GEOARCHAEOLOGICAL ANALYSIS OF A NORTHWEST COAST PLANK HOUSE:

FORMATION PROCESSES AT THE DIONISIO POINT SITE

By

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Abstract

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Since the later 19th century, the societies of the Northwest Coast have been recognized as complex hunter-gatherers. Archaeological research into the pre-contact history of these societies has been characterized as divided into two discussions, one concerning the evolutionary history of a complex hunting and gathering economies, and the other the rise of inequality. Increasingly, prehistoric plank house deposits are being seen as a nexus of these two research themes, providing archaeologists with the opportunity to explore the integration of ecology, economy, social organization, and culture at the local level. Research of this nature has typically focused on the spatial organization of evidence of production and consumption activities through stone tool, bone tool, and faunal remain analyses. This study broadens this research by focusing on plank house deposits as sedimentary data sets.

The goal of this study is to present the results of geoarchaeological analyses that demonstrate that we can establish better links between models of plank house formation processes and archaeological data through quantitative methods based in the soil and sedimentary sciences. To this end, sediment samples were collected from confirmed house deposits at a major Marpole phase village site at Dionisio Point on Galiano Island in southwestern British Columbia. Using current models of plank house cultural formation processes and the extensive ethnographic record for the region, a model of the sedimentary signatures of several plank house architectural features was generated. This permitted the prediction of expected values for a series of geoarchaeological assays. Laboratory determinations were compared to model expectations. Soil texture, organic matter enrichment, inorganic carbonate enrichment, and electrical conductivity were proximate measures of the presence and intensity of human activity, permitting the differentiation of house from non-house deposits as well as features internal to these structures. House features, as expected, reflected a range of non-cultural formation processes that could not be directly assessed through the artifact assemblage. Moreover, sediments demonstrated that cultural formation processes varied within these deposits between functionally analogous features. This variation is best identified as reflecting socio-economic differentiation of the family units that made up the household.

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Chapter One: Introduction

The archaeological record of the Northwest Coast of North America (Figure 1.1) provides one of the world's best opportunities to study the relationship between the emergence of large, multifamily households and institutionalized social inequality in small-scale foraging societies. The principal reason for this is the region's large, lengthy, and well-preserved record of house deposits. Approximately 4,000 years ago, large plank house-like structures appeared in the Fraser River Valley of southwestern British Columbia. The nature of these structure is unclear; they are followed by a 2,000 year hiatus in plank house occupation on the Central Coast. At the beginning of the Marpole phase (2400 - 1400 B.P.) they reappear in this sub-area, often in the context of large multi-house villages. They continue through following Gulf of Georgia phase (1400 B.P. - Contact) and into the post-contact period (e.g., Ames and Maschner 1999:159-161; Barnett 1955) as both as seasonal and year-round habitations.

The changes in house and household size and structure that appear during the Marpole phase indicate a shift in social organization (Grier 2006:97). They are also coincident with several other lines of data that suggest that social differentiation had, by this time, become institutionalized in this area. These include the emergence of a regional mortuary tradition centered around prominent tumuli and cairn burials (e.g., Lepofsky et al. 2000; Thom 1995), differential access to valuable grave goods, particularly by children and sub-adults, indicating ascribed rather than achieved status (e.g., Burley and Knusel 1989), and the emergence of a regional artistic tradition associated with high-status goods that may be associated with the construction of a regional elite identity (e.g., Grier 2003).

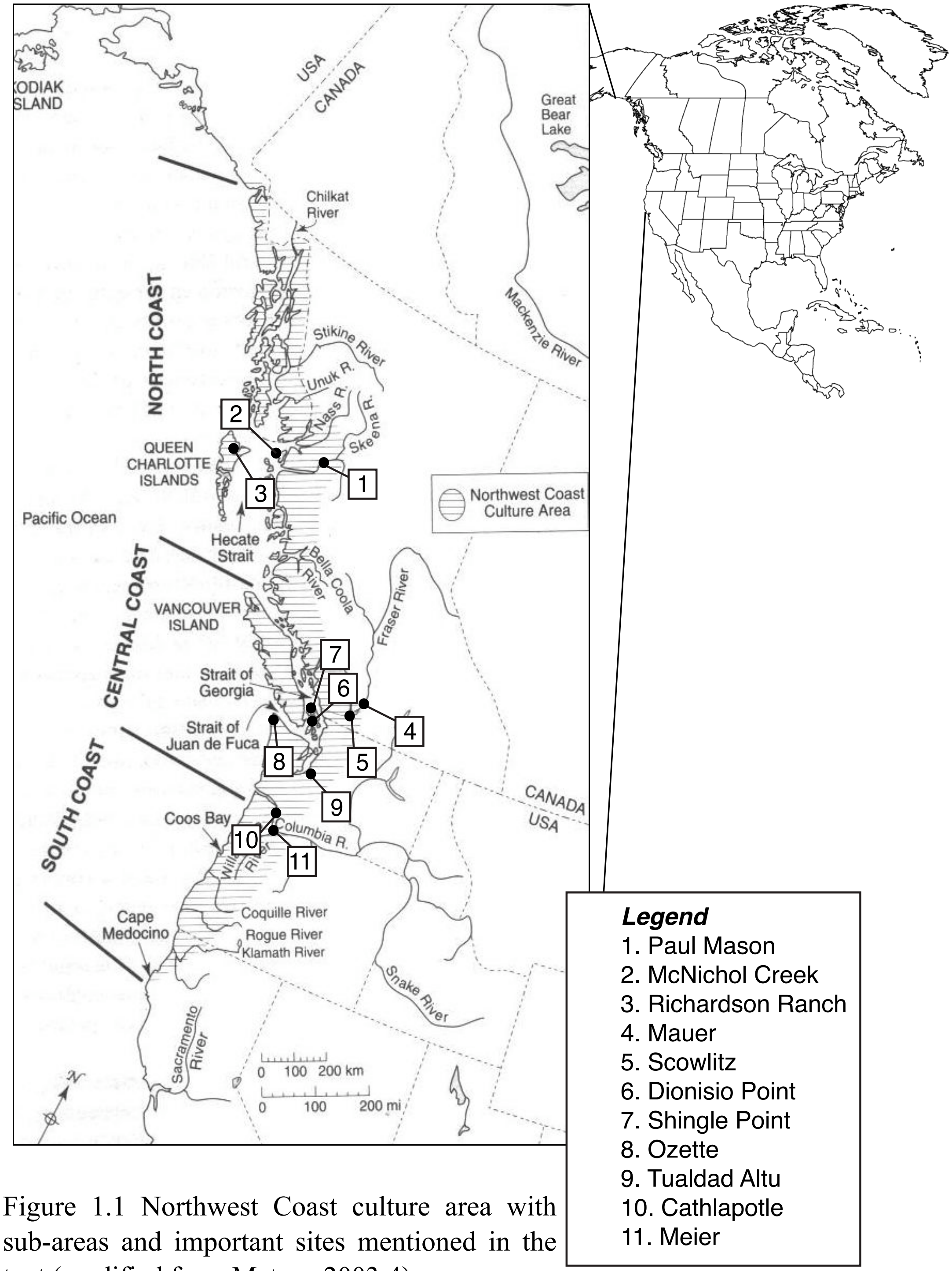


Figure 1.1 Northwest Coast culture area with sub-areas and important sites mentioned in the text (modified from Matson 2003:4)

Household archaeologists have recently begun to explore how Northwest Coast household organization was related to these processes (Chatters 1989; Coupland 1988, 2006; Grier 2003, 2006a); that is, what it may mean that dramatic changes in household and house size were coevolutionary with dramatic changes in the nature of social differentiation. The principal means of operationalizing this has been through intrasite spatial analysis of artifacts and faunal remains. Archaeologists have primarily targeted the spatial distribution of formed tools (Chatters 1989; Coupland 1988, 2006; Coupland et al. 2003; Grier 2006a; Samuels 2006) and faunal remains (Chatters 1989; Huelsbeck 1994; Wessen 1994) as means of reconstructing social, economic, and political relationships in these corporate groups (Grier 2006a:97). However, a weakness of these analyses has been their oftentimes informal treatment of what most archaeologists know commonly as *cultural formation processes* and *non-cultural formation processes* (Schiffer 1983), those processes that can be defined, for the moment, that distort the archaeological context from its original cultural systemic context.

I argue that Northwest Coast household archaeologists have rarely taken full advantage of the data coded into the most ubiquitous data set in plank house deposits, the sediment. This means that the processes that led to feature formation and alteration have been left largely unproblematized. Initial steps steps taken towards understanding these formation processes have for the most part not been sustained. Consequently, feature identification has frequently been informal, running the risk of uncritical reconstruction of plank house architecture, and as so many interpretations of household social, economic, and political organization rest on proper architectural reconstruction (e.g., Coupland et al. 2009; Grier 2006b; Marshall 1989), uncritical reconstruction of households themselves.

The goal of this study is the examination of the sedimentary characteristics of pre-contact Northwest Coast plank house features and the processes by which they were formed. To accomplish this, I drew on a data set from two plank house deposits at the Marpole phase village component of the Dionisio Point site on Galiano Island in southwestern British Columbia. Excavations at the site in 1997 and 1998 sampled two large Marpole phase plank houses. During these excavations, artifact, faunal, botanical, and sedimentary materials were collected. Sediment was sampled from a variety of architectural features, such as hearths, floors, benches, and entryways. These features were identified during excavation, by their form, contents, and context. Analysis of the lithic, bone tool, sumptuary goods (Grier 2006a), and faunal (Ewonus 2006; Lukowski and Grier 2009) components has already generated interpretations of the social, economic, and architectural character of these structures.

This situation provides a unique opportunity to evaluate the fit of formation process model expectations derived from existing archaeological and ethnographic data to the empirical results of an analysis of plank house features. The methods used are geoarchaeological, focusing on in-field qualitative soil description and quantitative laboratory-based bulk sediment analyses. The methods used were able to assess the cultural and non-cultural formation processes that created and altered these features during their use and following site abandonment.

The objective of this chapter is to briefly review the development of household archaeological on the Northwest Coast, specifically focusing on studies that have attempted to reconstruct patterns of social inequality within households with the objective of understanding their long-term evolutionary relationship. This discussion reveals the bias present in these studies towards the reconstruction of activities rather than cultural or non-cultural formation processes. Geoarchaeological analysis of archaeological sediments has presented as a means by which the nature and effects of some of these processes can be assessed.

Northwest Coast Household Archaeology

The earliest plank house excavations on the Northwest Coat were undertaken between the late 1960s and the early 1980s. These projects included excavations at the proto-historic Richardson Ranch site on Haida Gwaii (Fladmark 1973), the 4,500 year-old Mauer Site in the Lower Fraser River Valley (LeClair 1976; Schaepe 2003), and the proto-historic Ozette village site on the Pacific coast of Washington State (Samuels 1991a, 1994; Wechel 2005). All of these projects were innovative in their approach to Northwest Coast archaeology, which up until this time had focused on the excavation of shell middens towards the reconstruction of cultural historical sequences (e.g., Mtichell 1971a), or long-term cultural ecological trends (e.g., Fladmark 1975; Matson 1976). The innovations of these projects were principally conceptual and methodological. First and foremost, they recognized the plank house as a significant empirical unit deserving further research. Second, they established methods that continue to be used to effectively collect household data, focusing on the intrasite spatial analysis of the distribution of cultural remains between and within plank house deposits.

Yet, in spite of the innovations of these sites, these projects did not make as significant a contribution to our theoretical understanding of the early relationship between households and social inequality on the Northwest Coast, as none of them made explicit the possible connection between the appearance of plank houses and evidence of institutionalized social inequality. This connection was not made until several years later (e.g., Ames 1985; Coupland 1985, 1988).

Coupland's (1985, 1988) research at the Paul Mason site was among the earliest to address the emergence of inequality from the perspective of the household. The site, located in Kitselas Canyon in the Skeena River Valley in northwestern British Columbia, dates to 3200 B.P. making it the earliest known village occupation on the Northwest Coast. It consisted of several house deposits, all quite small, and a number of associated exterior storage facilities. Coupland (1988) interpreted the relatively equal floor areas and storage capacity, and lack of status goods as indication that these households were roughly equivalent in status. He adopted the concept of the residential corporate group from ethnoarchaeology and anthropology (e.g., Bell 1995a, b; Hayden and Cannon 1982), to discuss how the families of these households held collective ownership of resources, a concept that has been used in several other excavations (e.g., Grier 2006a). Coupland (1988) found that at the Paul Mason site the formation of residential corporate groups preceded the institutionalization of social inequality.

Extensively modifying an ecological argument made earlier by Matson (1983, 1985), Coupland (1988:28-31) suggested that territoriality, capital investment in production facilities, and labor organization in the context of circumscribed geography contributed to the emergence of institutionalized social inequality. However, Coupland's (1988) research was unable to specify how this production was organized within the corporate group. Relatively few artifacts or faunal remains were recovered from any of the deposits, in part because of the poor preservation of faunal remains, and in part perhaps because of abandonment behaviors of the site occupants. Excavators on the Central and Southern Coasts, having richer artifact and faunal data sets, have begun to address the topic of organization.

At the same time that Coupland was working on the North Coast, Chatters (1989) published a report on research southeast of Puget Sound in Western Washington. His research focused on the spatial distribution of artifact and faunal remains at the pre-contact Tualdad Altu site, occupied approximately at 1570 ± 90 B.P. The historic Sbabadid site was used to provide a model to for interpreting spatial patterns in artifacts and faunal remains under a logistically organized household economy. Chatters (1989:117) has emphasized that economic specialization within households may have been a response to spatially patchy distributions of contemporaneous resources.

In part due to Chatters' work, specialization has become an increasingly common framework for research. It has been demonstrated that families and perhaps even households were involved in organizing distinct productive activities by the Marpole phase in the Strait of Georgia (e.g., Grier 2006a), and by at least 700 B.P. on the Lower Columbia River (e.g., Smith 2004:177) and Olympic Penninsula (e.g., Samuels 2006). However, while these projects have regularly identified household economies as diversified, they have not placed the same causal weight upon ecology as a driving factor. In fact, these projects have begun to indicate that a number of processes were likely involved in the institutionalization of inequality, including the intensification of production and storage (Coupland 1988; Grier 2003:184-185), development of economic specialization (Chatters 1989; Coupland 2006: 89-90; Grier 2006a; Samuels 2006:227), the monopolization of exchange relationships (Coupland 2006:91; Grier 2006a:114), as well as a number of less materialist processes including the formation of elite identity through symbolic wealth (Grier 2006a:116), and the structuration of social and economic roles in households (Coupland 2006:88-89; Grier 2006b; Marshall 2006:41-42).

A number of these more recent interpretations have come as a result of more nuanced methods of analyzing the spatial distribution of artifacts within house deposits (e.g., Grier 2006a; Samuels 2006). These methods have resulted in a more rigorous identification of toolkit assemblages and better means of identifying the number and location of units for which assemblages are compared. Faced as many household archaeologists are by deposits with few artifacts and identifiable faunal remains (e.g., Coupland 2006:89-91; Coupland et al. 2003:161-167), it may not entirely surprising that statistical methods of spatial analysis are only infrequently used to identify toolkits, activity areas, or sub-assemblages of house deposits. Instead, archaeologists rely primarily on non-quantitative techniques, associating what few artifacts are present with other indicators of differences in economic organization or status within or between houses.

These conditions in mind, Northwest Coast household archaeologists rarely have the opportunity to pursue the analysis of cultural formation processes. Interpreting cultural formation processes from assemblages of less than two artifacts per cubic meter (e.g., Coupland et al. 2003:161) is far more tenuous than the broad interpretations of status differences between the inhabitants of the font and rear of these structures. Nevertheless, I suggest that archaeologists have regularly overlooked a form of data that could be used in these or other similar contexts where preservation is less than ideal, the house as a sedimentary deposit.

Cultural Formation Processes and Northwest Coast Research

Site formation process research in archaeology was formalized in the 1970s, soon after the emergence of Processual Archaeology in the 1960s. Processual archaeologists argued that the material remains of the archaeological record could be used to reconstruct "*total extinct* cultural system(s)" (Binford 1962:219, emphasis original). The analysis of how ecological, social, and cultural organization affected aspects of material culture was believed to allow archaeologists the ability to work backwards, reconstructing aspects of these non-material systems. Yet, at that time, there were few models that explained how the details of the archaeological record reflected the cultural system that created it. Archaeologists turned to a variety of new research frameworks such as ethnoarchaeology, the study of the material records of living societies, (e.g., Binford 1978; Gould 1968) and experimental archaeology (e.g., Ascher 1961) to explain these relationships. One of the consequences of this research was that archaeologists quickly came to realize that the patterns of the archaeological record were often not a perfect reflection of the cultural patterns that were the target of study. The concept of site formation processes was developed to aid in understanding how these archaeological patterns emerged (e.g., Ascher 1968; Binford 1981:195-199, 1983:144-149; Schiffer 1983:678-679).

The initial emphasis of this research was primarily on cultural patterns of disposal, maintenance, or unintentional modification of patterning, such as through trampling. These activities removed artifacts and ecofacts from the *primary context* of their production or use and placed them into *secondary contexts* of refuse management (Schiffer 1972:160). The activities that removed artifacts from their primary contexts were considered either to be "distortions" that must be removed (Schiffer 1983:677) or themselves part of the cultural system and reflections of, among other things, labor organization, mobility patterns, or curation patterns (Binford 1983:144; Carr 1985:306), thus deserving research in their own right.

On the Northwest Coast, formation process research has been dominated by a focus on cultural formation process. Studies have perceived these processes to be important in understanding patterns of site use through time (e.g., Grier 2006), or as distortions that complicate interpretation of activity patterns (e.g., Smith 2006), or a combination of the two (e.g., Huelsbeck 1994; Samuels 1991b, 2006). This variety of practices reflects the strong desire to interpret the production and consumption activities of these households (e.g., Smith 2006), while recognizing the complex cultural processes such as status differentiation mediate these processes (e.g., Grier 2006; Samuels 1991b).

The most prominent of these studies are those that were completed at Ozette (e.g., Samuels 1991b, 2006; Wessen 1994). During the Ozette excavations it was clear that cultural formation processes had altered the location of material cultural remains from their initial location of use or production, to their location of recovery. Samuels (1991b:232) tested models of housekeeping, trampling, curation, and unintentional alteration processes, identifying the first and third as the most influential in determining the distribution of faunal remains and artifacts in Houses 1 and 2. In spite of his (Samuels 1991b:196) conceptualization of cultural formation processes as distorting spatial patterns, following Schiffer (1983), he also identified as important these same processes for interpretations of status inequality of different households (following Binford 1983). He (Samuels 1991b:266) and Huelsbeck (1994:89) both argue that higher-status households may have had cleaner houses, potentially because they were involved in a number of social functions, such as feasting and dances that would have required their space to be quite clean.

Recently, Smith (2006) discussed similar processes at the Meier and Cathlapotle sites in northwestern Oregon. His analysis focused on the evidence of intrasite differences in production activities present in the distribution of different kinds of use wear. He looked at curation, maintenance, and trampling. Testing these models of cultural formation processes, he confirmed that the distribution his sample of over 1,000 tools was from primary rather than secondary deposits. Since, he was not interested on the cultural meaning of formation processes, he focused on them primarily as distortions of the archaeological record, rather than as aspects of the cultural system.

Unfortunately, while both of these studies are model formation process research projects, pragmatically neither can act as models for most household archaeology on the Northwest Coast. The Ozette site, the Meier site, and the Cathlapolte site are all unusual for their rich archaeological assemblages, contrary to the situation experienced by many other excavators as argued above. Few excavators are able to address the influence of housekeeping, curation, or trampling at their sites because the artifact data are simply too coarse. I argue, as I have above, that the analysis of archaeological sediments permits archaeologists to address many of these models without relying solely on the artifacts or faunal remains found on their sites. However, to accomplish this goal, household archaeologists will have to adopt methods that have, up until now, not been used for this purpose, such as geoarchaeology.

Natural Formation Processes and Northwest Coast Archaeology

Geoarchaeology, the study of geological problems in the archaeological record (Hasan 1980:267), developed as a distinct sub-field in archaeology much in tandem with site formation process research (e.g., Butzer 1982: 98; Schiffer 1983:676). In part, this was recognition of the fact the geoarchaeological methods are appropriate for this kind of research. They view the aarchaeological deposit in one sense as an aggregation of particles, the analysis of which provides information on their source, transportation agent, and the depositional environment (Stein 2001:44). They also work at a scale appropriate to archaeological research questions (Stein 1993). Until recently, in formation process research, the focus of geoarchaeological analysis were the archaeological effects of post-depositional processes. However, archaeological sediments in house deposits are predominantly cultural in origin. Schiffer (1983:690) and Stein (1987:378) have both advocated the treatment of humans as agents in geological processes on archaeological sites, effectively bringing cultural formation processes in geoarchaeological research. A number of geoarchaeological techniques now exist for addressing questions of cultural formation processes (e.g., Matthewes et al. 1997; Middleton and Price 1996; Sánchez Vizcaino and Cañabate 1999).

Geoarchaeological investigations have long been a part of archaeology on the Northwest Coast. They have been used predominantly in two capacities. First, in the geomorphological reconstructions of past landscapes, particularly with reference to changing sea-levels during the Holocene. Secondly, they have been used in the reconstruction of site formation processes, focusing on post-depositional alteration of the archaeological record. Rarely have quantitative geoarchaeological methods been applied to plank houses, nor have they focused on cultural site formation processes. One of the arguments of this study is that household archaeologists regularly use geoarchaeological methods informally, and often without exploring their full relevance to plank house architecture, or household organization.

Landscape-scale geoarchaeology projects are far more prominent in Northwest Coast archaeology than those that focus on site formation processes. They tend to focus on sea-level reconstruction (e.g., Fedje and Christiansen 1999; Fladmark 1975; Josenhans et al. 1995; Josenhans et al. 1997). These studies have generated information on one of the most interesting periods of human history in the region, its initial occupation, but share little more than their methods of geomorphological analysis with household geoarchaeology research.

Stein (1992a) has been one of the most vocal proponents of using geoarchaeological methods to address site formation processes. Much of her work has focused on midden analysis (e.g., Stein 1992b). The methods she uses rely upon high-resolution sampling within cultural deposits and the use of a wide range of geophysical (e.g., Dalan et al. 1992), geochemical (e.g., Linse 1992, Stein 1992b), and other geoanalytical techniques. Her emphasis in using these techniques in site formation process research has been on revealing how cultural patterns may in some cases reflect natural formation processes. While her methods have been focused on natural formation processes, they are appropriate to cultural formation processes, and the scale of household archaeological research. A number of her techniques have been adopted in this study.

As stated above, the kinds of quantitative natural formation analyses advocated by Stein (1992a) have been rare in household archaeology on the Northwest Coast. Perhaps unsurprisingly, those excavations that have been most explicit in their analysis of natural formation processes have been those that are also the most prominent in their study of cultural formation processes. Smith's (2006) research stands out as the most explicit testing of post-depositional processes in household archaeology. He analyzed evidence of water sorting, wind sorting, and bioturbation, coming to the conclusion that they had not significantly affected the distribution of artifacts at Meier or Cathlapotle. These processes were assessed, much as Stein (1987) advocated, by the use of geoarchaeological techniques designed to identify geological processes.

The goal of this project, as stated above, is to study both natural formation processes and cultural formation processes in plank house deposits through their archaeological sediments. The latter, which has not been attempted before. The process is different than typical cultural formation processes studies in that there are no models of how these cultural sediments should behave. Archaeologists who study cultural formation processes through the lens of artifacts, are able to rely upon a long history of experimental research. Geoarchaeological experiments used to study cultural formation processes are exceedingly rare, and are often targeted at agro-pastoral communities (e.g., MacPhail et al. 2003). No such projects have been undertaken on the Northwest Coast.

1. *Assessment of current models of cultural formation processes in prehistoric plank houses*. How well does the observed geoarchaeological data from Dionisio Point match the expectations generated by an ethnographic model? What are the discrepancies and why might they exist? What does this suggest about the applicability of current models of cultural formation processes in prehistoric shed-roof houses?

2. *Utility of feature analysis for interpreting the socio-economic organization of pre-Contact households.* Do features provide data not available from artifact data sets? If they do, what do these tell us about the inhabitants of these dwellings?

3. *Implications for prospection methods on the Coast*. Does the analysis suggest that there is a possibility of identifying some or all of the architectural contexts defined in

> Chapter Three? Which are most easily discriminated and which are the most difficult to define? What are the implications of these results for further excavations at Dionisio Point and for sites elsewhere?

This thesis is divided into six chapters. Chapter Two provides a brief overview of the Dionisio Point site, where the data used in this study were collected, as well as a summary of Dionisio Point and the Marpole phase in the emergence of large plank houses in Strait of Georgia. Chapter Three is separated into three sections that together comprise the geoarchaeological model the fit of which is measured by the results of the field and laboratory analysis. A section of this chapter is devoted to the variables used, a second to a discussion of the local environment, and the third to the ethnographic and archaeological data used to develop the cultural formation process model itself. Chapter Four discusses the data set, methods, and results of the analysis. Chapter Five presents the interpretations of these results and discusses their implications for household archaeology and the site formation process research in the region. Chapter Six summarizes the findings and presents conclusions and potential directions for future work.

Chapter Two: Dionisio Point

The Dionisio Point Site is located on the northern end of Galiano Island, one of the southern Gulf Islands of southwestern British Columbia (Figure 2.1). The southern Gulf Islands are located within the Strait of Georgia, the body of water that separates the mainland of British Columbia from Vancouver Island. Galiano Island is one of the outer Gulf Islands, furthest from Vancouver Island. The view from the eastern side of Galiano provides an unimpeded vista of British Columbia's Lower Mainland and the Fraser River Delta. Looking west one can see Kuper Island and Thetis Island, and beyond them the rising mountains of Vancouver Island.

Galiano Island is one of the largest of the southern Gulf Islands, measuring some 30 km from end to end and 3 km across at its widest point. It follows the trend shared by all of the southern Gulf Islands of being oriented roughly parallel to the Vancouver Island coastline. This orientation has been determined by the tectonic systems that underlie the Gulf of Georgia, generating the geological setting of the Gulf Islands over the past 50 million years (Johnstone 2006).

To the northwest of Galiano Island lies Valdes Island, separated by Porlier Pass (Figure 2.2). To the southeast lies Mayne Island separated by Active Pass. These highly turbulent passes are extraordinarily abundant resource patches (Grier 2001:99). Urchin (*Strongylocentrotus* sp.) is plentiful along with a variety of other shellfish, as are a number of marine mammals including seals (Phocidae), sea lions (Ottaridae), and more rarely orcas (*Orcinus orca*). Salmon are not abundant in this location, though schools of predominantly coho (*Oncorhynchus* kisutch) and pink (*O. gorbuscha)* salmon are seasonally present in the waters during their migrations to the mainland or Vancouver Island (Grier 2001:99; Kew 1992). Along with Gabriola Pass to the

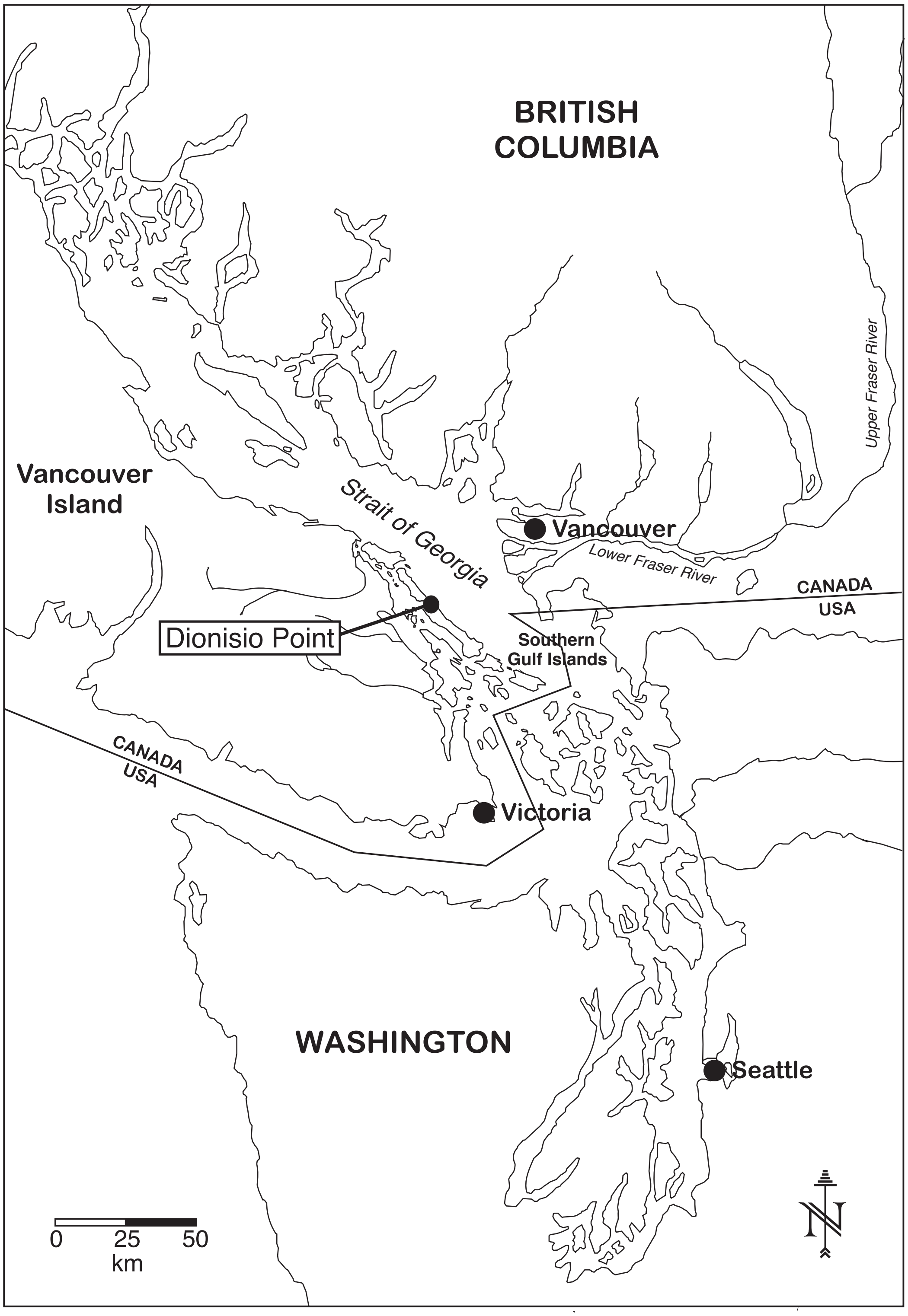


Figure 2.1 The location of Dionisio Point in the Gulf Islands of southwestern B.C. (from Grier 2001:94)

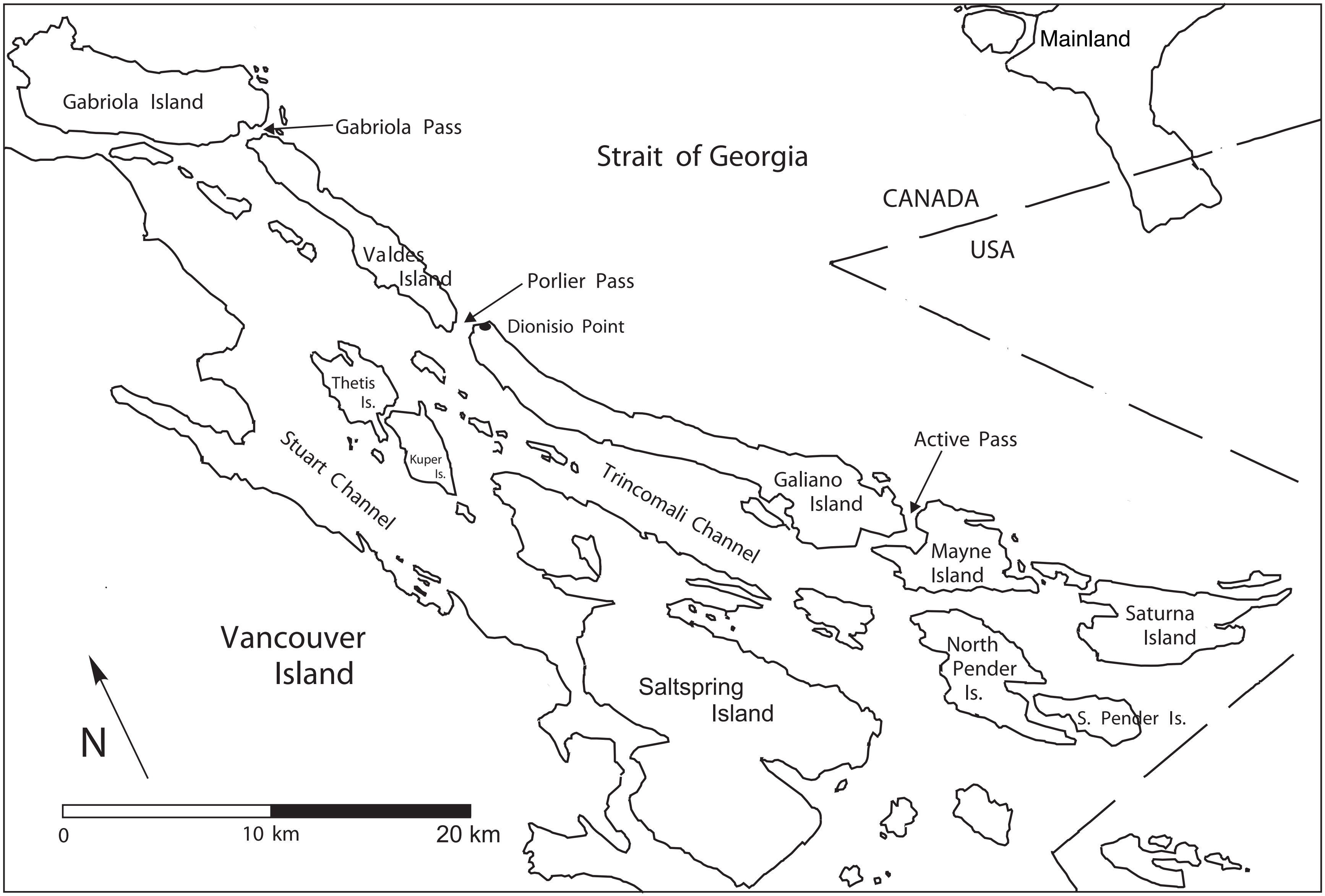


Figure 2.2. Southern Gulf Islands (from Grier 2001:95)

north of Valdes Island, these two passes are the only breaks in the outer Gulf Islands that allow direct maritime movement between southeastern Vancouver Island and the mainland.

