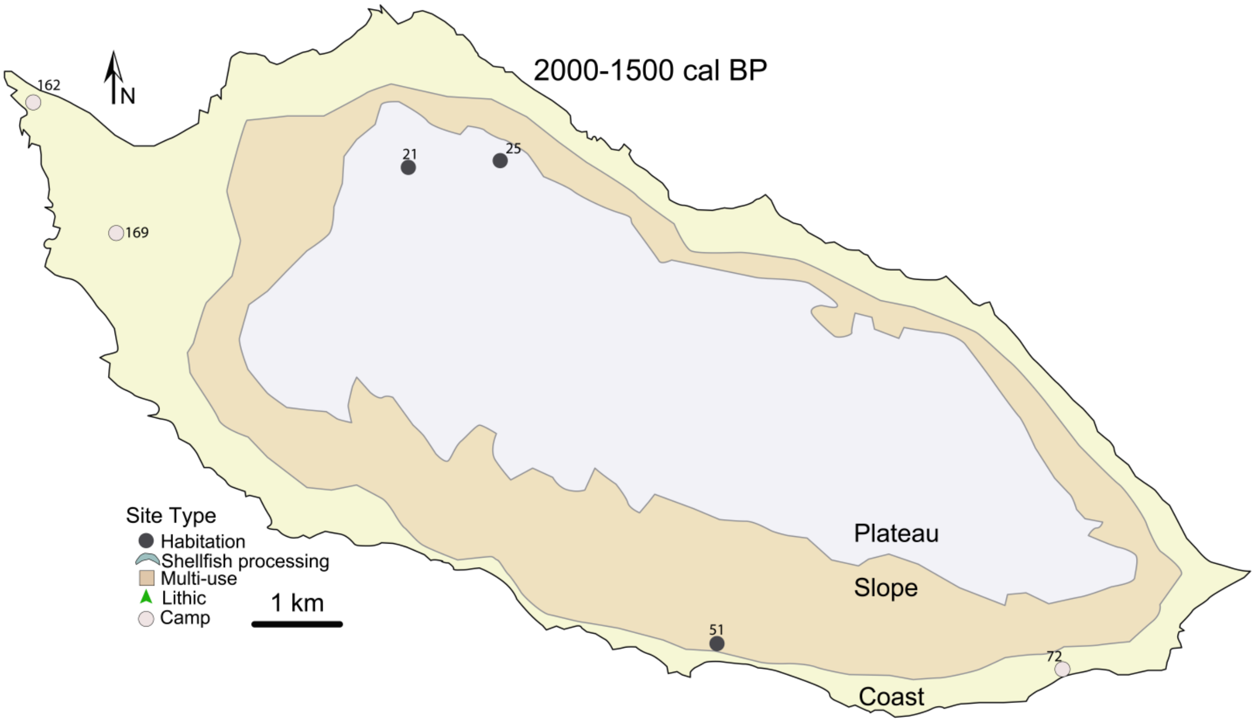


Figure 2.21. Site distribution on San Nicolas Island at 2000-1500 cal BP. Numbers indicate site numbers recorded in the California Office of Historic Preservation site database.

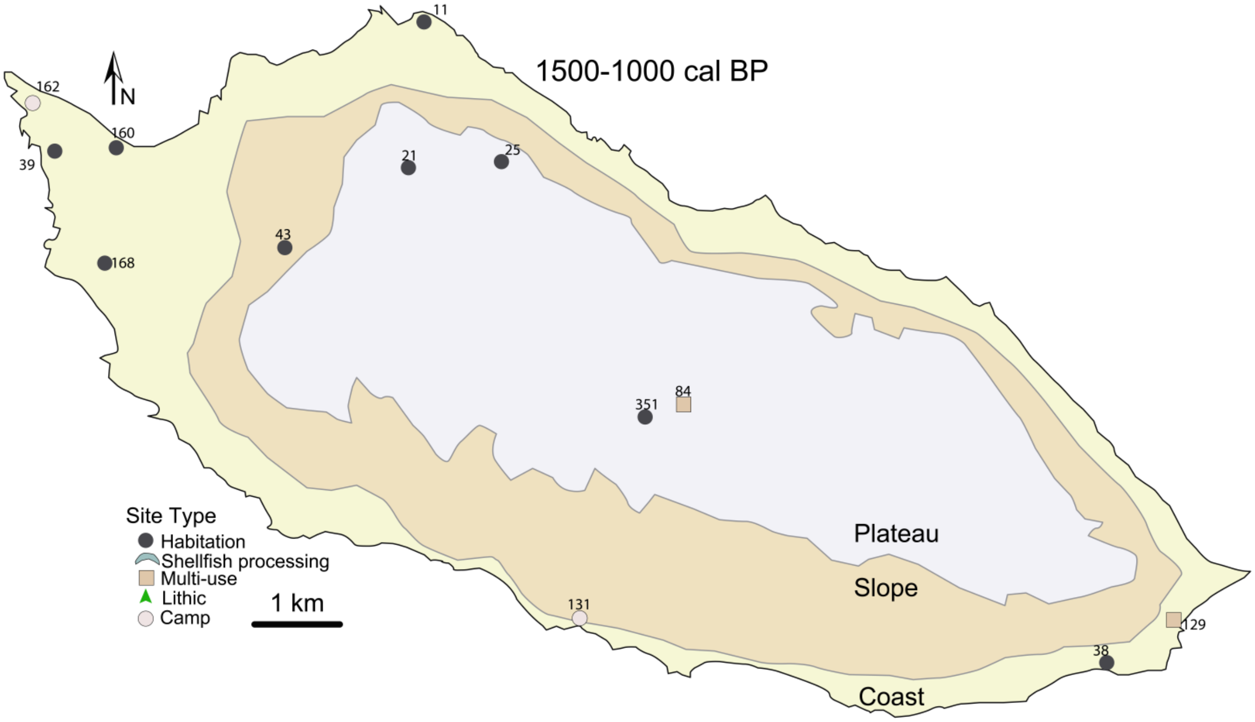


Figure 2.22. Site distribution on San Nicolas Island at 1500-1000 cal BP. Numbers indicate site numbers recorded in the California Office of Historic Preservation site database.

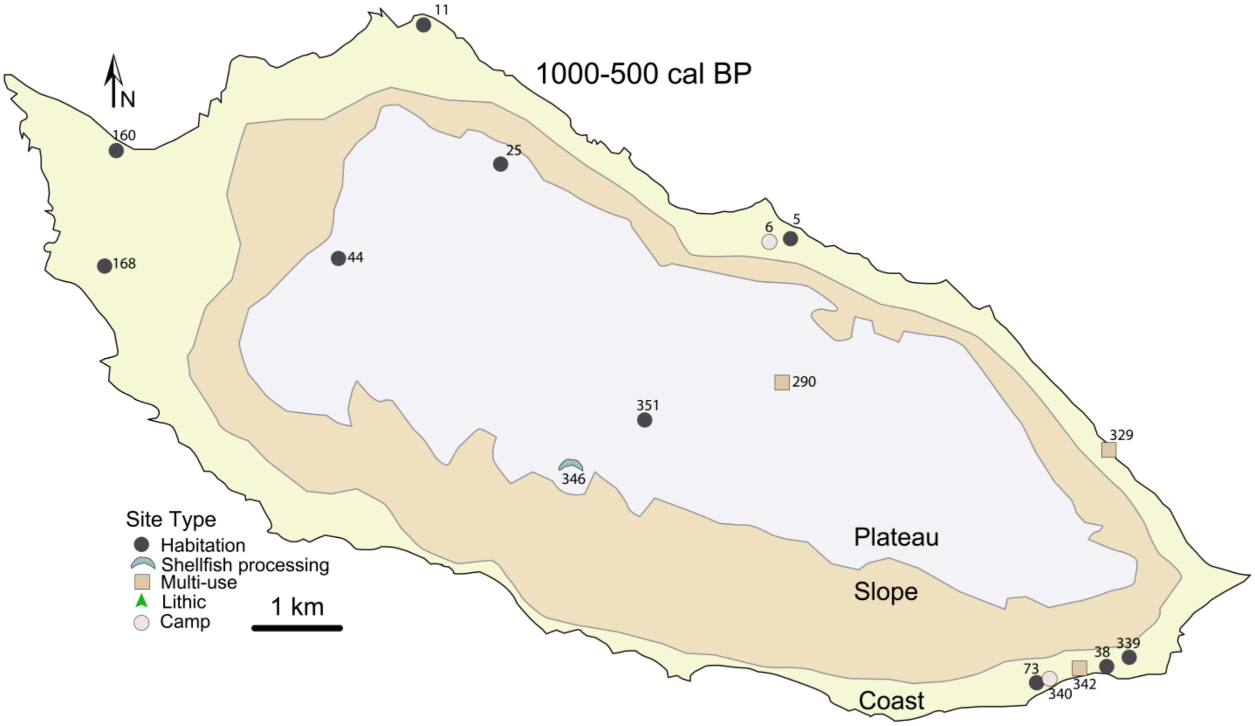


Figure 2.23. Site distribution on San Nicolas Island at 1000-500 cal BP. Numbers indicate site numbers recorded in the California Office of Historic Preservation site database.

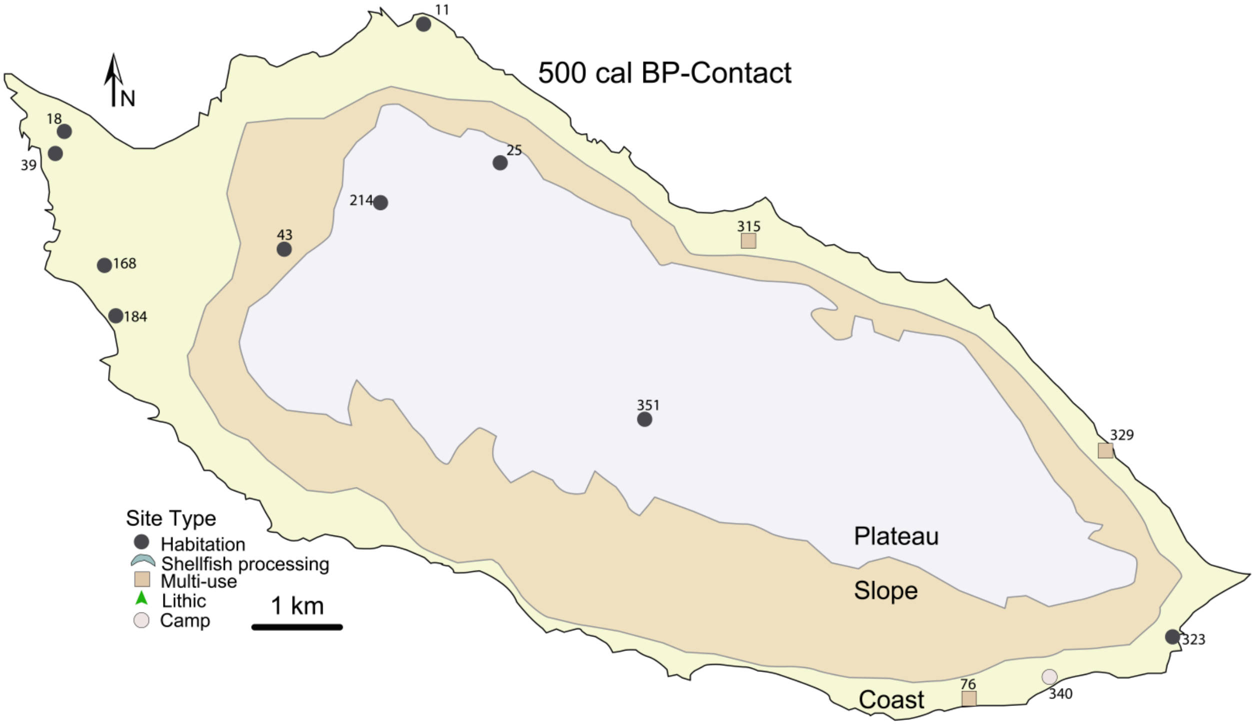


Figure 2.24. Site distribution on San Nicolas Island after 500 cal BP. Numbers indicate site numbers recorded in the California Office of Historic Preservation site database.

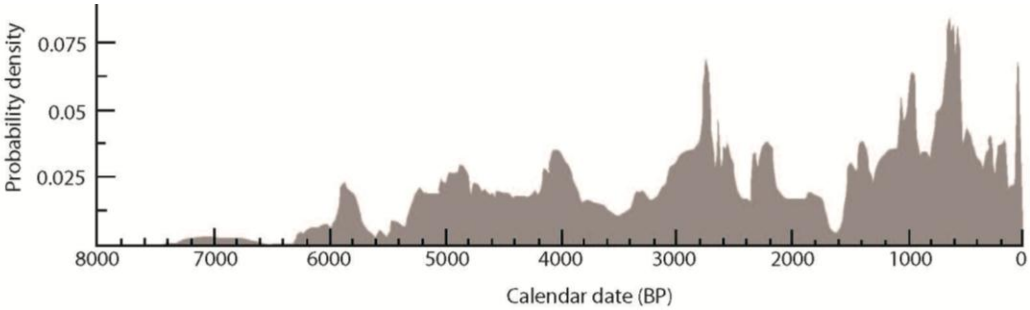


Figure 2.25. Summed probability plot for San Nicolas Island (*n* = 159 radiocarbon dates from 61 sites). Following the same protocol as Lepofsky et al. (2005), this plot incorporates only one date per site per 200-year interval to ensure that the better-dated sites do not bias the chronology.

Territoriality Predictions for San Nicolas Island

Based on paleoenvironmental shifts and settlement pattern data for San Nicolas Island, I propose a chronology for boundary defense and permeability. The arbitrary time periods used for both settlement pattern and lithic analysis are based on paleoenvironmental shifts and dating for the lithic assemblage from Tule Creek Village, Mound B. At 5000-4000 cal BP, I predict minimal boundary defense due to a low population. Costs of inter-group interactions may outweigh the benefits, but some informal interaction should occur to preserve social networks for marriage partners and exchange of prestige objects. At 3000-1500 cal BP and 500 cal BP-Contact, a cool and productive terrestrial climate should provide adequate food and water resources but due to a higher population, boundary defense should be focused on inland areas near highly productive resource patches. Less productive marine areas should be shared by a number of villages. Boundaries in inland areas should be less permeable than those in marine areas due to higher costs and lower benefits of inter-group interactions. For the 1500-500 cal BP period, adequate marine resources and impoverished terrestrial resource should encourage more boundary defense in highly productive marine areas. Due to lower costs and higher benefits of exchange and reciprocal access , informal inter-group interactions in marine areas should increase (Table 2.7).

Table 2.7. Prediction for boundary defense and permeability for San Nicolas Island based on paleoenvironmental and settlement pattern shifts during the Late Holocene.

		Resources		**Defense**		**Permeability**	
San Nicolas Island	**Population**	**Marine**	**Terrestrial**	**Water**	**Land**	**Water**	**Land**
500 cal BP-Contact	High	-	+	Low	High	High, informal	Low, formal
1500-500 cal BP	High	+	-	High	Low	Low, formal	High, informal
3000-1500 cal BP	High	-	+	Low	High	High, informal	Low, formal
5000-4000 cal BP	Low	-	+	Low	Low	Moderate, informal	Moderate, informal

Defensive Sites on San Nicolas Island

No sites with trenches, ditches, walls, or other evidence of defensive earthworks have been reported on San Nicolas Island. Lambert (1997) notes that on the narrow coastal plains of the Santa Barbara Channel, defensive sites are rare and poorly preserved. Kennett (2005:180-183) suggests that in the Late Holocene/Early Contact Period, the even distribution of communities on the Northern Channel Islands and lack of intervisibility between them is indicative of the partitioning of island areas into small territories owned by lineal descent groups. These groups were connected through marriage but in competition over resources. He suggests that the large village sites on Santa Rosa Island and San Miguel Island from this period are located near perennial water sources and strategically positioned to provide a view over the ocean and coast, suggesting defense against potential threats from the mainland or nearby villages. He also proposes that some villages had secondary habitation sites in the interiors to maintain access to interior plant resources and keep watch over the interior. Cemeteries may have served as territorial markers.

To test my predictions for boundary defense, I calculate Martindale and Supernant's (2009) measure for elevation, the ARCTAN of the elevation difference from the inside to the outside of the size divided by the site radius. I also calculate distance from site to a lookout point (greater than 200 degrees of visibility over water) (Appendix B). Site location is classified based on plateau, slope (steep escarpment slope from the plateau to the coastal plain), and coastal plain. As for the San Juan Islands case study I use two datasets to test the predictions below, one where sites are assigned to the earliest time period to which they date and one where sites are assigned to all time periods to which they date.

Based on the predictions for territorial behavior discussed above, if boundary defense is low at 5000-4000 cal BP, I predict significantly lower values for elevation and higher values for distance to lookout during this time period. In other words, site location should be chosen without regard to defensive qualities. The 3000-1500 cal BP and 500 cal BP periods should have higher values for inland sites and lower values for marine sites where boundary defense is predicted to be low. The reverse should be true for the 1500-500 cal BP period. Although boundary defense should only be higher at certain sites near productive resource areas, the higher defensive values for those sites should increase the overall mean elevation and distance to lookout values. The types of sites during these time periods should also differ in location with more residential sites located near important and productive resource patches.

Results of an ANOVA for both datasets indicate no significant differences between time periods in mean elevation or distance to lookout for all sites. This is the case if all sites are considered, if only marine sites are considered, or if only terrestrial sites are considered (Table 2.8, 2.9). Results of a χ^2 test reveals no statistically significant difference in site location between time periods whether considering all sites (χ^2 = 4.22, 6 df, *p* = 0.646) or habitation sites only (χ^2 = 2.35, 6 df, Fisher's exact *p* = 0.88) (Table 2.10, 2.11).

Table 2.8. Results of an ANOVA comparing mean elevation and distance to lookout for >5000-3000 cal BP, 1500-500 cal BP, 3000-1500 cal BP, and 500-Contact. Sites are assigned to the first period to which they date.

Sites	Time Per. (cal BP)	n	$\bar{x}$ Elevation	F	Sig.	$\bar{x}$ Distance to lookout (km)	F	Sig.
All	> 5000-3000	26	0.19	0.046	0.99	1.22	0.69	0.56
	3000-1500	12	0.17			1.15		
	1500-500	14	0.18			1.07		
	500-0	8	0.17			0.75		
Coastal	> 5000-3000	9	0.25	1.52	0.23	0.64	0.45	0.72
	3000-1500	6	0.11			0.86		
	1500-500	6	0.17			0.63		
	500-0	6	0.2			0.55		
Plateau/Slope	> 5000-3000	17	0.15	0.9	0.46	1.52	0.31	0.82
	3000-1500	6	0.24			1.45		
	1500-500	5	0.22			1.88		
	500-0	2	0.12			1.35		

Table 2.9. Results of an ANOVA comparing mean elevation and distance to lookout for >5000-3000 cal BP, 1500-500 cal BP, 3000-1500 cal BP, and 500 cal BP-Contact. Sites are assigned to all time periods to which they date.

Sites	Time Per. (cal BP)	*n*	$\bar{x}$ Elevation	F	Sig.	$\bar{x}$ Distance to lookout (km)	F	Sig.
All	> 5000-3000	26	0.19	0.227	0.877	1.22	0.182	0.91
	3000-1500	21	0.17			1.34		
	1500-500	23	0.18			1.2		
	500-0	16	0.21			1.13		
Coastal	> 5000-3000	9	0.25	0.99	0.409	0.64	0.317	0.81
	3000-1500	8	0.16			0.76		
	1500-500	12	0.17			0.59		
	500-0	8	0.21			0.54		
Plateau/Slope	> 5000-3000	17	0.16	0.381	0.767	1.52	0.29	0.83
	3000-1500	13	0.19			1.7		
	1500-500	11	0.19			1.85		
	500-0	8	0.21			1.71		

Table 2.10. Site location counts for each time period. All sites are assigned to the first time period to which they date.

	Time Period (cal BP)			
	>5000-3000	3000-1500	1500-500	500-Contact
Coastal Plain	9	6	9	6
Slope	12	3	1	1
Plateau	5	3	4	1

Table 2.11. Site location counts for each time period. All sites assigned to all time periods to which they date.

	Time Period (cal BP)			
	>5000-3000	3000-1500	1500-500	500-Contact
Coastal Plain	9	8	12	8
Slope	12	7	5	4
Plateau	5	6	6	4

These results are not consistent with shifts in defensive site characteristics on San Nicolas Island that mirror environmental shifts hypothesized to be associated with changes in active boundary defense. I also cannot rule out the possibility that the lack of statistically significant differences in measures of defensiveness between time periods is the small sample size. It is possible that site locations were chosen for reasons other than their defensive capabilities.

Alternatively, the lack of change through time in defensive characteristics of sites mayindicate a problem with elevation and distance to lookout measures in investigating defense characteristics of sites. Perhaps boundary defense was achieved using built defensive features that did not preserve well over time or were destroyed by the post-depositional processes that have greatly altered the San Nicolas Island landscape. It is also possible that locations on the landscape that people considered acceptable for establishing communities due to protection from the elements and access to food and water also had similar defensive characteristics.

Conclusions

Many Pacific Coast archaeology studies attempt to link cultural changes and climate changes (e.g., Arnold 1992; Fladmark 1975, Glassow 1996; Prentiss and Chatters 2003; Johnson 2004; Kennett 1998; Kennett and Kennett 2000; Lambert 1997; Lepofsky et al. 2005; Mitchell 1971; Morgan 2009; Raab et al. 1995; Raab and Larson 1997). The challenge of these studies is to provide a strong chronology for environmental change, determine how specific aspects of that environmental change affected people, and to determine if a chronology of cultural change corresponds with the environmental changes. In this chapter, I have established a chronology of environmental change for both study areas, discussed the specific impact of environmental changes on subsistence resources, and used settlement pattern to determine when precontact population on the San Juan Islands and San Nicolas might have been high enough that subsistence resource supply was at or near the level of demand.

To begin to test the territoriality hypothesis discussed in Chapter 1, I used data on the defensive characteristics of archaeological sites to determine if increases in active defense correspond to time periods when resources were abundant. For both study areas, visibility, elevation, and distance to lookout did not show statistically significant differences between time periods associated with shifts in resource availability. This may indicate that people in the San Juan Islands and San Nicolas Island did not defend boundaries around productive resource areas. It is also possible that their territorial behavior did not emphasize aggressive attacks on one another at the level of the village, but rather groups of villages joined together to face a common threat. This supports the alternative hypothesis for this study that is based on descriptions of the complex and interconnected communities from the ethnographic record in both study areas. Kin and marriage relationships may have rendered boundaries permeable to certain people or families regardless of the marine or terrestrial productivity. Alternatively, territorial behavior may not have centered on violent conflict but may instead have emphasized resource procurement. In the chapters that follow, I investigate whether toolstone procurement patterns indicate shifts in resource access that correspond with changes in resource availability during the Late Holocene.

Chapter 3: Stratigraphic Context and Dating of Lithic Assemblages

To investigate changes in territorial behavior on the Pacific Coast, I test predictions about lithic procurement patterns by analyzing toolstone availability and toolstone use at habitation sites on the San Juan Islands and southern Channel Islands. These sites include the Watmough Bay site (45-SJ-280) on Lopez Island, San Juan Islands, Washington and Tule Creek Village (CA-SNI-25) Mound B and CA-SNI-106 on San Nicolas Island, Channel Islands, California. Since predictions for change over time in boundary defense and permeability are tied to changes in resource abundance, it is necessary to compare precisely dated lithic assemblages from time periods associated with different climate regimes. In this chapter, I discuss stratigraphy and chronology at Watmough Bay, Tule Creek Village, and CA-SNI-106 to establish the temporal and spatial analytic units used in this study.

Excavations at Watmough Bay

The Watmough Bay site is an approximately 9,500 meter^2 shell midden located on southern Lopez Island on a northeast-facing bay. It is on land owned by the Washington State Bureau of Land Management and the San Juan County Land Bank (Figure 3.1). The site is on a beach bar between a sandy beach and an extensive freshwater marsh. The first investigations of the site were conducted by David Munsell in 1968 as a University of Washington field school. In 2004, Julie Stein and Laura Phillips directed a small excavation as part of a site stabilization project (Figure 3.2). Artifacts and sediment samples from Watmough Bay are housed at the Burke Museum , Seattle.

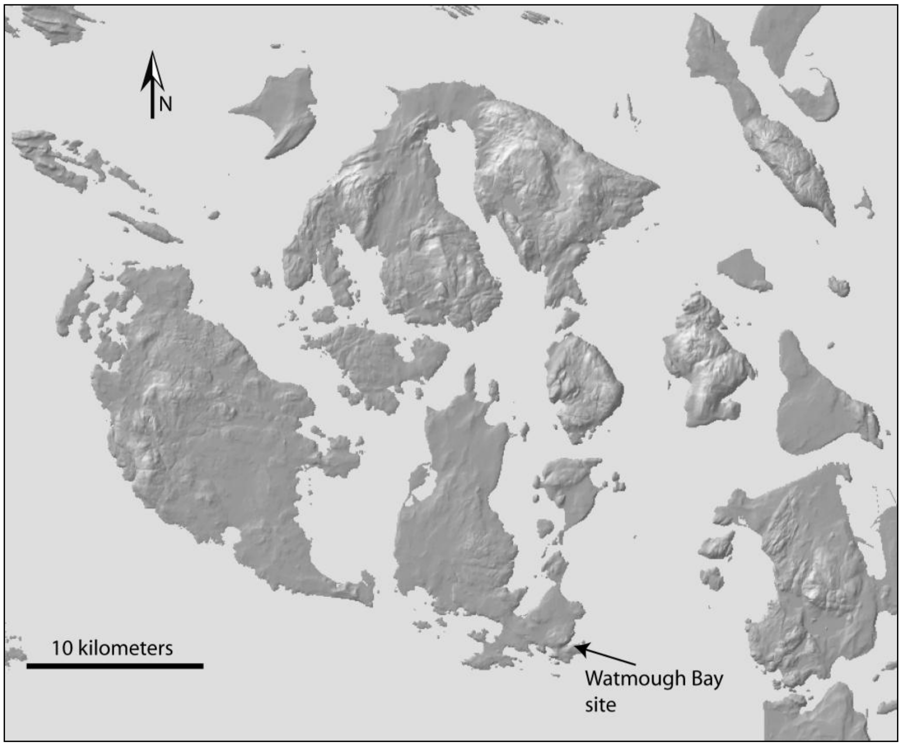


Figure 3.1. Map of the San Juan Islands showing the location of the Watmough Bay site.

Figure 3.2. View from above to the east of Watmough Bay showing the 1968 and 2004 excavation areas and surrounding landforms.

The 1968 excavation at Watmough Bay covered a 36 meter^2 area. Most units were 2 x 1 meters although some were expanded to investigate features. Three 1 x 1 meter balks between the units were excavated at the end of the project. The site was excavated by trowel and screened through ¼-inch mesh. Students usually excavated in 20-centimeter (cm) arbitrary levels, but in some cases, features were screened separately and assigned separate bag numbers (Bovy 2005:24-25; Bovy et al. 2007; Field Notebooks on file at the Burke Museum, Accn. 1996-121).

In August of 2004, Julie Stein and Laura Phillips directed the excavation of two 1 x 1 meter units on the east side of the Watmough Bay beach in association with a site stabilization project conducted by the Bureau of Land Management to minimize erosion of the shell midden (Figure 3.3). The project was a collaborative effort between the Burke Museum, the Bureau of Land Management, and the Samish Indian Nation. Based on methods used by Stein at the English Camp and Burton Acres shell midden excavations (Parr et al. 2002, 2011), the site was excavated by trowel in 10-cm arbitrary layers within larger natural layers. If excavators encountered <10-cm lenses of sediment that were different in color and texture than surrounding sediment, these lenses were excavated and screened separately. All sediment was screened through 1-inch, ½-inch, ¼-inch and ⅛-inch inch mesh on site. All cultural material was saved from 1-inch and ½-inch screens. Initially only material from every fourth bucket was saved from the ¼-inch screen and from every eigth bucket for the ⅛-inch screen. For layers below 2F in EXU1 and all of EXU2, 100% of the material recovered in the ¼ and ⅛- inch screen was saved (Bovy et al. 2007).

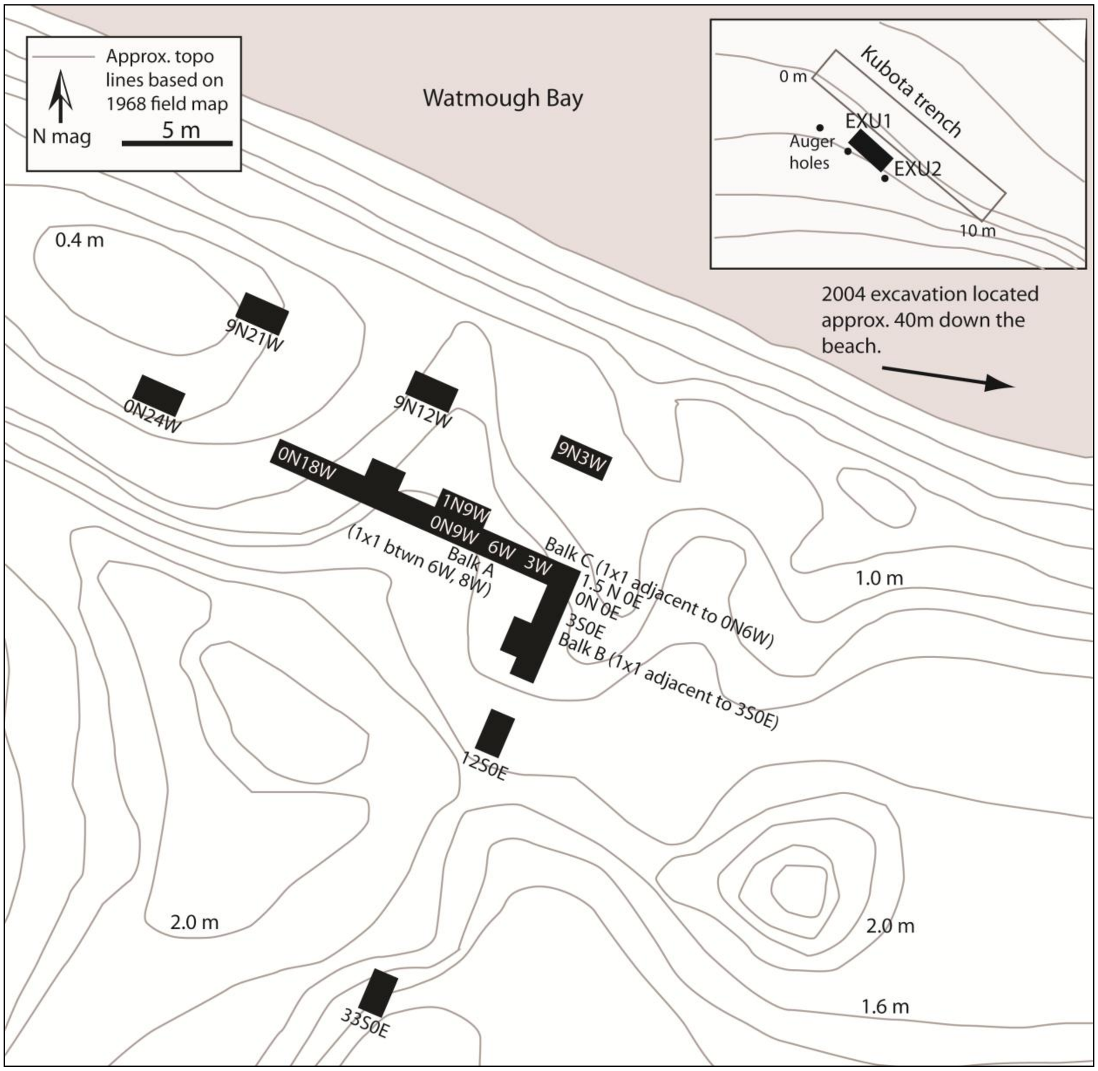


Figure 3.3 Plan view map of Watmough Bay showing the 1968 excavation. Modified from Bovy 2005 Figure 2.4). The Kubota trench was an area excavated as part of the bank stabilization project.

Stratigraphy and Dating at Watmough Bay

The typical stratigraphic profile at Wamough Bay is characterized by an upper plow zone approximately 30-50 cm thick composed of gray brown, brown, or dark brown sediment with small amounts of fragmented shell and historic artifacts. During the 1968 excavation, the plow zone was designated Stratum I and typically removed as one level. The plow zone is underlain by a 50-100 cm thick shell midden layer (Stratum II and III) with dark silty sediment, abundant artifacts, lenses of charcoal, ash, and sea urchin spines.

Below the shell midden layer lies a dark layer (Stratum IV) that contains little to no shell but relatively abundant cultural material, and a layer of natural beach sands and gravels, designated Stratum V (D. Croes, G. Jenkins, A. Richardson, R. Schalk field notebooks; Table 3.1; Figure 3.4). In other Northwest Coast shell middens, such as English Camp on San Juan Islands, geoarchaeological analysis indicates that post-depositional leaching of carbonate caused by inundation of sea water decreases the amount of shell present in the lowest strata of shell middens (Stein 1992). This process almost certainly accounts for the appearance of Stratum IV at Watmough Bay. Dating results indicate that the age of Stratum IV varies across the units (Figure 3.4, 3.5).

Excavators in 1968 and in 2004 observe spatial variation in stratigraphy across the site. Bovy (2005) notes that based on her review of field notebooks, the closest unit to the bay, 9N3W, contains more sparsely distributed shell than units to the southwest. It also contains layers of sand with abundant fish and bird bone below 136 cm below the surface (cmbs) and gravel layers. At EXU1 and EXU2 (2004 excavation), the stratigraphy follows the same basic description as units to the northwest; however, the plow zone is less than 10 cm thick and historic artifacts and modern objects were not encountered below 10 cm below the surface (cmbs) (Figure 3.6). The shell midden layer (Stratum II and III) was approximately 40 cm thick, which is thinner than the 1968 units. Additionally, in EXU1 at approximately 80-90 cmbs, excavators discovered a stone slab hearth feature (Figure 3.7).

Table 3.1. Basic field description of the stratigraphy at Watmough Bay based on descriptions in G. Jenkins' notebook.

Stratum	Color	Texture	Compaction	Cultural Materials
I	Brown	Silty soil		Moderate
II	Gray-brown	Fine silty soil		Many shell fragments
III	Brown	Sandy clay, gritty with gravel	Compact	Fine shell fragments, FMR
IV	Black	Sandy silt with pebbles, cobbles	Compact	Abundant charcoal, FCR, shell is scarce
V	Brown	Beach sand and gravel		None

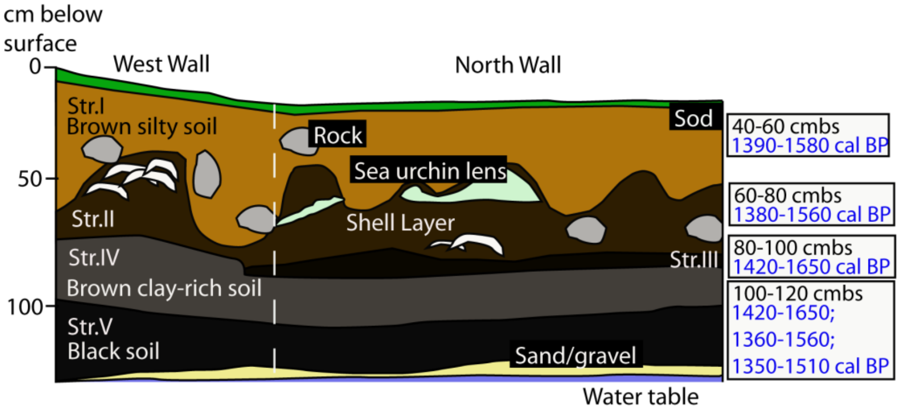


Figure 3.4 A typical stratigraphic profile at 0N18 W, modified from a profile drawing by Richardson and Jenkins.

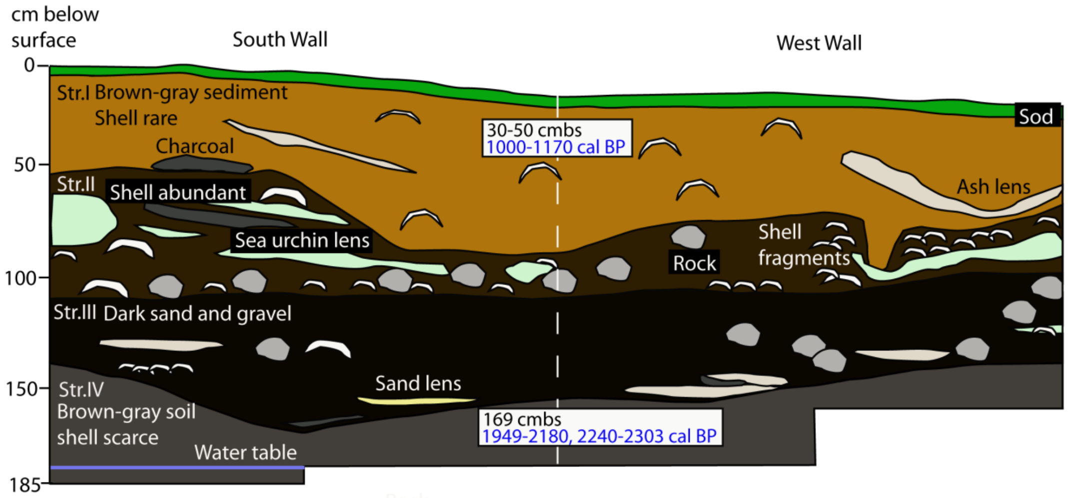


Figure 3.5. Stratigraphic profile at 0N9 W, modified from a profile drawing by Jeffrey and Kaschko.

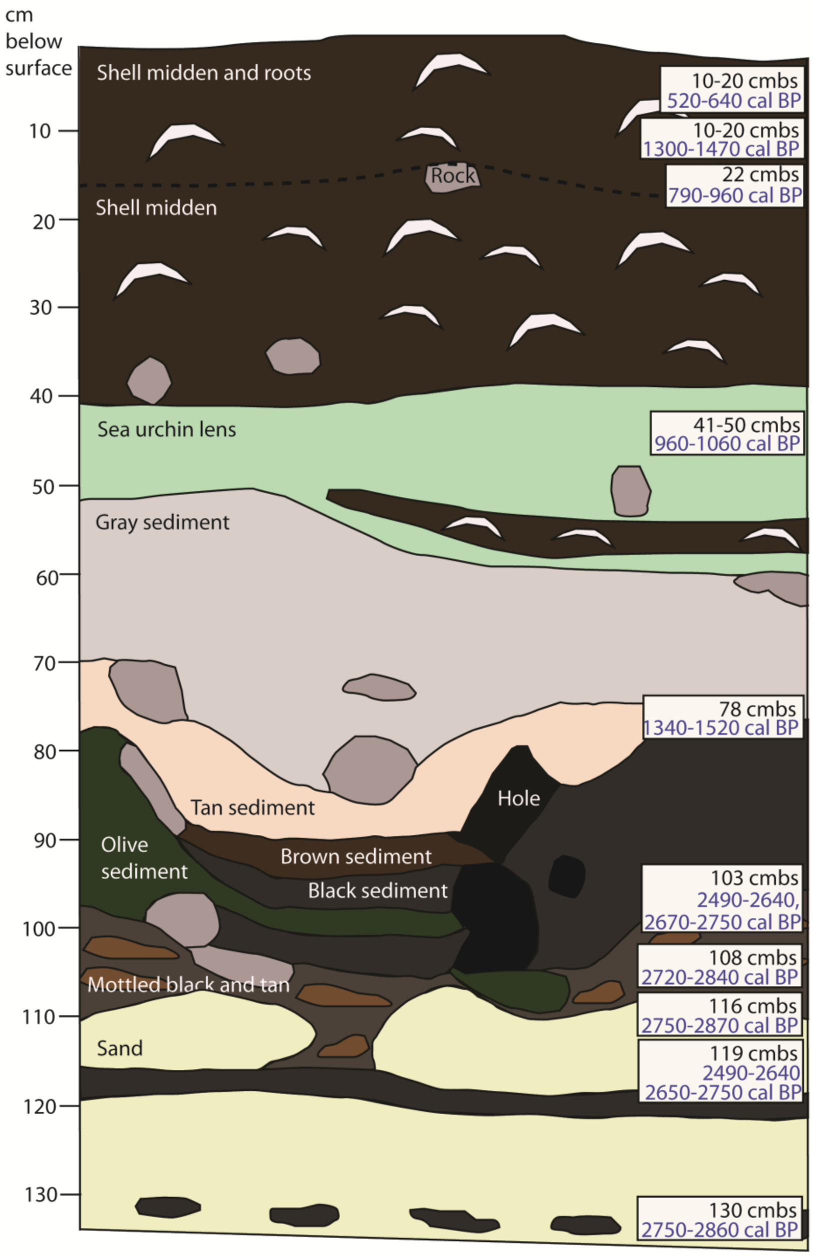


Figure 3.6. Profile drawing for west wall EXU1 based on field profile drawn by J.K. Stein and S. Johnson, August 2004.

Figure 3.7. Hearth feature at EXU1, Watmough Bay.

Both stratigraphy and dating indicate that beneath the plow zone, the site has been minimally disturbed by modern activities or erosion. A total of 51 radiocarbon dates have been obtained for the site (Bovy 2005; Bovy et al. 2007; Daniels 2009; Deo et al. 2004; Stein et al. 2003), including eight for this project (Table 3.2, 3.3). Dating results indicate that the site was occupied from as early as 3000 cal BP until the historic period. A majority of the dates occur at 1600-1200 cal BP, but there are also clusters of dates at 2800-2400 cal BP and 1000-400 cal BP indicating periods of more permanent occupation. In all units but 1N/9W and EXU1 there are no chronological reversals within the stratigraphic profile (Figure 3.6). In 1N9W, dates at 80-100 and 120-140 indicate a chronological reversal that may be due to erosion or post-depositional disturbance (Figure 3.8). In EXU1, dates at 10-20 cmbs and 22 cmbs are younger than an additional date at 10-20 cmbs. This may be due to a calibration issue since the older date is on shell and the younger dates are on wood. It is also possible that the younger wood date at 22 cmbs is attributable to a contaminated wood sample, or a sample that is from the inner part of a tree.

Chronology at the Watmough Bay site is relatively straightforward; however, there are some potential dating issues that I consider in creating analytic units. For example, in Unit 9N/3W, a shell sample (*Acme mitra*) and bird bone sample (Uria cf. aalge) from 120-140 cmbs date to 1250-1370 cal BP and 3580-3830 cal BP, respectively. The bird bone date is much older than dates found in strata below. Although it is possible that the >3000 cal BP date resulted from post-depositional disturbance, it seems more likely that the bone date is in error due to processing or calibration problems. In Unit EXU1, a date on a hardwood branch at 10-20 cmbs at 520-640 cal BP does not match a shell dated to 1300-1470 BP cal. from the same layer. If one date is from the top of the layer and the other is from the bottom, it is possible that the discrepancy does not indicate disturbance but rather very rapid accumulation. It is also possible that the upper layers have been disturbed by modern activities or wave action. Finally, in excavation units in the trench at 0N, >2000 cal BP deposits in lower levels of 0N9W indicate a potential older deposit, but there are too few dates in adjacent units to determine if older deposits are present at that depth across the site.

Table 3.2. Radiocarbon dates for the Watmough Bay site, 1968 excavation.

Sample #	Unit	Depth (cm)[a]	^{14}C Age BP	Cal. Age Range, 2 Sigma BP [b]	Material	Reported
OS89919	0N0E	0-40	2150 ± 30	1240-1370	Polyplacophora	Taylor 2012
OS89920	0N0E	160-180	2280 ± 25	1350-1510	*Balanus spp.*	Taylor 2012
OS45737	0N3W	40-60	2360 ± 30	1410-1600	*P. staminea*	Bovy 2005
OS88418	Blk.C	120-130	2290 ± 25	1360-1510	Bivalve	Taylor 2012
OS89921	0N6W	40-60	2340 ± 30	1390-1575	Polyplacophora	Taylor 2012
OS84405	0N9W	30-50	1930 ± 25	1000-1170	*P. staminea*	Taylor 2012
Beta119323	0N9W	169	2110 ± 50	1949-2180, 2240-2303	Charcoal	Stein et al. 2005
Beta119320	1N/9W	60	120 ± 50	0-0, 7-150, 170-280	Charcoal	Stein et al. 2005
OS42278	1N9W	60-80	2330 ± 30	1380-1560	Mollusca	Bovy 2005
OS42279	1N9W	80-100	2450 ± 35	1520-1710	*P. staminea*	Bovy 2005
CAMS56453	1N9W	120-140	2240 ± 50	1290-1500	*Stronglyocentrotus* sp.	Deo et al. 2004
Beta119321	1N9W	140	2200 ± 50	2065-2083, 2110-2340	Pseudotsuga menziesii	Deo et al. 2004
Beta119322	1N9W	153	2090 ± 40	1949-2152, 2280-2290	Charcoal	Stein et al. 2005
OS42360	Blk.A	60-80	2340 ± 30	1390-1580	*P. staminea*	Bovy 2005
OS42361	Blk.A	60-80	2320 ± 30	1380-1550	Polyplacophora	Bovy 2005
OS42362	Blk.A	60-80	2310 ± 30	1370-1540	*Tresus* sp.	Bovy 2005
OS42363	Blk.A	100-120	2360 ± 30	1410-1600	Polyplacophora	Bovy 2005
OS45738	0N18W	40-60	2340 ± 30	1390-1580	*P. staminea*	Bovy 2005
OS42364	0N18W	60-80	2330 ± 30	1380-1560	Polyplacophora	Bovy 2005
OS42365	0N18W	80-100	2380 ± 35	1420-1650	*P. staminea*	Bovy 2005
OS42366	0N18W	100-120	2400 ± 30	1480-1680	Bivalve	Bovy 2005
OS42735	0N18W	100-120	2300 ± 30	1360-1560	Bivalve	Bovy 2005
OS42736	0N18W	100-120	2280 ± 25	1350-1510	Bivalve	Bovy 2005
Beta119317	0N24W	60-80	1350 ± 100	1010-1030, 1050-1420, 1470-1510	Charcoal	Stein et al. 2005
Beta119318	0N24W	80-100	1560 ± 50	1350-1550	P. menziesii branch	Deo et al. 2004
CAMS56454	0N24W	80-100	2330 ± 50	1350-1610	Bivalve	Deo et al. 2004
CAMS56455	0N24W	100-120	2170±50	1220-1440	*Balanus* sp.	Deo et al. 2004
Beta119319	0N24W	100-120	1580±50	1350-1560	Conifer branch	Deo et al. 2004
OS89922	3S0E	0-40	2140 ± 35	1220 - 1370	*Nucella* spp.	Taylor 2012
OS84404	3S0E	40-60	2090±30	1170-1300	Bivalve	Taylor 2012
OS89923	3S0E	80-100	2200 ± 30	1270 - 1410	*P. staminea*	Taylor 2012
Beta119316	12S0E	61	2360 ± 50	2190-2190, 2210-2230, 2310-2520, 2530-2540, 2590-2620, 2640-2700	*Thuja/Tsuga* branch	Deo et al. 2004
CAMS56451	12S0E	60-80	3150 ± 40	2340-2610, 2630-2650	*P. staminea*	Deo et al. 2004
OS45739	9N3W	40-60	2130 ± 30	1220-1350	*Mytilus californianus*	Bovy 2005
OS42367	9N3W	120-140	2160 ± 30	1250-1370	*Acme mitra*	Bovy 2005
Beta193785	9N3W	120-140	3430 ± 40	3580-3740, 3740-3780, 3790-3830	*Uria* cf. *aalge* humerus	Stein et al. 2005
Beta119324	9N3W	165	2640 ± 40	2720-2840	Conifer branch	Deo et al. 2004
CAMS56452	9N3W	160-180	3320 ± 50	2520-2810	Gastropoda	Deo et al. 2004

[a] Depths are cm below surface. [b] The marine reservoir correction follows values established by Deo et al. (2004) and Daniels (2009). At 0-600 cal BP and 1000-3000 cal BP, ΔR = 400 years. At 600-1000 cal BP ΔR = 0 years.

Table 3.3 Radiocarbon dates for the Watmough Bay site, 2004 excavation.

Sample #	Unit	Depth (cm)[a]	^{14}C Age BP	Cal. Age Range, 2 Sigma BP [b]	Material	Reported
OS66822	EXU1	10-20	550 ± 30	520-560, 590-640	Hardwood branch	Daniels 2009
OS68460	EXU1	10-20	1840 ± 25	1300-1470	*P. staminea*	Daniels 2009
Beta203751	EXU1	22	970 ± 40	790-960	*P.menziesii* branch	Bovy et al. 2006
OS66820	EXU1	41-50	1110 ± 25	960-1060	Softwood twig	Daniels 2009
Beta203752	EXU1	78	1530 ± 40	1340-1520	Unidentified conifer	Bovy et al. 2006
Beta203753	EXU1	103	2550 ± 40	2490-2640, 2670-2750	Unidentified conifer	Bovy et al. 2006
Beta203756	EXU1	108	2640 ± 40	2720-2840	Charred plant	Bovy et al. 2006
Beta203754	EXU1	116	2700 ± 40	2750-2870	*Populus/Salix* sp.	Bovy et al. 2006
Beta203756	EXU1	119	2540 ± 40	2490-2640, 2650-2750	*Alnus* sp. small branch	Bovy et al. 2006
Beta203757	EXU1	130	2690 ± 40	2750-2860	Conifer	Bovy et al. 2006
OS68461	EXU2	10-20	1160 ± 25	320-470	*P. staminea*	Daniels 2009
OS66823	EXU2	10-20	665 ± 30	560-600, 630-670	*Alnus* sp. or *Betula* sp.	Daniels 2009
OS66847	EXU2	50-60	1080 ± 30	930-1020, 1020-1060	Hardwood cf. *Sambucus*	Daniels 2009

[a] Depths reported as cm below surface. [b] The marine reservoir correction used for the shell follows values established by Deo et al. (2004) and refined by Daniels (2009). At 0-600 cal BP and 1000-3000 cal BP, the regional correction value (ΔR) was 400 years. At 600-1000 cal BP ΔR was 0 years.

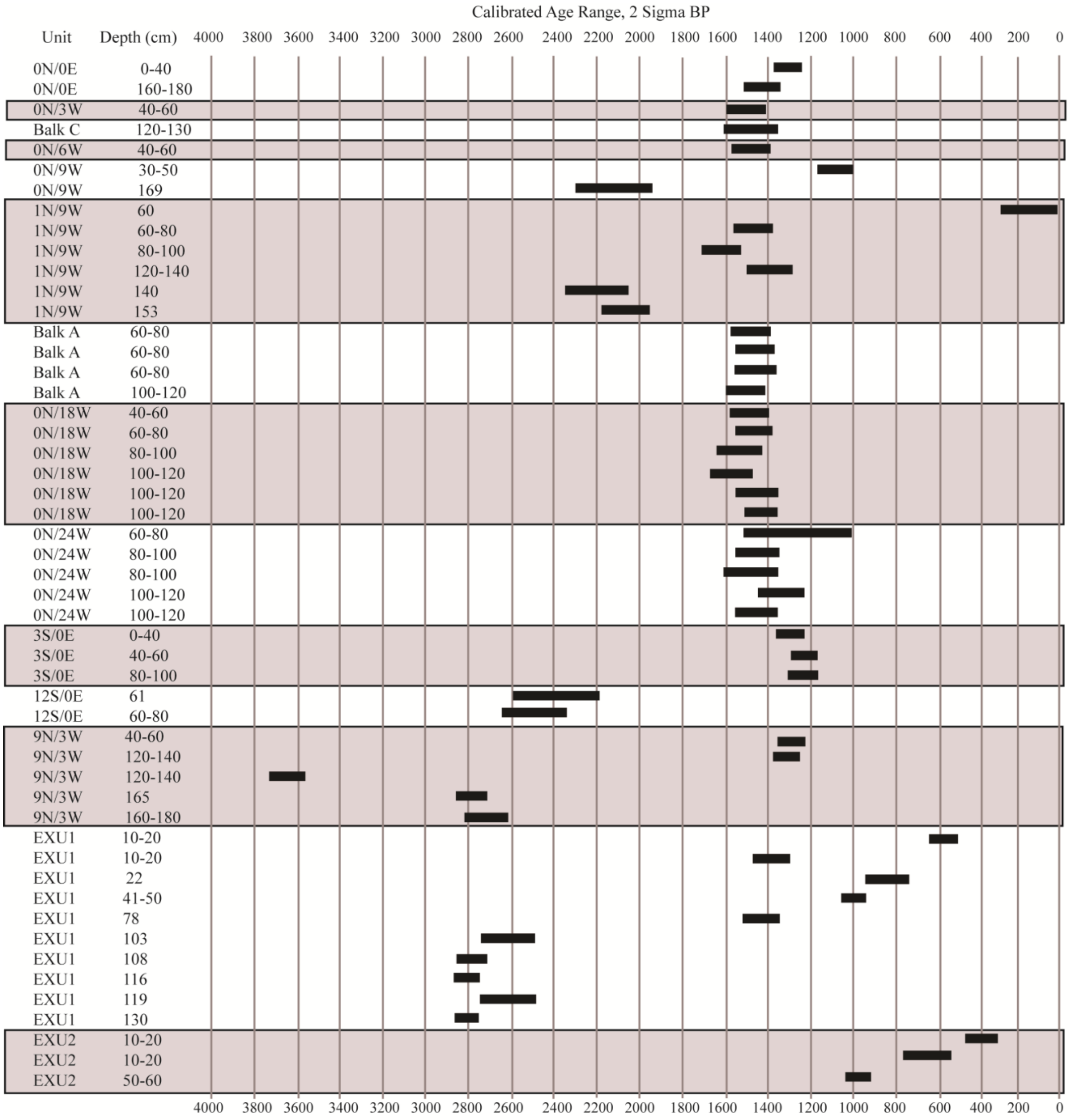


Figure 3.8. Watmough Bay dates (2-sigma calibrated).

Temporal Analytic Units for Watmough Bay

After dating and analyzing the stratigraphy at Watmough Bay, I divided the lithic assemblage into four temporal analytic units based on date clustering the timing of environmental shifts (Figure 3.9). The earliest period, 3500-2500 cal BP, corresponds to a period of cool and wet terrestrial conditions and productive marine conditions. The next period, 2500-1600 cal BP, is the beginning of the Fraser Valley Fire period when terrestrial conditions were warm and dry and marine conditions were productive. The 1600-1000 cal BP period at the end of the Fraser Valley Fire Period saw a continued warm dry terrestrial environment and a decline in marine productivity. Most artifacts from the Watmough Bay site and the English Camp site date to this period. The latest period at 600 cal BP-Contact corresponds to increased terrestrial moisture and increased in marine productivity. Most strata/level are assigned to a time period based on a radiocarbon date for that level. In some cases, such as Unit 0N15W, units had no radiocarbon dates but I assigned time periods based on dating from two adjacent units or an adjacent unit and a level above or below. In other cases, such as 33S0E where no nearby units were dated, it was not possible to assign the artifacts to a time period. Artifacts that were not assigned to a time period were not included in some of the lithic analyses depending on the research question.

Some of the lithic analyses require a comparison of two spatial areas with the sites. For Watmough Bay, I chose two areas that date to the 1600-1000 cal BP time period due to the larger sample size. I choose units with larger sample sizes that might potentially correspond to different household within the village because they are far away from one another. These include 0N24W and 0N18W on the northwest side of the site and 0N0E, 1.5N0E, 0N3W and Balk C on the southeast side of the site (Figure 3.10).

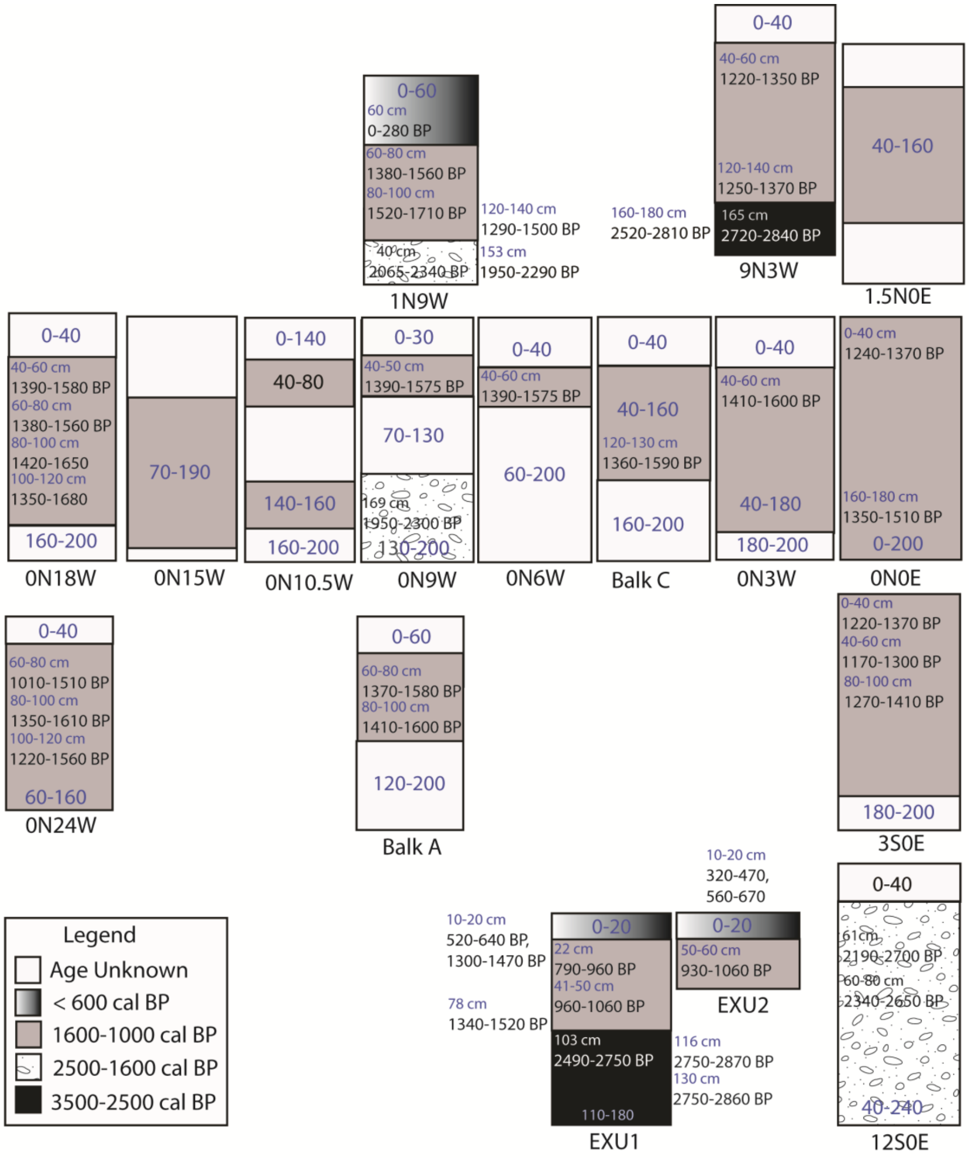


Figure 3.9. Dates and temporal analytic units at Watmough Bay, not to scale.

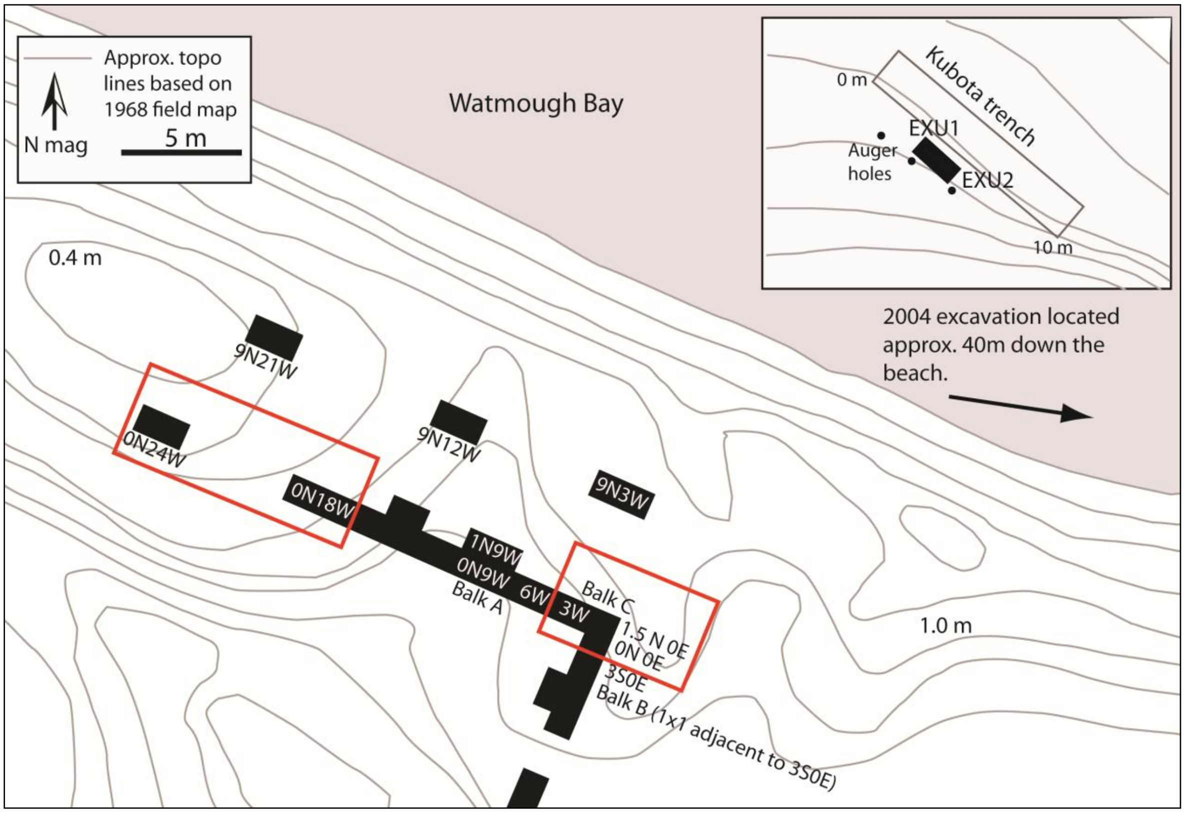


Figure 3.10. Spatial analytic units at Watmough Bay. Unit 1: 0N24W, 40-160 cmbs. Unit 2: 0N0E 0-200 cmbs, 1.5N0E 40-160 cmbs, 0N3W 60-180 cmbs, Balk C 0-160.

The San Nicolas Island Sites

To examine change over time in lithic procurement on San Nicolas Island, I created temporal analytic units for the lithic assemblages for Tule Creek Village (CA-SNI-25) Mound B and SNI-106. Temporal units were based on the stratigraphy and chronology of these sites and correspond to time periods associated with climate shifts. Lithic analysis focuses on Mound B, but also includes an assemblage from CA-SNI-106, an inland habitation site located 2.5 km southwest of Mound B (Figure 3.11).