The Dionisio Point Site: Prior Excavations

The northwestern tip of Galiano Island is broken by a series of erosional embayments. Evidence of pre-contact human activity has been found in all of these locations (Grier 2001:93). The Dionisio Point site (DgRv-003) is the largest of these sites. It is made up of two components. The stratigraphically lower and earlier of these is a Marpole phase village composed of five house depressions, visible from the surface of the site. This component overlies culturally sterile Pleistocene glacial drift deposits. The upper, later component is a late Marpole phase, or Transitional Gulf of Georgia phase (1400 - 1000 B.P.) seasonal resource exploitation camp and lacks evidence of permanent architecture (Grier 2006a:101). Recent excavations have revealed evidence of a plank house contemporary with these later deposits at the nearby DgRv-006 site, in Coon Bay (Grier and McLay 2007:Figure 4), suggesting a shift in settlement patterns between these two phases. The western boundary of the site is a sandstone bluff and beyond that a perennial creek. The eastern boundary is a similar sandstone ridge, and beyond that DgRv-006 and Parry Lagoon (Figure 2.3).

The earliest excavations at the site were undertaken by Mitchell (1971b) in 1964 as part of his validation of the Gulf of Georgia cultural historical sequence. Excavations were limited to several test units, one of which was located within House 2, and focused almost exclusively on the lithic assemblage. The site was revisited during 1997 and 1998 for the Dionisio Point Household Archaeology Project (DPHAP) by Grier (2001; 2003; 2006a). The goal of the

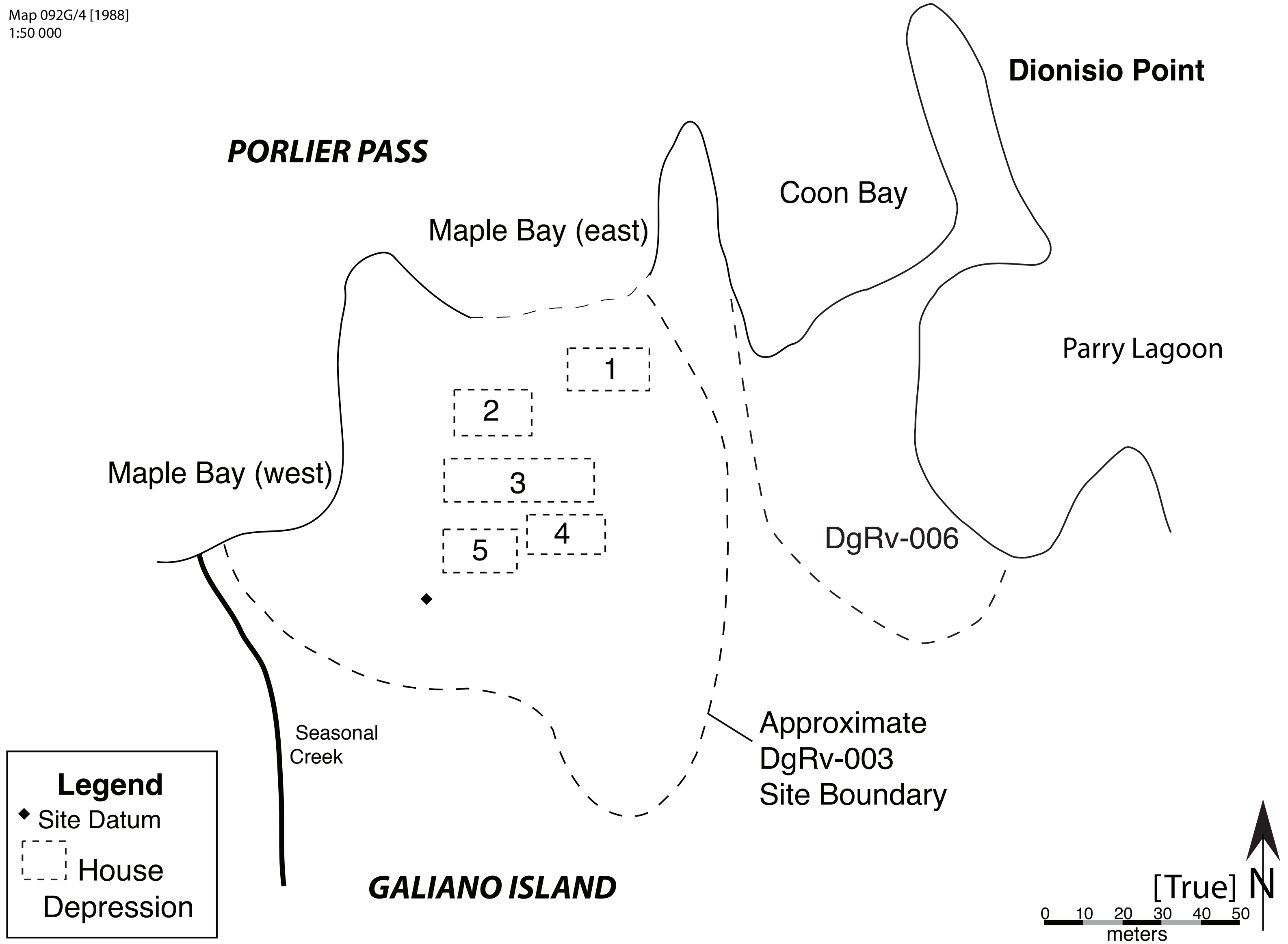


Figure 2.3: Dionisio Point site map. (adapted from an image courtesy of C. Grier).

DPHAP was to test the hypothesis that households were socio-economically internally differentiated units. Initial testing of two house depressions (House 2 and House 5) in 1997 led to extensive excavations in House 2 in 1998. During two field seasons, 77 m^2 of House 2 and 4 m^2 of House 5 were excavated. The excavation of approximately 40% of House 2 resulted in the recovery of a relatively large lithic and bone artifact assemblage , debitage (Grier 2001:111), and faunal assemblage (Ewonus 2006).

A suite of radiocarbon age determinations place the Marpole phase village occupation between 1770±70 to 1440±60 B.P. (Grier 2006a:100). This range represents the maximum possible length of occupation from presently-dated contexts. The probability distribution of radiocarbon dates indicates that the occupation may have lasted no longer than 50 years. Yet, the large amount of anthropogenic sediment (~50 cm) deposited during this time suggests that a 200 year occupation between 1680 and 1460 B.P. is a reasonable estimate (Grier 2006a:101). Given a possible life-span of 50 to 80 years for a Northwest Coast plank house (Ames 1996:145), this 200 year occupation may represent three or four rebuilding episodes, and as many as eight generations of inhabitants (Grier 2006a:101).

Grier (2006a, 2006b) has argued that spatial patterning in the data set reflects socio-economic differentiation of space within the house. It appears that the families inhabiting the west, center and eastern portions of the house were distinct socio-economic units organized within a wider corporate context. Each was associated with toolkits for a different suite of productive tasks, suggesting that these families may have been involved in organizing household production in these activities (Grier 2001:224; 2006a:108-110). The families inhabiting the domestic area around the eastern hearth (Feature 28) (Figure 2.4), appear to have been

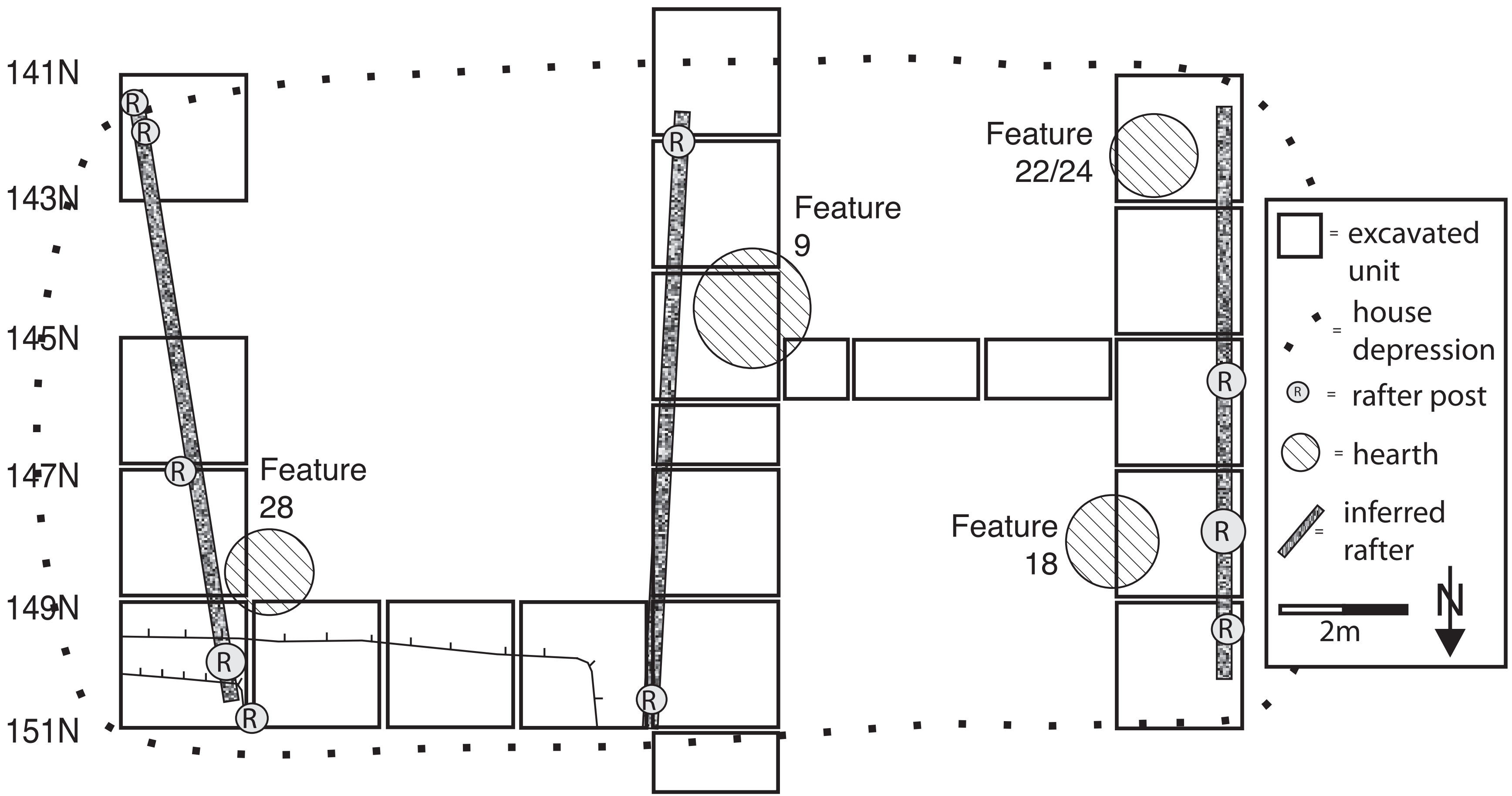


Figure 2.4: DPHAP 1998 House 2 excavation units and reconstructed architecture (adapted from Grier 2001:174).

differentiated from others by their involvement in marine hunting and fishing. The relative abundance of chipped-stone and projectile points in the western portion of House 2 suggests that the families living around Features 22/24 and 18 were focused on terrestrial hunting. The domestic area around Feature 9, in the center of the house, has a scarcity of production-related artifacts (Grier 2001:256), but the bulk of the sumptuary goods (slate beads, anthropomorphic stone bowls, and labrets)(Grier 2006a:113). The abundance and variety of sumptuary goods concentrated within the central part of the house illustrate status-related differences between the resident family and those occupying either the eastern or western portions of the house, neither of which have comparable assemblages.

Spatial variation in production activity toolkits and the location of sumptuary goods, provides strong evidence that the use of space within House 2 was affected by variation in socio-economic status, a pattern noted in the ethnographic record of the area (e.g., Suttles 1991), more so than differences in the functional use of space (Grier 2006a:101). Regional similarities in the stylistic attributes of the sumptuary goods recovered predominantly from the central of the house (Grier 2006a:110), suggest that the inhabitants of this area were likely the social “core” of the household and were involved in the accelerated construction of a regional elite identity that accelerated during the Marpole Phase (Grier 2003; 2006b).

Ewonus (2006) recently completed a quantitative analysis of a portion of the faunal data set from nine units in House 2 at Dionisio Point and has presented a different interpretation of the Marpole phase seasonality and socio-economic structure. He has suggested that the relatively high taxonomic diversity of the faunal assemblage indicates a seasonal mixed-economy, typically associated with a spring aggregation rather than a winter village (e.g.

Coupland 1991). Moreover, he claims that the low abundance of salmon and the species recovered (*O. gorbuscha*), identified through ancient-DNA analysis of five vertebrae, is evidence of infrequent, fresh, local capture rather than stored resources transported from other locations (Ewonus 2006:72).

This argument is based on two common models of salmon use on the coast. First, it is often argued that these large communities would have difficulty persisting through the scarcity of the winter season without these abundant, storable resources (e.g. Coupland 1991; Matson 1992), and thus House 2 having few salmon was probably not a winter village. The weakness with this argument is that salmon, while not the most abundant fish (NISP = 440), are comparable in number to dogfish (*Squalus* sp., NISP = 590) and rockfish (*Sebastes* sp., NISP = 590). Given that no other house excavation data are presented by Ewonus (2006), is it difficult to confirm that these numbers are "low". The aDNA identification of all five salmon vertebrae as sockeye (*O. nerka)*, commonly considered to be poor fish for storing because of their high fat content, might suggest that salmon were taken locally and eaten fresh. Notably, a subsequent analysis of a larger number of salmon vertebrae (Lukowski and Grier 2009), demonstrates greater diversity than identified by Ewonus' study and does not support a reliance solely upon sockeye.

Following patterns identified in the ethnographic record (e.g., Barnett 1955) and suggested archaeological records (e.g., Burley 1988; Coupland 1991), Ewonus (2006:85) argues that the various portions of House 2 were likely not inhabited contemporaneously; that families occupied the plank house throughout the spring, arriving as family-units rather than en masse. He (Ewonus 2006:85) maintains that having arrived at Dionisio Point and having their own domestic hearths around the perimeter of the structure, family-units used the central hearth as a communal space, an interpretation he supports by pointing towards the relatively low density of faunal remains recovered from the central hearth.

The contrast between the Grier's (2006a) and Ewonus' (2006) interpretations is in part indicative of the complexity of plank house deposits and the difficulties Northwest Coast archaeologists face in attempting to integrate different data sets, particularly in light of our imprecise models of what artifact and faunal assemblages from seasonal habitations should look like archaeologically. Part of this may be because they are based on different forms of information, Grier's (2003, 2006a) on production and sumptuary data in both a local and regional context, and Ewonus' (2006) on a subset of the consumption data. Both Barnett (1955:242) and Suttles (1951:272) identify extensive intrahousehold sharing of food resources, significantly obscuring the consumption data for each family.

Given the concerns raised above regarding Ewonus' (2006) interpretations of seasonality and house occupation based on questionable salmon data and uncritical models, I am inclined to read the faunal data in light of Grier's (2006a) reconstruction of the socio-economic differentiation of space in House 2. For example, the higher proportion of fish remains in the eastern portion of the house (64% of the total fish remains) (Ewonus 2006:46), agrees quite well with Grier's (2006a) interpretation of the inhabitants of this domestic space as organizing marine hunting and fishing if they tended to consume greater amounts of their own produce than other families. More pertinent to this study is Ewonus' (2006:57) identification of fewer faunal remains in the central portion of the house, which he attributes to a possible functional difference in this part of the house compared to either the eastern or western portion. I argue that given that we understand so little about cultural formation processes in House 2, we cannot discount the possibility that this area was treated differently by the inhabitants, while it broadly remained functionally analogous to the east and west. As suggested by the conclusions of this study, it is not clear that archaeologists can assume that different families did not maintain their domestic spaces differently (cf. Huelsbeck 1994:57).

Dionisio Point in a Regional Archaeological Perspective

The Marpole Phase in the Strait of Georgia shows both cultural change and continuity from the preceding Locarno Beach Phase (3300 - 2400 B.P.). There are a number of similarities, such as the continuation of microblade technologies, the use of labrets (though at a lower frequency), earspools, certain forms of net-sinkers, and a number of bone needles and awls (Burley 1980:36). These similarities have all but silenced early arguments that the Marpole phase represents an intrusive culture from the Fraser Canyon, either in the movement of people or of ideas (Mitchell 1971a).

There are a number of obvious changes between these two phases. Lithic technological organization transitions from predominantly chipped to ground stone tool kits. Large celts, nipple-topped stone hand mauls, widespread stone sculpture similar in style to ethnographic materials, and fixed unilaterally barbed harpoon heads are added to the material culture. The emergence of ascribed inequality is suggested by the replacement of labrets by cranial deformation as a status marker (Ames 1995:166), and burial with lavish grave goods (Burley and Knusel 1989). Most notably there is the earliest direct evidence of ethnographic-style large plank houses on the southwest British Columbia coast (Matson and Coupland 1995:201-9).

The recent analysis of faunal remains from a number of sites in the region has provided support for a connection between the Marpole Phase and the emergence a salmon-storage based economy (e.g., Matson 1992), which may have been necessary to support large sedentary winter villages (Ames 1996). However, while salmon rises to dominance, notably more clearly in some data sets (e.g., Matson 1992) than in others, a number of other economic pursuits remain important and a range of terrestrial and marine faunal were taken on a regular basis (e.g., Ewonus 2006). This "focal economy" (Ames and Maschner 1999:25-26) may reflect increasingly complex relationships between household-level and family-level economic practices (e.g., Chatters 1989; Grier 2006a).

The earliest consistent evidence of large houses in the Strait of Georgia dates to the beginning of the Marpole phase at 2400 B.P. (Burley 1980:63; Matson and Coupland 1995:209 - 211; Mitchell 1971a:53). Discussions of earlier household organization in the region are complicated by the lack of evidence of large house depressions from the previous Locarno Beach phase (Burley 1980:30), though the necessary tools appear to have been part of the toolkit at this time (Mitchell 1971a:59). However, while large house depressions have not been found, evidence of much smaller structures has been identified at a number of sites (Matson 2008:164). A small (5 x 6 m) depression at the Hoko River Wet/Dry site is one of the better reported examples, and appears to have been a seasonal spring dwelling (Matson and Coupland 1995:169) dating to approximately 2700 B.P. At the Crescent Beach site, a distinctive stratigraphic feature has been suggested to be a Locarno phase winter pithouse (3010±85 B.P.) (Matson 2008:161). Identification of this feature is insecure as it lacks an associated hearth feature, presumably necessary in a winter structure, and has uncertain evidence of post features. If this feature does represent a structure its small size (approximately 19 m^2) confirms the fact that large houses and presumably large households are a Marpole phase phenomenon.

Two very early structures have been identified on the British Columbia mainland in the Upper Fraser River Valley, one at Hatzic Rock and another at the Mauer site, both potentially dating to between 4500 - 3300 B.P. The Mauer site has been determined to be a house based on the evidence of hearth and post features, and associated lithic data set (Schaepe 2003:152). The long period of time between the abandonment of the two structures and the emergence of villages during the Marpole Phase (2400 - 1400 B.P.) during which no conclusive evidence for winter dwellings exists at any of the 28 reported Locarno Beach components (Matson and Coupland 1995:157), makes it difficult to constructively address the influence of the former in the historical development of plank house villages. As noted above, it is not until the Marpole Phase that house depressions aggregated in villages begin to appear. Nonetheless, only six Marpole-age components have evidence of such structures (Grier 2001:105). Of these, only two have received extensive excavation: Dionisio Point, and Tualdad Altu.

Chapter Three: A Geoarchaeological Framework

The previous chapter provided a brief overview of the history of archaeological work at the Dionisio Point site and its place in the development of large plank houses on the Central Coast. The purpose of this chapter is to create an archaeological model of Northwest Coast plank house formation processes that can be evaluated by geoarchaeological analytical method. Archaeological, paleoenvironmental, and ethnographic data are discussed, framed within the geoarchaeological variables selected for this study.

To allow plank house geoarchaeological signatures to be analyzed in the sedimentary record, three conditions must be met. First, a suite of variables must be identified that record the past activities of households and yet are resistant to post-depositional alteration, either in form or location. A suite of methods must then be selected that can accurately and precisely measure these variables. Achieving this goal represents a recursive exercise as variables are selected, tested, kept or discarded.

The second condition is that natural sources of variability are assessed. Natural environmental conditions are responsible for the range of natural formation processes that cause post-depositional alteration of cultural patterning; they introduce new material into the archaeological site that transform and transport existing materials, or remove them altogether. This process-based model was made explicit by Simonson (1959), is widely used in the soil sciences (Schaetzl and Anderson 2006:320), and is adopted for this study. Dramatic changes in the natural environment may elicit behavioral responses. Determining that the natural environment has not significantly changed over the occupation of the site removes this source of variability.

The third condition is that a model of past human activities must be generated from which to evaluate patterns in the field and laboratory determined on the selected variables. Unlike the analysis of other data sets, such as lithics or faunal remains, geoarchaeological analysis of cultural formation processes relies on data that cannot be uniquely linked to anthropogenic sources (Butzer 1982:81-82). Models of natural and anthropogenic formation processes are therefore necessary evaluative tools and must be combined with other material data sets. Archaeological collections from Dionisio Point provide an opportunity to satisfy these three conditions.

Analytical Variables

The methodology of this project is derived from the sedimentological and pedological sciences. Geologists, geomorphologists, and pedologists regularly use sedimentary texture, the analysis of particle-size distributions, in palaeoenvironmental research. Pedologists, those scientists who study the formation of soils, add to this a range of techniques that allow them to describe the processes involved in soil genesis. In fact, in spite of the thousands of soil families described in both the American (Soil Survey Staff 2006) and Canadian (Soil Classification Working Group 2006) soil systems, the complexities of pedogenesis (soil formation) are due to the interactions of a limited number of soil components and formation factors (e.g., Jenny 1994[1941]). By implication, these character of interactions can reveal a great deal of information about the genesis of any particular soil. This project draws on a number of those methods.

A suite of bulk sediment analyses were selected to address the anthropogenic and geogenic factors that contributed to the geoarchaeological record of House 2 and House 5 at the Dionisio Point site. These are low resolution analyses in that they measure only the changes in major soil constituents. They lack the precision necessary to analyze soil constituents that form the minor and trace proportions of a sample. While it is, for example, possible to measure each ionic element individually using titration (e.g., Cook and Heizer 1965) or inductively-coupled plasma mass-spectrometry (e.g., Middleton 2004), the anthropological meaning of their individual concentrations is not necessarily clear (Butzer 1982:82). Both of these methods also require large comparative data sets that are beyond the scope of this study. While the resolution of the analyses used here is comparatively low, the methods are appropriate to the data resolution of this study, are simple and straight-forward to apply and interpret and thus can be used in all projects with access to minimal laboratory equipment, and are supported by decades of use in the archaeological sciences (Butzer 1982; Deetz and Dethlefsen 1963; Weide 1966).

This project uses five methods common to pedological research: soil texture, organic matter content (OM), inorganic carbonate content (IC), electrical conductivity (EC) and pH. They form a standard suite used to characterize soil properties and differentiate anthropogenic from natural processes. Each is briefly described below.

I. Particle-Size Analysis

Soil texture breaks the continuum of grain sizes down into a number of size classes and sub-classes. The classes used in the Canadian and Standard U.S. Wentworth-Uddon systems are presented in Table 3.1.

Table 3.1 Comparison of Canadian and Standard U.S. Wentworth-Uddon grain-size classification systems

U.S. Standard Mesh [a]	phi unit (Φ)	Millimeters	Wentworth-Uddon Scale[b]	Canadian System
5	-2	4	Granule	Gravel
10	-1	2	Very Coarse Sand	Very Coarse Sand
18	0	1	Coarse Sand	Coarse Sand
35	1	0.5	Medium Sand	Medium Sand
60	2	0.25	Fine Sand	Fine Sand
120	3	0.1625	Very Fine Sand	Very Fine Sand
230	4	0.0625	Coarse Silt	
270	4.25	0.0053	-	Silt
-	5	0.0312	Medium Silt	
-	6	0.0156	Fine Silt	
-	6	0.0078	Very Fine Silt	
-	7	0.0039	Clay	
-	9	0.002	Colloid	Clay

[a] Sieves are capable of fractioning grain size classes larger than silt

[b] Dashes indicate the absence of Wentworth sizes corresponding to grain sizes

The Standard U.S. Wentworth-Uddon system of size classes was used in this project. Compared to the Canadian system, it overestimates the amount of silt and clay in a sample and consequently underestimates the amount of sand.

Pedologists are primarily interested in the relative proportion of clay in the soil profile. Clay is the "active" fraction of the soil texture (Wild 1993:29); larger grains are effectively inert with respect to soil chemical characteristics. Many labile soil constituents, such as free ions and carbonates, are rapidly leached in coarse-textured deposits for this reason. Clay minerals, which are often highly charged particles, readily adsorb nutrients and form organic-mineral complexes that protect organic matter from decomposition. Nevertheless, coarse-textured soils impart some characteristics to the soil. They accentuate the visible characteristics of humus, a constituent of organic matter, particularly its apparent depth. Coarse-textured soils, having a lower surface area to volume ratio are more easily coated by humus, suggesting deeper organic matter penetration than might truly exist (Schaetzl 1991).

Finally, the texture of a sedimentary deposit can reveal the provenience (origin), mode of transportation and mode of deposition of the sedimentary materials that for the deposit. This can be important in understanding past climates (e.g., Butzer and Harris 2007) as well as geomorphological changes to landscapes following human habitation that might bias or obscure the archaeological record (e.g., Field and Banning 1998).

II. Organic Matter

In natural soils, organic matter is derived primarily from the death and decomposition of local vegetation and biota that live both on and in the soil (Brady and Weil 2002:500). The accumulation of dead organic matter on the surface and in the subsurface, forms the primary source of food for a wide range of faunal and fungal communities. As they consume, digest, and excrete organic matter, these communities convert it from a particulate “light fraction” composed of macroscopic vegetal debris, to a relatively homogeneous “heavy fraction” composed of a variety of acids, fats, waxes, and other microscopic and sub-microscopic derivatives (Wild

1993). The constituents of the heavy fraction, "humus", provide the upper soil horizon with its dark color, generally lower pH, higher abundance of plant nutrients, and nutrient adsorption (holding) capacity. Organic matter enrichment may be used to identify buried soils (Birkeland 1984) or the location and intensity of human activity (Stein 1992d).

III. Inorganic Carbonates

Inorganic carbonate analysis provides a measurement of the abundance of carbonate (CO_3) compounds within the soil. Typically, these carbonates are present the form of either calcite (calcium carbonate – $CaCO_3$) or dolomite (calcium magnesium carbonate – $CaMg(CO_3)_2$). They accumulate via a range of mechanisms. They may be sedimentary in origin, accumulating from the *in situ* weathering of calcareous bedrock, introduced by calcareous eolian (wind-borne) dust, or the deposition of carbonate rich bioclastic sediments (e.g., shell). They may also accumulate in the form of "secondary" carbonates (also called "pedogenic" carbonates), that precipitate out of a carbonate rich groundwater solution as it passes through a substrate (Schaetzl and Anderson 2006:407). A third mode of deposition is through the combustion of vegetation and the creation of wood ash, which can deposit calcareous concretions (Karkanas et al. 2007).

IV. Electrical Conductivity

Electrical conductivity provides an indirect measure of the total dissolved solids or "free ions" in the soil solution (Corwin and Lesch 2003:458). The greater the abundance of these charged ions, the more capable the solution of conducting a charge and the higher the electrical conductivity of the soil.

Free ions have a number of sources. Foremost among these are weathering sediments, carbonates, and organic matter. The first derive their ions from the *in situ* weathering of bedrock, or a number of sedimentary processes that transport ion-rich sediment to the location. The dissolution of carbonates provides free calcium and magnesium ions to the soil solution. The breakdown of organic matter also releases ions that are bound as nutrients. All three of these processes contribute to the abundance of free ions as well as the soil's capacity to retain those ions. This is especially the case for organic matter, which has a pH-dependent capacity to retain ions. At higher pH levels, organic matter, through dissociation, becomes negatively charged and attracts free ions, which are positively charged. The exchange of electrons contributes to raising the soil pH (Schaetzl and Anderson 2006:359).

V. Acidity - pH

pH is is the negative-log transformation of the relative proportion of hydrogen ions of a soil. It is concentration independent. High electrical conductivity may be associated with either low or high pH. As the concentration of hydrogen ions in the soil solution increases, the pH decreases because of the negative-log transformation. A pH of 7 is considered to be neutral. The pH of Douglas-fir soils is generally acidic, ranging from 4 to 6. pH is an indication of a range of soil characteristics such as local climate, soil biota, dominant vegetation, and mineral parent material to name but a few (Weide 1966), as well as archaeological preservation (Matthiesen 2004).

Natural Setting

The natural setting of Dionisio Point has a direct impact upon the characteristics that were described above (Jenny 1994[1941]). Prior to human occupation of the site, the natural environment largely set limits of variability of many soil characteristics that are modified by cultural processes. During occupation, it can affect economic practices and settlement patterns, among other things. Following abandonment of the site, it is the cause of many of the non-cultural post-depositional formation processes that alter and destroy cultural patterns. This discussion focuses on those aspects of the natural setting that are the most influential in modifying the variables described above.

The organization of this section moves from the relatively unchanging geological and sedimentary foundation of the site, through the relatively rapidly changing aspects of local climate and vegetation. This organization emphasizes the natural setting as a source of natural formation processes over any affect it may have on the cultural system. This is principally because there appear to have been few significant changes in the natural setting of the site over the past two millennia.

Previous geological and pedological projects carried out in the region are drawn on for supporting evidence. The major pedological work is Green et al.'s (1989) soil survey of Galiano, Valdes, Thetis, Kuper and the minor Southern Gulf Islands. They provide pedological information for a number of soils found nearby Dionisio Point. Johnstone's (2006) analysis of the Nanaimo Formation provides the geological background of the bedrock that underlies a number of the Southern Gulf Islands. The discussion of Douglas-fir forest conditions is drawn primarily from Heilman et al. (1981).

Parent Material

The geology of Galiano Island is the Cretaceous age (90 - 65 mya) Nanaimo Formation, which underlies many of the Gulf Islands (Johnstone 2006). This formation is composed of a series of bedded sandstones, siltstones, and fine mudstones. In many places, including Dionisio Point, the softer materials have eroded away leaving the harder sandstone beds exposed. According to Johnstone's (2006:31-36) description of Nanaimo Formation non-clastic sandstone facies, these deposits vary in terms of their texture (coarse to medium grained), and bedding (swalley cross-stratified to hummocky cross-stratified deposits). This indicates that the initial mode of deposition of these bedsets was marine. Cementation is achieved by hematite and clay rather than carbonates, though detrital calcite is present (Johnstone 2006:130). Weathering of this material has resulted in the development of thin sandy, carbonate poor soils in many areas around the site. The characteristics of these soils, the *Saturna* series, which are the primary soils, are presented in Table 3.2.

Also overlying the Nanaimo Formation are a number of glacial drift deposits, laid down during the late Pleistocene/early Holocene Fraser (Wisconsin) glaciation (30,000 - 10,000 B.P.) (Clague and James 2002:71). Where these sediments have not eroded away, often in topographic depressions, they form deposits more than 1 m thick. Much like the *Saturna* sediments, these glacial sediments are predominantly sandy, with a slightly higher proportion of silt and clay. They also have slightly higher coarse clast content (25 - 50% by weight). The characteristics of soils that form in these sediments, called *Qualicum* soils are presented in Table 3.3. Soil surveys in the region have identified this sediment at Dionisio Point (Green et al. 1989:22), where it forms the secondary sediment in the immediate area of the site.

Table 3.2 Profile description of the typical Saturna series soil profile (from Green et al 1989:116)

Field Horizon	Depth (cm)	Color (moist)	Color (dry)	Org. C.[a]	CEC[b] : BS[c]	pH	Sand (%)	Silt (%)	Clay (%)
L	8 - 6								
FH	6 - 0			36.6					
Bm1	0 - 10	7.5YR4/4	10YR5/4	0.6	6.8 : 23	4.6	79	19	4
Bm2	10 - 45	7.5YR4/4	10YR5/6	1.4	8.6 : 25	4.8	70	26	2
R	45+								

[a] Green et al. (1989) report organic carbon rather than organic matter content. (OC x ~2.1) = OM

[b] CEC is the cation exchange capacity, the capacity to retain and exchange free ions

[c] BS is the base saturation, the number of exchange sites that are filled by base cations

Table 3.3 Profile description of the typical Qualicum series soil profile (from Green et al 1989:114)

Field Horizon	Depth (cm)	Color (moist)	Color (dry)	Org. C.[a]	CEC[b] : BS[c]	pH	Sand (%)	Silt (%)	Clay (%)
LF	3 - 0								
Ah	0 - 9	10YR3/2	10YR3/3	10.9	35.4 : 53	5.3	75	19	6
Bm1	9 - 45	2.5Y4/4	10YR5/4	1	8.4 : 35	5.3	83	15	2
Bm2	45 - 65	2.5Y4/4	2.5Y6/4	0.3	3.6 : 33	5.6	88	10	2
BC	65 - 100+	2.5Y5/4	2.5Y7/4		4.8 : 35	5	72	23	5

[a] Green et al. (1989) report organic carbon rather than organic matter content. (OC x ~2.1) = OM

[b] CEC is the cation exchange capacity, the capacity to retain and exchange free ions

[c] BS is the base saturation, the number of exchange sites that are filled by base cations

Parent materials impart various characteristics to soils, many of which should be evident from the above discussion. The soils around Dionisio Point are necessarily sand, with little amounts of silt and clay. Any shifts in the texture of on-site sediments indicates either human activity or natural alluvial or colluvial addition of finer sediments. They also can impart a number of mineral elements to soils, such as calcium or potassium that directly affect a number of other soil characteristics. However, there are two reasons to expect that few mineral elements found in soils are sedimentary in origin. Firstly, based on Johnstone's (2006) study I would expect few carbonates will be present in local soils (also Green et al. 1989:114, 116). Secondly, the coarse texture of the parent material means that natural soils are rapidly leached

Modern and Holocene Climatic Setting

The Douglas-fir Region extends approximately from Bella Coola in British Columbia to the Oregon – California border (Franklin 1981:92). It characterizes much of the Northwest region of the Coast-Cascade Mountain chain. The area around Dionisio Point falls within the much more accurate and spatially delimited Coastal Douglas-fir zone of the Biogeoclimatic Ecosystem Classification System, developed specifically for British Columbia (Meidinger and Pojar 1991) (Figure 3.1). This zone is found exclusively on the southeastern coast of Vancouver Island and a number of the Gulf Islands. Elevation is typically less than 150 m. In the case of the Gulf Islands, this places them within the rain shadow of the Olympic Mountains (~2400 m asl) and the spine of Vancouver Island (~2200 m asl) (Meidinger and Pojar 1991:82). Consequently, the Gulf Islands are among the sunniest (1400 h per year) and warmest (> 200 frost free days per year) areas in Canada (Green et al. 1989:16). Annual climatic data from 1971 to 2000 for Mayne

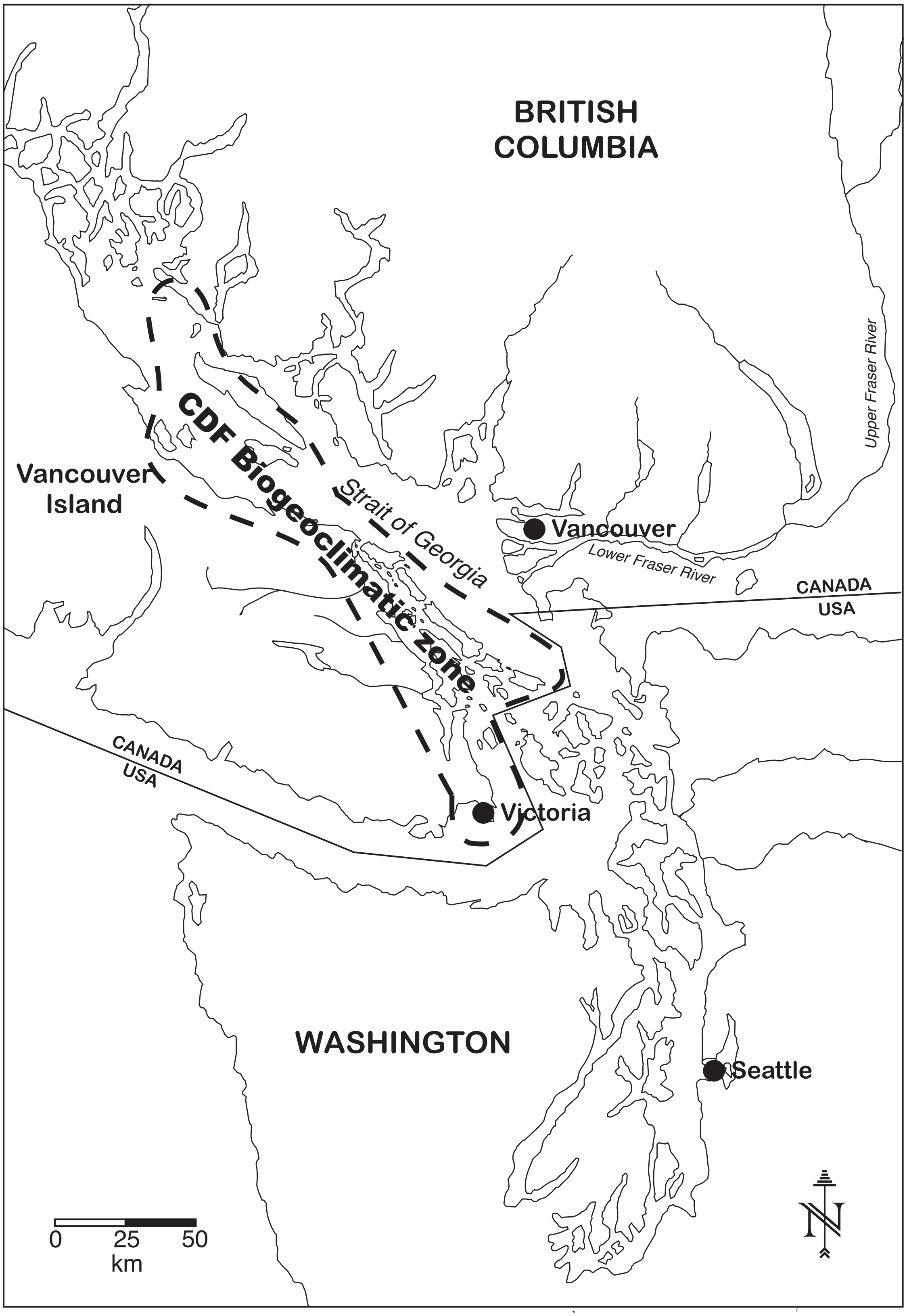


Figure 3.1 Location of the Coastal Douglas-fir Region in southwestern British Columbia (from Grier 2001:97)

Island, which has similar though somewhat drier conditions, are presented in Figure 3.2. They illustrate the relatively low annual precipitation and seasonal changes in temperature in the area.

Though the Northwest Coast receives a great deal of moisture every year, the Gulf Islands experience a summer moisture deficit as a result of their location. The Mayne Island weather station annually receives less than 850 mm of precipitation and only rarely do low temperatures approach freezing (Figure 3.2). This combination of factors provides an unusually warm, seasonally dry setting compared to the rest of the coast.

The modern floral community around Dionisio Point is predominantly coniferous (Grier 2001:96-98). Dominant tree species are Douglas-fir (*Psudeotsuga menziesii*), grand fir (*Abies grandis*), and bigleaf maple (*Acer macrophyllum*) in areas of intermediate soil moisture. Wet

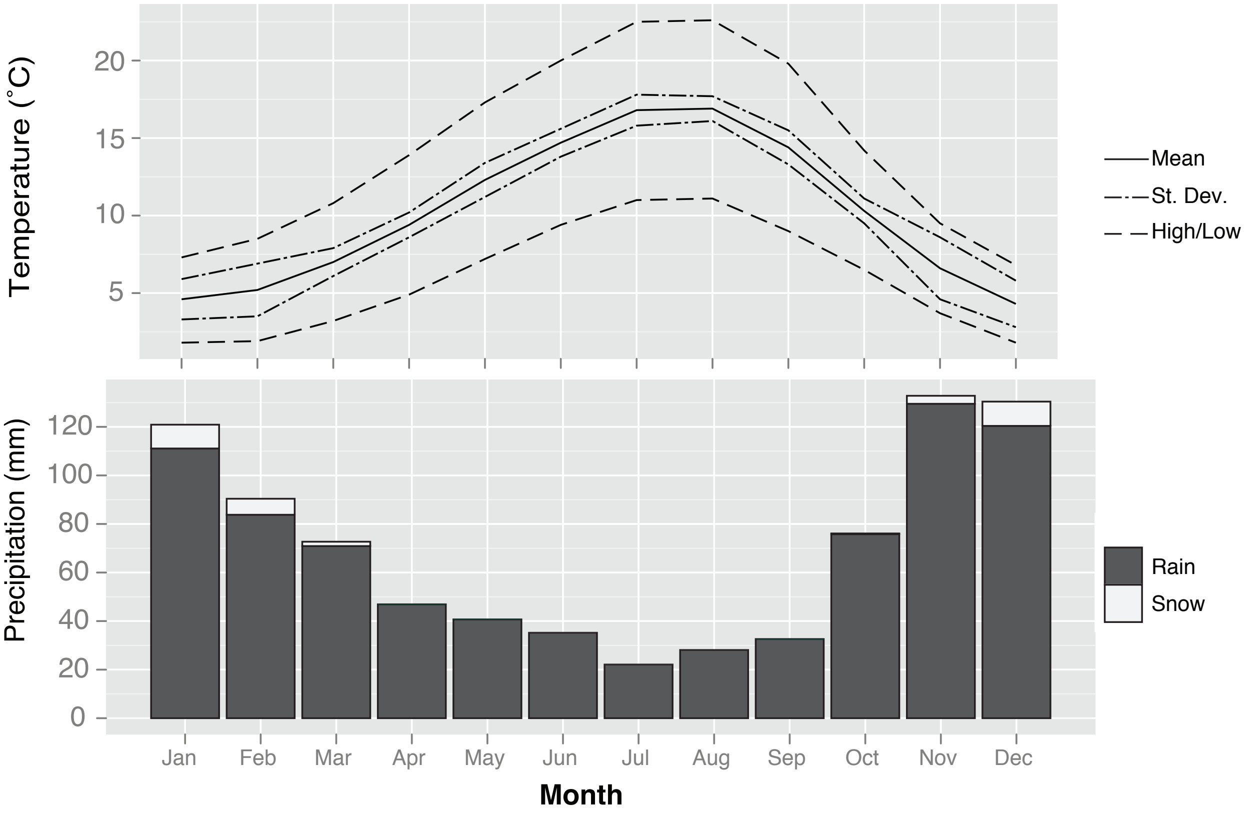


Figure 3.2 Climate normals for Mayne Island (1971 - 2000). Environment Canada. (accessed from http://www.climate.weatheroffice.ec.gc.ca, June 12th, 2009)

swales contain western redcedar (*Thuja plicata*). Arbutus (*Arbutus menziesii*) are present in dry locations. Understory vegetation is dominated by salal (*Gaultheria shallon*), dull Oregon-grape (*Mahonia nervosa),* and ocean spray (*Holodiscus discolor*). In restricted pockets, and in at least one location next to Dionisio Point, Garry oak (*Quercus garryana*) still thrives locally.

In a typical Douglas-fir forest floor, organic matter is composed primarily of humus, woody debris, needles, and branches, contributing a decreasing amount of organic matter to the soil in that order (Youngberg 1981:140). They do not require high concentrations of soil nutrients, analogous to the ions measured by electrical conductivity, for fertility (Heilman 1981:130). Conifers are typically “base cation cyclers”. Their litter is nutrient rich, but many of these nutrients are quickly taken up by the tree before they can be leached into the subsoil.

Modern climatic conditions appear to have prevailed over at least the past two millennia (Brown and Hebda 2002; Zhang and Hebda 2005). Late Pleistocene – Holocene (~12,000 B.P. to present) climatic reconstructions that focus on the Gulf Islands of British Columbia are currently unavailable. However, reconstructions based on palynological evidence are available for nearby southern Vancouver Island (Brown and Hebda 2002). They (Brown and Hebda 2002) found that relative precipitation was tracked by the ratio between two coniferous species: Douglas-fir and Western Hemlock. The Douglas-fir - Western Hemlock Index for the location most similar to Dionisio Point in terms of its protection from high annual precipitation (East Sook Fen, 45 km south of Dionisio Point), shows a gradual trend towards increasing moisture and cooling temperatures over the Holocene (Brown and Hebda 2002:359). Modern conditions appear to have been achieved by 2000 B.P. and have not significantly changed since that time.

Finer resolution data are available from an analysis of 706 Douglas-fir growth-ring records collected from a drowned forest at Heal Lake, 17 km northeast of East Sook Fen (Zhang and Hebda 2005). Sub-centennial changes in the climate were pronounced prior to 4000 B.P. but over the following four millennia climatic change were relatively muted (Zhang and Hebda 2005:3), supporting Brown and Hebda's (2002) reconstruction of Late Holocene climatic climatic variability. These studies demonstrate that few significant climatic changes have occurred within the past two millennia, and in particular over the 300 years of site occupation. Below (Table 3.4) formalized expectations are presented for the natural samples, derived from the above discussion. These characteristics are favorable for the recognition of cultural sediments and the reconstruction of cultural formation process; the cultural and natural samples vary inversely in most characteristics. Cultural samples are expected, for reasons explained a length below, to have enriched organic matter contents, electrical conductivity, inorganic carbonates, and finer texture.

Table 3.4 Expectations of natural soil characteristics

Variable	Expectation
Texture	Sandy
Organic Matter	Moderate to Low below the surface horizon
Inorganic Carbonates	Very Low
Electrical Conductivity	Low below the surface horizon
pH	4 - 6

Geoarchaeological Model

The final section of this chapter focuses on the construction of a model of the geoarchaeological characteristics of several architectural features identified at Dionisio Point. As first mentioned in the introduction to this project, this method is slightly different than that used in most formation process studies on the Northwest Coast. It draws on ethnographic and archaeological data from the Northwest Coast to generate expectations for the analytical variables presented at the opening of this chapter. It is separated into two parts. The first presents ethnographic data on the Coast Salish shed-roof plank house, the architectural form that dominated the Strait Of Georgia area at the time of Contact. The second discusses a number of geoarchaeological expectations derived from these ethnographic data in light of archaeological models that are currently used in the Strait of Georgia and elsewhere on the Northwest Coast.

The use of "geo-ethnoarchaeological" analogues has become increasingly common in geoarchaeological activity area research (e.g., Knudson et al. 2004; Middleton 2004; Shahack-Gross et al. 2003). In these studies, modern sites where contemporary cultural processes can be observed are studied for comparison with archaeological data. Unfortunately, these approaches are not feasible in the case of the Northwest Coast. Few post-contact-era houses have survived in a form that allows them to be ethnoarchaeological analogues to archaeological data (e.g., Mackie and Williamson 2003).

Facing this reality, archaeologists in the region have tried to unravel the complexity of house deposits by combining archaeological analysis with local and regional ethnographic data. The utility of this approach has been questioned by archaeologists in light of the demographic and socio-economic effects of Contact (e.g., Burley 1980:59-63) or who are generally suspect of ethnographic analogy (e.g., Maschner 1991). Yet, the “tyranny of the ethnographic record” (Wobst 1978:303) is not an intrinsic property of the ethnographic record itself. I argue, following Grier (2007), that the ethnographic record of the Northwest Coast is valuable as a source of testable hypotheses. By presenting the ethnographic material on shed-roof houses, I aim to highlight some of the data and assumptions that underlie the models used by archaeologists.

The Shed-Roof Plank House in an Ethnographic Perspective

This review focuses on the ethnographic work of Suttles (1951, 1991) and Barnett (1955). Their accounts and interpretations of Coast Salish domestic life in the early 20th century have provided the data archaeologists have used to generate and test hypotheses concerning social organization, economic organization, and house architecture. The emphasis in this study is upon those ethnographically described activities that contributed to the formation and maintenance of architectural features of interest, such as house floors, hearths, entryways, and benches. These include site preparation, house construction, food preparation and consumption, and housekeeping.

There are two reasons for focusing on the shed-roof house over other plank house plans. Grier (2001) has interpreted the distribution of post feature and hearth features identified in House 2 at the Dionisio Point site as corresponding more closely to a shed-roof plan than to alternative forms. Also, the shed-roof house has been the dominant form identified at other archaeological sites in the region (e.g., Ozette [Mauger 1991]).

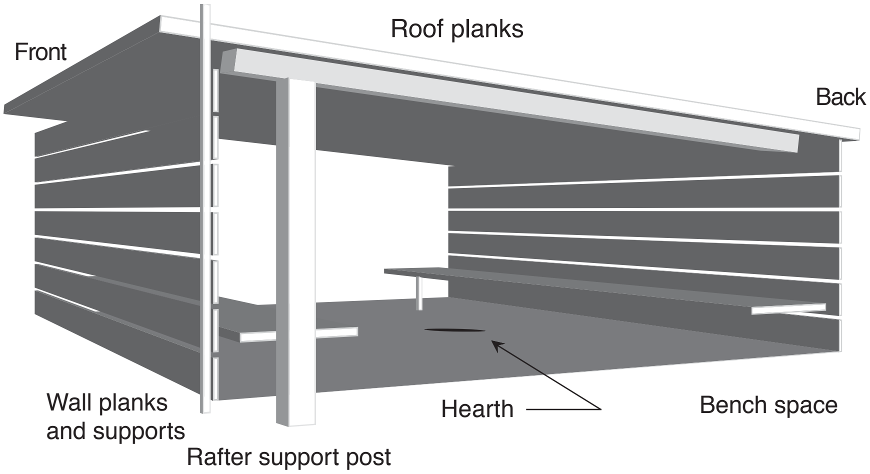


Figure 3.3 Model of a shed-roof plank house compartment, identifying the principal architectural features discussed in the text. Modeled after descriptions in Barnett (1955) and Suttles (1951).

The architectural plan of the shed-roof house is relatively simple when compared to the gable-roofed houses common on the North and South Coasts (Figure 3.2). Pairs of posts, one higher than the other, and two beams running between each high-low pair constituted the frame (Suttles 1991:212). Exterior cladding was composed of a series of overlapping horizontally slung planks. This cladding was not permanently attached to the structure, instead being supported by a series of smaller diameter vertical poles that surrounded the frame. This construction technique facilitated patterns of seasonal mobility in which the house was disassembled and the parts either used in smaller domestic structures or reassembled on other frames located elsewhere (Suttles 1991:216). It also permitted the household to respond to changes household size. Plank house frame and cladding could be expanded or contracted to accommodate the arrival or departure of family-units (Suttles 1991:215).

The interior was separated into a number of domestic spaces termed "compartments" (Suttles 1991:215). These compartments were frequently limited to the area between two sets of house posts along the length of the structure (Suttles 1991:215). Thus a shed-roof house with six house posts in three pairs is thought to have contained four families. Each domestic space was used by a nuclear or extended family, and had a hearth and storage area (Suttles 1991:215). Hearths lacked any associated furniture and could be readily moved when necessary. Stores were kept in the rafters, which allowed the house to act as an enormous smoke box (Ames 1996; Suttles 1991) and in boxes under sleeping platforms.

Platforms, approximately 1.5 m in width (Suttles 1951:258) and approximately 20 - 70 cm high (Barnett 1955:37; Samuels 1991:108), extended around the parts of or the whole of the interior perimeter of the house. It is likely that the shape, size, and distribution of these features were variable and tailored to suit the needs of the household. These may have constituted the only permanent furniture in the structures (Barnett 1955:38). Ethnographers are unanimous in describing the floor as earthen (Suttles 1991:214) or unplanked (Barnett 1955:38). Inhabitants may have used mats to protect themselves from the cold and possibly somewhat damp sediment.

It appears from the ethnographic record that the location of the entryway could be quite variable. Suttles (1991) identifies it as typically found in the long wall that faced the beach. Mauger (1991:157) suggests that it may not have had a permanent location in some shed-roof plank houses, and being little more than a gap in the horizontal wall planking facilitated their relation. In some instances, the entryways were extraordinarily complex, formed of a convoluted web of planks and posts. Some may have had extensive defensive mechanisms (Suttles 1991:219), hinged doors, or wind-breaks (Mauger 1991:157).

The ethnographic data suggests that several architectural features that can be productively assessed from the geoarchaeological record. Floors, hearths, benches, and post features are all candidates; they may leave permanent signatures that are identifiable by their color, texture or microscopic characteristics. Entryways are also features that may leave identifiable geoarchaeological traces due to their presumed association with housekeeping practices; all refuse that is not incorporated into the floor or bench features, must be transported through the entryway to exterior middens. Past discussions of plank house cultural formation processes have highlighted many of these same features. The following section discusses how these features have been treated by past models of cultural formation processes, and contrasts these with geoarchaeological expectations that are tested in this study.

Archaeological Models of Plank House Features

The geoarchaeological model draws on the preceding discussion of the ethnographic literature to identify architectural features that may leave a geoarchaeological signature. The discussion covers the anthropogenic alteration of the site prior to habitation, and the behaviors that may have contributed to the development of house floors, hearth, benches and entryways identified in the geoarchaeological record. Post features samples were unavailable for analysis from the Dionisio Point site and are not addressed here.

Pre-habitation site alteration

Few archaeologists systematically treat pre-habitation site alteration as a cultural formation process because they concentrate on materials deposited after site-preparation. However, accounting for these processes is a necessary step in geoarchaeological analysis as they alter the distribution of on-site natural sediments. The preparation of the site for a plank house construction resulted in the formation of a series of three stable terraces (Grier 2001:104,106), a practice also noted among the ethnographic Coast Salish (Barnett 1955:43, 51; Suttles 1991:214). Each of these terraces is 2 to 3 m in height, suggesting that many cubic meters of material was redistributed from the back of would-be house floors to the front.

This large-scale movement of sediment bodes well for the recovery of signatures of habitation activities. Soil constituents may be variable within a small area due to varying vegetation cover, as pect, and infiltration. The character of the underlying sediment, however, is fairly homogenous (Green et al. 1989) because it is only indirectly affected by these factors and predominantly reflects the characteristics of the parent material. Thus, the inversion and effective elimination of the forest soil removed one of the sources of variability that might confuse our interpretations of later activities. Comparison of on-site and off-site signatures is, therefore, primarily concerned with changes that occurred after site abandonment.

Hearth Deposits

I have chosen to begin with hearths for three reasons. First, if the dominant sources of organic matter, free ions, and fine sediments in the house are the preservation, preparation and consumption of food, these features should be the most enriched in the deposit, and thus should be readily "visible" in their geoarchaeological signatures. Second, with few exceptions, hearths are considered to be fundamental to the identification of plank house deposits. Third, hearths have also been regularly used to infer the number of families in a house (e.g. Grier 2006a), household social organization (Coupland et al. 2009), as well as the social status of the household (Samuels 1991b).

Few cultural or non-cultural formation process models presently exist to explain the characteristics of plank house hearth features. The common conceptualization of these features is that they functioned principally as domestic facilities, used to process food, give light, and provide heat. Drawing on the ethnographic record, it has been suggested that some hearths functioned as purely ceremonial facilities, and others purely domestic facilities. This argument has been supported with evidence that some hearths were treated differently than others, particularly by their location and size (Samuels 1991b:266). How far into the past this model can be used is unclear, particularly in light of evidence that ceremonial function appear to have been vested in specific families within the household as opposed to the entire household itself (e.g., Grier 2006a:114). Samuels (1991b) analysis of different size grades of faunal remains, excluding shell fish, has suggested that food waste may have been deposited directly into hearths after it was consumed in Houses 1 and 2 at the Ozette site.

When compared to natural samples, in the context of all other deposits in the plank house, hearths should have the highest enrichment in organic matter, the highest concentration of free ions (electrical conductivity), and the highest pH. Organic matter in this context is derived primarily from food and fuel residues. Food prepared around the hearth may have deposited oils, or particulate organic matter into the feature increasing its organic matter content. Carbonized wood fuel would also contribute to localized organic matter enrichment.

Wood ash, in sites in drier environments has been demonstrated to cause increased free ion content, particularly in the form of potassium (Marwick 2005:1361; Middleton and Price 1996:678; Weide 1966). Similar increases in forested environments have been identified in forestry studies, but they have also noted that in these latter environments, presumably because of nutrient uptake, coarse soils, and higher precipitation, these effects are only temporary. However, none of these studies the effects of ash disappear completely during their projects, suggesting that slight, localized signatures may still be present in archaeological deposits. Increased pH is a consequence of the deposition of free ions by ash, and has been noted in other archeological contexts (e.g., Marwick 2005:1361; Weide 1966).

Inorganic carbonate enrichment in hearths likely represents the *in situ* deposition of shellfish remains following either processing or consumption, the leaching of carbonates from nearby shell deposits, or from detrital calcite phytolithis formed by the combustion of wood fuel. Wood phytoliths likely contributes to a slight increase in carbonates in hearths, but it is unlikely that this results in a significant increase over the characteristics of the natural samples. Significant carbonate enrichment is probably only the result of either the first or the second process. It is, however, possible that phytoliths could contribute to slight increases in silt and clay content. Sedimentary analyses of ash texture has demonstrated that particles can range from clay to sand in size, the modality determined by the species of fuel plant, part of the plan, and temperature of the fire. One study of commercially produced wood ash demonstrates that as much as 50% are less than 100 μm or smaller, quite close to the 62.5 μm is the division between sand in silt used in this study (Demeyer et al. 2001:288). Given these characteristics, different temperatures of fires may also be reflected in grain size distributions.

House Floors

The term *house floor*, for many plank house deposits in the Strait of Georgia is something of a misnomer. Expect for rare occurrences of prepared floors (e.g., Lepofsky et al.

2000:398-399; Samuels 1991b:191), excavations have failed to locate evidence of well-preserved living floor strata traceable across an entire deposit (e.g., Grier 2001; Matson 2003). This is indirect support for the argument that pre-contact plank houses lacked planked floors, much like their post-contact representatives. However, it also means that few studies have dealt directly with the cultural formation process that create and affect house floor deposits or their assemblages.

Where floor formation processes have been discussed is in those excavations where discrete floors have been preserved, such as at the Ozette site (e.g., Huelsbeck 1994; Samuels 1991b). These discussions focus on the differential disturbance of primary deposits as a result of three processes: housekeeping, trampling, and curation (Samuels 1991b:232). These processes were suggested to affect the distribution of both artifacts and faunal remains in Houses 1, 2, and 5 at the site. Artifacts were much more likely to be curated by house occupations (Samuels 1991b:244), while faunal material appear to have reflected *in situ* processing locations as well as housekeeping practices (Sameusls 1991b:262). These processes, as I argue in the introduction, are most commonly addressed through the distributions of artifacts and faunal remains, both of which can be scarce at some sites. Sedimentary analysis, while not as sensitive as artifact remains, can provide an alternative data set.

Spatial analyses of floor assemblages have supported the argument that space in most pre-contact plank house deposits was redundant; that the house was not divided into functional areas, but that each compartment was used as a domestic space by an individual family (Grier 2006a). This suggests that the additions made to most floor areas were broadly similar. Should this be the case, it is likely that anthropogenic additions were dominated by residues from food production and consumption (e.g., Samuels 1991b), and tool production. Many of these residues, and particularly food residues, would have been difficult to remove from floors and would have, over time, accumulated in large amounts.

The incorporation of large amounts of organic matter would alter the floors pH and electrical conductivity. Organic matter typically has the affect of lowering pH through the production of organic acids. However, much like hearth deposits, this process was likely mediated by the incorporation of byproducts of wood fuel combustion that result in increased electrical conductivity and increased pH.

Once again, much like hearth deposits, inorganic carbonates have only two significant anthropogenic sources: marine shell and opal phytoliths. Shell deposition within houses has been demonstrated in deposits at Ozette (Wessen 1994), but otherwise appears to be a rare occurrence on the coast.

Bench Deposits

Ethnographic data on benches suggests that their size and layout were variable (Barnett 1955:37; cf. Suttles 1951:258, 1991:213), although there is consensus that it was used for sleeping, socializing, and storage. In spite of this structural variability, these deposits have been located in several excavations in the Strait of Georgia. They have been identified through two kinds of evidence. First, benches have been inferred from the presence of substantial post features that area associated with the frame of the structure but are not clearly rafter support beams. They are frequently smaller than rafter supports and are located approximately a bench-width away from the edge of the structure (Grier 2001:166-178; Mauger 1991:105).

Alternatively, changes in microtopography and texture have been used to identify bench deposits. Grier (2001:179) at the Dionisio Point site, and Lepofsky et al. (2000:398-399), at the Scowlitz site, have both identified benches based on gravelly, step-like features located in the edges of the deposit. Matson (2003:88) has suggested that loose black sediment around a portion of one of the compartments in the Shingle Point house represents a bench deposit.

The variety of data used suggests that archaeologists use several models to identify and interpret bench deposits in plank houses on the Central Coast. Many draw on Hayden and Cannon's (1982) discussion of benches as out-of-the-way places where valued artifacts may be kept and subsequently lost, or where, through size-sorting processes, larger artifacts and faunal remains will differentially accumulate through daily maintenance processes. The data Matson (2003:88) cites in identifying bench deposits suggests that this area was not trampled, and further implies that organic matter of some kind accumulated in this area, perhaps in the form of material transported from the center of the house floor.

If these features were created during initial preparation of the deposit by the piling of sediment around the perimeter of the house, the characteristics of these deposits should appear to be quite similar to those identified for natural samples. However, if as has been suggested, benches were locations where sediment accumulated during the occupation of the house, they may have characteristics quite different from the natural samples. If food resources were stored in these locations, I would expect that they would be enriched in organic matter, much as Matson (2003:88) identified at Shingle Point. Moreover, if they were locations where material accumulated, either intentionally or unintentionally, as Matson (2003:88) suggests, they may also contain traces of sediments generated by other features, and therefore appear to be moderately enriched in, for example, electrical conductivity and have slightly finer texture than non-bench floor deposits if hearth sediments were transported there. However, if bench space was not used for the storage of goods, nor did material accumulate there from cleaning activities, characteristics may be quite similar to those of non-bench floor deposits.

Entryways

As discussed in above, entryways have been poorly defined in both ethnographic and archaeological contexts. When archaeologists have identified these deposits it has been through two lines of data. First, entryways have been identified through "smears" of faunal material new walls (e.g., Huelsbeck 1994). It is argued that these patterns are the result of debris being moved out of the house. The long-term accumulation of faunal remains suggests that the house entryway was rarely, if ever, moved during the occupation of the structure. The second line of evidence is the presence of clusters of large numbers of post features near the edge of deposits. Following ethnographic descriptions of fortified doorways in some shed-roof plank houses, some archaeologists have interpreted these feature clusters as parts of these defencive mechanisms.