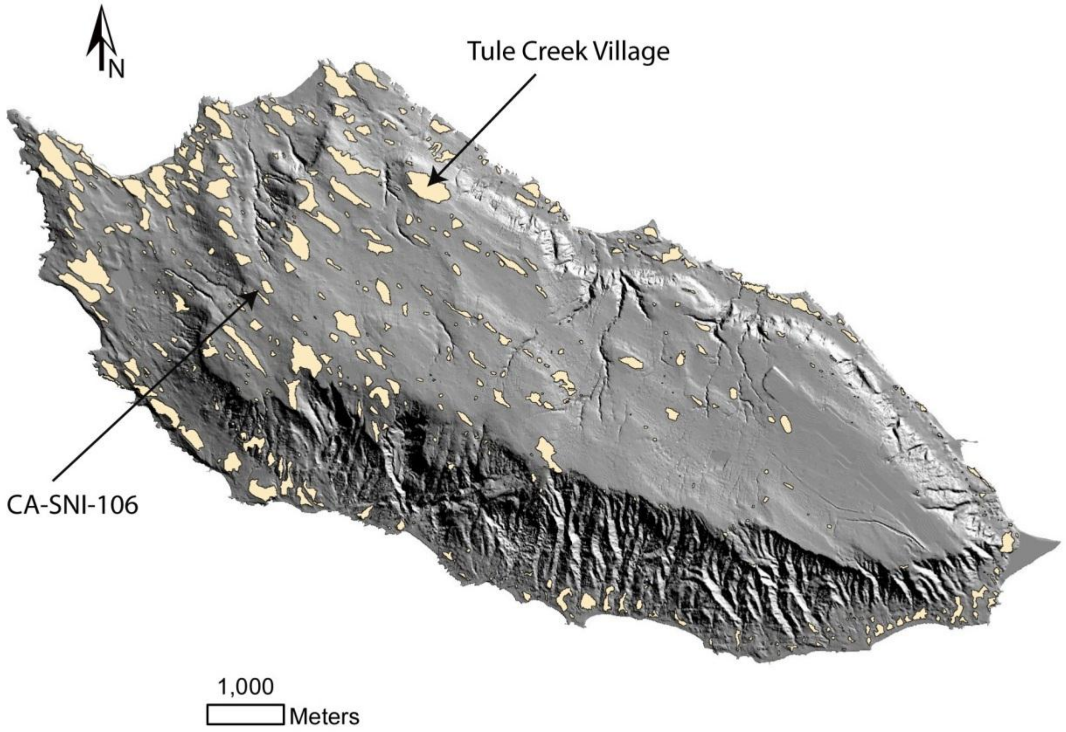


Figure 3.11. Map of San Nicolas Island showing the locations of Tule Creek Village and CA-SNI-106. White shaded areas indicate recorded site locations. The map was generated using ARCGIS and LIDAR data provided by Steve Schwartz and Richard Guttenberg.

Excavations at Tule Creek Village, Mound B

Tule Creek Village is an approximately 145,000 meter^2 shell-bearing site on the upper plateau of the northern coast of San Nicolas Island, located within a kilometer of the shoreline (Martz 2008). The site overlooks Corral Harbor, a protected inlet where marine resources and toolstone would are abundant. Inhabited as early as 5000 cal BP through the historic period, Tule Creek Village includes several discrete areas of dense artifacts and features. This study focuses on the area known as Mound B, an approximately 100 meter^2 area considered primarily a residential locality due to the diversity and abundance of artifact types (Figure 3.11, 3.12). Site information was first recorded by Reinman and Associates in 1984 and updated by California State University Los Angeles (CSULA) researchers in 1997 (Martz 2002, 2008; Reinman and Lauter 1984). Site testing was conducted by CSULA and Humboldt State University students under Dr. Patricia Martz in 1996 (Martz 2008).

The most recent excavations at Mound B began in 2001 under the direction of René Vellanoweth. Excavations were conducted during Humboldt State University field school through 2007 and CSULA field schools through 2009. All 1x1 meter units were excavated in arbitrary 10-cm levels within strata using trowels, brushes, and scoops. Excavated sediment and cultural materials were collected in 10-liter graduated buckets and sediment was screened through ⅛-inch mesh. Larger artifacts, shells, bones and stones were collected in the field. Material that remained in the screen and bulk samples were collected for further analysis in the lab. Cultural materials are housed at both at the CSULA laboratory and at the San Nicolas Island Archaeology Laboratory on San Nicolas Island. Lithic artifacts included in this study were analyzed at the CSULA laboratory and at the University of Washington Department of Anthropology.

Figure 3.12. View to the east of Tule Creek Village with Mound B excavation in the foreground. Photo courtesy of the Humboldt State University San Nicolas Island Field School.

Stratigraphy and Dating at Mound B

Excavations at Tule Creek Village (CA-SNI-25) exposed approximately 100 meter^2. Geoarchaeological investigations focused on a trench that bisected the mound from northwest to southeast and included units 12, 13, 32, 43, and 48. Lithic analysis was conducted on artifacts from only those units where stratigraphy and dating were well understood, including units 11, 13, 32, 43, 48, 52, and 58 (Figure 3.13). The stratigraphy and dating of these units is discussed below.

The basic stratigraphy at Mound B was characterized by a surface deposit of modern dune sand (Stratum I) underlain by a darker colored sandy layer with abundant artifacts (Stratum

II). In several units, excavators encountered a lighter colored compact surface that alternated with Stratum II. During the 2001-2008 field season, this stratum was designated Stratum IIA. During the 2009 field season, alternating light and compact layers and dark layers were given additional numerical designations. Stratum II was the first dark layer encountered and Stratum IIA was the first light layer encountered. Any subsequent light layers were numbered IIA1, IIA2, etc. Any subsequent dark layers were numbered IIB1, IIB2, etc. Darker and lighter cultural strata were underlain by a transitional sandy layer with fewer artifacts (Stratum IIB), and a non-cultural sandy layer (Stratum III) (Table 3.4).

Table 3.4. Basic field descriptions of strata at Mound B.

Stratum	Color	Texture	Compaction	Cultural Materials
I	10YR 3/2 Very dark grayish brown	Sand	Very loose	Moderate
II	10 YR 3/1 Very dark gray	Silty sand	Loose	Abundant
IIA	10YR 4/2 Dark yellowish brown	Silty sand	Compact	Abundant
IIB	10YR 3/2 Very dark grayish brown	Silty sand	Loose	Scarce
III	10YR 5/3 Brown	Fine sand	Very loose	Scarce or None

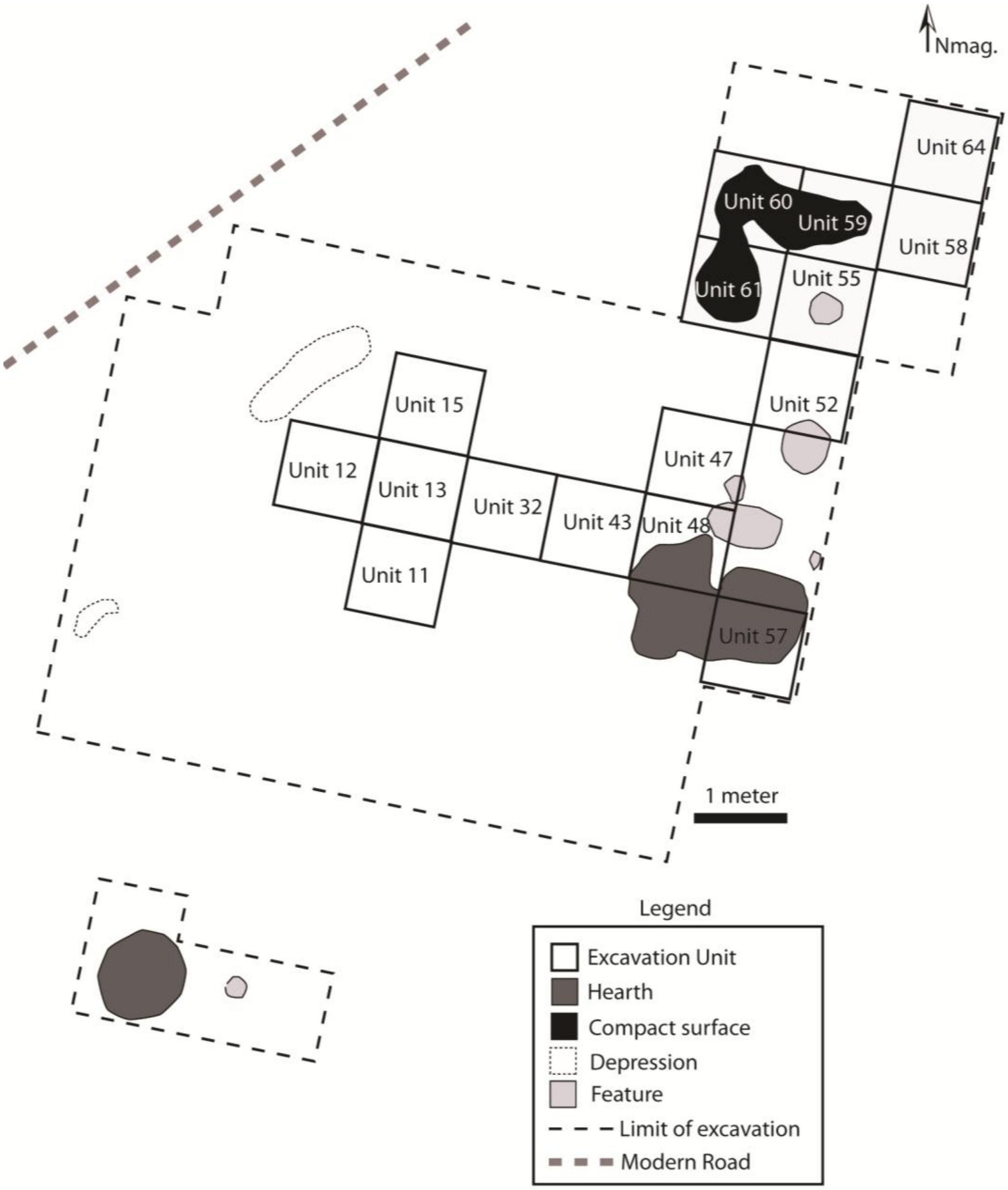


Figure 3.13. Map of CA-SNI-25 Mound B showing excavation units included in dating, geoarchaeological, and lithic analyses for this study. Modified from Cannon 2006 Figure 7.3). Lithic artifacts analyzed are from Units 11, 13, 32, 43, 48, 52 and 58.

Three sets of radiocarbon dates were submitted for the Mound B locality of Tule Creek Village, one reported by Cannon (2006) as part of her MA thesis research at Humboldt State University, a second submitted by Vellanoweth in 2008, and a third submitted as part of this dissertation research. All radiocarbon dating was conducted at the National Ocean Sciences

Accelerator Mass Spectometry (NOSAMS) Facility at Woods Hole, Massachusetts. Dates were calibrating using CALIB 6.0 (Stuiver et al. 2010). All but two of the radiocarbon samples were marine shell, and corrections for both global (Reimer et al. 2004) and regional variation in radiocarbon age of sea surface water were applied (Kennett et al. 1997; Prior et al. 1999; Rick et al. 2005b; Vellanoweth 2001).

Radiocarbon dating suggests that Mound B was inhabited from as early as 5000 cal BP to as late as 250 cal BP. The occupation may have been continuous, but clusters of dates at 5000-4400 cal BP, 2000-1500 cal BP, and 600-250 cal BP indicate potential for more intensive occupations separated by periods of use by smaller communities or perhaps abandonment (Table 3.5, Figure 3.14). In the four excavation units where Stratum IIA is absent, post-depositional disturbance is minimal. In each, the lower layers of Stratum I and the upper layers of Stratum II represent a ca. 250-600 cal BP occupation. Although no noticeable differences in color and texture of sediment were noted between upper and lower layers of Stratum II in the field, they accumulated during two different time periods. The middle and lower layers represent a ca. 1500-2000 cal BP occupation. In some units, the lowest levels of Stratum II and upper layers of Stratum IIB represent occupations older than 4000 cal BP (Table 3.5, Figure 3.13). In Unit 48, dates on features indicate that the inhabitants of Mound B sometimes altered the chronology of the stratigraphic profile. Here, a shell sample from a pit feature at 120 cm below datum (cmbd) dates to 280-460 cal BP, much later than the deposit surrounding it but consistent with use of the pit during the terminal occupation of the site (Figure 3.15).

Table 3.5. Radiocarbon dates for Tule Creek Village, Mound B

Sample #	Unit/Stratum/ Feature	Depth (cm)[a]	Uncorrected ^{14}C Age BP	Cal. Age Range, 2 Sigma BP[b]	Material	Reported
OS-54354	11 SII/L3	46	880 ± 30	150-160,190-210, 220-430	*H. cracherodii*	Cannon 2006
OS-69733	12 SII/L3	40	2160 ± 20	1370-1590	*H. cracherodii*	CSULA 2008
OS-69745	13 SIIA/L2	52	905 ± 20	260-430	*H. cracherodii*	CSULA 2008
0S-69739	13 SII/L4	64	2220 ± 30	1420-1680	*H. cracherodii*	CSULA 2008
OS-69744	13 SII/L4	87.4	1010 ± 20	320-490	*H. cracherodii*	CSULA 2008
OS-84406	32 SII/L1	36	3270 ± 30	2720-2930	*H. cracherodii*	Taylor 2012
OS-84407	32 SII/L5	47	860 ± 35	140-410	*H. cracherodii*	Taylor 2012
OS-69740	32 SII/L7	84.5	2270 ± 35	1490-1760	*M. californianus*	CSULA 2008
OS-69747	32 SIIB/L1	109	3220 ± 25	2690-2860	*H. cracherodii*	CSULA 2008
OS-84409	43 SII/L1	53	875 ± 30	150-160, 190-420	*Tegula* spp.	Taylor 2012
OS-69743	43 SIIB/L2	69	915 ± 20	260-430	*H. cracherodii*	CSULA 2008
OS-69742	43 SIIB/L2	86	4730 ± 30	4560-4820	*H. rufescens*	CSULA 2008
OS-69746	43 Pit 1	93	4720 ± 25	4550-4810	*H. cracherodii*	CSULA 2008
OS-55025	47 Fox Feature	77	1540 ± 35	1360-1520	*U. littoralis*	Cannon 2006
OS-54356	47 Fox Feature	79	2330 ± 30	2210-2220, 2310-2370, 2390-2400, 2410-2460	*U. littoralis*	Cannon 2006
OS-84410	48 SI/L2	57	1040 ± 30	330-520	*H. cracherodii*	Taylor 2012
OS-69737	48 SII/L1	70	1630 ± 30	830-1060	*H. cracherodii*	CSULA 2008
OS-69738	48 SII/L4 Feature 1	120	950 ± 20	280-460	*H. cracherodii*	CSULA 2008
OS-54413	52 Feature	63	225 ± 35	520-460[c]	*H. cracherodii*	Cannon 2006
OS-84408	52 SII/L1	70	2380 ± 25	1620-1860	*H. cracherodii*	Taylor 2012
OS-54357	55 Pit 1	85	4890 ± 35	4800-5030	*H. rufescens*	Cannon 2006
OS-54358	57 Hearth	94	4800 ± 30	4620-4900	*H. cracherodii*	Cannon 2006
OS-84411	58 SII/L1	51	935 ± 25	270-450	*Haliotis* spp.	Taylor 2012
OS-54359	58 Bird Feature	74	2450 ± 30	1700-1940	*H. cracherodii*	Cannon 2006
OS-84412	58 SII/L3	81	3230 ± 25	2700-2880	*H. cracherodii*	Taylor 2012
OS-54360	58 Pit 1	93	4750 ± 35	4570-4840	*H. cracherodii*	Cannon 2006
OS-54362	60 Compact	49	1670 ± 25	900-1100	*H. cracherodii*	Cannon 2006
OS-54361	61 Compact	50	1070 ± 45	330-550	*L. gigantea*	Cannon 2006
OS-69734	64 S3/L1	100	4590 ± 25	4390-4650, 4670-4670	*H. cracherodii*	CSULA 2008

[a] Depths are reported as cm below datum as originally recorded, but different datums were used for different units.

[b] Dates calibrated using CALIB 6.0 (Stuiver et al. 2010). For marine shell, a Marine09 calibration (Reimer et al. 2004) and ΔR value of 225 ± 35 were applied (Kennett et al. 1997; Prior et al. 1999; Rick et al. 2005b; Vellanoweth 2001a).

[c] 1 Sigma Cal BP date reported by Cannon 2006. CALIB 6.0 indicates that this age range cannot be calibrated.

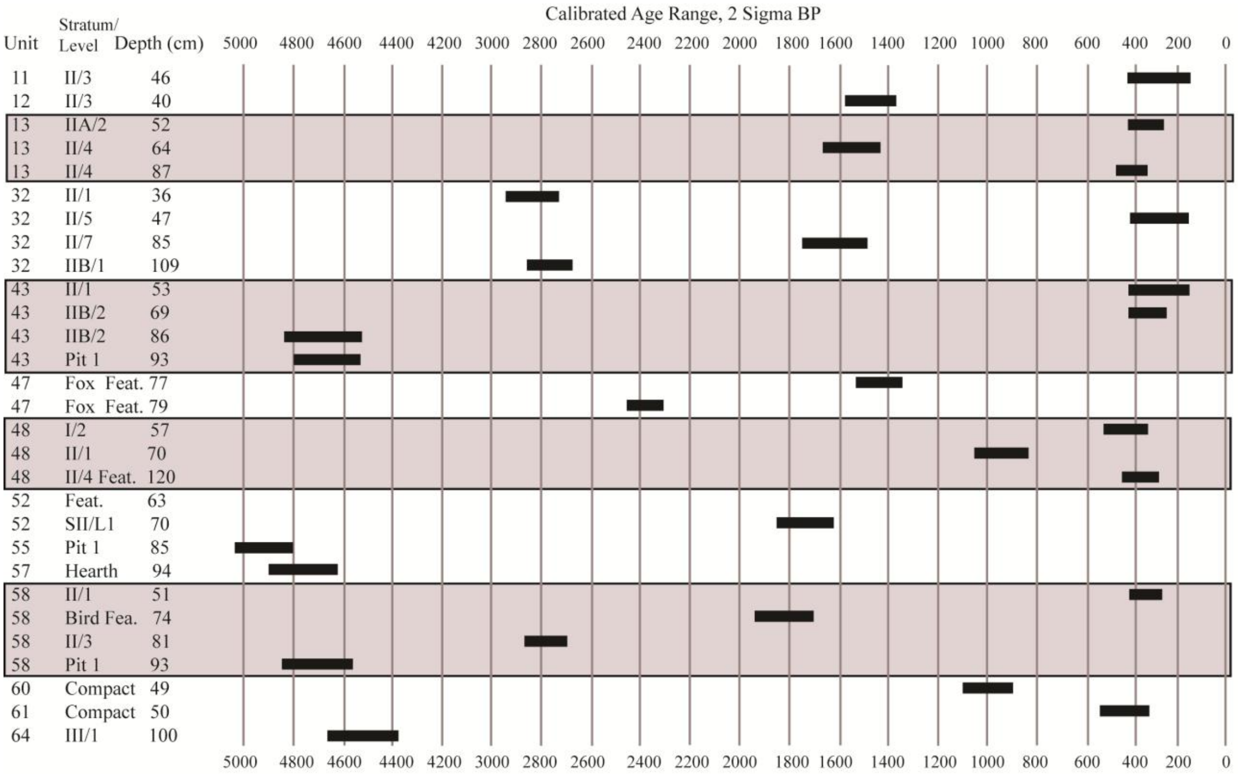


Figure 3.14. Tule Creek Village, Mound B dates (2-sigma calibrated). Dates reported by Cannon (2006), CSULA (2008), and as part of the current study.

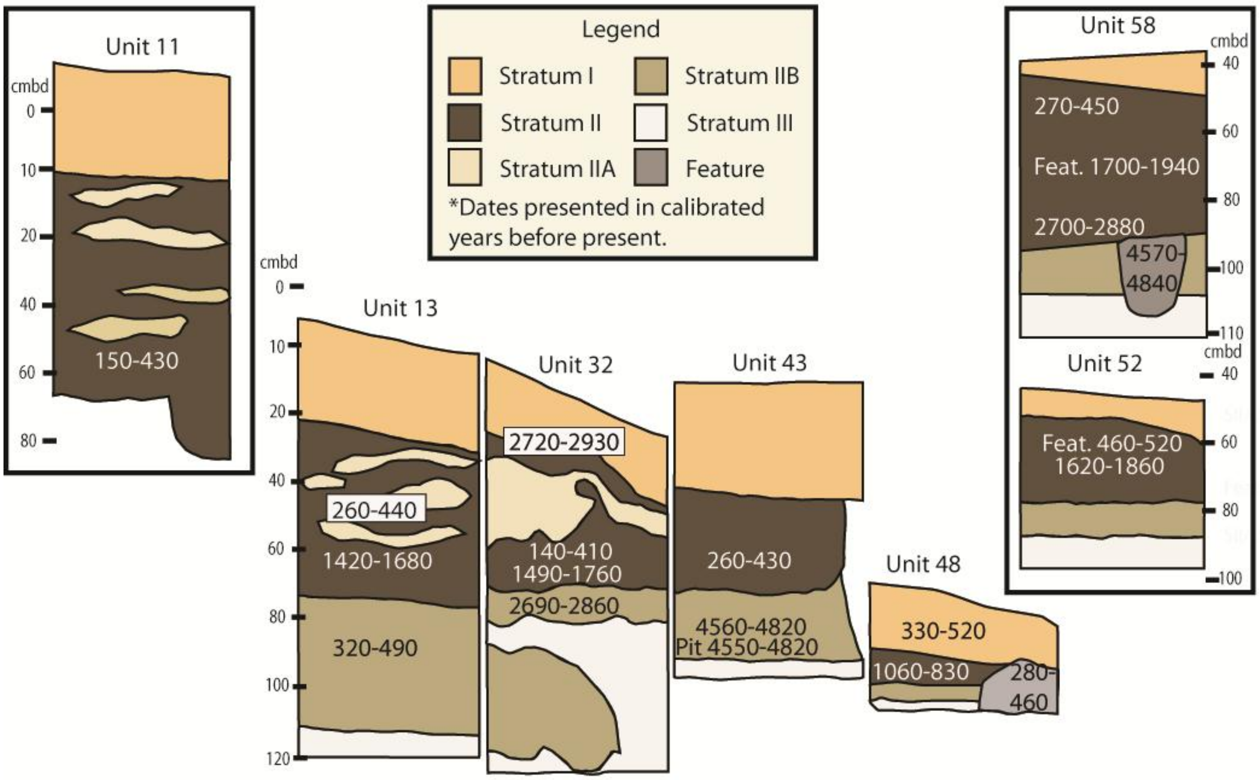


Figure 3.15. North wall profiles showing the locations of the samples dated and the corrected ages obtained for the samples. The profiles are the units used in the lithic analysis at Mound B. The horizontal dimension is at ½ scale.

In units where Stratum IIA is present, Mound B stratigraphy is complex. The compact and lighter-colored Stratum IIA was first encountered in units 59, 60, and 61 and also appeared in units 11, 12, 13, 15, and 32 (Figure 3.16, 5.17). Transitions between Stratum II and Stratum IIA are typically gradual and mottling is minimal. In 2008, the excavation team hypothesized that the stratigraphy represents post-depositional disturbance associated with the construction of a 1950s-era road adjacent to the site. The road is still present near the site, but little is known about the nature of its construction. Lighter-colored compact Stratum IIA could have resulted from the transport and redeposition of Stratum I by road construction, workers' shovels, or mechanical excavation equipment. Alternatively, lighter (Stratum IIA) strata might have resulted when clay particles washed downslope from the road, onto the site surface, downward through the profile. Another possibility is that Stratum IIA represents periods of intensive aeolian deposition of carbonate-rich silt. In these scenarios, darker layers might result from an increase in organic particles introduced by activities such as cooking, processing, or discard of refuse (Marty et al. 2010; Taylor et al. 2009b). Radiocarbon dating and sediment analysis were used to investigate these hypotheses.

Radiocarbon dating results support the hypothesis that the alternating light and dark layers were caused post-depositional disturbance caused by road construction. In units 11, 13, and 32, the profiles where Stratum IIA is present show chronological reversals (Figure 3.14). For example, in Unit 32, a date of 2720-2930 cal BP in the uppermost level of Stratum II is underlain by a date of 140-410 cal BP in Stratum II/Level 5 (Figure 3.17). In Unit 13, dates for the upper layers of Stratum IIA and Stratum II appear in chronological order; however, Stratum II appears to dip deep into Stratum IIB in the SE corner of the unit, and a date of 320-490 cal BP at 87 cmbd is younger than those above it although this could be due to a pit feature as in Unit 48 (Figure 3.18).

Figure 3.16. Plan view and north wall of Unit 43, Mound B, showing darker Stratum II overlying lighter-colored Stratum IIA.

Figure 3.17. North walls of Units 13 and 32, Mound B, showing the lighter-colored Stratum IIA within Stratum II.

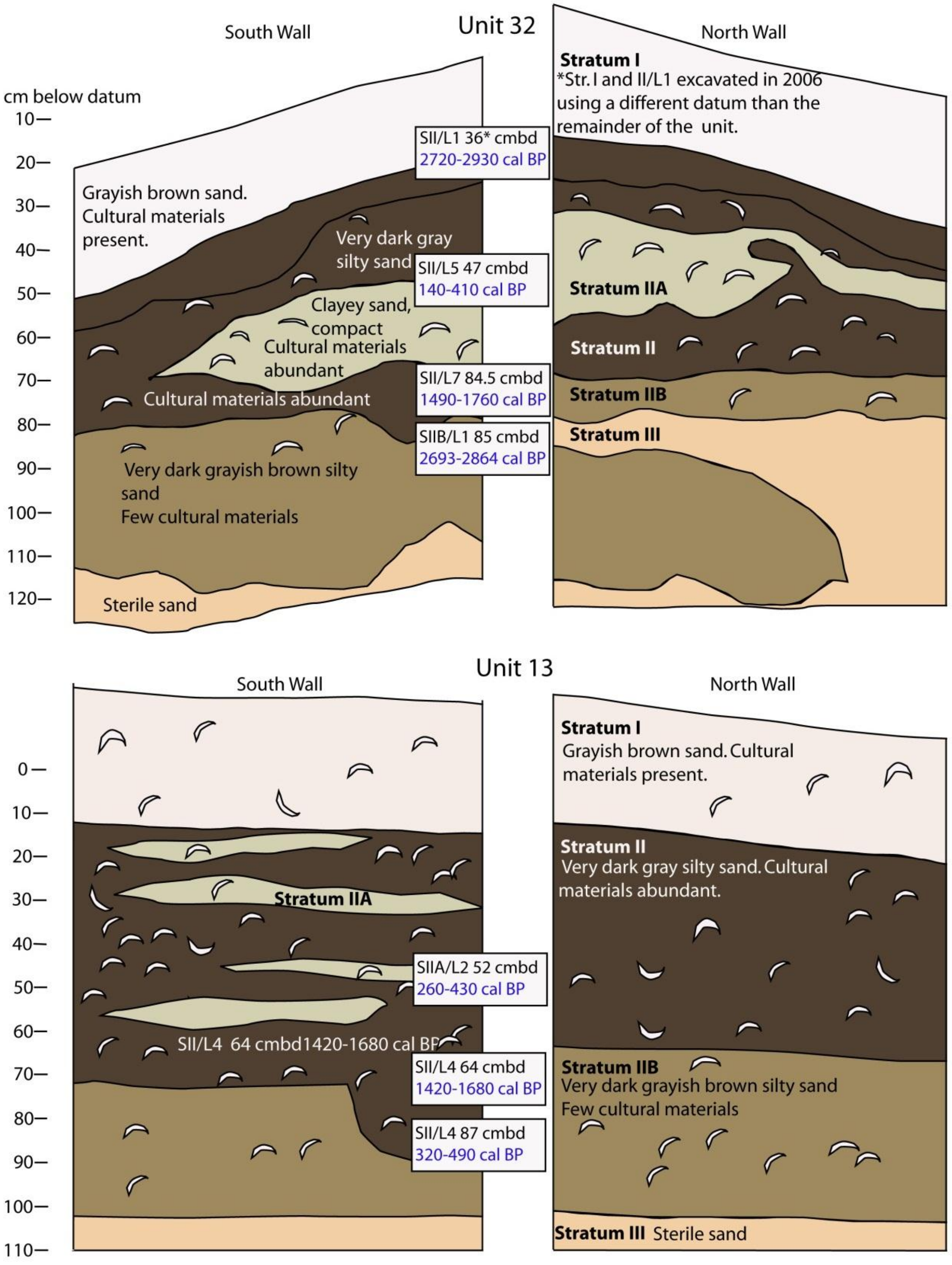


Figure 3.18. North and south wall profiles of units 32 and 13 showing stratigraphy and dating results. The profile drawing of Unit 32 is based on profiles drawn in the field and on level forms. The profile drawing of Unit 13 was based primarily on level forms.

Sediment analysis of bulk samples from units 11, 12, 13, 15, 32, and 43 also supports the hypothesis that alternating light and dark layers within Stratum II were caused by mechanical road construction disturbance. If the light, compact Stratum IIA had originated from downward movement of road clay or exotic wind-blown silt, the grain-size distribution of Stratum IIA samples would be different from the grain-size distribution from Stratum II samples. However, a grain-size analysis conducted with CSULA graduate students Johanna Marty and Nicholas Poister (152H type hydrometer and sieve shaker) shows no statistically significant difference in abundance of silt and clay-sized particles in light layers and dark layers (Marty et al. 2010; Taylor et al. 2009b). An independent samples *t*-test indicates that proportion of fines to sand is not significantly greater in light Stratum IIA layers ($\bar{x} = 6.20$, $n = 8$) than in darker Straum II layers ($\bar{x} = 5.70$, $n = 8$); t(df = 14) = 0.8325, $p = 0.73$ (Table 3.6, Figure 3.19). These results suggest that Stratum IIA more likely resulted from excavation, erosion, and deposition of Stratum I and II than from an increase in wind-blown silts and clays.

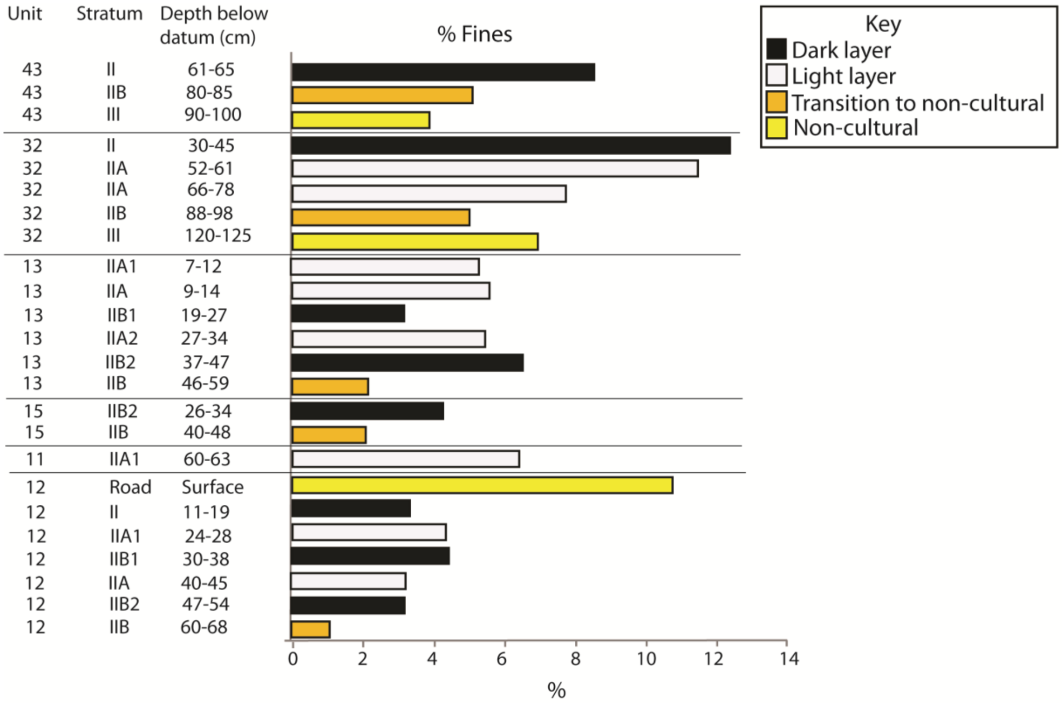


Figure 3.19. Percent fines (silt and clay) in units 43, 32, 13, 15, 11, and 12, Mound B based on work by Marty et al. (2010) and Taylor et al. (2009b).

A loss on ignition (LOI) analysis conducted by University of Washington undergraduate Jordan Martinez (Martinez 2010) suggests that compaction of Stratum IIA is likely attributable to higher carbonate content. An independent samples *t*-test indicates that percent carbonate was significantly higher in lighter layers ($\bar{x}$ = 13.62, n = 6) than in darker layers ($\bar{x}$ = 10.56, n = 7); t(df = 11) = 5.56; *p* = 0.00 (Table 3.7, Figure 3.20). Since the LOI analysis did not include a sample from the road or from Stratum I, it is difficult to determine why Stratum IIA had higher carbonate levels but presumably the road was made using a carbonate-rich material and it was deposited on the site during construction. The percentage of organic matter showed no significant difference in lighter ($\bar{x}$ = 2.31, n = 6) and darker strata ($\bar{x}$ = 2.04, n = 7); t(11) = 0.9344; *p* = 0.3702, which suggests that differences in cultural activities did not contribute significantly to color changes.

Table 3.6. Results of a grain size analysis at Mound B.

Unit	Stratum	Depth below datum (cm)	Field Description	Weight Sand	Weight Fines	% Fines
43	II	61-75	Dark	80.67	7.48	8.48%
43	IIB	80-85	Transition to non-cultural	85.25	4.57	5.09%
43	III	90-100	Sterile	82.04	3.32	3.89%
32	II	30-45	Dark	82.13	11.60	12.37%
32	IIA	52-61	Light	78.29	10.10	11.43%
32	IIA	66-78	Light	82.42	6.94	7.77%
32	IIB	88-98	Transition to non-cultural	85.11	4.55	5.07%
32	III	120-125	Sterile	89.76	6.72	6.96%
13	IIA1	7-12	Light	88.47	5.02	5.37%
13	IIA	9-14	Light/Disturbed	87.58	5.17	5.58%
13	IIB1	19-27	Dark	62.30	2.01	3.13%
13	IIA2	27-34	Light	87.52	5.04	5.44%
13	IIB2	37-47	Dark	86.79	6.06	6.52%
13	IIB	46-59	Transition to non-cultural	95.34	2.01	2.07%
15	IIB2	26-34	Dark	90.72	4.03	4.26%
15	IIB	40-48	Transition to non-cultural	94.54	2.01	2.08%
11	IIA1	60-63	Light	87.88	6.03	6.42%
12		Surface	Road	76.07	9.11	10.69%
12	II	11-19	Dark	89.67	3.02	3.25%
12	IIA1	24-28	Light	89.66	4.03	4.30%
12	IIB1	30-38	Dark	88.45	4.04	4.37%
12	IIA	40-45	Light	89.25	3.02	3.27%
12	IIB2	47-54	Dark	92.77	3.01	3.20%
12	IIB	60-68	Transition to non-cultural	92.12	1.00	1.08%

Table 3.7. Results of a loss-on-ignition analysis for bulk samples from units 43, 32, 13, and 15 at Mound B based on work by Martinez (2010).

Deposit	% Organic	% Carbonate	Field Description
Unit 43 SII.61-75	2.39	12.05	Dark
Unit 43 SIII.90-100	0.01	9.35	Sterile
Unit 32 SII.30-45	2.85	14.46	Dark
Unit 32 SIIA.52-61	2.27	14.93	Light
Unit 32 SIIA.66-78	1.77	10.65	Light
Unit 32 SIIB.88-98	1.08	10.32	Transition to non-cultural
Unit 32 SIII.120-125	1.04	12.66	Sterile
Unit 32 SIIA.9-14	2.87	12.76	Light
Unit 32 SII.48-59	1.22	9.56	Dark
Unit 32 SIIA.60-63	2.45	13.09	Light
Unit 32 SIIB.80-85	1.37	9.64	Transition to non-cultural
Unit 13 SIIA1.7-12	2.06	14.53	Light
Unit 13 SIIB1.19-27	2.03	10.66	Dark
Unit 13 SIIA2.27-34	2.31	11.97	Light
Unit 15 SIIA1.9-17	2.41	10.31	Light
Unit 15 SIIB2.26-34	2.48	10.78	Dark
Unit 15 SIIB2.40-48	1.24	9.92	Dark

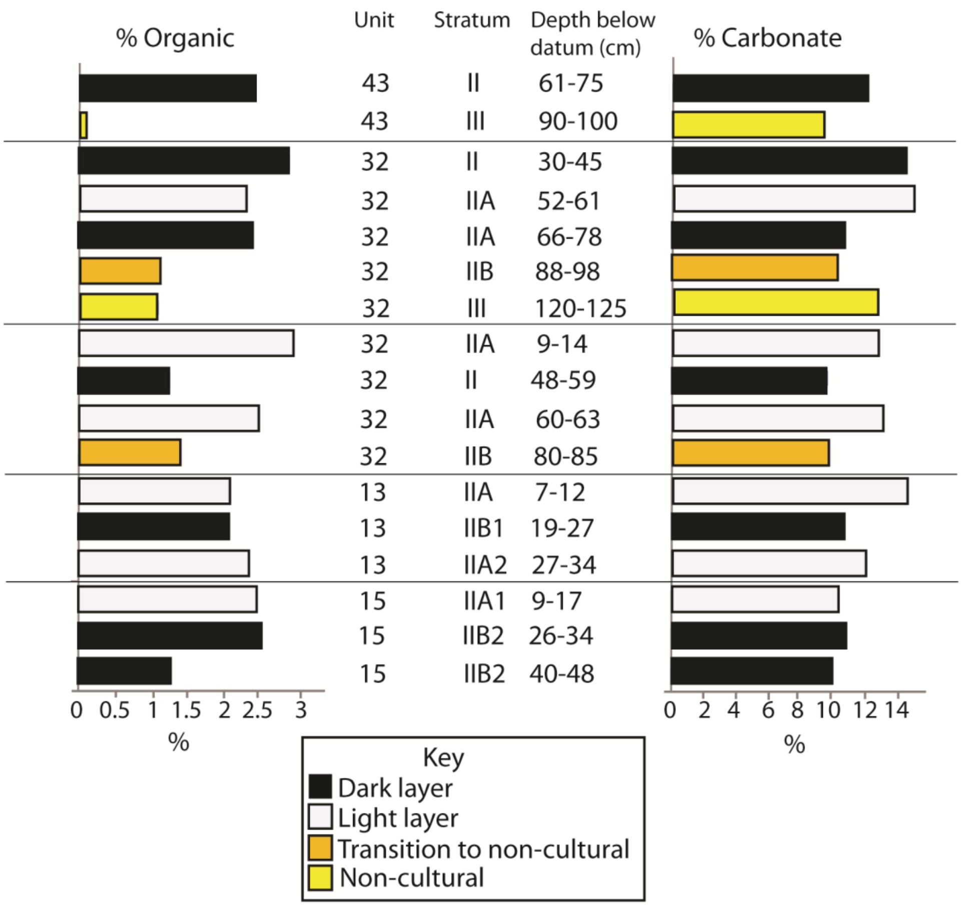


Figure 3.20. Percent organics and carbonates in units 43, 32, 13, and 15, Mound B based on work by Martinez (2010).

Temporal Analytic Units for Mound B

After dating and analyzing the stratigraphy at Mound B, I divided the lithic assemblage into temporal analytic units (Figure 3.21). Based on environmental shifts discussed in the previous chapter and the clustering of dates at Mound B, I break the chronology into four periods: At 5000-4000 cal BP both marine and terrestrial resources are abundant. For the 3000-1500 cal BP and 500 cal BP-Contact periods, terrestrial climate is cool and productive while marine environment is less productive. For the 1500-500 cal BP period, marine resources should be abundant and terrestrial resources should be less productive.

Because of post-depositional disturbance at Mound B in Units 11, 13, and 32, I excluded almost all of the disturbed upper layers of these units from the analysis and only included the lower levels below the area that appeared disturbed in the stratigraphic profile for which I had radiocarbon dates for that specific 10 cm level or which were between two dated levels. For Unit 11, I included 117 flakes from Stratum II levels 2 and 3 (500 cal BP-Contact) based on a date for Stratum III Level 3 and the location of both of these levels below the areas with the lighter Stratum IIA. For Unit 13 I included 69 flakes from a discrete lens of Stratum IIA level 2 that dated to 500 cal BP-Contact and which may represent a redeposited Stratum I. I also included 196 flakes from Stratum II Level 3 and 4 (1500-500 cal BP) based on their location below the disturbed area and a date for the upper part of the level. A younger date for the lower part of the level is problematic but because most of the artifacts came from the upper part of Stratum level 4 I chose to include them in the 1500-500 cal BP sub-assemblage. The very young data in Unit 13 Stratum IIB (lowest cultural stratum) is also problematic and may be caused by disturbance, but based on the appearance of the stratigraphy, only the two upper strata were affected by road construction and the younger date in Unit 13 Stratum IIB is more likely caused by a pit feature or another post-depositional event. For Unit 32, I included artifacts from below the areas with Stratum II Level 4 where dates and stratigraphy indicate that there was no additional disturbance. These included 32 flakes from Stratum II Level 6 (1500-500 cal BP) and 161 flakes from Stratum II Level 4 and 5 (500 cal BP-Contact). By including some artifacts from these disturbed units, I may have created a limited amount of mixing between time periods, but the dating is consistent enough in the majority of the assemblage that these effects should be swamped by the other artifacts.

Thus, spatial units for comparing lithic artifacts across the site within the same time period (500 cal BP-Contact) consist of Spatial Unit 1: Unit 58, Stratum I, Stratum II levels 1-2 and Spatial Unit 2: Unit 43, Stratum I and II. These areas of the site were chosen as spatial analytic units because they are far enough away from one another that they are probably not associated with the same household and because they are well-dated.

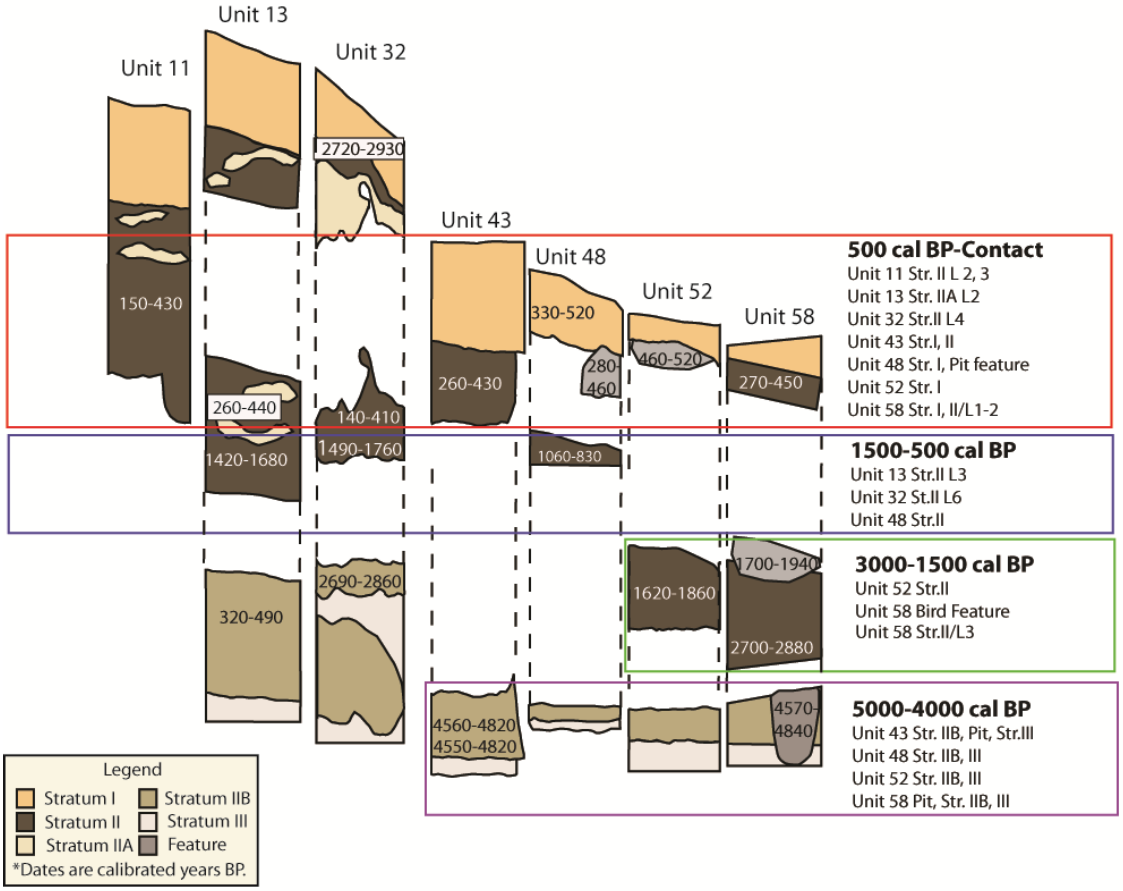


Figure 3.21. Temporal analytic units at Mound B, not to scale. Those strata that are not enclosed in a time period box were not included in some analyses because dating was uncertain. Spatial units (500 cal BP-Contact) consist of Unit 58, Stratum I, Stratum II levels 1-2 and Unit 43, Stratum I and II.

Excavation, Stratigraphy and Dating at CA-SNI-106

In addition to the lithic assemblage from Mound B, I also analyzed a small assemblage of lithic artifacts from CA-SNI-106. This approximately 20,000 m^2 habitation site on a sand dune was first investigated by Reinman and his students in 1984 (Martz 2002). The lithic assemblage comes from a 1.5 m x 1.5 m unit excavated in arbitrary levels during a CSULA field school directed by Martz in 1994. All sediment was screened through ⅛-inch mesh. The stratigraphy at this site is characterized by a thick (approximately 60 cm) shell-bearing stratum with lenses of silt and ash underlain by sand with no cultural materials present (Figure 3.22). Most artifacts were found at 10-20 cmbs, and a total of 480 lithic artifacts were recovered. This assemblage is located at the archaeology laboratory on San Nicolas Island.

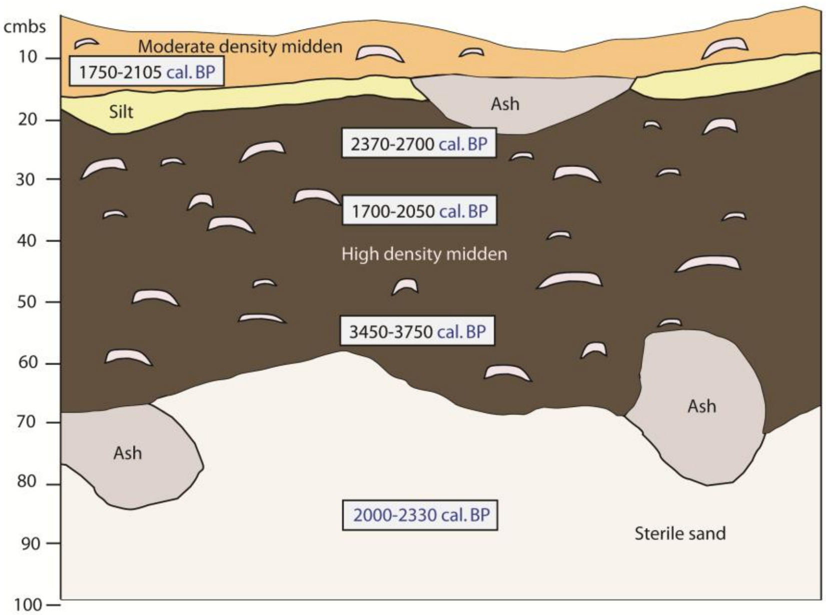


Figure 3.22. Stratigraphy and dating of an index unit at CA-SNI-106.

Table 3.8. Radiocarbon dates for CA-SNI-106.

Sample #	Unit/Stratum/Feature	Depth (cm)	Uncorrected ^{14}C Age BP	Calibrated Age Range, 2 Sigma BP[a]	Material	Reported
Beta 96686	Index Unit	10-18	2530 ± 60	1750-2110	charcol	Martz 2008
Beta 243467	Index Unit	20-30	3030 ± 40	2370-2700	*Olivella* sp. bead	Martz 2008
Beta 96687	Index Unit	30-40	2490 ± 70	1700-2960	charcol	Martz 2008
Beta 243466	Index Unit	50-60	3910 ± 40	3450-3750	*Mytilus* sp. bead	Martz 2008
Beta 96688	Index Unit	80-90	2740 ± 60	2000-2330	charcol	Martz 2008

[a] Dates calibrating using CALIB 6.0 (Stuiver et al. 2010)), for shell dates Marine09 calibration (Reimer et al. 2004) and ΔR value of 225 ± 35 were applied (Kennett et al. 1997; Prior et al. 1999; Rick et al. 2005b; Vellanoweth 2001a).

Dates reported by Martz (2008) suggest that the upper levels of the unit at SNI-106 are approximately 2000 years old with an occupation that ranges from 2000-3000 cal BP below 20 cmbs (Figure 3.20, Table 3.8). The charcoal dates are in stratigraphic order and the shell dates appear slightly older than the charcoal dates, which suggests a potential discrepancy with the shell calibration. The small shell beads could also have moved vertically within the profile. Artifacts from 10-18 cmbs were placed within a 1000-2000 cal BP analytic unit, and artifacts from 20-50 and 60-90 cmbs were placed within a 2000-3000 BP analytic unit. Those from 50-60 cmbs were excluded from the analysis due to the dating uncertainty.

Chapter Summary

In this chapter, I provided data on radiocarbon dating and stratigraphy at the Watmough Bay site on Lopez Island, Tule Creek Village on San Nicolas Island, and CA-SNI-106 on San Nicolas Island. I integrated these data with Late Holocene climate change information to divide the assemblages into sub-assemblages dating to approximately 1000-year time intervals. These temporal units will be used to determine if lithic procurement shifts parallel changes in resource abundance and predictability. I also created spatial units to compare between households within the Watmough Bay and Tule Creek Village sites to test hypotheses about differences in resource access based on kin affiliation.

Chapter 4: Results of Toolstone Surveys

Settlement pattern research provides an essential framework for investigating territory size and boundary defense. Lithic procurement patterns bridge landscape and site-scale analysis and provide further insight on circumscription, inter-village relationships, and resource access. In studies of highly mobile hunter-gatherers, source provenance analyses are often used to establish the presence and extent of lithic conveyance zones and mobility patterns within these areas (e.g., Bamforth 1990; Bettinger 1982; Blades 1999; Brantingham 2006; Dillian 2003; Eerkens 1999, 2010; Eerkens et al. 2008; Holdaway et al. 2010; Jones et al. 2003; Seeman 1994; Skinner et al. 2004; Smith 2010; Tankersley 1990; Walsh 1998). The sources of the toolstone are typically geochemically distinct and located in geographically limited areas. Travel is usually pedestrian and distance is roughly equivalent to travel cost. In many of these studies, exchange—transfer of objects or materials owned by one social group to another social group—is thought to be rare due to low population density.

On the Pacific Coast of North America, establishing the “lithic landscape” (Wilson 2007:391) is complicated by toolstone distribution, boat travel, and frequent exchange. Due to erosion by wave action, toolstone is often found in the form of rounded beach cobbles. In both the San Juan Islands and the southern Channel Islands, the geological deposits from which toolstone was collected stretched over hundreds of kilometers. People could have transported bulk loads of toolstone over long distances using both pedestrian transport and large boats. They also likely engaged in exchange of both everyday and extralocal or rare lithic raw material such as chert and obsidian. Despite these complexities, stone artifacts at archaeological sites in both study areas represent the resource acquisition activities of the people who lived there. Interpreting the lithic procurement record requires a creative and speculative approach that begins with a comprehensive understanding of the nature and extent of toolstone resources on the landscape. I focus mainly on flaked stone technology but also incorporate data from ground stone technology. In this chapter, I present the results of field and laboratory research on the lithic landscape of both study areas as an essential background to testing predictions regarding territorial strategies. I consider not only the characteristics of toolstone collection areas but also explore the question of desirability of different source areas to native inhabitants of the San Juan Islands and San Nicolas Island.

The Lithic Landscape of the San Juan Islands

The main source of toolstone for precontact communities of the San Juan Islands was fine-grained volcanic rock (FGV) (Figure 4.1). In Gulf of Georgia literature, this material is also referred to by archaeologists as basalt (Carlson 1960), dacite (Bakewell 1996, 2005), and crystalline volcanic rock or CVR (Close 2006, 2011) (see Bakewell 2005:1-8 for a detailed description of archaeological nomenclature for San Juan Islands toolstone). It is dark gray to black in color, fine-grained, and sometimes contains small (1 mm) white phenocrysts. Relative to chert and obsidian, the toolstone is difficult to work; however, it creates durable tools. Other types of toolstone present in small amounts in San Juan Islands assemblages include slate, schist, quartzite, quartz, metasedimentary rock, chert, and obsidian. Slate, schist, and quartz were all available at many local outcrops including a large slate outcrop at Watmough Bay. Quartzite was available in the form of local beach cobbles eroding out of glacial deposits.

Figure 4.1. Artifacts made from FGV found on a San Juan Island beach.

Unlike FGV, chert and obsidian are quite rare in most assemblages on the San Juan Islands. They are unavailable locally and would have been acquired during travel or through exchange. Chert deposits have been found in the Skagit drainage basin (Waitt 1977) and the Fraser River Valley (Lian and Hiscock 2001). There are numerous source areas for obsidian in Washington, Oregon, and British Columbia mapped by Craig Skinner on the Northwest Research Obsidian Studies Laboratory website (Skinner 2011). Carlson (1994) uses XRF data on artifacts from throughout British Columbia to analyze changes in exchange patterns in the Pacific Northwest. He finds a decrease in long-distance exchange and an increase in local Garibaldi obsidian after approximately 2500 cal BP. Reimer (2000:207) also surveys the distribution of Mt. Garibaldi obsidian in the Gulf of Georgia. Because the source area is small and difficult to find, he suggests that access may have been restricted to a small family groups. Large amounts of Garibaldi obsidian are found in assemblages in the Squamish River Drainage. Smaller amounts of this material are found as far as 100 kilometers away.

Ground stone artifacts at Watmough Bay are made from basalt, sandstone, shale, argillite, nephrite, and steatite. Nephrite and steatite may n**o**t be available locally but no formal survey has been conducted to determine if this is the case. Fraser Canyon nephrite was used throughout the Gulf of Georgia by 2,500 BP (Grier 2003). Nephrite occurs as alluvial cobbles along the Fraser River, and among British Columbia Plateau groups. Nephrite celts were likely considered status markers and were part of a trade system between the Fraser Canyon to the Shuswap Lakes and Nicola Valley (Darwent 1996).

Previous lithic analysis demonstrates that FGV toolstone was obtained in the form of small water-worn cobbles and pebbles (Bakewell 1996, 2005; Close 2006:159; Kornbacher 1992). In his dissertation research, Bakewell (1996, 2005) proposes that precontact native peoples of the San Juan Islands traveled by boat to southern British Columbia where they gathered cobbles of FGV. His geochemical analysis of San Juan Islands artifacts indicates that the ultimate source of the toolstone was an eruption from the Watts Point volcanic center, the southernmost volcanic flow of the Mt. Garibaldi volcanic belt on Howe Sound in southern British Columbia and approximately 0.02 km^3 (Bye et al. 2000:1) (Figure 4.2).

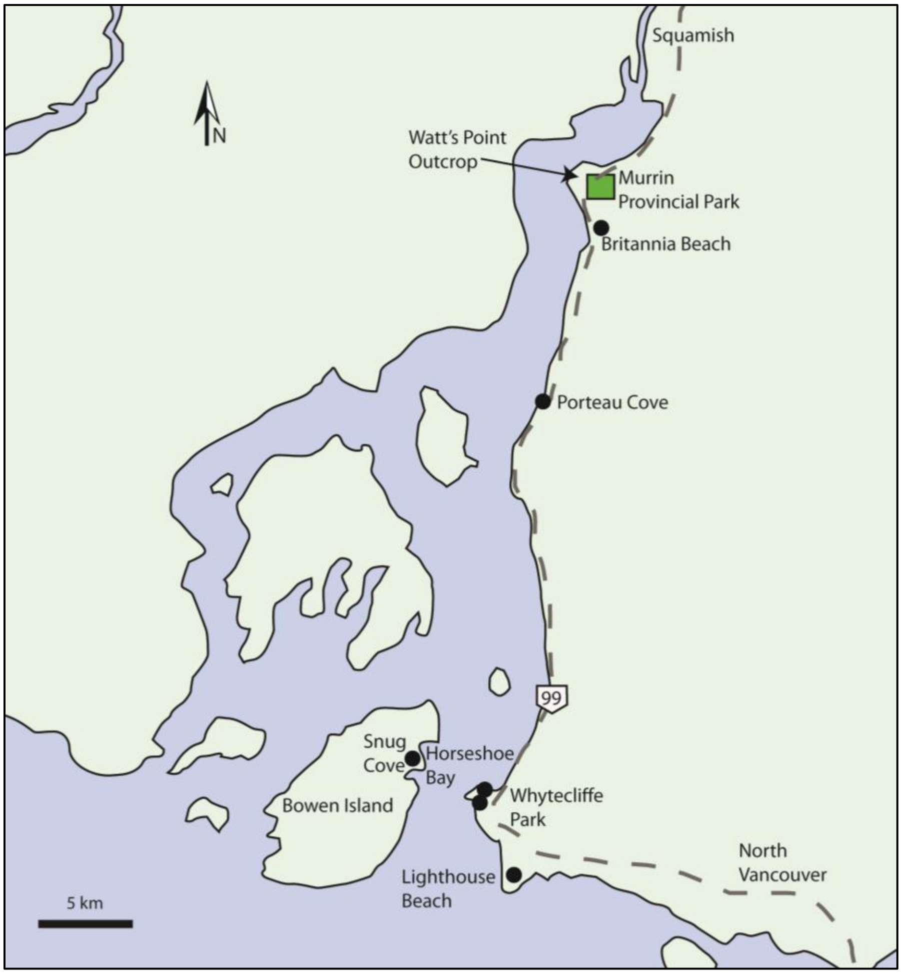


Figure 4.2. Map showin the Watts Point volcanic center. Beaches on Howe Sound where FGV cobbles were abundant are marked with black circles.

Bakewell (2005:85-86) suggests that Watts Point FGV was carried from the outcrop to the beaches of Howe Sound by longshore currents; it was collected and transported by boat to the San Juan Islands. He suggests that people did not collect FGV from beaches in the vicinity of English camp because (1) he found few natural FGV cobbles during a surface survey of the beaches near English camp, and (2) the smooth glassy appearance of the material suggests a post-glacial eruption (after 10,000 BP) in which case Watts Point FGV could not have been transported by glaciers to the San Juan Islands. Bakewell also based his assumption of a post-glacial Garibaldi eruption on potassium-argon dating conducted by Green (1989; Green et al.

1988); however, a review of Green's dating research indicates that the Watts Point flow dates to between 90,000 ± 30,000 BP to 130,000 ± 30,000 BP. He notes potential for an additional Holocene dacite flow but does not provide a date. Recent geological investigation of the Watts Point outcrop by Bye and her colleagues suggests that the eruption occurred in a subglacial or englacial environment, rather than a post-glacial environment, because the FGV is found beneath glacial till (Bye et al. 2000:1).

Many Northwest Coast researchers suggest that contrary to Bakewell's conclusions, precontact peoples in the San Juan Islands and throughout western Washington acquired cobbles of toolstone from local beaches rather than from Howe Sound (Conca 2000; Herbel et al. 2001; Kornbacher 1992; Morgan et al. 1999; Wessen 1993). Given a Middle or Late Pleistocene origin, Watts Point FGV could have been transported by ice to the San Juan Islands during the Fraser glaciation at 18,000-13,000 BP (Armstrong et al. 1965; Booth 1987; Dethier et al. 1995; Easterbrook 1969, 1986, 1992; Thorson 1980). As waves eroded glacial marine drift deposits on the San Juan Islands after the glacial ice melted, cobbles of Watts Point FGV and other stone would have eroded out of finer sediment and blanketed beaches where glacial marine drift was abundant in moraines, outwash, wave-cut banks, and creeks.

Prior to Kwarsick's (2008, 2010) thesis work and this project, only limited geochemical testing and survey had been conducted to address this hypothesis (e.g., Morgan et al. 1999:C4). Kwarsick collected cobbles from beaches and rivers on the northern Olympic Peninsula and surrounding areas and submitted 51 cobbles to the Northwest Research Obsidian Studies Laboratory for energy dispersive X-Ray Fluorescence (EDXRF) analysis. Of these, over 60% matched the Watts Point source. Of a sample of 111 artifacts from 54 archaeological sites on the Olympic Peninsula and surrounding region, 100 artifacts matched the Watts Point source.

Kwarsick's work supports glacial transport of Watts Point FGV throughout Western Washington. It is also demonstrates that people differentially selected this material as toolstone.

During the summers of 2007-2009, I conducted geological fieldwork and geochemical testing to resolve the source provenance of FGV toolstone for precontact peoples of the San Juan Islands. Geochemical analyses to characterize trace element composition of toolstone sources and artifacts were conducted by Craig Skinner at Northwest Research Obsidian Studies Laboratory using EDXRF with a Spectrace 5000 energy dispersive X-ray fluorescence spectrometer with a resolution of eV FHWM for 5.9 KeV X-ray (1000 counts per second) in an 30 mm^2 area. This method is relatively inexpensive, requires minimal sample preparation, is non-destructive, accurate, and has been used successfully for numerous FGV source provenance studies (e.g., Johnson 2010; Jones et al. 1997; Mills et al. 2008, 2010; Page 2008).

For geological samples, I removed flakes from FGV beach cobbles to provide flat, clean surfaces for irradiation.

For the XRF process, samples are subjected to radiation that moves electrons from higher to lower energy shells. Other electrons replace the one that have moved, releasing fluorescent X-rays. The energy released creates a signal specific to the chemical element present in the sample (Pollard et al. 2007). For the FGV samples submitted for this study, elements identified and quantified include zinc (Zn), lead (Pb), rubidium (Rb), strontium (Sr), yttrium (Y), zirconium (Zr), niobium (Nb), titanium (Ti), manganese (Mn), barium (Ba), sodium (Na), potassium (K), and iron oxide (Fe^2O^3). Elemental concentrations for the sample are calculated in parts per million by converting energy spectra peaks into measurable quantities using a regression calibration to known standards (Glascock et al. 1998). If diagnostic element values for geological samples and artifacts fall within approximately two standard deviations of upper and lower limits of chemical variability for the source material, the tested sample or artifact is identified to the source. The Northwest Reseach Obsidian Studies Laboratory provides additional information on their methodology on their website (http://www.obsidianlab.com/info_xrf.html). Below, I use biplots of Sr (ppm) and Zr (ppm) concentrations to visually display differentiation of Watts Point FGV and "Unknown FGV" source material.

Geological samples of Watts Point FGV were collected from a modern stone quarry at an exposure at the side of Route 99 (*n* = 4) and from nearby Murrin Provincial Park where FGV pebbles are located on the ground surface (*n* = 6). Survey of Howe Sound beaches indicates abundant FGV cobbles (Figure 4.2). Geochemical testing of these samples confirms that they are Watts Point FGV. Two samples from upper Boulder Creek near Mt. Baker, Washington displayed different geochemical signatures from San Juan Islands lithic artifacts and geological samples from Watts Point. Geological samples from beaches in the Puget Sound area at Double Bluff Beach on Whidbey Island, Quartermaster Harbor on Vashon Island, and the Dungeness Spit on the Olympic Peninsula also displayed an unknown FGV (Figure 4.3; Appendix C).