The sedimentary signature of entryways may be quite subtle. It likely tracks the same disposal processes that were identified at the Ozette site. I expect that many of the waste materials removed from houses were organic in origin, such as food and fuel waste. The overall patterns should be similar to those of floors and hearths. However, because the activities that generate these wastes are concentrated in other parts of the house, it is probable that the signature here will be considerably weaker.

Expectations

Table 3.5 summarizes the expectations for cultural samples characteristics based on the preceding discussion.

Table 3.5 Cultural versus natural sample geoarchaeological expectations

Context	Measurement	Expectations relative to natural sediments [a]	Zonation identified in Figure 3.x
Hearth	Soil Texture	● ●	Zone I
	Organic Matter	● ● ● ● ●	
	Inorganic Carbonates	●	
	pH	● ●	
	Electrical Conductivity	● ● ● ● ●	
Floor Center	Soil Texture	●	Zone II
	Organic Matter	● ● ●	
	Inorganic Carbonates	●	
	pH	●	
	Electrical Conductivity	● ● ●	
Floor Edge	Soil Texture	● ●	Zone III
	Organic Matter	● ●	
	Inorganic Carbonates	●	
	pH	●	
	Electrical Conductivity	● ●	
Entryway	Soil Texture	●	Zone IV
	Organic Matter	● ●	
	Inorganic Carbonates	●	
	pH	●	
	Electrical Conductivity	● ●	

[a] An increasing number of dots denotes increasing enrichment in OM and IC, higher pH and EC and increasing silt and clay content. A single dot denotes similarity to the natural sediments.

The overall pattern evident in Table 3.5 is that most features share the inputs, that is anthropogenic alteration is repeatedly on the same variables, and that the modifications are all in the same direction. The principal difference between features is the variability in the intensity of the alteration. The expected trend, therefore, is that hearths will be the most heavily modified of the features, followed by floors, benches, and finally entryways. The pattern, in fact, can be represented as a series of concentric circle away from hearths (Figure 3.3).

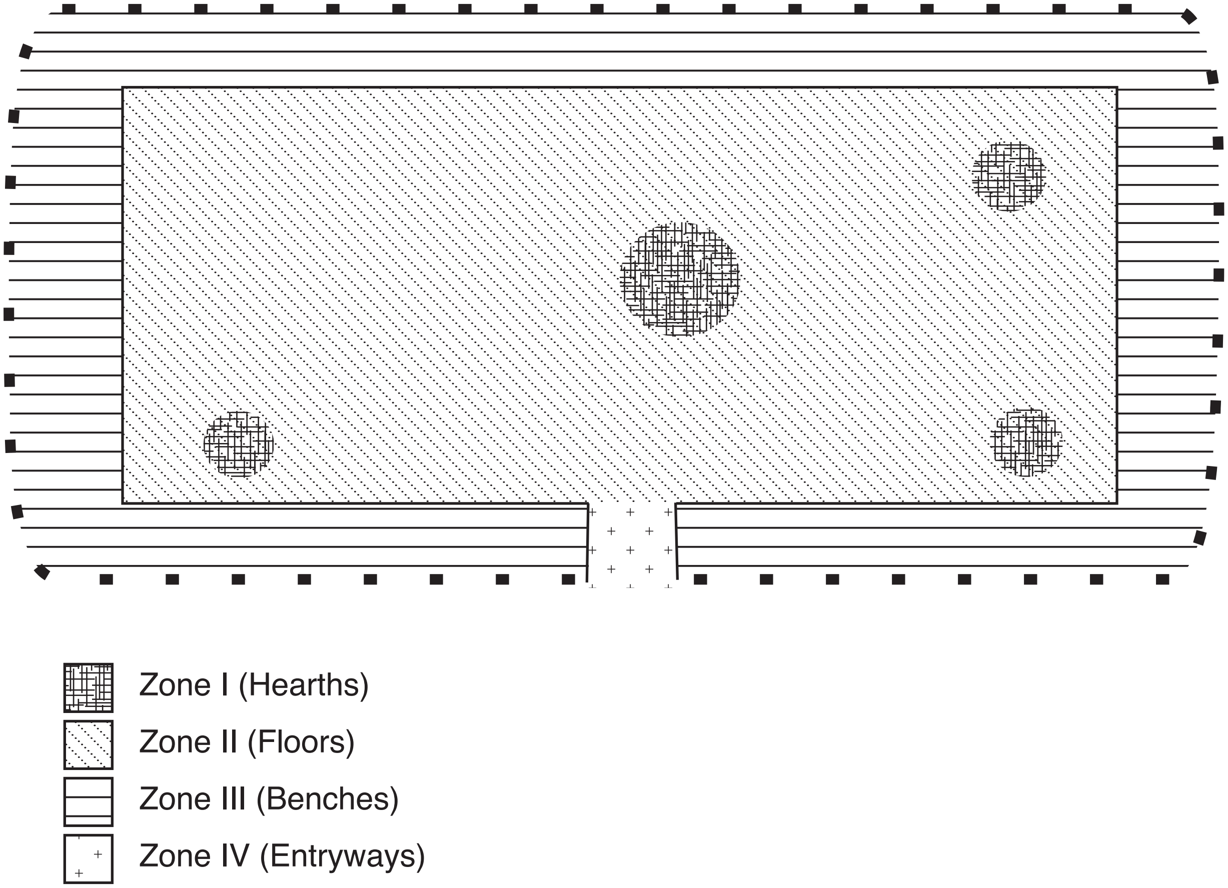


Figure 3.4 Schematic delineation of intensity of anthropogenic alteration of sediments within a shed-roof house. Based on the expectations derived from Table 3.5 as applied to House 2 at Dionisio Point. Not to scale.

The goal of this chapter has been to provide the environmental, ethnographic and archaeological background necessary to evaluate the results and discussion in Chapters Four and Five. Contemporary data on climate, geology and vegetation was presented to suggest what might be expected from natural samples collected from around the Dionisio Point site. Ethnographic and archaeological data pertaining to shed-roof plank house architecture and feature formation processes were identified to provide a basis for evaluating the cultural samples selected for this study. The implications of these three data sets for our archaeological models of plank houses and plank house formation processes will be raised throughout the remainder of this study.

Chapter Four: Methods and Results

This study focuses on the bulk sediment analysis of two data sets. The first of these is an archival collection of bulk sediment samples generated in 1997 and 1998 by the Dionisio Point Household Archaeology Project (DPHAP). These samples were collected from locations in House 2 and House 5 at the Dionisio Point site. The second data set is a series of bulk samples of non-anthropogenically altered sediments and soils from locations around the Dionisio Point site.

In the following discussion, natural strata are labeled according to pedological conventions, using capitalized Roman letters. However, the cultural strata at Dionisio Point have, in the past, been labeled using the same range of letters. Rather change conventions for either of these data sets, I have retained these label, but refer to a pedological stratum as a "horizon" and a cultural stratum a "layer".

Natural Samples

In 2007, eight off-site "natural" samples were collected at Dionisio Point. These samples were collected from three locations within the Dionisio Point Provincial Park boundaries, but outside of the known village area (Figure 4.1) and attempted to capture the range of variability of geology and vegetation in the area. Samples were collected from the organic-mineral "A" horizon, the illuvial "B" horizon, and the parent material "C" horizon. Where a clear boundary between the B and C horizon was absent, the label B/C was used. When possible, the overlying organic litter "L/F" horizon was excluded. One sample (SS200702) was discarded after it became clear that it had partially sampled the litter horizon. Samples consisted of 500 g of sediment, which were collected on May 22nd. 2007 and were transported to the Geoarchaeology lab at Washington State University for analysis.

Natural Sample Profile 1:

The first of the sampling locations was approximately 40 m south of the Marpole village site datum, at 10 m asl. It consisted of a 50 by 50 cm unit 53 cm deep. The in-field description of the profile indicates the presence of a 12 cm thick litter horizon (L/F), composed of undecomposed to partially decomposed twigs, needles, and woody material. This horizon directly overlay a weakly formed illuvial B horizon that was grayish brown (10YR5/3) from 0 to 20 cm below surface and a dark yellowish brown (10YR4/4) B/C horizon from 21 to 53 cm below surface. The field identification of the texture was loose gravelly sand. Below the litter horizon, there were a few fine roots. Samples were collected from each of these three horizons.

Natural Sample Profile 2:

The second unit was located approximately 100 m southeast of the site datum, at 10 m asl. It consisted of a 50 by 50 cm unit 30 cm deep. The in-field description of the profile indicates the presence of an approximately 10 cm thick litter horizon (L/F). This horizon directly overlay a weakly formed B horizon that was dark brown (10YR3/3) from 0 to 20 cm below surface, and a brown (10YR5/3) B/C horizon from 21 to 31 cm below surface. The field identification of the texture was a loose gravelly sand. Below the litter horizon there were a few fine roots. Samples were collected from both the B and B/C horizons.

Natural Sample Profile 3:

The third unit was located approximately 180 m east-northeast of the site datum, on the erosional west bank of Parry Lagoon. The elevation was between 1 and 2 m asl. The in-field description of the profile indicates that there was a 26 cm thick black (10YR2/1) A horizon developing under short grasses. The A horizon directly overlay a thick dark grayish brown (10YR3/2) B horizon from 26 to 70 cm below surface. The samples collected from the B horizon were located adjacent to one another. The B horizon contained evidence of dark yellowish brown (10YR3/6) mottles (oxidized, iron-rich accumulations) or root casts, both these and the presumed *in situ* soil were sampled. The field identification of the texture was loose sand. There were a few fine roots in the B horizon. Samples were collected from the A horizon and B horizon soils and mottles/root casts.

Cultural Samples

During the DPHAP excavations, sediment samples were collected with the goal of activity area research. Every 10 cm cultural layer in each 1 m^2 or 4 m^2 excavation unit was represented by the collection of a single sample. When features were encountered, they were sampled as a single unit, except when the feature was quite large. Feature 9, the approximately 1.5 m^3 central hearth in House 2, for example, generated several samples. Each of these samples was approximately 4 liters in volume

At the time of this study, 52 cultural samples were appropriate to the kind of research questions and methods pursued here. This data set consisted of forty-four on-site matrix samples selected from the 1997 excavations in addition to eight on-site sediment samples from the 1998

1998 excavation. As a consequence of the availability of samples, this study focused on several excavation units intensively. The primary sampling locations are shown in Figure 4.2. In spite of the fact that this is a much reduced data set when compared to the full extent of excavations in House 2 in 1998, the results are highly interpretable. Samples from all three cultural strata, representing both village and post-village occupation, were available from the units selected for this study.

Dionisio Point Cultural Stratigraphy

Four stratigraphic layers were identified during excavation, labeled A, B, C, and E (Basal Gravels) (Figure 4.3). The uppermost, Layer A was interpreted to be a Gulf of Georgia Phase reoccupation of parts the site as a shellfish processing camp. This interpretation is based on radiocarbon dates, the relative abundance of urchin remains in the faunal assemblage (Ewonus 2006:42), and the relative abundance of Gulf of Georgia Phase diagnostic artifacts compared to artifacts diagnostic to other phases in this stratum (Grier 2001:112).

Layers B and C were associated with the the Marpole Phase village and contemporary deposits. They were black (10YR2/1) to very dark brown (10YR2/2) and ranged from 20 to 50 cm in thickness and contained a rich Marpole Phase artifact assemblage, including distinctive anthropomorphic stone bowls (Grier 2006a) and a predominance of ground stone tools (46% of the formal tool assemblage) typical of mid to late Marpole phase assemblages (Grier 2001:51). A large suite of radiocarbon dates from the deposits supported this interpretation (Grier 2006a).

Layers B and C contained all known Marpole phase house features, except where these features intruded into the basal glacial till. Four large hearth complexes were identified: two on

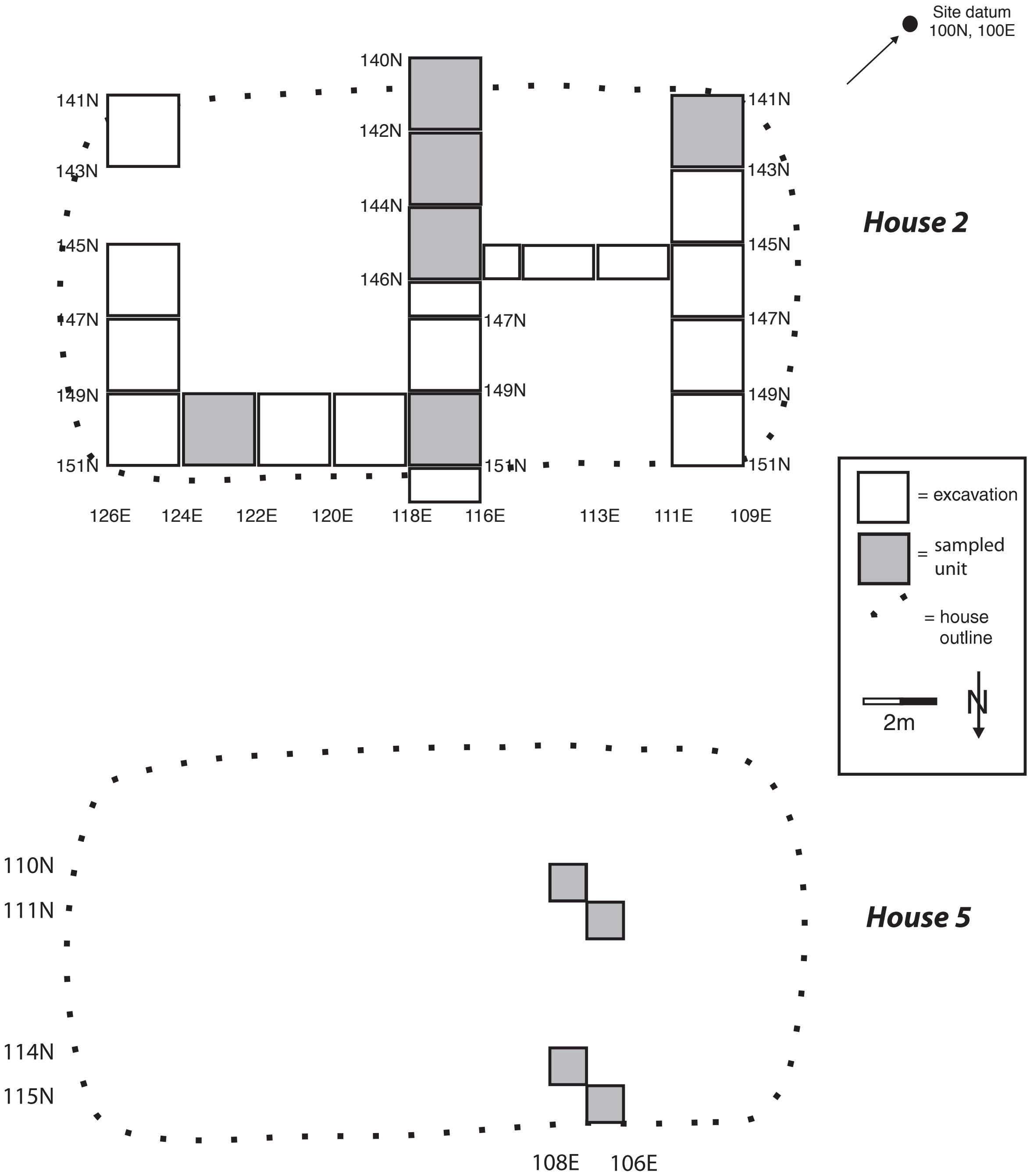


Figure 4.2 DPHAP excavation units sampled for this study (adapted from Grier 2001:174)

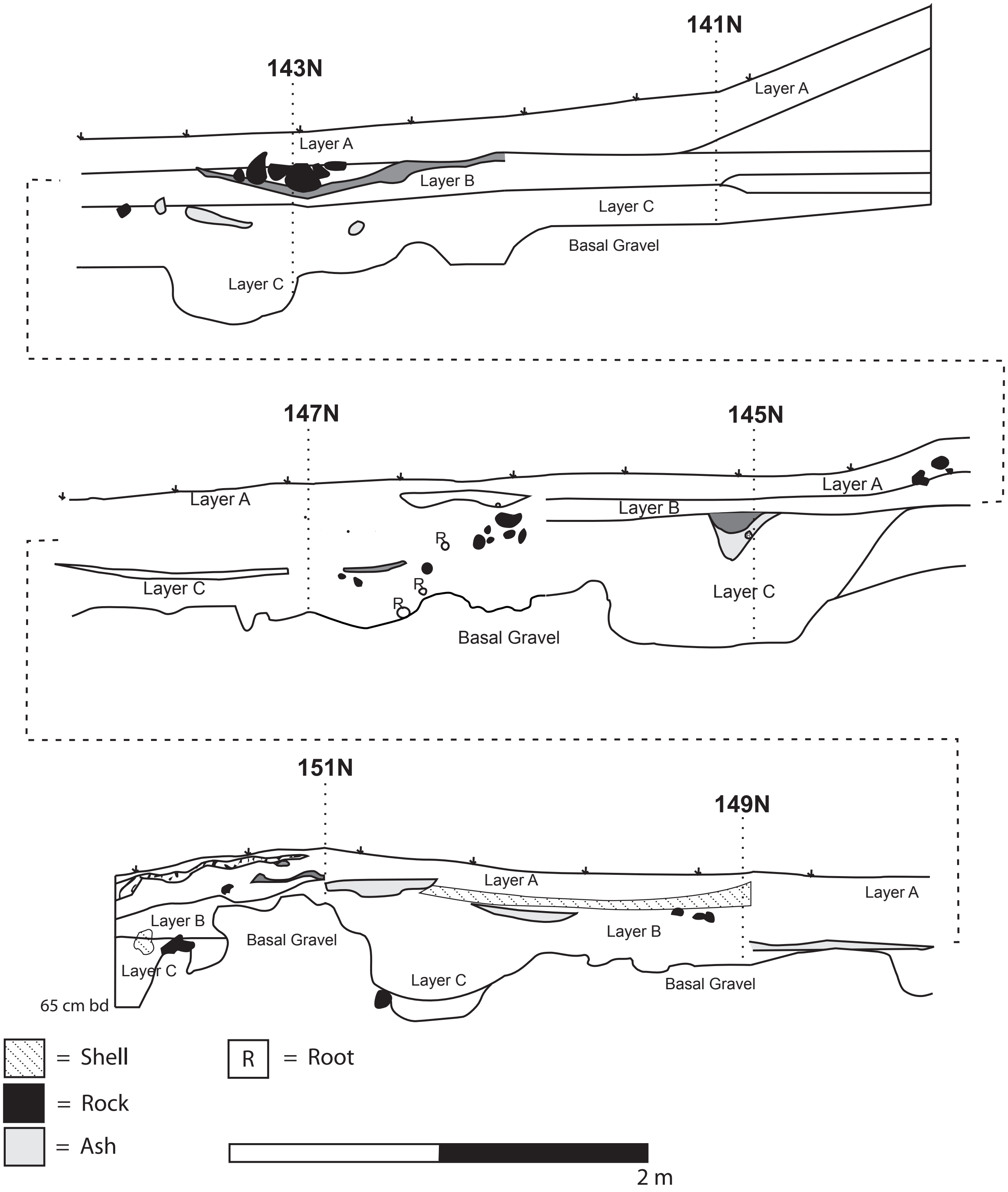


Figure 4.3 Profile of the east wall House 2 Trench 2 at Dionisio Point (116E) showing the stratigraphic relationship of cultural layers A, B, C, and E.

the western side of the structure, a comparatively larger hearth complex in the center, and a smaller one in the east. A fifth hearth complex may exist in an unexcavated area in the southeast corner of the deposit (Grier 2001:174). The term hearth complex is used here because these features extend through much of the 50 cm of Marpole phase occupation, representing long-term structured reuse of this feature. No discrete floor surface was identified during excavation, though groups of artifacts lying horizontally may represent relict house floors (Grier 2001:154).

Stratum E was the basal, culturally-sterile sediment. It consisted of a combination of Pleistocene age glacial tills, and *in situ* weathered sandstone deposits. House features were intrusive from the overlying Marpole phase house deposits. Table 4.1 summarizes the cultural stratigraphy of the site and presents pertinent field notes and radio carbon dates.

Table 4.1 Generalized descriptions of site stratigraphy (from Grier 2001:102-130)

Field Identification	Thickness (cm)	Description	Cultural Component	Radiocarbon Dates (B.P.) *
A	20 - 30	10YR2/2; humic material of loose, very dark brown	Post-Marpole occupation of the site; no associated house depressions	955 ± 50 (GX-25808); 1265 ± 65 (GX-25807)
B C	20 - 30 20 - 30	10YR 2/1; carbon-rich fine black silts of various degrees of compaction	Marpole village; extensive deposition of phase-specific artifacts	1440 ± 60 (Beta-130056); 1770 ± 70 (WSU-5032)
E	-	10YR4/4 - 6/6; loose gravelly sands	Precedes Marpole phase occupation. Contains evidence of intrusive house features.	N/A

* Dates from Grier (2001:119)

Feature Descriptions

This study undertook the analysis of several features from both components at Dionisio Point. Each is described briefly below in Tables 4.2 and 4.3. Features 1, 4 10, 11, and 12 all belong to the post-Marpole phase plank house occupation at the site. Feature 34, a possible rock heating feature, is included in this component as it could not be securely associated with the House occupation either structurally or stratigraphically. Features 2, 9, 16, 24, and 28 were located within the Marpole village occupation Layers B and C.

Methods

Table 4.2 Feature Descriptions for Layer A (from DPHAP field notes)

Feature	Location	Form	Field Color	Notes
1	Unit 114N/107E	Combustion feature. 70 cm in diameter		Composed of a dark greasy silt containing numerous small pebbles and fragments of fire-altered rock. Fragments of burned bone were retrieved in the 3 mm screen, but otherwise there were few faunal remains or artifacts in the feature
4	Unit 144N/116E	Fire-altered rock cluster		A partial elliptical cluster of 12 large fire-altered granitic rocks and 64 smaller fire-altered rocks. Associated with Feature 5, a patch of oxidized shell, and partially overlies Feature 9.
10,11, and 12	Unit 149N/116E	Combustion features. ~ 60 cm in diameter		Oxidized patches of sandstone fragments and shell. Features 10 and 12 were only partially exposed during excavation and were amorphous in shape. Feature 11 as roughly circular.
34	Unit 149N/122E	Fire-altered rock feature.		Roasting Feature (?). It consisted of 78 fire-altered rock fragments, with not associated oxidized matrix or faunal material. Carbonized material was found throughout the feature.

Table 4.3 Feature Descriptions for Layers B and C (from DPHAP field notes).

Feature	Location	Form	Color	Notes
2	Unit 114N/107E	Combustion feature. 60 cm in diameter	Very dark grayish brown (2.5YR3/2)	Composed of loose sediment, contains abundant pebbles. No fire-altered rock or faunal material was recovered.
9	Unit 144N/116E	Combustion feature. 2 m in diameter; 50 cm thick	Predominantly black (10YR2/1) silty sediment with dark yellowish brown (10YR3/4) oxidized concentrations	Composed of two levels: an upper layer of mounded silt and abundant fire-altered rock, and a lower layer of silt filling a shallow circular depression. Few faunal remains and no shell were recovered.
16	Unit 142N/116E	Combustion feature. 1 m in diameter	Black (10YR2/1) carbonized silty sediment with yellowish-brown (10YR5/6) oxidized concentrations	Contained large amounts of fire-altered rock, carbonized and oxidized material within a shallow bowl-like depression. Few faunal remains, shell or artifacts were recovered.
24	Unit 141N/109E	Combustion feature. ~1.2 m in diameter; 40 cm thick		Very little fire-altered rock was located within the feature, which contained abundant herring vertebrae, a fragmented stemmed point, and a fragmentary dog mandible.
28	Units 149N/122E, 147N/124E, and 149N/124E	Combustion feature. ~1 m in diameter	Predominantly black (10YR2/1) silty material	A broad, shallow depression filled with ash and burned shell. The core of the feature contained fire-altered rock. The surface of the feature contained scattered gravel.

All samples were run through a series of standardized bulk sediment analyses. Samples were subsampled to 500g and dry-screened on a Ro-Tap to whole-Φ units (see Table 2.2). Visible particulate organic matter was removed from the < 4 Φ fraction. For particle-size analyses, carbonates removed with 1N HCl, diluted in de-ionized H_2O, left overnight and the supernatant removed. Salts were removed with de-ionized H_2O, left overnight, and the supernatant removed. Organic matter was removed from the samples with 30% H_2O_2, which was allowed to digest overnight and the supernatant was removed. The high concentration of H_2O_2 was necessary because of visibly high organic matter content of all cultural samples. Soil texture was determined with either a Malvern Mastersizer “S” Laser Particle-Size Analyzer or hydrometer following Gee and Orr (1986) and Day (1965).

The amount of organic matter enrichment and inorganic carbonate enrichment in each sample was determined through loss-on-ignition (LOI) modified from Stein (1984). Samples were initially dried to 105ºC. Combustion of organic matter was completed by heating each sample to 550ºC for four hours. Combustion of inorganic carbonates was completed by further heating each sample to 950ºC for two hours. Organic matter and inorganic carbonate measurements are presented in percent by weight to the nearest ten-thousandth of a gram. pH was determined on a 1:1 aqueous slurry measured with a Beckman 300 Series pH meter. Electrical conductivity was determined on a 1:1 aqueous slurry measured with an Exstik EC400 Conductivity meter. Electrical conductivity measurements are presented in microseimens per centimeter (μS/cm).

All of these methods evaluate sediment/soil characteristics that are considered to be proximate measures of degree and kind of human activity as described in Chapter Three.

Replicate samples were run on every fifth sample for Loss-on-Ignition, pH, and electrical conductivity determination. Replicates were run on hydrometer samples on a judgmental basis. Expanded descriptions of these methods can be found in Appendix 1.

Instrument Error

Errors that are the result of method or instrument precision are frequently evaluated by the manufacturer or by independent review (e.g., Hieri et al. 2001). Table 4.4 provides the precision-based error ranges for the methods used in this analysis.

Table 4.4 Methods and error margins used in this analysis

Method	Error	Source
Organic Matter (LOI)	± 1.7%	Heiri et al. (2001)
Inorganic Carbonates (LOI)	±1.2%	Heiri et al. (2001)
Electrical Conductivity	±.01%	Extech Instruments (n.d.)
pH	±.01	Beckman Series 300 (n.d.)
Texture	< 2% at clay	Gee and Orr (2002)

Hieri et al.'s (2001) evaluation of the method determined that error in precision, though partially determined by the characteristics of the sample, is also the result of the degree of standardization of the protocol. This study used the same protocol for all determinations. The error margins identified above for organic matter and inorganic carbonate determinations are those published by Heiri et al. (2001) for samples with characteristics that most closely matched the samples analyzed here. As a consequence of these system errors, measurements of cultural sample characteristics must exceed these error margins to be considered meaningful. pH and electrical conductivity error rates have been published by the manufacturer. Human error is the greatest source of erroneous measurements for particle size analysis, particularly when using the hydrometer method. All measurements were taken by myself and only after extensive practice with replicates of samples with known texture.

Results

Bulk Analysis of Natural Samples

The following discussion presents the results of the bulk analysis of the natural samples from Profiles 1, 2, and 3. Table 4.5 presents the profile, field horizon identification, and laboratory determination for all 8 samples. Note that while SS200702 is presented here, it is not used in later analyses. The sample was collected from the litter horizon in Profile 1 and is not comparable to any context in the cultural data set. The addition of sample 97M21 in Table 4.6, from the DPHAP matrix archive acts as a replacement for SS200702. The laboratory determined characteristics of this sample are comparable to those collected from off-site. Descriptions of all samples can be found in Appendix 2.

Table 4.5 Natural Samples Bulk Sediment Characteristics

Sample	Profile	Horizon	Depth (cm)	OM (%)	IC (%)	pH	EC (µS/cm)	Sand (%)	Silt (%)	Clay (%)
SS200702	1	L/F	12 - 0	18.9	0.6	5.8	78.6	89.5	9.3	1.2
SS200701		B	0 - 22	5.8	0.6	5.8	77.4	82.9	12.2	4.7
SS200703		B/C	23 - 53	5.9	0.5	5.7	51.8	85.6	11.4	3.1
SS200705		B	0 - 20	4.3	0.6	5.9	108.2	95.7	3.1	0.8
SS200704	2	B/C	21 - 30	3.3	0.6	6.2	64.6	89.6	7.7	2.3
SS200708	3	A	0 - 26	7.6	0.5	6.2	43.6	88.7	8.6	2.8
SS200706		B/C	26 - 70	2.8	0.7	5.6	109.3	87.9	10.6	1.2
SS200707		B/C	26 - 70	3.6	0.2	5.5	100.3	86.3	11.8	1.6

Profile 1:

Organic matter decreased with depth in Profile 1. The litter horizon (L/F), which was comprised of undecomposed and partially decomposed plant matter, had an organic matter content of over 18%. This decreased to a little over 5% in the B and B/C horizons. The stark difference in organic matter content between the L/F and B horizons suggests that little was transported down-profile by insects, arachnids, earthworms, or other macro-fauna. Decomposition of organic matter was probably dominated by fungal activity (Green et al. 1993:15).

Neither inorganic carbonates nor pH significantly changed through the profile. In fact, inorganic carbonate content in all natural profiles was negligible. They were both low measurements and invariant. This supports the suggestion made earlier that carbonates do not constitute the cementing agent of the underlying sedimentary bedrock and therefore are not a significant component of the parent materials on site. Neither did pH significantly change throughout the profile. pH values were comparable to those measured by Green et al. (1989:116) for soils similar to those in the study area.

As measured by electrical conductivity, free ions decreased with depth. Elevated electrical conductivity recorded in the horizon B was likely due to leaching of nutrients from the organic horizon that immediately overlay it. The approximately 25 µS/cm decrease between horizon B and B/C was due to its relative distance from the litter horizon. Fewer free ions were added to horizon B/C and most were rapidly leached from the profile.

The soil texture of profile was classified as a loamy sand. The relative sand content decreased with depth in the profile, while silt and clay both increased. Down profile movement of fine sediment is a process identified in many natural soils (Birkeland 1984). This is likely the process that is responsible for changes in texture with depth in this profile.

Profile 2:

Profile 2 showed a pattern that was, overall, similar to that noted for Profile 1, with the exception that the L/F horizon was not sampled in this profile. Organic matter decreased by 1% through the profile. The inorganic carbonate content showed no change through the profile. The 0.3 pH increase between the B and B/C horizons was within the error margin of the instrument. The approximately 43 µS/cm decrease in electrical conductivity between the two horizons was probably the result of pedogenic processes. Free ions accumulated in the B horizon, but were extensively leached in the layer B/C horizon. Higher absolute electrical conductivity values in this profile, when contrasted with Profile 1, were the result of additional free ions derived from the chemical and physical weathering of a nearby sandstone ridge in combination with forest litter. The soil texture of profile was classified as sand. The textural changes between horizons was likely the result of the same processes responsible for this pattern in the first profile.

Profile 3:

Profile 3 had high organic matter content in the surface layer that decreased with depth from 7.6 to 2.8%. A substantial A horizon had formed as a result of both local topography and vegetation. The profile was found at the foot of a gentle grassy slope and collected far more water and sediments, and received more subsoil biomass, than did the other profiles in this data set. Inorganic carbonates did not show significant change with depth. The 0.5% difference in inorganic carbonate enrichment between the two B/C samples was within the error margin of the protocol. SS200707 was collected from a suspected mottle (an iron-oxide concentration) that was properly identified as a root cast in the laboratory.

The decrease in pH through the profile cannot be readily explained. The surface sample contained no greater inorganic carbonate enrichment than lower samples nor did it have higher free ion concentration, both of which would act to mediate acidification. I would also expect the higher organic matter concentration at the soil surface to contribute to increased acidification. The measurement may reflect relatively minor pedogenic processes which are not accounted for in this analysis.

Electrical conductivity showed an increase with depth from 43.6 to 109.3 μS/cm. This was the reverse of the pattern in either of the other natural profiles and there were several contributing factors that are unique to the location of this profile. First, the pattern of increasing electrical conductivity with depth reflected the local absence of base-cycling coniferous forest vegetation. Second, analysis of the B/C samples suggests that sample SS200707 may have been collected from a root cast that could have promoted local through-flow of water from the surface. Finally, sea water can be an abundant source of free ions either via submergence of the profile or sea spray (Essington 2003:501). The latter was likely the dominant process in the case of Profile 3. It appears that sea spray had deposited more free ions in the B/C than the A horizon.

All three samples were classified as sand. The changes in texture were minor. The less than 3% decrease in sand and as much as 1.2% decrease in clay with depth through the profile was balanced by a 2% or more increase in silt. It is likely that the decrease in sand was the result of the downward mobilization of fine sediments has in Profile 1 and 2.