To determine if Watts Point FGV was transported by glaciers, I collected FGV pebbles and cobbles from beaches and glacial deposits in the San Juan Islands. I submitted rocks collected from Schoen Beach (*n* = 2), Agate Beach (*n* = 29) Deadman's Cove (*n* = 3), False Bay (*n* = 36), Watmough Bay (*n* = 11), and from Blind Bay glacial deposits (*n* = 9). Of the 72 cobbles visually identified as FGV from surface deposits, 64 were identified geochemically as Watts Point FGV (Figure 4.4, 4.5). One possible explanation for the presence of Watt Point FGV on San Juan Islands beaches is that people brought the cobbles to archaeological sites and materials from these sites are eroding out onto the beaches at Schoen Beach, Blind Bay, and Watmough Bay. This argument is not supported by the presence of Watts Point FGV in glacial deposits and the presence of Watts Point FGV at Deadman's Cove, False Bay, and Agate Beach where no archaeological sites have been recorded. The most parsimonious explanation is that the cobbles are eroding out of the glacial deposits. Many of the small pebbles collected from pits excavated into glacial deposits at Blind Bay (*n* = 8 of 9) and False Bay (*n* = 8 of 10) were identified as an unknown FGV source. This suggests that the larger FGV cobbles found on the beach are size sorted by wave action, and many of the cobbles that are an appropriate size for use as cores are Watts Point FGV.

To assess the ubiquity of Watts Point FGV in San Juan Islands tool assemblages, I sent FGV artifacts from the Deane site (45-SJ-150; *n* = 20), the Watmough Bay site (45-SJ-280; *n* = 50), and the English Camp site (45-SJ-24; *n* = 30) to Northwest Research Obsidian Studies Laboratory for geochemical analysis. I chose artifacts that had at least one non-cortical flat surface. I also chose samples from different time periods and/or different areas of the site to ensure that the samples represent the spatial and temporal diversity of toolstone at each site. By far the majority of the artifacts (*n* = 93 of 100) were identified as Watts Point FGV (Figure 4.4, 4.5; Appendix C). These data support the hypothesis that native communities carefully selected a particular type of cobble and that they primarily procured toolstone from local beaches rather than traveling to Howe Sound, although they may have done so occasionally.

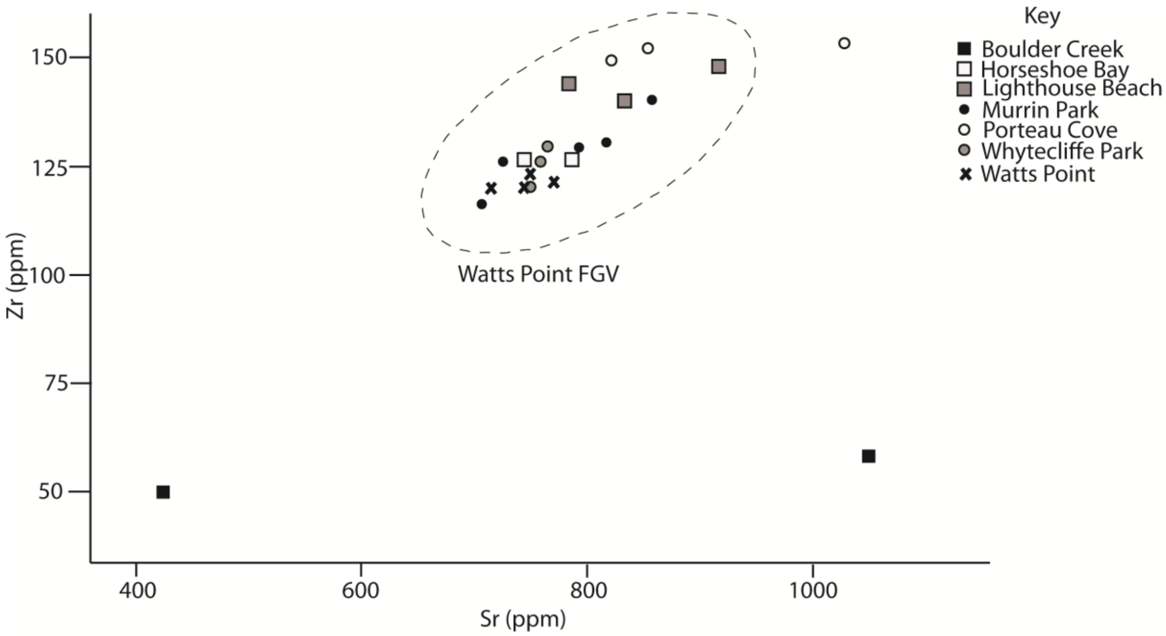


Figure 4.3. Biplot of zirconium and strontium concentrations (ppm) from EDXRF data for Howe Sound and Mt. Baker samples. Data points within the ellipse are identified as Watts Point FGV.

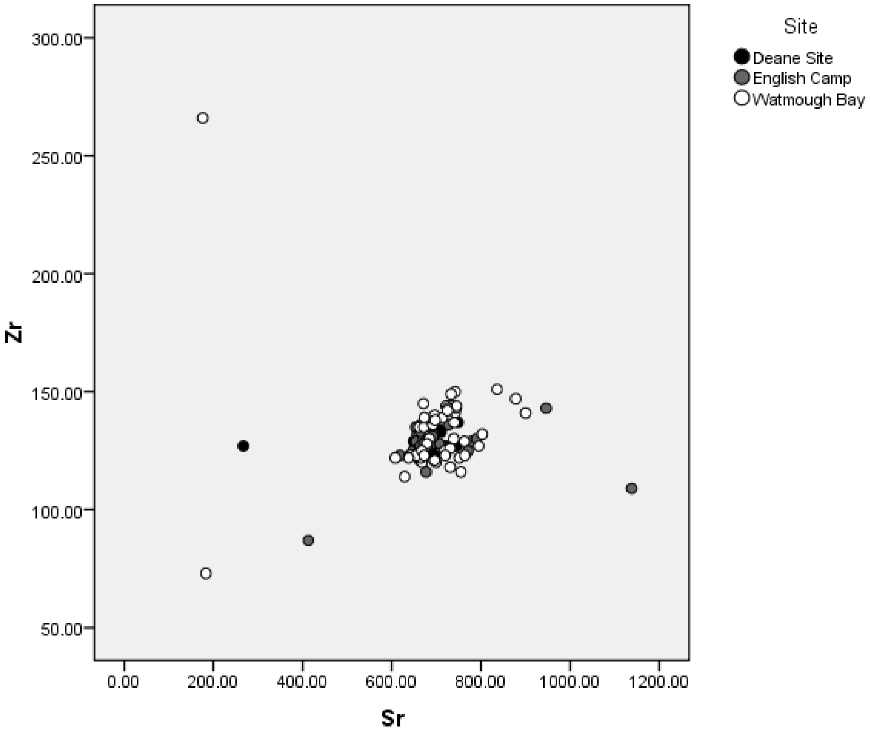


Figure 4.4. Biplot of zirconium and strontium concentrations (ppm) from EDXRF data for stone artifacts from the Deane site, English Camp, and Watmough Bay.

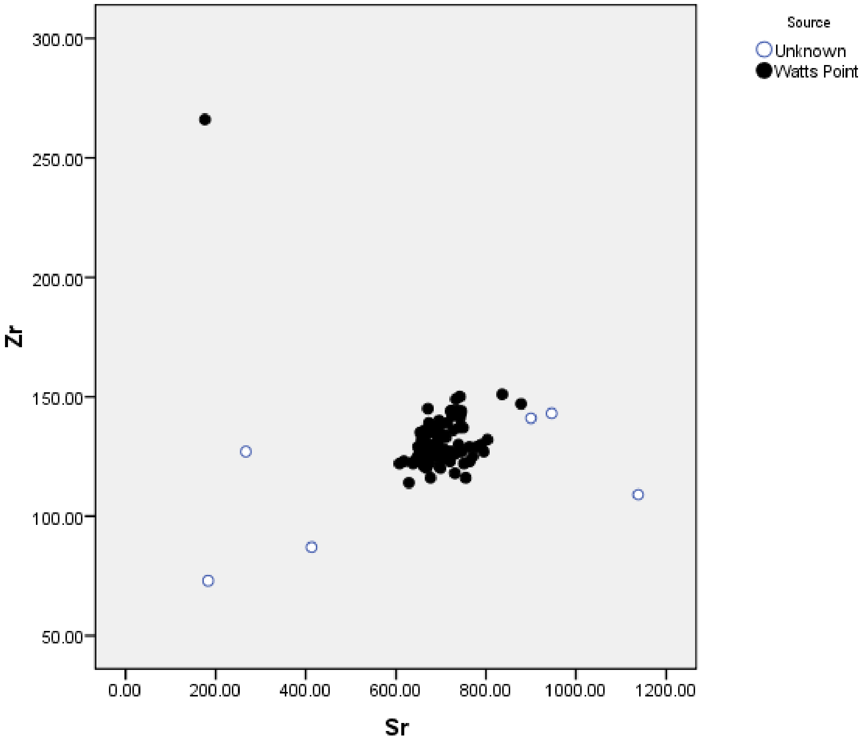


Figure 4.5. Biplot of zirconium and strontium concentrations (ppm) from EDXRF data for stone artifacts from the Deane site, English Camp, and Watmough Bay showing Watts Point and unknown source FGV distribution.

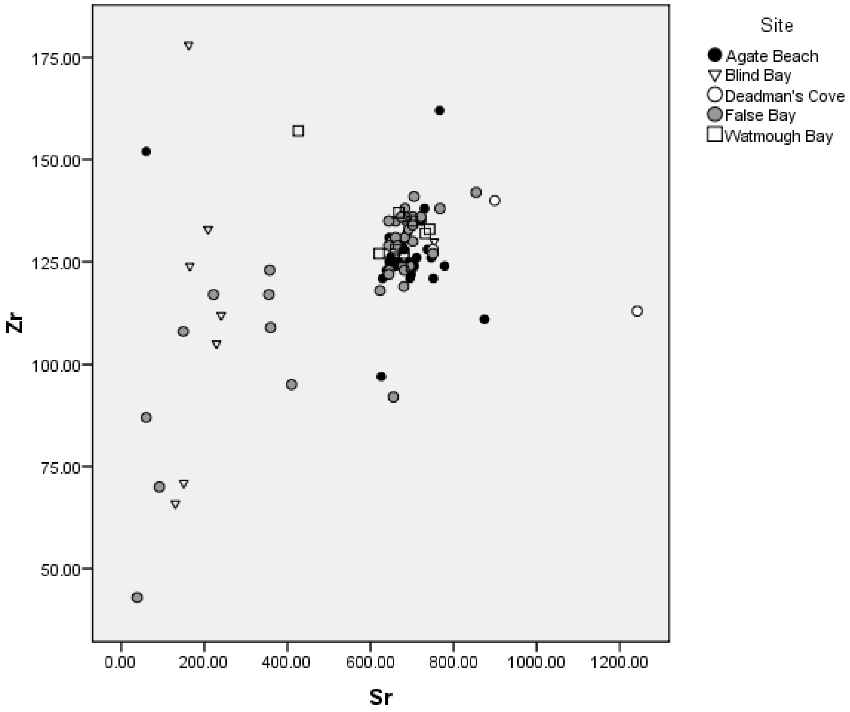


Figure 4.6. Biplot of zirconium and strontium concentrations (ppm) from EDXRF data for geological samples from San Juan Islands cobble areas.

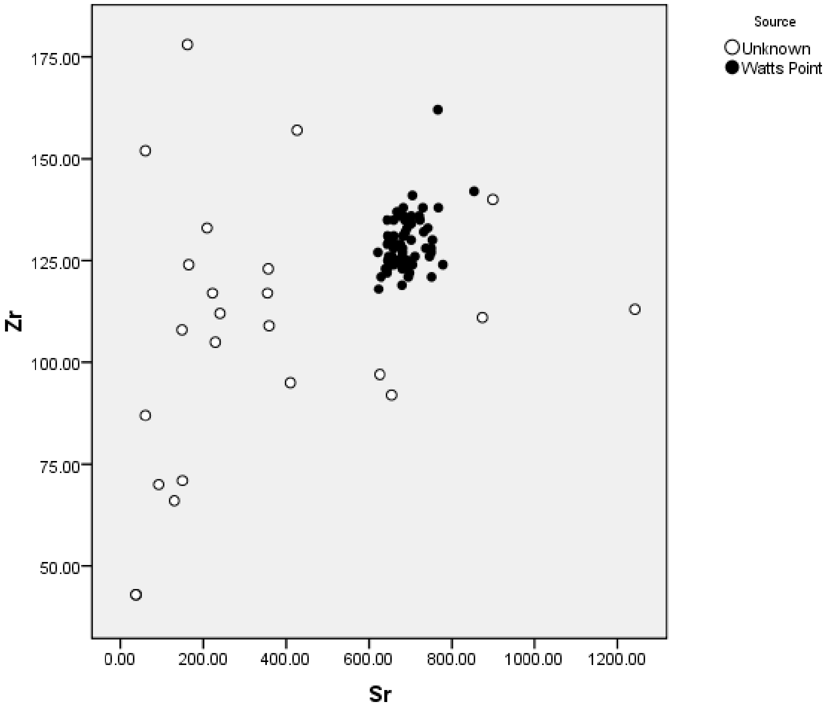
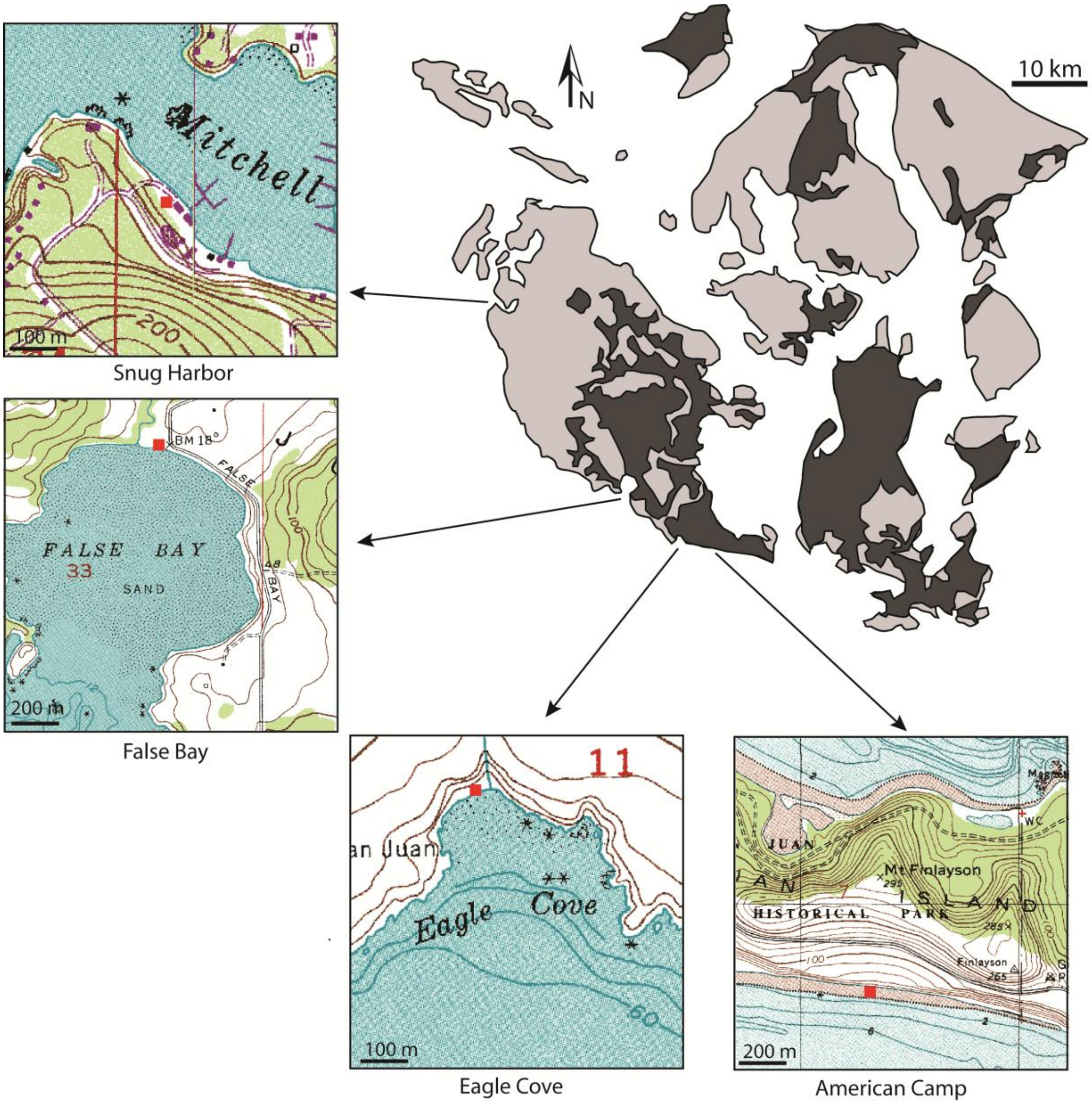


Figure 4.7. Biplot of zirconium and strontium concentrations (ppm) from EDXRF data for geological samples from San Juan Islands cobble areas showing Watts Point and unknown source FGV distribution.

Cobble Surveys in the San Juan Islands

It may not be possible to use a traditional geochemical source provenance analysis to determine where past communities in the San Juan Islands acquired their toolstone; however, information about the range of variation in size and shape of the cobbles on local beaches provides important clues about procurement behavior. I systematically surveyed six cobble beaches on the San Juan Islands during the summer of 2010 (Figure 4.8, 4.9). I chose beaches for survey that were within a boat ride from the Watmough Bay site and had high potential for exposed glacial deposits. On all six beaches, quaternary glacial deposits are present and high wave energy deflates large cobbles out of glacial deposits and erodes away sand and pebble-sized rocks. Recent GIS work by Finlayson (2006) identified moderate to high fetch beaches. FGV cobbles are visually distinct from other material types due to their dark color and reddish-brown to black cortex appearance. I conducted cobble surveys in 100 meter^2 areas at American Camp, Watmough Bay, False Bay, Snug Harbor, Agate Beach, and Aleck Bay. Survey areas were located in the sections of the beaches where cobbles appeared most abundant. I surveyed at one-meter intervals within the survey areas and recorded cortex appearance and dimensions of FGV cobbles for all cobbles over 2 cm in maximum dimension. Below I briefly describe the characteristics of each cobble survey area.


Snug Harbor

False Bay

Eagle Cove

American Camp

Figure 4.8 Cobble survey areas on San Juan Island. Dark gray areas indicate quaternary glacial deposits.

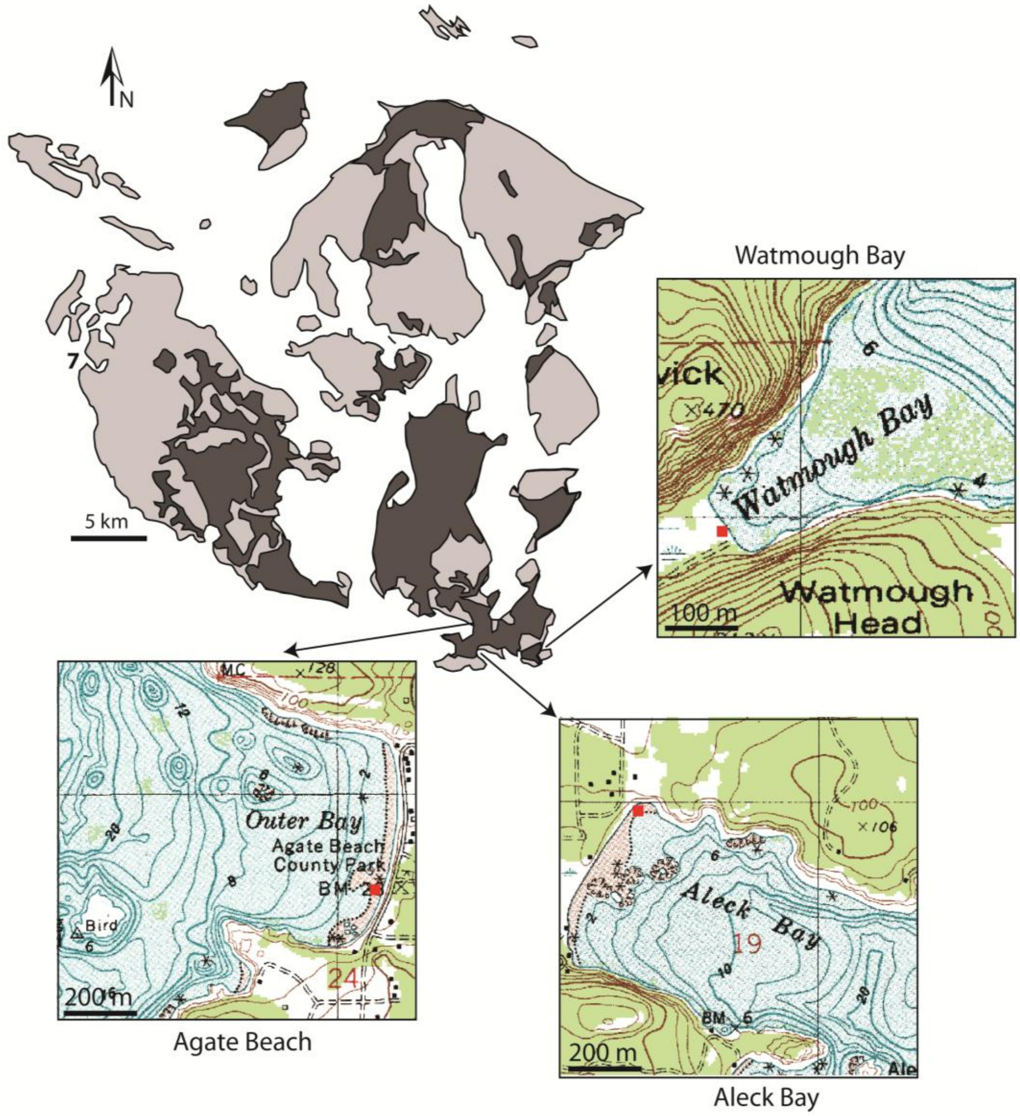


Figure 4.9 Cobble survey areas on Lopez Island. Dark gray areas indicate quaternary glacial deposits.

Watmough Bay beach is owned by the Bureau of Land Management and the San Juan County Land Bank. It is approximately 6980 meter^2, bounded to the southeast and northwest by large bedrock outcrops. To the southwest lies the archaeological site and a large wetland. Due to relatively low wave energy and/or the source sediment, the beach is predominantly composed of sand and many FGV cobbles there are relatively small (< 3 cm in maximum dimension). I noted a total of 64 FGV cobbles within the 100 meter^2 survey area (Figure 4.10).

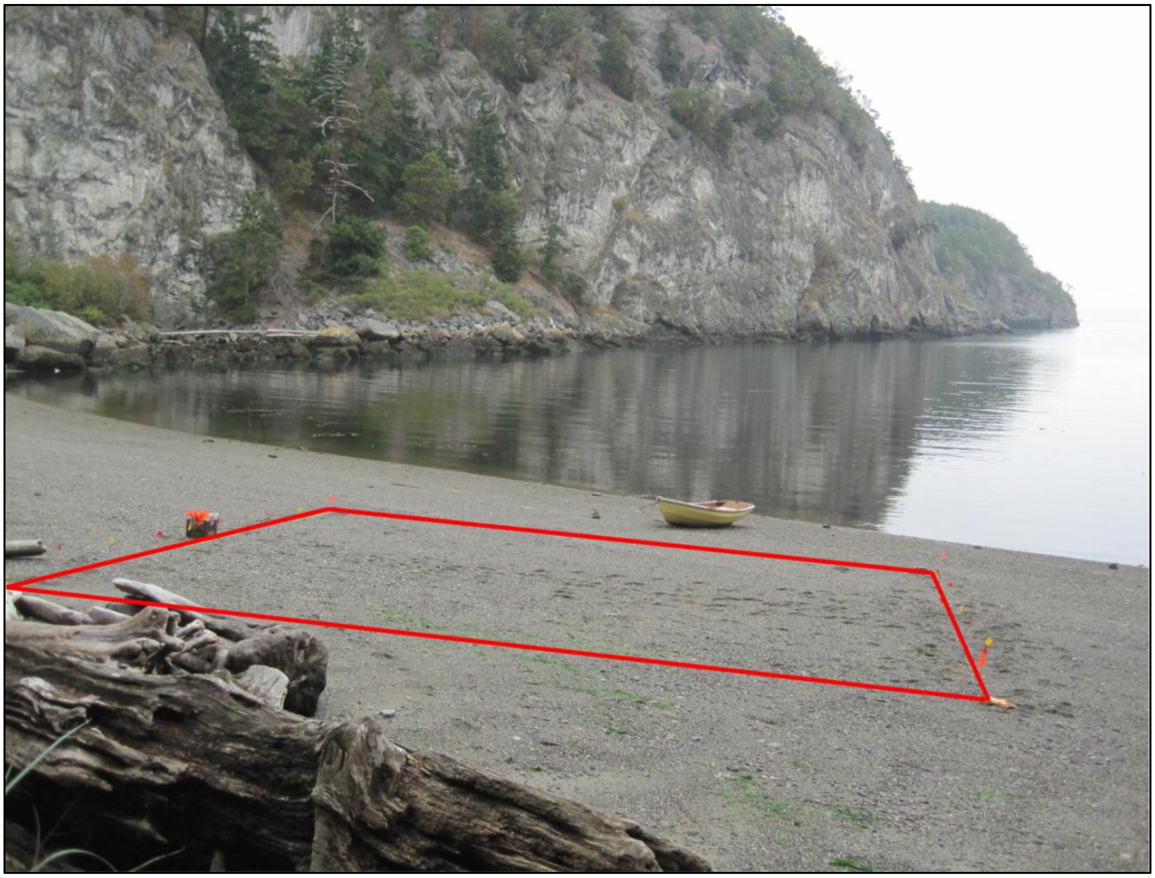


Figure 4.10. View to the north of the 10 x 10 meter survey area at Watmough Bay.

The 100 meter^2 survey area on Aleck Bay beach, Lopez Island, is located on private land owned by the Mendez family. Based on the Department of Archaeology and Historic Preservation (DAHP) database, there are no recorded archaeological sites sites on Aleck Bay. The Mendez property includes a section of the cobble beach that extends around the bay. The total area of this beach is approximately 8818 meter^2. The abundance of large driftwood logs suggests that there are periods of high wave energy on Aleck Bay beach. I noted 30 cobbles in the 100 meter^2 survey area; however, approximately 20% of the area was obscured by seaweed and driftwood (Figure 4.11).

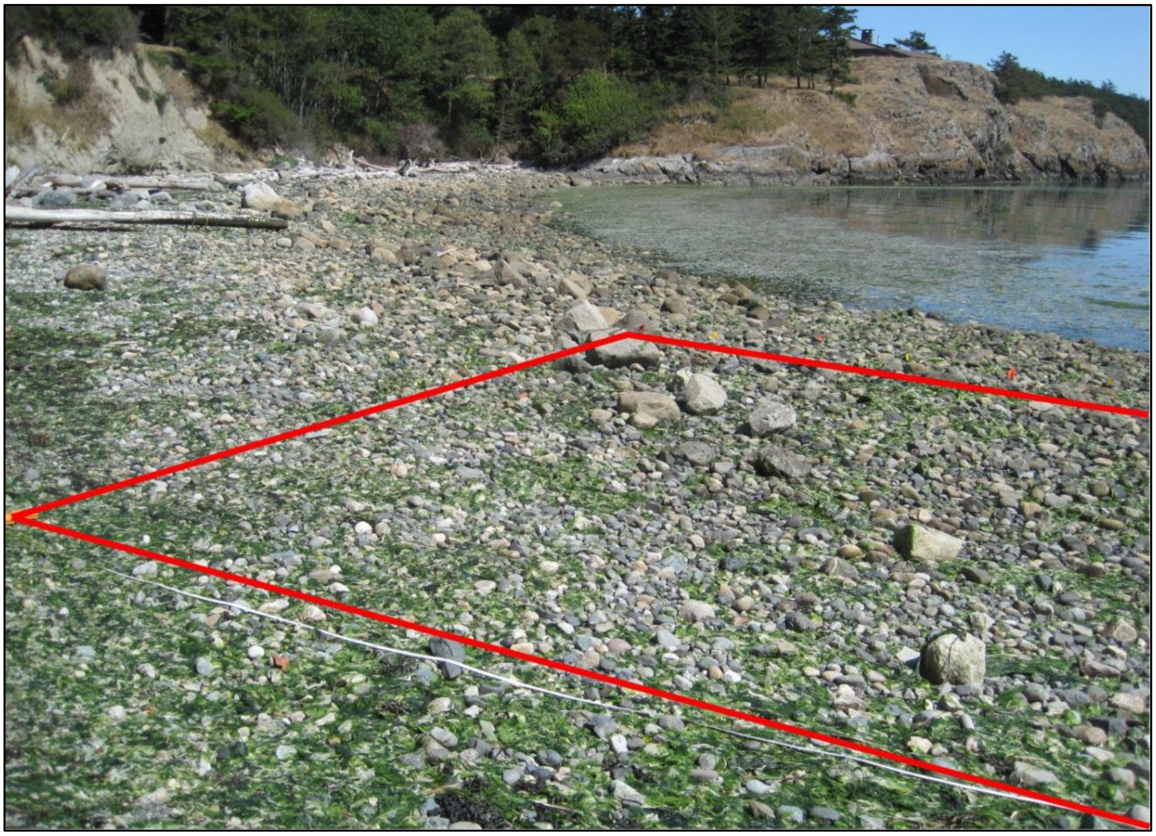


Figure 4.11 View to the northeast of the 10 x 10 meter^2 survey area at Aleck Bay beach.

Agate Beach on Lopez Island is located on land owned by San Juan County Parks. No archaeological sites have been recorded on or near Agate Beach. Rounded and waterworn FGV cobbles are abundant on this beach intermixed with other rock types. The total size of this beach is approximately 4900 meter^2. Because the pebbles on the beach decrease in size towards the intertidal zone, I created a 5 x 20 meter survey area closer to the high-tide line. Approximately 20% of the survey area was obscured by driftwood. I noted 69 FGV cobbles within the 100 meter^2 survey area (Figure 4.12).

Figure 4.12. View to the southeast of the survey area at Agate Beach.

The beach at American Camp on San Juan Island is located on land owned by San Juan Island National Historic Park. The western end of this beach, Eagle Cove, is on land owned by San Juan County Parks. The entire southern end of this island is a long glacial moraine and the cobble beach is composed of waterworn pebbles deflated from this moraine and outwash. Because this landform is so large (approximately 81,538 meter^2), I surveyed within two 10 x 10 m^2 areas to better estimate the range of variability in cobble abundance, size and shape. The first survey was located in the middle section of the landform. Most rocks were too small to be used as toolstone and a variety of rock types were present. A total of 10 FGV cobbles were found in this area (Figure 4.13). At the western end of the landform at Eagle Cove, 60% of the survey area was obscured by driftwood, but I identified a total of 26 FGV cobbles within the 10 x 10 meter^2

survey area (Figure 4.14). No archaeological sites have been recorded in the vicinity of American Camp beach although a shell midden has been recorded at Eagle Cove.

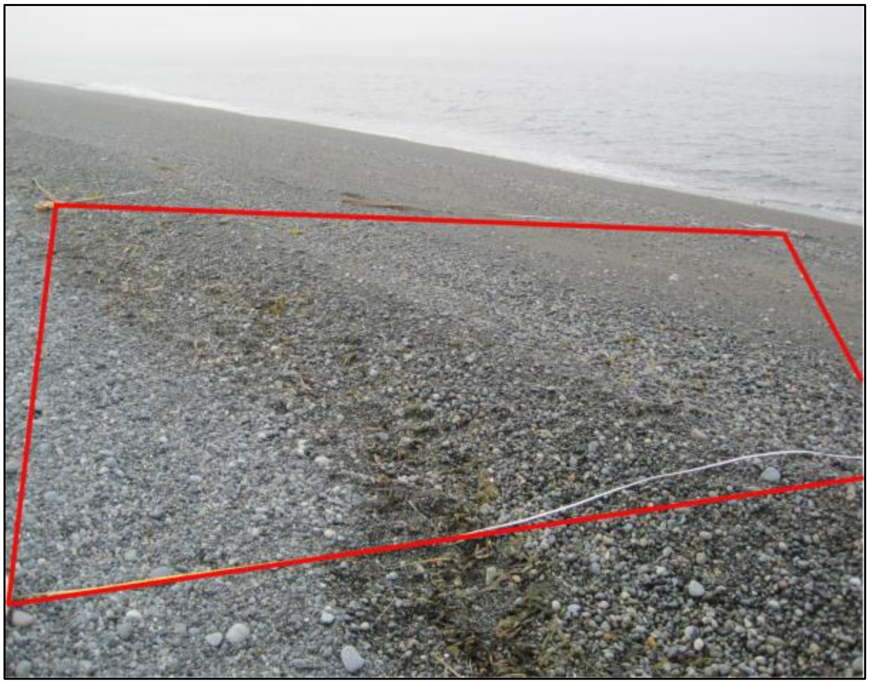


Figure 4.13. View to the southeast at the the survey area at American Camp.

Figure 4.14. View to the east of the survey area at Eagle Cove.

False Bay Beach on San Juan Island is located on land owned by the University of Washington. The beach is approximately 33,743 square meters and it is backed by a high cliff composed of glacial marine drift. Due to the rapidly rising tide, I surveyed within a 5 x 20 meter area at the high tide line. Approximately 40% of the survey area was obscured by seaweed, driftwood, and silt and clay but I found a total of 94 FGV cobbles, both rounded and angular. There are no recorded sites at False Bay (Figure 4.15).

Figure 4.15. View to the northwest of the survey area at False Bay.

Snug Harbor beach is located on land owned by Snug Harbor Resort and Marina on Mitchell Bay, San Juan Island. Today, the cobble beach is approximately 33,743 meter^2; however, extensive modern disturbance associated with the construction of the marina, resort, parking lot, and sea wall have changed the size of the original cobble collection area. In the 10 x 10 meter survey area I found both round and angular cobbles (Figure 4.16). A shell midden is eroding from behind the seawall adjacent to the beach, and I noted FGV artifacts, tested cobbles (one flake removed), and cores in the survey area.

Figure 4.16. View to the southeast at Snug Harbor.

San Juan Islands Toolstone Summary Statistics

Differences in the characteristics of toolstone available at Watmough Bay and at other nearby beaches are essential to evaluating change over time in land use by precontact peoples in the context of shifting territorial behavior. When people live in smaller and more highly defended territories, they should be constrained in their choice of toolstone to the cobbles on

Watmough Bay beach. When territories are larger and more poorly defended, people should procure cobbles from other cobble beaches. To distinguish Watmough cobbles from other cobble beaches, I investigate the cobble assemblages to determine if there are significant differences in size and shape. In the final section of this chapter, I use Wilson's (2007a,b; 2011; Browne and Wilson 2011) quarry attractiveness calculation to evaluate which cobble areas on the island would have been most desirable to native inhabitants.

To investigate whether differences in the composition of glacial marine drift and beach morphology affect the size and shape of cobbles on different beaches on the San Juan Islands, I use length as a proxy for size and measure and describe several dimensions of shape. Cobble *flatness* is measured as a ratio of length + width/2 x thickness (Wentworth 1922) where higher values represent flatter cobbles. Cobble *elongation* is measured as a ratio of width x 100/length (Sames 1966) where elongated cobbles have lower values. In the field, I classified cobbles into general categories of "round" or "angular", described cortex as black or gray, and described texture as unpolished (rough) or polished (smooth and waterworn).

Results of an ANOVA test to compare sample means indicate a statistically significant difference in mean length (used as a proxy for size) between Watmough Bay cobbles and mean length from all other cobble areas except American Camp. Watmough Bay cobbles are significantly smaller than cobbles from the other beaches. Most cobble areas are significantly different from one another in mean length (Table 4.1, 4.2, 4.3). Results of ANOVA also suggest a statistically significant difference in mean elongation between cobble areas; a Bonferroni post-hoc analysis indicates that only Watmough Bay and False Bay are significantly different in mean elongation ($p = 0.05$) whereas all other cobble areas are statistically similar in mean elongation (Watmough Bay and Agate Beach $p = 0.08$, all other comparisons $p = 1.0$) therefore this measure is not helpful in distinguishing between cobble areas. Roundness and flatness measures show no significant differences between cobble beaches on the San Juan Islands.

Results of χ^2 tests indicate that “round” versus “angular” categories may be more helpful in distinguishing between cobble areas. Although Watmough Bay is not significantly different in proportion of round and angular cobbles from other beaches, Aleck Bay and American Camp have significantly higher proportions of angular cobbles and False Bay has significantly higher proportions of round cobbles (Table 4.4). Results of χ^2 tests also indicate that Watmough Bay and Agate Beach have significantly higher proportions of smooth cobbles and False Bay has significantly higher proportions of rough cobbles (Table 4.4). Results of ANOVA tests and χ^2 tests confirm that size, shape category, and cortex texture are all useful for tracing change over time in lithic procurement in the San Juan Islands. In Chapter 6, I use this information to determine when people procured more toolstone from Watmough Bay beach and when they procured toolstone from elsewhere on the San Juan Islands.

Table 4.1 Descriptive statistics for six FGV cobble areas in the San Juan Islands.

	Max. length (mm)			Flatness (mm)			Elongation (mm)		
Watmough Bay	min	max	x̄	min	max	x̄	min	max	x̄
Quarry Area (m^2): 6980	20	70	37.13	1	4.36	1.65	33.33	109.09	71.17
Survey Area (m^2): 100	σ	var.		σ	var.		σ	var.	
Total FGV cobbles >2 cm: 64	11.68	136.46		0.51	0.26		17.64	311.22	
Aleck Bay	min	max	x̄	min	max	x̄	min	max	x̄
Quarry Area (m^2): 8820	46	137	76.77	11.16	2.53	1.71	6.25	105.88	75.62
Survey Area (m^2): 100	σ	var.		σ	var.		σ	var.	
Total FGV cobbles >2 cm: 30	23.74	563.5		0.32	0.1		17.5	306.35	
Agate Beach	min	max	x̄	min	max	x̄	min	max	x̄
Quarry Area (m^2): 4910	34	108	58.39	1.08	3.23	1.73	28.41	122.64	79.33
Survey Area (m^2): 100	σ	var.		σ	var.		σ	var.	
Total FGV cobbles >2 cm:70	15.98	255.46		0.45	0.2		15.13	228.95	
American Camp/Eagle Cove	min	max	x̄	min	max	x̄	min	max	x̄
Quarry Area (m^2): 81540	23	85	44.47	1.03	3.17	1.61	43.18	129.41	76.35
Survey Area (m^2): 100	σ	var.		σ	var.		σ	var.	
Total FGV cobbles >2 cm: 36	13.49	182.03		0.39	0.16		18.65	347.66	
False Bay	min	max	x̄	min	max	x̄	min	max	x̄
Quarry Area (m^2): 33740	31	141	69.73	0.86	2.94	1.59	6.17	142.31	79.23
Survey Area (m^2): 100	σ	var.		σ	var.		σ	var.	
Total FGV cobbles >2 cm: 94	20.26	410.35		0.32	0.11		17.78	316.19	
Snug Harbor	min	max	x̄	min	max	x̄	min	max	x̄
Quarry Area (m^2):760	32	79	51.34	1.04	21.17	1.69	41.18	131.7	75.69
Survey Area (m^2): 100	σ	var.		σ	var.		σ	var.	
Total FGV cobbles >2 cm: 130	9.71	94.26		1.75	3.05		15.75	248.12	

Table 4.2. Results of an ANOVA for cobble size/shape data for San Juan Islands beaches.

		df	x̄ sq.	F	Sig.
Max. Length	Between Groups	5	12284.99	51.74	**0.00**
	Within Groups	418	237.458		
	Total	423			
Flatness	Between Groups	5	0.223	0.211	0.96
	Within Groups	418	1.056		
	Total	423			
Elongation	Between Groups	5	638.032	2.263	**0.05**
	Within Groups	418	281.985		
	Total	423			

Table 4.3. Results of a Bonferonni post-hoc analysis for cobble length for cobble areas on the San Juan Islands.

Source Area	Source Area	Mean Difference (I-J)	Std. Error	Sig.
Watmough	Agate	-21.26	2.67	**0.00**
	Aleck	-39.64	3.41	**0.00**
	American	-7.35	3.21	0.34
	False Bay	-32.61	2.50	**0.00**
	Snug	-14.21	2.35	**0.00**
Agate	Watmough	21.26	2.67	**0.00**
	Aleck	-18.38	3.36	**0.00**
	American	13.91	3.16	**0.00**
	False Bay	-11.35	2.43	**0.00**
	Snug	7.05	2.28	0.03
Aleck	Watmough	39.64	3.41	**0.00**
	Agate	18.38	3.36	**0.00**
	American	32.29	3.81	**0.00**
	False Bay	7.03	3.23	**0.00**
	Snug	25.43	3.12	0.45
American	Watmough	7.35	3.21	0.34
	Agate	-13.91	3.16	**0.00**
	Aleck	-32.29	3.81	**0.00**
	False Bay	-25.26	3.02	**0.00**
	Snug	-6.87	2.90	0.28
False Bay	Watmough	32.61	2.50	**0.00**
	Agate	11.35	2.43	**0.00**
	Aleck	-7.03	3.23	0.45
	American	25.26	3.02	**0.00**
	Snug	18.40	2.09	**0.00**
Snug	Watmough	14.21	2.35	**0.00**
	Agate	-7.05	2.28	0.03
	Aleck	-25.43	3.12	**0.00**
	American	6.87	2.90	0.28
	False Bay	-18.40	2.09	**0.00**

Table 4.4. Results of χ^2 tests for ordinal values recorded for cobble area data for the San Juan Islands.

	Round	Expected	Angular	Expected	Total	χ^2	df	*p*	Adjusted Residuals
Watmough Bay	39	36.38	25	27.62	64	41.97	5	<0.01	0.72
Agate Beach	36	39.79	34	30.21	70				-1
Aleck Bay	11	17.05	19	12.95	30				**-2.31**
American Camp	11	20.46	25	15.54	36				**-3.33**
False Bay	77	53.43	17	40.57	94				**5.56**
Snug Harbor	67	73.89	63	56.12	130				-1.47
	Black	Expected	Gray	Expected	Total	χ^2	df	*p*	Adjusted Residuals
Watmough Bay	46	45.43	18	18.57	64	30.08	5	<0.01	0.17
Agate Beach	41	49.69	29	20.31	70				**-2.51**
Aleck Bay	20	21.30	10	8.70	30				-0.54
American Camp	17	25.56	19	10.44	36				**-3.29**
False Bay	65	66.73	29	27.27	94				-0.45
Snug Harbor	112	92.29	18	37.71	130				**4.58**
	Unpolished	Expected	Polished	Expected	Total	χ^2	df	*p*	Adjusted Residuals
Watmough Bay	7	29.11	48.00	25.89	55	125.6	5	<0.01	**-4.1**
Agate Beach	4	27.52	48.00	24.48	52				**-4.48**
Aleck Bay	20	15.88	10.00	14.12	30				1.03
American Camp	14	14.29	13.00	12.71	27				-0.08
False Bay	77	47.10	12.00	41.90	89				**4.36**
Snug Harbor	77	65.10	46.00	57.90	123				1.48

The Lithic Landscape of San Nicolas Island

Toolstone on San Nicolas Island is available primarily in the form of metavolcanic and metasedimentary cobbles from an Eocene-era cobble conglomerate strata (Vedder and Norris 1963; Figure 4.17). This deposit is the only major source of toolstone on the island (Clevenger 1982). Cobbles eroding out of the conglomerate are easily accessible and densely distributed on beaches. They are available but more sparsely distributed in canyon drainages and inland blowouts (Clevenger 1982). Clevenger (1982) located nine potential quarry locations on San Nicolas Island. In the 1980s, Reinman and his students mapped approximately 40 cobble locations throughout the island. These data were included in a GIS database for island cultural and natural resources. Of these previously recorded cobble areas, I chose six areas to survey based on proximity to Tule Creek Village and SNI-106. I included both inland and beach cobble areas to investigate variability in material type, size, and shape based on setting.

Pinpointing the exact provenance of a cobble is not possible based on material type or geochemistry because they all come from the same geological deposit (Clevenger 1982:29). Differences in geomorphology and geology of cobble areas produce differences in cobble size, shape, and material type, thus I use data from cobble surveys to investigate change through time in procurement strategies. Erlandson et al. (2008) note that in the Channel Islands, cobbles with internal fractures and those made of softer material are destroyed by waves on beaches but remain intact in inland outcrops. Sandstone outcrops tend to be accessible on beaches due to the surface geology of the island and erosion of other sediment by waves.

Figure 4.17. Cobbles eroding out of an Eocene-era cobble conglomerate stratum.

In choosing inland cobble areas to survey, I considered the degree to which modern erosion altered the modern distribution of cobbles relative to the precontact distribution of cobbles on San Nicolas Island. During the 1850s, sheep ranching began on the island and continued through the 1940s. Island vegetation was destroyed and large sand dunes formed (Schwartz and Rossbach 1993). The dunes move gradually across the landscape and cover up both archaeological sites and cobble collection areas. In other areas, dune erosion creates a palimpsest where artifacts that date to several time periods are redeposited onto the same surface. Because postcontact inland blowouts and streambeds are not in the same place as precontact inland cobble areas, my data from cobble surveys in those areas may not represent the exact cobble areas used by native communities but are representative of the kinds of inland outcrops that were used. In beach cobble areas, wave energy is the most important erosional force along the coast. Cobble beaches exist where the cobble conglomerate layers are present at the surface.

Due to the unique geology of the island, lithic assemblages on San Nicolas Island are primarily composed of metamorphic rocks that erode out of a softer sedimentary matrix. These cobbles are hard and some are coarse-grained and difficult to work. Metasedimentary cobbles and finer-grained metavolcanic cobbles fracture more easily than metavolcanic cobbles that are highly porphyritic with large feldspar crystals (Rosenthal 1996). Rosenthal (1996:304) notes that the geology of San Nicolas Island provides “few materials suitable for flaked stone tool manufacture” other than the “less desirable” metamorphic cobbles; however, another perspective is that for the Nicoleño who were accustomed to this material type, adequate toolstone was ubiquitous on the landscape. It may have been more difficult to work than chert or obsidian, but given the abundance of lithic artifacts made from local toolstone on sites across the island, native communities found metavolcanic and metasedimentary rock well-suited to their technological needs.

Taşkiran (2001:55-60) describes in detail the rock types available on the southern Channel Islands and notes that the metamorphism of the San Nicolas Island cobbles can be classified as "low grade" because parent rocks can be identified by mineralogical composition. These include metamorphosed equigranular and aphanitic latite, basalt, and rhyolite. Since the mineralogical composition of the rock was difficult to determine macroscopically with a high degree of precision, I used broader categories for metavolcanic rocks following the California State University Los Angeles archaeology laboratory protocol. (1) *Metavolcanic* rocks have few to no phenocrysts (larger crystals within a finer groundmass) (Figure 4.18); (2) *Porphyritic metavolcanic* rocks have phenocrysts (5-50%) but they do not dominate the groundmass (Figure 4.19); (3) *Metavolcanic porphyry* rocks have abundant (50%) phenocrysts. These rocks are typically coarse-grained, although in some cases, the phenocrysts fuse together and the rock is fine-grained (Figure 4.20). This classification system for metavolcanic rocks is not based on geological terminology but on a macroscopically consistent archaeological typology relevant to stone tool manufacture.

Figure 4.18. A metavolcanic cobble split in the lab.

Figure 4.19. Porphyrtic metavolcanic artifacts from Tule Creek Village. Photo courtesy of Jay Flaming's archaeological photography students.

Figure 4.20. A metavolcanic porphyrtic cobble still embedded in the matrix.

Quartzite artifacts are identifiable based on their crystalline and sugary appearance characteristic of recrystallized sandstone (Figure 4.21). Small amounts of quartz (Figure 4.22) and fine-grained metasedimentary rock known as "island chert" are also found in assemblages on San Nicolas Island.   These materials were available in small quantities throughout the islands although exact source locations for these materials are unknown.

Along with local toolstone, native peoples of San Nicolas Island also used chert that came from other islands and the mainland. Chert artifacts are present in the Tule Creek Village assemblage and range in appearance from banded, solid colored, and translucent. No chert has been found on San Nicolas Island but some have been located on the Northern Channel Islands. Santa Cruz Island chert ranges from white to dark brown to gray and was used to create microblades by craft specialists as part of a shell bead industry during the Late Holocene (Arnold 1987, 1990b, 1992). Cico Chert (4.23) is found on northeastern San Miguel Island. It is translucent and ranges in color from white to gray to brown with some reddish brown and purple rocks and parallel layers or homogenous veins (Erlandson et al. 1997) . Erlandson et al. (2008) also report an outcrop of "Tuquan" Monterey Chert on eastern San Miguel Island. They note that there may also be a source of toolstone-quality Monterey banded chert and siliceous shales on Santa Rosa Island and elsewhere on San Miguel Island. Monterey chert (Figure 4.24) is widespread along the mainland coast from the Camp Pendleton area to San Francisco. Franciscan chert, which comes in a variety of colors but is not banded, is widespread along the mainland coast from north of Santa Barbara to Oregon. (Cannon 2006:81). Most obsidian comes from the Coso volcanic field inland (Rick et al. 2001a; Figure 4.25).

Regarding ground stone, the Nicoleño crafted vessels, shaft straighteners, beads, and ceremonial objects from sandstone, steatite, and serpentine. Tabular sandstone slabs were also used to make saws likely used in the production of shell tools and ornaments (Kendig et al. 2010). While sandstone was available on San Nicolas Island, steatite and serpentine were not. It would have been acquired directly or through exchange from Santa Catalina Island or from the mainland (Cannon 2006:82; Hudson and Blackburn 1987:35). Following previous work in the Channel Islands (e.g., Cannon 2006), I assume that most exotic stone was brought to San Nicolas through exchange in return for sandstone objects, ceremonial *toshaawt* stones, food resources, and *Olivella* beads (Cannon 2006; Vellanoweth et al. 2002). The cost of travel to procure these materials would have been great due to the distance between the island and the other sources (Figure 4.25). If people had quarried and collected the material directly, it probably would have been present at sites in larger quantities. Exchange is a more parsimonious explanation, but the possibility of direct procurement cannot be ruled out.

Figure 4.21. Quartzite artifacts from Tule Creek Village, San Nicolas Island. Photo courtesy of Jay Flaming's archaeological photography students.

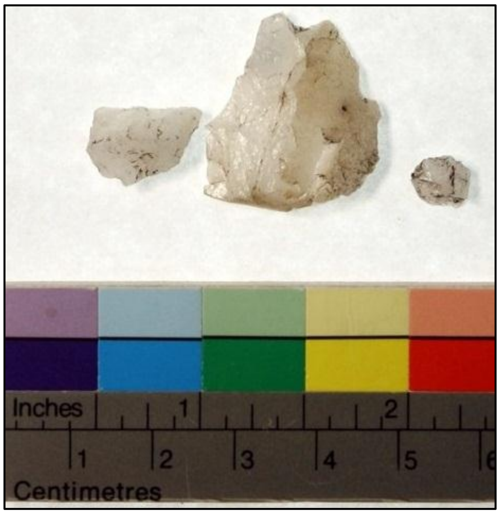


Figure 4.22. Quartz artifacts from Tule Creek Village, San Nicolas Island. Photo courtesy of Jay Flaming's archaeological photography students.

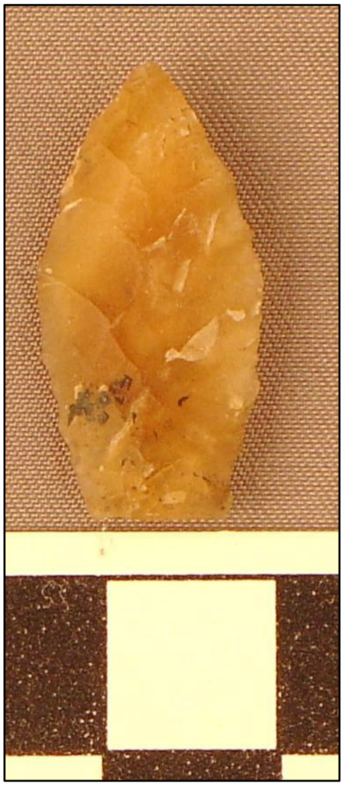


Figure 4.23. Cico chert biface from Tule Creek Village, Mound B.

Figure 4.24. Monterey banded chert biface from Tule Creek Village, Mound B

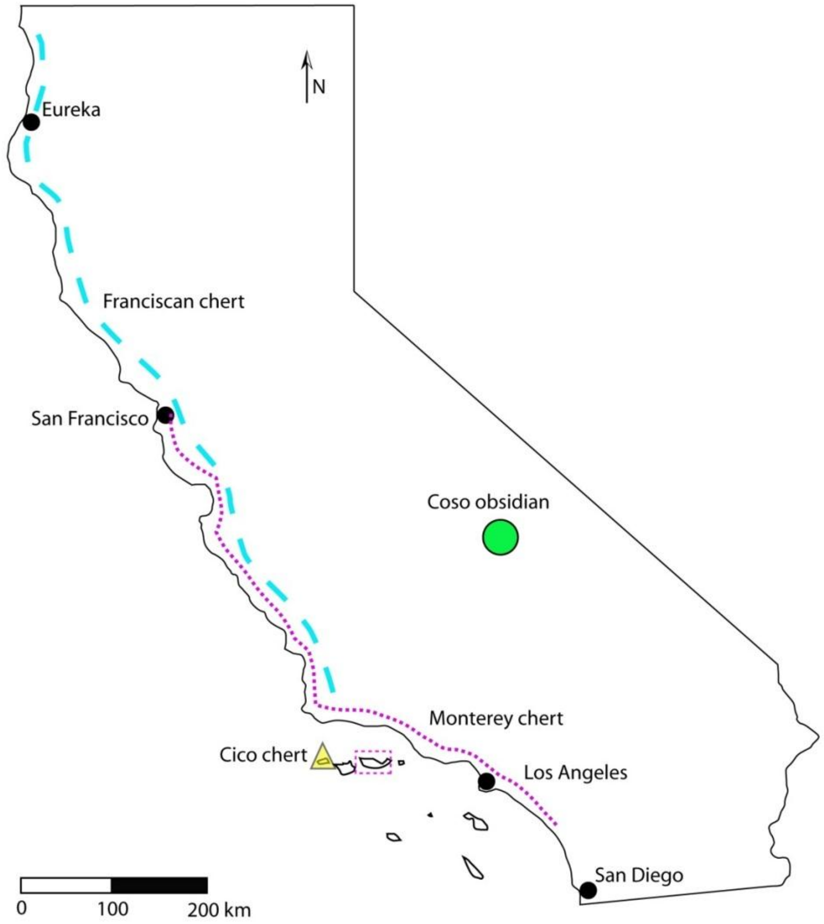


Figure 4.25. Map of extra-local toolstone sources for San Nicolas Island, California. The dashed line shows the distribution of Franciscan chert on the mainland. The dotted line shows the distribution of Monterey chert on the mainland and on Santa Cruz Island. The triangle shows the location of Cico chert on San Miguel Island. The circle shows the location of Coso obsidian.

Cobble Surveys on San Nicolas Island

During the summer of 2009 I worked with field school students at California State University, Los Angeles (CSULA) to record characteristics of cobble deposits on northwest San Nicolas Island in the vicinity of Tule Creek Village, Mound B and CA-SNI-106. Surveys were conducted in 50-200 meter^2 areas at 3 beaches and 3 inland areas (Figure 4.26). All cobbles over 2 cm in maximum dimension were recorded along transects spaced 1 meter apart. During cobble surveys, we could distinguish between metavolcanic, quartzite, and sandstone but quartzite is likely underrepresented because weathered cobbles were more difficult to identify.

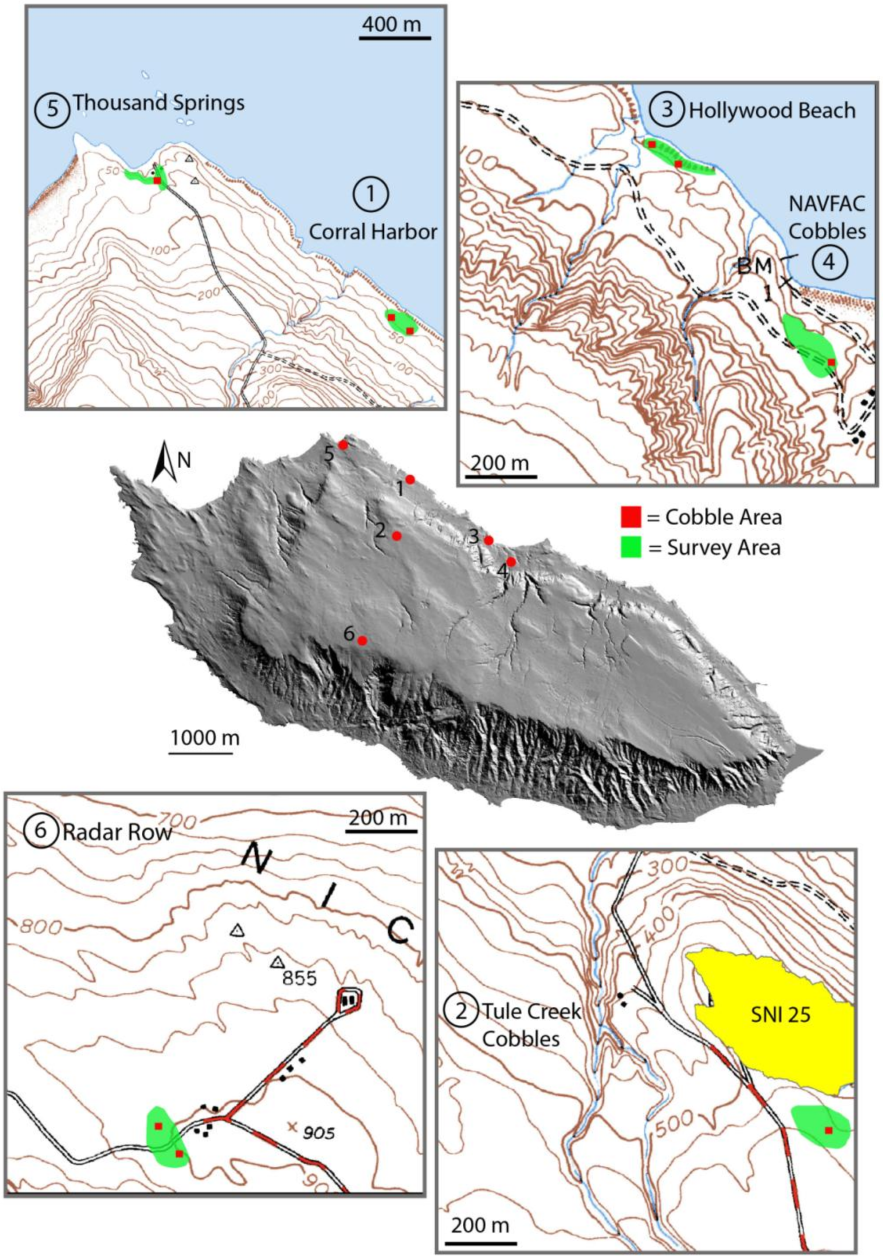


Figure 4.26. Map showing the locations of cobble survey areas on San Nicolas Island. 1 – Corral Harbor 2 – Tule Creek Cobble Area 3 – Hollywood Beach 4 – NAVFAC Cobble Area 5 – Thousand Springs 6 – Radar Row.

The beach cobble area nearest to Tule Creek Village is at Corral Harbor, a cove protected by a sandstone outcrop that would also have served as an optimal location for fishing, hunting sea mammals, and gathering shellfish. At this approximately 5040 meter^2 cobble area, I set up a 10 x 10 meter survey area on the east side of the beach and a 5 x 20 meter survey area on the west side of the beach. This beach is characterized by both abundant metamorphic cobbles and abundant sandstone due to the erosion of a large sandstone outcrop. Within both survey areas I noted a total of 1075 cobbles of which 497 were identified as metavolcanic (Figure 4.27, 4.28).

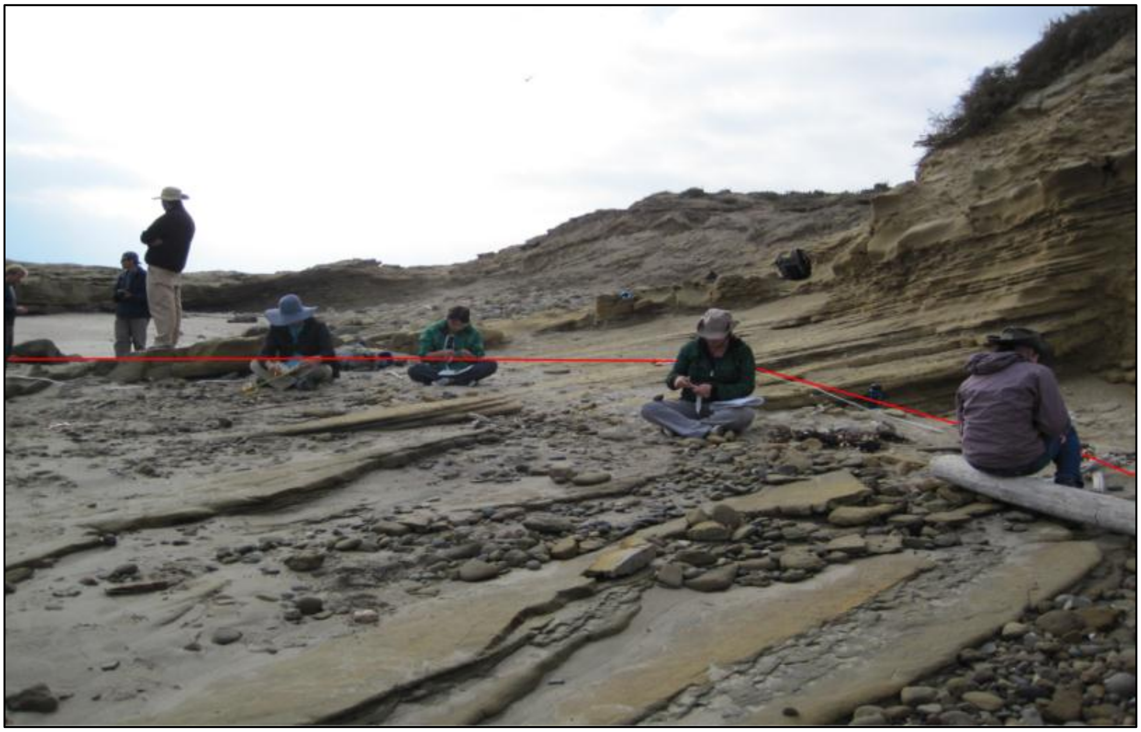


Figure 4.27. Survey Area 1 at Corral Harbor, view to the southeast. Sandstone outcrop in the background.

Figure 4.28. Survey Area 2 at Corral Harbor, view to the northeast. Protected harbor in the background.