Natural Sample Analysis

Excluding sample SS200702 in Profile 1 from the comparison, the soil characteristics of the natural samples were highly consistent. As expected from Green et al.'s (1989) discussion of *Qualicum* and *Saturna* soils, and field observations made during this study, these soils strongly reflected the local bedrock and glacial parent material, and the local coniferous forest vegetation community.

Organic matter content (mean= 4.8%, s = 1.7) was both relatively low and invariant. Variability was predominantly a reflection of local vegetation. The higher organic matter content of the surface sample in Profile 3, relative to other natural samples, was due to local A horizon formation. A horizons did not form in other profiles where semi-closed forest conditions prevailed.

The near-absence of inorganic carbonates (mean = 0.5%, *s* = 0.2) was a reflection of the near absence of carbonates in either glacial (Green et al. 1989) or sandstone (Johnstone 2006) parent materials found in the area and the acidic conditions of the forest solum (combined A and B horizons). Without carbonates, which act to slow the process of acidification, and because conifers reabsorb many of nutrients they deposit as litter, pH levels in the natural soils in the area were moderately acid. At these these levels (mean = 5.9, *s* = 0.3), these soils would be characterized as "moder soils", indicating that decomposition was largely due to fungal activity (Green et al. 1993:15).

Electrical conductivity showed the greatest variation between samples, ranging from 43.6 to 109.3 µS/cm (mean = 79.3 µS/cm, *s* = 21.2). This was not unexpected, free ions are the most mobile of all the soil constituents measured in this analysis (via leaching and cycling) and variation over a few centimeters within any profile was expected. The sea-spray affected samples in the subsurface horizons in Profile 3 inflated the average electrical conductivity of the natural soils. All samples were classified as loamy sand or sand. Sand content for every sample was greater than 80% (mean = 87.6%, *s* = 4.0), silt less than 13% (mean = 9.8%, *s* = 3.3), and clay less than 5% (mean = 2.4%, *s* = 1.3).

For the purpose of later analyses, the tendencies and variation in the natural samples were summarized by their mean and standard deviation. These statistics are calculated with the addition of sample 97M21, a sample collected from the basal gravels, presented below in Table 4.6. This sample is part of the archaeological data set, and although it was collected from the sterile sediments beneath House 2 it corresponds so closely to the natural samples that it has been included in that data set.

Table 4.6 Summary statistics of natural controls with the addition of 97M21

Location	House	Sample	Layer/ Level	OM (%)	IC (%)	pH	EC (µS/ cm)	Sand (%)	Silt (%)	Clay (%)
Mean [a]				4.8	0.5	5.8	79.3	88.1	9.2	2.3
SD [a]				1.7	0.2	0.3	27.2	4	3.1	1.3
114N/ 107E	5	97M21	E	5.4	0.6	6.0	105.2	84.0	13.2	2.8
Mean [b]				4.8	0.5	5.9	82.6	87.6	9.8	2.4
SD[b]				1.6	0.2	0.3	26.8	4	3.3	1.3

[a] Calculated from values Table 4.5

[b] Sample n = 8

The soil characteristics of sample 97M21 fit well within the range of variability observed in the natural samples. Its addition makes the natural samples a more robust data set for future comparison.

Bulk Analysis of Cultural Samples

The raw data for the cultural samples is presented in Table 4.7. Cultural strata are delineated by their Roman letter. The associated Arabic numeral represents the arbitrary 10 cm level the sample was collected from within the cultural layer. Features are designated by their in-field feature identification number except where no identification number was provided. Samples were provided with individual sample identification codes for the purposes of this project. The first two digits indicate the year of collection, M indicates a matrix sample, and the last two digits are a unique number for each sample. PEB samples are archaeobotanical samples, each of which has a unique two-digit code.

Table 4.7 Cultural Samples Bulk Sediment Characteristics

Location	House	Sample	Layer/ Level	Feature	OM (%)	IC (%)	EC (µS/ cm)	pH	Sand (%)	Silt (%)	Clay (%)
110N/107E	5	97M01	A1		17.0	0.9	145.8	5.9	79.0	12.0	9.0
110N/107E	5	97M02	A1		14.5	0.7	150.3	5.6	83.0	12.0	5.0
110N/107E	5	97M06	A2		10.8	0.8	126.2	6.0	81.0	15.0	4.0
110N/107E	5	97M09	A3		8.3	1.0	160.1	6.0	81.1	16.3	2.0
110N/107E	5	97M19	C1		14.5	1.0	68.2	6.2	78.0	17.2	4.7
110N/107E	5	97M26	C2		15.0	1.0	114.0	6.2	78.0	17.0	3.8
111N/106E	5	97M08	A1		15.9	0.6	227.1	5.5	83.0	17.0	
111N/106E	5	97M14	A2		14.5	0.7	155.1	5.5	82.0	13.0	5.0
111N/106E	5	97M20	A3		10.7	0.8	99.6	6.1	82.5	17.5	
111N/106E	5	97M24	B1		9.8	0.8	189.1	5.9	83.0	13.5	3.5
111N/106E	5	97M25	B1		6.0	0.7	160.9	6.2	77.1	19.4	2.2
111N/106E	5	97M36	C2		7.5	0.7	185.9	5.8	81.6	15.2	1.6
111N/106E	5	97M38	C3		7.0	0.8	443.0	6.4	86.0	11.0	3.0
111N/106E	5	97M39	C3	F6	10.5	1.3	148.2	6.1			
111N/106E	5	97M57	C3		10.4	0.9	84.4	6.0			
114N/107E	5	97M03	A2	F1	15.8	0.9	96.6	5.7	83.0	13.0	4.0
114N/107E	5	97M04	A3	F1	16.7	1.0	83.8	5.9	81.0	15.0	4.0
114N/107E	5	97M05	B1		13.1	0.7	194.6	6.2	87.3	11.4	1.2
114N/107E	5	97M07	C1		14.0	0.8	188.4	6.2	84.5	14.0	1.6
114N/107E	5	97M22	C2	F2	8.2	0.7	241.0	5.9	84.0	12.2	3.8
114N/107E	5	97M10	C3		15.5	1.1	84.5	5.9	80.0	16.0	4.0
114N/107E	5	97M15	C4		12.0	0.9	94.0	6.0	80.0	20.0	
114N/107E	5	97M21	E		5.4	0.6	105.2	6.0	84.0	13.2	2.8
115N/106E	5	97M11	A1		15.4	0.9	142.0	5.9	83.0	12.5	4.5
115N/106E	5	97M23	A2		16.1	0.8	682.0	6.0	83.2	16.8	
115N/106E	5	97M55	A3	Feature	16.9	0.9	151.6	5.7	81.7	13.2	4.8
115N/106E	5	97M56	A3	Feature	16.2	0.9	132.6	5.7			
140N/116E	2	PEB 30	C1	F16	11.7	0.8	104.4	6.1	83.5	15.7	1.5
141N/109E	2	PEB 35	B4	F24	11.1	0.9	84.7	6.2	83.6	16.4	
142N/117E	2	PEB 06	B2	F16	14.3	0.8	126.5	5.7	85.0	12.0	3.0
142N/117E	2	PEB 07	B2	F16	14.6	0.8	82.3	6.1	86.0	10.9	3.1
144N/116E	2	97M41	C1		12.0	0.7	70.1	5.7	86.0	10.3	3.7

Location	House	Sample	Layer/ Level	Feature	OM (%)	IC (%)	EC (µS/ cm)	pH	Sand (%)	Silt (%)	Clay (%)
144N/116E	2	97M51	C2	F9	17.9	0.9	85.8	5.6	85.0	15.0	
144N/117E	2	97M32	A2	F4	19.3	1.0	150.1	5.6	84.0	12.6	3.4
144N/117E	2	97M27	B1		11.8	0.8	94.7	5.8	85.9	11.5	3.5
145N/116E	2	97M16	B1		9.0	0.6	145.2	6.2	86.6	11.6	1.6
145N/116E	2	97M18	B2		18.3	0.7	182.0	5.4	86.0	14.0	
145N/116E	2	97M46	C2	F9	13.0	1.2	125.0	5.9	81.8	14.8	2.9
145N/116E	2	97M49	C2	F9	15.0	0.6	134.4	6.1	84.4	13.0	2.2
145N/117E	2	97M52	C2	F9	25.2	1.4	81.7	5.6	86.0	14.0	
149N/116E	2	97M17	A2		12.5	1.0	149.2	5.8	87.0	10.0	3.0
149N/116E	2	97M37	A3		21.7	2.2	218.2	6.6	85.0	15.0	
149N/116E	2	97M47	A3	F11	6.7	3.2	114.2	7.0	83.1	12.0	5.0
149N/116E	2	97M58	A3		24.3	0.9	184.4	6.3			
149N/116E	2	97M54	C2		15.8	0.6	97.3	5.6	77.6	22.4	
149N/117E	2	97M44	A3	F10	11.6	4.4	139.7	6.9			
150N/116E	2	97M53	C1		9.4	0.6	151.2	6.1	83.1	14.1	2.4
150N/117E	2	97M43	A3	F12	8.7	1.1	155.6	6.7	86.0	10.7	3.3
149N/120E	2	PEB 52	A	F34	9.0	2.9	197.2	7.3	88.7	9.2	1.9
149N/122E	2	PEB 44	B	F28	8.3	6.3	209.0	6.9	82.0	12.7	5.3
149N/122E	2	PEB 46	B	F28	9.9	2.9	99.6	6.9	83.0	13.6	3.4
149N/122E	2	PEB 49	C2	F28	8.5	1.3	103.6	6.8	85.7	11.0	3.3

As noted in chapter two, House 2 was sampled in 2 by 2 m units. Every effort was made to assign samples to 1 m by 1 m quadrants via plot maps and field notes to make them comparable to the 1 by 1 m units excavated in House 5. This was successful for almost all samples. When this was not possible, samples were left with the unit designations made in the field, which default to the southwestern corner of the 2 m by 2 m unit. However, the samples from the same unit were not necessarily stratigraphically superimposed; they may be dislocated by up to 2 m in horizontal position.

As illustrated in the beginning of this chapter, three cultural strata were identified at Dionisio Point. These strata were termed Layers, A, B, and C. The characteristics of these strata are summarized in Table 4.8.

Table 4.8: Mean and standard deviations of cultural strata sedimentary characteristics [s]

Layer	n	OM (%)	IC (%)	pH	EC (µS/cm)	Sand (%)	Silt (%)	Clay (%)
A	12	15.1 (4.5)	0.9 (0.4)	5.9 (0.3)	159.8 (37.5)	82.7 (2.1)	14.1 (2.9)	4.6 (2.2)
B	6	11.3 (4.2)	0.7 (0.1)	5.9 (0.3)	161.1 (37.4)	84.3 (3.8)	13.5 (3.4)	2.4 (1.1)
C	10	12.3 (3.3)	0.8 (0.2)	6.0 (0.3)	117.1 (46.9)	81.9 (3.2)	14.4 (2.6)	3.1 (1.1)
N[b]	8	4.8 (1.6)	0.5 (0.2)	5.9 (0.3)	82.6 (26.8)	87.6 (4.0)	9.8 (3.3)	2.4 (1.3)

[a] Values in parentheses are standard deviations.
[b] N denotes the natural sample statistics identified in Table 4.6, presented here for comparative purposes.

Layer A

Based on artifacts and features attributed to this stratum, the Layer A occupation was interpreted to have been a temporary special use site focused on the exploitation of the highly productive environment around Porlier Pass. Layer A samples were available from four units in

House 5 and one unit in House 2. Unit 149N/116E was located near the northern end of the central trench in House 2. Units 110N/107E and 111N/106E were both located in the center of the western end of House 5. Unit 115N/106E was located at the northern edge of House 5, and was truncated by a feature below 20 cm (DBS) that prevented further excavation.

All Layer A samples were highly enriched in organic matter (8.3 to 24.3%) and exhibited moderate variability (mean = 15.1%; *s* = 4.5). This is a reflection of the fact that these samples were regularly also the pedological A horizon on-site. They reflected both natural and anthropogenic sources of organic matter. The potential impacts of pedogenic processes are addressed in Chapter Five.

The inorganic carbonate content and the pH of the Layer A subset fell within the natural range of variation for soils in the area. Inorganic carbonates ranged from 0.6 to 2.2% (mean = 0.9%; *s* = 0.4), demonstrating a lack of pronounced anthropogenic additions during this phase of habitation. pH ranged from 5.5 to 6.6 (mean = 5.9; *s* = 0.3). The pH range was slightly greater than that of the natural samples, however the mean and standard deviation were identical.

Electrical conductivity measurements were well above above the natural range of variation, ranging from 99.6 to 682.0 µS/cm (mean = 203.3 µS/cm; *s* = 154.9). The high variability evident in the summary was largely the effect of the Layer A2 sample from 115N/106E (97M23). Re-measurement of the electrical conductivity of this sample consistently provided results above 650.0 µS/cm. It is possible that this sample was affected by the underlying burial feature. Decomposing bone would have deposited large amounts of calcium into the immediate soil. Given the unique context of this sample, it was reasonably to remove it for analysis of electrical conductivity. When it was removed, Layer A was noticeably less variable (*s* = 37.5 µS/cm). The majority of the sample's texture ranging from sandy loam to sand, and were generally finer than the natural samples. They contained, on average, 5% less sand, 4% more silt and 2% more clay.

Layer B

Layer B samples were available from four units. Units 144N/117E and 145N/116E were part of the same 2 by 2 m unit opened in the center of House 2 during 1997. Unit 111N/106E was located in the center of House 5. Unit 114N/107E was located at the northern edge of House 5 west of the midline of the depression.

Organic matter content of Layer B samples ranged from 6.0 to 18.3% (mean = 11.3%; *s* = 4.2). This was approximately twice the mean of the natural samples, yet the lowest of any cultural stratum. Inorganic carbonates (0.6 to 0.8%; mean = 0.7%; *s* = 0.1%) and pH (5.4 to 6.2; mean = 6.0; *s* = 0.3), like those samples from Layer A and Layer C, were indistinguishable from the natural range of variation.

Electrical conductivity values were higher than the natural samples. In Layer B they ranged from 94.7 to 194.6 µS/cm (mean = 161.1 µS/cm; *s* = 37.4), reflecting a variety anthropogenic sources. The samples from Layer B range from sandy loam to sand, and were on average finer than the natural range of variation. They contained less sand (mean = 84.3%; *s* = 3.8), and more silt (mean = 13.5%; *s* = 3.4) than natural samples. Clay content falls within the natural range (1.2 to 3.5%; mean = 2.4%; *s* = 1.1).

Layer C

Layer C samples were available from six units. Unit 144N/116E was located in the center of House 2. Units 149N/116E and 140N/116E were located at opposite ends of the central trench in House 2. The former was at the northern and the latter at the southern end. Unit 110N/107E and 111N/106E were located in the center of House 5. Unit 114N/116E was located at the northern edge of House 2, west of the midline of the structure.

The organic matter content of these samples ranged from 7.0 to 15.8% (mean = 12.2%; *s* = 3.3), nearly three times that of the natural samples. Variation between Layer C and Layer B was less than the error introduced by the laboratory methods. Inorganic carbonates ranged from 0.6 to 1.1% (mean = 0.8%; *s* = 0.2). This range and tendency and that of pH measurements (5.6 to 6.4, mean = 6.0; *s* = 0.3) were well within the natural range of variation. Electrical conductivity was enriched compared to the natural samples, ranging from 68.2 to 443.0 µS/cm (mean = 149.7 µS/cm; *s* = 112.1). Layer C samples ranged from sandy loam to sand in texture. They were finer than the natural samples, containing less sand (mean = 81.5%; *s* = 3.3), more silt (mean = 14.3%; *s* = 2.6) and comparable amounts of clay.

Features

Feature analysis is taken up separately in this chapter because of the dramatic variability that is evident in the results presented in Table 4.7. The variables that are important to feature analysis are not the same as those important to the analysis of non-feature cultural samples. Specifically inorganic carbonates play a larger role in the discussion of features than they do above.

Two groups of features were analyzed in this study, one from Layer A and and another from Layer B/C. They are taken up separately below. No attempt was made to statistically average the feature characteristics from either the entire class of data or from any one feature. Samples are too small from any one feature, and combining features conflates evidence of between feature variability that is important for further analysis.

Layer A

The features attributed to the post-Marpole occupation of the site were quite diverse in form and function. Several appeared to be hearths. Features 1 and 4 were *in situ* hearth features with fire-altered rock arrangements, ash and carbonized sediment. Three samples were available from these two features, which share consistent characteristics. All three were enriched in organic matter relative to the natural background. Organic matter content ranged from 15.8 to 19.3%, more than three times the natural average. Inorganic carbonate content was similar to the natural samples (0.9%), as was the pH (5.7 to 5.9). Electrical conductivity was the most variable, exceeding the natural range (83.8 to 150.1 µS/cm). The texture of the samples was sandy loam to loamy sand, indicating less sand and more silt (12.6 to 15%) than natural samples.

Features 10, 11 and 12 formed a complex of oxidized sandstone/shell features in unit 149N/116E. The range of organic matter enrichment (6.7 to 11.6%) partially exceeded the natural range. The inorganic carbonate content was unusual in that was significantly higher than the natural range (1.1 to 4.4%) as was pH (6.7 to 7.0). Electrical conductivity partially overlapped with the range of the natural samples (114.2 to 155.6 µS/cm). Texture was available for only two of the samples, both of which were loamy sands, quite similar to the natural samples apart from their higher clay content (3.3 to 5.0%).

Feature 34 was located across two units, 149N/120E and 140N/122E. It may have been an intrusive roasting or rock heating feature associated with the post-Marpole village occupation. One sample was available from this feature. Organic matter (8.9%) was twice that of the natural samples. Inorganic carbonate content was significantly higher (2.9%) than the natural samples as was electrical conductivity values (197.2 µS/cm). This feature had the highest pH determination of any sample in the cultural data set (7.3). The texture was loamy sand and fell well within the range of natural variation.

Layers B and C

The second group of feature samples were all attributed to the Marpole village component of the site. They were hearths or hearth-like features. In spite of their formal similarity, there was a wide range of variation between them. Features 9, 24, and 28 were interpreted as domestic hearths. Feature 9 was the central hearth in House 2, Feature 24 was the domestic hearth in the southwestern domestic area of the same structure, and Feature 28 the domestic hearth in the northeastern domestic area. The sedimentary characteristics of these three features were quite heterogeneous.

Feature 9 (Figure 4.4) was highly enriched in organic matter (12.9 to 25.2%). Inorganic carbonates fell within the natural variation (0.6 to 1.4%), as did pH (5.6 to 6.1). Electrical conductivity partially exceeded the natural range of variation (85.8 to 134.4 µS/cm). Full textural analyses were available for two of the samples, one of which was a sandy loam and the other a loamy sand. Both of the remaining samples were loamy sands based on their sand and the combined silt/clay content.

Figure 4.4: Feature 9 (Unit 145N 116E) (courtesy of C. Grier).

One sample was available from Feature 24. The organic matter content of this sample (11.1%) was approximately twice as high as the maximum of the natural samples. Both inorganic carbonate content (0.9%) and pH (6.2) fell within the upper range of the natural samples. Electrical conductivity (84.7 µS/cm) fell in the middle of the natural range. Full textural analysis was not available but likely would be classified as a sandy loam to a loamy sand based upon the known textural data.

Three samples were available from Feature 28 (Figure 4.6). These samples were notable for having among the lowest enrichment of organic matter in the cultural data set (8.3 to 9.9%), very close to the natural range of variation. Inorganic carbonate (1.3 to 6.3%) and pH (6.8 to 6.9) were, conversely, among the highest of the data set, substantially higher than the natural samples. Electrical conductivity determinations exceeded the natural variation (99.6 to 209.0 μS/cm). All three samples were loamy sands, containing slightly more silt (11 to 13.6%) and clay (3.3 to 5.3%) than the natural samples.

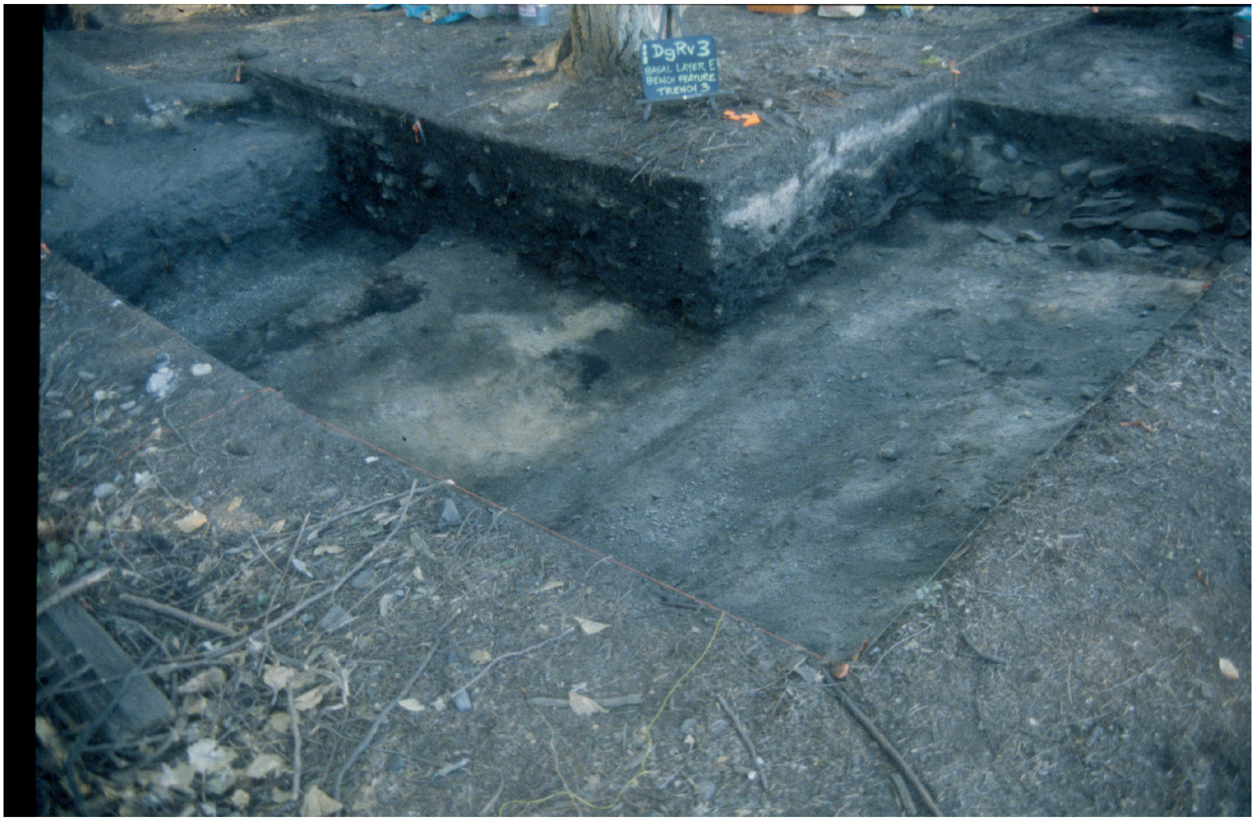


Figure 4.5 The northeast corner of House 2. Feature 28 is visible in the north-facing profile to the right of center in the picture (courtesy of C. Grier)

There are two additional features that are hearth-like, but during excavation were determined not be domestic hearths. Feature 2 was a small feature uncovered during excavations in Unit 114N/107E in House 5. This sample was unusual in its relatively low organic matter content (8.2%). Both the inorganic carbonate content (0.7%) and the pH (5.9) were well within the natural range. The electrical conductivity determination was among the highest in the cultural data set (241.0 µS/cm), well outside the upper limit of the natural range. The texture of the sample was loamy sand, containing more silt (12.2%) and slightly more clay (3.8%) than the natural range.

Feature 16 was unusual in that it was the sole large hearth-like feature that first appeared in Layer B, rather than C. It was located in Unit 142N/116E at the rear of House 2. Organic matter content was enriched relative to the natural samples (11.7 to 14.6%). Inorganic carbonates (0.7 to 0.8%), pH (5.7 to 6.1) and electrical conductivity (82.3 to 126.5 µS/cm) on the other hand either fell entirely within or only slightly exceeded the natural range of variation. Sample texture ranged from sandy loam to loamy sand, containing more silt (10.9 to 15.7%) than natural samples.

Summary

The differences between the natural and cultural samples demonstrates that an anthropogenic signal has been preserved in the Dionisio Point sedimentary record in organic matter content, electrical conductivity and particle-size, particularly in the Layer B/C Marpole village component. Some of the values generated by these analyses suggest further that the processes that have created and affected the two cultural components of the site might be different, especially in terms of the affects of modern-day natural inputs and pedogenic processes as discussed below. The broader trends in these patterns are explored in the following chapter.

Chapter Five: Discussion

The previous chapter presented the results of the analyses of this study. Several interesting patterns were suggested by these data. Among these was the strong evidence that an anthropogenic pattern has been preserved in the sediments in Houses 2 and 5 at Dionisio Point. Variability in this pattern further suggested that the various architectural contexts of shed-roof houses, identified in Chapter 3, have discrete formation processes. The goal of this chapter is to discuss these patterns, their implications for assessing natural formation processes at Dionsio Point, and most importantly the evidence they provide that specific cultural formation process have been preserved in these deposits.

This chapter is divided into five sections. The first summarizes the results presented in the previous chapter. It assesses the utility of the methods that were used for distinguishing the archaeological samples from the natural samples. The second describes the evidence that supports the interpretation of geoarchaeological patterning at Dionisio Point as anthropogenic rather than pedogenic. The third presents an evaluation of the cultural models presented in Chapter Three through the lens of the geoarchaeological record. The fourth is a discussion of how these models can help us understand the plank house socio-economy, using Dionisio Point as an example. The final section evaluates the potential utility of these methods for plank house feature prospection in the archaeological record of the Strait Of Georgia region. These five sections follow the three research themes that were identified in the introduction to this study.

Research Themes:

1. *Assessment of current models of cultural formation processes in prehistoric plank houses*. How well does the observed geoarchaeological data from Dionisio Point match the expectations generated by an ethnographic model? What are the discrepancies and why might they exist? What does this suggest about the applicability of current models of cultural formation processes in prehistoric shed-roof houses?

2. *Utility of feature analysis for interpreting the socio-economic organization of pre-Contact households.* Do features provide data not available from artifact data sets? If they do, what do these tell us about the inhabitants of these dwellings?

3. *Implications for prospection methods on the Coast.* Does the analysis suggest that there is a possibility of identifying some or all of the architectural contexts defined in Chapter Three? Which are most easily discriminated and which are the most difficult to define? What are the implications of these results for further excavations at Dionisio Point and for sites elsewhere?

Evaluating Results – Utility of the Methods

The results presented in the previous chapter suggested that the methods used in this analysis effectively identified differences between the cultural and natural sample data sets. Tables 5.1, 5.2, and 5.3 present the results of statistical analyses of the differences between natural samples and each of the cultural strata identified at the site. Only non-feature samples were used in this analysis. Feature samples would in all cases likely accentuate any differences, but would at the same time be more difficult to normalize and thus would require the use of less robust tests of significance. Two-group difference of means tests were used in all cases where the data could be normalized. In cases where the data could not be normalized, two-group difference of medians tests were used to assess significance.

Only organic matter enrichment, inorganic carbonate enrichment, electrical conductivity, and pH were assessed. The texture differences between all three subsets of the cultural data sets was best presented graphically (Figure 5.1).

Table 5.1 Cultural layer A versus the natural data set difference of means and difference of medians tests

Analysis	Value*	dF	p[c]
Organic Matter	8.45	27	< 0.001
Inorganic Carbonate[a]	3.94	$n_1 = 21, n_2 = 8$[b]	< 0.001
Electrical Conductivity[a]	3.46	$n_1 = 21, n_2 = 8$[b]	< 0.001
pH	1.51	27	0.07

* Student's t-test unless otherwise noted

[a] Mann-Whitney U test

[b] Sample size of Mann-Whitney U test, n_1 is the cultural data set, n_2 is the natural data set

[c] One-tailed probability

Table 5.2 Cultural layer B versus the natural data set difference of means and difference of medians tests

Analysis	Value*	dF	p[c]
Organic Matter	5.59	17	< 0.001
Inorganic Carbonate[a]	3.32	$n_1 = 11, n_2 = 8$[b]	< 0.001
Electrical Conductivity	3.21	17	< 0.001
pH	1.53	17	0.072

* Student's t-test unless otherwise noted

[a] Mann-Whitney U test

[b] Sample size of Mann-Whitney U test, n_1 is the cultural data set, n_2 is the natural data set

[c] One-tailed probability

Table 5.3 Cultural layer C versus the natural data set difference of means and difference of medians tests

Analysis	Value*	dF	p[b]
Organic Matter	6.94	25	< 0.001
Inorganic Carbonate	3.89	25	< 0.001
Electrical Conductivity[a]	2.39	24	< 0.02
pH	1.24	25	0.12

* Student's t-test unless otherwise noted

[a] Log-transformed

[b] One-tailed probability

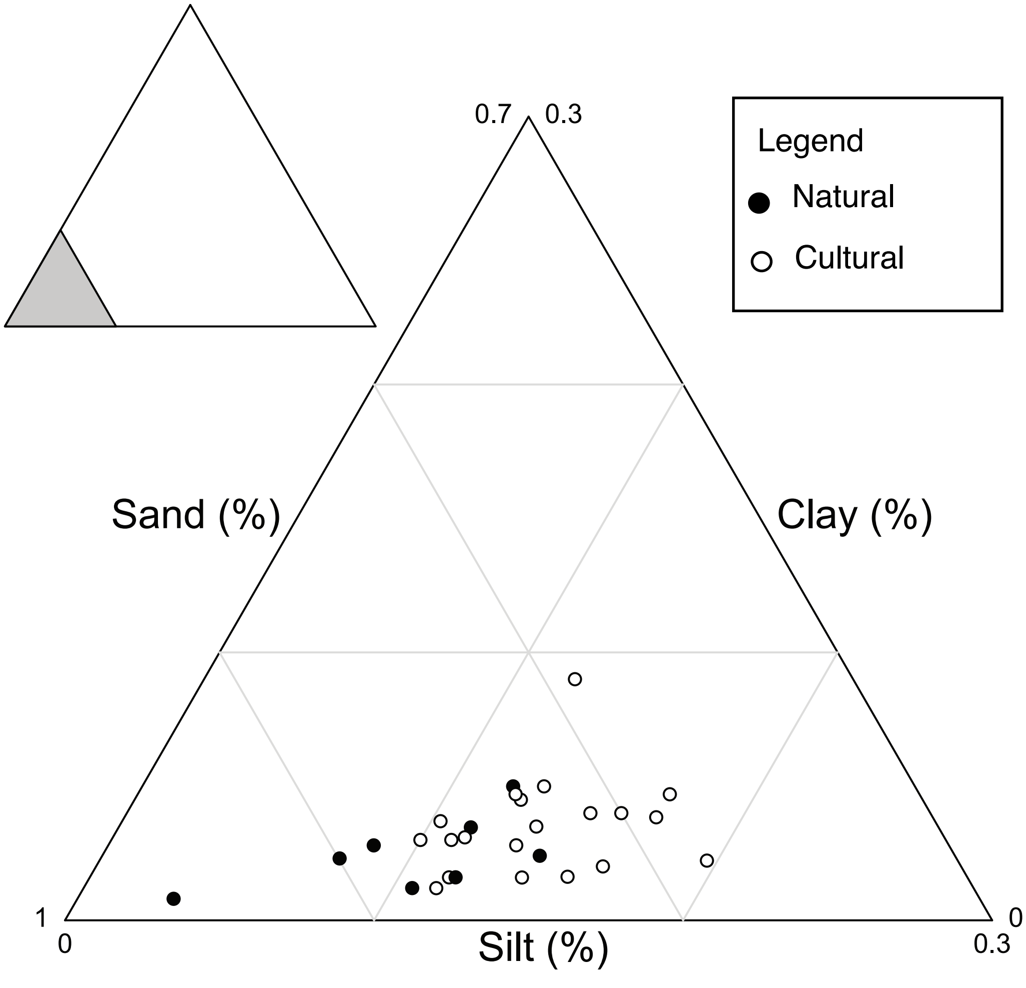


Figure 5.1 Particle-size Analysis of Floor samples from Layer B/C

The pattern presented in all three subsets of the cultural data set is clear. Several analyses discriminated well between the natural and cultural data sets. Organic matter enrichment and electrical conductivity were significantly higher in the cultural data set than the natural data set. In no subset was pH significantly different between from the natural data set. Inorganic carbonate enrichment in all three subsets was significantly higher in the cultural data than the natural data. However, this difference never exceeded the error margin for the protocols used in the analysis and, thus, these values cannot be considered to be archaeologically meaningful. Differences in texture were not statistically verified, but suggest that the cultural samples trend towards being finer than the natural samples. The difference in this case consists almost entirely in trade-offs between the sand and silt content. Clay does not vary by more than 2%.