The inland cobble area nearest to Tule Creek Village is an extensive blowout adjacent to the site. It measures 1545 meter^2. I could not be sure that this blowout would have been present at the time that the site was occupied, but since there was a creek nearby, but since there is a creek nearby, cobbles were likely present in the creek bed. The presence of flakes and cores also indicates procurement from this cobble area. Within a 10 x 10 meter survey area I noted a total of 129 cobbles of which 74 were metavolcanic. Many of the cobbles were identified as broken or “low quality” indicating that they were made of soft and crumbling metasedimentary rock (Figure 4.29).

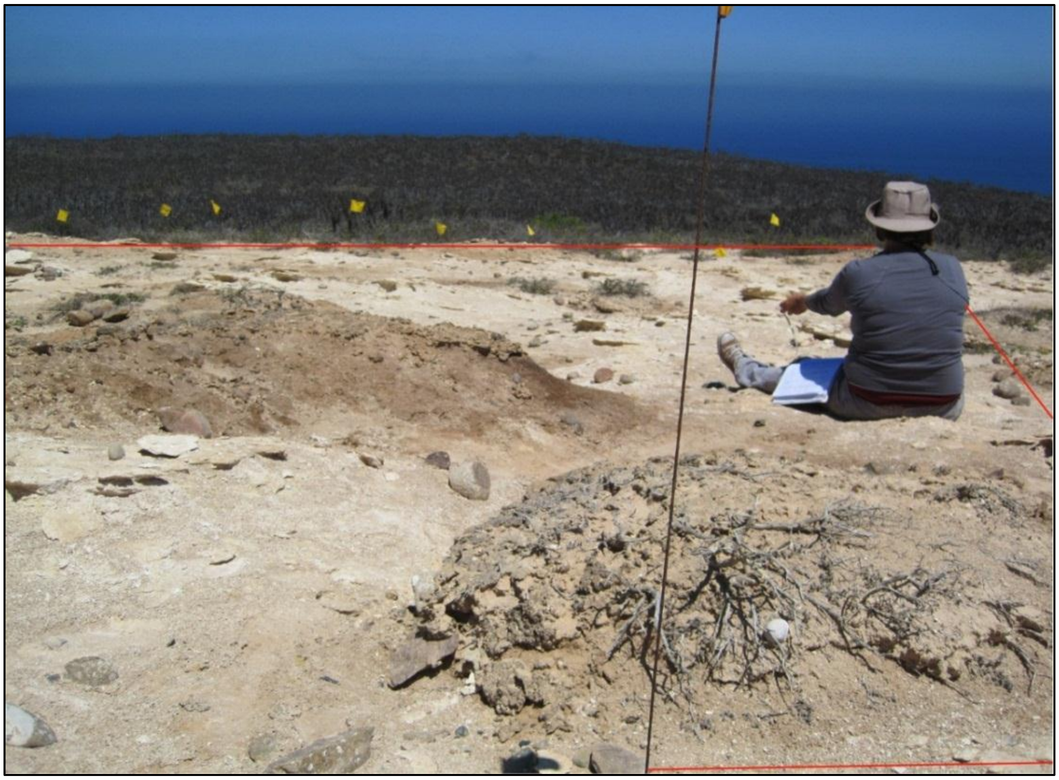


Figure 4.29. Survey area near Tule Creek Village.

Another beach cobble area southeast of Corral Harbor designated “Hollywood Beach” would have been readily accessible to the occupants of CA-SNI-25. Sandstone outcrops surround the beach. At this approximately 28,010 meter^2 quarry area, I set up two 5 x 5 meter survey areas, one on the east side of the beach and the other on the west side of the beach. Both metamorphic cobbles and sandstone slabs are abundant at this quarry area. I recorded a total of 663 cobbles of which 223 were identified as metavolcanic (Figure 4.30, 4.31).

Figure 4.30. Survey Area 1 at Hollywood beach, view to the southeast. Sandstone outcrop and eroding bank in the background.

Figure 4.31. Survey Area 2 at Hollywood beach, view to the northwest. Protected cove in the background.

Near the NAVFAC building on an inland beach terrace approximately 100 meters inland is large blowout with abundant cobbles in some locations. The area where cobbles were present on the surface was approximately 3750 meter^2. Within a 10 x 10 meter survey area I counted 101 cobbles of which 79 were identified as metavolcanic. Sandstone was not abundant in this area (Figure 4.32).

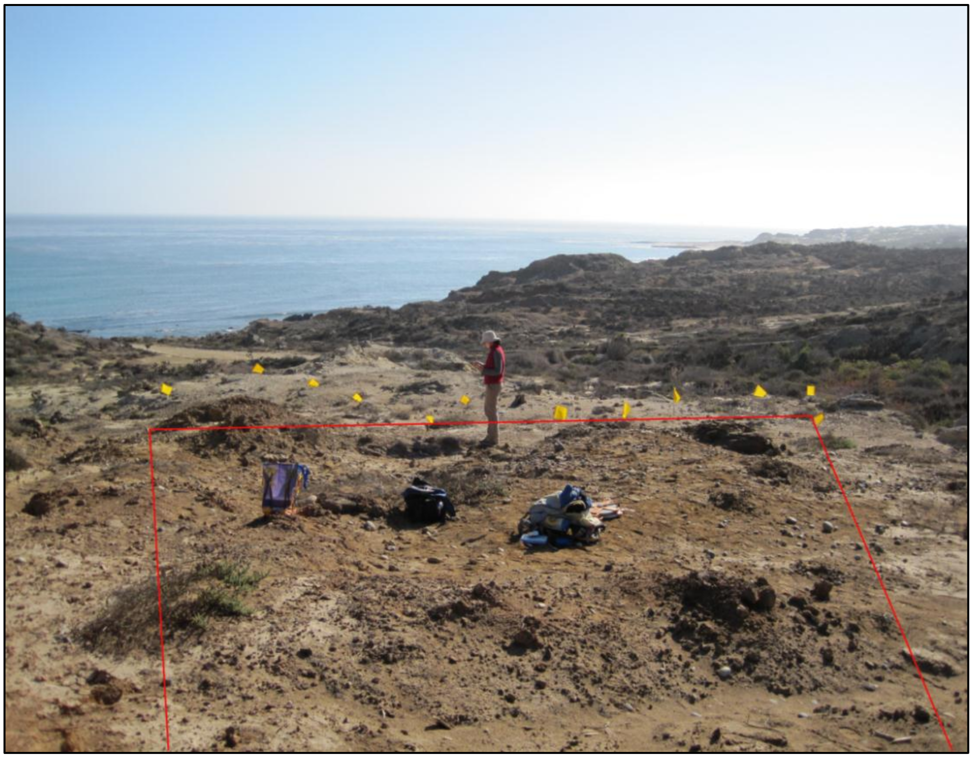


Figure 4.32. NAVFAC survey area, view the northeast.

On the northwestern tip of the island, the Thousand Springs cobble area is located on a high eroding cobble conglomerate cliff. Vegetation is sparse and the top of the cliff is an erosional surface due to high wind. There may be modern disturbance associated with road construction. Cobbles are also abundant on the beach below. In the approximately 5740 meter^2 area where cobbles were abundant on top of the cliff, we surveyed a 10 x 10 meter area. I noted a total of 1612 cobbles of which 1452 were metavolcanic. Sandstone was not abundant in this area. (Figure 4.33).

Figure 4.33. Cobble area at Thousand Springs, view to the north.

At the southern edge of the high interior plateau on San Nicolas Island, blowouts with exposures of cobbles are abundant because vegetation in scarce. One area of dense cobbles is located off of Radar Row Road. In an approximately 10,130 meter^2 area, I surveyed one 10 x 10 meter area on the south side of the road (Area 1) and another 10 x 10 meter area on the north side of the road (Area 2). I recorded a total of 146 cobbles of which 90 were metavolcanic. Many of the cobbles were identified as broken or "low quality" indicating that they were made of soft and crumbling metasedimentary material. Sandstone in this area was scarce (Figure 4.34, 4.35).

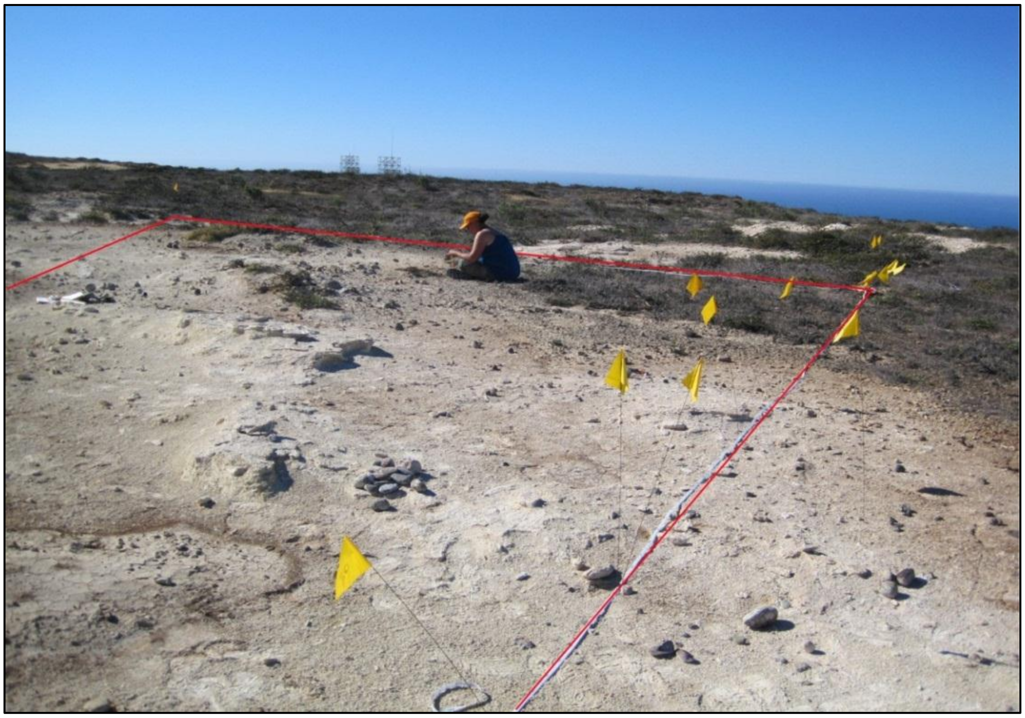


Figure 4.34. Radar Row Survey Area 1 on the south side of the road.

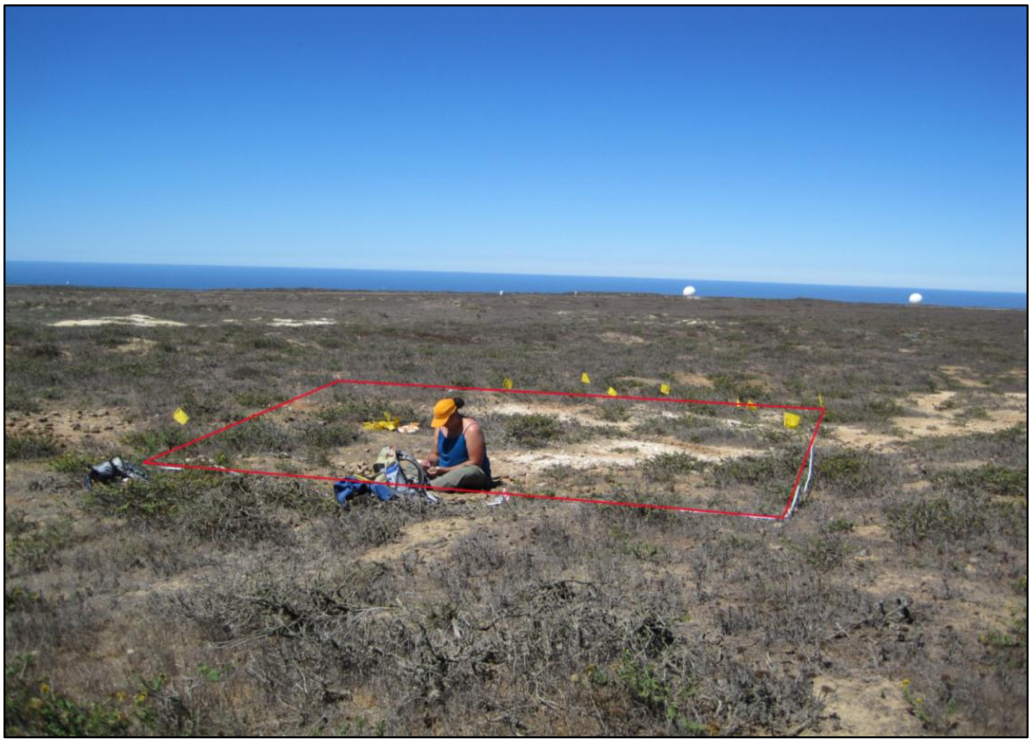


Figure 4.35. Radar Row Survey Area 2 on the north side of the road.

San Nicolas Island Toolstone Summary Statistics

Differences in the characteristics of toolstone available near Tule Creek Village and CA-SNI-106 and other cobble area are used to investigate territorial circumscription during the Late Holocene. To determine if and when people defended smaller territories, I compare toolstone available near Tule Creek Village and CA-SNI-106 and toolstone available elsewhere on the landscape. Proportions of material types (metavolcanic, quartzite, and sandstone) differ substantially between cobble areas with higher amounts of quartzite at Corral Harbor and Thousand Springs and higher amounts of sandstone at Corral Harbor and Hollywood Beach (Table 4.5). In comparisons of cobble shape and size, I focus on metavolcanic rock cobbles because the lithic assemblage is composed predominantly of that material type thus sample size is large enough conduct statistical analyses comparing lithic assemblage to cobble assemblage characteristics.

Table 4.5. Proportions of material types at each cobble area on San Nicolas Island.

Cobble Area	Metavolcanic	Sandstone	Quartzite
Corral Harbor	497	510	48
Tule Creek	74	1	6
Hollywood Beach	223	291	14
NAVFAC	79	3	3
Thousand Springs	1452	40	98
Radar Row	90	0	6

To investigate whether differences in the composition of glacial marine drift and beach morphology affect the size and shape of cobbles on different beaches on the San Nicolas Island, I use length as a proxy for size and measure several dimensions of shape. Unlike the San Juan Islands cobbles, all metamorphosed cobbles on San Nicolas Island are relatively round. To distinguish between cobbles with different degrees of roundness, I quantify this variable as both a ratio of maximum to minimum circumference to determine the regularity of the shape (higher numbers are more regular) and as an average of the ratio between each dimension (width/length + thickness/length + thickness/width)/3 (Armstrong et al. 2003). Based on this measure, I define “flat” cobbles as cobbles with roundness values below 0.5 or above 1.5 to and round cobbles as those with roundness values between 0.5-1.5. *Cobble flatness* is a ratio of length + width/2 x thickness (Wentworth 1922) where higher values represent flatter cobbles. Cobble *elongation* is a ratio of width x 100/length (Sames 1966). Elongated cobbles have lower values.

Results of an ANOVA test comparing mean length, circumference ratio, flatness, and elongation measures for metavolcanic rocks indicate significant differences in cobble size and shape between almost all of cobble areas (Table 4.6, 4.7). Bonferonni post-hoc analyses show which areas are significantly different from one another in mean size and shape measurements (Table 4.8-4.11). Mean cobble size quantified as mean length for Hollywood Beach and Tule Creek (approximately 8-9 cm) are significantly lower than for Thousand Springs and Corral Harbor (approximately 6 cm). For circumference ratio, the major difference is between Thousand Spring which has a higher mean ratio ($\bar{x} = 1.39$) and Corral Harbor ($\bar{x} = 1.29$), therefore this measure is less useful unless it necessary to distinguish between those two specific cobble areas. For flatness, Corral Harbor has a significantly lower mean flatness value ($\bar{x} = 1.41$) and Hollywood Beach has significantly higher mean flatness value ($\bar{x} = 2.61$), suggesting a higher abundance of flatter cobbles. This result is also reflected in a Bonferonni post-hoc analysis for elongation. Mean elongation value for Corral Harbor cobbles ($\bar{x} = 96.54$) is significantly greater than all other cobble areas. Thus, for metavolcanic cobbles, size varies between cobble areas and shape is different for Corral Harbor, Hollywood Beach, and Thousand Springs cobble areas.

Table 4.6. Descriptive statistics for metavolcanic cobbles at six cobble areas on San Nicolas Island.

	Max. length (mm)			Circumference Ratio (mm)			Roundness (mm)			Flatness (mm)			Elongation (mm)		
Corral Harbor	min	max	x̄	min	max	x̄	min	max	x̄	min	max	x̄	min	max	x̄
Quarry Area (m^2): 6980	20	300	60.22	0.99	3	1.29	0.29	2.98	0.94	0.27	18	1.41	33.33	300	96.54
Survey Area (m^2): 200	σ	var.		σ	var.		σ	var.		σ	var.		σ	var.	
Total MV cobbles >2 cm:497	2.9	8.4		0.26	0.07		0.28	0.08		1.13	1.28		31.33	981.29	
Tule Creek Cobbles	min	max	x̄	min	max	x̄	min	max	x̄	min	max	x̄	min	max	x̄
Quarry Area (m^2): 1545	40	160	86.55	1.05	4.75	1.39	0.42	3.1	0.63	0.24	4	2.17	38.89	112.5	76.76
Survey Area (m^2): 100	σ	var.		σ	var.		σ	var.		σ	var.		σ	var.	
Total MV cobbles >2 cm: 74	2.59	6.68		0.43	0.19		0.31	0.09		0.7	0.49		15.24	232.3	
Hollywood Beach	min	max	x̄	min	max	x̄	min	max	x̄	min	max	x̄	min	max	x̄
Quarry Area (m^2): 2810	50	220	96.03	1	3	1.34	0.31	1.1	0.56	0.8	6.33	2.61	37.5	150	75.53
Survey Area (m^2): 100	σ	var.		σ	var.		σ	var.		σ	var.		σ	var.	
Total MV cobbles >2 cm:223	2.74	7.5		0.22	0.05		0.12	0.02		1.02	1.04		15.35	235.68	
NAVFAC Cobbles	min	max	x̄	min	max	x̄	min	max	x̄	min	max	x̄	min	max	x̄
Quarry Area (m^2): 3750	50	130	74.56	1	7.5	1.4	0.33	0.82	0.59	1.25	5.75	2.18	33.33	116.67	71.28
Survey Area (m^2): 100	σ	var.		σ	var.		σ	var.		σ	var.		σ	var.	
Total MV cobbles >2 cm: 79	2.01	4.06		0.73	0.54		0.11	0.01		0.77	0.59		15.56	242.06	
Thousand Springs	min	max	x̄	min	max	x̄	min	max	x̄	min	max	x̄	min	max	x̄
Quarry Area (m^2): 5740	30	210	62.86	0.82	21	1.39	0.29	4.85	0.64	0.15	11	2.01	14.29	375	77.46
Survey Area (m^2): 100	σ	var.		σ	var.		σ	var.		σ	var.		σ	var.	
Total MV cobbles >2 cm: 1452	2.04	4.18		0.83	0.68		0.2	0.04		0.73	0.53		21.99	483.55	
Radar Row	min	max	x̄	min	max	x̄	min	max	x̄	min	max	x̄	min	max	x̄
Quarry Area (m^2):10,130	50	230	89.61	1	1.94	1.39	0.39	2.87	0.61	0.27	3.67	2.17	50	112.5	74.2
Survey Area (m^2):50	σ	var.		σ	var.		σ	var.		σ	var.		σ	var.	
Total MV cobbles >2 cm: 90	2.54	6.43		0.18	0.03		0.26	0.07		0.61	0.38		13.67	186.95	

Table 4.7. Results of an ANOVA for metavolcanic cobbles on San Nicolas Island comparing means for size and shape measurements.

		df	Mean Square	F	Sig.
Max. Length	Between Groups	5.00	2369.62	204.89	0.00
	Within Groups	3720.00	11.57		
	Total	3725.00			
Circum.Ratio	Between Groups	5.00	0.85	2.43	0.03
	Within Groups	3720.00	0.35		
	Total	3725.00			
Flatness	Between Groups	5.00	196.30	177.11	0.00
	Within Groups	3720.00	1.11		
	Total	3725.00			
Elongation	Between Groups	5.00	53710.91	91.27	0.00
	Within Groups	3720.00	588.51		
	Total	3725.00			

Table 4.8. A Bonferroni post-hoc analysis of ANOVA results comparing mean length for metavolcanic cobbles from six cobble areas on San Nicolas Island.

Maximum Length		x̄ difference	Std. Error	Sig.
Tule Creek	Corral Harbor	1.44	0.32	**0.00**
	Thousand Springs	2.53	0.31	**0.00**
	NAVFAC	1.31	0.45	0.06
	Radar Row	0.12	0.41	1.00
	Hollywood Beach	-2.40	0.33	**0.00**
Corral Harbor	Tule Creek	-1.44	0.32	**0.00**
	Thousand Springs	1.09	0.13	**0.00**
	NAVFAC	-0.13	0.35	1.00
	Radar Row	-1.32	0.30	**0.00**
	Hollywood Beach	-3.84	0.17	**0.00**
Thousand Springs	Tule Creek	-2.53	0.31	**0.00**
	Corral Harbor	-1.09	0.13	**0.00**
	NAVFAC	-1.22	0.35	**0.01**
	Radar Row	-2.41	0.29	**0.00**
	Hollywood Beach	-4.93	0.16	**0.00**
NAVFAC	Tule Creek	-1.31	0.45	0.06
	Corral Harbor	0.13	0.35	1.00
	Thousand Springs	1.22	0.35	**0.01**
	Radar Row	-1.19	0.44	0.10
	Hollywood Beach	-3.71	0.36	**0.00**
Radar Row	Tule Creek	-0.12	0.41	1.00
	Corral Harbor	1.32	0.30	**0.00**
	Thousand Springs	2.41	0.29	**0.00**
	NAVFAC	1.19	0.44	0.10
	Hollywood Beach	-2.52	0.31	**0.00**
Hollywood Beach	Tule Creek	2.40	0.33	**0.00**
	Corral Harbor	3.84	0.17	**0.00**
	Thousand Springs	4.93	0.16	**0.00**
	NAVFAC	3.71	0.36	**0.00**
	Radar Row	2.52	0.31	**0.00**

Table 4.9. A Bonferroni post-hoc analysis of ANOVA results comparing mean circumference ratio for for metavolcanic cobbles from six cobble areas on San Nicolas Island.

Circum. Ratio		x̄ difference	Std. Error	Sig.
Tule Creek	Corral Harbor	0.03	0.06	1.00
	Thousand Spring	-0.04	0.05	1.00
	NAVFAC	-0.04	0.08	1.00
	Radar Row	-0.03	0.07	1.00
	Hollywood Beach	-0.06	0.06	1.00
Corral Harbor	Tule Creek	-0.03	0.06	1.00
	Thousand Spring	-0.07	0.02	**0.05**
	NAVFAC	-0.06	0.06	1.00
	Radar Row	-0.06	0.05	1.00
	Hollywood Beach	-0.09	0.03	**0.05**
Thousand Springs	Tule Creek	0.04	0.05	1.00
	Corral Harbor	0.07	0.02	**0.05**
	NAVFAC	0.00	0.06	1.00
	Radar Row	0.01	0.05	1.00
	Hollywood Beach	-0.02	0.03	1.00
NAVFAC	Tule Creek	0.04	0.08	1.00
	Corral Harbor	0.06	0.06	1.00
	Thousand Spring	0.00	0.06	1.00
	Radar Row	0.01	0.08	1.00
	Hollywood Beach	-0.02	0.06	1.00
Radar Row	Tule Creek	0.03	0.07	1.00
	Corral Harbor	0.06	0.05	1.00
	Thousand Spring	-0.01	0.05	1.00
	NAVFAC	-0.01	0.08	1.00
	Hollywood Beach	-0.03	0.05	1.00
Hollywood Beach	Tule Creek	0.06	0.06	1.00
	Corral Harbor	0.09	0.03	**0.05**
	Thousand Spring	0.02	0.03	1.00
	NAVFAC	0.02	0.06	1.00
	Radar Row	0.03	0.05	1.00

Table 4.10. A Bonferroni post-hoc analysis of ANOVA results comparing mean flatness for for metavolcanic cobbles from six cobble areas on San Nicolas Island.

Flatness		$\bar{x}$ difference	Std. Error	Sig.
Tule Creek	Corral Harbor	0.62	0.10	**0.00**
	Thousand Springs	0.07	0.10	1.00
	NAVFAC	-0.12	0.14	1.00
	Radar Row	-0.03	0.13	1.00
	Hollywood Beach	-0.92	0.10	**0.00**
Corral Harbor	Tule Creek	-0.62	0.10	**0.00**
	Thousand Springs	-0.55	0.04	**0.00**
	NAVFAC	-0.74	0.11	**0.00**
	Radar Row	-0.65	0.09	**0.00**
	Hollywood Beach	-1.54	0.05	**0.00**
Thousand Springs	Tule Creek	-0.07	0.10	1.00
	Corral Harbor	0.55	0.04	**0.00**
	NAVFAC	-0.18	0.11	1.00
	Radar Row	-0.10	0.09	1.00
	Hollywood Beach	-0.99	0.05	**0.00**
NAVFAC	Tule Creek	0.12	0.14	1.00
	Corral Harbor	0.74	0.11	**0.00**
	Thousand Springs	0.18	0.11	1.00
	Radar Row	0.09	0.14	1.00
	Hollywood Beach	-0.81	0.11	**0.00**
Radar Row	Tule Creek	0.03	0.13	1.00
	Corral Harbor	0.65	0.09	**0.00**
	Thousand Springs	0.10	0.09	1.00
	NAVFAC	-0.09	0.14	1.00
	Hollywood Beach	-0.90	0.10	**0.00**
Hollywood Beach	Tule Creek	0.92	0.10	**0.00**
	Corral Harbor	1.54	0.05	**0.00**
	Thousand Springs	0.99	0.05	**0.00**
	NAVFAC	0.81	0.11	**0.00**
	Radar Row	0.90	0.10	**0.00**

Table 4.11. A Bonferroni post-hoc analysis of ANOVA results comparing mean elongation for metavolcanic cobbles from six cobble areas on San Nicolas Island.

Elongation		$\bar{x}$ difference	Std. Error	Sig.
Tule Creek	Corral Harbor	-18.19	2.26	**0.00**
	Thousand Spring	-1.92	2.22	1.00
	NAVFAC	5.60	3.22	1.00
	Radar Row	2.32	2.93	1.00
	Hollywood Beach	3.16	2.33	1.00
Corral Harbor	Tule Creek	18.19	2.26	**0.00**
	Thousand Spring	16.27	0.96	**0.00**
	NAVFAC	23.79	2.52	**0.00**
	Radar Row	20.51	2.14	**0.00**
	Hollywood Beach	21.34	1.20	**0.00**
Thousand Springs	Tule Creek	1.92	2.22	1.00
	Corral Harbor	-16.27	0.96	**0.00**
	NAVFAC	7.52	2.49	**0.04**
	Radar Row	4.24	2.10	0.65
	Hollywood Beach	5.07	1.12	
NAVFAC	Tule Creek	-5.60	3.22	1.00
	Corral Harbor	-23.79	2.52	**0.00**
	Thousand Spring	-7.52	2.49	**0.04**
	Radar Row	-3.28	3.14	1.00
	Hollywood Beach	-2.45	2.59	1.00
Radar Row	Tule Creek	-2.32	2.93	1.00
	Corral Harbor	-20.51	2.14	**0.00**
	Thousand Spring	-4.24	2.10	0.65
	Thousand Spring	3.28	3.14	1.00
	Hollywood Beach	0.84	2.22	1.00
Hollywood Beach	Tule Creek	-3.16	2.33	1.00
	Corral Harbor	-21.34	1.20	**0.00**
	Thousand Spring	-5.07	1.12	**0.00**
	NAVFAC	2.45	2.59	1.00
	Radar Row	-0.84	2.22	1.00

Table 4.12. A χ^2 test comparing proportions of "flat" metavolcanic cobbles (roundness values < 0.5 or > 1.5 to "round" metavolcanic cobbles (roundness value 0.5-1.5) at San Nicolas Island cobble areas.

	Flat	Expected	Round	Expected	Total	χ^2	df	p	Adjusted Residuals
Corral Harbor	42	82.52	455.00	414.48	497.00	156.75	5	**<0.001**	**-5.48**
Tule Creek	18	12.29	56.00	61.71	74.00				1.81
Hollywood Beach	97	37.03	126.00	185.97	223.00				**11.33**
NAVFAC	20	13.12	59.00	65.88	79.00				**2.11**
Thousand Springs	204	241.10	1248.00	1210.90	1452.00				**-4.14**
Radar Row	20	14.94	70.00	75.06	90.00				1.46

Quarry Attractiveness

Surveys of local cobble beaches and outcrops on both the San Juan Islands and San Nicolas Island reveal that in both places, people could have chosen from a number of toolstone collection areas. To examine how territorial circumscription may or may not have influenced procurement choices, I consider the relative value of each quarry in terms of desired toolstone shape and size, collection costs, and transport costs. To facilitate a standardized evaluation of quarry “attractiveness,” I employ a toolstone attractiveness index (AI) developed by Wilson (2007a,b, Wilson 2011; Browne and Wilson 2011). Wilson’s AI is based on economic research on the attributes that draw people to places or products. Wilson (2007) notes that gravity models can be useful in understanding the sources that “should” have been used based on geographic and geologic factors, with the assumption that deviations from those predicted patterns should be useful in elucidating the “human factors” that also influence toolstone choice. Her measure is expressed as a ratio of the quality of the source, extent of the source, and size of the average cobble to the difficulty of the terrain, cost of extraction, and scarcity of the material.

$$\boxed{\text{AI} = \frac{(\text{toolstone quality})\,(\text{extent of source})\,(100)}{(\text{difficulty of terrain})\,(\text{extraction cost})} \times \frac{\text{size}}{\text{scarcity}}}$$

Below I define each variable in the formula and discuss how I measure it. I define *toolstone quality* for a cobble area based mainly on the variety of material available. Sites for which more than one rock type was abundant were ranked a “3” because this would have allowed people to choose between different tool types to create tools for different purposes. Those where only one rock type was abundant was ranked a “2”. Cobble areas on San Nicolas Island where soft and friable rocks were abundant I ranked a “1” because people would have had to sort through lower quality material to ensure that the toolstone that they selected was hard enough to be flaked.

I determined *extent of source* through GPS mapping in the field and ranked each area from 1-4 based on the range and average size of smaller and larger sites in both study areas (1 = 0 = 100 meters^2; 2 = 100-2500 meters^2; 3 = 2500 – 10,000 meter^2; 4 > 10,000 m^2). This variable is important in terms of toolstone reliability. A source is more attractive if people are certain that toolstone will be abundant and easy to find. The *cost of extraction* variable was given a “1” in all cases because almost all cobbles can be found loose on beaches or in blowouts and quarrying would have been minimal. Because this variable is the same in all cases, the value is not meaningful.

For Wilson’s formula, *size* and *scarcity* are considered as a ratio to provide an overall measure of the size of cobbles at a site that is most determined by the most abundant size classes but also incorporates rarer size classes. *Size* is defined as the maximum dimension (cm) of the modal size. *Scarcity* is determined by the amount surface area covered by cobbles of that size (1 = > 50% ; 2 = 25-50%; 3 = 5-25%, 4 < 5%). As a baseline, I considered 100% surface area coverage to be one cobble per every square meter of the survey area. First, the modal size/scarcity ratio is calculated. Additional size/scarcity ratios are added in order of decreasing abundance of the size class, but with each ratio, the denominator is raised to a higher power (squared, then cubed, etc.) so that the less abundant size classes are given less weight. To provide an example, the most abundant cobble size class at a cobble area is 6 cm; the second most abundant is 5 cm, and the third most abundant is 4 cm. The 6 cm cobbles are given a “1” scarcity ranking because they all cover >50% of the surface area of the site. The 5 cm cobbles are given a “2” scarcity ranking because they cover 25-50% of the surface area of the site. The 4 cm cobbles are given a “4” scarcity ranking because they cover less than 5% of the surface area of the cobble area. The size/scarcity value is calculated as $6/1 + 5/2^2 + 4/4^3$.

To calculate a *difficulty of terrain* variable, I modify Wilson’s (2007a, b) protocol to estimate travel cost in terms of kcal/hour to account for boat travel and for least cost path distance rather than straight-line distance from site to source for pedestrian travel (Browne and Wilson 2011). Boats change the basics of transport costs associated with lithic procurement in coastal areas by allowing transport of heavy or bulky loads and by facilitating faster and farther travel between islands and the mainland and into the interior (Ames 2002; Arnold and Bernard 2005; Blair 2010; Durham 1060; Fitzhugh and Kennett 2010; Renouf 1988). Ease of boat access to a shellfish bed, fishing stream, or lithic source is limited by beach morphology or the distance a boat can travel up a river or creek.

No direct archaeological evidence of watercraft has yet been discovered in the San Juan Islands, but people likely used dugout canoes made from western red cedar logs similar to those recorded historically (Holm 1994; Neel 1995). The earliest palynological evidence for red cedar in the Gulf of Georgia occurs at 6000-7000 BP (Moss et al. 2007) followed by widespread distribution of adzes, wedges, and other woodworking tools after 5000 BP (Hebda and Mathewes 1984). During historic times, Northwest Coast dugout canoes could carry as much as five tons and allowed a foraging radius of 30 km per day (Ames 2002). If toolstone was not directly collected at a site, the most efficient way to transport the material on the islands would be to use canoe. I calculate calories per kilometer in paddling a canoe based an average rate of 400 calories per hour assuming 6.5-8 kilometers an hour (Dillon and Oyen 2008). Canoe travel is more efficient relative to pedestrian travel in the San Juan Islands than the Channel Islands because the wave energy is much lower and vegetation in the inland areas is denser. For the purposes of this study, I assume that whenever possible, people traveled by canoe rather than walking.

That people reached the Channel Islands during the Terminal Pleistocene indicates sophisticated watercraft technology from the earliest settlement of the island (Erlandson et al. 2009; Rick et al. 2001b). The emergence of sewn plank canoe technology observed during the historic period has not yet been resolved (Arnold 1995b; Cassidy et al. 2004; Des Lauriers 2005; Fagan 2004; Gamble 2002; Heizer 1938, 1940; Jones and Klar 2005). Arnold (1992, 1995b) describes specialized knowledge required to chop, plane, sew, and caulk boards of redwood or pine that drifted to the islands from northern California, a process requiring over 500 person-hours of labor. In historic times, plank canoes carried up to two tons of cargo at 20 kilometers per hour (see also Hudson et al. 1978:137). Although people likely transported abundant material, including toolstone, by boat both between islands and between different points on the island, I presume that given the high energy wave environment and the long distances between inland sites and the coastline, pedestrian transport was the more efficient way to carry cobbles from inland cobble areas to inland sites and from beach cobble areas to beach sites.

To determine travel cost based on pedestrian travel on San Nicolas Island, I create cost surfaces based on a raster digital elevation model using Path Distance and Cost Path tools in ArcGIS ESRI^{TM} with Spatial Analyst extension. Following Wilson's example, I based round-trip calorie expenditure between cobble areas and archaeological sites based on estimates created by Jones and Madsen (1989). After generating the cost paths, I break the lines into segments and calculate the number of calories burned per segment based on the gradient for both the trip to the source and the return trip. Because denudation of plants and associated erosion substantially changed the topography of the island, I consider the cost paths to represent general estimates of the cost of pedestrian travel between source and site rather than a representation of a path that the Nicoleño might have used (Figure 4.36, 4.37). For CA-SNI-106, I calculate the cost path between the site and the Radar Row cobble area as a representation of the probable distance between the site and an inland cobble area, though not necessary that particular area. I calculate the cost path to Vizcaino point as the nearest beach cobble area even though I was not able to access those cobbles at the time that the fieldwork was conducted.

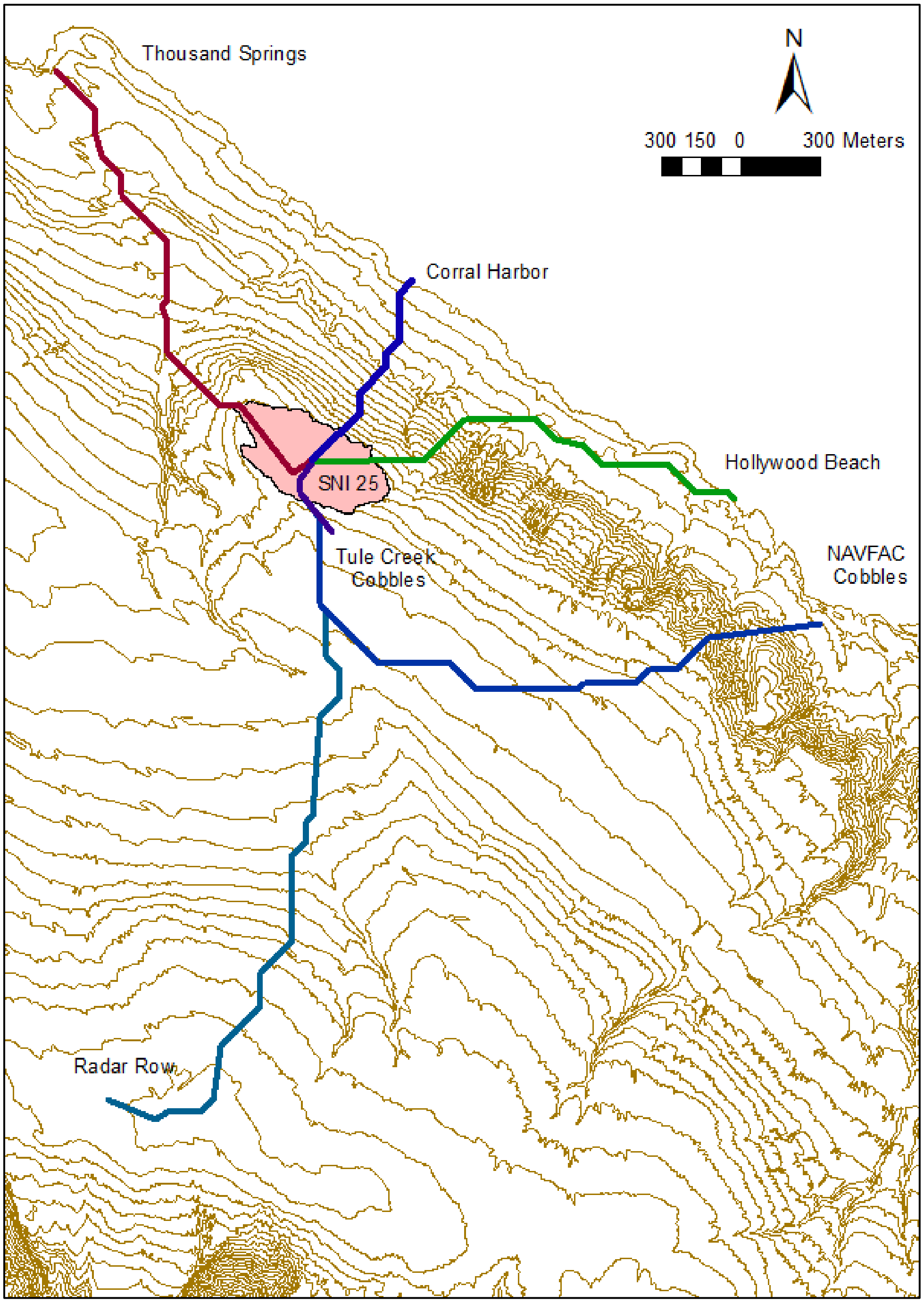


Figure 4.36. Least cost paths between Tule Creek Village and surrounding cobble areas.

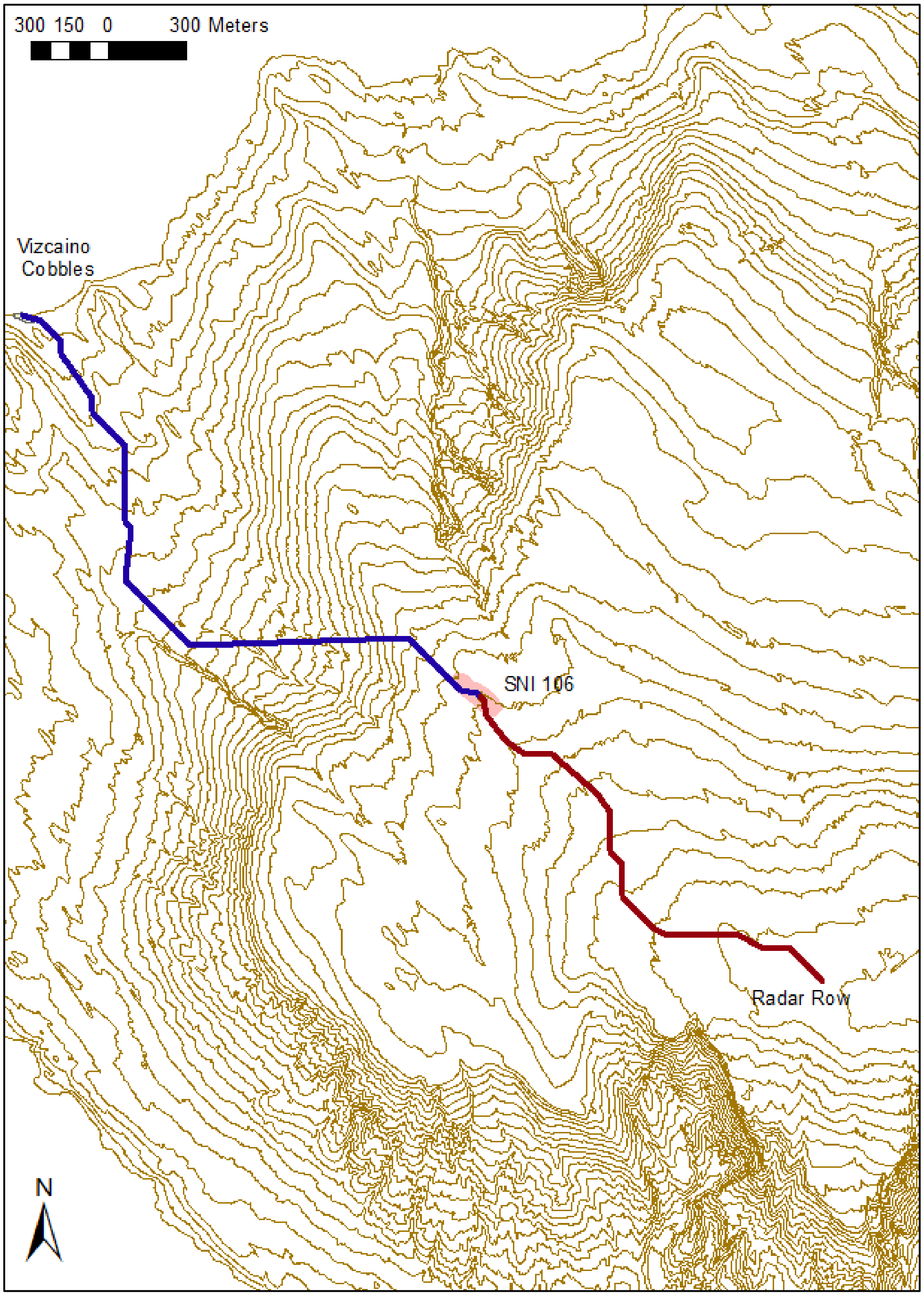


Figure 4.37. Least cost paths between CA-SNI-106 and surrounding cobble areas.

Calculations and Conclusions

Based on all of the variables discussed above, by far the most attractive cobble area for precontact inhabitants of the Watmough Bay site would have been the Watmough Bay cobbles (Table 4.13). Despite the small size of the cobbles, the low transport cost should encourage people to take cobbles from the beach adjacent to the site if enough were available. Given the low density of adequate FGV cobbles on the beach, it is possible that families may have exhausted the supply of the toolstone on the beach faster than erosion could have replenished it. If that was the case, the next most desirable location based on these calculations is Aleck Bay followed by Agate Beach. If people at Watmough Bay did not choose Watmough cobbles, it may be because they ran out, or because they desired cobbles of a different size or shape to make their tools. This calculation demonstrates, however, that if during times of increased boundary defense people were constrained in their toolstone procurement opportunities to Watmough Bay beach, this should be a relatively attractive option for them. Transport costs are minimal and slate is available to provide a secondary toolstone source. The other cobble areas are all relatively similar in their AI value.

On San Nicolas Island, the most attractive area overall would have been Hollywood beach due to the abundance and variety of material available, the size of the area, and the relatively low cost of travel down a more gentle slope (Table 4.14). If only metavolcanic cobbles are considered, Thousand Springs is the most attractive area due to the density of high quality cobbles. These data suggest that although there are cobbles near Tule Creek Village, if people wanted to procure a larger amount of high quality toolstone, despite the travel costs, it might be more efficient to travel to another point on the landscape to procure cobbles. If people were unable to travel freely, they may have had to rely on cobble areas closer to home.

Chapter Summary

Data on the material types, size, shape, and attractiveness of the cobble areas on both the San Juan Islands and on San Nicolas Islands provides an essential background for generating predictions about procurement activities in the context of proposed changes in territorial behavior during the Late Holocene on the Pacific Coast. In both study areas, toolstone is ubiquitous locally; however, subtle differences in the characteristics of cobble areas defined peoples' procurement choices and leave a signature of their "lithic landscape" to determine where they did and did not travel to collect cobbles. Understanding the characteristics of cobble areas provides an insight into how people could have collected cobbles if they could move freely across the landscape and if they were not constrained in their toolstone choices based on their technology. My research explores scenarios for procurement given constraints on movement and the organization of flake-tool technologies.

Table 4.13. Wilson's Attractive Index values for San Juan Islands cobble areas for Watmough Bay.

Cobble Area	Size/ Scarcity	Extent Value	Quality	Extraction Cost	Distance by Water from Watmough (m)	Rate of Calorie Burn	Terrain Difficulty (Cal/km)	AI
Watmough Bay	2.09	3	3	1	0.01	0.5	0.5	**3766.7**
Aleck Bay	2.72	3	2	1	6.42	321	321	5.08
Agate Beach	2.43	3	2	1	10.83	541.5	541.5	2.7
American Camp	1.35	4	2	1	18.07	903.5	903.5	1.2
False Bay	3.06	4	2	1	26.29	1314.5	1314.5	1.86
Snug Harbor	3.54	2	2	1	38.68	1934	1934	0.73

Table 4.14. Wilson's Attractive Index values for San Nicolas Island quarry areas for Tule Creek Village.

Cobble Area	Size/Scarcity	Size/Scarcity (MV)	Extent	Quality	Quality (MV)	Extraction	Terrain Difficulty (Cal/km)	AI	AI (MV)
Corral	18.95	4.76	3	3	2	1	481.77	35.4	5.93
Tule Creek	4.26	3.69	2	1	2	1	52.1	16.35	28.33
Hollywood	105.01	19.15	3	2	2	1	537.69	**117.18**	21.37
NAVFAC	4.12	4.12	3	2	2	1	744.12	3.32	3.32
Thousand	35.22	39.09	3	3	2	1	571.81	55.43	**41.02**
Radar	7.77	7.32	4	1	2	1	552.54	5.62	10.6

Chapter 5: Flaked Stone Technology on the Pacific Coast

To test hypotheses regarding change over time in lithic procurement associated with shifts in territoriality on the Pacific Coast, I develop and test predictions for lithic assemblages from archaeological sites on the San Juan Islands and the southern Channel Islands. The predictions center on procurement, processing, reduction strategies, toolstone conservation, and exchange. To develop these predictions, I first establish the steps of the manufacturing process for the lithic technologies at each site. In both study areas, precontact peoples relied primarily on flake tools. This type of technology is often referred to as expedient technology, characterized by minimal core preparation and retouch (Andrefsky 2009; Bleed 1986; Kelly 1988; Nelson 1991; Odell 1998; Parry and Kelly 1987; Teltser 1991). My focus in this chapter is on flaked stone tools, but I also provide data on ground stone tools from each assemblage. I draw on previous lithic studies in each study area and empirical data from the Watmough Bay, Tule Creek Village Mound B, and CA-SNI-106 assemblages to investigate the technological traditions for each site.

General Analytic Methods

During analysis, each artifact was given a unique number linking the artifact to a site, unit, stratum, level, and/or depth, and artifact type ("f" for flake, "c" for core, or "t" for tool). Where more than one artifact type for that unit/level/stratum was present, artifacts were numbered sequentially and bagged together. For example, the first flake analyzed from Watmough Bay, Unit 0N9W from the 150-160 cmbs level was identified as 280.0N9W.150-160.F.1. The first flake analyzed from Mound B Unit 13 Stratum II Level 2 was identified as 25B.13.2.2.F.1. Where more than one flake, core, or tool is analyzed from a single site/unit/stratum/level/depth, they are distinguishable for future analysis by weight. Details of measurements and identification of attributes for flakes, cores, and tools are noted in Table 5.1. Individual attribute measurements and descriptions were chosen based on lithic studies that demonstrate their utility in identifying different stages of reduction or manufacturing techniques such as bipolar and biface reduction, particularly in combination with one another (e.g., Andrefsky 2009; Close 2006; Dibble 2005; Inizan et al. 1999; Odell 2004; Root 2004; Steffen et al. 1998).

Regarding statistical analyses in this chapter and the following chapter, I use χ^2 tests to evaluate differences in the distribution of nominal and ordinal variables (e.g., platform type, number of dorsal scars, cortex location) between two populations, in this case sub-samples of an assemblage from two or more time periods. A significant p-value (≤ 0.05) indicates that the proportions of each class are not randomly distributed given the magnitude of the differences and the sample size of both populations. Adjusted residuals (AR) are used to determine which classes are driving significant differences (Everitt 1977; Grayson and Delpech 2003). To analyze differences in means of ratio variables for assemblages (e.g., length, width, thickness), I use Student's *t*-tests (two populations) and ANOVA tests with Bonferroni post-hoc analysis (more than two populations) if sample sizes are similar. Statistically significant differences are demonstrated if $p \leq 0.05$. Statistical analyses were completed using SPSS ® 11.5.

Table 5.1. Measurement descriptions for lithic analysis of flaked stone tools.

All Artifacts	**Measurement Description**
Material	Type, color, coarse/smooth, glossy/dull
Cortex	Appearance (rough, smooth), location, approximate % of total possible surface area that could be cortical given artifact type.
Size Class	Measured for all artifacts using a chart with concentric circles at 1 cm intervals. Artifacts were assigned a size class based on the smallest circle by which they could be circumscribed.
Original Cobble	Describe shape of original cobble if possible and note which dimensions, if any, indicate the size of the original cobble.
Use	Extent, location, appearance of chipping or dulled edges
Weight	Measured for all artifacts (grams).
Flakes	**Measurement Description**
Platform	Cortical, *lisse* , dihedral, faceted
Platform Shape	Round vertical (parallel to the direction of force), Round horizontal (perpendicular to the direction of force), flat.
Platform lip	Present/Absent
Platform Angle	Interior angle between the platform and ventral face
Bulb of Percussion	Pronounced/Diffuse
Termination	Feathered/Hinged/Step/Overpassed
Concavity	Ventral face concave, convex, or straight
Transverse Cross-Section	Oval/triangle/semicircle/irregular
Dorsal scars	Number and orientation (parallel, bidirectional, or mixed).
Maximim Length	Parallel to the direction of force (if unbroken) (mm).
Maximim Width	Perpendicular to the direction of force (if unbroken) (mm).
Maximim Thickness	Perpendicular to maximim length and width (mm).
Breakage	Orientation of breakage relative to direction of force.
Cores	**Measurement Description**
Length	Parallel to the main axis of flaking (mm).
Width	Perpendicular to the main axis of flaking (mm).
Thickness	Perpendicular to length and width (mm).
Platform	Number, type (lisse, dihedral, multifaceted, cortical, crushed), angle to flaking surface.
Removals	Number, orientation (unidirectional, bidirectional, multidirectional).
Rotation	Rotated/Semi-rotated
Retouched tools	**Measurement Description**
Length	Parallel to the retouched, sharp, or pointed end (mm).
Width	Perpendicular to length. (mm)
Thickness	Perpendicular to length and width (mm).
Origin	Tool made on a flake/core.
Flake features	Features of the platform, dorsal face, termination that are apparent despite retouch/use are recorded and/or measured.
Core feature	Features of the platform(s), removals that are apparent despite retouch/use are
Retouch features	Morphology of retouch (scaled/parallel), angle of retouch (abrupt, semi-abrupt, low), direction (obverse/inverse/alternative/crossed/bifacial), extent (short/long/invasive/covering), location and distribution (entire/partial), delineation (straight, convex, concave, sinuous, shoulder).

The Watmough Bay Lithic Assemblage

I analyzed a total of 2367 flakes (including slate fragments), 242 cores (including fragments), 219 ground stone tools, and 282 formal tools (Table 5.2, 5.3). A majority of the artifacts (63% of the flakes and 56% of the cores) come from the 1600-1000 cal BP time period with smaller samples from the 3500-2500 cal BP, 2500-1600 cal BP, and 600 cal BP-Contact time periods.

Table 5.2. Frequencies of flakes and cores from the Watmough Bay site.

Site	Watmough Bay	Watmough Bay	Watmough Bay	Watmough Bay	Watmough Bay
Time Period	3500-2500 cal BP	2500-1600 cal BP	1600-1000 cal BP	600 cal BP-Contact	Undated
Flakes					
Coarse-grained volcanic	2	4	17	0	7
Chert	3	0	10	0	3
FGV	78	92	753	50	370
Schist	10	3	39	0	25
Slate	68	7	582	41	72
Argillite	0	1	0	0	2
Quartz	0	2	70	3	10
Quartzite	0	1	7	0	2
Metasedimentary	0	0	2	0	1
Metavolcanic	0	0	2	0	1
Nephrite	0	0	2	0	0
Sandstone	0	0	1	0	0
Unknown	4	0	11	0	4
Total	179	110	1496	94	496
Cores (FGV)					
Unworked	3	0	0	0	2
Unidirectional	1	0	6	0	4
Split/Tested	4	0	6	1	4
Exhausted	1	1	3	0	2
Bipolar	1	5	6	0	3
Multidirection Unpatterned	1	1	15	1	5
Flaked flake	0	1	3	2	0
90 Degree	0	1	7	1	7
Fragment	0	8	45	2	11
Chopper	0	0	4	1	0
Rotated	0	0	5	0	6
Opposed Platform	0	1	6	0	1
Unidentifable	0	0	3	0	2
Total	11	18	109	8	47
Cores (Chert)					
Multidirection Unpatterned	0	0	1	0	0
Fragment	1	2	0	0	0
Cores (Quartz)					
Unworked	0	0	1	0	0
Fragment	0	0	17	0	1
Cores (Coarse-grained volcanic)					
Split/Tested	0	0	1	0	1
Bipolar	0	0	1	0	0
Fragment	0	0	1	0	0
Chopper	0	0	1	0	0
Cores (Nephrite)					
Unworked	0	0	1	0	0
Cores (Quartzite)					
Unidirectional	0	0	1	0	0
Fragment	0	0	0	2	0
Cores (Slate)					
Fragment	0	0	0	0	1

Table 5.3. Basic statistics on tools and groundstone from the Watmough Bay site. Material types is FGV unless noted otherwise.

Site	Watmough Bay	Watmough Bay	Watmough Bay	Watmough Bay	Watmough Bay
Time Period	3500-2500 cal BP	2500-1600 cal BP	1600-1000 cal BP	600 cal BP-Contact	Undated
Tools (FGV unless noted)					
Scrapers	1	6 (1 chert)	18 (2 chert)	0	12 (1 chert)
Retouched Flakes	1	1	22 (1 chert, 1 shale, 1 quartzite, 1 slate)	0	6
Choppers	0	1	5	0	3 (1 quartzite)
Knives	0	2 (slate)	12 (6 slate, 5 schist)	0	14 (7 slate, 4 schist, 3 metasedimentary)
Pointed Tools	0	1	10	0	2
Hammerstones	0	0	2	0	0
Bifaces	1 (CGV)	2 (1 undet.)	26 (2 undet., 3 schist, 2 slate, 2 CGV)	2	4 (1 slate)
Leaf-Shaped Points	0	0	1	0	0
Projectile Points	0	0	6 (1 undet.)	1	2 (1 slate)
Stemmed Points	0	0	4 (1 slate)	0	1
Corner-notched poin	0	0	0	0	1 (chert)
Triangles	0	0	7	1	2
Notches	0	0	2	0	3 (1 slate, 1 CGV)
Scaled Pieces	3	12 (1 undet.)	46 (1 slate)	0	37 (2 CGV, 3 slate, 1 schist, 1 quartzite)
Total	6	25	161	4	87
Bead/Ornament	1	0	2	0	5
Net weight	0	1	15	0	11
Incised shale/other	0	1	31	1	7
Unmodified shale/other	0	6	70	0	22
Misc. Ground stone	0	0	0	0	3
Abrader	0	0	3	0	1
Adze/Axe	0	0	3	0	1
Labret	0	0	0	0	1
Flaked slate/shale/other	0	0	2	0	0
FMR	0	2	11	0	6
Grinding stone	0	0	1	0	0
Pecked Stone	0	0	2	0	2
Point	0	0	2	0	2
Vessel Fragment	0	0	1	0	0
Hammerstone	0	0	0	0	0

A comparison of the Watmough Bay assemblage to published analyses of the English Camp lithic artifacts (Close 2006, 2011; Kornbacher 1989, 1992) and an intra-site comparison of material excavated in 1968 by Munsell and Stein and Phillips in 2004 indicates that the Munsell excavators did not consistently collect small flakes (< 10 mm in maximum dimension) and flakes without platforms. Considering only FGV, the Stein/Phillips assemblage contains a higher proportion of small flakes (*n* = 23,16%) than the Munsell excavation (*n* = 4, 0.3%). The Stein/Phillips excavation contains a higher proportion of FGV flakes without platforms (*n* = 117, 81.3%) compared to the Munsell excavation (*n* = 686, 57.2%). The ratio of FGV flakes to cores also differs substantially between the two Watmough assemblages and the English Camp OpD (45-SJ-24) assemblage. At OpD, there is a ratio of 5387 flakes to 83 cores including unworked cobbles (64.9 flakes per core). The Munsell assemblage contains 1200 FGV flakes and 169 cores (7.10 flakes per core), and the Stein excavation contains 144 flakes and 10 cores (4.4 flakes per core). Differences in core/flake ratios between OpD and Watmough Bay could be the result of differences in the manufacturing process between the sites; however, I suspect that flakes are under-represented at Watmough Bay. The field notes on the Watmough Bay excavation do not describe a process by which flakes were selected or discarded in the field by the excavation team.

Difference in the amounts of slate and schist from the two Watmough excavations also suggests that the Munsell excavation team collected less of the slate they encountered than the Stein/Phillips excavation team. The Munsell excavation contains 333 slate fragments of 1650 total flakes (2%). The Stein/Phillips excavation contains 517 slate fragments of 717 total flakes (72%). The Stein/Phillips excavation is closer to the slate outcrop and many of these fragments were deposited naturally into the shell midden, but different collection strategies likely contributed to such a large difference in the proportion of slate between the two areas of the site. I take these factors into consideration in my analysis.

In analyzing the debitage, I was guided by two published analyses of San Juan Islands lithic assemblages from the English Camp shell midden site. Kornbacher (1989,1992) provides an analysis of lithic artifacts from the Operation A (OpA) assemblage that date to ca. 1700 cal BP – Contact (Stein et al. 2003). Kornbacher concludes that expedient flake tool technology is the primary goal of lithic manufacture at the site. She tests the hypothesis that a decrease in abundance of chipped stone artifacts after 1000 cal BP is associated with a shift in lithic technology rather than just a decrease in the use of flaked stone tools. Despite a decrease in microblades and an increase in tool classes, similarities in flake attributes before and after 1000 cal BP do not support an overall change in manufacturing practices. Kornbacher (1992) proposes a hypothetical model of cobble reduction where a first flake is removed from the edge of a cobble and subsequent removals widen the flaking surface so that the remainder of the cobble can be flakes with minimal cortex on the dorsal face and margins of the flake.

Close (2006, 2011) presents a chaîne opératoire approach to technological organization at English Camp Operation D (OpD) by investigating the social context of the entire life history of the artifacts from raw material procurement, production (creation of blanks, selection and shaping of blanks for retouched tools, selection of unshaped blanks for scaled pieces), and management (use, maintenance, discard). The site dates to ca. 2000-1000 cal BP with most dates clustering at 1550-1250 cal BP (Stein et al. 2003). Close finds that a major emphasis of the lithic technology at this site was to create multipurpose flake tools with cortical backs, some that show splintering from use (scaled pieces) and others that do not (naturally backed flakes). Close (2006:18) distinguishes scaled pieces from cores by removals that are too small to be used as tools. She distinguishes them from retouched flakes based on the presence of removals that were not intended to shape the flake. People at OpD made triangular points in a spatially separate area of the site from the flaked tools. The two different technological trajectories may indicate differences in manufacturing and tool use activities based on gender.

Based on Close's analysis, lithic procurement at OpD centered on small irregularly-shaped beach cobbles (Close refers to these as pebbles). The manufacturing process began with the "decapitation" of a corner of cobble using a natural edge to channel the force of a hard hammer percussion blow to create a long flaking surface. First flakes are thin, cortical flakes with a relatively high maximum length/maximum width ratio (Close 2006:161). Subsequent flakes were struck from a cortical platform adjacent to the first flake scar. The high frequency of secondary and tertiary flakes with wide cortical platforms and/or cortical margins, many of which are opposite non-cortical margins that show extensive wear, suggest that knappers intentionally set up cores to create flakes that retain cortex on one edge (Figure 5.1, 5.2). When one platform was exhausted, the core could be rotated 180 degrees to exploit an additional cortical platform and repeat the process described above.

Close also suggests that people made triangular projectile points on non-cortical flakes with feathered terminations. The thicker proximal end was shaped to a point by retouch but additional retouch shaping on the rest of the flake was usually minimal. The bases of most triangles were often thin and asymmetrical with dulled corners. Close describes, explores, and verifies this manufacturing process using extensive description and quantitative analysis.

Figure 5.1. FGV flake from an angular cobble from Watmough Bay, obverse (280.1N9W.40-60.F.2).

Figure 5.2. FGV flake from an angular cobble from Watmough Bay, reverse (280.1N9W.40-60.F.2).

The manufacturing process at Watmough Bay appears to be similar to English Camp as described by Close rather than Kornbacher. Based on the uniform high quality of the FGV and the presence of 17 tested (one flake removed) cobbles, raw material was sometimes tested at the site. Given the low number of first flakes (*n* = 32) per the total number of cores (*n* = 242), some cobbles may have been tested where they were collected. Cobble surveys indicate that both round and angular cobbles were available on the beaches of the San Juan Islands, but people more often chose angular ones. A total of 11 of the cores at Watmough Bay are made on smooth round waterworn cobbles while 48 are identified as angular; the reminder could not be matched to a cobble type. That the mean length/width ratio is significantly higher for flakes with cortical platforms and no dorsal flake scars ($\bar{x}$ = 1.26) and flakes with cortical platforms and 4+ dorsal flake scars ($\bar{x}$ = 0.94) suggests that people made an effort to create a longer than average flakes to begin the reduction sequence (Table 5.4). Some of the cores are made on waterworn cores from earlier deposits.

Table 5.4. Results of an ANOVA test comparing length, width, thickness, length/width ratio by flake type from the Watmough Bay assemblage, FGV only. Flake type is determined by platform type (1 = *lisse*, 4 = cortical) and number of dorsal flake scars.

Platform	Single	Single	Single	Single	Cortical	Cortical	Cortical	Cortical	F	Sig.	Bonferonni Sig.
Dorsal Scars	0	1	2,3	4+	0	1	2,3	4			
Flake Type	1.0	1.1	1.2	1.4	4.0	4.1	4.2	4.4			
Length *n*	12.00	48.00	73.00	54.00	27.00	64.00	80.00	43.00	3.10	**0.00**	1.2 and 1.4 - **0.04**
Length $\bar{x}$	39.01	32.06	**30.70**	36.38	38.04	33.06	32.83	**37.85**			
Width *n*	10.00	40.00	66.00	53.00	27.00	65.00	72.00	46.00	4.06	**0.00**	1.2 and 4.2 - **0.00**;
Width $\bar{x}$	30.79	30.40	**27.30**	32.32	31.79	33.61	**35.18**	**37.35**			1.2 and 4.4 - **0.00**
Thickness *n*	13.00	50.00	79.00	61.00	30.00	72.00	87.00	50.00	2.15	**0.04**	
Thickness $\bar{x}$	11.26	8.83	8.73	10.31	10.60	9.42	9.98	10.91			
Length/Width *n*	10.00	38.00	63.00	47.00	24.00	60.00	66.00	39.00	2.59	**0.01**	4.2 and 4.0 - **0.04**
Length/Width $\bar{x}$	1.31	1.21	1.18	1.17	1.32	1.06	0.99	1.09			

After the decapitation flake was removed from the cobble, flintknappers at Watmough Bay removed additional flakes in a variety of ways based on the shape, size, and workability of the cobble as well as the desired end product (Figure 5.3). The most common strategy was to flake the core from multiple platforms in an unpatterned manner (Table 5.2, Figure 5.4-5.9). There are a total of 28 cores of this type of which 4 are exhausted (Figure 5.10-5.12). There are also 14 multiple-platform cores where flakes were removed mainly at 90 degree angles from one another. Secondary and tertiary flakes are removed from flat cortical platforms adjacent to the initial flaking surface. There are 18 cases of cortical platforms and 18 cases of single facet platforms on the cores. The small number of flakes with a single facet platform and 100% dorsal cortex (*n* = 15) suggests that it was more common to use a non-cortical flaking surface later on in the reduction sequence. At some point, the core was rotated or partially rotated, the core was decapitated again, and the flintknapper began flaking from the new flaking surface maintaining a cortical margin.

Another common flaking strategy at Watmough Bay was to decapitate or split a cobble and remove flakes from a cortical platform all around the flaking surface, producing a rotated multi-directional core (*n* = 12). This technique creates flakes with wide cortical platforms (Figure 5.13-5.18). Unidirectional cores (*n* = 12) are similarly designed but flakes are removed from a flat cortical surface or flaked surface around the outside of a cobble along the same axis (Figure 5.19-5.20).

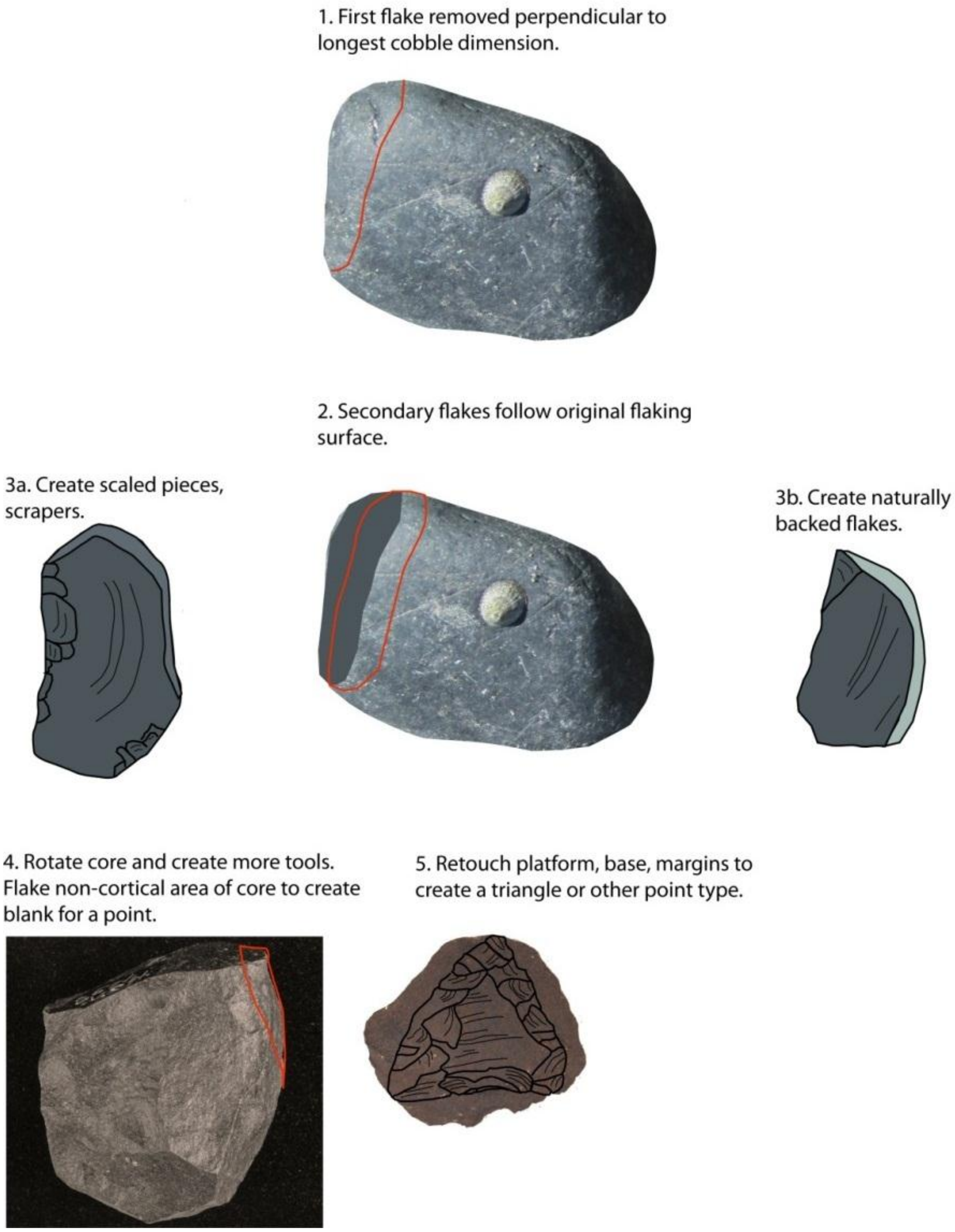


Figure 5.3. Proposed manufacturing process for angular FGV cobbles at Watmough Bay. The white circular object attached to the rock is a barnacle.

Figure 5.4. Photograph of a multi-platform unpatterned FGV core from Watmough Bay, obverse (280.BalkF.40.C.1).

Figure 5.5. Photograph of a multi-platform unpatterned FGV core from Watmough Bay, reverse (280.BalkF.40.C.1).

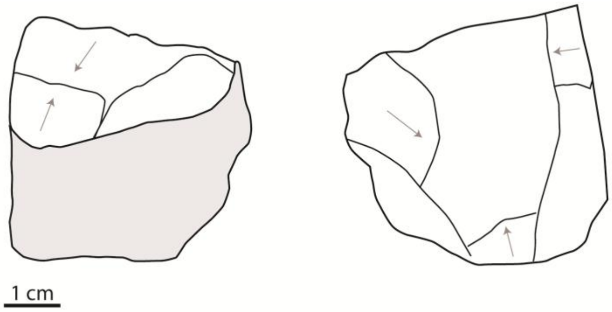


Figure 5.6. Plan-view schematic of a multi-platform unpatterned FGV core from Watmough Bay (280.BalkF.40.C.1).

Figure 5.7. A multi-platform 90 degree FGV core from Watmough Bay, obverse (280.0N9W.50-70.C.2).

Figure 5.8. A multi-platform 90 degree FGV core from Watmough Bay from Watmough Bay, reverse (280.0N9W.50-70.C.2).

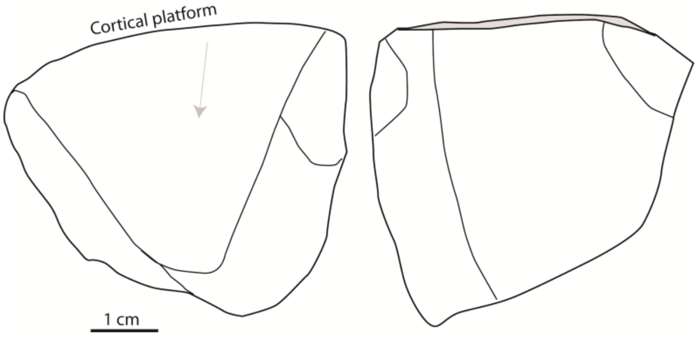


Figure 5.9. Plan-view schematic of a multi-platform 90 degree FGV core from Watmough Bay (280.0N9W.50-70.C.2).

Figure 5.10. An exhausted multiple platform FGV core from Watmough Bay, obverse (280.0N24W.40-60.C.1).

Figure 5.11. An exhausted multiple platform FGV core from Watmough Bay, reverse (280.0N24W.40-60.C.1).

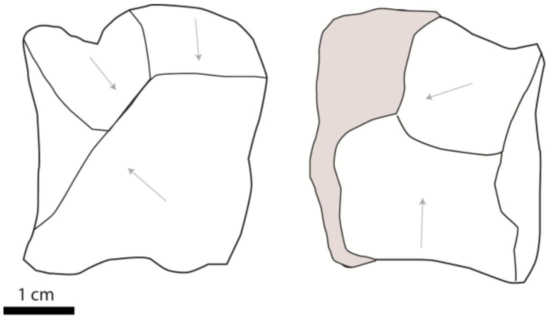


Figure 5.12. Plan-view schematic of a an exhausted multiple platform FGV core from Watmough Bay (280.0N24W.40-60.C.1)

Figure 5.13. A FGV rotated core from Watmough Bay, obverse (280.0N15W.130.C.1).

Figure 5.14. A FGV rotated core from Watmough Bay, reverse (280.0N15W.130.C.1).

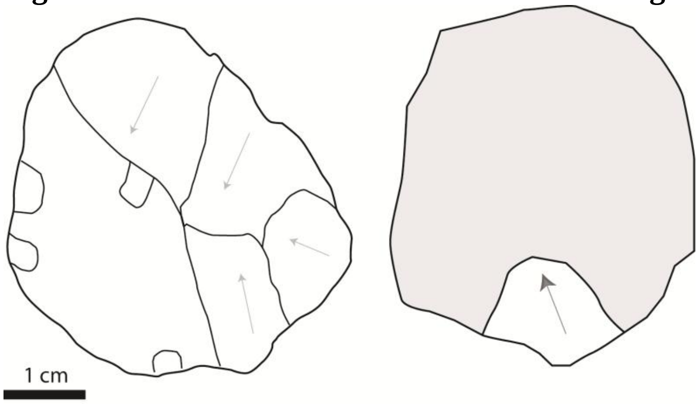


Figure 5.15. Plan-view schematic of a FGV rotated core from Watmough Bay (280.0N15W.130.C.1).

Figure 5.16. A FGV rotated core from Watmough Bay, obverse (280.0N0E.Oversize.280-300.C.1).

Figure 5.17. A FGV rotated core from Watmough Bay, reverse (280.0N0E.Oversize.280-300.C.1)

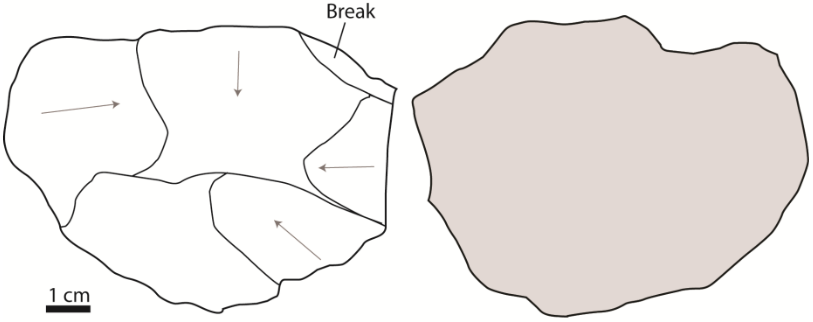


Figure 5.18. A plan-view schematic of a FGV rotated core from Watmough Bay (280.0N0E.Oversize.280-300.C.1).

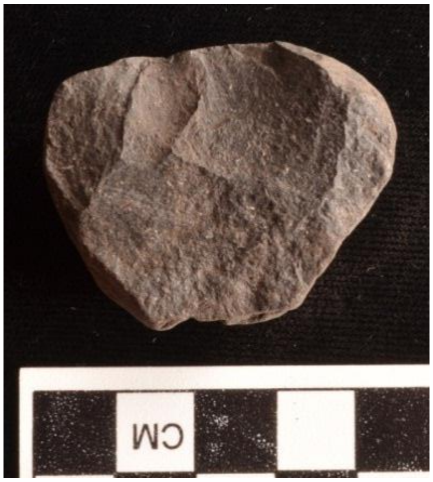


Figure 5.19. Photograph of a unidirectional FGV core from Watmough Bay, obverse (280.3S0E.180-200.C.2).

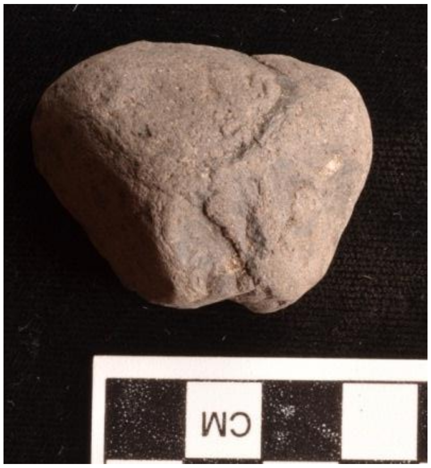


Figure 5.20. Photograph of a unidirectional FGV core from Watmough Bay, reverse (280.3S0E.180-200.C.2).

Round cobbles were flaked using opposed platform or chopper core strategies. For a bipolar opposed platform technique, the rock was placed on an anvil and force was applied from above, often splitting the cobble and/or flaking it on two faces (Figure 5.21, 5.22). Battering is typically present on both ends of these cobbles on their longer axis. Some of the flatter angular cores were also reduced using this technique. For the "chopper" strategy, the cobble was decapitated on one end and then that flake scar was used as a platform for a second flake creating an acute edge (Figure 5.23, 5.24).

Figure 5.21. Opposed platform core on a round waterworn cobble, obverse (280.12S0E.50.C.1).

Figure 5.22. Opposed platform core on a round waterworn cobble, reverse.

Figure 5.23. Chopper core on a round waterworn FGV cobble (280.0N0E.30.C.1).

Figure 5.24. Chopper core on a round waterworn FGV cobble.

Along with FGV cores at Watmough Bay, there are also a small number of quartz cores (*n* =18). All are unpatterned chunks or fragments therefore some may just be shatter. There are also quartzite cores (two fragments and one unidirectional core), and chert cores (two fragments, 1 exhausted, and 1 multi-directional unpatterned core). There is also one unworked nephrite cobble at the site.

A size comparison of Watmough Bay cores and cobbles from Watmough Bay beach and the other cobble areas that I surveyed on the San Juan Islands indicates that people at Watmough Bay preferred larger cobbles than those found on the beach adjacent to the site. For FGV cores with two opposite cortical surfaces, it is possible to measure a dimension of the original cobble (intact cobble dimension or ICD*)*. The ICD is equal to or smaller than the maximum dimension of the original cobble, therefore mean ICD for an assemblage should underestimate mean cobble size for the cobbles from which the cores were made . Results of an ANOVA comparing mean ICD for Watmough cores and cobble lengths for surveyed beaches on the San Juan Islands indicates a significantly larger ICD for Watmough cores compared to cobble lengths for Watmough Bay beach (Table 5.5). This suggests that either people picked the largest cobbles on the beach or that they often went elsewhere to collect toolstone.

Table 5.5. Results of an ANOVA and Bonferroni post-hoc analysis comparing ICD for Watmough Bay FGV cores and length dimensions for FGV cobbles from six cobble beaches on the San Juan Islands (F = 39.42; Sig. = 0.00). For 48 cores that had an ICD, $\bar{x}$ = 50.17.

		n	$\bar{x}$	Mean Difference	Std. Error	Sig.
Watmough ICD	American Camp	36	44.47	5.70	3.59	1.00
	Watmough	64	37.13	13.05	3.11	**0.00**
	False Bay	94	69.73	-19.56	2.89	**0.00**
	Snug Harbor	130	51.34	-1.17	2.75	1.00
	Agate Beach	70	58.39	-8.21	3.05	0.15
	Aleck Bay	30	76.77	-26.60	3.79	**0.00**

As at OpD, it appears that the primary goal of lithic manufacture at Watmough Bay was to create flake tools and scaled pieces which have invasive splintering and crushing caused by use (Figure 5.25-5.28). People also made scrapers with unifacial retouch designed to create a steep edge (Figure 5.29, 5.30), and other intentionally retouched flakes such as pointed and notched tools. Some scaled pieces were later retouched and some flakes were retouched, used as scrapers, and also used in a manner that caused bifacial splintering and crushing. Because of the overlap between these tool categories, I considered all scaled pieces and scrapers within a single framework of "flake tool" and recorded the nature and degree of use and retouch (e.g., unifacial or bifacial, one or more margin, continuous or discontinuous, short or invasive). A total of 232 flakes show macroscopic evidence of damage on at least one margin (Figure 5.31, 5.32), but I cannot determine without microscopic analysis and/or residue analysis if that damage is caused by use, manufacture, or post-depositional processes. Because all FGV flake tools are at least 40 mm in maximum dimension, I did not include flakes smaller than 40 mm in maximum dimension in χ^2 tests comparing flake tools and flakes to determine preferences for creating flake tools. People at Watmough Bay did not consider FGV flakes smaller than approximately 40 mm in maximum dimension to be useful for creating tools.

Figure 5.25 FGV scaled piece from Watmough Bay, obverse (280.3S0E.80.T.1).

Figure 5.26. FGV scaled piece from Watmough Bay, reverse.

Figure 5.27. FGV Scaled piece from Watmough Bay, obverse (280.0N15W.34.T1).

Figure 5.28. FGV Scaled piece from Watmough Bay, reverse.

Figure 5.29. FGV scraper from Watmough Bay, obverse (280.9N3W.32.T.1).

Figure 5.30. FGV scraper from Watmough Bay, reverse.

Figure 5.31. FGV flake showing edge damage from Watmough Bay, obverse (280.0N9W.146.T.1).

Figure 5.32. FGV flake showing edge damage from Watmough Bay, reverse.

The relationship between cortical margins and use observed by Close at OpD is present at Watmough Bay but is not statistically meaningful. For FGV scaled pieces, 44 of 83 scaled pieces have a cortical margin either opposite from or adjacent to the scaled edge. In most cases, the cortical edges are either adjacent or adjacent and opposite to the cutting or scraping end of the tools. In other cases the cortical margins are opposite from the cutting or scraping end of the tool (Table 5.6). A χ^2 test comparing proportions of FGV flakes $\geq$ 40 mm in maximum dimension with cortical margins with FGV scaled pieces with cortical margins does not show a statistically significant difference ($\chi^2 = 3.37$, 1 df, $p = 0.07$) in cortical and non-cortical margins. This does not support the hypothesis that people specifically chose flakes with cortical margins to create scaled pieces. For FGV scrapers, 19 of 17 have a cortical margin either opposite from or adjacent to the retouched edge (Table 5.6). A χ^2 test comparing proportions of FGV flakes $\geq$ 40 mm in maximum dimension with cortical margins with FGV scrapers with cortical margins does not show a statistically significant difference ($\chi^2 = 1.21$, 1 df, $p = 0.27$) in cortical versus non-cortical margins, which does not support the hypothesis that people specifically chose flakes with cortical margins to create scrapers. Scaled pieces and scrapers are statistically similar in incidence of cortical margins ($\chi^2 = 2.58$, 1 df, $p = 0.12$), and similar in incidence of opposite and adjacent cortical margins ($\chi^2 = 0.20$, 1 df, $p = 0.65$).

Table 5.6. Location of cortex and location of use-wear or retouch for FGV flake tools from Watmough Bay.

	Cortex Location Relative to Use/Retouch								
	Ajacent	Opposite	Same	Undet.	Adjacent/ Opposite	Adjacent/ Same	Opposite/ Same	All Margins	Total
Scaled Pieces	24	15	1	1	2	0	1	0	44
Retouched Flakes	10	4	1	0	3	0	0	0	18
Scrapers	11	2	1	0	5	0	0	0	19

Scaled pieces made from FGV do not have significantly more dorsal flake scars than $\geq$ 40 mm FGV flakes ($\chi^2 = 2.94$, 1 df, $p = 0.09$). There were no significant differences in platform facet between non-used, used flakes and scaled pieces ($\chi^2 = 3.52$, 1 df, $p = 0.06$). Flakes with both cortical and non-cortical platforms were used to make these tools. Only a handful of flakes with dihedral or multi-faceted platforms were found in the assemblage. Scaled pieces had significantly more round vertical platforms (platforms that are curved longitudinally rather than flat) than expected given the ratio for non-used flakes although sample size is small ($\chi^2 = 36.15$, 1 df, $p = 0.00$ (Table 5.7).

Table 5.7. Results of a χ^2 test comparing proportions of round and flat platforms for FGV flakes and scaled pieces at Watmough Bay.

		Platform				
Artifact Type (FGV)	Stats	Round Vertical	Flat	χ^2	DF	p
Scaled Pieces	Count	18	14	36.15	1	**<0.001**
	Expected	5.57	26.43			
	AR	**6.01**	**-6.01**			
Flakes $\geq$ 40 mm	Count	61	361			
	Expected	73.43	348.57			
	AR	**-6.01**	**6.01**			

Results of a several *t*-tests indicate that the people at Watmough Bay selected sturdier flakes for scaled pieces and wider flakes for minimal retouch. Scaled pieces have significantly greater mean lengths and thicknesses than $\geq$ 40 mm unmodified FGV flakes. Retouched flakes (excluding perforators and notched tools) have significantly greater mean widths than unmodified flakes. Scrapers are not significantly different from the unmodified flakes in any dimension. For length and width, this is potentially because extensive retouch decreases the length and width of the original flake, although thickness should not be affected (Table 5.8)

Along with the flake tools, the Watmough assemblage also contains bifaces (*n* = 34), shapes flakes or cores that are flaked on both faces from parallel opposing axes (Kelly 1988:718) (Figure 5.33, 5.34) and projectile points (*n* = 26). Along with unidentifiable tips and fragments (*n* = 9) points types include one willow leaf-shaped point, one corner-notched point, stemmed points (*n* = 5, Figure 5.35, 5.36) and triangles (*n* = 10, Figure 5.37, 5.38). Because the projectile points have been heavily worked, I had difficulty determining the kinds of flakes that were preferred to make these artifacts. FGV is the most common material type with three points/bifaces made from coarser grained volcanic rock, 1 made from chert, and 11 made from slate, schist, or other metasedimentary material that do not facture conchoidally. Cortex is present on only a few bifaces. The FGV bifaces are significantly wider than the average unworked > 40 mm FGV flake, suggesting that people picked wider flakes for use (Table 5.8). Length and thickness were not significantly different for FGV flakes and bifaces, but this may be because people chose thicker and longer-than-average flakes that were thinned and reduced in size through bifacial thinning and shaping.

Figure 5.33. Two FGV bifaces from Watmough Bay, obverse (left - 280.0N0E. 25.T.1, right – 280.0N0E.45.T1).

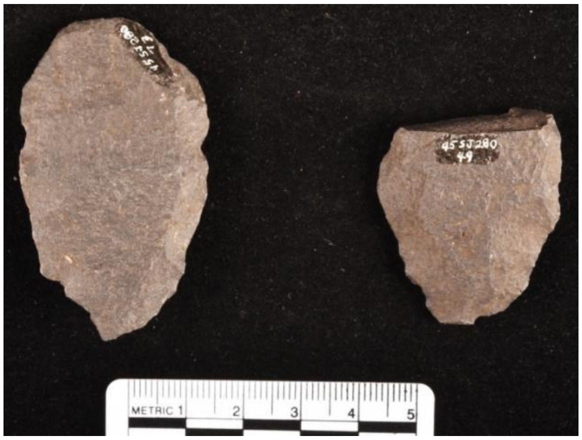


Figure 5.34. Two FGV bifaces from Watmough Bay, reverse.

Figure 5.35. FGVwillow leaf-shaped point (left -280.0N15W.106.T.1) and stemmed point (right - 280.9N24W.70.T.1) from Watmough Bay, obverse.

Figure 5.36. FGV willow leaf-shaped point (left -280.0N15W.106.T.1) and stemmed point (right - 280.9N24W.70.T.1) from Watmough Bay, reverse.

Figure 5.37. FGV triangular points from Watmough Bay, obverse (left – 280.0N0E.100.T.1, middle – 280.2S0E.70.T.1, right – 280.0N18W.36.T.1)

Figure 5.38. FGV triangular points from Watmough Bay, reverse (left – 280.0N0E.100.T.1, middle – 280.2S0E.70.T.1, right – 280.0N18W.36.T.1)

Table 5.8. Results of independent samples *t*-tests (equal variances not assumed) comparing mean length, width and thickness for > 40 mm unmodified FGV flakes, FGV scrapers, and FGV scaled pieces at Watmough Bay.

Dimension	Flakes	Scrapers	F	Sig.	t	df	Sig. (2-tailed)
Length *n*	444.00	33.00	0.06	0.51	-1.75	37.2	0.09
Length $\bar{x}$	36.33	39.63					
Width *n*	500.00	33.00	0.13	0.72	0.291	37.6	0.77
Width $\bar{x}$	33.32	32.80					
Thickness *n*	908.00	33.00	2.31	0.13	-1.97	33.66	0.06
Thickness $\bar{x}$	9.69	11.39					
Dimension	Flakes	Scaled Pieces	F	Sig.	t	df	Sig. (2-tailed)
Length *n*	444.00	87.00	7.77	0.01	-2.21	105.66	**0.03**
Length $\bar{x}$	36.33	39.92					
Width *n*	500.00	87.00	0.57	0.05	-2.18	117.21	**0.03**
Width $\bar{x}$	33.32	36.18					
Thickness *n*	908.00	87.00	21.26	0.00	-4.12	94.48	**0.00**
Thickness $\bar{x}$	9.69	12.29					
Dimension	Flakes	Retouched flakes	F	Sig.	t	df	Sig. (2-tailed)
Length *n*	444.00	25.00	4.07	0.04	-1.03	25.47	0.31
Length $\bar{x}$	36.33	39.41					
Width *n*	500.00	25.00	3.31	0.07	-2.56	25.51	**0.02**
Width $\bar{x}$	33.32	40.96					
Thickness *n*	908.00	25	5.46	0.02	-0.74	24.71	0.47
Thickness $\bar{x}$	9.69	10.53					
Dimension	Flakes	Bifaces	F	Sig.	t	df	Sig. (2-tailed)
Length *n*	444.00	22	0.249	0.62	-0.91	23.88	0.37
Length $\bar{x}$	36.33	38.19					
Width *n*	500.00	22	2.34	0.13	2.28	25.29	**0.03**
Width $\bar{x}$	33.32	33.32					
Thickness *n*	908.00	22	4.23	0.04	0.67	23.4	0.05
Thickness $\bar{x}$	9.69	9.69					

Along with FGV flaked stone manufacture, the Watmough Bay site contains evidence of flaked and ground slate technology. Large pieces of slate could be removed from an outcrop on the southeast end of the beach or at the base of the cliff. Slate bifaces (*n* = 5), chipped slate unifaces (*n* = 14) (Figure 5.39, 5.40), and ground slate tools such as net weights, adzes, and points are present at the site. There are also a number of rough unifaces (*n* = 9) and bifaces (*n* = 2) made from schist, a material that is coarser-grained and more durable than slate and also probably available locally. On the Northwest Coast, unifacially or bifacially chipped and/or ground slate fragments are often called knives. They are associated with fish processing due to their thin edges and the ease of resharpening (Hayden 1989; Graesch 2007). Byproducts of slate knife production are small chips that would slide through ¼" mesh (Graesch 2007:583), therefore evidence of slate processing at the Munsell excavation was likely only partially recovered.

Graesch's (2007) reduction sequence for slate provides a useful baseline for the artifacts at Watmough Bay. Slate fragments could be removed from the bedrock using hard hammers or they could be collected from the beach. Further thinning could be accomplished using bipolar or hard hammer percussion. These fragments can be used without further chipping or they can be chipped along the margins using soft-hammer percussion or pressure flaking to thin and shape the fragile edge. Some slate knives from Northwest Coast assemblages were ground on their edges using sandstone abraders because a more regular edge would break and chip less easily during use. Among the Coast Salish during the post-contact period, slate knives were sometimes hafted (Barnett 1955).

Figure 5.39. Slate knife, obverse (280.1.5N0E.175-180.T.1).

Figure 5.40. Slate knife, reverse.

San Nicolas Island Lithic Analysis

For this research I analyzed a total of 4597 flakes (including ground sandstone fragments), 114 cores, and 168 retouched and groundstone tools from the Tule Creek Village site (CA-SNI-25, Mound B). At CA-SNI-106, I analyzed a total of 474 flakes, 1 retouched tool, and 6 cores (Table 5.9). Similar to the lithic technology of the San Juan Islands, San Nicolas Island lithic technology centers primarily on expedient tools. Large metavolcanic and metasedimentary cobbles are split or decapitated and flaked to create flake tools, some of which show damage to their margin (n = 217 at Mound B, n = 6 at SNI-106). Many flakes from Mound B were probably used but do not show evidence of use damage because of the hardness and coarse grain of the material. The Nicoleño also made retouched scrapers, choppers, drills, reamers, and bifaces from local toolstone and from off-island chert. In addition to flaked stone, the Mound B and SNI-106 assemblages contain ground stone tools and debris such as sandstone fragments from vessels, saws, pestles, and other objects, and steatite and serpentine beads and ornaments. Other lithic materials include angular, discolored, and potlidded fire-affected rock (FAR), tarring pebbles that were used to apply asphaltum to baskets and other items, iron concretions, calcite, waterworn pebbles, and a variety of other miscellaneous rocks. All stone material at Mound B and SNI-106 was brought there by people; no rock occurs naturally on the sandy dunes where the sites are located. This research focuses primarily on the flaked stone assemblage but I also present data on the other lithic materials for Mound B (Table 5.10).

Table 5.9. Descriptive data for the Mound B and SNI-106 flakes and cores.

Site	Tule Creek	Tule Creek	Tule Creek	Tule Creek	Tule Creek	CA-SNI-106	CA-SNI-106	CA-SNI-106
Time Period	5000-4000 BP	3000-1500 BP	1500-500 BP	500 BP-Contact	Undated	3000-1500 BP	1500-500 BP	Undated
Flakes								
Metavolcanic	81	144	452	971	1685	113	225	35
Metasedimentary	4	11	18	56	63	0	0	0
Quartzite	14					34	21	
Quartzite	14	18	85	171	216	34	21	3
Sandstone	7	2	34	51	173	0	1	0
Exotic Chert	9	8	15	40	63	3	2	0
Obsidian	0	0	0	0	1	0	0	1
Island Chert	1	0	2	1	5	0	1	0
Quartz	1	12	10	47	87	20	12	2
Total	131	195	616	1337	2293	204	283	41
Cores (Metavolcanic unless noted)								
Unworked Cobble				1 (quartzite)				
Tested Cobble	1	1	0	0	0	0	0	
Split Rotated	0	0	0	7 (1 quartzite)	9 (2 quartzite)	0	0	
Diagonal Cores	0	1	1	1 (sandstone)	7 (1 quartzite)	0	0	
Decaptation Cores	0	0	1	1	2	0	0	
Exhausted Cores	1	0	4 (1 quartzite)	8 (2 sandstone)	12 (1 quartzite, 1 metasedimentary, 1 quartz)	1	0	
Cores on Flakes	0	0	1	1	6 (1 sandstone)	0	0	
Core Fragments	0	0	15 (1 sandstone, 1 quartzite, 1 quartz)	9 (5 sandstone, 1 chert, 1 quartzite)	21 (4 quartzite, 4 sandstone)	4 (1 quartzite, 1 sandstone)	1	

Table 5.10. Descriptive data for the Mound B and SNI-106 formal tools and other miscellaneous stone artifacts.

Site	Tule Creek	Tule Creek	Tule Creek	Tule Creek	Tule Creek	CA-SNI-106	CA-SNI-106	CA-SNI-106
Time Period	5000-4000 BP	3000-1500 BP	1500-500 BP	500 BP-Contact	Undated	3000-1500 BP	1500-500 BP	Undated
Tools (Metavolcanic unless noted)								
Damaged Flakes	4	3	33	59	118	1	5	
Retouched Flakes	2	4	0	4 (1 chert, 1 quartzite)	6 (1 chert)	0	0	
Drill	2	1	15 (1 metased., 1 chert, 3 quartz, 2 quartzite, 1 sandstone)	12 (2 chert, 2 quartzite)	15 (3 chert, 1 silicious shale, 2 quartzite, 2 quartz)	0	0	
Biface/Point	0	2 (1 quartzite, 1 chert)	2 (1 chert)	2 (1 chert, 1 quartz)	11 (2 quartz, 2 chert)	0	0	
Scraper/Knife	0	1	11 (1 quartzite)	14 (3 metasedimentary, 1 quartzite)	6 (4 chert, 1 quartzite)	0	1	
Reamer	0	0	1	0	5 (4 sandstone, 1 quartzite)	0	0	
Chopper	0	0	0	0	5 (1 quartzite)	0	0	
Ground Stone	1	0	0	2 (1 sandstone, 1 serpentine)	3	0	0	
Bead/Ornament	0	1 (quartz crystal)	3 (steatite)	3 (2 steatite)	11 (6 serpentine, 5 steatite)	0	0	
Saw Fragment	0	0	1 (sandstone)	0	8 (sandstone)	0	0	
Other tool type	0	1	2	0	6	0	0	
FAR	8	46	39	242	287			
Tarring Pebbles	6	2	8	95	166			

In contrast to lithic research on the Northern Channel Islands that investigates microblades (Arnold 1990b; Arnold et al. 2001) and bifaces (Cassidy 2004; Pletka 2001), previous research on flaked stone tools on San Nicolas Island explores expedient flake tool technology (but see Rosenthal 1996). Clevenger's (1982) thesis research on the lithic assemblage at CA-SNI-11 investigates reduction strategies and cobble sources on the island. She describes a split round cobble reduction strategy with a continuum of flexible actions performed to create flake tools used without further modification. Taşkiran (2001) builds on Clevenger's research and investigates the ways that availability, quality, and characteristics of available toolstone affects technological organization on San Nicolas Island and San Clemente Island. Based on research at CA-SNI-39 she suggests that tabular and oval cobbles were often split diagonally rather than lengthwise , which results in several different potential round and flat cobble reduction trajectories. Taşkiran's results suggest that because cobbles were abundant on San Nicolas Island, metavolcanic and metasedimentary rock was not conserved. Core preparation was designed to facilitate reduction of desired flake types rather than reduction to exhaustion.

Rosenthal's (2008) study of stone artifacts from 20 units from sites across San Nicolas Island adds a broader perspective to previous site-focused studies. She uses data from the index units to learn about artifact production, use, and discard. Rosenthal observes fewer cores than expected given the volume of flakes. She suggests that core reduction occurred at the cobble source; however, some exhausted cobbles may also have been smashed to create flakes. Rosenthal also notes that index units have unequal proportions of material types indicating differential access to source materials, selection of certain material types, or both.

My analysis of core and flake types at Mound B supports Taşkiran's assertion that people on San Nicolas Island used different core reduction strategies depending on the original cobble shape. At SNI-106, all cores are either exhausted cores or core fragments but I assume that similar technological processes took place there. At Mound B, a common reduction strategy for round and ovoid cobbles is to place a cobble on an anvil stone and strike perpendicular to the anvil to split the cobble in half. The next step is to remove flakes from the rounded cortical surface towards the center of the split face (Clevenger 1982; Taşkiran 2001; Figure 5.41). This centripetal reduction results in a "tortoise shell" appearance for a rotated split cobble core (Rondeau 1995). In some cases, after the core is worked to the point that the platform angle becomes too obtuse to flake effectively, it is rotated 90 degrees and additional flakes are removed using the non-cortical flaked split face as a platform. Taşkiran describes that in a variation of the split cobble core, the cobble is split and then flakes re removed using the non-cortical split face as a platform. The core is then rotated. Because I did not identify any cores that fit this description and noted few first flakes with *lisse* platforms and 100% dorsal cortex, I cannot demonstrate that this technique was used at Mound B or SNI-106. I identified seven split rotated cores in the Mound B assemblage (Figure 5.42-5.44).

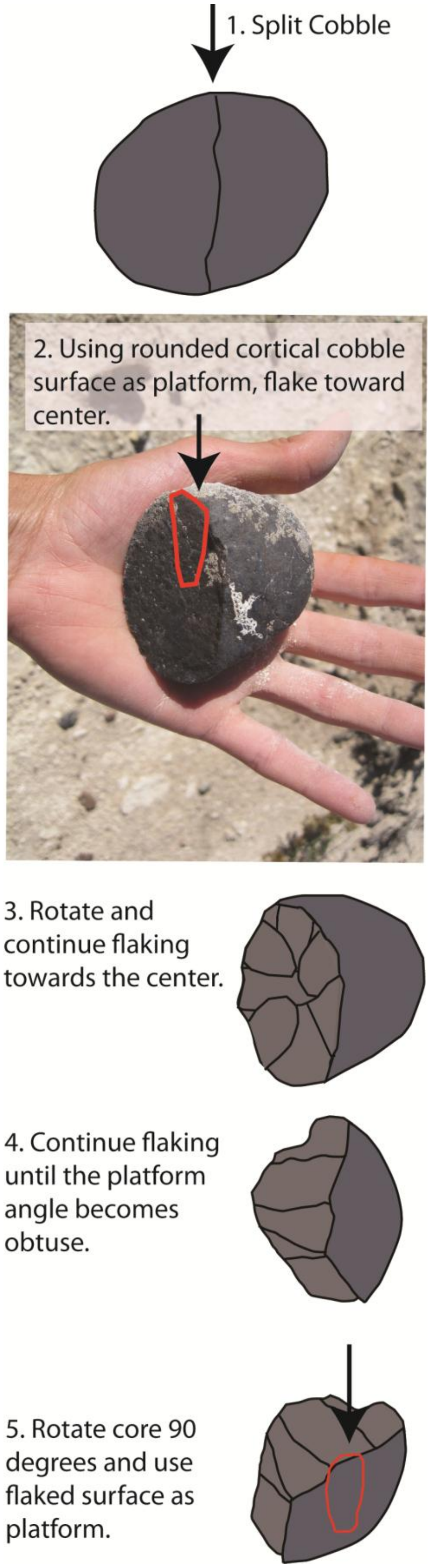


Figure 5.41. Split cobble reduction sequence.

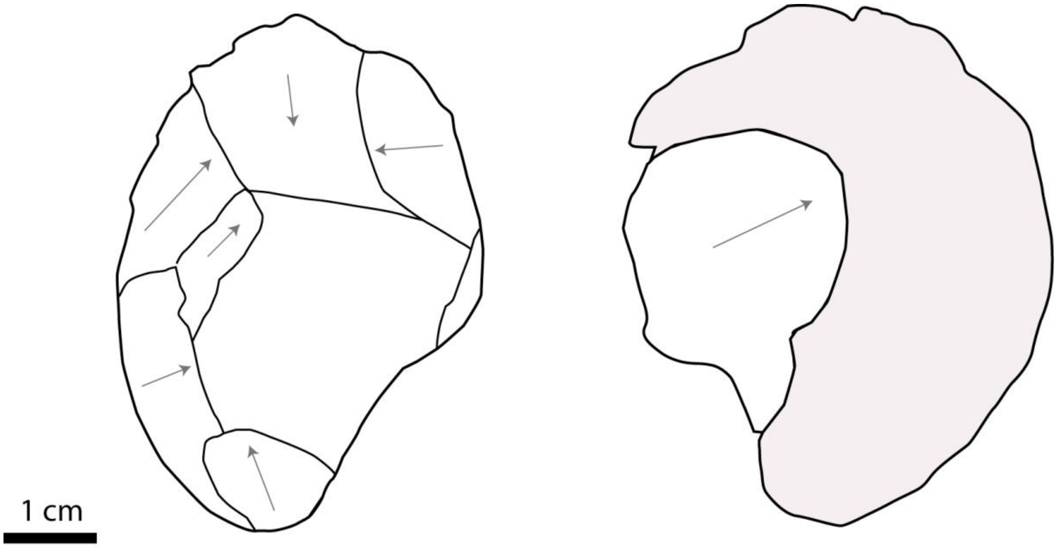


Figure 5.42. Schematic showing plan view of obverse and reverse of split cobble core from Mound B (25B.32.2.4.C.3)

Figure 5.43. Split cobble cores from Mound B, obverse. Top row (left - 25B.52.I.3.shell-lithic feature.C.1, right - 25B.32.II.3.C.1). Middle row (left - 25B.11.II.3.C.2, right - 25B.48.I.2.C.1. Bottom row (left - 25B.11.1.2.C.5, right - 25B.52.I.3. shell-lithic feature. C.2.).

Figure 5.44. Split cobble cores from Mound B, reverse. Top row (left - 25B.52.I.3.shell-lithic feature.C.1, right - 25B.32.II.3.C.1). Middle row (left - 25B.11.II.3.C.2, right - 25B.48.I.2.C.1. Bottom row (left - 25B.11.1.2.C.5, right - 25B.52.I.3. shell-lithic feature. C.2.).

For oblate and tabular cobbles, people favored diagonal and decapitate core reduction sequences described by Taşkiran (2001). In the diagonal reduction sequence, the cobble is placed on an anvil and split diagonally down the long axis. Flakes are then removed from the split face, using the round cortical surface as a platform (Figure 5.45). The core can be rotated or semi-rotated to remove additional flakes. I identified 4 cores matching this description at Mound B (Figure 5.46-5.48).

For the decapitate reduction sequence, a flake is removed from one end of the cobble using a flat cortical surface as a platform. Additional flakes are struck using the same platform, the force of the blow following the ridge made by the first flake scar (Figure 5.49). I identified 4 cores matching this description at Mound B (Figure 5.50, 5.51). Taşkiran describes a similar core reduction sequence where a tabular cobble is decapitated and then the flake scar is used as a platform for the next flake, but I did not identify any cores matching this description.

These reduction sequence descriptions produce flakes with considerable variation at the beginning of the reduction sequence, but later in the reduction sequence as the cobble core is flaked and rotated, the flakes that result become more similar to one another. Cores at this stage are multidirectional and unpatterned or exhausted (Figure 5.52-5.54).

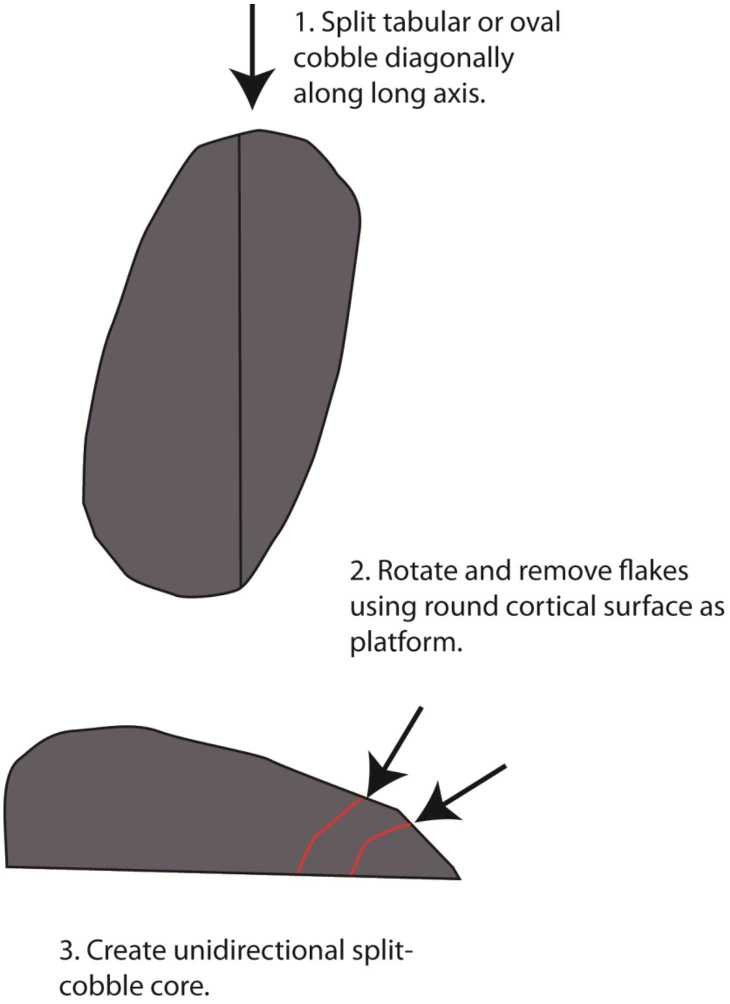


Figure 5.45. Diagonal core reduction sequence.

Figure 5.46. Diagonal cobble core from Mound B, obverse (25B.52.2.1.C.2).

Figure 5.47. Diagonal cobble core from Mound B, reverse.

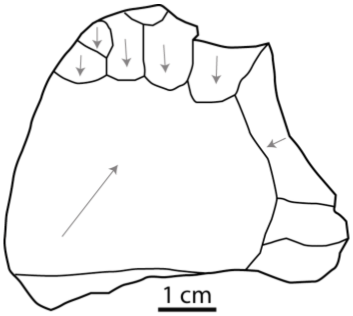


Figure 5.48. Plan-view schematic of diagonal cobble core from Mound B, obverse (25B.52.2.1.C.2).

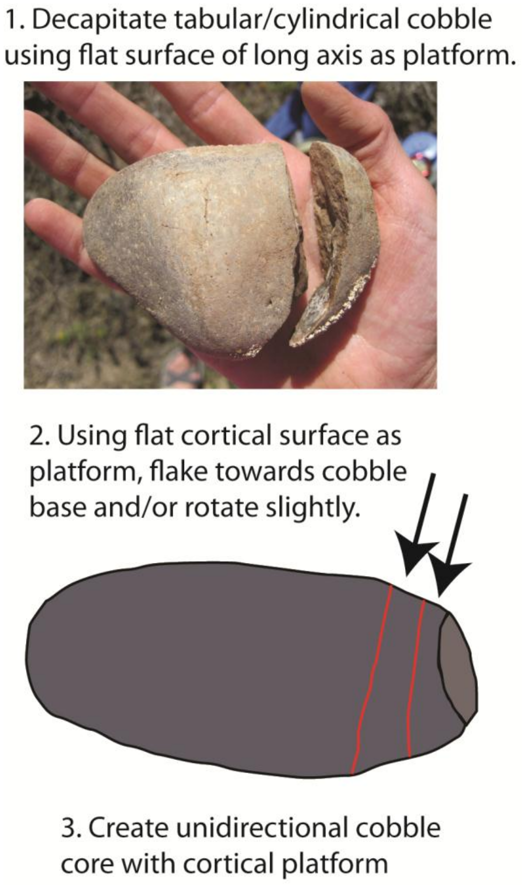


Figure 5.49. Decapitate reduction technique.

Figure 5.50. Decapitated core from Mound B, obverse (25B.11.II.3.C.1).

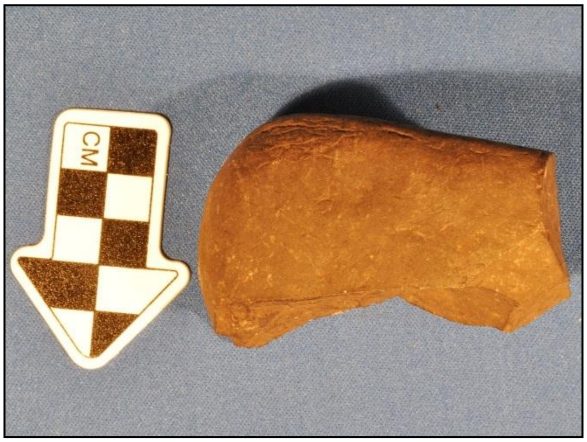


Figure 5.51. Decapitated core from Mound B, reverse.

Figure 5.52. Unpatterned multidirectional cores from Mound B, obverse (Top - 25B.52.I.3.Shell-lithic.C.3, Bottom - 25B.32.II.1b.C.2).

Figure 5.53. Unpatterned multi-directional cores from Mound B, reverse.

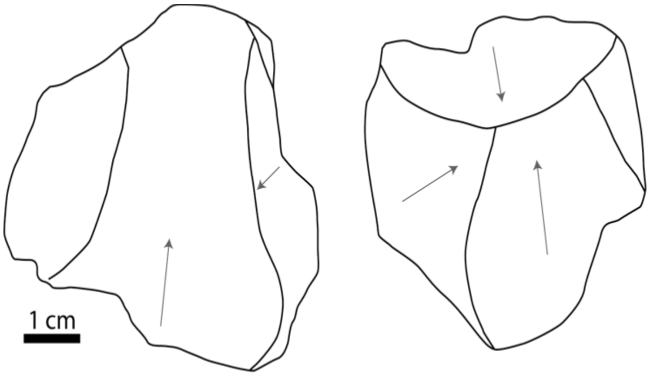


Figure 5.54. Plan-view schematic of an unpatterned multidirectional cores from Mound B (25B.32.II.1b.C.2).

For the Mound B assemblage, a majority of the cores were fragments or exhausted and substantially smaller than cobbles at the cobble areas therefore it was not possible to calculate an estimate for original cobble size. Based on macroscopic analysis of flake margins, 141 flakes show chipping and damage that may be caused by use, manufacture, or post-depositional processes (Figure 5.55, 5.56). Most flakes were likely used without retouch or other modification and do not show evidence of wear from scraping or chopping. Given the abundance of chipped stone tools at the site and the scarcity of formal tools made from metavolcanic rocks, the goal of most lithic manufacture was to create flake tools to be used immediately for tasks at Mound B or potentially elsewhere on the landscape. Based on the core reduction strategies, people at Mound B did not attempt to remove cortex from the flakes prior to use, but rather, used the cortex as a natural back.

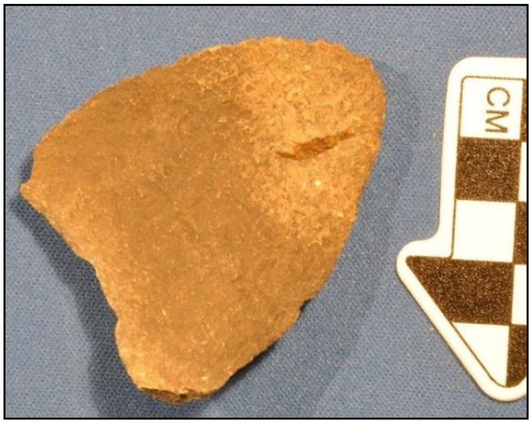


Figure 5.55. Flake from Mound B with damage on the margin, obverse (25B.43.2.3.F.3-40, 42-43).

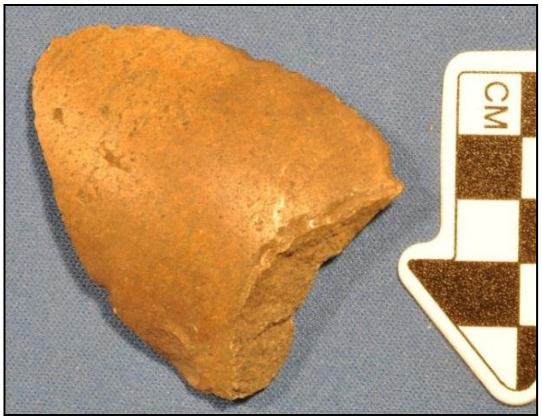


Figure 5.56. Flake with Mound B with damage on the margin, reverse.

A total of 10 of the 168 retouched tools from Mound B were made on cores, with the remainder of the retouched tools made on flakes. Many of the formal tools are made from exotic cherts and rarer fine-grained island materials such as quartz and siliceous shale. Focusing on the two largest retouched tool assemblages from the 1500-500 cal BP and 500 cal BP-Contact assemblages from Mound B, the most common tools are drills (Figure 5.57-5.60) and scrapers (Figure 5.61-62) with a handful of bifaces/projectile points (Figure 5.63, 5.64), retouched flake tools, choppers, and reamers. Drills are made from a variety of different materials including chert, metavolcanic rock, quartzite, quartz, and sandstone. There are several different manufacturing methods (Preziosi 2001).Some are made by minimally shaping a small flake or bade or by taking advantage of a break. Other drills are made by bisecting a flake with an axial break and have a triangular cross-section. In some cases, small flakes are removed from the distal end of a flake at an oblique angle, creating a trapezoidal cross section. If a drill bit becomes dull it can be resharpened through retouch (Figure 5.59, 5.60). The scrapers and bifaces at Mound B also come in a variety of forms. Some show extensive retouch on one or more margins; others show minimal retouch on a single margin. For 1500-500 cal BP and 500 cal BP-Contact sub-assemblages, material type is relatively evenly distributed. Most scrapers are made using metavolcanic rock or quartzite. Finally, another important tool used at Mound B is the sandstone saw. These tools are made on first flakes from sandstone cores. The proximal ends are thinned through secondary retouch and then the tool is used without further modification (Figure 5.65) (Kendig et al. 2008, 2010:200).

Figure 5.57. Drills from Mound B, obverse (25B.11.2.2.T.1-3).

Figure 5.58. Drills from Mound B, reverse.

Figure 5.59. Retouched drill from Mound B, obverse (25B.32.2.1.T.1).

Figure 5.60. Retouched drill from Mound B, reverse.

Figure 5.61. Scrapers from Mound B, obverse (25B.11.1.1.T.1-2).

Figure 5.62. Scrapers from Mound B, reverse.

Figure 5.63. Bifaces from Mound B, from left 25B.44.II.1.T.2, 25B.31.I.1.T.1; 25B.34. I.4.T.1, and 25B.49.I.2.T.2, obverse.

Figure 5.64. Bifaces from Mound B, from left 25B.44.II.1.T.2, 25B.31.I.1.T.1; 25B.34. I.4.T.1, and 25B.49.I.2.T.2, reverse.

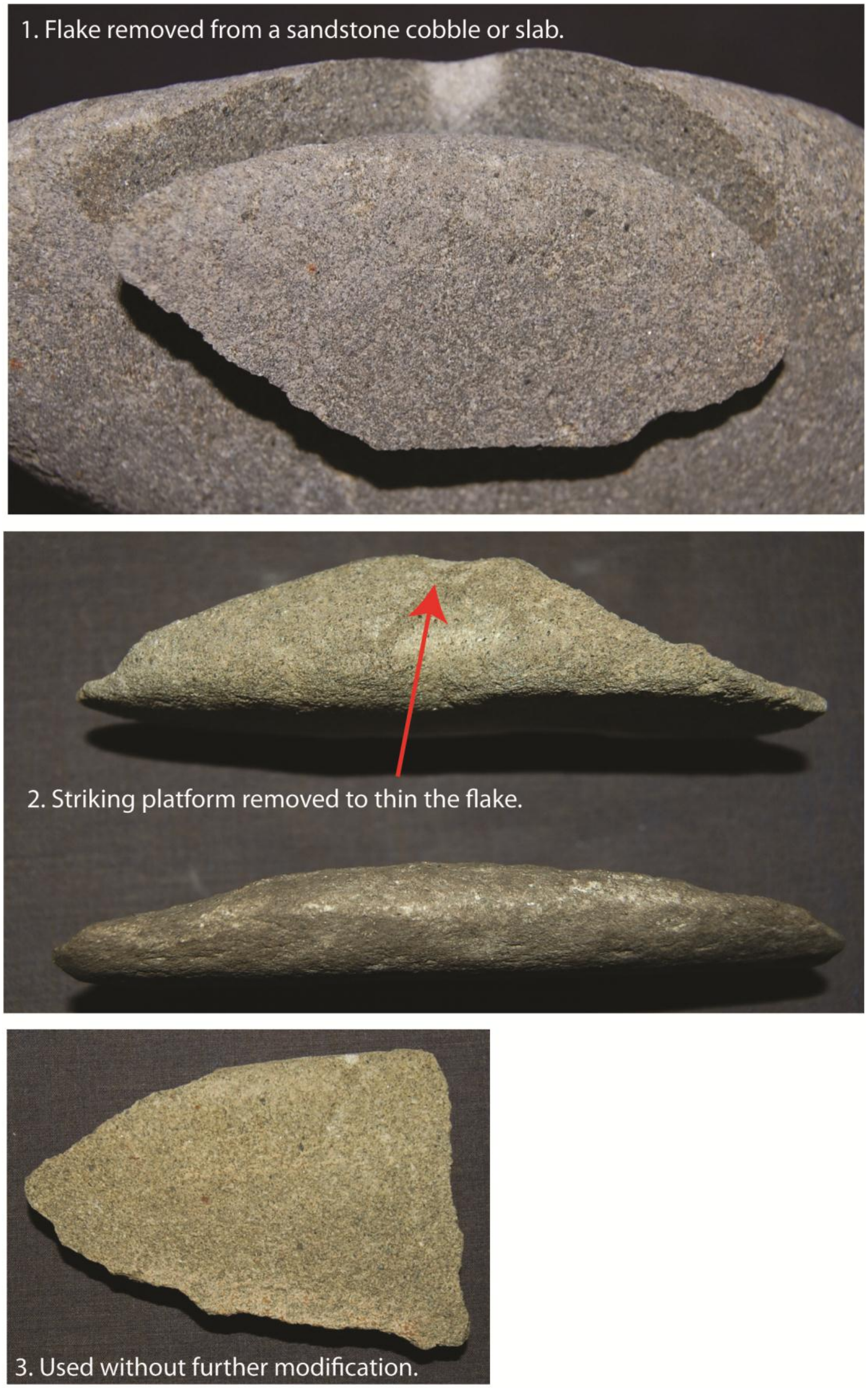


Figure 5.65. Manufacture of a sandstone saw. Photos courtesey of Bill Kendig, CSULA.

Conclusions and Comparisons

The cobble-core expedient flake tool technologies of the San Juan Islands and southern Channel Islands provided people with an important toolkit for tasks such as cleaning fish, processing meat, processing plant foods, and a range of other activities. The study of two assemblages characterized by similar technologies, material types, and cobble availability provides important insights on flaked beach cobble technology.

First, analyses of cores indicate that people selected different shaped cobbles for different purposes. They also approached reduction of angular, round, oblate, and flat cobbles in different ways. People at Watmough Bay specifically chose angular cobbles and used the natural ridges to channel the force of the blow to decapitate the cobble and remove the first few flakes. People at Mound B used round, oval, and tabular cobbles and they typically split their cobbles rather than decapitating them. This is at least partly attributable to the fact that the metamorphic toolstone on San Nicolas Island was harder and more difficult to work than the FGV on the San Juan Islands. In both study areas, however, people had their choice of a number of different core reduction strategies that were based on cobble shape and desired flake morphology. Unpatterned cores are more common than patterned cores in both study areas.

An interesting similarity in the flake tools created by people on both the San Juan Islands and on San Nicolas Island is the use of cortex as a natural back as described by Close (2006) for the OpD site on San Juan Island. Cores were set up to create flakes with cortex either adjacent to or opposite from the sharp edge perhaps to serve as a handle to push or pull the tool with greater force. In both study areas, flakes chosen for use were often thicker more robust flakes than those that were not, and they often had round platforms and multiple dorsal flake scars. That sturdier flakes are used for the cutting and scraping tasks that un-modified flakes is not surprising—they would have been easier to hold, broken less frequently, and performed tasks more efficiently. The prevalence of used and modified flakes with multiple dorsal flake scars may indicate that at times it took a few tries to set up a core in such a way that the appropriate flake could be removed. This demonstrates the planned and purposeful nature of flake tool technology despite a lack of formal or standardized end product.

Chapter 6: Toolstone Procurement Predictions and Lithic Analysis

Archaeologists who study highly mobile hunter-gatherers often use toolstone procurement patterns to investigate changes in mobility and territory size (e.g., Beck et al. 2002; Blades 1999; Féblot-Augustins 1993, 2009; Gamble 1999; Jones et al. 2003; Kuhn 1995, 2004). Assuming that “raw material is embedded in basic subsistence schedules” (Binford 1979:259), researchers imagine a small group of people moving between habitation sites and subsistence opportunities, encountering toolstone outcrops as they travel. They discard exhausted formal tools, collect and work toolstone, and continue across the landscape with cores and blanks. In contrast, archaeologists’ concept of lithic procurement among sedentary or semi-sedentary people is a small group traveling from a village to gather a bulk load of unprocessed toolstone. They bring it home, make several informal flake tools, and store the rest for later use (e.g., Blair 2010; Close 2006; Odell 1998, 2000). Procurement concepts from mobility studies can be applied to more sedentary coastal peoples but must be fine-tuned to account for flake tool technology, logistical procurement, boat transport, exchange, use of beach cobbles, and other characteristics of the coastal record. In this context, procurement patterns reflect the limits of landscape access due to social and physical boundaries.

In Chapter 1, I outlined hypotheses for lithic procurement behaviors in different territorial contexts based on economic defensibility and social networking models. I suggested that boundary defense should center on parts of the landscape where resources are adequate to the needs of the population—not so abundant that theft or reciprocal access would be tolerated and not so scarce that the costs of defending the resource would have outweighed the benefits. Boundary permeability should be facilitated by increased benefits and decreased costs of inter-group interaction associated with an unstable or impoverished resource base. In coastal settings, separate terrestrial and marine environmental shifts should foster complex territorial strategies that, in turn, affect lithic procurement, processing, and conservation.

In this analysis, I also address an alternative hypothesis. If boundary defense did not occur at the level of the village, access to resource areas might instead be determined by kin groups that transcend village boundaries. If this is the case, different families within a village have access to different parts of the landscape including toolstone collection areas. This territorial organization should be reflected in differences in material type within different parts of the site. For each study area in this study, I focus first on testing the primary hypotheses that are based on economic defendability models. I then briefly explore how the data fit with the alternative hypothesis. This party of the study is less detailed because more spatial data and analysis would be required to more fully explore access to resources on the landscape determined by kin affiliation.

Toolstone Procurement and Processing Predictions

Based on economic defensibility models, if a habitation site is located in an area considered , increased boundary defense and associated use of a smaller territory should encourage toolstone procurement near a habitation site. Decreased boundary defense associated with scarce or unpredictable resources allows toolstone procurement from the most attractive sources on the landscape because people move over larger spaces. Change over time in access to certain material types, cobble size, and cobble shape should reflect change over time in access to different parts of the landscape.

Shifts in resource access should also be reflected in degree of processing at a cobble area prior to transport. Using a central place foraging model framework, degree of processing at a quarry depends on travel costs. Toolmakers seek to minimize costs of transport and field processing (material testing and early stage core reduction) and maximize the amount of high utility toolstone delivered to a habitation site from a source (Bettinger et al. 1997; Metcalfe and Barlow 1992). *Utility* is defined as the amount of material from a core that is usable as a tool (Bettinger et al. 1997). This model has been applied to quarry behavior in several instances (e.g., Beck et al. 2002; Elston 1990; Kelly 2001; but see Brantingham 2003 for an alternative perspective). These studies indicate that when a quarry site is far from a habitation site, people are likely to increase load utility by testing cobble quality, a practice that has been documented ethnographically and archaeologically at quarry sites (Binford and O'Connell 1984; Ericson 1984; Ross et al. 2003; Torrence 1986). They may also begin early stage reduction to open a flaking surface and remove cortex. Particularly for coastal groups with access to efficient boat travel, distance may be secondary to boundary defense in determining travel cost on a crowded and sociopolitically complicated landscape. People traversing contested areas may incur social and economic costs, face a threat to their well-being, or risk retribution. They should increase the utility of the load prior to transport to ensure that it carries a high enough value to be worth the dangerous trip (Figure 6.1).