Returning to the models laid out in Chapter Three, these overall patterns were expected from the kinds of activities that were discussed. It should be noted that these statistical patterns only described trends in the overall data set. Therefore, neither inorganic carbonate content nor pH were discounted from further study if the values for individual samples exceeded the error margin and the natural range. This was the case for several feature samples, which would have been swamped by the non-features samples in a statistical analysis. However, in spite of the fact that these patterns match the expectations, it is possible that they are not anthropogenic. This is discussed below.

Evaluating Results – Pedogenic versus Anthropogenic Processes

The previous section demonstrated that cultural samples were significantly different from natural samples on a number of variables, specifically organic matter and electrical conductivity.

Texture variation, although not statistically tested, were consistently different between the two data sets. However, it is not clear from the previous section whether or not the processes that contributed to these patterns were natural or cultural. That is, are these patterns the result of human activity during the occupation of the Dionisio Point site, or are they primarily the result of natural, post-depositional processes?

Stein's (1992c) discussion of anthropogenic versus pedogenic sources of organic matter at archaeological sites is a useful heuristic for this discussion. She raised the issue of identifying which of these two sources was dominant in the formation of organic matter in any given archaeological deposit. She described three settings where, in a profile:

- Organic matter is entirely anthropogenic
- Organic matter is entirely pedogenic
- Pedogenic organic matter has formed in an anthropogenic matrix

Clearly, the danger that is faced is the interpretation as cultural, signatures that are natural in origin. While she (Stein 1992c) directs her attention towards organic matter content, all of the geoarchaeological signatures in this study could have been affected in the same manner.

The statistical analyses presented above demonstrate that the signatures are not the result of the natural, pedogenic formation of any of the measured constituents, with the exception of pH. The question that remains is whether or not the patterns were directly cultural or whether they were only indirectly cultural. In the first case, interpretations can be made on the present results. In the latter, the anthropogenic signatures are masked by natural signatures. If the anthropogenic patterns of the Marpole village component of the site were substantially altered by pedogenic processes, their interpretability is severely limited.

Depth diagrams, in which changes in various soil constituents are plotted against depth, permitted me to evaluate whether the processes that led to patterning were primarily anthropogenic or pedogenic. If the signatures were pedogenic, the changes with depth would be predictable based upon pedogenic processes identified in the natural soils found around the site. I expected that with depth: organic matter enrichment would sharply decrease, inorganic carbonate enrichment would remain the same, electrical conductivity measurements would decrease, and texture would become finer. Decreasing organic matter enrichment would be a reflection of the location of most organic inputs, at the surface of the soil. Electrical conductivity would be the highest at the surface and decrease with depth as a result of organic matter content. Slight increases in pH would result from the reduction of organic acids with depth. If the patterns depart from these expectations we can be fairly confident that the primary processes affecting these soils have been anthropogenic. Three units permitted this kind of analysis: 110N/107E (Figure 5.2), 111N/106E (Figure 5.3) and 114N/107E (Figure 5.4).

In Layer A in all three profiles, organic matter enrichment and electrical conductivity behave as though they were predominantly natural in origin. They are highest at the surface and gently decrease with depth over 20 to 30 cm. As expected, inorganic carbonate enrichment is relatively invariant with depth. pH shows a pattern that suggests that it is reacting to organic acids, increasing as organic matter decreases. The transition from Layer A to Layer B/C is marked by either a dramatic change in organic matter enrichment, electrical conductivity, or both. Rather than continue the trends of Layers A, these two constituents often show dramatic

Figure 5.2: 110N/107E Depth Diagram

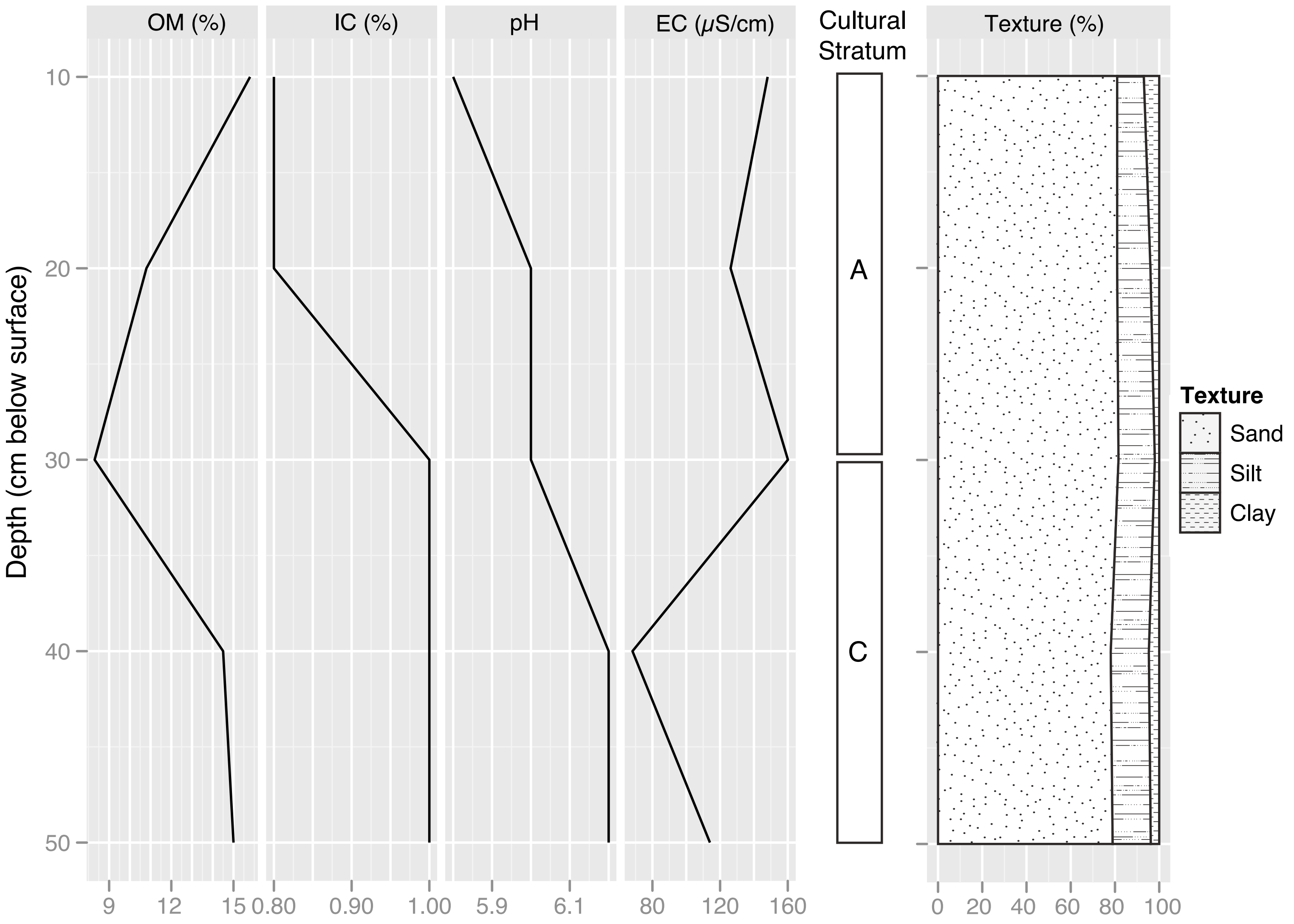


Figure 5.3: 111N/106E: Depth Diagram

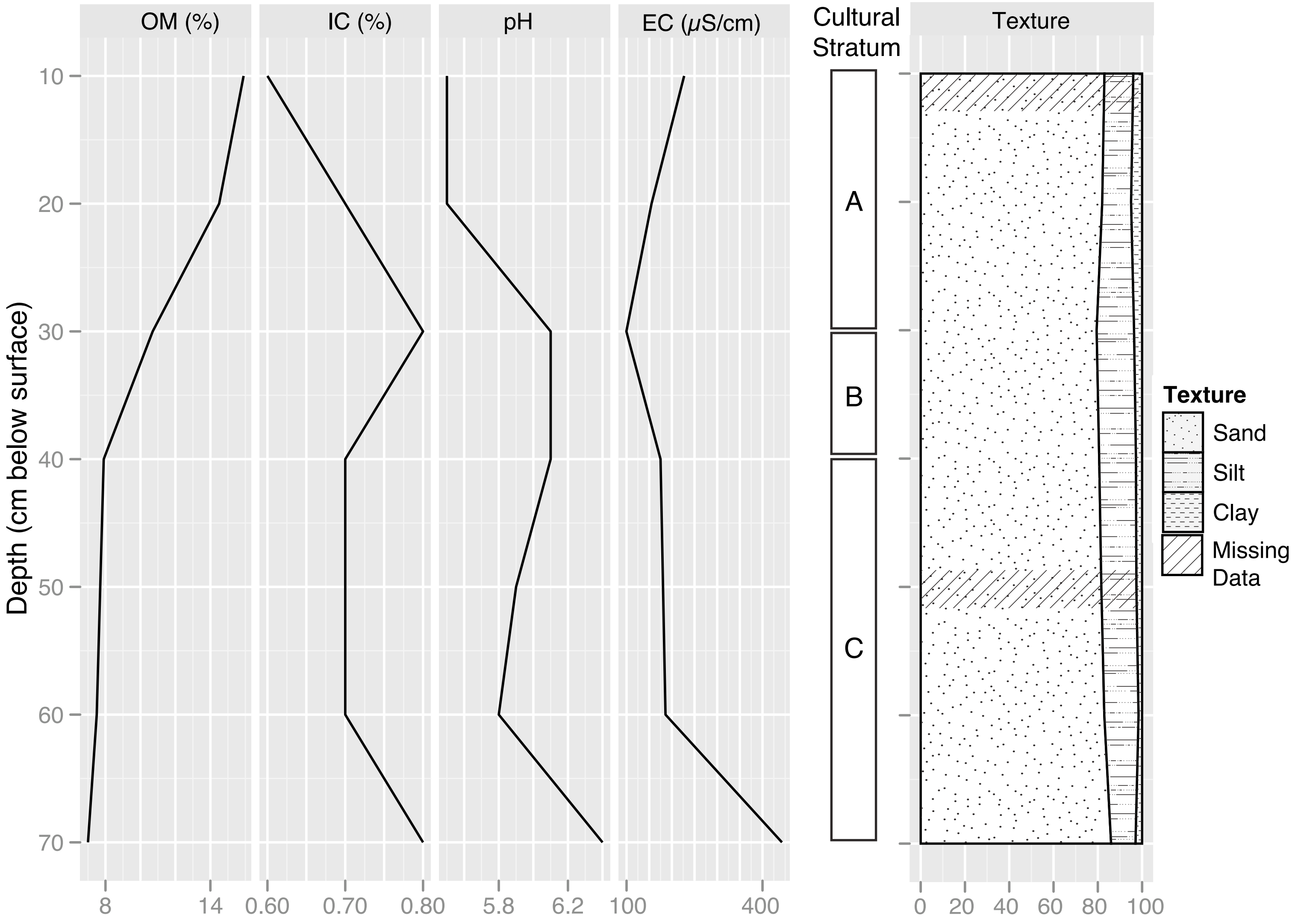
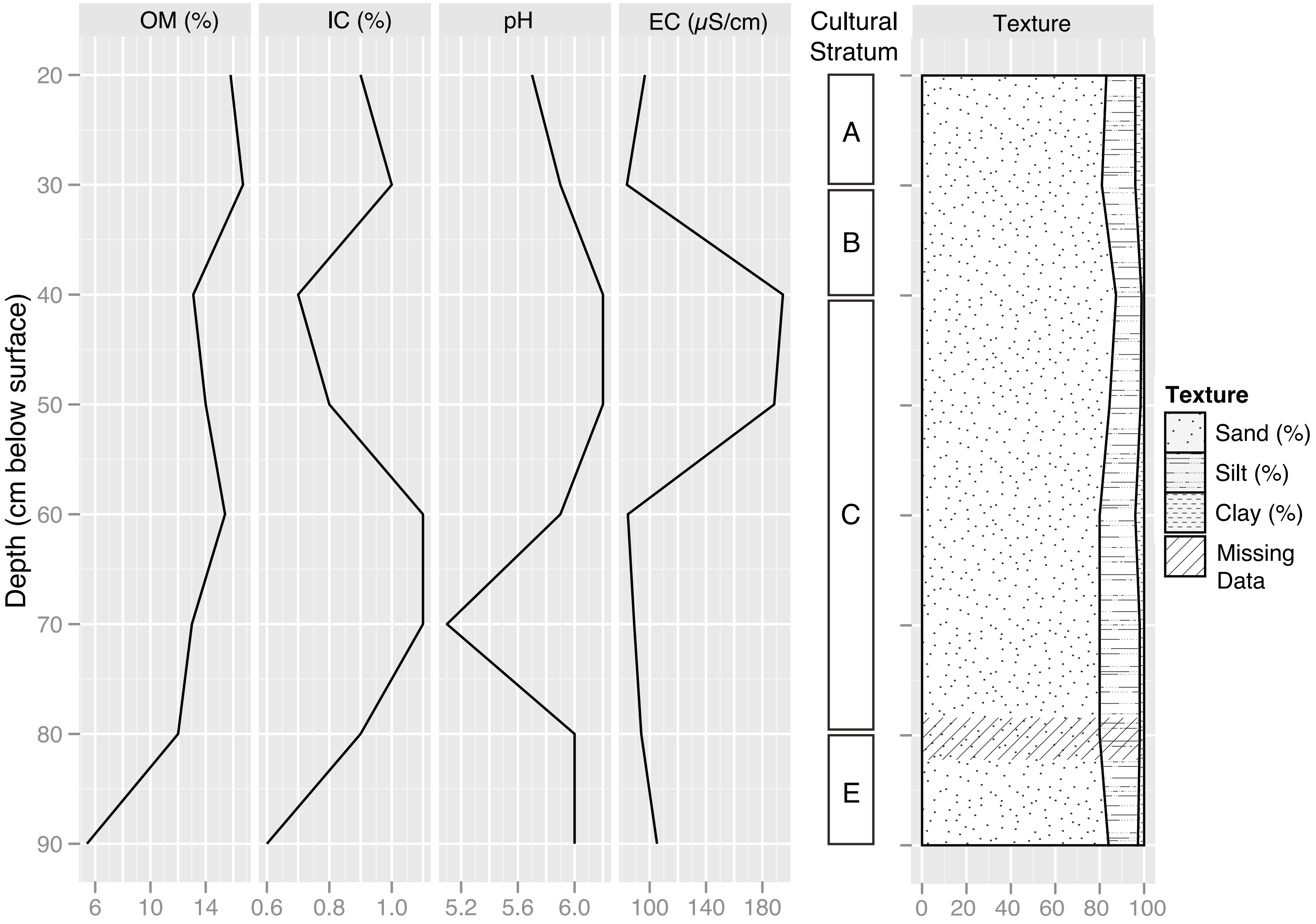


Figure 5.4: 114N/107E: Depth Diagram



increases at depths that cannot be accounted for by pedogenic processes.

Dramatic increases in electrical conductivity (as at 50 cm below surface in Figure 5.2, 70 cm below surface in Figure 5.3, and 40 cm below surface in 5.4) cannot be explained by similarly substantial changes towards finer textured sediments, as might be argued in natural profiles. Clays are noted for their capacity to trap free ions on their charged surfaces. Though clay content often rises in Layer B/C, it is not significantly higher than the average of the natural samples (*p* > 0.2) and thus cannot account for the substantial elevation of electrical conductivity. Nor can it account for samples where electrical conductivity and clay content were negatively correlated. Alternatively, it may be that through bioturbation processes, free-ion-bearing water is being transported directly to these locations, much as was suggested, though not confirmed, for

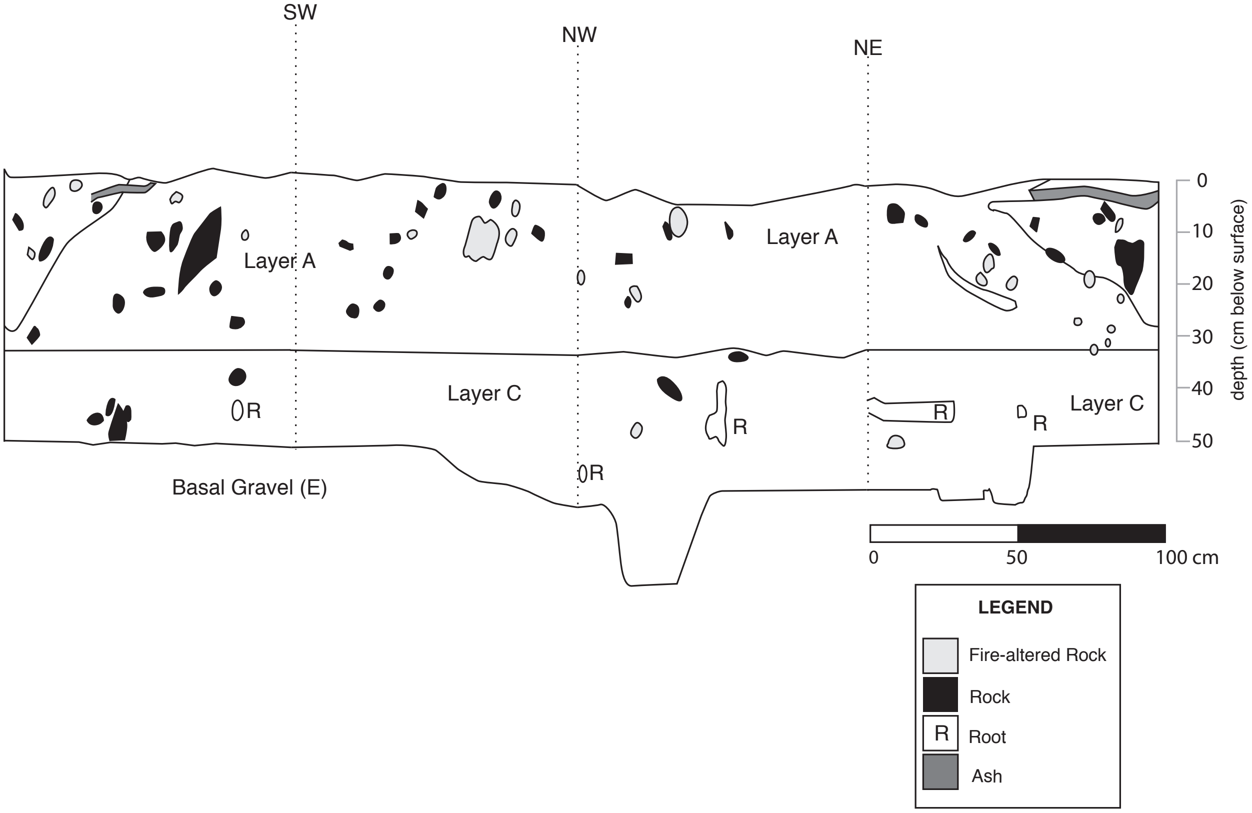


Figure 5.5: 110N/107E: Unit profile

samples in the Natural Profile 3. These may be the result of root intrusion or faunalturbation. However, as argued for organic matter deposition, below, it does not appear likely that site-wide patterns of sediment characteristics can be attributed to either flora or fauna. The primary source of free ions, measured by electrical conductivity, was likely not natural.

Dramatic increases in organic matter enrichment (as at 40 cm below surface in Figure 5.2 and 60 cm below surface in Figure 5.4) cannot be explained by pedogenic processes. Natural sources of organic matter at depth are limited primarily to forms of bioturbation. At Dionisio Point, the roots of coniferous forest species have been noted to follow the transition from Layer C to the glacial tills, probably because nutrients are rapidly leached from sediments at greater depths. Profile drawings record the presence of roots in Layers B and C (Figure 5.5). However, roots at these depths were rare, small-diameter (less than 5 to 10 cm) lateral branching roots. There are two reasons to doubt that roots are the cause of organic matter enrichment. First it is unlikely that roots would result in systematic increase in organic matter enrichment across all samples. Second, organic matter enrichment in the units described by Figures 5.2 and 5.4 begins at least 10 cm above this transitional layer. Faunalturbation of surficial organic matter to great deapths either by earthworms (e.g., Stein 1983), or by larger soil fauna is unlikely. Organic matter processing is typically completed by fungal mats in moder soils (Green et al 199). Natural samples showed no signs of faunal disturbance. Pedogenic or bioturbation processes likely do not account for these rises in organic matter at depth in the lower cultural strata. The principal source, therefore, is probably anthropogenic.

Changes in pH and inorganic carbonate content below Layer A (also the A horizon) appear to be responses to more than simply pedogenic processes. In Figures 5.2 and 5.3, the relationship between the two characteristics, as expected from a natural profile, is positive. However, the changes in inorganic carbonate content in these levels are minor, as is suggested to be the case for entire site by the statistical analyses in the previous section. In Figure 5.4, the two vary inversely. This appears to be the result of anthropogenic alteration of the sediments. The pH measurements below 30 cm below surface in the unit described in Figure 5.2 rise with increasing organic matter enrichment. This is contrary to what would be expected from a natural system, organic matter enrichment typically being positively associated with organic matter-driven acidification. The positive relationship between these two variables in this unit suggests that the organic matter at this depth is old, inert material rather than material transported down from the surface. However, given the low absolute variation in either pH or inorganic carbonate enrichment these patterns are suggestive rather than conclusive. It is not possible to use either pH or inorganic carbonate enrichment independent of other variables, expect where they are dramatically higher than the natural range of variation, to interpret cultural formation processes.

Taking into account the occupational history of the site and the expected correlations between organic matter, electrical conductivity, and human activity, the gross trends seen in these profiles are indicative of anthropogenic modification. The decrease in organic matter through Layer A (0 to 30 cm below surface) may be an indication of pedogenic processes, yet the rise in Layer B/C (> 30 cm below surface) is a reflection of high organic input during Marpole phase occupation. Mirroring of the organic matter content by the electrical conductivity is expected under conditions of organic-driven acidification.

Cultural Stratigraphy at Dionisio Point

Until this point the cultural stratigraphy at Dionisio Point has been treated as having three distinct cultural layers overlying a culturally-sterile glacial till. However, Grier (2006a) has interpreted cultural strata Layer B and Layer C as representing the deposition of a single occupational phase of the Marpole phase village component of the site. This aggregation was not challenged by Ewnous' (2006) analysis of the faunal remains of the site; artifacts, architecture, and faunal remains all suggest that these two layers represent a single phase of occupation.

This occupation was probably punctuated by seasonal and perhaps longer periods of abandonment. The stability of the material record through these two strata supports their treatment as a single unit, both in terms of the artifact assemblage and complex of features, which do not substantially change their spatial position during this period. This consistency in spatial arrangement applies to the architectural layout of the house, in terms of hearth and post features (Grier 2006a:105), as well as artifact distributions (Grier 2006a:111).

Based on the data presented above in Tables 5.2, 5.3, the depth diagrams, and the descriptions of both Layers B and C, there is no geoarchaeological reason to dispute the aggregation of these two cultural strata into a single unit suggested by the artifact analysis. These strata have similar trends when compared to the natural range of variation. A possible exception is the difference in electrical conductivity measurements. Layer C's average electrical conductivity was nearer the natural range than Layer B (though even then it is significantly different [$t = 1.8$; $df = 1,15$; $p < 0.05$]).

Identifying formation processes of plank house features

Combustion Features

It is clear that there were a variety of combustion features present at Dionisio Point. Many of these were hearths in the sense of "domestic hearths", used for a range of domestic practices including daily food preparation. Others were traces of temporary activities or residues from hearths elsewhere in the structure. Returning the the model provided in Chapter Three, hearths were expected to have the highest organic matter enrichment, electrical conductivity, and finest texture of any cultural context (Table 5.4).

Table 5.4 Expected characteristics of cultural sediments from Hearth Features

Context	Measurement	Expectations relative to natural sediments[a]
Hearth	Soil Texture	● ●
	Organic Matter	● ● ● ● ●
	Inorganic Carbonates	●
	pH	● ●
	Electrical Conductivity	● ● ● ● ●

[a] An increasing number of dots denotes increasing enrichment in OM and IC, higher pH and EC and increasing silt and clay content. A single dot denotes similarity to the natural sediments.

These expectations were based on the assumption that hearths were locations where large amounts of food residues, carbonized wood, and other organic debris and mineral wood ash were deposited on a daily basis. Organic matter-driven acidification should be reduced by the mediating affects of mineral wood ash. Finer texture is the result of the removal of larger clasts and the incorporation of fine free ions associated either directly or indirectly with mineral ash deposition. Feature locations and approximate sizes are illustrated in Figure 5.6. The geoarchaeological data on soil constituents (Figure 5.7: A to D) and particle-size analysis (Figure

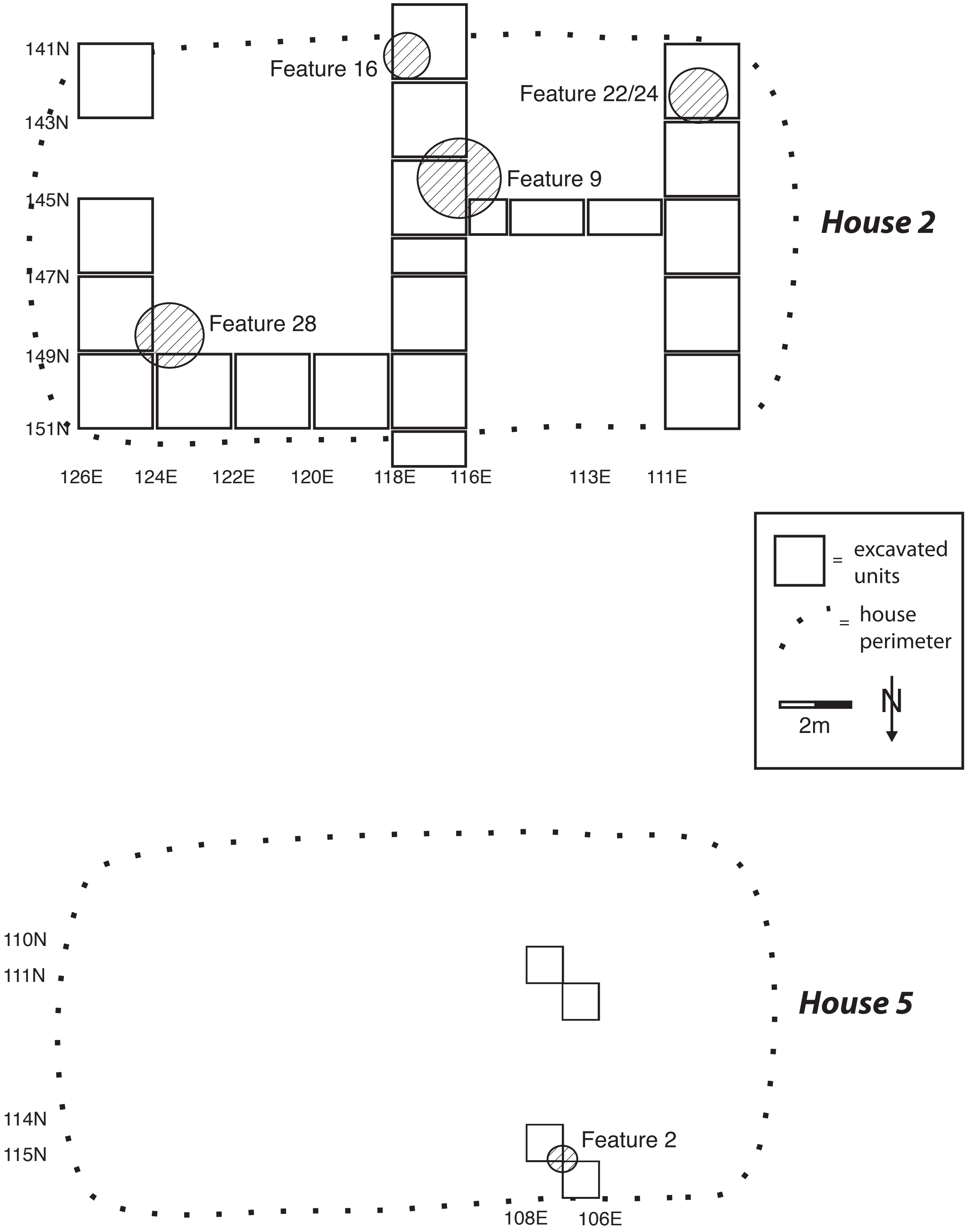


Figure 5.6: Hearth feature locations and approximate sizes in House 2 and House 5.

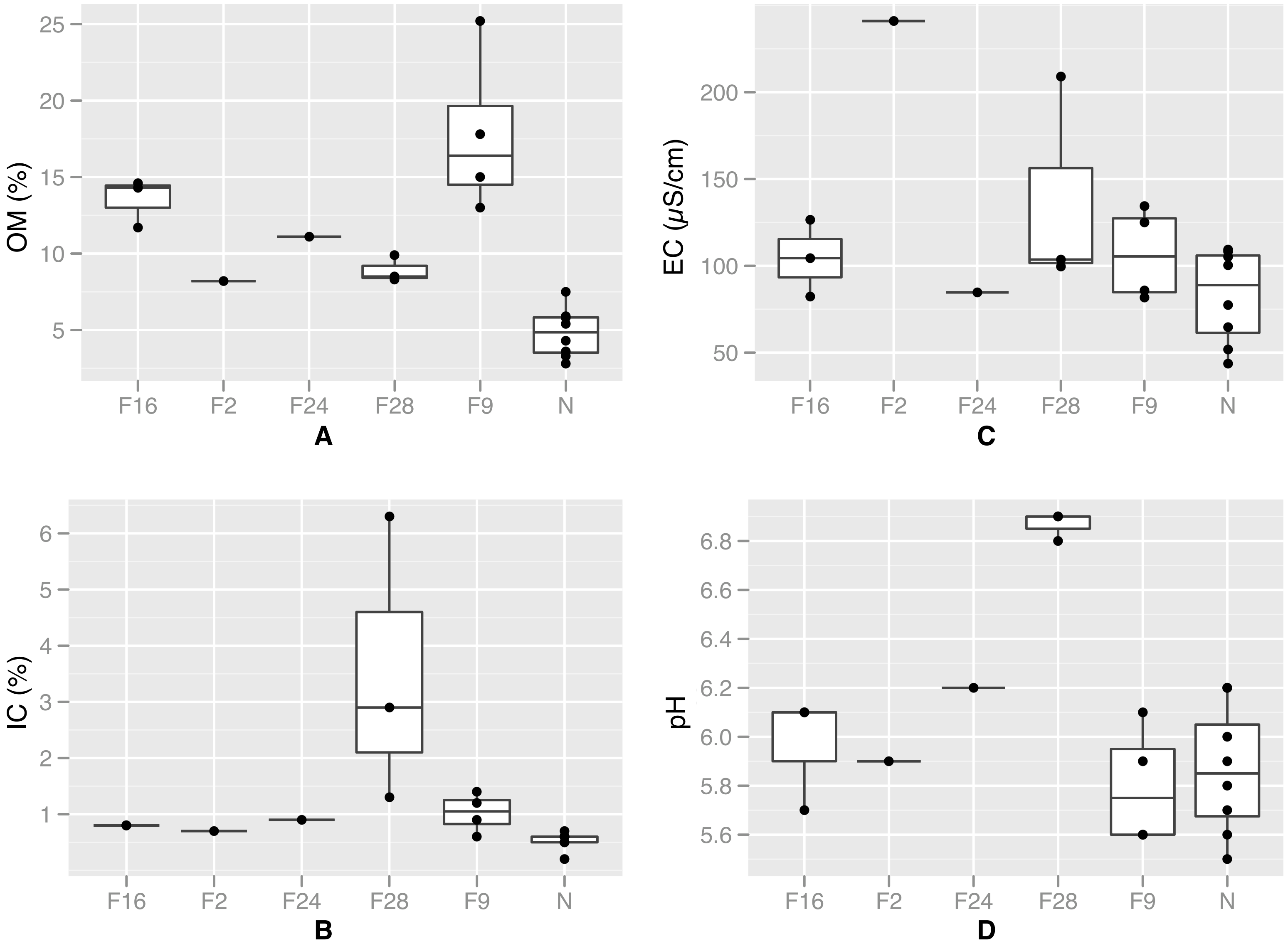


Figure 5.7: Layer B/C feature versus Natural box plots of soil constituents

5.8) from each feature assigned to Layer B/C are presented below.

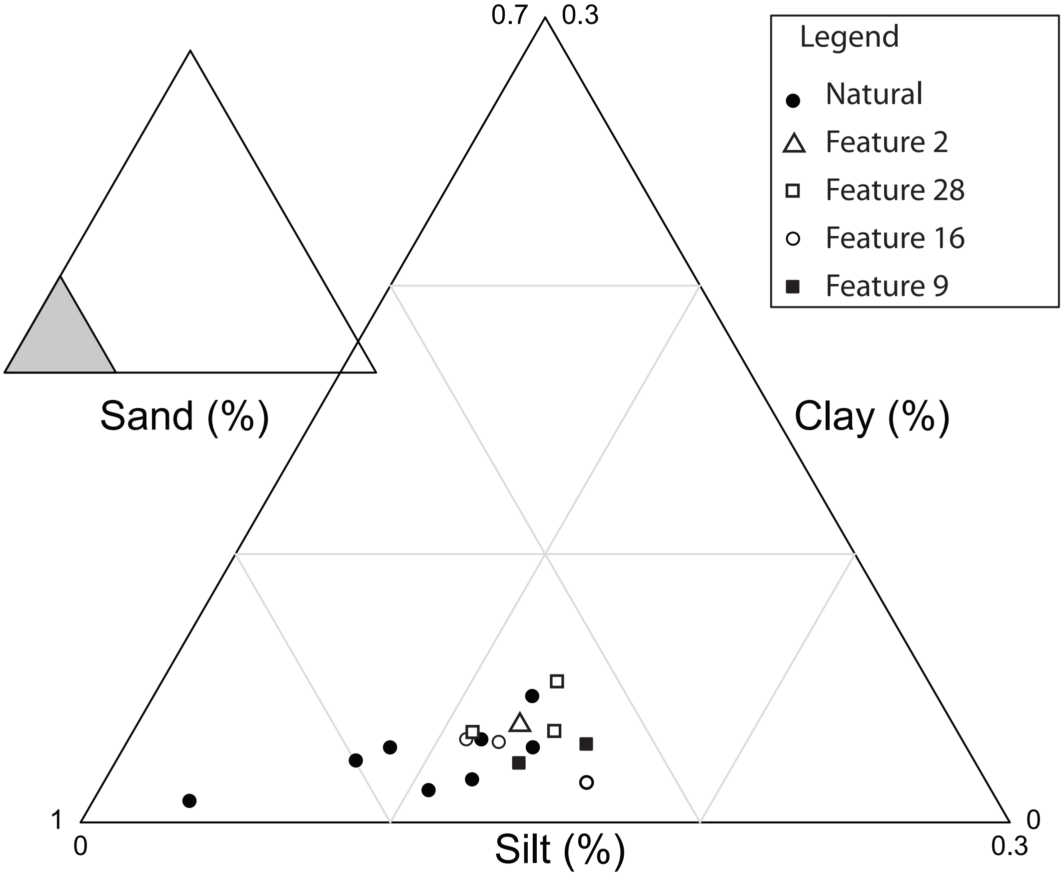


Figure 5.8 Particle-size Analysis of Feature samples from Layer B/C

Feature 2

Feature 2 is the only combustion feature from Layer B/C that was revealed during the excavation of House 5 (Figure 5.6:C). It was a small (~60 cm in diameter) lens of loose ash, with no evidence of fire-altered rock or faunal material. The abundance of ash was reflected in the electrical conductivity measurement (241 µS/cm), which was the highest in the feature data set (Figure 5.7:C). Organic matter enrichment fell within the error margin of the natural range or variation. Feature 2 inorganic carbonate content, pH, and unexpectedly texture was within the natural range of variation, and did not suggest anthropogenic alteration.

Based on the form of the feature, its lack of fire-altered rock, few faunal remains, and its low organic matter, higher electrical conductivity, and finer texture than natural samples, it does not appear to be a hearth. I argue instead, based upon these characteristics, that it was an ash dump. If the predominant constituent of the feature were ash, this would explain both the low organic matter enrichment and high electrical conductivity of the feature.

It is interesting that it was collected from the edge of House 5 and may illustrate evidence of housekeeping practices. I would expect that significant amounts ash would have been created, within the house, only in hearth contexts. I also expect that hearths were likely not constructed at the edge of structures where they may have threatened to spread to the rest of the structure. Despite the suggestion that construction materials were naturally fire retardant, I do not believe that people would have tempted the situation. If Feature 2 is the refuse from a local hearth, this would suggest that hearth residues may not always have been removed from the house entirely but were deposited in out-of-the-way areas.

Feature 9

Feature 9, the central hearth in House 2 (Figure 5.6:A), represents the best fit to the model hearth predictions made in Chapter Three. As expected, the organic matter enrichment (12.9 to 25.2%) of this hearth was far higher than the natural range of variation. This reflects substantial inputs of organic matter during its use-life, likely in the form of food and fuel residues. Inorganic carbonate enrichment is comparable to the natural range, illustrating the lack of deposition of shell within the feature. However, Feature 9 does not meet the all of the expectations of the model. Electrical conductivity (85.8 to 134.4 μS/cm) within the feature was lower than expected. It was the largest of the hearths in House 2 and if the volume of ash generated during its use was related to its present volume, an estimated 1.57 m^3, from the 2 m diameter by 50 cm thick lenticular exposure, I expect that electrical conductivity would be higher. Lower electrical conductivity may be explained in one of two ways. First, acidification, driven by abundant organic matter enrichment resulted in the loss of the free ions present in the form of wood ash. Alternatively, wood ash was not a major constituent of this hearth at the time of sampling.

Loss of mineral wood ash-derived free ions as a result of acidification is unlikely. A few small concentrations of ash and other oxidized material were located within the perimeter of the feature as described in excavation field notes. Were lower electrical conductivity to be explained by acidification, one would have to explain the persistence of these lenses. It appears far more likely that ash was not a component of this hearth at the time of sampling. If this is the case, it can be accounted for by two alternative models. The first suggests that ash was consciously removed from the hearth during its use. The second suggests that the fire was rarely hot enough to create substantial amounts of ash.

Low ash content could be explained if the feature was regularly cleaned of its contents. Ash contents would be removed and likely dumped outside of the house, or, as suggested for Feature 2, in low-traffic areas (i.e., bench) of the house. This would explain the lack of ash and the resulting low electrical conductivity values. Any woody debris remaining in the feature is likely to be charcoal, which is physically and chemically inert, and contributes little to electrical conductivity either as a source of free ions or material to that traps free ions as does non-carbonized organic matter. It would also account for the dominance of fragmentary unidentifiable rather than whole bone in the feature (Ewonus 2006:50), as small fragments would be likely to be missed during regular cleaning episodes.

Preferential cleaning of this feature may be accounted for in a variety of ways. It may be that the debris generated by such a large feature, assuming that its diameter reflects the size of the fire and not a smaller migrating fire (which cannot be confirmed), would require more frequent cleaning merely as a safety precaution. It is possible that leaving large amounts of semi-combusted refuse around the large hearth would be a hazard, possibly leading to an uncontrolled fire. Alternatively, Feature 9 and the area around it were kept clean because of the use of that space; neither household members nor guests would appreciate treading on yesterday's meal, nor would a "core" family who may have played the role of host more often than other families in the household.

The second possibility is that the central hearth in House 2 was often used for low temperature fires, the principal functions of which would have been light, and perhaps heat. Following on the suggestion that the family inhabiting the area around Feature 9 was the social core of the household, a suggestion supported by the recovery of almost all sumptuary goods from these units (Grier 2006a:111-114), it may be that this hearth was used in a range of activities that were not organized around the consumption of food including socializing, story telling, or dancing. These activities may have been structured around the core family of the household as the title holding group. As suggested by ethnographic data, this family may have been responsible for more stories, which would have diversified the use of their domestic space requiring broader functionality in their hearth. This possibility would suggest that other hearths with similar electrical conductivity values and organic matter were used possibly used for similar functions. This suggestion is discussed in relation to Feature 24 below.

Notably, these alternatives are not mutually exclusive. Large, low temperature hearths would have required more intense cleaning as would the use of this space for social functions. These characteristics indicate that the structuring constraints on this hearth were social as much as functional, dictated in part by the socio-economic standing of the core family.

Feature 16

Feature 16 was located in Unit 142N/116E (Figure 5.6:A). It was unusual in that it was associated solely with Layer B rather than both Layers B and C. It is described as containing large amounts of fire-altered rock, carbonized material with lower amounts of oxidized sediment. Few faunal remains or artifacts were recovered from this feature. Its texture, like Feature 9 was finer than some of the natural samples, containing slightly more silt (12.9%) than the natural range (Figure 5.7). It shared many of the same trends with most other features in terms of pH (5.7 to 6.1) and inorganic carbonates (0.7 to 0.8%), which showed little variation beyond the natural range. Electrical conductivity (82.3 to 126.5 µS/cm) was similar to that of Feature 9 and partially exceeded the natural range of variation. Organic matter was enriched by comparison to the natural samples (11.7 to 14.6%).

Feature 16 fit the model predictions as well as Feature 9. In fact, in light of Feature 16, Feature 9 does not appear unique. Both were characterized by greater organic matter enrichment than ash, and contained comparatively little inorganic carbonate enrichment. They had finer texture than any other feature and partially exceeded the natural range of variation. The location of this hearth nearby Feature 9 may suggest that it was subject to a similar intensity of cleaning, accounting for their comparable characteristics.

Feature 24

Feature 24 was located in Unit 141N/109E (Figure 5.6A). It has been interpreted to be the domestic hearth in the southwestern corner of House 2. It was partially uncovered during excavation in the northeastern corner of the unit. It was approximately 1.2 m in diameter and 40 cm thick (~ 0.45 m^3). Very little fire-altered rock was found within the feature, which contained a fragmented stemmed point, abundant herring vertebrae, and a fragmentary dog mandible. Few of the geoarchaeological characteristics of this feature were particularly notable. It had organic matter enrichment higher than the natural range of variation (11.1%). Yet, all other constituents were well within the natural range, making further interpretation difficult (Figure 5.7:B to D).

This feature was raised above as a having similar characteristics to Feature 9, which was argued to derive its characteristics from a combination of broad functionality and more intensive maintenance. Grier (2006a:112) identified the location of the second stone bowl recovered from House 2 as Unit 141N/109E, the same unit where this hearth is located. Although this hearth is not of the same size as Feature 9, it is possible that the family that occupied it was also involved in social activities. However, given the small sample, and few sumptuary goods, this conclusion must remain tentative.

Feature 28

Feature 28, was the large domestic hearth found in the northeastern corner of House 2 (Figure 5.6:A). In the DPHAP field notes it was described as a large hearth feature dominated by ashy, brown (10YR4/3), burned shell matrix sitting in a shallow depression. The center of the feature was noted to have a patch of burned black (10YR2/1) sediment.

The chemical and physical signature of this feature corresponds quite closely to the field description. The dominance of ash in the feature matrix was reflected by the organic matter content, which was substantially lower than any of the other combustion features (8.3 to 9.9%) (Figure 5.7: A). The abundance of shell was readily visible in its inorganic carbonate enrichment (1.3 to 6.3%) and pH (6.8 to 6.9) data, both of which were higher than the natural range of variation (Figure 5.7:B, D). The inorganic carbonate values generated by this feature were the highest of any sample and have the widest range. When they were compared to the remainder of the cultural data set, it was evident that the feature's carbonates originated in the shell content of the feature matrix. This abundant shell-derived carbonate had an appreciable effect on the feature's electrical conductivity (84.7 to 209.0 µS/cm), which was also the high in the data set (Figure 5.7: C). Notably, the features that most closely match the characteristics of Feature 28 were Features 10, 11, and 12 from Layer A, all three of which were interpreted to be shellfish roasting features.

Feature 28 has been interpreted to be a domestic hearth based on its location, near the bench area zone in the northeast corner of House 2, and its size, at least 1.2 m in diameter. The density of faunal material is higher in this area than in any other area of the house (Ewonus 2006:Table 5, 6, 7, and 8) and the artifacts suggest marine-focused subsistence activities (Grier

2006a:108-109). The preponderance of evidence suggests that this is a domestic space. It is unlikely that this hearth was functionally different than other hearths in the house, despite its unique characteristics. This was not "the shellfish roasting hearth" in the house that was used by all families for that specific purpose. The variability in this feature is likely a reflection of the socio-economic practices of the domestic group that inhabited this area of the house. The consumption of shellfish is generally described as a low-status activity in spite of archaeologists' attempts to de-stigmatize it (e.g., Moss 1993). The abundance of shellfish in this domestic area may suggest the presence of a low-status domestic group, particularly in light of the absence of any sumptuary items in these units. It has been argued (Samuels 1991b:202), following ethnographic evidence, that low-status families may have had imperatives to keep their domestic space clean. Thus, the combined evidence of shellfish consumption and a relatively "messier" compartment indicates that this family may not have enjoyed the same status as the families occupying either the areas around Feature 9 or Feature 24, a point driven home by the lack of sumptuary goods around Feature 28.

Feature Summary

The preceding discussion of feature samples from the DPHAP collection revealed that there was far greater variability in the hearth feature samples than was predicted by the model presented in Chapter Three. It appears that two factors controlled the geoarchaeological signatures of these features, their faunal content and their treatment during use. The fact that this variability was finite and that three distinct categories of signatures were evident, even with this limited sample size suggests that variation was meaningfully patterned:

1. *High organic matter.* Low conductivity features characterized by large amounts of charcoal, little ash and low pH values.

2. *High ash content*. Electrical conductivity higher than combustion features without ash, pH slightly higher. These can be distinguished from floor deposits by their unusually low organic matter content.

3. *High ash content*, with significant shell contribution. At Dionisio Point these samples were readily recognizable by substantially higher inorganic carbonates.

The causes of this variation were, in at least one case (Feature 2) identified to be functional. Feature 2 suggests that, in some cases, features designated to be "hearths" in the field, may be other types of features entirely. Functional variability in hearth features has been suggested in past archaeological investigations (e.g., Samuels 1991b). However, this has often targeted large hearths has ceremonial rather than domestic. This study makes no such suggestion. The functional variability that is being discussed here is in the much smaller, ephemeral features found in House 2 and likely other structures. A functional analysis of these smaller features has not been undertaken in the published literature, archaeologists regularly focusing on larger hearth features.

There are two capacities in which this kind of functional analysis could be useful. The first in the functional interpretation of space. In a number of excavations architectural feature identification, such as door, or bench feature identification is unclear. It may be possible to use the identification of smaller features to infer the architectural nature of these features from indirect evidence. Aggregations of ash dumps may, for example, identify low-traffic areas as suggested above. This study was not able to pursue this line of research at length as a result of the small data set, but indications are that it may be productive to pursue sampling of small features for this purpose.

This feature analysis also suggests that variation in the social constraints on individual families may affect the nature of hearth features. Inasmuch as domestic activities varied between family-units, the nature of domestic hearths could be quite variable. The functional model suggests that the same domestic groups use different hearths for different functions. Thus domestic hearths and ceremonial hearths are mutually exclusive classes of features. The social model is distinguished by arguing that, where the evidence supports the presence of a domestic space around the hearth, that inter-hearth variability is the result of the socio-economic status of these groups. That is, all hearths may be domestic hearths, but high status families may be engaged in activities that require them to treat their domestic hearth differently.

Features 9 and 28 are the best examples, in this data set, of domestic hearths that appear to have been treated in quite different manners as a consequence of differences in social status. As argued above, Feature 9 sedimentary characteristics indicate that it was predominantly composed of inert organic matter at the time of sampling. The low electrical conductivity values recorded for it were surprising in the context of the hearth model presented in Chapter Three. However, in light of the artifact analysis previously undertaken for this compartment, the low electrical conductivity, suggested to reflect low ash content, is explicable as a reflection of the domestic requirements of the high-status "core" family that inhabited the area around it. Ethnographically, the title-holding core of the household was responsible for hosting other households in a number of social activities. In House 2 at Dionisio Point, the distribution of sumptuary goods within the central compartment, surrounding Feature 9 suggests that this family enjoyed greater ability to gain access to these goods (Grier 2006a:114). The possession of these goods was likely related to elite identity (Grier 2003), and very likely were involved in the activities centered around Feature 9, the same activities that required this space to be maintained to a greater degree than the spaces around it.

Feature 28 has been suggested to be the domestic hearth of a low-status family based on the abundance of shellfish, a low-status food ethnographically, and the far density of faunal debris found in this location. The predominance of shellfish in this location was evident in the inorganic carbonate content of the sediment samples. Wether shellfish were in fact a low-status resource at the time that House 2 at Dionisio Point was occupied is not clear. However, if they were it would explain both the greater degree of "messyness" of this part of the house, that is the higher density of most data sets, as well as the absence of an sumptuary goods.

These two very different hearth signatures suggest that social differentiation was recorded in these features. The alternative that these were functionally different structures is difficult to maintain in light of the domestic artifacts located around Feature 9 (Grier 2001). Nor can it be simply argued that Feature 28 was the shellfish-roasting hearth in the house. These socially determined constraints on the use of space should be of interest to archaeologists who are attempting to address questions of the emergence of social differentiation in households. Differences in the treatment of space should be coevolutionary with the activities that alter the distribution of sumptuary goods, and may be appropriate to assess when artifact assemblages are not appropriate for these kinds of questions.

Floor Contexts

Three different floors contexts were presented in this analysis: Center, Edge (Bench), and Entryway. These contexts were chosen to reflect important aspects of the ethnographic and archaeological models of shed-roof house architecture. Figure 5.9, illustrates an idealized model of the functional division of space within the ethnographic shed-roof plank house (B), and the units that were sampled from House 2 (B) and House 5 (C). Variability of soil constituents between the three types of floor deposits is presented in Figure 5.10 (A to D), and results of the particle-size analysis in Figure 5.11.

Comparison of the soil constituents revealed that there were few significant differences between the three floor contexts. pH and inorganic carbonates failed to exceed the natural range of variation. The electrical conductivity of all three samples exceeded the natural range but was broadly similar between contexts as was organic matter, though samples clustered slightly differently.

Center Deposits

Table 5.5 presents the expectations for Center samples. Center samples were collected from Unit 144N/116E of House 2, and Units 110N/106E and 111N/107E House 5. The Center deposits within the plank house are the open space that surrounds domestic hearths and was used for a variety of activities. Barring post-depositional alteration, patterning of floor residues will reflect the amount of time that debris was allowed to remain in contact with the floor surface. Samuels (1991b) and Huelsbeck (1994) argue for a similar process in the macroscopic artifact and faunal record at Ozette. The model presented in Chapter Three predicts that floor deposits will be enriched in both organic matter and electrical conductivity, and that other soil constituents and soil texture will remain largely unchanged.

Table 5.5 Expected characteristics of cultural sediments from Floor-Center Deposits

Context	Measurement	Expectations relative to natural sediments [a]
Floor Center	Soil Texture	●
	Organic Matter	● ● ●
	Inorganic Carbonates	●
	pH	●
	Electrical Conductivity	● ● ●

[a] An increasing number of dots denotes increasing enrichment in OM and IC, higher pH and EC and increasing silt and clay content. A single dot denotes similarity to the natural sediments.

Center samples in almost all of the analyses had the widest range of variability of the floor deposits, reflecting their complex stratigraphic history. There was overlap between center samples and the natural range of variation on all four constituents (Figure 5.10: A to D), particularly inorganic carbonates and pH. Unexpectedly, electrical conductivity was higher (Figure 5.10:C) and the texture finer (Figure 5.11) than most feature samples.

Lower organic matter enrichment of floors demonstrates that organic debris was not allowed to accumulate or was not deposited there in substantial amounts. The electrical conductivity of floor deposits was significantly higher than most feature deposits. It is very likely that ash was the source of high electrical conductivity in floor deposits as well a suggestion that is supported by the particle-size data.

Little archaeological research is available on the particle-size distribution of wood ash created by small anthropogenic fires. As noted earlier, most engineering studies suggest that grain size distributions of ash vary from gravel to clay, but tends towards to range from fine sand

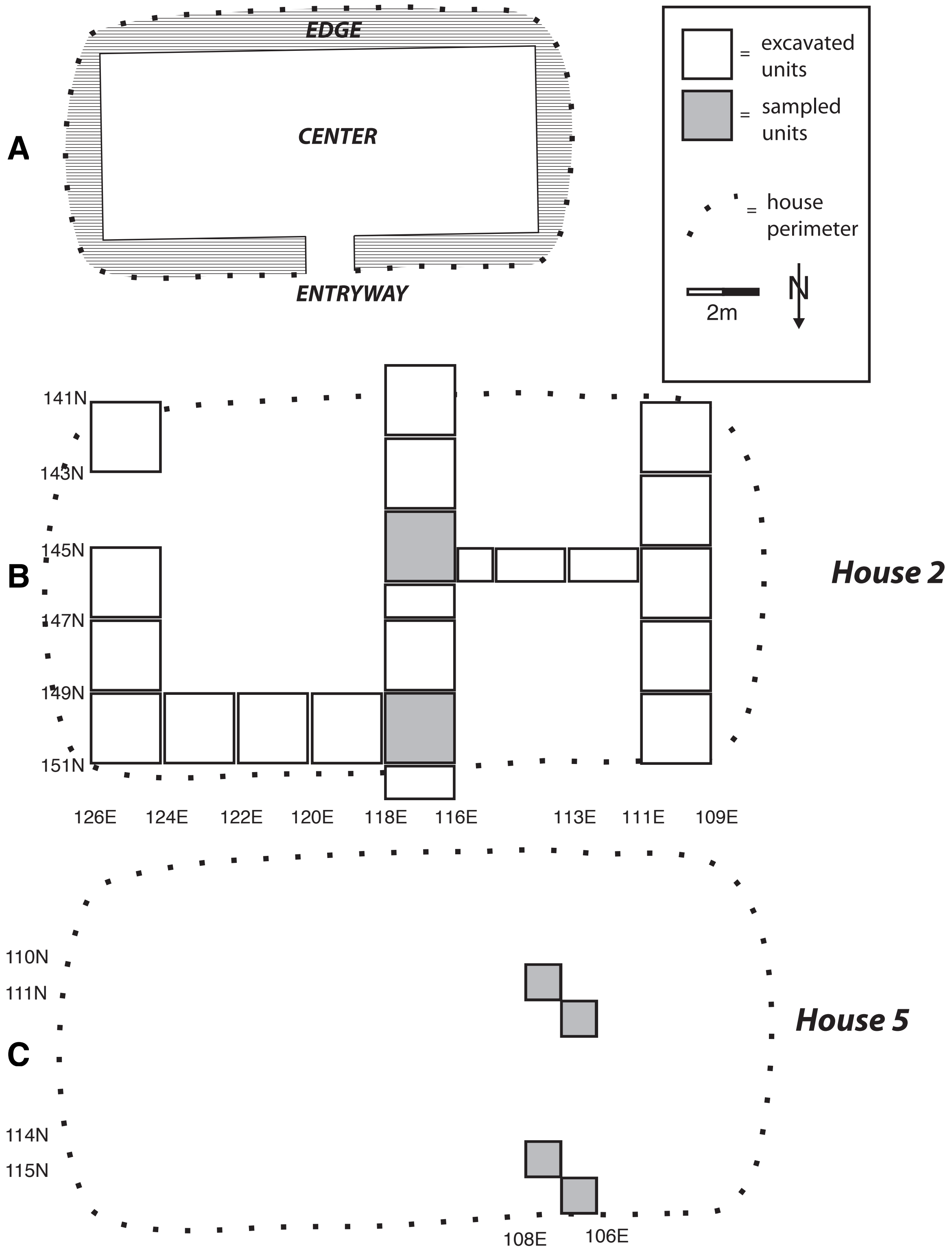


Figure 5.9. Shed-roof plank house division of space A. Idealized functional division of space, B. Sampled units in House 2, C. Sampled units in House 5.

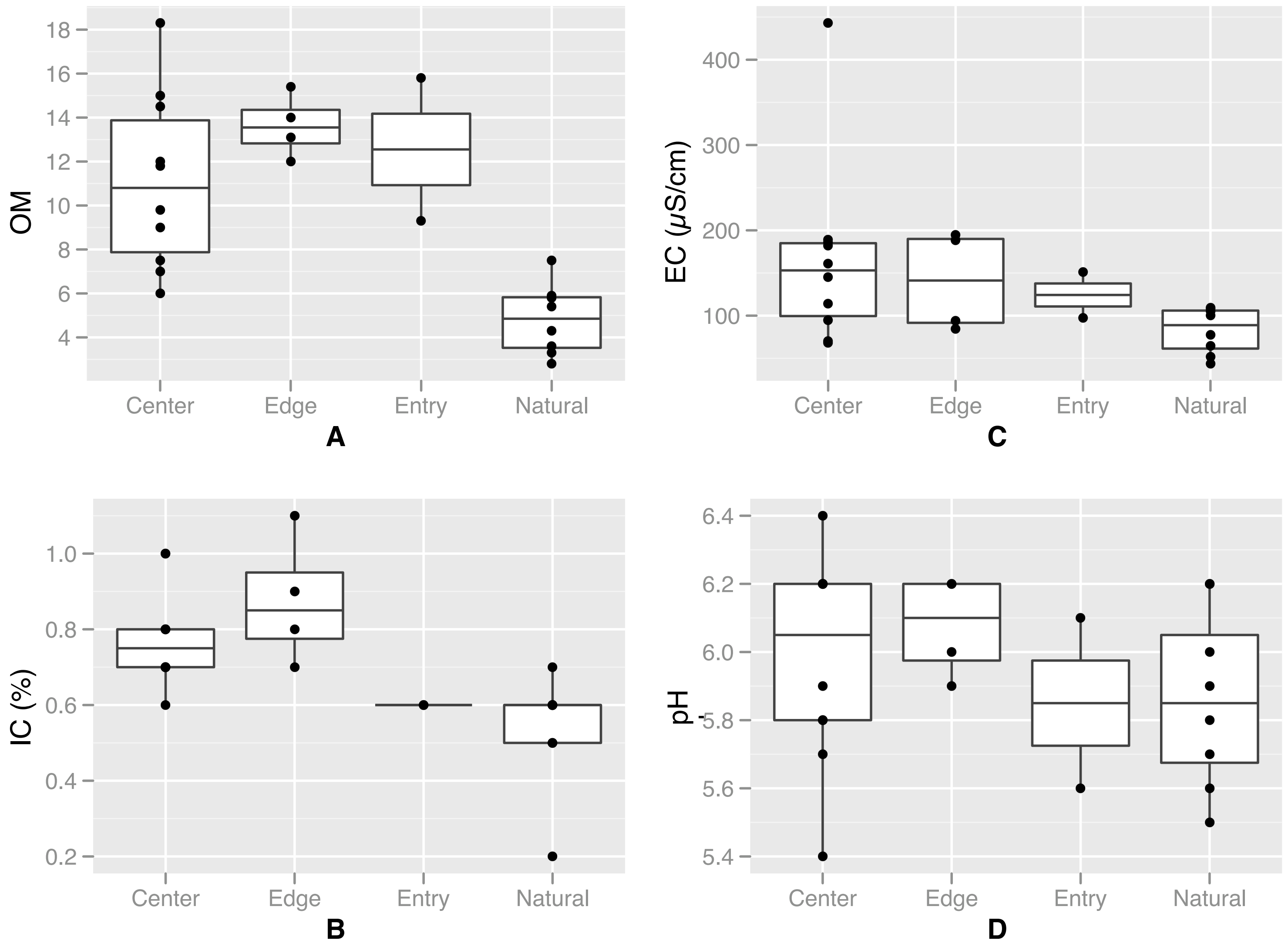


Figure 5.10: Layer B/C floor versus Natural box plots of soil constituents

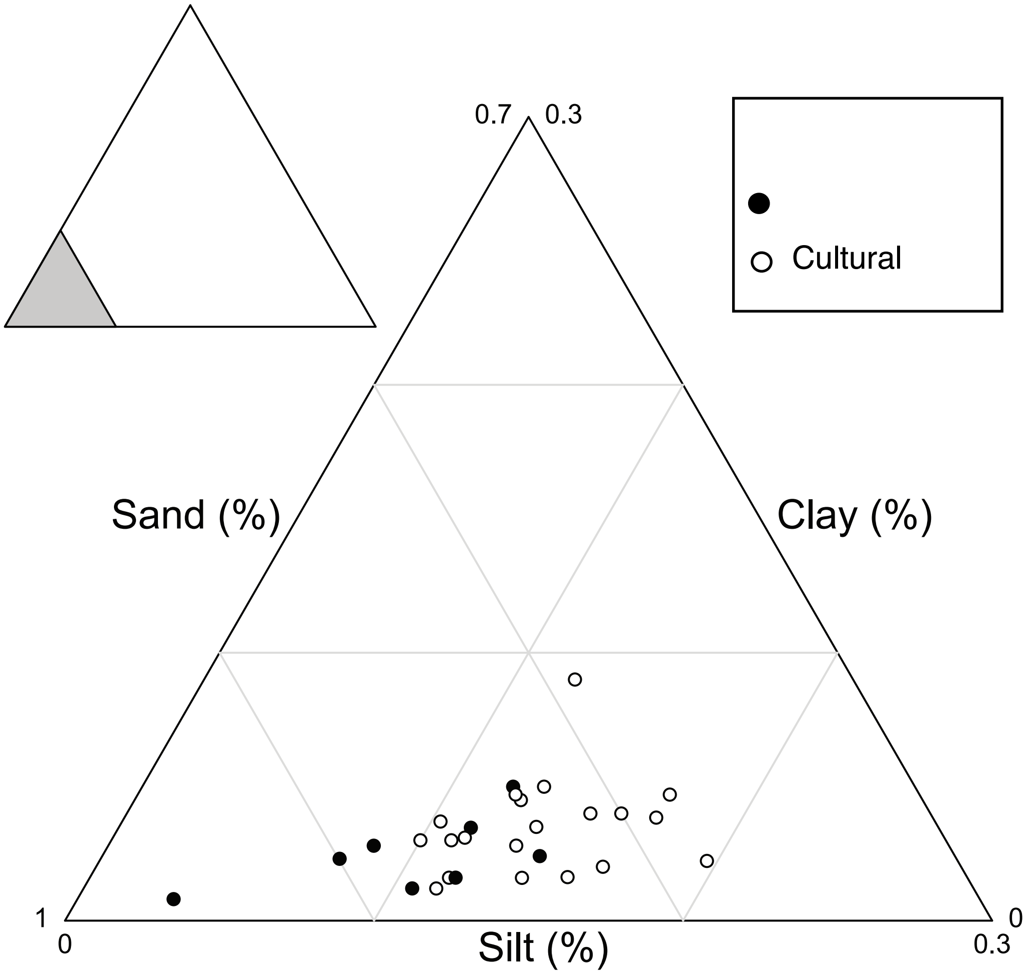


Figure 5.11 Particle-size Analysis of Floor samples from Layer B/C

to clay-sized particles (Demeyer et al. 2001:288). I expect that much of the ash that is found in floor deposits was not intentionally deposited, but was instead the result the settling of a fine airborne component, which would necessarily be silt-sized and smaller as sand grains would not be entrained within a shelter. Figure 5.11 supports this suggestion. Natural and cultural sediments are differentiated primarily by their silt content.

It is unlikely that this pattern was created by the tracking of fine sediments into the house during its use (e.g., Butzer 1982:80). While this process would generate the particle-size distribution patterns noted in Figure 5.11, mineral silt additions cannot fully account for the significantly higher electrical conductivity patterns noted in Figure 5.9 (C). Some of the natural samples with equivalent silt content were shown to have lower electrical conductivity values. Local organic matter enrichment could account for increased electrical conductivity, but does not explain the grain size differences. It is more likely that ash or a derivative of wood combustion connected to ash is the primary cause of elevated electrical conductivity (e.g., Weide 1996), indicating that ash is an important constituent of the matrix of Center deposits.

It is not difficult to envision a number of practices that would have tracked ash throughout the house, as occupants moved around their domestic space. Feature 2, evidence of an episode of hearth cleaning, demonstrates that ash could be and was moved around the house. Hoever, housekeeping practices were probably ineffective at removing fine ash residues, perhaps suggested by the slightly finer texture of Feature 2 as compared to floor deposits. Ethnographically, fine residues were managed by regularly moistening the floor (Suttles 1951:313). However, the electrical conductivity values from Dionisio Point illustrate how effectively these materials could become incorporated into floor deposits.

Edge Deposits

As mentioned in Chapter Three, archaeological evidence of benches has often been lacking during the excavation of prehistoric structures. Evidence of post features (Mauger 1991:105), changes in soil color, and changes in texture, for example, have been used to suggest the presence of bench features (e.g. Grier 2001:166-178; Lepofsky et al. 2000:398-399; Matson 2003:88). Under many circumstances, it is difficult to either confirm or deny their existence;

dark black, loose, silty deposits (Matson 2003:88) could, in fact, represent bench deposits. I argue that geoarchaeological analysis is a more robust means of describing and interpreting the characteristics of these deposits, and may yet provide a means for spatially defining them.