Another possible interpretation of lithic procurement strategies is that people who are taking toolstone from another groups' territory without permission would work quickly to load up a boat or basket with stones without attracting the attention of their neighbors, therefore toolstone collected from a distance from a habitation site in a territorial regime would not be processed, contrary to the above logic. I propose that this strategy may have been used at times, but given probable inter-connectedness between groups, it would have been more effective to communicate with the other group and use the opportunity to engage in exchange or ceremonial activities. If inter-village relationships were so tense that they could not engage in such relationships, they could have made due with more local material, shell, or bone until the relationship improved. Thus, for villages in high boundary defense/low permeability contexts located near toolstone areas, I expect minimal testing prior to transport and toolstone conservation if local resources are limited. If toolstone areas are located outside of territorial boundaries, increased processing at the source reflects increased social or economic cost in obtaining the resource. Low boundary permeability should be reflected in more formal exchange relationships.

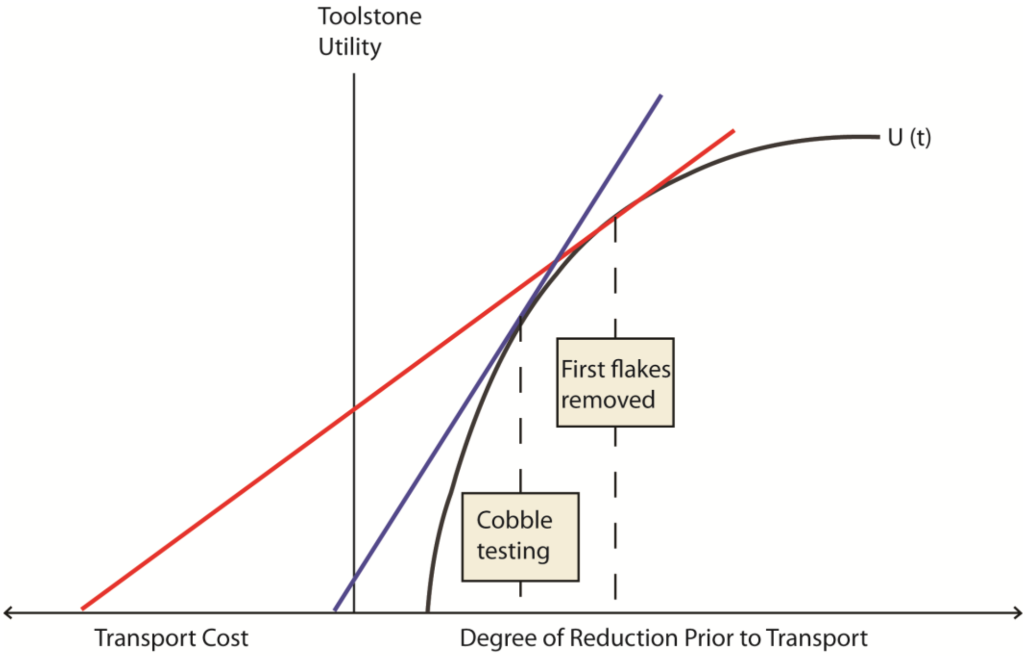


Figure 6.1. Graphical representation of the central place foraging model applied to cobble reduction strategies when toolstone (modified from Beck et al. 2002 Figure 5).

In contrast, for sites in low defense/high permeability areas, people should acquire toolstone from the most attractive source areas on the landscape. If those areas are far away and travel costs are high, testing offsets a higher transport cost. If travel costs are low, all processing should occur at the habitation site. Toolstone conservation should be minimal unless travel costs are extremely high. Higher boundary permeability and greater benefits of inter-group relationships should lead to more intensive and less formal exchange relationships (Figure 6.2).

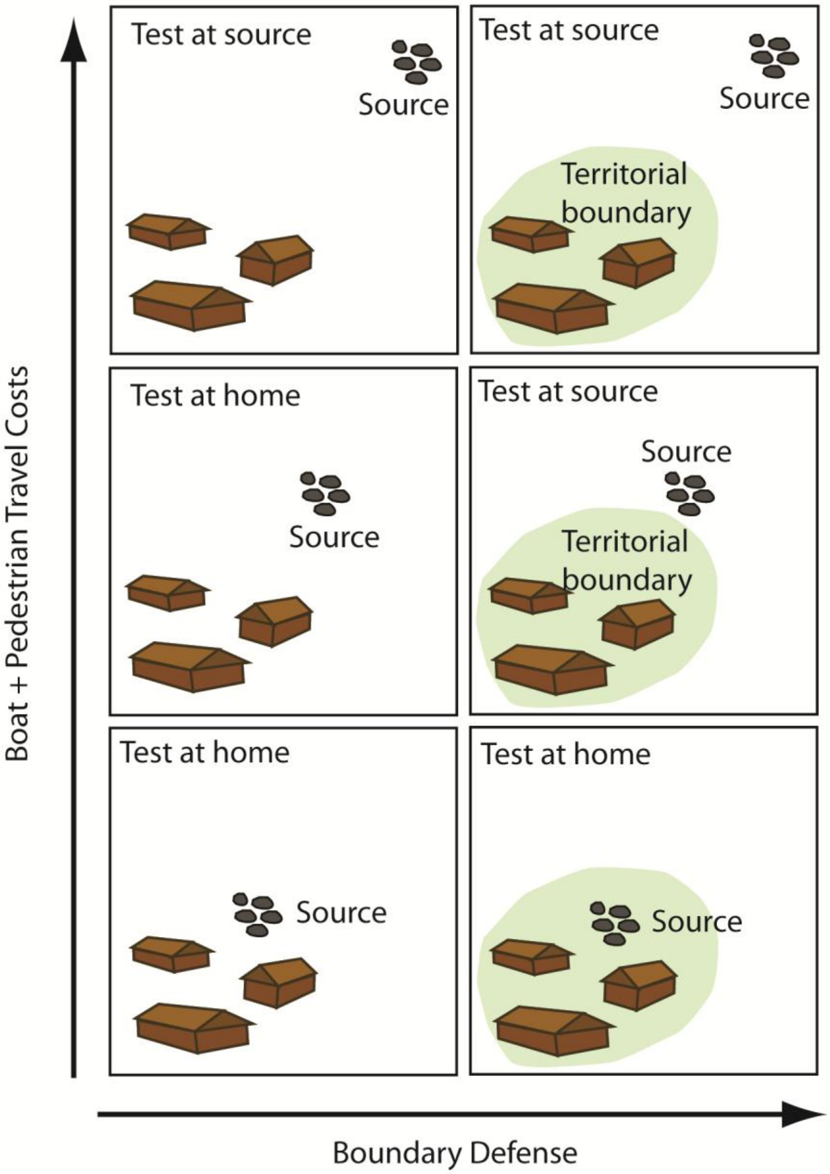


Figure 6.2. Proposed processing strategies for sites with high and low boundary defense strategies.

To test hypotheses about change over time in territorial behavior on the Pacific Coast, I use these general predictions to guide the development of predictions more specific to the archaeological record of the San Juan Islands and southern Channel Islands. I take into account the lithic technology, paleoenvironmental shifts, distribution of toolstone, and transport strategies for each study area. To determine the validity of the predictions I use data collected on local toolstone abundance and morphology and individual attribute analysis of stone artifact assemblages from the Watmough Bay site on Lopez Island, and Tule Creek Village Mound B and CA-SNI-106 on San Nicolas Island.

Analytic Methods: Reduction Sequence Analysis

On both the San Juan Islands and on San Nicolas Island, source areas cannot be identified using geochemical methods, but material type, cobble size, cobble shape, quarry processing decisions, and toolstone conservation efforts provide insights on where and how people acquired toolstone. Investigating these behaviors requires reduction sequence analysis, defined as the culturally and physically patterned way that people in the past reduced pieces of stone into useful tools (Bleed 2001). Reduction sequence analysis, originated by Holmes (1894), breaks up a continuous and flexible stone tool manufacturing process into abstract stages (Bleed 2001; Johnson 1989; Pecora 2001). Analyses conducted by researchers who employ a similar *chaîne opératoire* approach (e.g., Andouze 1999; Bodu 1996; Boeda 1995; Close 2006; Inizan et al. 1999; Sellet 1993), consider the entire life history of a tool from procurement to discard in the context of the social and cultural traditions of the toolmakers. For this research, I focus on procurement and processing decisions prior to transport to a habitation site in the larger social context of boundary defense and permeability.

For each assemblage, I define early, middle, and late stage reduction based on core types, debitage analysis, and other information on the manufacturing process for each site. Platform facets, percent cortex, dorsal flake scars, and flake termination characteristics for debitage associated with early, middle, and late-stage reduction have been well-established for biface technology (e.g. Andrefsky 2005; Dibble et al. 2005; Kessler et al. 2009; Phillips 2011). These concepts must be adjusted to the core-and-flake technologies used on the San Juan Islands and southern Channel Islands. Debitage attributes associated with reduction stages for each assemblage are defined based on the reduction sequence for each site, a diacritical approach (Sellett 1993). Although I also considered a cortical surface analysis to assess degree of reduction prior to transport (e.g., Douglass and Holdoway 2011; Douglass 2008), I found that this analysis was not sensitive to reduction behavior in either study area because toolmakers attempted to retain cortex on flake tools. To examine processing decisions, I use individual attribute analysis of cores and flakes to determine the degree to which the earliest stages of reduction are represented at the habitation sites.

Testing Model Predictions: Toolstone Conservation

Traditional models of technological organization equate highly mobile people with curated technology—formal tool forms designed for portability in anticipation of flexible use far from a toolstone source (Bamforth 1986; Binford 1973, 1979; Bleed 1986; Odell 1996). Sedentary people who can better predict time and place of tool use often rely on quickly made but “wasteful” expedient technology characterized by minimal core preparation and retouch (Andrefsky 2009; Bleed 1986; Kelly 1988; Nelson 1991; Odell 1998; Parry and Kelly 1987; Teltser 1991). Although the curation concept emphasizes the role of mobility in determining technological organization, many researchers have demonstrated that raw material quality, shape and availability are equally if not more important than mobility (Andrefsky (1994 a,b; Bamforth

1991; Bradbury and Franklin 2000; Kuhn 1991; MacDonald 2008; Wallace and Shea 2006). Low quality or highly abundant material tends to be associated with informal tools that are relatively effective for most tasks (Andrefsky 2009; Frison 1979). Likewise, increased sedentism may restrict access to high quality toolstone, Thus, when toolstone is more difficult to acquire due to increased boundary defense, people will make more of an effort to conserve the resource by minimizing waste (e.g., Shott 1989; Dibble 1995) and maximizing cutting edge relative to toolstone volume (e.g., Bradbury and Franklin 2000; Brantingham and Kuhn 2005; Braun 2005; Kuhn 1991; Prasciunas 2007).

In this study I consider use of cores to exhaustion to assess evidence of conservation. In general, when people choose a more conservative manufacturing strategy, they favor more formal prepared core designs to maximize the ratio of perimeter to volume of raw material (Andrefsky 1987; Brantingham et al. 2000; Brantingham and Kuhn 2001; Goodyear 1979:4-6; Morrow 1997). They also may use cores to exhaustion and smash exhausted cores to produce additional flakes. Evidence for this technique includes exhausted cores, core fragments, “chunks”, and non-cortical bipolar flakes with multiple dorsal flake scars. Bipolar flakes are difficult to identify for coarser-grained materials. They are characterized by evidence of force on opposite ends such as two bulbs of percussion, negative flake scars on the ventral face, crushing on both ends, axial breakage, and opposing concentric rings or ripples (Close 2006:12-15; Odell 1996:70). Intensive bipolar flaking of exhausted cores should also be evident in increased non-cortical shatter, defined as pieces smaller than < 30 mm that do not show any flake features. I also consider retouch intensity to determine if people are taking steps to make their formal tools last longer based on the degree of invasiveness of retouch flakes (e.g., Clarkson 2002).

Testing Model Predictions: Exchange

Exchange was an important means of lithic procurement on the Pacific Coast. If direct access to toolstone sources was restricted, exchange relationships may have provided an alternative way to acquire toolstone (Morrow and Jeffries 1989; Whallon 2006). Archaeologists have difficulty separating direct procurement from reciprocal access and exchange using stone artifacts alone. It is equally difficult to distinguish different types of exchange such as middleman and down-the-line methods (Earle 2010; Gould and Saggars 1985; Renfrew 1977). Renfrew and his colleagues (Renfrew et al. 1968, Renfrew 1975, 1977) propose that different kinds of access, including exchange, result in different “fall-off curves” when percentage of lithic raw material is plotted against distance from the source (and see McCoy et al. 2002, 2010 for more recent examples). Torrence (1986) suggests that there is a distance beyond which people directly acquire material (dependent on transport technology, the value of the material, and other variables). As noted by McCoy et al. (2010:2553) and Earle (2010), use of gravity models often leads to problems of equifinality and other methodological and theoretical difficulties.

To explore exchange on the Pacific Coast, I use chert and other extra-local materials as a potential marker of exchange. People could have traveled long distances to directly procure chert, and perhaps sometimes they did, but it also would have been passed between kin, friends, and allies to mark relationships. Chert has a markedly different color and texture than the local material in both study areas. It also tends to be made into more formal tools, perhaps indicating that people considered it to be useful for different kinds of social and technological traditions than FGV on the San Juan Island or metavolcanic rock on the Channel Islands. Other materials that people may have considered to be fundamentally different from local toolstone are rare local toolstones with different flaking properties such as quartz and nephrite. At times when exchange was infrequent and formal due to higher boundary defense, small amounts of extra-local or rare material should be concentrated in discrete areas of the site representing formal relationships between certain individuals or families with other communities. At times when exchange was more frequent and informal due to higher boundary permeability, many people in the village could engage in exchange and other inter-village relationships. Exotic tools and flakes should be spread more evenly across the site.

Procurement Predictions for the Watmough Bay Site

Based on the territoriality models discussed in Chapter 2, I predict that lithic procurement patterns at Watmough Bay at 3500-2500 and 2500-1600 cal BP should reflect minimal boundary defense due to low population density and food and water resource abundance well beyond the demands of the communities on the San Juan Islands. People should gather toolstone from the most attractive sources on the islands. Inter-community interactions should be informal but moderately frequent. With fewer people on the landscape, people would have interacted freely to obtain resources, information, marriage partners, and exchange partners.

I expect increased boundary defense and decreased permeability at 600 cal BP-Contact when population density increased and both terrestrial and marine environments were productive. Subsistence resources would have been just adequate for some groups near productive resource areas like Watmough Bay and inadequate for others. If people at Watmough Bay defended the area around the site and, as a result, focused more resource procurement nearby, this should have several ramifications for lithic procurement. People should increase their use of FGV from Watmough Bay beach, decrease processing prior to transport because transport costs were so low, and increase use of local slate. Since Watmough Bay had a relatively sparse FGV cobble density, I expect intensive toolstone conservation. Exchange between sites on the islands should be limited and formal.

At 1600-1000 cal BP, impoverished terrestrial and marine resources should encourage minimal boundary defense. At the Watmough Bay site, people should acquire toolstone from the most attractive sources on this island, which include Agate Beach and Aleck Bay. Boat transport would have kept transport costs relatively low, but more core testing should occur when toolstone was acquired from beaches beyond Watmough Bay than when it was acquired from the beach adjacent to the site. Toolstone conservation should be minimal due to easy access to more toolstone. Increased boundary permeability should be apparent based on higher amounts of chert distributed more evenly across the site (Figure 6.3; Table 6.1).

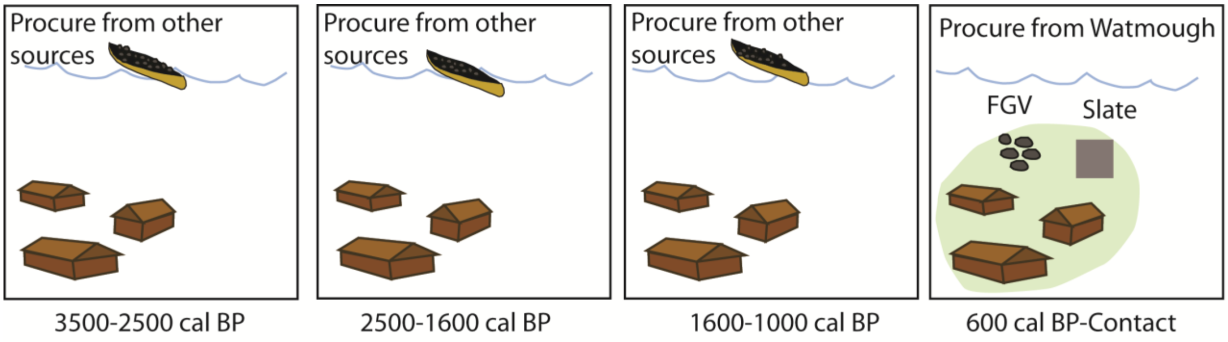


Figure 6.3. Predictions for lithic procurement at Watmough Bay during the Late Holocene. The gray/green shaded area represents territorial boundaries around a village site.

Table 6.1. Predictions for the Watmough Bay lithic assemblage.

	3500-2500 cal BP	2500-1600 cal BP	1600-1000 cal BP	600 cal BP-Contact
Territoriality	Minimal defense/moderate permeability	Minimal defense/moderate permeability	Minimal defense/high permeability	High defense/low permeability
FGV Source	Aleck Bay, Agate Beach, Watmough	Aleck Bay, Agate Beach, Watmough	Aleck Bay, Agate Beach, Watmough	Watmough
Slate	↓	↓	↓	↑
Exchange	Moderate, informal	Moderate, informal	Frequent, informal	Limited, formal
Testing/Early Stage Reduction	↑	↑	↑	↓
Conservation	↓	↓	↓	↑

Testing Procurement Predictions at Watmough Bay: Material Type

To test the prediction that the inhabitants of Watmough Bay were more geographically restricted in their lithic procurement at 600 cal BP-Contact, I investigate whether people increased their reliance on the slate outcrops adjacent to the site during that time period. Based on ethnographic examples, Northwest Coast archaeologists have proposed that change over time in slate use correlates with increased salmon processing (Graesch 2007; Mitchell 1971; Morin 2004; Lepofsky et al. 2000). Another potential explanation is that for people at Watmough Bay, slate supplemented their raw material needs when FGV was more difficult to access. Despite differences in toolstone characteristics, if people needed a sharp edge for cutting and scraping and FGV was scarce due to territorial circumscription, they may have increased their use of slate. Even if some of the slate in the Watmough assemblage was deposited in the shell midden through natural processes, if there is a dramatic increase in slate tool manufacture, I expect a parallel increase in slate debris created during the manufacturing process.

To test this prediction, I consider the Munsell and Stein/Phillips excavations separately to control for different collection strategies for unmodified slate fragments. For the Munsell excavation, I assume that only the bigger fragments were collected but that they were collected consistently. The Stein/Phillips team collected most or all of the slate they encountered, therefore results for that sub-assemblage are more reliable. For both excavations, comparison of slate and FGV by percent weight is not consistent with my predictions. For the Stein/Phillips excavation, percent slate is much lower for the 600 cal BP-Contact assemblage (48.49%) than the 1600-1000 cal BP assemblage (71.75%). In the Munsell assemblage, there is a lower percentage of slate for the 600 cal BP-Contact assemblage (3.22%) than the 2500-1600 cal BP (20.72%) or the 1600-1000 cal BP assemblage (38.44%). These results may be affected by small sample sizes in all but the 1600-1000 cal BP assemblages (Table 6.2; Figure 6.4, 6.5).

Results of χ^2 tests comparing counts of FGV and slate also fail to support the prediction that slate use intensified during times of hypothesized territorial circumscription. To ensure that differential breakage in different units did not bias the results, I divided the assemblage into > 3 cm maximum dimension and $\leq$ 3 cm maximum dimension flakes. I chose this size category as the point to divide the assemblage because this is the size class for the smallest flaked tools (of any material type) in the assemblage and therefore smaller flakes might be considered a byproduct rather than an end product. For the Stein/Phillips excavation there is significantly more slate than expected in the 3500-2500 cal BP assemblage both for all flakes and for $\leq$ 3 cm maximum dimension flakes (Table 6.3). If only the 1600-1000 cal BP and 600 cal BP-Contact are considered, difference in slate and FGV counts are not significant ($\chi^2 = 1.104$, 1 df, $p = 0.293$).

For the Munsell excavation, there is significantly more slate than expected in the 3500-2500 cal BP assemblages and less than expected in the three later assemblage for all flakes. Results are similar for flakes > 3 cm and ≤ 3 cm in maximum dimension (Table 6.4).

One possible explanation for this result is that the slate the people used to make tools at Watmough Bay was not the same as that available from the outcrop near the site. Some of the finished tools are made out of material that looks similar—light gray, fragile, and slightly metamorphosed. Other tools appear to be made of a denser material. In future research I plan to determine the variability of slate quality near the site and at other outcrops both on the San Juan Islands and on the mainland. A preliminary result of this analysis, however, does not indicate that people used more slate at times of hypothesized increased boundary defense and may indicate the opposite, that people used were more restricted to local raw material at 3500-1500 cal BP.

Table 6.2. Material type counts and weights for flake assemblages from the Stein/Phillips and Munsell excavations from the Watmough Bay site, Lopez Island.

Excavation	Stein/Phillip	Stein/Phillips	Stein/Phillips	Munsell	Munsell	Munsell	Munsell
Time Period (cal BP)	3500-2500	1600-1000	600 - Contact	3500-2500	2500-1600	1600-1000	600 - Contact
FGV	11	117	7	67	92	637	43
Metavolcanic/Basalt	0	2	0	2	4	17	0
Argillite	0	0	0	0	1	0	0
Chert	1	2	0	2	0	8	0
Schist/Metasedimentary	0	0	0	10	3	43	0
Nephrite	0	1	0	0	0	1	0
Quartz	0	32	3	0	2	38	0
Quartzite	0	4	0	0	1	3	0
Sandstone	0	0	0	0	0	1	0
Slate	11	463	38	57	7	120	3
Undetermined	0	6	0	0	0	5	0
Total	23	627	48	138	110	873	46
Frequency %							
FGV	47.83%	18.66%	14.58%	48.55%	83.64%	72.97%	93.48%
MV/Basalt	0.00%	0.32%	0.00%	1.45%	3.64%	1.95%	0.00%
Argillite	0.00%	0.00%	0.00%	0.00%	0.91%	0.00%	0.00%
Chert	4.35%	0.32%	0.00%	1.45%	0.00%	0.92%	0.00%
Schist/Metasedimentary	0.00%	0.00%	0.00%	7.25%	2.73%	4.93%	0.00%
Nephrite	0.00%	0.16%	0.00%	0.00%	0.00%	0.11%	0.00%
Quartz	0.00%	5.10%	6.25%	0.00%	1.82%	4.35%	0.00%
Quartzite	0.00%	0.64%	0.00%	0.00%	0.91%	0.34%	0.00%
Sandstone	0.00%	0.00%	0.00%	0.00%	0.00%	0.11%	0.00%
Slate	47.83%	73.84%	79.17%	41.30%	6.36%	13.75%	6.52%
Undetermined	0.00%	0.96%	0.00%	0.00%	0.00%	0.57%	0.00%
Weight (g, sum)							
FGV	42.8	417.3	21.6	419.7	531	2089.1	412.3
Slate	17.2	1076	20.9	323	146.7	1738.5	13.7
Schist/Metasedimentary	0	0	0	78.7	20.9	437.7	0
Quartz	0	6.2	0.6	0	9.4	202.7	0
Chert	0.001	0.1	0	1.5	0	54.3	0
Total	60.001	1499.6	43.1	822.9	708	4522.3	426
Weight %							
FGV	71.33%	27.83%	50.12%	51.00%	75.00%	46.20%	96.78%
Slate	28.67%	71.75%	48.49%	39.25%	20.72%	38.44%	3.22%
Schist/Metasedimentary	0.00%	0.00%	0.00%	9.56%	2.95%	9.68%	0.00%
Quartz	0.00%	0.41%	1.39%	0.00%	1.33%	4.48%	0.00%
Chert	0.00%	0.01%	0.00%	0.18%	0.00%	1.20%	0.00%

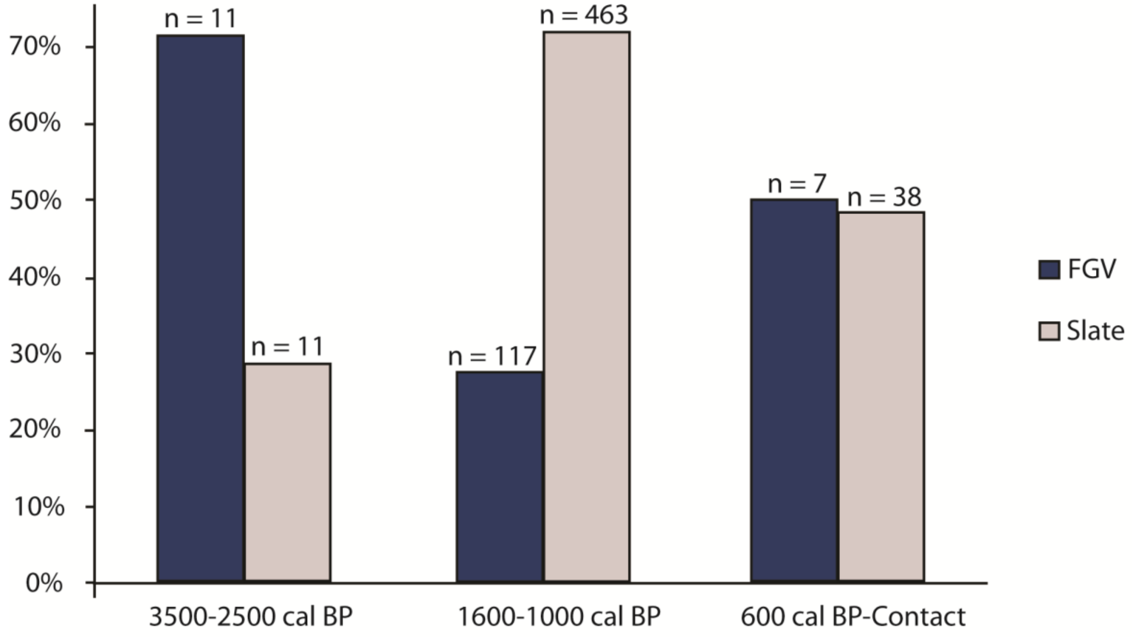


Figure 6.4. Proportions of FGV and slate by weight (g) for the Stein/Phillips excavation, Watmough Bay, Lopez Island.

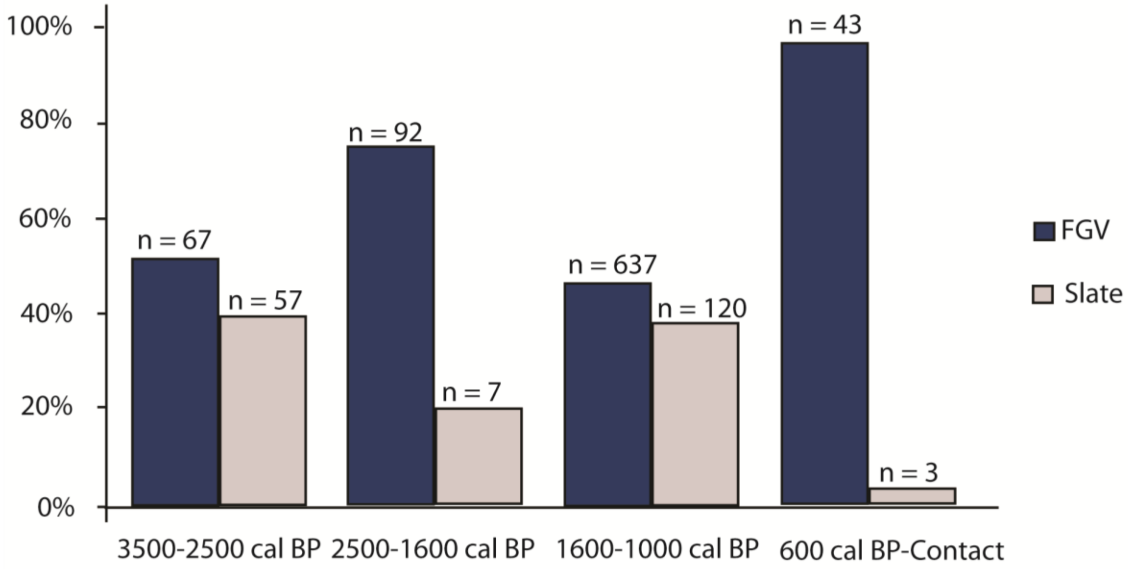


Figure 6.5. Proportions of FGV and slate by weight (g) for the Munsell excavation, Watmough Bay, Lopez Island.

Table 6.3. Results of χ^2 tests comparing proportions of FGV and slate by count for the Stein/Phillips excavation, Watmough Bay, Lopez Island.

Time Per. (cal BP)	Flake Size	Stats	FGV	Slate	χ^2	DF	p
3500-2500	All	Count	11.00	11.00	12.92	2	**0.002**
		Expected	4.56	17.44			
		AR	**3.44**	**-3.44**			
1600-1000		Count	117.00	463.00			
		Expected	120.31	459.69			
		AR	-1.06	1.06			
600-0		Count	6.00	38.00			
		Expected	9.13	34.87			
		AR	-1.20	1.20			
3500-2500	≤ 3 cm	Count	9.00	9.00	12.84	2	**0.002**
		Expected	3.55	14.45			
		AR	**3.28**	**-3.28**			
1600-1000		Count	89.00	370.00			
		Expected	90.56	368.44			
		AR	-0.55	0.55			
600-0		Count	4.00	36.00			
		Expected	7.89	32.11			
		AR	-1.61	1.61			

Table 6.4. Results of χ^2 tests comparing proportions of FGV and slate by count for the Munsell excavation, Watmough Bay, Lopez Island.

Time Per. (cal BP)	Flake Size	Stats	FGV	Slate	χ^2	DF	p
3500-2500	All	Count	67.00	57.00	79.39	3	**<0.001**
		Expected	101.49	22.60			
		AR	**-8.53**	**8.53**			
2500-1600		Count	92.00	7.00			
		Expected	80.96	18.04			
		AR	**3.02**	**-3.02**			
1600-1000		Count	637.00	120.00			
		Expected	619.03	137.97			
		AR	**3.30**	**-3.30**			
600-0		Count	43.00	3.00			
		Expected	37.62	8.38			
		AR	**2.10**	**-2.10**			

Time Per. (cal BP)	Flake Size	Stats	FGV	Slate	χ^2	DF	p
3500-2500	> 3	Count	34.00	42.00	73.32	3	**<0.001**
		Expected	61.28	14.72			
		AR	**-8.33**	**8.33**			
2500-1600		Count	62.00	6.00			
		Expected	54.83	13.17			
		AR	**2.30**	**-2.30**			
1600-1000		Count	510.00	103.00			
		Expected	494.26	118.74			
		AR	**3.36**	**-3.36**			
600-0		Count	35.00	3.00			
		Expected	30.64	7.36			
		AR	1.83	-1.83			

Time Per. (cal BP)	Flake Size	Stats	FGV	Slate	χ^2	DF	p
3500-2500	≤ 3 cm	Count	33.00	15.00	11.24	1	**0.001**
		Expected	40.34	7.66			
		AR	**-3.35**	**3.35**			
1600-1000		Count	125.00	15.00			
		Expected	117.66	22.34			
		AR	**3.35**	**-3.35**			

Testing Procurement Predictions at Watmough Bay: Size, Shape, and Cortex Appearance

If people were restricted to Watmough Bay for lithic procurement at 2500-1600 cal BP and 500 cal BP-Contact, their cores and debitage should reflect the size, shape, and cortex appearance of the cobbles on that beach. As demonstrated in Chapter 5, Watmough Bay beach cobbles are significantly smaller than those at nearby Aleck Bay and Agate Beach. In fact, they are smaller than cobbles from all of the other beaches included in the survey. Although the proportion of round cobbles at Watmough Bay beach is not significantly greater than at the other beaches on the island, given the apparent preference for angular cobbles and the relative scarcity of cobbles at Watmough, restriction to Watmough beach would result in increased use of round cobbles. Watmough Bay also has significantly more polished (highly waterworn) cobbles than most other beaches in the survey except nearby Agate Beach. Thus, when people were collecting from Watmough Bay, core and flake assemblages should indicate use of smaller, rounder, and smoother cobbles than during periods when they were collecting cobbles from elsewhere on the islands.

Beginning with cobble size, only the 1600-1000 cal BP assemblage contains enough cores with original cobble dimensions intact to characterize original cobble size. I predicted that during this period people were not restricted to Watmough Bay beach. Results of an ANOVA comparing mean length for cores and cobbles indicates that mean core size is significantly larger than average cobble size for Watmough Bay. It is also significantly smaller than mean cobble size at Agate Beach and Aleck Bay. The Watmough Bay cores are most similar in size to cobbles found at American Camp and Snug Harbor (Table 6.5). If people were selecting the larger cobbles from the southern Lopez Island beaches, I would expect a lower coefficient of variation for the cores than for the cobble areas. However, the core COV is actually higher than for the cobble areas. A consideration of the distribution of size classes for the Watmough Bay cobbles and the cores with intact cobble dimensions from the 1600-1000 cal BP cobble assemblage shows a slightly different different distribution of cobble sizes. For the Watmough Bay beach FGV cobbles (*n* = 66), a majority of the cobbles fall into the 20-30 mm (37.9%), 30-40 mm (28.8%) and 40-50% (21.2%). Comparing Watmough FGV cores with intact dimensions (*n* = 31) indicates fewer 20-30 mm cobbles (9.7%), but similar numbers of 30-40 mm cobbles (29.0%) and 40-50 mm cobbles (25%), and greater number of 50-60 mm cobbles (16.1%). Sample sizes are small enough that these results can only be considered prelimary. I also cannot rule out the possibility that people simply preferred and chose the slightly larger cobbles available on the beach.

Table 6.5. Basic statistics for FGV cores from Watmough Bay that have original cobble dimensions intact and cobbles from beaches on the San Juan Islands. Results of an ANOVA comparing mean cobble dimensions for cores from the 1600-1000 cal BP assemblage with cobbles from beaches on the San Juan Islands.

	n	Mean	SD	COV	F	Sig.	Bonferroni Sig.
Watmough Bay Cores	31	48.24	15.90	32.95%	44.04	0.00	
American Camp	36	44.47	13.49	30.34%			1.00
Watmough Bay Beach	64	37.13	11.68	31.47%			**0.02**
False Bay	94	69.73	20.26	29.05%			**0.00**
Snug Harbor	130	51.34	9.71	18.91%			1.00
Agate Beach	70	58.39	15.98	27.37%			**0.05**
Aleck Bay	30	76.77	23.74	30.92%			**0.00**

To test the hypotheses about cobble shape I use χ^2 tests to compare proportions of cores and flakes made from angular and round cobbles from the 1600-1000 cal BP assemblage with cobbles from the natural beaches. The data indicate a significantly higher proportion of angular cobble cores at the Watmough Bay site than at Watmough Bay beach ($p < 0.001$), Snug Harbor ($p < 0.001$), and Agate Beach ($p < 0.001$). The core assemblage from Watmough Bay is similar in proportion of angular and round cobbles to American Camp ($p = 0.146$), False Bay ($p = 0.916$)

and Aleck Bay (*p* =0.069; Table 6.6). These results indicate that at 1600-1000 cal BP, people were accessing cobble areas other than Watmough Bay beach.

Table 6.6. Results of χ^2 tests comparing proportions of cores (1600-1000 cal BP) made on angular and round cobbles from Watmough Bay with cobble areas on the San Juan Islands.

Type	Stats	Angular	Round	χ^2	DF	p
1600-1000 cal BP Cores	Count	47	11	2.111	1	0.146
	Expected	44.13	13.87			
	AR	1.45	-1.45			
American Camp Cobbles	Count	23	11			
	Expected	25.87	8.13			
	AR	-1.45	1.45			
Type	Stats	Angular	Round	χ^2	DF	p
1600-1000 cal BP Cores	Count	47	11	21.632	1	**<0.001**
	Expected	34.9	24			
	AR	**4.65**	**-4.65**			
Watmough Bay Cobbles	Count	21	34			
	Expected	33.1	21.9			
	AR	**-4.65**	**4.65**			
Type	Stats	Angular	Round	χ^2	DF	p
1600-1000 cal BP Cores	Count	47	11	0.011	1	0.916
	Expected	47.25	10.76			
	AR	-0.11	0.11			
False Bay Cobbles	Count	76	17			
	Expected	75.76	17.25			
	AR	10.76	-0.11			
Type	Stats	Angular	Round	χ^2	DF	p
1600-1000 cal BP Cores	Count	47	11	17.529	1	**<0.001**
	Expected	33.94	24.06			
	AR	**4.19**	**-4.19**			
Snug Harbor Cobbles	Count	63	67			
	Expected	2.24	3.16			
	AR	**-4.19**	**4.19**			
Type	Stats	Angular	Round	χ^2	DF	p
1600-1000 cal BP Cores	Count	47	11	14.39	1	**<0.001**
	Expected	36.7	21.3			
	AR	**3.8**	**-3.8**			
Agate Beach Cobbles	Count	34	36			
	Expected	44.3	25.7			
	AR	**-3.8**	**3.8**			
Type	Stats	Angular	Round	χ^2	DF	p
1600-1000 cal BP Cores	Count	47	11	3.304	1	0.069
	Expected	43.5	14.5			
	AR	1.82	-1.82			
Aleck Bay Cobbles	Count	19	11			
	Expected	22.5	7.5			
	AR	-1.82	1.82			

To test predictions about cortex appearance, I compare FGV flakes from the 2500-1600 cal BP, 1600-1000 cal BP, and 600-0 cal BP periods with the cobble assemblages. I expected a higher number of smooth and polished cobbles at 2500-1600 cal BP and 600 cal BP-Contact. Proportions of smooth and polished flakes for these three assemblages were not significantly different ($\chi^2 = 0.56$, 2 df, $p = 0.76$). A comparison of the 1600-1000 cal BP FGV flake assemblage with all of the cobble areas shows no significant differences between in proportions of smooth and rough cortex (Table 6.7). There are too few cores to compare cortex appearance between time periods, but I instead compare the large 1600-1000 cal BP core and flake assemblages with the cobble beaches. There are no significant differences in proportions of smooth and rough cortex cores and cobble areas (Table 6.8). This measurement is effectively neutral with respect to my predictions.

Table 6.7. Results of a χ^2 test comparing proportions of smooth and rough cortex FGV flakes at Watmough Bay (1600-1000 cal BP) with smooth and rough cortex cobbles at each cobble area. Aleck Bay and Watmough Bay are not included due to a small sample size for rough cobbles.

Type	Stats	Smooth	Rough	χ^2	DF	p
1600-1000 cal BP flakes	Count	374.00	59.00	0.43	1.00	0.51
	Expected	372.73	60.27			
	AR	0.65	-0.65			
American Camp Cobbles	Count	28.00	6.00			
	Expected	29.27	4.73			
	AR	-0.65	1.06			
Type	Stats	Smooth	Rough	χ^2	DF	p
1600-1000 cal BP flakes	Count	374.00	59.00	0.01	0.00	0.94
	Expected	373.76	59.24			
	AR	0.08	-0.08			
False Bay Cobbles	Count	74.00	12.00			
	Expected	74.24	11.76			
	AR	-0.08	0.08			
Type	Stats	Smooth	Rough	χ^2	DF	p
1600-1000 cal BP flakes	Count	374.00	59.00	0.03	1.00	0.87
	Expected	374.55	58.45			
	AR	-0.16	0.16			
Snug Harbor	Count	113.00	17.00			
	Expected	112.45	17.55			
	AR	0.16	-0.16			
Type	Stats	Smooth	Rough	χ^2	DF	p
1600-1000 cal BP flakes	Count	374.00	59.00	2.28	1.00	0.13
	Expected	377.91	55.09			
	AR	-1.51	1.51			
Agate Beach	Count	65.00	5.00			
	Expected	61.09	8.91			
	AR	1.51	-1.51			

Table 6.8. Results of χ^2 tests comparing proportions of smooth and rough cortex FGV cores from Watmough Bay (1600-1000 cal BP) with smooth and rough cortex cobbles at each cobble area.

Type	Stats	Smooth	Rough	χ^2	DF	p
1600-1000 cal BP Cores	Count	374.00	59.00	0.43	1.00	0.51
	Expected	372.73	60.27			
	AR	0.65	-0.65			
American Camp Cobbles	Count	28.00	6.00			
	Expected	29.27	4.73			
	AR	-0.65	0.65			
Type	Stats	Smooth	Rough*	χ^2	DF	p
1600-1000 cal BP Cores	Count	374.00	59.00			
	Expected					
	AR					
Watmough Bay Cobbles	Count	55.00	0.00			
	Expected					
	AR		*Small sample size			
Type	Stats	Smooth	Rough	χ^2	DF	p
1600-1000 cal BP Cores	Count	80.00	13.00	0.00	1.00	1.00
	Expected	80.01	12.99			
	AR	-0.05	0.03			
False Bay Cobbles	Count	74.00	12.00			
	Expected	73.99	12.01			
	AR	0.05	-0.03			
Type	Stats	Smooth	Rough	χ^2	DF	p
1600-1000 cal BP Cores	Count	80.00	13.00	0.04	1.00	0.85
	Expected	80.49	12.51			
	AR	0.00	0.00			
Snug Harbor Cobbles	Count	112.51	17.49			
	Expected	77.88	17.57			
	AR	0.00	0.00			
Type	Stats	Smooth	Rough*	χ^2	DF	p
1600-1000 cal BP Cores	Count	80.00	13.00	1.90	1.00	0.17
	Expected	82.73	10.27			
	AR	-1.38	1.38			
Agate Beach Cobbles	Count	65.00	5.00			
	Expected	62.27	7.73			
	AR	1.38	-1.38			
Type	Stats	Smooth	Rough	χ^2	DF	p
1600-1000 cal BP Cores	Count	80.00	13.00			
	Expected	62.18				
	AR	2.03				
Aleck Bay Cobbles	Count	29.00	1.00			
	Expected	22.82				
	AR	-2.03	*Small sample size			

Overall, results for cobble size and shape provide several clues regarding the provenance of cobbles collected by people from the Watmough Bay site during the 1600-1000 cal BP period (Table 6.9). Based on an analysis of cores and flakes, the cobbles that people used were on average larger and more angular than those found on Watmough Bay beach. Results for cortex appearance do not indicate significant differences between the 1600-1000 cal BP assemblage and Watmough Bay beach or any other beach, suggesting that people did not have a preference for a particular cortex texture or that they collected cobbles from a variety of beaches. These data suggest that at 1600-1000 cal BP, people collected toolstone from nearby Aleck Bay, Agate beach, or other beaches throughout the islands. Due to smaller sample sizes for the other time periods, I was not able to determine if the data are consistent with toolstone procurement shifts through time.

Table 6.9. Summary of results for shape, size, and appearance of artifacts from Watmough Bay. Cells left blank indicate that sample size was too low to reach meaningful conclusions.

	3500-2500 cal BP	2500-1600 cal BP	1600-1000 cal BP	600 cal BP-Contact
Size Predictions	↑	↑	↑	↓
Results			Cores from cobbles larger than those found at Watmough Bay beach.	
Shape Predictions	More Angular	More Angular	More Angular	More Round
Shape Results			Cores/flakes indicate more angular than round cobbles.	
Cortex Predictions	Different proportions of smooth/rough from Watmough Beach.	Different proportions of smooth/rough from Watmough Beach.	Different proportions of smooth/rough from Watmough Beach.	Similar to Watmough Beach
Results		No significant differences between flake assemblages.	No significant differences between cores and cobble areas, flakes and cobble areas, or flake assemblages.	No significant differences between flake assemblages.

Testing Procurement Predictions at Watmough Bay: Processing

To investigate procurement strategies on the San Juan Islands, I also consider processing decisions using reduction sequence analysis and other observations of the assemblage. Based on the reduction sequences described in Chapter 5, cobble test and the first steps of the reduction process should be characterized by the removal of a fully cortical decapitation flakes and perhaps a second flake that follows the ridge of the first flake scar to open a flaking surface and determine the quality of the material. Second flakes removed from the core have cortical platforms, a single dorsal flake scar, and often have a cortical margin. In contrast, later stage flakes have cortical platforms and multiple dorsal flake scars or single facet platforms and multiple flake scars.   I expect that if people acquired cobbles primarily from Watmough Bay beach at 600 cal BP-Contact, lack of processing prior to transport should be reflected in larger number of first and second flakes relative to later stage flakes found at the site during those time periods.

Results indicate no first flakes in the two earlier assemblages. The sample size of flakes identified as “first” or “later” is too small in the 3500-2500 cal BP period (*n* = 6) to be useful for analysis. That there are no first flakes in the 2500-1600 cal BP assemblage and 19 later stage flakes may indicate that first flakes may be removed elsewhere. A χ^2 test comparing first flakes and later stage flakes for the later two assemblages reveals no significant difference in flake types between periods, but sample size for the 600 cal BP-Contact period is too small to reach a definitive conclusion (Table 6.10). A χ^2 test comparing numbers of dorsal flake scars between time periods indicates significantly more flakes with 0 or 1 flake scars during the 600 cal BP-Contact time period than during the other time periods (Table 6.11).

Table 6.10. FGV flake types at Watmough Bay and χ^2 results comparing first flakes and later flakes between 1600-1000 cal BP and 600 cal BP-Contact time periods.

Time Per. (Cal BP)	Stats	First flake	Later flake			
3500-2500 *	Count	0	6			
2500-1600 *	Count	0	19	*Not included in χ^2 test, small sample size.		
				χ^2	DF	Fisher's exact p
1600-1000	Count	21	100	0.987	1	0.390
	Expected	22.17	98.83			
	AR	-0.99	0.99			
600-0	Count	3	7			
	Expected	1.83	8.16			
	AR	0.99	-0.99			

Table 6.11. Results of χ^2 tests comparing number of dorsal flake scars between time periods at Watmough Bay.

Per. (Cal. BP)	Stats	0,1	2,3	4+	χ^2	DF	p
3500-2500	Count	11.00	12.00	8.00	18.49	6	**0.005**
	Expected	12.27	11.88	6.85			
	AR	-0.48	0.04	0.51			
2500-1600	Count	23.00	33.00	13.00			
	Expected	27.32	26.45	15.24			
	AR	-1.13	1.72	-0.69			
1600-1000	Count	198.00	197.00	113.00			
	Expected	201.12	194.71	112.18			
	AR	-0.63	0.47	0.20			
600-0	Count	19.00	1.00	6.00			
	Expected	10.29	9.97	5.74			
	AR	**3.57**	**-3.69**	0.12			

Toolstone Conservation at Watmough Bay

If high quality lithic raw material was difficult to acquire during times of increased territorial circumscription at 600 cal BP-Contact, people would have used toolstone conservation strategies to make their supply last longer. One way to look for conservation is to determine the degree to which cores were flaked to exhaustion rather than just discarded when they became more difficult to flake due to small size or obtuse platform angles.

Regarding cores, for the 2500-1600 cal BP time period, there are 11 core fragments/exhausted cores and 9 cores of other types. For the 1600 -1000 cal BP period, there are 67 core fragments and exhausted cores and 57 cores of other types. For both periods, this suggests some degree of conservation and potential bipolar smashing of exhausted cores, but there is no discernible difference between time periods. Sample sizes for the 3500-2500 cal BP time period and 600 cal BP-Contact time period are too small to analyze quantitatively. A comparison of non-cortical shatter between time periods is not useful for this case study because the Munsell excavation collection strategy was biased against smaller flakes and the Stein-Phillips excavation sample is too small.

I also consider retouch intensity to determine if people are taking steps to make their formal tools last longer based on the degree of invasiveness of retouch flakes (e.g., Clarkson 2002). A qualitative assessment of retouch intensity suggests that the later two assemblages are more heavily retouched than the earlier ones. In the 3500-2500 cal BP assemblage, there are 3 scaled pieces, a scraper with minimal retouch, a more extensively retouched flake, and a rough biface. In the 2500-1600 cal BP assemblages, there are 12 scaled pieces, 2 rough bifaces, 1 unretouched chopper, 1 retouched pointed tool, 1 minimally retouched flake, and 6 scrapers. Of these, three are minimally retouched with short retouch flake scars that cover only part of one margin. In contrast, two others have short flake scars that cover the entirety of one or margin. A chert scraper shows extensive retouch with invasive flake scars on all margins.

In the 1600-1000 cal BP assemblage, there are 46 scaled pieces and 26 bifaces (most of which are early stage and assymetrical with large flake scars) but also a large number of retouched tools. The leaf-shaped (*n* =11), stemmed (*n* = 4) triangular (*n* = 7), and projectile point tips and fragments (*n* =6) show extensive retouch, mainly long or invasive flake scars on the entirety of both lateral margins. For the scrapers (*n* = 17), the three with long retouch flake scars have retouch covering the entire margins. For those with short flake scars, about half are partial and the other half are entire. For the 600 cal BP-Contact assemblage, there are no scaled pieces and two extensively retouched projectile points. The only assemblage that contained flakes identified as biface thinning flakes was the 1600-1000 cal BP assemblage, likely because of the larger sample size.

Overall, data are not sufficient to test whether conservation efforts at Watmough Bay increased at 2500-1600 cal BP and 600 cal BP-Contact. The presence of both exhausted cores and other core types during the 1600-1000 cal BP and 600 cal BP-Contact as well as a substantial number of extensively retouched formal tools during these periods are consistent with some degree of toolstone conservation, but the high ratio of cores to flakes in general suggest that conservation did not guide manufacturing decisions.

Exchange at Watmough Bay

The amount of exotic raw material found during any time period at Watmough Bay is almost insignificant (Table 6.2), which makes it difficult to test predictions for boundary permeability. I predicted increased boundary permeability during times of food scarcity at 1600-

1000 cal BP and decreased permeability with increased subsistence resource abundance and increased boundary defense during the 600 cal BP period. There are three chert flakes and one core in the 3500-2500 cal BP assemblage, 1 chert scraper and 2 cores in the 2500-1600 cal BP assemblage, 10 chert flakes, 1 core, and 3 retouched tools, in the 1600-1000 cal BP assemblage, and no chert in the 600 cal BP- Contact assemblage. The higher amount of chert in the 1600-1000 cal BP assemblage and the lack of chert in the 600 cal BP-Contact assemblage are consistent with predictions, but the larger sample size would have the same effect. Sample size for the other time periods that the results for these are tentative at best.

Only the 1600-1000 cal BP period has a large enough sample size to analyze the distribution of chert and other rare materials across the site. My prediction for this time period was that frequent and informal exchange should be reflected in an even distrution of extra-local and rare toolstone across households at Watmough Bay. On the basis of visual inspection, I found that chert, nephrite, steatite, serpentine, and quartz tools and flakes were dispersed relatively evenly, although they were not abundant (Figure 6.6). I also considered the distribution of incised shale—small tabular stones with lines, dashes, and patterns—as potential markers of household identify or status. Site chronology is not precise enough to determine if these objects were deposited contemporaneously since these units were deposited over hundreds of years, but I assume that household identity and location remained constant over several generations. There are clusters where three or more extra-local/rare objects occur in 0N24W, EXU1, 9N3W, and 3S0E, but overall, the distribution of these material is relatively even across the site. This distribution is consistent with a more informal exchange pattern during this time period.

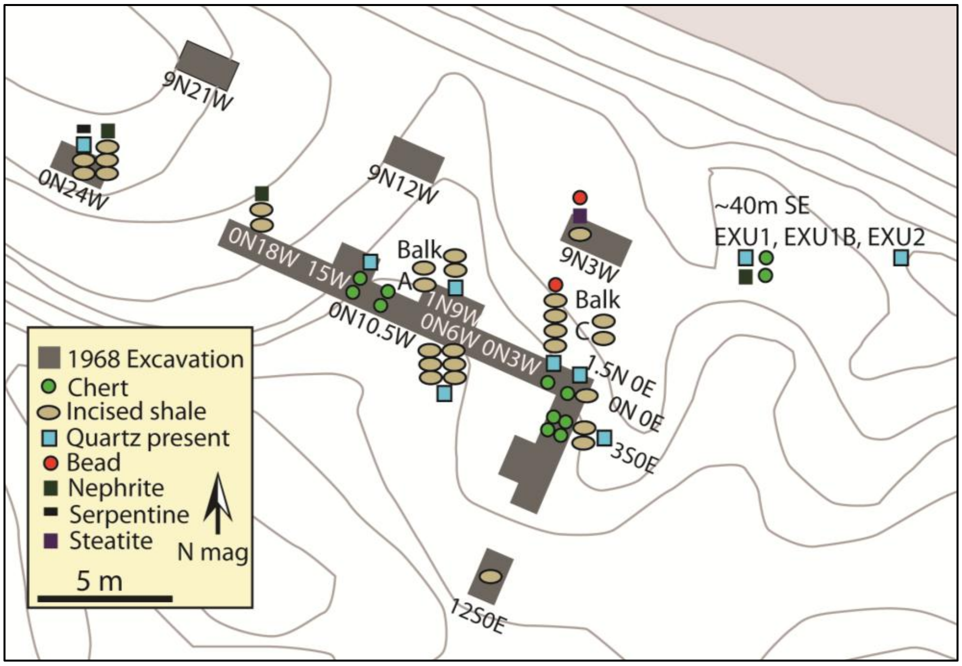


Figure 6.6. Distribution of extra-local materials, beads, ornaments, and incised shale at Watmough Bay.

Summary of Toolstone Procurement Results for Watmough Bay

The Watmough Bay dataset provides mixed results regarding the prediction that the 600 cal BP-Contact sub assemblages should indicate decreased use of local FGV beach cobbles and nearby slate outcrops. The small datasets for several of the time periods made it difficult to fully employ a diachronic perspective, I was able to assess whether the 1600-1000 cal BP assemblage reflected procurement, processing, and conservation behaviors associated with minimal territorial circumscription.

Based on results for slate use, in most cases weights and counts of this local material do not increase at 600 cal BP-Contact despite predictions that people should rely more heavily on toolstone available at Watmough Bay. Consistent with my prediction that lithic procurement did not take place at Watmough Bay at 1600-1000 cal BP, cobble size and cobble shape for the lithic assemblage dating to that period indicates the use of larger and more angular cobbles than would be the case if people relied exclusively on Watmough Bay beach. Regardless of where people were getting toolstone, ratios of first flakes to later flakes and cortical surface analysis indicates little or no processing of toolstone prior to transport to Watmough Bay. Some effort was made to conserve toolstone, but based on the numbers of exhausted cores, core fragments, and extensively retouched tools, conservation does not define the technology during any time period. Regarding boundary permeability, the distribution of chert, quartzite, and steatite in the 1600-1000 cal BP assemblage is consistent with infrequent but informal interactions between groups. Other types of stone, foodstuffs, or perishables might be better indicators of exchange, or exchange may not play a large role in daily life at Watmough Bay.

Evaluating an Alternative Hypothesis for Lithic Procurement at Watmough Bay

As an alternative hypothesis, I propose that territoriality and resource access that operated at the family or household level rather than at the level of the community. To address this alternative hypothesis, I compare the two spatial areas that date to 1600-1000 cal BP: Area 1 (0N24W and 0N 18W, *n* = 98 flakes) on the northwest side of the site and Area 2 (0N0E, 1.5N0E, 0N3W and Balk C, *n* = 204 flakes) on the southeast side of the site. If different families had access to different toolstone as a result of kinship ties beyond the village, there should be a significant difference in the ratio of FGV to slate flakes. A preliminary exploration of this hypothesis indicates that there is a significant difference in the amount of slate > 3 cm in maximum dimension between the two spatial areas. There is a higher proportion of slate in Area 1, which is farther away from the bedrock outcrop (Table 6.12).

Table 6.12. Results of a χ^2 test comparing counts of > 3 cm slate and FGV in Area 1 and Area 2 at Watmough Bay. Sample size for the $\leq$ 3 cm fraction was too small for quantitative analysis

Spatial Units	Stats	Slate	FGV	χ^2	DF	p
Area 1	Count	26	39	26.437	1	**<0.001**
	Expected	12.6	52.4			
	AR	**5.14**	**-5.14**			
Area 2	Count	12	119			
	Expected	25.4	105.6			
	AR	**-5.14**	**5.14**			

Access to different beaches by different families should also be apparent in differences in cobble size, angularity, cortex appearance, and processing strategy. Results of χ^2 tests comparing proportions of smooth and rough cortex flakes do not show significant differences between areas ($\chi^2 = 0.91$, 1 df, $p = 0.34$). Sample sizes for other cobble variables were too small for quantitative comparisons. There is no significant difference between early and later stage flakes ($\chi^2 = 0.83$, 1 df, $p = 0.18$). This preliminary analysis is not consistent with dramatic differences in the spatial distribution of toolstone at Watmough Bay that would be associated with differential lithic procurement by households.

Procurement Predictions for San Nicolas Island

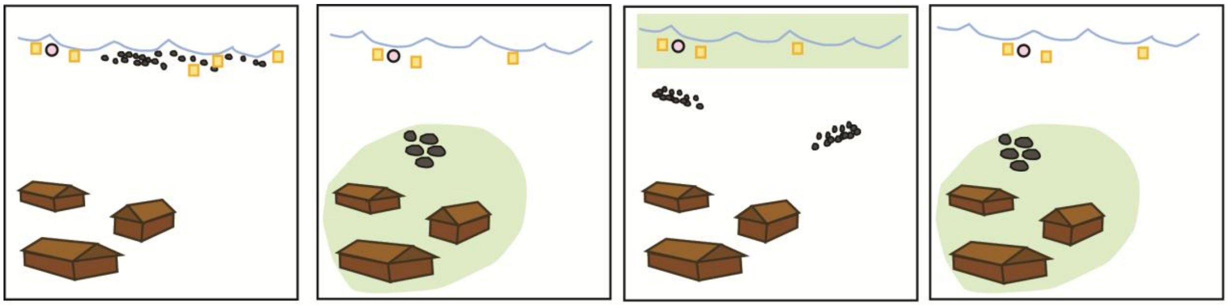
To address hypotheses on territorial behavior using the San Nicolas Island record, I test predictions for lithic procurement patterns using assemblages from Tule Creek Village Mound B and CA-SNI-106. I compare assemblages from these sites dating to 5000-4000 cal BP, 3000-1500 cal BP, 1500-500 cal BP and 500 cal BP-Contact. The assemblage from CA-SNI-106 dates to the middle two time periods. I make predictions for the San Nicolas Island lithic assemblages based on the environmental history, demographic information, toolstone availability, and lithic technology specific to this study area (Table 6.19). Because both Tule Creek Village and CA-SNI-106 are inland sites, I assume that most transport of local toolstone is pedestrian, therefore travel distance is a rough proxy for travel cost.

For the 5000-4000 cal BP assemblage I predict minimal evidence for boundary defense due to a lower population and food and water resources that would have far exceeded the needs of the communities on the islands. Unconstrained movement on the landscape should be apparent in procurement from the most attractive cobble area at Thousand Springs where all types of toolstone are abundant, densely distributed, and accessible. The lithic assemblage should indicate testing (removal of a first and second flake) of all toolstone prior to transport due to a relatively high travel cost over land. Since toolstone was abundant and accessible, toolstone conservation should be minimal. Because boundaries would be poorly defended and the small groups of people would have interacted as part of social networks to gain marriage partners, information, and prestige items, exchange should be moderate. Chert and obsidian artifacts should be relatively few but evenly distributed across the site, consistent with limited informal exchange.

At 3000-1500 cal BP and 500 cal BP-Contact, population was higher, the terrestrial climate was cool and wet, and the marine environment was unproductive. I predict increased evidence for inland-focused territoriality for groups near productive resource patches (adequate but not exceeding the needs of the community), including Mound B because it was located adjacent to a freshwater creek. If people defended a smaller territory at this time, this should be reflected in a decrease in quartzite and sandstone that would have been scarce near the site. Short travel distance should be apparent in minimal testing and working of metavolcanic rock at the nearby cobble area prior to transport to the site. Metavolcanic rock should be conserved at Mound B due to a limited supply of high quality material nearby. This should not be the case at SNI-106 which was near a more secondary resource area without ready access to freshwater and associated resources. The costs of protecting the resources near that site should outweigh the benefits therefore people should acquire metavolcanic rock from a larger area.

During special purpose trips to acquire coastal resources including quartzite and sandstone, inhabitants of both sites would have had to negotiate access through contested inland areas. Once at the beach cobble areas, they should take time to test quartzite prior to transport to offset high costs of travel and access by increasing the utility of the load. I also predict conservation of quartzite and sandstone to minimize trips to marine areas. Due to low boundary permeability in terrestrial areas, chert and quartz should be rare at the site but the flakes and tools that are present should be clustered in certain parts of the site reflecting formal relationships between kin or friends with other groups.

At 1500-500 cal BP, marine resources were abundant and predictable while terrestrial resources were relatively impoverished. Since territoriality should be focused on the island shorelines, people occupying Tule Creek Village and SNI-106 during these times would have had their choice of inland quarry areas. Due to longer travel distances overall, people should test metavolanic rock prior to transport. Efforts to conserve metavolcanic toolstone should be minimal. Access to marine resources, including quartzite and sandstone, would have been more difficult than the periods before and after because it would have required a relationship with a group in the marine zone. As during the 3000-1500 cal BP and 500 cal BP-Contact periods, I predict early stage reduction of quartzite prior to transport because access to that resource incurs both travels costs and negotiation costs. For the same reasons, I also predict toolstone conservation to minimize trips to resupply. Chert and quartz should increase due to decreased inland boundary defense and increased need to share terrestrial resources. It should be spread more evenly across the site reflecting more informal exchange (Figure 6.7; Table 6.13).



5000-4000 cal BP
Procure all toolstone from attractive sources

3000-1500 cal BP
Procure MV from Tule Creek. Procure Quartzite and Sandstone from the beach.

1500-500 cal BP
Procure MV from inland sources. Procure Quartzite and Sandstone from the beach.

500 cal BP-Contact
Procure MV from Tule Creek. Procure Quartzite and Sandstone from the beach.

Figure 6.7. Graphical depiction of procurement predictions for Mound B. Gray/green shaded area indicates territorial boundaries around a village.

Table 6.13. Table summarizing predictions for lithic analysis at Mound B and SNI-106.

	Site and Date (Cal BP)					
	Mound B 5000-4000	**Mound B 3000-1500**	**Mound B 1500-500**	**Mound B 500 - Contact**	**SNI-106 3000-1500**	**SNI-106 1500-500**
Territoriality	Defense low, permeability high.	Terrestrial	Marine	Terrestrial	Terrestrial	Marine
Metavolcanic Source	Thousand Springs	Tule Creek	Inland quarries	Tule Creek	Multiple inland quarries	Multiple inland quarries
Quartzite/Sandstone Source	Thousand Springs	Corral Harbor	Most attractive	Corral Harbor	Beach quarries	Beach quarries
Exchange	Informal	Formal	Formal	Formal	Formal	Formal
Testing/Early Stage Reduction at Source	All toolstone	Quartzite and sandstone	All material	All toolstone	All toolstone	All toolstone
Conservation	Minimal	All toolstone	Quartzite and sandstone	All toolstone	Quartzite and sandstone	Quartzite and sandstone

Testing Procurement Predictions on San Nicolas Island: Material Type

Since sandstone and quartzite are significantly more abundant in shoreline cobble areas than inland cobble areas, changes in abundance of these materials is one indicator of shifts in access to coastal areas on San Nicolas Island. If people had complete access to any toolstone area at 5000-4000 cal BP, this should be evident in a more even distribution of material types. At 1500-500 cal BP, if the most attractive cobble areas near the shoreline were controlled by nearby villages during a marine territoriality regime, inland groups like those as Tule Creek Village and CA-SNI-106 would have relied more heavily on nearby inland cobble sources where sandstone and quartzite were rare. The 3000-1500 cal BP and 500 cal BP periods of terrestrial-centered boundary defense should fall somewhere in between because travel to the shoreline may have been limited by other inland communities but coastal areas themselves should be open.

To test these predictions, I compare proportions of material type by weight and count for the debitage assemblage to determine both the overall amount of material at the site and the amount and size of debitage. I include both groundstone and sandstone flakes because they can be hard to distinguish from each other, and because grinding and flaking were often part of the same technological processes to make sandstone saws, bowls, and other objects. A comparison of proportions of material type by weight (Table 6.14; Figure 6.8) indicates that in accord with the predictions there is relatively more quartzite in the 5000-4000 cal BP Mound B assemblage than during any other period. The high percentage of sandstone in the 3500-1500 cal BP period is attributable to one very large sandstone bowl fragment. That the second largest amount of sandstone is in the 5000-4000 cal BP assemblage is in accord with the predictions. That the amounts of sandstone and quartzite are lower in the three later periods at Mound B is also consistent with the predictions, but the fact that these percentages are not *lowest* during the 1500-500 cal BP period is less consistent with my predictions.

At SNI-106, there is almost no sandstone present in the assemblage (1 sandstone fragment was found in the 1500-500 cal BP assemblage and none were found in the 500-0 cal BP assemblage), which is consistent with difficult access at inland sites and/or preference for other material types. Percent quartzite indicates a slightly smaller amount at 1500-500 cal BP than at 500 cal BP-Contact, which is consistent with the predictions (Table 6.14, Figure 6.9).

Table 6.14. Material weights for Mound B and SNI-106 based on debitage only.

Site	Mound B	Mound B	Mound B	Mound B	SNI-106	SNI-106
Time Period	5000-4000 BP	3000-1500 BP	1500-500 BP	500 BP-Contact	3000-1500 BP	1500-500 BP
Count						
Metavolcanic	81	144	452	971	113	225
Metasedimentary	4	11	19	56	0	0
Quartzite	14	18	85	171	34	21
Sandstone	7	2	34	51	0	1
Exotic Chert	9	8	13	40	3	3
Quartz	1	12	10	47	20	12
Total	116	195	613	1336	170	262
Frequency %						
Metavolcanic	69.80%	73.85%	73.74%	72.68%	66.50%	85.90%
Metasedimentary	3.50%	5.64%	3.10%	4.19%	0.00%	0.00%
Quartzite	12.10%	9.23%	13.87%	12.80%	20.00%	8.00%
Sandstone	6.00%	1.03%	5.55%	3.82%	0.00%	0.40%
Chert	7.80%	4.10%	2.12%	2.99%	1.80%	1.20%
Quartz	0.90%	6.15%	1.63%	3.52%	11.80%	4.60%
Weight (g, sum)						
Metavolcanic	337.6	797.6	3142.4	5391.7	510.4	1066.6
Quartzite	137.5	53.9	496.7	802.9	109.9	164.1
Sandstone	109.6	593.6	384.3	712.8	0	0
Chert	13.7	15.9	38	61.2	11.1	6.1
Quartz	0	16.4	24.1	96.4	45.5	164.1
Total	598.4	1477.4	4085.5	7065	676.9	1400.9
Weight %						
Metavolcanic	56.40%	53.99%	76.92%	76.32%	68.90%	76.10%
Quartzite	23.00%	3.65%	12.16%	11.36%	14.80%	11.70%
Sandstone	18.30%	40.18%	9.41%	10.09%		
Chert	2.30%	1.08%	0.93%	0.87%	1.50%	0.40%
Quartz	0.00%	1.11%	0.59%	1.36%	6.10%	11.70%

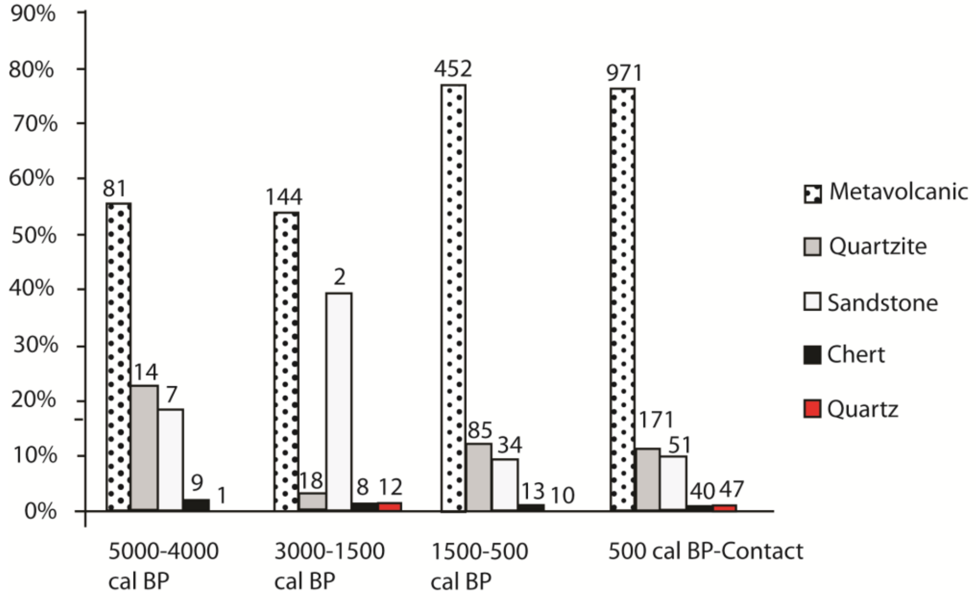


Figure 6.8. A comparison of material type proportions by weight for flakes at Mound B.

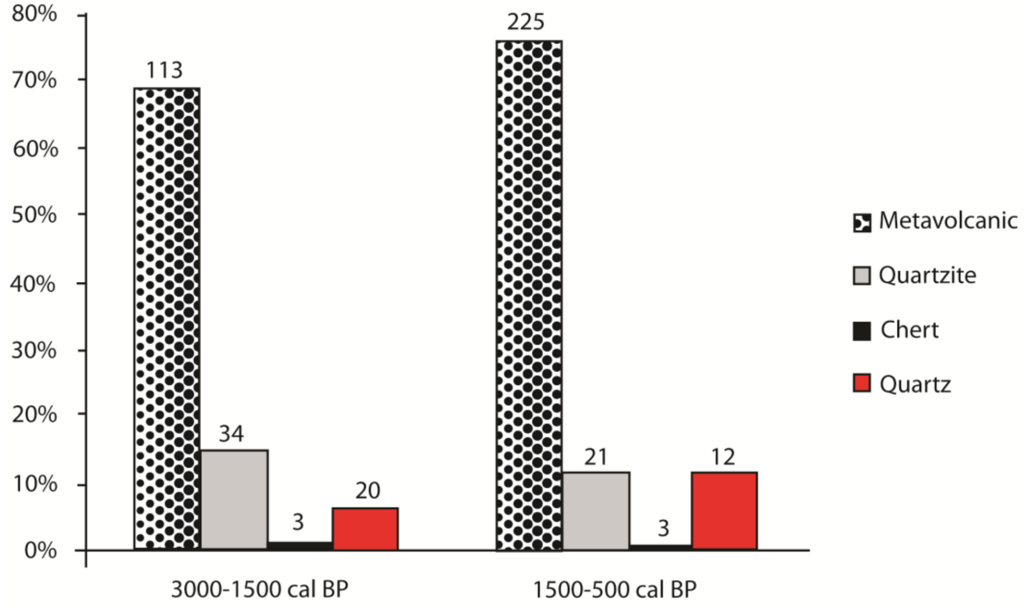


Figure 6.9. A comparison of material type proportions by weight for flakes at SNI-106.

Results of χ^2 tests comparing counts of metavolcanic, quartzite, and sandstone flakes indicate no significant differences in proportions of material type between time periods at Mound B. Significant differences in proportions of metavolanic and quartzite flakes at SNI-106 are in accord with the predictions. For these analyses, I compare three sub-groups of flakes: all flakes, > 3 cm maximum dimension flakes, and ≤ 3 cm maximum dimension flakes. I chose this size class to divide the assemblage because with the exception of one broken drill, all tools are 3 cm in maximum dimension or greater. Separating the smaller fraction reveals bias caused by large amounts of small shatter. A χ^2 test comparing proportions of metavolcanic and quartzite flakes for all flake sizes for the Mound B assemblages indicates no significant differences between the four assemblages ($\chi^2 = 2.21$, 3 df, $p = 0.53$). There are also no significant differences for > 3 cm ($\chi^2 = 4.30$, 3 df, $p = 0.23$) and ≤ 3 cm ($\chi^2 = 3.20$, 3 df, $p = 0.36$) sub-samples. In comparing only the two larger assemblages, 1500-500 cal BP and 500 cal BP-Contact, there are no significant differences in proportions of metavolcanic and quartzite flakes whether considering all flakes ($\chi^2 = 0.02$, 1 df, $p = 0.65$), > 3cm flakes ($\chi^2 = 0.25$, 1 df, $p = 0.62$), or ≤ 3 cm flakes ($\chi^2 = 0.05$, 1 df, $p = 0.83$). Proportions of metavolcanic flakes and sandstone flakes/fragments for the 1500-500 cal BP and 500 cal BP- Contact assemblages are not significantly different for all flakes ($\chi^2 = 2.5$, 1 df, $p = 0.11$), > 3 cm flakes ($\chi^2 = 1.4$, 1 df, $p = 0.23$) or ≤ 3 cm flakes ($\chi^2 = 1.07$, 1 df, $p = 0.30$).

For CA-SNI-106, χ^2 tests indicate significantly greater proportions of quartzite flakes than expected in the 3000-1500 cal BP time period for all flakes and for ≤ 3 cm flakes. The 0.08 *p*-value for > 3 cm flakes is nearly significant (Table 6.15). This result and the lack of sandstone at this site meets the prediction that people would have had the most difficulty accessing quartzite-rich marine cobble areas during the 1500-500 cal BP time period.

Table 6.15. Results of χ^2 tests comparing proportions of metavolcanic and quartzite flakes between time periods at CA-SNI-106, significant values in bold.

Time Per. (cal BP)	Flake Size	Stats	Metavolcanic	Quartzite	χ^2	DF	p
3000-1500	All	Count	113	34	17.466	1	**<.001**
		Expected	126.8	20.2			
		AR	**-4.2**	**4.2**			
1500-500		Count	226	20			
		Expected	212.2	33.8			
		AR	**4.2**	**-4.2**			

Time Per. (cal BP)	Flake Size	Stats	Metavolcanic	Quartzite	χ^2	DF	p
3000-1500	> 3cm	Count	39	10	3.176	1	0.08
		Expected	42.3	6.7			
		AR	-1.8	1.8			
1500-500		Count	68	7			
		Expected	64.7	10.3			
		AR	1.8	-1.8			

Time Per. (cal BP)	Flake Size	Stats	Metavolcanic	Quartzite	χ^2	DF	p
3000-1500	≤ 3cm	Count	74	24	14.977	1	**<.001**
		Expected	84.5	13.5			
		AR	**-3.9**	**3.9**			
1500-500		Count	158	13			
		Expected	147.5	23.5			
		AR	**3.9**	**-3.9**			

Another material difference that I considered in investigating differences in territorial circumscription between time periods is sub-type of metavolcanic rock: metavolcanic (MV, few or no phenocrysts), porphyritic metavolcanic (PMV, many phenocrysts), and metavolcanic porphyry (MVP, groundmass dominated by phenocrysts). MV rock is often finer grained and MVP is almost always coarser grained, although in some cases, the MVP has been subject to so much heat and pressure that the phenocrysts and groundmass have completely fused. Different raw materials have strengths and weaknesses for different tasks because they fracture differently. Materials that are easy to work tend to be less durable (Bradbury et al. 2008; Frison 1991; Terry et al. 2008). The MV toolstone would have been easier to work but PMV and MVP may have been preferred for cutting or sawing activities. Change over time in proportions of metavolcanic rock types could reflect natural differences in the cobble areas used, changes in cobble collection areas, or changing preference in tool type. When people at Mound B had more options available in collecting MV toolstone (5000-4000 cal BP and 1500-500 cal BP) they may have selected more MV rock. When they were more limited in their collection opportunities due to inland-centered territoriality (3000-1500 cal BP and 500 cal BP-Contact), MV should decrease and PMV and MVP should increase. At SNI-106, proportions of MV should stay the same through time if their boundary defense strategies did not change.

Results of χ^2 test comparing proportions of MV, PMV, and MVP flakes for all size classes at Mound B and for $>$ 3 cm and $\leq$ 3cm flakes show mixed results (Table 6.16). Considering all size classes, the proportion of PMV flakes is significantly higher during the 3000-1500 cal BP period and significantly lower during the 1500-500 cal BP period. Contrary to the predictions, however, the proportion of MVP flakes is significantly higher during the 1500-500 cal BP period (Table 6.17). Results of χ^2 tests for the $>$ 3cm ($\chi^2 = 9.72$, 6 df, $p = 0.137$) and $\leq$ 3 cm flakes ($\chi^2 = 7.41$, 6 df, $p = 0.28$) do not show statistically significant differences between time periods. At SNI-106, consistent with predictions, there is significantly more MV during the 1500-500 cal BP period than the 3000-1500 cal BP for all flakes, $>$ 3 cm flakes, and $\leq$3 cm flakes (Table 6.18).

Table 6.16. Data on proportions (count and weight) of metavolcanic, porphyritic metavolcanic, and metavolcanic porphyrtic toolstone at Mound B and SNI-106.

Site	Mound B	Mound B	Mound B	Mound B	SNI-106	SNI-106
Time Period	5000-4000 BP	3000-1500 BP	1500-500 BP	500 BP-Contact	3000-1500 BP	1500-500 BP
Count						
MV	22	24	111	215	22	97
PMV	54	101	262	536	81	105
MVP	5	16	77	113	10	23
Total	81	141	450	864	113	225
Frequency %						
MV	27.50%	17.02%	24.67%	30.94%	19.50%	43.10%
PMV	67.50%	71.63%	58.22%	77.12%	71.70%	46.70%
MVP	6.25%	11.35%	17.11%	16.26%	8.80%	10.20%

Table 6.17. Results of a χ^2 test comparing proportions of metavolcanic, porphyritic metavolcanic, and metavolcanic porphyry flakes at Mound B, all flakes included.

Time Per.(cal BP)	Size	Stats	MV	PMV	MVP	χ^2	DF	p
5000-4000	All	Count	22.00	54.00	5.00	14.89	6.00	**0.02**
		Expected	19.63	50.24	11.13			
		AR	0.63	0.89	-2.03			
3000-1500		Count	24.00	101.00	16.00			
		Expected	34.17	87.45	19.38			
		AR	**-2.10**	**2.47**	-0.87			
1500-500		Count	111.00	262.00	77.00			
		Expected	109.06	279.09	61.86			
		AR	0.25	**-1.97**	**2.47**			
500-0		Count	215.00	535.00	113.00			
		Expected	209.14	535.23	118.63			
		AR	0.70	-0.02	-0.84			

Table 6.18. Results of χ^2 tests comparing proportions of metavolcanic, porphyritic metavolcanic, and metavolcanic porphyry flakes at SNI-106.

Time Per. (cal BP)	Size	Stats	MV	PMV	MVP	χ^2	DF	p
3000-1500	All	Count	22	81	10	20.641	2	**<.001**
		Expected	39.8	62.2	11			
		AR	**-4.3**	**4.4**	-0.4			
1500-500		Count	97	105	23			
		Expected	79.2	123.8	22			
		AR	**4.3**	**-4.4**	0.4			
Time Per.(cal BP)	Size	Stats	MV	PMV	MVP	χ^2	DF	p
3000-1500	> 3cm	Count	9	28	2	9.958	2	**<.001**
		Expected	14.3	20.2	4.4			
		AR	**-2.2**	**3.1**	-1.5			
1500-500		Count	30	27	10			
		Expected	24.7	34.8	7.6			
		AR	**2.2**	**-3.1**	1.5			
Time Per. (cal BP)	Flake Size	Stats	MV	PMV	MVP	χ^2	DF	p
3000-1500	≤ 3cm	Count	13	53	8	13.808	2	**0.001**
		Expected	25.5	41.8	6.7			
		AR	**-3.7**	**3.2**	0.6			
1500-500		Count	67	78	13			
		Expected	54.5	89.2	14.3			
		AR	**3.7**	**-3.2**	-0.6			

To summarize material type comparisons, although the weight results indicate the highest proportion of quartzite at Mound B during the 5000-4000 cal BP period when boundary defense is predicted to be minimal, flake count results do not show significant differences between time periods. For SNI-106, however, a significantly higher proportion of quartzite in the 3000-1500 cal BP assemblage is consistent with less boundary defense around marine areas where quartzite was more abundant. The scarcity of sandstone at SNI-106 may reflect differences in manufacturing activities compared to Mound B, or more difficult access due to the greater distance between SNI-106 and sandstone sources. Results comparing MV, PMV, and MVP suggest increases in coarser grained metavolcanic rock in the 3000-1500 cal BP assemblage at Mound B when inland territoriality may have hindered raw material choice. There is also an increase in finer-grained metavolcanic rock at SNI-106 during the 1500-500 cal BP period when decreased inland boundary defense would have allowed more open access to any inland quarry areas and allowed people more choice in their raw material procurement.

Testing Procurement Predictions on San Nicolas Island: Cobble Shape

Data on original cobble shape provides additional information on change over time in procurement patterns. Based on field observations and cobble measurements from beaches and outcrops on San Nicolas Island, most areas had a mixture of round cobbles that people considered suited to their split cobble reduction sequence and flatter cobbles suited to diagonal, decapitation, and chopper reduction strategies. For this analysis, I assume that people sought both cobble types to create different flake tool forms, although one or the other may have been more efficient or favored for other reasons. Tabular metavolcanic cobbles (those with roundness values below 0.5 or above 1.5) are much rarer than round metavolcanic cobbles at all of the quarries. If people were more limited in their cobble access at 3000-1500 cal BP and 500 cal BP-Contact time periods due to inland boundary defense at Mound B, I therefore expect fewer flakes associated with diagonal and decapitation strategies. I expect that flakes associated with round and flat reduction sequences at SNI-106 should remain similar through time. Core sample sizes are too small to provide meaningful data to address this prediction.

Debitage associated with different reduction sequences can be used to distinguish flat and round reduction strategies in assemblages. Each reduction strategy creates a trajectory of flake types identified by unique combinations of platform shapes, platform facets, dorsal flake scars, and cortex location. Combinations of flake attributes can also be used to categorize flakes as primary, secondary, tertiary, or middle stage flakes in the reduction sequence (Table 6.19). For round cobble reduction sequences, primary (defined as 1.1 in Table 6.19) flakes associated with the Split Cobble 1 reduction sequence have round cortical platforms (6.10, 6.11) with no dorsal cortex because they are removed from the round cortical perimeter towards the center of the split face. The second set of flakes (1.2) might have a few dorsal flake scars because the toolmaker has already gone around the perimeter once. The next group of flakes (1.3) are struck from that same cortical perimeter towards the center of the split face but because multiple flakes have been struck from that surface, there are multiple dorsal flake scars. Flakes defined as 1.4 are struck from a split rotated core that is rotated 90 degrees so that the original flaking surface becomes the platform. Flakes have dihedral or multi-faceted platforms, dorsal cortex, and few dorsal flake scars. Flakes defined as 1.5 are removed in the same manner but have more dorsal flake scars as the knapper continues to work the increasingly exhausted core.

For Split 2 cores, which are also associated with round cobbles, the cobble is split and the first flakes are removed using the split face as a platform around the perimeter of the cobble. First flakes (2.1) have a flat *lisse* platform and 100% dorsal cortex. The next set of flakes (2.2) are similar but have more dorsal flake scars because the toomaker has gone around the perimeter once. When the core is rotated and the original flaking surface is used as a platform, the next set of flakes (2.3) have lisse, dihedral, or mutli-faceted platforms and no dorsal cortex. As more flakes are removed from this surface, flakes have more dorsal flake scars (2.4).

The flat cobble reduction sequences produce different flake from the split cobble sequences, although there is some overlap between flakes created using different core reduction strategies. The first flakes removed during the diagonal reduction sequence should have round cortical platforms with one dorsal flake scar and a step termination (3.1). As the toolmaker continues to work from the cortical platform using the ridge of previous flake scars to direct the force of the blow, the next set of flakes (3.2) will be similar to the first flakes but will have more dorsal flake scars. If the core is rotated, the platform may come from the flatter side of the cobble (3.3). First flakes removed the decapitate or chopper reduction sequences have round cortical platforms and dorsal cortex with no flakes scars (Figure 6.12, 6.13; 4.1, 5.1). For the decapitate sequence, the next set of flakes removed from the cortical flat platform adjacent to the initial flaking surface (4.2) follow the original flake scar and therefore have one flake scar. The next sets of flakes (4.3, 4.4) have more flake scars. The second set of flakes (5.2) removed during the chopper reduction sequence are struck the original flake scar (platform) and therefore have a flat *lisse* platform and dorsal and lateral cortex. The third set of flakes have less dorsal cortex because they are flaked onto a previously flaked surface surface (5.3) and the next set of flakes have more dorsal flake scars as the toolmaker continues to remove flakes, alternating sides of the cobble (5.4).

I do not expect that these flake types are absolutely diagnostic of each reduction sequence due to overlap and idiosyncrasies of the knapping process. In some cases, flake attributes associated with two different reduction techniques overlap. Split Cobble 1 tertiary flakes have round cortical platforms with cortex located on the platform and a lateral margin, and have multiple flake scars. These attributes also define Diagonal reduction sequence tertiary flakes. Characteristics of secondary, tertiary, and later stage flakes for each of these reduction sequences are described in the table below. The table describing the flake types for round and split cobble reduction sequences provides a general overview of flakes more likely to be associated with rounder and flatter reduction sequences, and a place to start in assessing change through time in use of cobbles of different shapes.

Figure 6.10. Flake with a round platform, obverse (25B.13.2A.3.F.4).

Figure 6.11. Flake with a round platform reverse (25B.13.2A.3.F.4).

Figure 6.12. Decapitation flake from decapitate or chopper reduction sequence, obverse (25B.58.IIB.1.F.5).

Figure 6.13. Decapitation flake from decapitate or chopper reduction sequence, reverse.

Table. 6.19. Primary, secondary, tertiary, and later stage flakes associated with different San Nicolas Island core reduction strategies.

		1	2	3	4	5
Split 1	Platform Shape	Round	Round	Round	Flat	Flat
Type 1	Platform Facet	Cortical	Cortical	Cortical	Dihedral, Multi	Multi
	Cortex Location	Platform	Platform/Lateral	Platform/Lateral	Dorsal	Dorsal, Margins, or None
	Dorsal Flake Scars	1	2, 3	4+	0-2	3+
	Termination	Feather	Feather/Hinge			
	Overlap			3.3		2.4
Split 2	Platform Shape	Flat	Flat	Flat	Flat	
Type 2	Platform Facet	Lisse	Lisse	Lisse, Dihedral, Multi	Dihedral, Multi	
	Cortex Location	Dorsal	Dorsal	None	None	
	Dorsal Flake Scars	0	1+	1	2+	
	Overlap	5.2			1.5	
Diagonal	Platform Shape	Round	Round	Flat/Round		
Type 3	Platform Facet	Cortical	Cortical	Cortical		
	Cortex Location	Platform/Lateral	Platform/Lateral	Platform/Lateral		
	Dorsal Flake Scars	1	2,3	4+		
	Termination	Step	Step			
	Overlap			4.4, 1.3		
Decapitate	Platform Shape	Round	Round/Flat	Flat	Flat	
Type 4	Platform Facet	Cortical	Cortical	Cortical	Cortical	
	Cortex Location	Platform, dorsal, lateral	Platform and Lateral/Distal	Platform/Lateral/Distal	Platform/Lateral/Distal	
	Dorsal Flake Scars	0	1	2	3+	
	Termination		Feather			
	Overlap	5.1			3.3	
Chopper	Platform Shape	Round	Flat	Flat	Flat	
Type 5	Platform Facet	Cortical	Lisse	Lisse	Lisse	
	Cortex Location	Platform and dorsal, lateral	Dorsal/Lateral	Lateral	Lateral	
	Dorsal Flake Scars	0	0	1	2+	
	Overlap	4.1	2.1			

Overall, a total of 423 flakes from dated strata were identifiable to a particular reduction sequence at Mound B with 23 of those from overlapping categories. A total of 47 flakes were identifiable at SNI-106 with 3 of those from overlapping categories (Table 6.20).

Table 6.20. Flake type counts at Mound B and SNI-106.

	Time Period (Cal BP) Mound B				SNI-106	
Flake Type	5000-4000	3000-1500	1500-500	500-0	3000-1500	1500-500
1.1	1	1	5	11	2	3
1.2	3	3	10	22	2	5
1.3		3	7	17	1	5
1.4		1				
2.2			4	7		
2.3					3	5
2.4	1	1	1	7	5	13
3.1				2		
3.2	1		1	2		
4.2	5	2	22	48		
4.3	4	8	18	64		
4.4	3	8	52	53		
5.1				1		
5.3		1				
1.3/3.3				2		
1.3/3.4			2	1		
1.5/2.4					1	2
2.1/5.2	1		1	5		
3.3/4.4			4	5		
4.1/5.1	1			1		

Results of χ^2 tests comparing proportions of round (Split Cobble) and flat (Diagonal, Decapitate, and Chopper) reduction sequence debitage in the 1500-500 cal BP and 500 cal BP-Contact assemblages showed no significant differences through time ($\chi^2 = 1.04$, 1 df, $p = 0.31$). This was also the case for SNI-106 for 3000-1500 and 1500-500 cal BP assemblages ($\chi^2 = .029$, 1 df, $p = 0.864$). These results are not consistent with the prediction that there should be fewer flat reduction sequence flakes at 3000-1500 cal BP and 500 cal BP - Contact.

A comparison between Mound B and SNI-106 showed significantly different proportions of round and flat reduction flakes during the 1500-500 cal BP period. There were significantly more flat cobble reduction sequence flakes at Mound B and significantly more round cobble reduction sequence flakes at SNI-106 (Table 6.21). This suggests that the inhabitants at SNI-106 had access to cobble areas with more flat cobbles, which is consistent with my prediction. I cannot rule out the possibility that they preferred flat cobbles to create their tools or had different manufacturing processes at SNI-106 than elsewhere on the island.

Table. 6.21. Results of a χ^2 test comparing proportions of round and flat reduction sequence debitage at Mound B and SNI-106 at 1500-500 cal BP.

Time Per. (cal BP)	Stats	Round	Flat	χ^2	DF	p
Mound B	Count	34	109	31.92	1	**<.001**
	Expected	50.16	92.84			
	AR	**-5.65**	**5.65**			
SNI-106	Count	33	15			
	Expected	16.84	31.16			
	AR	**5.65**	**-5.65**			

Toolstone Procurement on San Nicolas Island: Processing Prior to Transport

Change over time in toolstone processing decisions provides an important source of data to further investigate procurement behaviors on San Nicolas Island. I use proportions of first flakes compared to later stage flakes as an indicator of processing prior to transport. Based on my predictions, the analysis should show minimal testing of metavolcanic toolstone at Mound B at 3000-1500 cal BP and 500 cal BP - Contact when increased territorial circumscription encouraged procurement near the habitation site. For SNI-106, all toolstone should show similar moderate processing prior to transport. If people were never constrained to procuring metavolcanic rock from near the site, people should always test and process prior to transport to ensure that the costs of transport were outweighed by the utility of the stone. For both sites, since quartzite cobbles were more abundant at a distance from the habitation sites and would have required negotiation with other groups to access the source, I expect to see testing and the earliest stages of processing prior to transport during all time periods, but particularly at 1500-500 cal BP when marine territoriality would have made coastal resources more difficult to access for inland groups. Bringing back a higher-utility toolstone load would ensure less frequent visits into unfriendly territory.

Early stage reduction of metavolcanic and quartzite cobbles prior to transport should be evidenced by a small number of first and second flakes relative to later stage flakes and a higher expected to actual cortical surface ratio at the habitation site. To examine the representation of reduction sequence at Mound B and SNI-106, I use the flake types for each reduction sequence described in Table 6.24. I group the primary flakes from each reduction sequence (first flakes struck from a core), the secondary flakes from each reduction sequence (the second or third set of flakes struck from a core, and the tertiary flakes from each reduction sequence (the next identifiable set of flakes struck from a core). Results of an ANOVA test for the Mound B assemblage demonstrates significant differences in both mean weight and size class (flake maximum dimension grouped by 1 cm intervals) for secondary and tertiary flakes. The mean for tertiary flakes is significantly higher than the mean secondary flakes for both measurements (Table 6.22). This result is consistent with San Nicolas Island lithic reduction sequences that do not progress from large to small flakes. Along with primary, secondary, and tertiary flakes, I also analyze the dorsal flake scars and percent cortex because these variables are strongly associated with reduction stage (Table 6.23).

Table 6.22. Results of ANOVA tests comparing mean weight and size for primary, secondary, and tertiary flakes.

						Bonferroni Post-Hoc Analysis				
Dependent	Reduction Stage	*n*	Mean	F	Sig.	Reduction Stage Comparison		$\bar{x}$ Difference	Std. Error	Sig.
Weight	1	23.00	7.84	7.85	0.00	1	2	0.97	2.78	1.00
							3	-4.36	2.87	0.39
	2	252.00	6.87			2	1	-0.97	2.78	1.00
							3	-5.33417*	1.35	**0.00**
	3	138.00	12.2			3	1	4.36	2.87	0.39
							2	5.33417*	1.35	**0.00**
SizeClass	1	23.00	4	7.95	0.00	1	2	0.09	0.32	1.00
							3	-0.52	0.33	0.34
	2	252.00	3.91			2	1	-0.09	0.32	1.00
							3	-.61301*	0.15	**0.00**
	3	138.00	4.52			3	1	0.52	0.33	0.34
							2	.61301*	0.15	**0.00**

Table 6.23. Attributes related to reduction for Mound B and SNI-106.

		Reduction			Dorsal Scars					Platform Facet					% Cortex[1]			
		1	2	3	0	1	2	3	4+	Cortical	Lisse	Dihedral	Multi	Crushed	0%	1-25%	25-50%	50-100%
Mound B (Cal BP)																		
5000-4000 cal BP	Metavol.	2	9	3	0	12	11	11	11	19	10	0	0	1	10	15	3	3
	Quartzite	0	3	0	0	3	6	1	2	1	3	0	1	0	4	2	1	0
3000-1500	Metavol.	1	12	10	3	18	16	14	20	35	11	1	3	0	12	25	10	2
	Quartzite	0	2	0	1	0	4	1	1	2	2	0	0	0	2	1	1	0
1500-500	Metavol.	1	2	2	14	61	71	62	75	104	49	2	1	2	43	83	23	2
	Quartzite	2	9	10	2	12	12	16	11	26	8	0	0	1	6	16	12	1
500-0	Metavol.	14	125	55	26	157	171	95	111	209	81	6	2	10	74	157	63	8
	Quartzite	1	25	7	8	19	35	20	8	35	17	1	0	0	9	25	13	4
SNI-106 (Cal BP)																		
3000-1500	Metavol.	1	5	7	0	10	15	9	15	15	7	1	0	0	7	9	6	1
	Quartzite	1	0	3	0	2	4	4	6	5	1	1	0	0	2	5	0	0
1500-500	Metavol.	2	19	23	0	17	31	23	20	31	29	2	2	0	31	15	18	0
	Quartzite	1	3	1	0	3	3	0	3	6	2	0	0	0	2	1	5	0

[1] Includes only flakes with platforms because % cortex is estimated based on total possible cortical area on platform and dorsal surface.

Results of reduction sequence analysis at Mound B and SNI-106 are consistent with some but not all of the predictions. Proportions of tertiary flakes are significantly higher during the

1500-500 cal BP compared to the 500 cal BP-Contact periods at Mound B both if all flakes are considered and if only metavolcanic flakes are considered. More later stage reduction at 1500-500 cal BP is consistent with procurement from a broader geographical area and processing prior to transport. That there are no significant differences in flake types for SNI-106 is consistent with the prediction that procurement of metavolcanic rock should change little over time at that site. Results of χ^2 tests comparing attribute states associated with reduction stage do not indicate statistically significant differences at Mound B or at SNI-106. Sample size for quartzite flakes is too small to test most of the predictions (Table 6.24, 6.25, 6.26). The small number first flakes at the site relative to other kinds of debitage is unsurprising because there is only one first flake per core.

Table 6.24. Results of χ^2 tests comparing proportions of flake types and attributes associated with earlier and later stage reduction at Mound B and SNI-106.

Site	Variable	Material	Time Periods (Cal BP)	χ^2	df	p
MoundB	Flake Type	All	1500-500, 500-0	13.16	2	**<0.001**
MoundB		Metavolcanic	1500-500, 500-0	9.42	2	**0.01**
MoundB		Quartzite	1500-500, 500-0	*NA		
SNI-106		Metavolcanic	3000-1500, 1500-500	0.25	2	0.89
MoundB	Dorsal Scars	All	All	14.36	9	0.11
MoundB		Metavolcanic	All	13.76	9	0.13
MoundB		Quartzite	1500-500, 500-0	3.86	3	0.28
SNI-106		Metavolcanic	3000-1500, 1500-500	1.78	2	0.62
MoundB	% Cortex	All	1500-500, 500-0	1.51	3	0.68
MoundB		Metavolcanic	1500-500, 500-0	*NA		
MoundB		Quartzite	1500-500, 500-0	*NA		
SNI-106		Metavolcanic	3000-1500, 1500-500	2.8	2	0.25
*NA = sample size too small						

Figure 6.25. Results of a χ^2 test comparing proportions of flake types at 1500-500 cal BP and 500 cal BP-Contact at Mound B, all material included.

Time Per. (cal BP)	Material	Stats	1	2	3	χ^2	DF	p
1500-500	All	Count	5.00	62.00	57.00	13.2	2	**0.001**
		Expected	6.81	75.63	41.56			
		AR	-0.88	**-3.09**	**3.62**			
500-0		Count	15.00	160.00	65.00			
		Expected	13.19	146.37	80.44			
		AR	0.88	**3.09**	**-3.62**			

Figure 6.26. Results of a χ^2 test comparing proportions of flake types at 1500-500 cal BP and 500 cal BP-Contact at Mound B, only metavolcanic rock included.

Time Per. (cal BP)	Material	Stats	1	2	3	χ^2	DF	p
1500-500	Metavolcanic	Count	3.00	51.00	45.00	13.2	2	**0.001**
		Expected	5.74	59.47	33.79			
		AR	-1.45	**-2.14**	**2.92**			
500-0		Count	14.00	125.00	55.00			
		Expected	11.26	116.53	66.21			
		AR	1.45	**2.14**	**-2.92**			

Toolstone Conservation on San Nicolas Island

The predictions of the territoriality hypotheses for San Nicolas Island indicate that increased terrestrial territorial circumscription at 3000-1500 cal BP and 500 cal BP-Contact should encourage increased conservation of toolstone at Mound B. At 5000-4000 cal BP and 1500-500 cal BP, free access to resources across the landscape would require minimal conservation. Marine territoriality at 1500-500 cal BP would require conservation of quartzite and sandstone because they would have been more difficult to obtain. At SNI-106 there should be minimal conservation of metavolcanic rock at 3000-1500 cal BP or 1500-500 cal BP due to minimal boundary defense. As at Mound B, quartzite should be conserved, particularly at 1500-500 cal BP.

Evidence to test these predictions comes from core, flake, and formal tool assemblages. Given the small number of cores per the amount of debitage at the site, many cores were probably smashed into shatter during bipolar reduction. In all of the assemblages, exhausted cores and fragments by far outnumber patterned cores. Because toolstone is so difficult to work on San Nicolas Island, people likely used bipolar reduction throughout the reduction sequence and particularly in the early stages of reduction to split open the cores and at the end of the reduction sequence to create useful flakes from angular and exhausted cores. In the 1500-500 cal BP assemblage, 19 of 22 cores are fragments or exhausted. In the 500 cal BP-Contact assemblage, 18 of 27 cores are fragments or exhausted. There are too few quartzite cores (n = 2 in the 1500-500 cal BP assemblage and n = 3 in the 500 cal BP-Contact assemblage) to compare them to the metavolcanic cores. The small number of cores relative to flakes for all of the assemblages may indicate that all were worked to exhaustion, consistent with toolstone conservation during all time periods.

To further investigate change over time in bipolar reduction of exhausted cores, I test the flake assemblage for change over time in debitage associated with bipolar manufacture. One potential indicator of flake production from exhausted or later-stage cores are non-cortical multi-faceted platform flakes with multiple dorsal flake scars; however, there were fewer than 10 of these flakes in each assemblage at Mound B. For SNI-106, a significantly higher proportion of these flakes were identified in the 3000-1500 cal BP assemblage than the 1500-500 cal BP assemblage if all material types are considered (Table 6.27).

Table 6.27. Results of χ^2 tests comparing proportions of exhausted core flakes between time periods at SNI-106.

Material	Time Per. (cal BP)	Stats	Exhausted core flakes	Other	χ^2	DF	p
All	3000-1500	Count	27.00	144.00	5.70	1.00	**0.02**
		Expected	19.31	151.69			
		AR	**2.39**	**-2.39**			
	1500-500	Count	22.00	241.00			
		Expected	29.69	233.31			
		AR	**-2.39**	**2.39**			
Material	Time Per. (cal BP)	Stats	Exhausted core flakes	Other	χ^2	DF	p
Metavolcanic	3000-1500	Count	18.00	95.00	3.21	1.00	0.07
		Expected	13.04	99.96			
		AR	1.79	-1.79			
	1500-500	Count	21.00	204.00			
		Expected	25.96	199.04			
		AR	-1.79	1.79			

If people were using cores to exhaustion and then smashing them on an anvil to create additional usable flakes, this should be indicated by an increase in non-cortical flakes with bipolar features and non-cortical shatter. Bipolar features include a crushed platform, a crushed distal end, breakage parallel to the direction of force, and flaking on the ventral face. This analysis must be considered tentative because none of these features alone guarantee that a flake was created through bipolar reduction, and there are only eight cases where flakes have two bipolar attributes. Almost half of the flakes with bipolar attributes have only breakage parallel to the direction of force. At Mound B, there is no significant differences in flakes with bipolar attributes between time periods ($\chi^2 = 5.40$, 3 df, *p* = 0.145). Sample size is too small for quantitative comparison for SNI-106.

Non-cortical shatter $\leq$ 3 cm in maximum dimension and lacking an identifiable dorsal or ventral face is another potential indicator of bipolar reduction of exhausted cores. At Mound B, a χ^2 test comparing proportions of shatter and debitage indicates a significantly low proportion of shatter in the 1500-500 cal BP assemblage both if all toolstone is considered and if only metavolcanic toolstone is considered. For metavolcanic flakes, there is also a significantly higher proportion of shatter in the 500 cal BP-Contact assemblage (Table 6.28). There is no significant difference in non-cortical shatter between 1500-500 cal BP and 500 cal BP-Contact time periods for quartzite ($\chi^2 = 0.11$, 1 df, $p = 0.74$).

Table 6.28. Results of χ^2 tests comparing proportions of non-cortical shatter and other flakes at Mound B.

Time Per. (cal BP)	Material	Stats	Shatter	Other	χ^2	DF	p
5000-4000	All	Count	30.00	86.00	11.44	3.00	**0.01**
		Expected	27.09	88.91			
		AR	0.66	-0.66			
3000-1500		Count	47.00	148.00			
		Expected	45.54	149.46			
		AR	0.26	-0.26			
1500-500		Count	114.00	503.00			
		Expected	144.10	472.90			
		AR	**-3.36**	**3.36**			
500-0		Count	338.00	999.00			
		Expected	312.26	1024.74			
		AR	**2.60**	**-2.60**			
Time Per. (cal BP)	Material	Stats	Shatter	Other	χ^2	DF	p
5000-4000	Metavolcanic	Count	20.00	61.00	10.96	3.00	**0.01**
		Expected	17.25	63.75			
		AR	0.76	-0.76			
3000-1500		Count	27.00	117.00			
		Expected	30.67	113.33			
		AR	-0.78	0.78			
1500-500		Count	74.00	378.00			
		Expected	96.27	355.73			
		AR	**-3.00**	**3.00**			
500-0		Count	230.00	741.00			
		Expected	206.81	764.19			
		AR	**2.84**	**-2.84**			

In contrast to Mound B, at SNI-106 there are no significant differences in proportions of non-cortical shatter whether all material types are included or if only metavolcanic flakes are included (Table 6.29). Comparing quartzite and metavolcanic shatter at SNI-106 and Mound B, there is no significant difference between the two material types for the 1500-500 cal BP time period ($\chi^2 = 0.092$, 1 df, $p = 0.761$) or during the 500 cal BP-Contact time period ($\chi^2 = 1.58$, 1 df, $p = 0.21$). Results for non-cortical shatter for Mound B are consistent with decreased non-cortical shatter and potentially toolstone conservation at 1500-500 cal BP. At 500 cal BP, non-cortical shatter increases. This may fit with the prediction that that people had to conserve toolstone at 500 cal BP due to territorial circumscription. For SNI-106 there are no significant differences in proportions of shatter over time (the *p* value is significant but adjusted residuals do not show significant differences between time periods), which is consistent with a hypothesis of no change in boundary defense strategies. An increases in flakes from exhausted cores at 3000-1500 cal BP is not consistent with that prediction, but this may result from a small sample size.

Table 6.29. Results of χ^2 tests comparing proportions of non-cortical shatter and other flakes at SNI-106.

Material	Time Per. (cal BP)	Stats	Non-cortical shatter	Other	χ^2	DF	p
All	3000-1500	Count	58.00	113.00	2.73	1.00	0.10
		Expected	66.19	104.81			
		AR	-1.65	1.65			
	1500-500	Count	110.00	153.00			
		Expected	0.66	0.42			
		AR	1.65	-1.65			
Material	Time Per. (cal BP)	Stats	Non-cortical shatter	Other	χ^2	DF	p
Metavolcanic	3000-1500	Count	34.00	79.00	3.18	1.00	0.07
		Expected	41.46	71.54			
		AR	-1.78	1.78			
	1500-500	Count	90.00	135.00			
		Expected	82.54	142.46			
		AR	1.78	-1.78			

Another index of conservation to consider is intensity of retouch of formal tools. I predicted that intensity of retouch of formal tools should be higher at 500 cal BP-Contact, but the small sample sizes make it difficult to test that prediction. For drills, 2 of 15 tools have retouch flaking at 1500-500 cal BP and 1 of 12 has retouch flaking at 500 cal BP-Contact. For scrapers, most show minimal retouch limited to part of one margin with short flake scars. There are a few instances where the flake scars are present on an entire margin and are long, invasive, or covering. Approximately half of the scrapers show evidence of use. In the 1500-500 cal BP period, all scrapers have retouch on only one margin and only 2 of 10 have more than partial retouch on a margin. In the 500 cal BP-Contact period, 2 scrapers of 14 have retouch on more than one margin, and 4 have retouch on entire margins rather than part of a margin. These patterns indicate a potential increase in retouch during the later period at Mound B.

To summarize results for conservation, I predicted increased conservation at 3000-1500 cal BP and 500 cal BP-Contact as a result of inland territoriality at Mound B. I also predicted an increase in conservation of quartzite at 1500-500 cal BP at both Mound B and SNI-106 as a result of more difficult access to coastal cobble areas. Tests of these predictions using exhausted cores, bipolar reduction of exhausted cores, and retouched tools generally did not support this prediction. The low abundance of cores and high proportion of exhausted cores and core fragments for assemblages for all time periods from both sites indicates either some degree of conservation at all times, or that smashing cores was part of the technology. There was no significant difference in non-cortical flakes associated with exhausted cores from Mound B. The significantly lower proportion of non-cortical shatter from Mound B at 1500-500 cal BP is also indicates decreased conservation efforts at that time. The lack of increase in non-cortical shatter at SNI-106 is consistent with unchanged boundary defense strategies that would have maintained similar lithic procurement strategies. Quartzite samples were too low to test most of the predictions. There was no significant difference in proportion of metavolcanic and quartzite non-cortical shatter at 1500-500 cal BP and 500 cal BP-Contact. Regarding formal tools, data on scraper retouch indicate a potential increase in retouch during the 500 cal BP-Contact period, but drill retouch does not appear to change over time.

Exchange on San Nicolas Island

Toolstone procurement, processing, and conservation are associated with boundary defense. Boundary permeability is an equally important component of a territoriality strategy that

I investigate using evidence for informal and formal exchange on San Nicolas Island. Based on a social network model hypotheses, I suggest that at 5000-4000 cal BP, exchange should be infrequent among resource-secure and sparsely distributed communities. At 3000-1500 cal BP and 500 cal BP to contact, increased boundary defense in the San Nicolas Island interior should be associated with lower boundary permeability. Chert and quartz should be rare at Mound B but the flakes and tools that are present should be distributed in clusters reflecting formal relationships between households and kin in other groups. For the 1500-500 cal BP assemblage, increased boundary permeability associated with a more resource poor inland environment should be associated with an increase in chert and quartz across the site and a more even distribution of these materials.

I test predictions about exchange using extra-local chert, mainly Franciscan and Monterey banded chert that would have traded between islands and within groups on the island. It is fine-grained and highly visible. As well as being useful for creating retouched tools it was also likely a toolstone that carried symbolic weight. The lack of cores made from non-local material suggests that chert was imported as tools or blanks (Taşkiran 2001). I also consider quartz as a possible inter-island trade material. Available in small veins and outcrops on the island, it may have been accessible on a variety of beaches but is also a highly visible and rare material. Quartz crystals were used for ceremonial purposes (Bartelle et al. 2010). Because there were few chert and quartz flakes > 3 cm at either site, I was not concerned that a large number of small flakes might be skewing the counts so I did not separate the larger and smaller size fractions.

Consistent with expectations for small groups that interacted widely across territorial boundaries to maintain ties with friends and marriage partners, results of χ^2 tests results show a significantly higher proportion chert flakes compared to metavolcanic flakes during the 5000-4000 cal BP period at Mound B. With a total of 81 metavolcanic flakes, 9 chert flakes makes up a larger proportion than for any of the other sub-assemblages even though the sample size itself is not larger (Table 6.30). If that earliest assemblage is removed, differences in proportion of chert flakes between time period are not significantly different (χ^2 = 2.259, 2 df, *p* = 0.32). Also at Mound B there is a higher amount of quartz in the 3000-1500 cal BP assemblage (Table 6.36). At SNI-106, there are no significant differences in chert between time periods (χ^2 = 0.73, 1 df, Fisher's *p* = 0.41) but there is a significantly higher proportion of quartz at 3000-1500 cal BP (Table 6.31). Results showing more extralocal and rare material at 3000-1500 cal BP are not in accord with predictions for decreased boundary permeability during this time period.

Table 6.30. Results of χ^2 tests comparing proportions of chert and quartz to metavolcanic flakes at Mound B .

Time Per. (cal BP)	Stats	Chert	Metavolcanic	χ^2	DF	p
5000-4000	Count	9.00	81.00	10.62	3.00	0.01
	Expected	3.67	86.33			
	AR	**2.92**	**-2.92**			
3000-1500	Count	8.00	144.00			
	Expected	6.19	145.81			
	AR	0.78	-0.78			
1500-500	Count	13.00	452.00			
	Expected	18.95	446.05			
	AR	-1.63	1.63			
500-Contact	Count	40.00	971.00			
	Expected	41.19	969.81			
	AR	-0.30	0.30			
Time Per. (cal BP)	Stats	Quartz	Metavolcanic	χ^2	DF	p
3000-1500	Count	12.00	144.00	9.88	2.00	**0.01**
	Expected	6.58	149.42			
	AR	**2.27**	**-2.27**			
1500-500	Count	10.00	452.00			
	Expected	19.49	442.51			
	AR	**-2.59**	**2.59**			
500-Contact	Count	47.00	971.00			
	Expected	42.94	975.06			
	AR	1.03	-1.03			

Table 6.31. Results of a χ^2 test comparing proportions of quartz to metavolcanic flakes at SNI-106.

Time Per. (cal BP)	Stats	Quartz	Metavolcanic	χ^2	DF	p
3000-1500	Count	20.00	113.00	10.73	1.00	**<0.001**
	Expected	11.5	121.50			
	AR	**3.28**	**-3.28**			
1500-500	Count	12.00	225.00			
	Expected	20.50	216.50			
	AR	**-3.28**	**3.28**			

Regarding the spatial distribution of chert and quartz I found too many unknowns in controlling for spatial and temporal issues to draw firm conclusions. There are only two units that date to the 1500-500 cal BP period, thus spatial patterning cannot be assessed. For the 500 cal BP-Contact period, chert and quartz artifacts are relatively evenly spread throughout the units with slightly of these artifacts more found in Unit 43 (*n* = 30) than in the other units.

San Nicolas Island Lithic Procurement Summary

To examine lithic procurement patterns to investigate change over time in territoriality, I considered access to different material types, access to different shaped cobbles, processing prior to transport, conservation, and exchange. I predicted minimal boundary defense and high boundary permeability at 5000-4000 cal BP, inland boundary defense at 3000-1500 cal BP and 500 cal BP-Contact, and marine boundary defense at 1500-500 cal BP. During times of inland boundary defense, people at Mound B and SNI-106 would have been restricted in their procurement opportunities to the area around the site where quartzite, sandstone, and flatter cobbles are rarer. In general, their toolstone options would have been more limited. During the 1500-500 cal BP period they could have procured cobbles from a variety of inland sources, but access to quartzite and sandstone would still have been limited, perhaps even more so, by boundary defense by people who lived in marine areas.

In testing these scenarios, I found that small sample sizes for the earliest assemblage at 5000-4000 cal BP and for quartzite and sandstone artifacts made it difficult to fully address all of my predictions. The rarity of quartzite and sandstone at both Mound B and Tule Creek Village is consistent with either restricted ability to access that material or use of nearby toolstone simply because rocks are heavy and convenience was more important than material type.

If shifts in territoriality occurred during the time periods when I predicted, and these shifts truly determined resource access, at least most of the indices that I used to distinguish between procurement strategies should have shown some kind of significant difference, even if it was not in the predicted direction. Instead, most of the indices do not show significant differences between time periods. For the 1500-500 cal BP period, more of the indices of procurement and manufacture support the predictions than during the other periods. At Mound B, there is a decrease in PMV and at at SNI 106, there is an increase in MV. This may reflect less restriction on resource access and increased testing of cobbles from inland sources. There are also more tertiary flakes at Mound B, which would be consistent with more processing prior to transport. The decrease in non-cortical shatter indicates decreased conservation efforts. For the other time periods, however, the data largely show no significant differences or are not in accord with the predictions. There are also few significant differences in chert and quartz that would support changes in boundary permeability during the time periods predicted.

The incongruence in results for Mound B and SNI-106 provides additional evidence that my predictions are not supported by the data. For example, during the 1500-500 cal BP period, there is an increase in finer-grained MV toolstone at SNI-106 and a decrease in PMV toolstone at

Mound B. Flake types associated with flat cobbles increase at Mound B and those associated with round cobbles increase at SNI 106. The cortex ratio is low at Mound B and high at 106. Non-cortical shatter increases at Mound B and decrease at SNI-106. All of these differences may simply reflect different manufacturing activities at the two sites or sampling error; however, greater similarities for the two sites would support a more important role for lithic procurement in determining those manufacturing traditions.

An Alternative Hypothesis for Lithic Procurement on San Nicolas Island

To further address my research questions, I evaluate an alternative hypothesis that boundary defense operated beyond the scale of the village. As a preliminary test, I compare lithic artifacts from strata/levels that date to the 500 cal BP-Contact time period in two separate spatial areas that may correspond to separate households: (1) Unit 58, Stratum I, Stratum II levels 1-2, and (2) Unit 43, Stratum I and II. Results of χ^2 tests comparing proportions of metavolcanic flakes and sandstone, chert, and quartz indicate significantly higher proportions of sandstone, chert, and quartz in Spatial Unit 1 and quartzite in Spatial Unit 2 (Table 6.32). A comparison of tools from the two units also reveals significant differences, but toolstone distribution does not mirror the flake results. In Spatial Unit 1 there are 12 retouched tools, none of which are chert. The tools consist of scrapers, drills, and retouched flakes. There are also two ground stone beads. In Spatial Unit 2 there are also 12 tools but material type includes not just metavolcanic toolstone but also quartz and chert. There are no beads in this unit, and there is one projectile point. Further research is required to distinguish between manufacturing activity differences and resource procurement differences.

Table 6.32. Results of χ^2 tests comparing proportions of material types for two spatial areas at Mound B.

Spatial Unit	Stats	Metavolcanic	Quartzite	χ^2	DF	p
1	Count	181	21	14.56	1	**<0.001**
	Expected	164.17	37.83			
	AR	**3.82**	**-3.82**			
2	Count	266	82			
	Expected	282.83	65.17			
	AR	**-3.82**	**3.82**			
Spatial Unit	Stats	Metavolcanic	Sandstone	χ^2	DF	p
1	Count	181	16	8.94	1	**0.003**
	Expected	187.76	9.24			
	AR	**-2.99**	**2.99**			
2	Count	266	6			
	Expected	259.24	12.76			
	AR	**2.99**	**-2.99**			
Spatial Unit	Stats	Metavolcanic	Chert/Quartz	χ^2	DF	p
1.00	Count	181.00	14.00	1.26	1.00	0.26
	Expected	177.53	17.47			
	AR	1.12	-1.12			
2.00	Count	266.00	30.00			
	Expected	269.47	26.53			
	AR	-1.12	1.12			

Chapter Summary

The results of lithic analysis for Watmough Bay, Mound B, and SNI-106 demonstrate both the potential and the challenges of using a lithic procurement approach to examine territorial behavior in coastal settings. In both study areas, the question became, were there time periods when people used more toolstone from near the site than from elsewhere on the landscape? If they relied on toolstone collected near the site, is this because there was territorial circumscription associated with increased boundary defense?

For Watmough Bay, at least during the 1600-1000 cal BP period, the data indicate that people did not primarily procure toolstone from the beach near the site. The size and shape of cores and cortex appearance for cores and flakes is more similar to beaches on southern San Juan Island than on southern Lopez Island, a relatively easy boat ride away. There are several different ways to explain procurement in this context. People from Watmough Bay could have visited southern San Juan Island to collect subsistence or water resources or meet with kin. If Watmough was used seasonally and families lived in other areas during summer or spring months as indicated in the ethnographic record, they could have collected larger and more angular cobbles in these areas to bring them back to Watmough Bay in the winter, knowing that this resource would be limited. The distribution of chert, quartz, and incised shale suggests little change through time, minimal use of these materials, and a relatively even distribution across the site. My ability to investigate change through time in boundary permeability at Watmough Bay was limited due to the small sample of extra-local and rare toolstone. Other material types must be considered to further address this aspect of my research question.

For the San Nicolas Island case study, the lithic landscape is more complex and so are the predictions. The lithic record does not indicate that people were limited in their procurement opportunities to Tule Creek at 3000-1500 and 500 cal BP-Contact. There is slightly more evidence for procurement from a variety of toolstone sources and decreased toolstone conservation at Mound B at 1500-500 cal BP, but the record for SNI-106 shows the opposite pattern. It would have been interesting to compare in more detail differences between sandstone, quartzite, and metavolcanic procurement practices, but the smaller sample of quartzite and sandstone made that difficult. The weight of the evidence is against boundary defense playing a significant role in toolstone procurement on San Nicolas Island. Similarities in the distribution of chert and quartz over time do support change over time in boundary permeability expressed through changes in exchange patterns. In combination with the settlement pattern data, the lithic data do not support boundary defense or permeability at the level of the village on San Nicolas Island during the Late Holocene. My preliminary analysis evaluating differences in toolstone access at different parts of the site at 500 cal BP-Contact reveals different proportions of material types, but flake toolstone and retouched tool toolstone are dissimilar at different parts of the site. Further research on lithics in both areas would be required to disentangle manufacturing and procurement. Analysis of the stratigraphy and spatial distribution of other artifacts would be required to assess potential separation of households at Mound B.

Chapter 7: Conclusions

In this research, I explored territorial behavior in two study areas on the Pacific Coast, the San Juan Islands and southern Channel Islands. By testing hypotheses drawn from human behavioral ecology models using settlement pattern and lithic procurement data, I investigated whether territorial behavior occurred at the scale of the village in response to shifts in marine and terrestrial resources. A comparative perspective facilitated rigorous hypothesis testing and contributes to a more detailed understanding of coastal settlement patterns, lithic procurement strategies, and technologies. Investigating change over time in territorial behavior on the Pacific Coast is fundamental to larger questions about the development of social, political, and economic inequalities in semi-sedentary communities, human-environment interactions, and human response to climate change.

This study centered on boundary defense and permeability strategies as an adaptation to resource abundance and predictability. Based on economic defensibility models, I hypothesized that when subsistence resources far exceed or fall far short of a community's needs, the costs of defending a territory will outweigh the benefits. When subsistence resources are abundant and predictable enough to just adequately fulfill resource needs, people should defend small territories around villages that are located near productive resource patches. Due to temporal and spatial fluctuations in the environment, some people will always have less and will therefore attempt to encroach on others' territory. As a result, resource procurement near productive patches—including procurement of toolstone—is restricted to smaller areas. During times of resource scarcity, people should invest more effort toward maintaining inter-village ties to buffer against resource shortfall; during times of adequate abundance they should invest less effort toward exchange and other inter-group activities due to higher costs of crossing aggressively defended boundaries and lower benefits of risk management.

When I used this basic hypothesis to create scenarios for the development of territorial behavior during the Late Holocene in the San Juan Islands and southern Channel Islands, I considered shifts in marine and terrestrial environments, the locations of habitation sites relative to those resources, and settlement pattern information. As an alternative hypothesis, I suggested that village boundaries may have always been permeable to resource acquisition by multiple groups due to strong kin relationships, marriage, and friendship ties between villages. Because of the spatially and temporally unpredictable nature of coastal resource distribution and/or social and cultural phenomena that are not affected by subsistence strategies, families within villages may have maintained access to specific resource areas and shared access or resources—including toolstone—with other related families.

I tested predictions specific to the archaeological record of both study areas using data on the defensive characteristics of archaeological sites and lithic procurement patterns. Landscape and site scale data provided two different perspectives on potential shifts in boundary defense and permeability. For a landscape perspective on boundary defense around villages, I analyzed defensive properties of sites from across both study areas. Built earthworks are almost non-existent in the Gulf of Georgia and southern Channel Islands, but choice of site location also reveals strategies for defense against unwanted visitors. I measured site defensiveness based on visibility, elevation, and distance to lookouts for all dated sites on the San Juan Islands and measured elevation and distance to lookouts for all dated sites on San Nicolas Island. I then compared defensive properties of sites between time periods associated with different environmental regimes.

Site-scale data on toolstone procurement provides an additional perspective on territorial behavior. The majority of my dissertation analysis focuses on toolstone access at Watmough Bay on Lopez Island and Tule Creek Village Mound B and SNI-106 on San Nicolas Island. Because toolstone sources cannot be pinpointed to specific geographic locations in either study area, I compared proportions of material types, cobble shapes, cortex appearance, and other features of the lithic assemblages with cobbles from potential toolstone collection areas both adjacent to the sites and elsewhere on the landscape. I investigated whether the lithic assemblages matched the toolstone available in the vicinity of the site during periods when I predicted smaller and more aggressively defended territories. In exploring toolstone procurement, processing, and conservation at each site, I considered boat and pedestrian transport, reduction sequences for cobble-centered technologies, and lithic traditions characterized mainly by unmodified flake tools.

Summary of Results for the San Juan Islands

For the San Juan Islands case study, neither defensive site data nor lithic procurement analysis were consistent with predicted changes through time in boundary defense and permeability at the scale of the village. I predicted that at 600 cal BP-Contact, adequately productive marine resources and higher populations would have encouraged communities near productive resource patches to defend the area surrounding the village to maintain an adequate resource supply. Boundary defense should be lower during periods of lower population (3500-2500 cal BP and 2500-1600 cal BP) when resources would have been extremely abundant relative to the population and at 1600-1000 cal BP when a drop in marine productivity would have made resources too scarce to be worth defending in most areas. Boundary permeability should be highest at times of resource scarcity. Further analysis is required to determine whether the incongruence between the data and the predictions is attributable to stability in territorial behavior through time, were not consistent with the predictions because territorial behavior did not change over time, because the data or model were inadequate, or because territoriality did not occur at the scale of the village.

Results of comparisons of visibility, elevation, and distance to lookout values before and after 600 cal BP indicated no significant difference between time periods (Table 7.1). Perhaps coastal site locations were more strongly determined by access to fish, shellfish, sea birds, or other resources. People may also have chosen habitation sites based on their ability to pull a canoe onshore or fish offshore. If the reason that the defensive characteristics did not register change through time is because multiple communities banded together against groups to the north or the south, investigating those strategies would require an analysis of different parts of the islands for sites that could be used as lookouts, areas from which to attack intruders, or refuges where people could hide from invading groups.

Table 7.1. Predictions and results for change over time in defensive sites on the San Juan Islands.

	3500-2500 cal BP	2500-1600 cal BP	1600-1000 cal BP	600 cal BP-Contact	Supports hypothesis?
Territoriality	Minimal defense/moderate permeability	Minimal defense/moderate permeability	Minimal defense/high permeability	Increased defense/low permeability	
Defensive site predictions	↓	↓	↓	↑	
Results	No sig. differences in visibility, elevation, distance to lookout.	No sig. differences in visibility, elevation, distance to lookout.	No sig. differences in visibility, elevation, distance to lookout.	No sig. differences in visibility, elevation, distance to lookout.	No

Results of lithic analyses to investigate changes through time in lithic procurement centered on determining if the lithic assemblage from Watmough Bay that dates to 600 cal BP-

Contact indicates lithic procurement from a smaller (actively defended) area in the vicinity of Watmough Bay while assemblages from the previous time periods reflect a population that procured resources from a larger area. Small sample sizes for all but the 1600-1000 cal BP assemblage precluded a full diachronic analysis of lithic artifacts from the Watmough Bay site, but most measures did not support an increase in boundary defense at 600 cal BP-Contact (Table 7.2). I predicted that people should increase their use of the slate outcrop near the Watmough Bay site at 600 cal BP-Contact, but comparisons (by weight and by count) of slate during different time periods were not consistent with this trend. I also predicted an increase in flakes with smooth cortex at 600 cal BP-Contact similar to those found on Watmough Bay beach, but I found no significant differences between the four time periods in cortex appearance for flakes.

Analyses designed to explore changes in processing and conservation strategies linked to hypotheses about procurement also indicated few changes through time (Table 7.3). I predicted that procurement adjacent to Watmough Bay at 600 cal BP – Contact should be associated with decreased processing prior to transport due to minimal travel costs. I found no significant differences in proportions of first flakes between the assemblages although there were significantly more flakes with 0 or 1 flake scars rather than multiple flake scars for the 600 cal BP-Contact assemblage. I also predicted increased conservation of FGV at 600 cal BP-Contact due to the scarcity of cobbles of appropriate size and shape on Watmough Bay beach. I found no significant differences in the numbers of exhausted cores between the 2500-1600 cal BP and 1600-1000 cal BP time periods for which sample size was large enough to compare between assemblages. Retouch intensity was intensive during the 1600-1000 cal BP and 600 cal BP-Contact time periods during the two earlier periods, but due to small samples sizes and the subjectivity of this analysis, this result is inconclusive.

Finally, some analyses tentatively confirmed procurement of FGV from beyond Watmough Bay beach during the 1600-1000 cal BP time period in which the lithic assemblage was largest (Table 7.2). Cores (with original cobble dimensions intact) from Watmough Bay beach dating to 1600-1000 cal BP were typically larger than the cobbles from the beach. An analysis of cores and flakes from this time period also indicates the use of more angular cores than would have been available at Watmough Bay beach. People could have chosen the larger or more angular cobbles from this beach, but based on my field observations, the supply of large angular cobbles on the beach would have been insufficient to sustain communities over the hundreds of years that Watmough Bay was occupied. The substantially higher number of cores and flakes with rough cortex rather than the smooth waterworn cortex found on cobbles at Watmough Bay beach also indicates the use of other beaches during this time period. These findings are consistent with my hypothesis that people procured toolstone from a relatively large area at 1600-1000 cal BP when marine resources were scarcer; however, I cannot determine whether this behavior represents a shift in territorial behavior or a strategy for lithic procurement that remained unchanged through time.

Table 7.2. Predictions and results for change over in time lithic procurement at Watmough Bay based on lithic assemblage analyses.

	3500-2500 cal BP	2500-1600 cal BP	1600-1000 cal BP	600 cal BP-Contact	Supports hypothesis?
Territoriality	Minimal defense/moderate permeability	Minimal defense/moderate permeability	Minimal defense/high permeability	Increased defense/low permeability	
FGV Source	Aleck Bay, Agate Beach, Watmough	Aleck Bay, Agate Beach, Watmough	Aleck Bay, Agate Beach, Watmough	Watmough	
Size Predictions	↑	↑	↑	↓	
Results			Cores from cobbles larger than those found at Watmough Bay beach.		Yes
Slate predictions	↓	↓	↓	↑	
Slate Weights		Munsell ↓	Munsell, Stein/Phillips ↑	Munsell, Stein/Phillips ↓	No
Slate Counts	Munsell, Stein/Phillips ↑	Munsell, Stein/Phillips ↓	Munsell, Stein/Phillips ↓	Munsell, Stein/Phillips ↓	No
Shape Predictions	More Angular	More Angular	More Angular	More Round	
Results			Cores/flakes indicate more angular than round cobbles.		Yes
Cortex Predictions	Different proportions of smooth/rough from Watmough Beach.	Different proportions of smooth/rough from Watmough Beach.	Different proportions of smooth/rough from Watmough Beach.	Similar to Watmough Beach	
Results		No sig. differences between flake assemblages.	No sig. differences between flake assemblages. Sig. more rough cortex cores/flakes than at Watmough beach.	No sig. differences between flake assemblages.	Inconclusive

Table 7.3. Predictions and results for change over time in conservation and processing at Watmough Bay based on lithic assemblage analyses.

	3500-2500 cal BP	2500-1600 cal BP	1600-1000 cal BP	600 cal BP-Contact	Supports hypothesis?
Territoriality	Minimal defense/moderate permeability	Minimal defense/moderate permeability	Minimal defense/high permeability	Increased defense/low permeability	
FGV Source	Aleck Bay, Agate Beach, Watmough	Aleck Bay, Agate Beach, Watmough	Aleck Bay, Agate Beach, Watmough	Watmough	
Conservation predictions	↓	↓	↓	↑	
Exhausted cores		No sig. difference	No sig. difference		Inconclusive
Resouch intensity		Less retouch	More intensive retouch	More intensive retouch	Inconclusive
Processing predictions	↑	↑	↑	↓	
Results		No first flakes	No sig. difference in proportion of first flakes.	No sig. difference in proportion of first flakes. Sig. more flakes with 0 or 1 flake scar.	Inconclusive

Along with testing hypotheses about boundary defense, I also considered change over time in boundary permeability. I hypothesized that during times of resource scarcity, higher benefits of cooperating and exchanging information and lower costs of transgressing boundaries would encourage increased inter-group interaction at 1600-1000 cal BP. Inter-group relationships should be lower at 600 cal BP-Contact when resources were adequate and boundary defense was high. During the earlier time periods from 2500-1600, small populations should encourage moderate interaction for information exchange and marriage partners. I tested those predictions using extra-local and rare toolstone at Watmough Bay. As predicted, I noted an increase in chert at 1600-1000 cal BP and an absence of chert at 600 cal BP-Contact; however, these results are likely a function of the larger sample at 1600-1000 cal BP and small sample at 600 cal BP-Contact.

I also predicted that during times of high boundary defense, inter-group interaction should be more formal and involve fewer families. This should be evidenced through an uneven distribution of extra-local and rare lithic raw material across the site. The only assemblage for which there was enough extra-local or rare raw material to test this prediction was the 1600-1000 cal BP assemblage. The even distribution of raw material across the site is consistent with informal inter-group interactions predicted during this time period (Figure 7.4). Without the ability to compare the distribution of chert, quartz, and nephrite between time periods, the distribution of these materials does not provide conclusive answers about group interaction systems in the San Juan Islands during the Late Holocene.

Table 7.4. Predictions and results for change over time in boundary permeability at Watmough Bay based on analyses of extralocal and raw materials.

	3500-2500 cal BP	2500-1600 cal BP	1600-1000 cal BP	600 cal BP-Contact	Supports hypothesis?
Territoriality	Minimal defense/moderate permeability	Minimal defense/moderate permeability	Minimal defense/high permeability	Increased defense/low permeability	
Exchange predictioncs	Moderate, informal	Moderate, informal	High, informal	Low, formal	
Results	Small amount of chert.	Small amount of chert.	More chert, evenly distributed across the site.	No chert.	Inconclusive

Overall, lithic procurement data are not consistent with the hypothesis that there was increased boundary defense and decreased permeability at 600 cal BP-Contact in the San Juan Islands. These results may, in fact, signify that territorial behavior did not develop until the Contact period, but there are other important possibilities to consider regarding sample size, the scale of boundary defense, the impact of climate change on resource distribution, potential problems with the model in predicting territorial behavior, and the sensitivity of the data to territoriality. I discuss these possibilities after summarizing results for the San Nicolas Island analyses.

Summary of Results and Directions for San Nicolas Island

Similar to the San Juan Islands case study, defensive site and lithic procurement data for the San Nicolas Island study area did not support the hypothesis that shifts in territorial behavior correspond to shifts in subsistence resource productivity on the landscape. Further research must be conducted to determine whether those results indicate that the Nicoleño were never territorial or whether there was a problem with the research approach or analysis.

Regarding defensive sites, I predicted that at 5000-4000 cal BP, subsistence resources should far exceed the needs of the small population on the island therefore boundary defense should be minimal. At 2500-1500 cal BP and 500 cal BP-Contact, boundary defense should center on terrestrial resources. Sites near productive patches should exhibit defensive characteristics consistent with aggressive defense of adequate resources against intruders. At 500 cal BP-Contact, an increase in marine productivity should be associated with increased defensive characteristics of sites located near productive marine resources. Results of an ANOVA comparing mean elevation and distance to lookout values failed to show significant differences in defensive characteristics of sites between time periods for all sites, coastal sites, inland sites, or habitation sites (Table 7.5). This may indicate minimal boundary defense during any time period on San Nicolas Island, but it is probably more indicative of a lack of sensitivity of elevation and distance to lookout measurements to shifts in territorial behavior. People may have chosen particular areas for habitation sites due to proximity to resources, protection from the elements, access to streams, community traditions, or social values. If all of the communities on the island considered themselves to be part of a larger San Nicolas Island community, those habitation sites with the best visibility to watercraft approaching from the mainland or from other islands should have the most prominent lookouts. Sites that were often the first point of attack should have the highest elevation values because sites with higher elevation values are more difficult to access. Villages could communicate with one another about potential threats by signaling or messengers. Further research on potential water routes between islands might provide an avenue for research on the defensive characteristics of San Nicolas Island as an island community.

Table 7.5. Predictions and results for defensive characteristics of sites on San Nicolas Island. Defensive characteristics are based on site elevation measures and distance to lookout.

	5000-4000 cal BP	3500-1500 cal BP	1500-500 cal BP	500 cal BP-Contact	Supports hypothesis?
Territoriality	Minimal defense/high permeability	Inland defense/Marine permeability	Marine defense/Inland permeability	Inland defense/Marine permeability	
Predictions for defensive sites	Minimal	Terrestrial	Marine	Terrestrial	
All sites	No sig. differences	No sig. differences	No sig. differences	No sig. differences	No
Coastal sites	No sig. differences	No sig. differences	No sig. differences	No sig. differences	No
Inland sites	No sig. differences	No sig. differences	No sig. differences	No sig. differences	No

Regarding lithic procurement on San Nicolas Island, I predicted two different trajectories for Tule Creek Village Mound B and SNI-106 because Mound B was more likely a productive terrestrial resource area and SNI-106 was more likely a secondary resource area. If the area around Mound B was defended more intensely at 3500-1500 cal BP and 500 cal BP-Contact due to more abundant and predictable terrestrial resources, lithic procurement should take place within a smaller area surrounding Tule Creek Village. This would result in decreased access to the finest-grained metavolcanic rock (MV) and increased use of the round cobbles that are more common at Tule Creek than at coastal sites. Processing prior to transport should decrease since the distance from the cobble area to the habitation site is short. People should conserve metavolcanic rock because high-quality material would have been relatively limited. At SNI-106, none of these factors should show changes through time because with scarcer and less predictable resources, the people at that habitation site would be less likely to engage in costly boundary defense activities.

My results indicate few changes through time in lithic procurement at either site (Table 7.6, 7.7). At Mound B there were no significant differences in MV toolstone through time. Based on proportions of flakes associated with round and flat cobble reduction sequences, there was also minimal change through time in access to round and flat cobbles. One analysis that may be consistent with increased conservation of metavolcanic rock at 500 cal BP-Contact is a decrease in tertiary flakes relative to other flake types during that time period, suggesting more primary reduction at the site. Since many other manufacturing processes and technological factors could contribute to that shift, this positive result alone is inconclusive. Finally, based on proportions of exhausted cores, flakes from exhausted cores, flakes with bipolar attributes, and non-cortical shatter, the only potential change through time in toolstone conservation is a significant increase in metavolcanic non-cortical shatter at 500 cal BP-Contact. Because other technological and manufacturing strategies could cause that shift and none of the other indices of conservation showed positive results, my overall impression is that conservation strategies changed little through time.

Table 7.6. Results of lithic analyses for Mound B.

	5000-4000 cal BP	3500-1500 cal BP	1500-500 cal BP	500 cal BP-Contact	Supports hypothesis?
Sources	Most attractive	Tule Creek/Beaches	Inland areas/Beaches	Tule Creek/Beaches	
Material Type Predictions	More quartzite, sandstone, finer-grained metavolcanic rock	Some quartzite, sandstone, coarser-grained metavolcanic rock	Least quartzite, sandstone, fine-grained metavolcanic rock	Some quartzite, sandstone, coarser-grained metavolcanic rock	
Quartzite/Sandstone Weight	Quartzite ↑, Sandstone ↑	Quartzite lowest, Sandstone ↑	Quarzite ↓, Sandstone ↓	Quarzite ↓, Sandstone ↓	Yes
Quartzite/Sandstone Count	No sig. differences	No sig. differences	No sig. differences	No sig. differences	No
Metavolcanic results	No sig. differences	PMV ↑	PMV ↓ MVP ↑	No sig. differences	No
Cobble Shape Predictions	Flat/Round	Flat/Round	Fewer Flat	Flat/Round	
Flake Types		No sig. differences	No sig. differences	No sig. differences	No
Processing prior to transport Predictions	Metavolcanic ↑ Quartzite ↑	Metavolcanic ↓ Quartzite ↑	Metavolcanic ↑ Quartzite ↑	Metavolcanic ↓ Quartzite ↑	
Results		No sig. differences	Metavolcanic tertiary flakes ↑	Metavolcanic tertiary flakes↓	Yes
Conservation Predictions	None	Conserve MV, Q	Conserve Q	Conserve MV, Q	
Exhausted cores			Many	Many	Neutral
Flakes from exhausted cores	Few	Few	Few	Few	No
Flakes with bipolar attributes	No sig. differences	No sig. differences	No sig. differences	No sig. differences	No
Non-cortical shatter			MV↓, Quartzite no sig. difference	MV↑, Quartzite no sig. difference	Yes
Retouch				Potential increase in retouch intensity.	Yes

At SNI-106, some results point towards change over time in procurement strategies and others are more consistent unchanged strategies. The significant decrease in MV toolstone at 3500-15000 cal BP and the increase in this material at 1500-500 cal BP indicates reduced procurement opportunities during the later time period; however, a significant decrease in flakes from exhausted cores at that time supports the opposite conclusion. The lack of significant differences in flakes associated with flat and round reduction sequences and unchanged proportion of non-cortical shatter indicates unchanged boundary defense strategies. (Table 7.7). Overall, these results tentatively support an unchanged boundary defense strategy and the need for further research linking lithic procurement activities and territorial behavior.

Table 7.7. Results of lithic analyses for SNI-106.

	3500-1500 cal BP	1500-500 cal BP	Supports hypothesis?
Territoriality	Inland defense/Marine permeability	Marine defense/Inland permeability	
Sources	Inland areas/Beaches	Inland areas/Beaches	
Material Type Predictions	Some quartzite, sandstone, metavolcanic rock similar	Least quartzite, sandstone, metavolcanic rock similar	
Quartzite/Sandstone Weights	Sandstone rare, quarzite ↑	Sandstone rare, quartzite ↓	Yes
Quartzite/Sandstone Counts	Quartzite ↑	Quartzite ↓	Yes
Metavolcanic results	MV ↓	MV ↑	No
Cobble Shape Predictions	Flat/Round	Flat/Round	
Flake Types	No sig. differences between time period at 106, but more flat reduction sequence flakes than at Mound B.	No sig. differences	Yes
Processing prior to transport Predictions	All toolstone	All toolstone	
Results	No sig. differences	No sig. differences	Yes
Conservation Predictions	Conserve Q but not metavolcanic	Conserve Q but not metavolcanic	
Flakes from exhausted cores	↑	↓	No
Non-cortical shatter	No sig. differences	No sig. differences	Yes

Along with analyzing metavolcanic rock, I also consider shifts in access to quartzite and sandstone in the context of proposed shifts in territorial strategies. At both Mound B and SNI-

106, I predicted that access to these materials (which are more abundant in coastal cobble areas) would be most difficult at 1500-500 cal BP when villages near productive marine resource patches should aggressively defend their territories. Access to quartzite, sandstone, and other marine resources would have been negotiated with shoreline villages and therefore have exacted a higher cost than during periods when marine resources were more accessible. In considering material proportions by weight for Mound B, I found less quartzite and sandstone at 1500-500 cal BP than at 500 cal BP-Contact, although quartzite percentages were lowest during the preceding period at 3500-1500 cal BP. When considering material type by count, there were no significant differences between time periods (Table 7.6). At SNI-106, sandstone was rare both at 3500-1500 cal BP and 1500-500 cal BP. Proportions of quartzite were lower at 1500-500 cal BP both considering count and weight (Table 7.7). Thus at SNI-106, if preference or manufacturing strategies are not a factor, access to quartzite may have been more difficult when predicted during a time of marine territoriality. Detailed analysis of other marine resources at this site would be beneficial in isolating changes in the ways that people accessed coastal areas at 1500-500 cal BP. Likewise, lithic resources are important to separating environmental and social reasons for shifts in procurement because rocks are not affected by upwelling or sea surface temperature.

Finally, another aspect of my lithic analysis for San Nicolas Island was to determine whether shifts in boundary permeability through time at Mound B (sample size of extra-local material at SNI-106 was too small for this analysis) reflected my prediction for increased inter-group interactions at 1500-500 cal BP when terrestrial resources were scarce and marine resource were less accessible. During this period, communication and reciprocal access between inland groups would have yielded greater benefits than during times of resource abundance.

Movement across the inland landscape would also have been less difficult during this period.

Contrary to my predictions, I found no significant differences in chert or other rare lithic materials such as quartz during the later two time periods at Mound B (Table 7.8). There was a significantly higher proportion of chert at 5000-4000 cal BP when I predicted only moderate inter-group relationships to maintain marriage partners and information exchange. This could be a function of a small sample size. The proportion of quartz was highest at 3500-1500 cal BP when I predicted infrequent exchange. Due to small sample sizes and limited spatial information from Mound B, I was not able to reach definite conclusions about the intensity of formal of exchange on the island. Future research may focus on increasing the sample size of chert and quartz from throughout this site to determine the distribution of the material and change over time in proportions of rare toolstone through time.

Table 7.8. Results of boundary permeability analyses at Mound B and SNI-106.

	5000-4000 cal BP	3500-1500 cal BP	1500-500 cal BP	500 cal BP-Contact	Supports hypothesis?
Territoriality	defense/high permeability	defense/Marine permeability	defense/Inland permeability	defense/Marine permeability	
Exchange Predictions	Moderate, informal	Infrequent, formal	Frequent, Informal	Infrequent, formal	
Results Mound B	Chert ↑	Quartz ↑	No sig. diff.	No sig diff.	No
Result SNI-106		Quartz ↑, chert no sig. diff.	Chert no sig. diff.		No

The lithic procurement data for Mound B and SNI-106 are not consistent with my hypotheses for shifts in territorial behavior primarily determined by shifts in marine and terrestrial resource access. These results may indicate that communities on San Nicolas Island shared resource ownership and allowed full access throughout the Late Holocene. It is also possible that territoriality did not take place at the scale of the village, that millennial-scale climate change did not affect resource distribution on the ground, that the model may not be useful for accurately predicting territorial behavior, or that the data are not sensitive to shifts in territoriality.

Territoriality and Scale

One possibility in interpreting my primarily negative results is that boundary defense and resource ownership took place at a scale larger than the village. In discussing the defensive characteristics of archaeological sites above, I suggested several potential ways to test whether communities on the San Juan Islands or San Nicolas Island banded together to defend their land and resources against groups from other islands or the mainland. In testing my proposed alternative hypothesis, I also examined this issue of scale by examining whether resources belonged to kin who shared goods and resources across permanently permeable boundaries between family groups in different villages. I suggested that if different families shared access between groups, different spatial areas of archaeological sites should show differences in toolstone access. My preliminary results for the Watmough Bay site indicated that for the 1600-1000 cal BP period there may have been differences in use of FGV and slate in Spatial Unit 1 and 2 but there were no differences in processing or conservation activities. At Mound B, results of χ^2 tests comparing proportions of metavolcanic flakes and sandstone, chert, and quartz for the 500 cal BP-Contact assemblage indicate significantly higher proportions of sandstone, chert, and quartz in Spatial Unit 1 and quartzite in Spatial Unit 2 (Table 6.39). A comparison of tools from the two units also reveals significant differences, but toolstone distribution does not mirror the flake results.

To more fully explore household access to toolstone, it will be necessary to conduct more detailed analysis of households and household boundaries (e.g., Ames 1996, 2006; Ames et al.

1992; Arnold 2006; Arnold et al. 1997; Graesch 2000; Hayden 1997, 1998; Hayden et al. 1996; Lepofsky et al. 2009; Prentiss et al. 2008; Rick 2007). For both Watmough Bay and Mound B, it is possible that the two defined spatial areas are close enough together that they were actually part of the same household. Analysis of the stratigraphy of contemporaneous deposits dating to 1600-1000 cal BP at Watmough Bay does not indicate distinct and separate house features. The hearth found in the 2004 excavation unit EXU1 is likely far enough away that it represents a separate household or activity area from the Munsell units, but differences in collection strategies between the two excavations makes it difficult to compare between them. At Mound B, the areas of the site that are well-dated are relatively close to one another. A comparison of the Mound B artifacts with those from a contemporaneous residential area of Tule Creek at Mound A may be more appropriate for determining differences in access to toolstone based on household. At Mound B, households are difficult to identify due to an absence of distinct floor, wall, hearth, and post hole features. Further complicating the issue, for both sites families may extend beyond the confines of a house structure and members of different households may share resources with one another.

Another challenge of testing a permanent permeability hypothesis is that differences in material type ratios, original size and shape of cobbles, processing, and conservation may be attributable to differences in manufacturing activities, technological preferences, tool use, or other differences in household activities across the sites. To control for this possibility, it will be necessary to address the broader picture of resources procurement at the site. For Watmough Bay, shellfish and bird assemblages have been analyzed (Bovy 2005; 2007; Daniels 2009) but fish, mammal, and macrobotanical analyses have not been conducted. For Mound B, these analyses are in progress by the California State University, Los Angeles Archaeology

Laboratory. Because marine resources come from a distance from Tule Creek Village, differences in fish and shellfish assemblages would be particularly useful in determining if different families fished and collected shellfish on different beaches. To more rigorously test whether territoriality took place at a more regional scale, it may also be helpful to further investigate connections between sites by examining the distribution of extra-local toolstone at multiple sites on the landscape.

Climate Change and Resource Access

Another avenue for investigating the lack of congruence between my predictions and data is that the millennial-scale marine and terrestrial climate change data that I discuss in Chapter 2 may not have affected people at a local scale in the manner that I predicted. In other words, shifts in upwelling in the Gulf of Georgia may bring about a slight decrease in salmon and herring, but not enough to affect peoples' perceptions of subsistence resources and risk. A warmer and drier terrestrial climate on San Nicolas Island may decrease availability of freshwater but increases availability or distribution of other plant resources such as sagebrush and grasses used to make containers or scrub used for firewood (Thomas 1995). Another possibility is that during times of scarcity, resources were abundant in certain pockets of the landscape—where the salmon run remained adequate or where freshwater was always available, and these may have always been loci of boundary defense for the groups who lived nearby. Perhaps resources were always so patchy and unpredictable in these coastal settings that it made sense for kin and friends to ensure reciprocal access to nearby resource areas. Alternatively, fish, shellfish and small game may have always been so abundant that people did not feel the need to defend particular spots.

To address resource availability and distribution at a more local scale, I plan to synthesize published research from archaeological studies and site reports from both study areas to determine whether, when, and where marine and terrestrial resource were actually scarce on the ground. In particular, studies that provide data on resource depression of high-ranked prey (e.g., Daniels 2009) provide information on the degree to which people were affected by resource stress. Data that indicates active efforts to maintain a stable and sustainable resource base must also be part of the conversation about resource scarcity (Campbell and Butler 2010). As discussed above, ongoing research on faunal research at Mound B will provide invaluable information on subsistence strategies at that site. For both study areas, improved resolution of the paleoenvironmental record and the distribution of resources on the landscape will help in testing models that relate resource access to human behavior. Further study of ethnographic examples of boundary defense and permeability would also be helpful in redefining the expectations of the model.

Modeling Territorial Behavior

This study demonstrates both the utility and the shortcomings of a human behavioral ecology approach to articulate expectations for the behaviors of complex hunter-gatherer fishers groups that considers both the natural and cultural environment. Although human behavioral ecology models are more commonly applied to small egalitarian hunter-gatherers, they are also is increasingly applied to hunter-gatherers identified as “complex” in that they exhibit differences in economic, social, and political rank both within and between groups (e.g., Fitzhugh 2003; Kohler and Van West 1996; Neiman 1997; Prentiss and Kuijt 2004). Using human behavioral ecology models to create hypotheses about human territoriality allowed me to construct explicit and testable predictions for the archaeological record. One way to interpret my results is that people in both study areas maintained relatively permeable boundaries because they evaluated the costs and benefits of defending village boundaries in a manner that was not primarily defined by shifts in resource access but rather by considerations more purely in the social realm.

A human behavioral ecology model provides a good place to start in generating an explanation for the development of territoriality but may be inadequate for capturing the many unpredictable nuances of human decision making about who to exclude from a community, where to access resources, and with whom to share or exchange resources. Hill et al. (2009:188) note that humans show a capacity for cooperative and altruistic behavior with both kin and nonkin. In this light, it may be difficult to predict territoriality in the context of environmental change. A more inductive approach that incorporates and discusses possibilities for both competition and cooperation may allow me to examine patterns in the data on stone artifacts that I had not considered in generating predictions that focus on boundary defense. This approach would allow me to consider several possibilities for territorial behavior simultaneously, rather than emphasizing one primary hypothesis to test.

Data Sensitivity to Territorial Behavior

A final consideration in interpreting my results concerns the sensitivity of my data to shifts in boundary defense and permeability. Small sample sizes of extra-local materials for both the Watmough Bay and Mound B assemblages make addressing boundary permeability particularly problematic. There is also the problem of small sample sizes, particularly for the two earlier assemblages at Watmough Bay and Mound B and for the entire assemblage at SNI-106. Increasing the samples through more dating at Mound B to increase the 500 cal BP-Contact assemblage would be particularly useful in re-testing the hypotheses discussed here. For Watmough Bay, increasing the sample would be more difficult because all lithic artifacts were analyzed and most deposits were dated. Increasing the sample from the 600 cal BP-Contact period would require more excavation in the area of the 2003 excavation units where both older and younger deposits were found.

Another important consideration regarding data sensitivity is that although people may have maintained and defended boundaries surrounding food resources such as fishing areas or shellfish beds, they may not have done so with toolstone because it was so abundant both in the San Juan Islands and on San Nicolas Island. People may have tolerated the "theft" of toolstone when other groups came in their canoes or on foot to procure a load of cobbles. It is also possibly that although theft was not tolerated, people who lived near good sources of lithic raw material participated in exchange for other resources with groups. For these reasons, toolstone may not serve as a good proxy for territorial behaviors.

Utility of a Comparative Approach

A comparison of two study areas reveals intriguing similarities and differences in the ways that people procured cobbles and where and how they flaked the cobbles to create tools. In the San Juan Islands case study, people chose angular cobbles of a specific size to make their tools. The most likely scenario is that they piled cobbles in their watercraft, perhaps along with other supplies, and brought them to the site with minimal testing or early stage reduction prior to transport. They do not appear to have emphasized toolstone conservation given the high ratio of cores to flakes at the site and the scarcity of bipolar shatter. Cores were reduced with minimal preparation and in many cases, the desired tool was created by removing a large flake from the core and then using it for a scraping or cutting task.

On San Nicolas Island, people would have had to carry toolstone from cobble areas on beaches and blowouts across the island back to the site. The low proportion of primary flakes compared to later stage flakes may reflect testing and early stage reduction prior to transport reflecting higher transport costs than on the San Juan Islands. Similar to the other case study, most cores were prepared minimally although patterned cores are somewhat more common for the Mound B assemblage. Many flakes struck from the cores were considered waste products but many others were used without further modification. Unlike the scaled pieces from the Watmough Bay assemblage, the used flakes from Mound B show less visible wear. Some flakes show signs of edge damage but it is difficult to link that damage to use. The metavolcanic toolstone from Mound B is slightly harder than the FGV at Watmough Bay. In both cases, the skill with which the toolmakers reduced cores and created flake tools demonstrates that the "expedient" technology that they relied on involved not only physical strength, but also foresight and planning.

During collection, there would have been more uncertainty regarding toolstone quality on San Nicolas Island than on the San Juan Islands because the San Nicolas Island cobbles vary more in hardness and in grainsize. It would have been difficult to determine type of toolstone for the cortex alone, although experienced collectors were probably able to use subtle visual clues to determine quality. In both study areas, it would have been easier to split the cobbles on the beach because of availability of natural rock anvils and hammers that would have been heavy to bring up to the sites, and because of the strenuous activity and disturbance created by these activities.

Implications for Social Complexity Studies

A study of territorial adaptations on the Pacific Coast that indicates potential for high levels of boundary permeability through time could provide new insights on complex hunter-gatherers and explanations for the emergences of social complexity on both the Northwest Coast and in the Channel Islands. Further research is required for me to draw that conclusion for either study areas; however, the lack of clear indication of village boundary defense during time periods when other signs of social complexity occur may provide insights for cooperation-focused models. In contrast to Pacific Coast complexity models that emphasize competition (e.g., Matson 1983, 1985; Matson and Coupland 1995; Raab and Larson (1997), some models explore the ramifications of different forms of cooperation within and between villages. For example, Lepofsky et al. (2005) provide a cooperation-focused model in which regional differences in resource availability due to the warmer and drier Fraser Valley Fire Period spurred social interactions between Gulf of Georgia villages to maintain access to the relatively rich Fraser Valley during a time of scarcity. Families with access to Fraser Valley kin saw a rise in social and economic status. Similarly, for the Channel Islands, Kennett and Kennet's (2000) research on both competitive and cooperative responses to climate change in the Northern Channel Islands indicates more cooperative strategies after 650 cal BP as marine productivity increased and terrestrial food and water availability decreased.

Relevance to Contemporary Issues

Research on boundary defense and permeability has broader implications for modern studies about conflict in the context of resource scarcity and human response to climate change in general. With more development, my research may support arguments by political ecologists that resource scarcity does not necessarily lead to conflict. Although earlier political ecology research assumed scarcity and conflict to be linked, especially with regard to water (Huth 1996; Vasquez 1993), researchers increasingly find that people use ingenuity and inter-group cooperation to deal with difficulties in accessing water (Toset et al. 2000). They may also move away, attempt to use other resources, begin new forms of cooperation (Ostrom 1990; O'Lear 2005; Ostrom et al. 1994), and management of resources (Thompson and Price 2002). Facing increased resource unpredictability due to global climate change, political ecologists may be able to draw on archaeological examples of sustained cooperative relationships through periods of environmental upheaval to understand when, how, and why people share resources across boundaries.

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Appendix A. Defensive characteristics for sites on the San Juan Islands, Washington.

Site 45SJ#	**Landform**	**Size**	**Time range occupied (cal BP)**	**Degrees visibility**	**Degrees visibility/ degrees approach**	**Distance to lookout (m) (vis. >180 degrees)**	**Elev. difference (site interior to exterior) (m)**	**Site radius (m)**	**arctan radians**	**Elevation (arctan degrees/90)**
1.00	Sloping bluff	Big	2500-1000	70	0.19	300	12	50	0.24	0.15
2.00	Lagoon and spit	Big	2500-1600	153	0.43	700	2	40	0.05	0.03
3A	Lagoon and spit	Small	2500-1600	170	0.65	500	2	10	0.20	0.13
3C	Lagoon and spit	Small	600-0	180	0.72	300	1	5	0.20	0.13
6.00	Lagoon and spit	Small	600-0	200	0.63	200	3	10	0.29	0.19
9.00	Beach	Big	600-0	130	0.36	400	5	20	0.24	0.16
23.00	Beach	Small	1600-1000	80	0.22	200	2	5	0.38	0.24
24A	Beach	Big	1600-0	130	0.36	200	5	10	0.46	0.30
24D	Inland area	Big	2500-1000	180	0.50	300	12	30	0.38	0.24
26.00	Beach	Small	600-0	130	0.36	300	2	2	0.79	0.50
27.00	Beach	Small	600-0	160	0.44	600	3	5	0.54	0.34
47.00	Beach	Small	600-0	70	0.19	150	1	10	0.10	0.06
60.00	Beach	Small	600-0	60	0.17	250	3	2	0.98	0.63
61.00	Bluff over beach	Small	600-0	90	0.25	250	6	15	0.38	0.24
70.00	Bluff over beach	Small	2500-1600, 600-0	200	0.56	0	6	40	0.15	0.09
71.00	Beach	Small	600-0	200	0.56	0	1	10	0.10	0.06
72.00	Beach	Small	600-0	220	0.61	0	2	5	0.38	0.24
89.00	Beach	Small	600-0	180	0.50	3000	2	10	0.20	0.13
95.00	Beach	Small	600-0	160	0.44	800	5	10	0.46	0.30
105.00	Isthmus	Big	2500-1600, 600-0	150	0.42	400	4	10	0.38	0.24
120.00	Beach	Small	600-0	220	0.61	0	6	25	0.24	0.15
124.00	Tombolo	Small	600-0	200	1.00	0	2	25	0.08	0.05
147.00	Bedrock Point	Small	600-0	220	0.61	0	2	15	0.13	0.08
150.00	Beach	Small	600-0	120	0.33	500	3	10	0.29	0.19
165.00	Beach	Big	3500-2500, 1600-1000	160	0.44	1000	12	30	0.38	0.24
169.00	Tombolo and lagoon	Big	2500-1600, 600-0	180	0.50	600	10	40	0.24	0.16
201.00	Beach	Small	600-0	240	0.67	0	3	5	0.54	0.34
202.00	Beach	Small	600-0	270	0.75	0	6	50	0.12	0.08
225.00	Point	Small	600-0	170	0.47	450	6	20	0.29	0.19

Appendix A, continued. Defensive characteristics for sites on the San Juan Islands, Washington.

Site 45SJ#	Landform	Size	Time range occupied (cal BP)	Degrees visibility	Degrees visibility/ degrees approach	Distance to lookout (m) (vis. >180 degrees)	Elev. difference (site interior to exterior) (m)	Site radius (m)	arctan radians	Elevation (arctan degrees/90)
239.00	Beach	Small	1600-1000	130	0.36	200	3	5	0.54	0.34
251.00	Beach	Small	600-0	240	0.63	0	6	10	0.54	0.34
254.00	Beach	Big	1600-0	180	0.50	700	6	100	0.06	0.04
274.00	Spit	Big	1600-0	150	0.57	600	3	10	0.29	0.19
277.00	Beach	Small	600-0	170	0.47	500	2	10	0.20	0.13
278.00	Beach	Big	3500-0	180	0.50	800	3	10	0.29	0.19
279.00	Beach	Big	1600-0	180	0.50	1200	3	20	0.15	0.09
280.00	Beach	Big	3500-0	50	0.19	600	2	10	0.20	0.13
282.00	Point	Small	1600-0	260	0.72	0	6	40	0.15	0.09
307.00	Beach	Small	600-0	150	0.42	300	12	30	0.38	0.24
324.00	Beach	Small	600-0	50	0.14	150	5	5	0.79	0.50
364.00	Beach	Small	600-0	130	0.36	1800	2	10	0.20	0.13
407.00	Lagoon and spit	Small	2500-1600	130	0.36	650	5	3	1.03	0.66
450.00	Tombolo	Small	1600-0	100	0.67	100	3	10	0.29	0.19
451.00	Beach	Small	600-0	80	0.22	100	2	5	0.38	0.24
453.00	Bluff over beach	Small	600-0	180	0.50	600	6	5	0.88	0.56
460.00	Beach	Small	600-0	120	0.33	50	5	5	0.79	0.50
461.00	Beach	Small	600-0	90	0.25	100	3	10	0.29	0.19
481.00	Beach	Small	600-0	70	0.24	60	3	10	0.29	0.19
483.00	Beach/ inland area	Big	600-0	170	0.47	150	12	50	0.24	0.15
507.00	Beach	Small	600-0	60	0.17	250	3	5	0.54	0.34
509.00	Beach	Small	600-0	100	0.28	200	2	5	0.38	0.24

Appendix B. Defensive characteristics for sites on San Nicolas Island, California.

Site CASNI#	**Landform**	**Type**	**Elev. Change**	**Distance to water Lookout (> 180 degrees over water) (m)**	**Time range (cal BP)**	**Elevation difference (interior to exterior of site) (m)**	**Site radius (m)**	**arctan (radians)**	**Elevation (arctan degrees/90)**
5	Coastal Plain	Residential	50	0.5	1500-500	50	100	0.46	0.30
6	Coastal Plain	Camp	5	0.6	1500-500	5	50	0.10	0.06
8	Coastal Plain	Residential	25	0.1	5000-3000	25	100	0.24	0.16
11	Coastal Plain	Residential	50	0	5000-3000, 3000-500, 500-0	50	100	0.46	0.30
14	Coastal Plain	Residential	25	0.9	5000-3000	25	100	0.24	0.16
15	Coastal Plain	Residential	50	0.3	>5000	50	50	0.79	0.50
16	Coastal Plain	Residential	75	0.3	5000-3000	75	250	0.29	0.19
18	Coastal Plain	Residential	75	0.9	500-0	75	150	0.46	0.30
21	Slope	Residential	5	1.8	5000-3000, 1500-500	5	50	0.10	0.06
25	Plateau	Residential	75	1.9	5000-3000, 3000-500, 500-0	75	150	0.46	0.30
38	Coastal Plain	Residential	5	0.7	1500-500	5	25	0.20	0.13
39	Coastal Plain	Residential	50	1	3000-0	50	150	0.32	0.20
40	Slope	Residential	25	1.5	5000-3000	25	50	0.46	0.30
41	Coastal Plain	Residential	50	0.5	>5000	50	75	0.59	0.37
43	Slope	Residential	25	3.5	5000-3000, 3000-500, 500-0	25	100	0.24	0.16
51	Slope	Residential	125	0.5	3000-1500	125	175	0.62	0.39
56	Coastal Plain	Residential	75	2.3	5000-3000	75	200	0.36	0.23
72	Coastal Plain	Camp	5	0.5	3000-1500	5	50	0.10	0.06
73	Coastal Plain	Residential	5	0.4	1500-500	5	75	0.07	0.04
74	Coastal Plain	Residential	5	0.15	3000-1500	5	50	0.10	0.06
76	Coastal Plain	Fishing, small	5	0.7	500-0	5	25	0.20	0.13
79	Plateau	Residential	5	2	1500-500	5	50	0.10	0.06
84	Plateau	Stone artifact manufacture/shellfish processing	5	3	1500-500	5	12.5	0.38	0.24
102	Plateau	Camp	5	2.1	3000-1500	5	50	0.10	0.06
105	Plateau	Camp	25	2.5	5000-3000, 3000-1500	25	150	0.17	0.11
106	Plateau	Residential	25	2.8	3000-1500	25	100	0.24	0.16
117	Slope	Shellfish processing	75	0.7	3000-1500	75	100	0.64	0.41
129	Coastal Plain	Multi-use	25	0.6	1500-500	25	50	0.46	0.30
130	Coastal Plain	Camp	5	0.9	3000-1500	5	50	0.10	0.06
131	Coastal Plain	Camp	5	0.4	5000-3000, 1500-500	5	50	0.10	0.06

Appendix B, continued. Defensive characteristics for sites on San Nicolas Island, California.

Site CASNI#	Landform	Type	Elev. Change	Distance to water Lookout (> 180 degrees over water) (m)	Time range (cal BP)	Elevation difference (interior to exterior of site) (m)	Site radius (m)	arctan (radians)	Elevation (arctan degrees/90)
147	Coastal Plain	Fishing camp	5	1	3000-1500	5	25	0.20	0.13
157	Slope	Residential	25	1.3	5000-3000	25	150	0.17	0.11
160	Coastal Plain	Residential	50	1.4	1500-500	50	250	0.20	0.13
161	Coastal Plain	Residential	25	0.95	5000-3000, 3000-1500	25	50	0.46	0.30
162	Slope	Small shell midden	5	0.5	1500-500	5	50	0.10	0.06
163	Coastal Plain	Fishing camp	5	0.6	1500-500	5	50	0.10	0.06
164	Slope	Shell midden	25	0.9	5000-3000	25	50	0.46	0.30
165	Slope	Residential	25	0.7	5000-3000	25	25	0.79	0.50
168	Slope	Residential	50	0.7	5000-3000, 3000-500, 500-0	50	200	0.24	0.16
169	Slope	Camp	5	0.9	5000-3000, 3000-1500	5	12.5	0.38	0.24
170	Slope	Stone artifact manufacture and shellfish processing	5	0.9	5000-3000	5	50	0.10	0.06
171	Slope	Residential	5	1.3	5000-3000, 3000-1500	5	50	0.10	0.06
184	Coastal Plain	Residential	5	0.5	500-0	5	50	0.10	0.06
204	Slope	Camp	75	1.8	3000-1500	75	150	0.46	0.30
214	Plateau	Residential	5	2.2	500-0	5	500	0.01	0.01
238	Coastal Plain	Fishing camp	5	1.6	3000-1500	5	25	0.20	0.13
284	Slope	Multi-use	5	2.1	5000-3000	5	25	0.20	0.13
290	Plateau	Multi-use	5	2.1	1500-500	5	12.5	0.38	0.24
315	Slope	Shellfish processing	5	0.5	500-0	5	12.5	0.38	0.24
316	Plateau	Multi-use processing	5	1.1	5000-3000	5	25	0.20	0.13
323	Coastal Plain	Residential	25	0.4	500-0	25	25	0.79	0.50
328	Coastal Plain	Residential	5	0.3	1500-500	5	6.25	0.67	0.43
329	Coastal Plain	Multi-use	5	0.4	500-0	5	25	0.20	0.13
339	Slope	Residential	25	0.5	>5000, 1500-500, 500-0	25	50	0.46	0.30
340	Coastal Plain	Camp	5	0.4	500-0	5	50	0.10	0.06
342	Coastal Plain	Multi-use	5	0.6	1500-500	5	50	0.10	0.06
346	Plateau	Shellfish processing	25	1.8	1500-0	25	25	0.79	0.50
347	Plateau	Shellfish processing	5	1.7	5000-3000	5	12.5	0.38	0.24
351	Plateau	Residential	5	2.6	>5000, 3000-0	5	150	0.03	0.02
361	Plateau	Multi-use	5	0.8	3000-1500	5	25	0.20	0.13

Appendix C. Zirconium and strontium concentrations (ppm) for archaeological and geological samples of fine-grained volcanic rock from the San Juan Islands, WA.

Site	**No.**	**Catalog No.**	**Specimen Type**	**Zr (ppm)**	**±**	**Sr (ppm)**	**±**	**Source**
Watts Point Quarry	50	1621-1	Geological	121	8	773	12	Watts Point
Watts Point Quarry	51	1621-2	Geological	121	8	753	12	Watts Point
Watts Point Quarry	52	1621-3	Geological	120	8	719	12	Watts Point
Watts Point Quarry	53	1621-4	Geological	123	8	753	11	Watts Point
Porteau Cove	32	1616-1	Geological	149	8	824	12	Watts Point
Porteau Cove	33	1616-2	Geological	152	8	855	12	Watts Point
Porteau Cove	34	1616-3	Geological	153	8	1030	12	Unknown
Lighthouse Beach	35	1617-1	Geological	140	8	834	12	Watts Point
Lighthouse Beach	36	1617-2	Geological	148	8	918	12	Watts Point
Lighthouse Beach	38	1617-3	Geological	144	8	786	12	Watts Point
Horseshoe Bay Ferry Beach	39	1618-1	Geological	126	8	745	12	Watts Point
Horseshoe Bay Ferry Beach	40	1618-2	Geological	126	8	787	11	Watts Point
Whytecliffe Park	41	1619-1	Geological	129	8	767	12	Watts Point
Whytecliffe Park	42	1619-2	Geological	121	8	754	11	Watts Point
Whytecliffe Park	43	1619-3	Geological	125	8	758	12	Watts Point
Murrin Park	44	1620-1	Geological	140	8	860	12	Watts Point
Murrin Park	45	1620-2	Geological	129	8	795	12	Watts Point
Murrin Park	46	1620-3	Geological	126	8	728	12	Watts Point
Murrin Park	47	1620-4	Geological	130	8	819	12	Watts Point
Murrin Park	48	1620-5	Geological	116	8	708	12	Watts Point
Murrin Park	49	1620-6	Geological	123	8	752	12	Watts Point
Boulder Creek	55	1623-1	Geological	50	8	424	11	Unknown
Boulder Creek	56	1623-2	Geological	58	8	1050	12	Unknown
Watmough Bay	23	1726-1	Geological	127	7	621	9	Watts Point
Watmough Bay	24	1726-2	Geological	137	7	668	9	Watts Point
Watmough Bay	25	1726-3	Geological	124	7	698	10	Watts Point
Watmough Bay	26	1726-4	Geological	128	7	660	10	Watts Point
Watmough Bay	27	1726-5	Geological	127	7	681	10	Watts Point
Watmough Bay	28	1726-6	Geological	132	7	732	9	Watts Point
Watmough Bay	29	1726-7	Geological	126	7	681	10	Watts Point
Watmough Bay	30	1726-8	Geological	157	7	426	9	Unknown
Watmough Bay	31	1726-9	Geological	126	7	656	9	Watts Point
Watmough Bay	32	1726-10	Geological	133	7	742	10	Watts Point
Watmough Bay	33	1727-1	Geological	135	7	701	9	Watts Point
Agate Beach	34	1727-2	Geological	125	7	663	10	Watts Point
Agate Beach	35	1727-3	Geological	128	7	737	10	Watts Point
Agate Beach	36	1727-4	Geological	129	7	664	9	Watts Point
Agate Beach	37	1727-5	Geological	121	7	751	10	Watts Point
Agate Beach	38	1727-6	Geological	128	7	681	10	Watts Point
Agate Beach	39	1727-7	Geological	122	7	698	10	Watts Point
Agate Beach	40	1727-8	Geological	123	7	639	9	Watts Point
Agate Beach	41	1727-9	Geological	125	7	666	9	Watts Point
Agate Beach	42	1727-10	Geological	124	7	778	10	Watts Point
Agate Beach	43	1727-11	Geological	126	7	711	10	Watts Point
Agate Beach	44	1727-12	Geological	126	7	746	10	Watts Point

Appendix C, continued. Zirconium and strontium concentrations (ppm) for archaeological and geological samples of fine-grained volcanic rock from the San Juan Islands, WA.

Site	No.	Catalog No.	Specimen Type	Zr (ppm)	±	Sr (ppm)	±	Source
Agate Beach	45	1727-13	Geological	138	7	730	10	Watts Point
Agate Beach	46	1727-14	Geological	162	7	766	10	Watts Point
Agate Beach	47	1727-15	Geological	135	7	723	10	Watts Point
Agate Beach	48	1727-16	Geological	132	7	688	10	Watts Point
Agate Beach	49	1727-17	Geological	126	7	648	9	Watts Point
Agate Beach	50	1727-18	Geological	129	7	676	9	Watts Point
Agate Beach	51	1727-19	Geological	121	7	695	10	Watts Point
Agate Beach	52	1727-20	Geological	131	7	645	9	Watts Point
Agate Beach	53	1727-21	Geological	152	7	60	9	Unknown
Agate Beach	54	1727-22	Geological	124	7	660	9	Watts Point
Agate Beach	55	1727-23	Geological	124	7	705	10	Watts Point
Agate Beach	56	1727-24	Geological	125	7	666	9	Watts Point
Agate Beach	57	1727-25	Geological	131	7	685	9	Watts Point
Agate Beach	58	1727-26	Geological	97	7	626	9	Unknown
Agate Beach	59	1727-27	Geological	111	7	874	10	Unknown
Agate Beach	60	1727-28	Geological	125	7	645	9	Watts Point
Agate Beach	61	1727-29	Geological	125	7	693	9	Watts Point
Agate Beach	62	1727-30	Geological	121	7	629	9	Watts Point
False Bay	13	1725-1	Geological	108	7	149	9	Unknown
False Bay	14	1725-2	Geological	123	7	357	9	Unknown
False Bay	15	1725-3	Geological	142	7	854	10	Watts Point
False Bay	16	1725-4	Geological	138	7	683	9	Watts Point
False Bay	17	1725-5	Geological	123	7	645	9	Watts Point
False Bay	18	1725-6	Geological	136	7	702	9	Watts Point
False Bay	19	1725-7	Geological	135	7	660	9	Watts Point
False Bay	20	1725-8	Geological	135	7	644	10	Watts Point
False Bay	21	1725-9	Geological	138	7	767	10	Watts Point
False Bay	22	1725-10	Geological	135	7	687	10	Watts Point
False Bay	31	FalseBay.s.18	Geological	117	7	222	9	Unknown
False Bay	32	FalseBay.s.19	Geological	141	7	705	9	Watts Point
False Bay	33	FalseBay.s.20	Geological	136	7	684	9	Watts Point
False Bay	34	FalseBay.1.20-30.1	Geological	92	7	655	9	Unknown
False Bay	35	FalseBay.1.20-30.2	Geological	43	7	38	9	Unknown
False Bay	36	FalseBay.1.30-85.1	Geological	109	7	359	9	Unknown
False Bay	37	FalseBay.1.85-140.1	Geological	87	7	60	9	Unknown
False Bay	38	FalseBay.2.0-20.1	Geological	95	7	410	9	Unknown
False Bay	39	FalseBay.2.0-20.2	Geological	70	7	92	9	Unknown
False Bay	40	FalseBay.2.30-50.1	Geological	117	7	355	9	Unknown
False Bay	16	FalseBay.s.3	Geological	130	7	702	9	Watts Point
False Bay	17	FalseBay.s.4	Geological	124	7	695	10	Watts Point
False Bay	18	FalseBay.s.5	Geological	136	7	721	9	Watts Point
False Bay	19	FalseBay.s.6	Geological	131	7	682	9	Watts Point
False Bay	20	FalseBay.s.7	Geological	133	7	692	9	Watts Point
False Bay	21	FalseBay.s.8	Geological	136	7	674	9	Watts Point
False Bay	22	FalseBay.s.9	Geological	134	7	702	9	Watts Point

Appendix C, continued. Zirconium and strontium concentrations (ppm) for archaeological and geological samples of fine-grained volcanic rock from the San Juan Islands, WA.

Site	**No.**	**Catalog No.**	**Specimen Type**	**Zr (ppm)**	**±**	**Sr (ppm)**	**±**	**Source**
False Bay	23	FalseBay.s.10	Geological	130	7	650	9	Watts Point
False Bay	24	FalseBay.s.11	Geological	119	7	680	10	Watts Point
False Bay	25	FalseBay.s.12	Geological	131	7	660	9	Watts Point
False Bay	26	FalseBay.s.13	Geological	129	7	664	9	Watts Point
False Bay	27	FalseBay.s.14	Geological	124	7	677	9	Watts Point
False Bay	28	FalseBay.s.15	Geological	122	7	644	9	Watts Point
False Bay	29	FalseBay.s.16	Geological	129	7	644	10	Watts Point
False Bay	30	FalseBay.s.17	Geological	123	7	681	10	Watts Point
False Bay	14	FalseBay.s.1	Geological	118	7	623	10	Watts Point
False Bay	15	FalseBay.s.2	Geological	127	7	750	10	Watts Point
Blind Bay	1	Deane.1.20-35.1	Geological	130	7	753	9	Watts Point
Blind Bay	2	Deane.1.35-50.1	Geological	71	7	150	9	Unknown
Blind Bay	3	Deane.1.50-60.1	Geological	43	7	37	9	Unknown
Blind Bay	4	Deane.1.50-60.2	Geological	124	7	165	9	Unknown
Blind Bay	5	Deane.1.50-60.3	Geological	66	7	130	9	Unknown
Blind Bay	6	Deane.2.0-20.1	Geological	133	7	209	9	Unknown
Blind Bay	7	Deane.2.60-70.1	Geological	112	7	240	9	Unknown
Blind Bay	8	Deane.2.60-70.2	Geological	105	7	229	9	Unknown
Blind Bay	9	Deane.2.60-70.3	Geological	178	7	162	9	Unknown
Deadman's Cove	10	Deadman.s.1	Geological	128	7	750	10	Watts Point
Deadman's Cove	11	Deadman.s.2	Geological	140	7	899	10	Unknown
Deadman's Cove	12	Deadman.s.3	Geological	113	7	1242	10	Unknown
Schoen Beach	57	1624-1	Geological	126	8	674	11	Watts Point
Schoen Beach	58	1624-2	Geological	128	8	768	11	Watts Point
Double Bluff	59	1625-1	Geological	213	8	522	11	Unknown
Quartermaster Harbor	54	1622-1	Geological	149	8	259	11	Unknown
Dungeness Spit	13	Dungeness.s.1	Geological	49	7	270	9	Unknown
English Camp (45-SJ-124)	1	SAJH 4231	Artifact	135	7	687	10	Watts Point
English Camp (45-SJ-124)	2	SAJH 42951	Artifact	136	7	664	9	Watts Point
English Camp (45-SJ-124)	3	SAJH 43001	Artifact	134	7	663	9	Watts Point
English Camp (45-SJ-124)	4	SAJH 43103	Artifact	132	7	657	9	Watts Point
English Camp (45-SJ-124)	5	SAJH 43126	Artifact	135	7	654	9	Watts Point
English Camp (45-SJ-124)	6	SAJH 43138	Artifact	125	7	648	9	Watts Point
English Camp (45-SJ-124)	7	SAJH 104523	Artifact	126	7	711	9	Watts Point
English Camp (45-SJ-124)	8	SAJH 104654	Artifact	123	7	618	9	Watts Point
English Camp (45-SJ-124)	9	SAJH 104708	Artifact	128	7	659	9	Watts Point
English Camp (45-SJ-124)	10	SAJH 104709	Artifact	129	7	655	9	Watts Point
English Camp (45-SJ-124)	11	SAJH 104776	Artifact	127	7	663	9	Watts Point
English Camp (45-SJ-124)	12	SAJH 104782	Artifact	129	7	779	10	Watts Point
English Camp (45-SJ-124)	13	SAJH 104783	Artifact	128	7	692	10	Watts Point
English Camp (45-SJ-124)	14	SAJH 104805	Artifact	116	7	677	10	Watts Point
English Camp (45-SJ-124)	15	SAJH 104812	Artifact	123	7	648	9	Watts Point
English Camp (45-SJ-124)	16	SAJH 104869	Artifact	109	7	1138	10	Unknown
English Camp (45-SJ-124)	17	SAJH 104870	Artifact	143	7	946	10	Unknown
English Camp (45-SJ-124)	18	SAJH 104871	Artifact	132	7	693	9	Watts Point

Appendix C, continued. Zirconium and strontium concentrations (ppm) for archaeological and geological samples of fine-grained volcanic rock from the San Juan Islands, WA.

Site	**No.**	**Catalog No.**	**Specimen Type**	**Zr (ppm)**	**±**	**Sr (ppm)**	**±**	**Source**
English Camp (45-SJ-124)	19	SAJH 104895	Artifact	128	7	707	9	Watts Point
English Camp (45-SJ-124)	20	SAJH 104905	Artifact	130	7	671	9	Watts Point
English Camp (45-SJ-124)	21	SAJH 104906	Artifact	130	7	790	10	Watts Point
English Camp (45-SJ-124)	22	SAJH 104909	Artifact	136	7	727	9	Watts Point
English Camp (45-SJ-124)	23	SAJH 104910	Artifact	133	7	664	10	Watts Point
English Camp (45-SJ-124)	24	SAJH 104938	Artifact	129	7	677	9	Watts Point
English Camp (45-SJ-124)	25	SAJH 104975	Artifact	124	7	659	9	Watts Point
English Camp (45-SJ-124)	26	SAJH 125816	Artifact	125	7	771	9	Watts Point
English Camp (45-SJ-124)	27	SAJH 125901	Artifact	87	7	413	9	Unknown
English Camp (45-SJ-124)	28	SAJH 125902a	Artifact	131	7	692	9	Watts Point
English Camp (45-SJ-124)	29	SAJH 125902b	Artifact	128	7	672	9	Watts Point
English Camp (45-SJ-124)	30	SAJH 125928	Artifact	123	7	641	9	Watts Point
Deane Site (45-SJ-150)	1	3	Artifact	134	7	694	9	Watts Point
Deane Site (45-SJ-150)	2	16	Artifact	127	7	267	9	Unknown
Deane Site (45-SJ-150)	3	19	Artifact	127	7	746	10	Watts Point
Deane Site (45-SJ-150)	4	34	Artifact	122	7	673	10	Watts Point
Deane Site (45-SJ-150)	5	45	Artifact	121	7	662	10	Watts Point
Deane Site (45-SJ-150)	6	51	Artifact	124	7	704	9	Watts Point
Deane Site (45-SJ-150)	7	69	Artifact	127	7	699	10	Watts Point
Deane Site (45-SJ-150)	8	75	Artifact	125	7	686	9	Watts Point
Deane Site (45-SJ-150)	9	77	Artifact	137	7	749	9	Watts Point
Deane Site (45-SJ-150)	10	86	Artifact	130	7	658	9	Watts Point
Deane Site (45-SJ-150)	11	101	Artifact	127	7	655	9	Watts Point
Deane Site (45-SJ-150)	12	120	Artifact	127	7	655	9	Watts Point
Deane Site (45-SJ-150)	13	136	Artifact	129	7	677	9	Watts Point
Deane Site (45-SJ-150)	51	SJ150.32	Artifact	144	7	724	10	Watts Point
Deane Site (45-SJ-150)	52	SJ150.27	Artifact	129	7	667	9	Watts Point
Deane Site (45-SJ-150)	53	SJ150.33	Artifact	129	7	649	9	Watts Point
Deane Site (45-SJ-150)	54	SJ150.134	Artifact	134	7	707	9	Watts Point
Deane Site (45-SJ-150)	55	SJ150.105	Artifact	131	7	694	9	Watts Point
Deane Site (45-SJ-150)	56	SJ150.105	Artifact	127	7	722	10	Watts Point
Deane Site (45-SJ-150)	57	SJ150.92	Artifact	133	7	711	10	Watts Point
Watmough Bay (45-SJ-280)	1	1	Artifact	150	8	742	11	Watts Point
Watmough Bay (45-SJ-280)	2	2	Artifact	145	8	671	12	Watts Point
Watmough Bay (45-SJ-280)	3	3	Artifact	151	8	836	12	Watts Point
Watmough Bay (45-SJ-280)	4	4	Artifact	144	8	733	11	Watts Point
Watmough Bay (45-SJ-280)	5	5	Artifact	144	8	722	11	Watts Point
Watmough Bay (45-SJ-280)	6	6	Artifact	141	8	742	11	Watts Point
Watmough Bay (45-SJ-280)	7	7	Artifact	138	8	679	11	Watts Point
Watmough Bay (45-SJ-280)	8	8	Artifact	140	8	696	11	Watts Point
Watmough Bay (45-SJ-280)	9	9	Artifact	118	8	731	11	Watts Point
Watmough Bay (45-SJ-280)	10	10	Artifact	132	8	803	11	Watts Point
Watmough Bay (45-SJ-280)	11	11	Artifact	135	8	661	11	Watts Point
Watmough Bay (45-SJ-280)	12	12	Artifact	143	8	744	11	Watts Point
Watmough Bay (45-SJ-280)	13	13	Artifact	144	8	736	11	Watts Point

Appendix C, continued. Zirconium and strontium concentrations (ppm) for archaeological and geological samples of fine-grained volcanic rock from the San Juan Islands, WA.

Site	**No.**	**Catalog No.**	**Specimen Type**	**Zr (ppm)**	**±**	**Sr (ppm)**	**±**	**Source**
Watmough Bay (45-SJ-280)	42	LB88/3	Artifact	122	7	665	9	Watts Point
Watmough Bay (45-SJ-280)	43	LB88/4	Artifact	114	7	629	9	Watts Point
Watmough Bay (45-SJ-280)	44	LB88/5	Artifact	123	7	655	9	Watts Point
Watmough Bay (45-SJ-280)	45	LB88/6	Artifact	125	7	667	9	Watts Point
Watmough Bay (45-SJ-280)	46	LB88/7	Artifact	73	7	183	9	Unknown
Watmough Bay (45-SJ-280)	47	LB88/8	Artifact	123	7	673	10	Watts Point
Watmough Bay (45-SJ-280)	48	LB88/9	Artifact	123	7	720	10	Watts Point
Watmough Bay (45-SJ-280)	49	LB88/10	Artifact	122	7	638	9	Watts Point
Watmough Bay (45-SJ-280)	50	SJ150.80	Artifact	123	7	764	9	Watts Point
Watmough Bay (45-SJ-280)	14	14	Artifact	143	8	725	11	Watts Point
Watmough Bay (45-SJ-280)	15	15	Artifact	139	8	714	11	Watts Point
Watmough Bay (45-SJ-280)	16	16	Artifact	129	8	763	11	Watts Point
Watmough Bay (45-SJ-280)	17	17	Artifact	144	8	745	11	Watts Point
Watmough Bay (45-SJ-280)	18	18	Artifact	135	8	672	12	Watts Point
Watmough Bay (45-SJ-280)	19	19	Artifact	139	8	673	11	Watts Point
Watmough Bay (45-SJ-280)	20	20	Artifact	266	8	176	11	Unknown
Watmough Bay (45-SJ-280)	21	21	Artifact	149	8	733	11	Watts Point
Watmough Bay (45-SJ-280)	22	22	Artifact	127	8	795	12	Watts Point
Watmough Bay (45-SJ-280)	23	23	Artifact	125	8	719	11	Watts Point
Watmough Bay (45-SJ-280)	24	24	Artifact	142	8	725	11	Watts Point
Watmough Bay (45-SJ-280)	25	25	Artifact	136	8	692	11	Watts Point
Watmough Bay (45-SJ-280)	26	26	Artifact	120	8	699	11	Watts Point
Watmough Bay (45-SJ-280)	27	27	Artifact	138	8	697	11	Watts Point
Watmough Bay (45-SJ-280)	28	28	Artifact	147	8	878	12	Watts Point
Watmough Bay (45-SJ-280)	29	29	Artifact	137	8	740	11	Watts Point
Watmough Bay (45-SJ-280)	30	30	Artifact	122	8	751	12	Watts Point
Watmough Bay (45-SJ-280)	31	LB94/4	Artifact	123	7	642	9	Watts Point
Watmough Bay (45-SJ-280)	32	LB94/5	Artifact	141	7	900	10	Unknown
Watmough Bay (45-SJ-280)	33	LB94/6	Artifact	130	7	739	10	Watts Point
Watmough Bay (45-SJ-280)	34	LB94/7	Artifact	130	7	684	9	Watts Point
Watmough Bay (45-SJ-280)	35	LB94/8	Artifact	127	7	678	9	Watts Point
Watmough Bay (45-SJ-280)	36	LB94/9	Artifact	128	7	679	9	Watts Point
Watmough Bay (45-SJ-280)	37	LB94/10	Artifact	121	7	696	10	Watts Point
Watmough Bay (45-SJ-280)	38	LB92/2	Artifact	126	7	731	10	Watts Point
Watmough Bay (45-SJ-280)	39	LB92/3	Artifact	116	7	755	10	Watts Point
Watmough Bay (45-SJ-280)	40	LB92/4	Artifact	122	7	608	10	Watts Point
Watmough Bay (45-SJ-280)	41	LB88/2	Artifact	120	7	668	9	Watts Point

VITA

Amanda Taylor was born in New York City and raised in Croton-on-Hudson, New York. She earned a Bachelor of Arts degree in Archaeology and American Studies at Hamilton College in Clinton, New York in 2002. At the University of Washington, Seattle, Amanda earned a Master of Arts in Anthropology in 2006 and a Doctor of Philosophy in Anthropology in 2012. She has conducted archaeological fieldwork in the Great Basin, New York State, the Pacific Northwest, Alaska, and the California Channel Islands. She currently lives in Seattle, Washington and will begin working as a Visiting Assistant Professor of Anthropology at Pacific Lutheran University, Tacoma, in Autumn of 2012.