Table 5.6 summarizes the expectations for Edge deposits.

Table 5.6 Expected characteristics of cultural sediments from Floor-Edge Deposits

Context	Measurement	Expectations relative to natural sediments [a]
Floor Edge	Soil Texture	● ●
	Organic Matter	● ●
	Inorganic Carbonates	●
	pH	●
	Electrical Conductivity	● ●

[a] An increasing number of dots denotes increasing enrichment in OM and IC, higher pH and EC and increasing silt and clay content. A single dot denotes similarity to the natural sediments.

The Edge units sampled for this study were 114N/106E and 115N/107E. These two units were located at the northern edge of the House 5 depression. Field notes indicate that these samples were not identified as bench deposits during excavation, yet they were located in a space analogous to that proposed for bench deposits in House 2 (Grier 2001:Figure 36) (Figure 5.9:B, C). This discussion, therefore, is not a test of either the model as proposed in Chapter Three, or the field identification of the deposits. The following treatment is a step towards providing a better means of addressing these difficult archaeological signatures.

Edge samples, like Center samples partially overlapped with the natural range in electrical conductivity, pH, and inorganic carbonates. However, unlike Center samples, their organic matter content fell well outside of the natural range (Figure 5.10:A). A portion of the organic matter, likely in the form of carbonized material, removed from Center Deposits during cleaning activities was deposited in Edge deposits. Comparison of the feature (Figure 5.7) and non-feature (Figure 5.10) box plots reveals that Edge deposits contain a median organic matter content comparable to Feature 9, supporting the suggestion that some portion of the domestic debris generated by a family accumulated beneath benches. The discussion of Feature 2 has already illustrated the possibility that ash was dumped along the edge of house deposits, conceivably beneath benches. It appears that Feature 2 could simply be a specific example of a more generalized process of housekeeping and maintenance. Alternatively, benches in the ethnographic literature were storage locations as well as sleeping quarters and social space (Suttles 1991). A pattern of higher organic matter enrichment, higher electrical conductivity determinations, similar to that suggested above to be the result of housekeeping, could also be the result of the *in situ* degradation of materials kept in this location. Unfortunately, the methods used here are unable to resolve between these two alternatives. Both processes may have been active and coexistent. Yet, until we develop better means of identifying the specific sources of organic matter or electrical conductivity, the more influential of these two processes cannot be determined.

The suggestion that Edge samples have been affected because of their proximity to exterior shell middens can be abandoned. Shell middens would generate both higher electrical conductivity and organic matter enrichment. However, I would expect there to be a similar increase in inorganic carbonate content in the form of calcium carbonate. This is not the case. Calcium carbonate is known to degrade under acidic conditions and should leach into the surrounding matrix (Stein 1992b). The ~0.2% difference between the median inorganic carbonate value of Edge deposits and the natural range was firm evidence that these samples were been affected by calcium carbonate rich materials, such as shell.

Entryway Deposits

The presence of entryways has been difficult to identify archaeologically because of their possible variability in construction from informal gaps in wall planks to fortified gates. Grier's (2001) identification of a possible cluster of post features and abrupt cut in a gravel bench formation in House 2 suggested that there was an opportunity to test Huelsbeck's (1994) "door model" against the geoarchaeological record. In this model, Huelsbeck (1994:57) interprets the spatial concentration of a variety of small fragmentary debris within the house floors at Ozette as evidence of entryways and suggests that this may be a wide geographic phenomenon that Northwest Coast archaeologists use to find "doors".

Table 5.7 presents the expected characteristics of Entryway deposits.

Table 5.7 Expected characteristics of cultural sediments from Entryway Deposits

Context	**Measurement**	**Expectations relative to natural sediments** [a]
Entryway	Soil Texture	●
	Organic Matter	● ●
	Inorganic Carbonates	●
	pH	●
	Electrical Conductivity	● ●

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[a] An increasing number of dots denotes increasing enrichment in OM and IC, higher pH and EC and increasing silt and clay content. A single dot denotes similarity to the natural sediments.

The only unit identified as a possible entryway deposit during excavation was 149N/116E in House 2 (Figure 5.9). The data set used in this analysis was extraordinarily small, consisting of only two samples. Apart from higher organic matter content (Figure 5.10:A), the characteristics of Entryway samples partially overlapped with the natural range of variation. The electrical conductivity of the Entryway sample was slightly higher than the natural range. The median pH and inorganic carbonate content of the Entryway samples were among the lowest in the data set, overlapping extensively with the natural range.

These characteristics are largely indistinguishable from the Edge deposits. The similarity between these two cultural contexts should not be taken to suggest that the Entryway samples were, in fact, drawn from bench deposits. First, the Edge samples cannot be verified to be drawn from bench deposits themselves, and second, it is largely a working hypothesis that these two contexts should have different signatures. Higher-than-expected electrical conductivity and organic matter content of these samples results not only because material is being removed from inside, but because, unintentionally, material is being brought in from outside (Butzer 1982:80).

The past treatment of plank houses as closed systems may largely stem from the kinds of data sets that have been analyzed. Archaeologists studying tools or faunal remains rarely need to address the possibility that materials are being unintentionally tracked into structures. However, for microscopic data sets, this is a possible cultural formation process (Butzer 1980:82). Organic matter and minerals that contribute to electrical conductivity could and likely were tracked into these structures. The discussion of Center deposits above has already demonstrated evidence this process in the "tracking-in" of large amounts of silt. These materials would be trampled into the floor deposits around the entryway preserving them there and generating a geoarchaeological signature similar to that of Edge deposits.

All of this suggests that Huelsbeck's (1994) method of using faunal materials for the identification of doors does not work for bulk sediment analysis. Entryways and Edges are simply too similar to be differentiated on these five analytical variables. Importantly, Huelsbeck (1994) had a very high resolution data set at his disposal, and had the opportunity to pick up patterns that this data set could not. It may be that will a more intensive geoarchaeological sampling strategy could differences between these two contexts.

Floor Summary

In the cultural model in Chapter Three it is suggested that the primary source of variability within floor deposits, here including Center, Edge and Entryway samples, was housekeeping practices. While activities surrounding food preparation, consumption and storage were responsible for introducing the large amounts of organic matter and mineral wood ash to these deposits that elevated them above the natural background, it was the intentional and unintentional re-deposition of these materials via housekeeping that ultimately led to the patterns recorded geoarchaeologically.

This is best seen in the variability between Center and Edge (bench) deposits. It is evident from the differences in organic matter content between the two spaces that human activities either preferentially removed organic matter in the former or deposited in the latter (or both). I believe that a combination of the two is the most accurate interpretation of the geoarchaeological data. As has been previously argued, the unintentional tracking-in of fine sediment would not be sufficient to result in the ~ 4% drop in organic matter content between Edge and Center deposits. Nor can we attribute accumulation of large amounts of organic matter to the proximity of Edge deposits to middens (though the *in situ* decomposition of stored materials may have made a contribution to the geoarchaeological signature). Further support for a model of organic matter re-deposition away from Center deposits and into Edge deposits is found in two places. First, the characteristics of Edge deposits are best matched by hearth debris. I am, therefore, certain that bench areas were sometimes, if not always, the location of the accumulation of domestic debris through the cleaning of domestic areas. The second source of evidence is less strong, but is potentially more telling. Comparison of non-feature and feature samples from Layer B/C in Unit 144N/116E, the only unit where substantial numbers of samples are available for both, reveals that though organic matter overlaps between the two, it is notably different (Figure 5.10). I suggest that this is because floor areas were regularly cleaned.

The data set used in this analysis is, however, unable to address variation in housekeeping practices through either one of the houses sampled at Dionisio Point. Variation in the density of faunal remains within House 2 has been interpreted to reflect functional variation in the use of space (Ewonus 2006:85). The central compartment, in this interpretation, is argued to be a communal space used by several families living around it. An alternative interpretation is that different areas of the house were subject to different degrees of housekeeping during their occupation. Smith (2006) has argued that lithic debris was removed from high-traffic areas around hearths. This same argument could be extended to a range of debris, including faunal materials. If the domestic area in the central compartment of House 2 was occupied by the elite core of the household, that space may have had cause to be cleaned more frequently. The elite family may have hosted more feasts, or possibly may have reproduced its status in part by keeping a cleaner domestic space than the remaining domestic groups in the house.

This interpretation of the geoarchaeological evidence has implications for the reconstruction of plankhouse economic organization. Huelsbeck (1994:57) suggests that there is no reason to expect differential cleaning of domestic spaces within a plankhouse, as this would constitute little more than pushing the dirt around the room. Huelsbeck's (1994) model assumes a high level of household social integration in the prehistoric shed-roof household. However, ethnographically while the families shared in a number of activities, both economic and social, they were distinct units and were largely responsible for their own space (Suttles 1991:214). Grier (2006b:148) has recently illustrated the underlying tensions that existed in the shed-roof household between the social elite "core" family and the "tenant" families that had been attracted to it, the former wanting to attract the best labor and the latter desiring to be part of the best household.

While Huelsbeck (1994) marshals both ethnographic and archaeological material to support his argument, the model of within-household uniformity in maintenance practices does not appear to apply to Dionisio Point. This has important implications for the reconstruction of household socio-economic activities from artifact and faunal data. The possibility that some shed-roof compartments were differentially treated by their occupants forms the basis for economic reconstruction of household organization. However, archaeologists have only recently paid appropriate attention to the complicated cultural formation processes that these deposits represent (Grier 2006a; Smith 2004). If differential maintenance is a spatially consistent practice through time, archaeologists must look for evidence of it, such as presented here, prior to interpreting results based on artifact or faunal data sets.

Implications for socio-economic reconstruction shed-roof households

The distribution of artifacts and faunal remains within plank house deposits represents the end result of a complex pattern of domestic and non-domestic activities. Geoarchaeological data reflects a similar complexity of activities, but it is often more difficult to link patterns to specific behaviors. Attempts to integrate these data sets have proven to be neither simple nor straight-forward (e.g., Ewonus 2006; Grier 2006a) and yet a holistic approach is necessary to account for the complex nature of plank house remains. This study has succeeded in addressing present models of the processes that generate the features that we use to identify plank house deposits: hearths, floor, and bench deposits.

None of the formation process models presented in Chapter Three were found to wholly or accurately describe the characteristics of features identified at Dionisio Point. In large part this is because these models were unable to address variability in the data set. Previous examinations of artifacts and architecture at Dionisio Point in combination with the data presented here suggest that this variability was generated by social as well as functional constraints. Which of these was dominant in any one spatial content within a plank house, at least in this data set, was not random; social and functional variability follow patterns.

Variability between domestic areas is primarily a function of variability of social status (privileges and obligations) between the domestic groups that occupied the plank house. That is, higher-status and lower-status families were seen to use and treat their space differently. The variability within any one of these domestic areas, however, was partially a consequence of the functional divisions of space into floor, bench, and hearth deposits. These interpretations suggest that household archaeologists need to continue to analyze the internal economic and social organization of plank house households in the context of the concept of the corporate group.

Under the broad definition of corporate groups as groups that share inalienable rights to property, they exist at various social and political scales, ranging from small-scale hunter-gatherer communities, to nuclear families, and the citizenry of nation-states (Bell 1995a:826). It is important to keep this variability in mind when we think of corporate groups on the Northwest Coast. Under a fairly inflexible conceptualization of this unit, it might be difficult to understand how a corporate group could show evidence of patterned variability in consumption debris; a corporate group is an economic unit that by definition grants access to resources for all members. Under this definition the variability that we see in housekeeping practices within the households at Dionisio Point is not explicable. However, I think that it is useful to point out that household archaeological work on the Northwest Coast has repeatedly revealed that Marpole phase households were not simple corporate groups (e.g., Chatters 1989; Grier 206a). Corporate group rights appear to, at this time. exist alongside emergent individual property rights.

Ethnographic and ethnohistoric examples of this pattern exist in agropastoral communities, in which leadership ranges from the ephemeral to the enduring. Archaeologists studying this development have looked to these communities for insight, often identifying socio-economic processes as the basis for change. The production of an economic surplus (Hayden 1995), intensification of production (Johnson and Earle 2000; Price and Brown 1985), development of economic specialization (Cobb 2000), and the monopolization of exchange relationships (Spencer 1994; Wiessner 2002) have all been interpreted as causal forces. Many of these same processes have been explored on the Northwest Coast (see Chapter One).

The importance of the residential corporate group in this discussion is the central role that it can play as both the social and economic setting for the emergence of inequality. Ethnographic and, increasingly, archaeological evidence suggests that residential corporate groups form coherent economic units in small-scale societies. The social and economic settings for the emergence of inequality involve the same core group of individuals as suggested by the importance of the kinship ethic that dominates socio-economic relationships in many of these societies (Cobb 1993:46-49). Household archaeology is one of the ways in which Northwest Coast archaeologists can enter and contribute constructively to this wider discussion.

Prospects for Geoarchaeological Prospection

One of the goals at the outset of this study was to establish geoarchaeological signatures of plank house features for the purposes of prospecting for houses prior to or in lieu of excavation. The southwestern coast of British Columbia contains an large number of dense shell middens, some of which were plank house villages in the past. Excavation techniques are unable to test the large areas of the shell midden necessary to identify the presence of plank house features (Ames et al. 1992; Bulakis-Onat 1985; Lyman 1991). It was hoped that this study would provide a means for assigning geoarchaeological samples to various specific features. However, during analysis of the data set, it became clear that the bulk sediment methods used here were not able to provide the discrimination between contexts that is necessary to distinguish floors from hearths or benches. One need only compare the results of organic matter and electrical conductivity analyses for each context to see that there are large areas of overlap (Figure 5.11).

Where the results of this study may be most effective is in terms of prospection at Dionisio Point and nearby sites. The natural sources of variability are not so great that the conclusions presented here would not apply to other houses at the site. Implications for feature identification through the geoarchaeological signature have been presented throughout this discussion. Two facts are evident from the discussion of combustion feature signatures above:

1. Combustion features are the location of the highest anthropogenic inputs in the houses, be those inputs organic matter or inorganic carbonates

2. These additions create extreme values that are readily picked up by the analyses used in this study. The implication of the presence of distinct hearth signatures, is that hearths and their associated domestic spaces can be found in buried plankhouses from fairly small matrix samples (e.g. < 10 g).

There is convincing evidence that these signals will hold for the remaining houses at Dionisio Point. However, the signatures cannot be exported wholesale to other sites with visibly different natural and, conceivably, different cultural formation processes.

Chapter Six: Conclusions and Future Research

Indigenous households seasonally occupied large post-and-beam plank houses on the Northwest Coast as early as 4500 B.P. These houses form long-term records of the domestic and non-domestic activities of their occupants and have been shown to preserve these records for millennia. This study demonstrates that geoarchaeological analyses of bulk sediment samples can be a fruitful data set to pursue alongside artifacts, faunal, and botanical remains. Furthermore, it may be able to identify patterns in the use of space when these other data sets are lacking.

The approach used was successful in assessing the validity of present models of cultural formation processes In contrast to models that emphasize variability in housekeeping processes at the household level (e.g., Huelsbeck 1994), this study supports a model in which social differentiation between families within houses is likely an important variable in these activities. This has a number of methodological implications, the most immediate are for the analysis of the spatial distribution of artifacts and ecofacts. Archaeologists working on the coast have treated this process with due caution as a great deal of interpretive weight is placed on the spatial association of features and artifacts. The complex cultural processes that move cultural materials from locations of primary to secondary and tertiary deposition have been rigorously studied in this context (Ames et al. 1992; Grier 2006a; Samuels 1991b; Smith 2006). However, it remains difficult to associate specific artifacts with their original locations of production, use or discard, and it may be that geoarchaeological materials provides a means of addressing this weakness. .

Geoarchaeologists working elsewhere have demonstrated that microresidues of activities preserved in sedimentary deposits are more resistant to change and relocation following deposition (King 2008:1225), and thus are more directly related to the location where the associated activities took place. This is true only in part for the data used here. The evidence suggests that very fine microresidues may remain in place and become trampled into house floors, such was the case for very fine ash residues that have raised the electrical conductivity of House 2 and House 5 floor deposits at Dionisio Point. One of the strengths of this bulk analysis was that sediments could often be traced from their origins to their place of final deposition. Ash, for example, produced presumably in domestic hearths, could be traced to locations along the interior wall of both House 2 and House 5, the former showing evidence of general free ion enrichment and the latter evidence of a spatially discrete ash dump. These methods may be used, therefore, to reconstruct the potential pathways that other data sets may take as a result of housekeeping activities, much as Ames et al. (1992) and Smith (2006) have attempted at the Meier site.

Geoarchaeological analysis was also successfully used to address questions specific to Dionisio Point. The anthropogenic signal of the central hearth feature in House 2 revealed that differences in maintenance rather than in use were responsible for the low density of faunal remains recovered from in and around it. This, minimally, does not support the argument that the center compartment of the house was functionally different from the others. When combined with interpretations from the artifact and architectural data sets, there is strong evidence that this was a domestic space rather than solely a ceremonial hearth. This does not preclude the hearth from also being used for ceremonial purposes. If, as Grier argues, Dionisio Point was a winter village, ceremony would likely have played a large role in the activities of the inhabitants (Barnett 1955; Suttles 1991). Subsistence during the long, cold winter months was based on stored goods on the Northwest Coast and ceremonial activities dominated the calendar (Ames and Maschner 1999:123).

This project was less successful at addressing its original research goal of providing a means of geoarchaeologically identifying architectural features in Northwest Coast plank houses. Two factors affected its success. First, of the analytical variables chosen, only three: particle-size, organic matter and electrical conductivity, were found to differentiate most cultural contexts from the natural background, and second, those variables that were significantly different between the cultural and natural deposits suggested but did not provide robust means of differentiating between kinds of cultural deposits, such as hearths, floors or entryways. These results may be most useful during future research at Dionisio Point.

Finally, it should be recalled that the data set used in this analysis was archival. Large archival sedimentary data sets have been generated from some of the most important excavations in British Columbia's archaeological history, such as the Marpole site at the mouth of the Fraser River, or the Pender Canal site on the Gulf Islands. Little has been done with these data sets since their collection. This study demonstrates the utility of these kinds of collections when methods and research questions operate at the same resolution. If these methods are developed to the point that a post-feature or hearth signal can be generated for these sites, analysis of these archival collections will provide a fruitful data set for research.

Future Research

This project has had a number of implications for excavations at Dionisio Point as well as the use of geoarchaeological methods more widely on the Northwest Coast. The project was, admittedly, a pilot study. Several future research directions present themselves as a result of this work.

Many of the conclusions of this study are based upon samples that represent broad vertical and/or horizontal contexts. Several complex features, for example, are represented by a single sample. Higher resolution sampling strategies are necessary in these complex house deposits. However, they must be research-directed. I advocate for the use of mixed strategies, focused on the range of methods that are being used. Organic matter enrichment and electrical conductivity were found to be important indicators of human activity in this study. Neither of these methods requires a large amount of sediment. Large numbers of small samples could be rapidly collected across an activity area. In fact, electrical conductivity can be measured on site with a portable meter, increasing the volume and speed of data collection. Particle-size analysis, on the other hand, consumes a large amount of sediment. Sampling strategies for this kind of analysis should focus on taking fine-resolution column samples systematically across the house floor. These need not be in every unit as textural differences are likely not that drastic. Finally, features should be sampled at the finest possible resolution. Bulk samples conflate the record of individual events. In particular, variability within features may be quite high. The averaging affect of bulk sediments results in the loss of a great deal of information.

This project was also based on a limited set of bulk sedimentary geoarchaeological methods. These are the simplest of a large array of methods that currently exist in the field that could be used to more specifically pinpoint formation processes. Two of these may be applicable to Northwest Coast plankhouse data sets. The first is soil micromorphology, the study of soil monoliths at the microscopic level. This method has been used successfully in a range of environments to address questions of floor deposit formation, hearth function (Mallol et al. 2007), and post-depositional alteration (Courty et al. 1989; Goldberg and MacPhail 2006). However, this should be directed toward sites that have finer soils. Sandy soils, such as those identified at Dionisio Point do not preserve microstructure well. It may also be useful in hearth contexts where laminae of ash and carbonized material are often recorded in field notes and profiles.

The second method, multi-elemental characterization of deposits, may also be a technique worth exploring in terms of its ability to identify feature from surface sediments (Entwistle et al. 2000). It is unlikely that it would provide a meaningful source of information within the vertical house deposits at Dionisio Point as they rarely contain a floor in the common sense. At sites where a prepared floor is present, geochemical identification of bench versus floor deposits may be a quick and inexpensive means of achieving a fuller understanding of the architectural layout of the house.

There are also other techniques that are broadly characterized as geoarchaeological that may be useful in the interpretation of formation processes. Chief among these, given the evidence of large number of productive activities that took place within plank houses (e.g. Chatters 1989; Grier 2006a; Smith 2006), is microdebitage analysis (Metcalf and Heath 1990). Using samples very similar to those used in bulk sedimentary analysis, a microdebitage analysis could provide another means of tracking housekeeping activities. Such an analysis is not simple, but would provide a very useful data set for supplementing small artifact assemblages.

Finally, subsurface prospection may be best undertaken with traditional geophysical methods, particularly magnetometry and resistivity. If the goal is the mapping of subsurface features prior to excavation, these may provide the most expedient methods currently available. Matson (2003) successfully undertook a resistivity survey of Shingle Point prior to excavation and was able to more carefully select excavation units based upon its results. Many archaeologists may be satisfied with identifying the location of buried hearths, to confirm the positive identification of a plank house and to locate all of the domestic spaces.

Geoarchaeology, like archaeobotany on the Northwest Coast, has been under-utilized in the excavation of pre-contact plank houses. During this time, a suite of methods have been developed in other parts of the world that can and should be successfully applied to the Northwest Coast data. If we are going to learn what pre-contact plank house households were (Ames 2006), and provide new and exciting research into the larger academic community, we are going to have to expand our range of analytical methods and theory to bring us up to speed with archaeologists who have have been working with domestic structures for far longer than we.

Appendices

Appendix A: Methods

Methods

The methods used in this analysis are those used in any basic soil science field and laboratory analysis. They are intended to capture many of the basic characteristics of a soil such as: acidification, fertility, texture, nutrients, and genesis. The original application of many of these variously qualitative or quantitative assessments was agricultural. As such, the formation of any given soil was considered to be primarily pedological, or “natural”. The use of these methods in archaeological context requires that we rethink the methods as well as the results, such that they are altered or corrected to fit our models of soil genesis that contain an explicitly anthropogenic developmental pathway.

Initial sample separation was achieved though the fractional shovelling technique (Gerlach et al. 2002). Each bulk sample was separated into five equal piles by consecutively “shovelling” approximately 10g of sample into each pile until the original sample was entirely split. One of the sub-samples was retained for futher analysis. The remaining sub-samples were re-aggregated and stored.

Soil Texture

Particle size analysis, or granulometry, was determined using two different techniques. A number of the samples were assessed using a Malvern Mastersizer S laser particle size analyzer. The remaining samples were assessed through hydrometer analysis. Table x indicates how each sample’s texture was recorded. The two methods diverge in a number of details and so are described separately below.

Laser Particle Size Analysis

Laser particle size analysis measures the three dimensional shape and size of each grain introduced to the unit. It is the most accurate means of collecting grain size data on sediments smaller than 4Φ (D = < 0.002mm). 100g samples of ≤ -1Φ (D = < 2mm) sediment were dry-sieved for a minimum of 10 minutes on Ro-Tap machines through standard Wentworth size-class sieves, removing sediment at every whole-Φ unit. For samples with coarser-grained textures, larger samples were sieved (up to 200g). 5g of sediment from the <1Φ fraction were collected for carbonate pre-treatment and organic matter digestion. Material from each whole-Φ screen was retained and weighed to the nearest tenth of a gram.

Low carbonate samples were treated in warm, dionized water for a period of 24 hours. High carbonate samples were treated with 10mL 0.5M NaOAc, heated to 75°C for 1 hour and let sit for 24 hours. Samples were centrifuged and the supernatant poured off.

All samples were pre-treated for high organic matter content. Treatment included digestion in 5ml 30% H_2O_2 buffered with < 1 ml glacial acetic acid for 24 hours. If organic matter was not digested at this time, the treatment was repeated until digestion was complete. Complete digestion was assessed based on the abundance and color of effervescence at the surface of the sample. Low abundance and white effervescence, as opposed to brown or black, were taken as indication of complete organic matter digestion. Samples were centrifuged and the supernatant poured off.

All samples were then dispersed in 10mL $Na(PO_3)_6$ prior to texture determination to deflocculate clays. Approximately 3 – 5ml aliquots were introduced to the Malvern Mastersizer S unit using a Malvern Hydro SM small volume dispersion unit and mixed with a volume of deionized water until the appropriate ratio of sample to water was reached. 5000 passes were made on each sample. Data was output to an excel spreadsheet and grain sizes assessed at 0.25Φ intervals. Computation within excel provided the silt and clay proportions for each sample which were then added to the weight data from the initial dry-sieving to calculate the whole-sample proportion of sand, silt and clay.

Hydrometer Analysis

The following hydrometer method is an unmodified use of Huckleberry (WSU lab notes). Hydrometer analysis requires a much larger sample than does laser particle size analysis and is based on fundamentally different principles. Hydrometer analysis depends on the rate at which a grain of a given size and density falls through a laminar fluid. The rate of descent is calculated for an idealized spherical grain of quartz, inasmuch as grains diverge from this assumption, the hydrometer may introduce minor error. The hydrometer measures the

Initial sample weights ranged from 200g to over 600g depending on the proportion of sediment < 1Φ (D < 0.62mm). Samples were dry-sieved on a Ro-Tap machine through standard Wentworth size-class sieves for a minimum of 10 minutes and each whole-Φ sub-sample was collected and weighed separately. 50g of the < 1 Φ was collected and separated. Each of the 50g samples was dried in (brand) oven at 105°C for a minimum of 12 hours to remove moisture. Each was then reweighed to measure the amount of moisture loss. Prior to carbonate and organic matter digestion, macroscopic organic matter was removed with tweezers and the aid of a hand lens.

Carbonates were digested with 10 ml of HCl for a period of at least 8 hours. Samples were allowed to settle and the supernatant was pipetted off. Soluble salts were removed with a deionized water rinse and again allowed to settle for a period of at least 8 hours. Sample organic matter was digested in 0.5ml glacial acetic acid, 20ml H_2O_2, and 80ml deionized water. Samples were allowed to sit for a period of at least 12 hours. If organic matter was not digested at this time, the treatment was repeated until digestion was complete. Complete digestion was assessed based on the abundance and color of effervescence at the surface of the sample. Low abundance and white effervescence, as opposed to brown or black, were taken as indication of complete organic matter digestion. If possible the supernatant was pipetted off of the sample. Otherwise, the sample was centrifuged and the supernatant poured off.

Samples were dispersed in 100ml of $Na(PO_3)_6$ and mixed for a minimum of 10 minutes to ensure complete sample dispersion. Each sample was then introduced to a 1000ml settling tube and filled to the 1000ml mark with deionized water. The sample was plunged 15 times, the plunger rinsed and removed. If bubbles were present on the surface prior to hydrometer introduction, a small amount of 50% isopropyl alcohol was added to break the surface tension. Hydrometer measurements were taken 40 second, 4 minutes, 60 minutes and 120 minutes after the withdrawal of the plunger. Each time the hydrometer was introduced to the settling tube, lowered as close as possible to the expected reading and then released, making sure not to allow the hydrometer bulb to contact the sides of the settling tube. The reading was taken and the hydrometer removed, cleaned and lain aside. For each hydrometer measurement, the sample temperature was taken in degrees Celsius; the hydrometer measurements are finely tuned to specific sample temperatures, the real temperature was used to adjust hydrometer measurements in the final calculation.

Hydrometer measurements and temperature measurements were introduced into an excel spreadsheet that calculated the proportion of sand, silt and clay in the sample. The proportions were multiplied by the sample weight and the resulting weights used to calculate the total sample proportion of sand, silt and clay, including the information from the dry-sieve analysis.

Loss-on-Ignition

Loss-on-ignition assays were conducted on all samples. Every fifth sample was replicated. 10g of sediment < - 1 Φ was collected from a larger sample of variable weight dry-sieved for a minimum of 10 minutes in a Ro-Tap machine through standard Wentworth size-class sieves. Sample weights were measured on one of two analytical balances (Ohaus) to the nearest 0.0000g. Samples were heated to 105°C for 12 hours, to remove soil moisture. Each sample was then heated to 550°C for 4 hours to remove organic matter and 950°C for 2 hours to remove inorganic carbonates. The sample was weighed between each heating to determine the proportion of each of these constituents in the sample.

Electrical Conductivity

Electrical Conductivity (EC) was measured for all samples. Samples were made into a 1:1 aqueous paste in a 15mL container. An Exstik EC400 Conductivity meter was used to measure EC. Results are provided in dS/cm.

pH

The same sample prepared for EC was used to measure soil pH. A Beckman 300 Series pH meter was used to retrieve soil pH from all samples to the nearest 0.00 pH unit, with an error of ± 0.01 pH units.

Appendix B: Sample Descriptions

Project	Site	Unit (N/E)	House No.	Layer/ Level	Feature	Sample	Dry Colour	Wet Colour
Dionisio Point	DgRv-003	110/107	5	C1		97M19	10YR2/1	10YR2/1
Dionisio Point	DgRv-003	111/106	5	A3		97M20	10YR2/1	10YR2/1
Dionisio Point	DgRv-003	114/107	5	E		97M21	2.5Y4/2	10YR2/2
Dionisio Point	DgRv-003	114/107	5	D	F2	97M22	10YR3/2	10YR2/1
Dionisio Point	DgRv-003	115/106	5	A2		97M23	10YR3/2	10YR2/1
Dionisio Point	DgRv-003	111/106	5	B1		97M24	10YR3/2	10YR2/1
Dionisio Point	DgRv-003	111/106	5	B1		97M25	10YR3/2	10YR2/1
Dionisio Point	DgRv-003	110/107	5	C2		97M26	10YR2/1	10YR2/1
Dionisio Point	DgRv-003	144/117	2	B1		97M27	10YR3/2	10YR2/1
Dionisio Point	DgRv-003	144/117	2	A2	F4	97M32	10YR2/1	10YR2/1
Dionisio Point	DgRv-003	111/106	5	C2		97M36	10YR2/1	10YR2/1
Dionisio Point	DgRv-003	149/116	2	A3		97M37	10YR2/1	10YR2/1
Dionisio Point	DgRv-003	115/106	5	C3		97M38	10YR2/1	10YR2/1
Dionisio Point	DgRv-003	111/106	5	C3	F6	97M39	10YR4/2	10YR2/1
Dionisio Point	DgRv-003	144/116	2	C1		97M41	10YR3/1	10YR2/1
Dionisio Point	DgRv-003	149/116	2	A3	F12	97M43	10YR3/1	10YR2/1

Ball test	HCl test	Organic Content	Bone Content	Rock Content	Aggregate Content	Charcoal
Slight	Negative	< 5% fine roots	None	< 15% gravel	Positive	Negative
Negative	Slight	< 5% fine roots	None	< 25% gravel	Positive	Negative
Negative	Negative	< 5% fine roots	None	~50% gravel	Negative	Negative
Slight	Negative	< 5% fine roots	None	< 25% gravel	Negative	Negative
Negative	Slight	< 5% fine roots	None	< 25% gravel	Positive	Negative
Negative	Negative	< 5% fine roots	None	< 25% gravel	Negative	Negative
Negative	Negative	< 5% fine roots	None	< 15% gravel	Negative	Negative
Negative	Negative	< 5% fine roots	None	< 25% gravel	Negative	Negative
Slight	Negative	< 5% fine roots	None	< 25% gravel	Negative	Negative
Negative	Negative	< 5% fine roots	None	< 25% gravel	Positive	Positive
Negative	Negative	< 5% fine roots	None	< 15% gravel	Positive	Negative
Negative	Negative	< 5% fine roots	None	< 25% gravel	Positive	Negative
Negative	Negative	< 5% fine roots	None	< 15% gravel	Negative	Negative
Negative	Negative	< 5% fine roots	None	< 25% gravel	Negative	Negative
Negative	Negative	< 5% fine roots	None	< 25% gravel	Positive	Negative
Negative	Slight	< 5% fine roots	None	< 25% gravel	Negative	Negative

Project	Site	Unit (N/E)	House No.	Layer/ Level	Feature	Sample	Dry Colour	Wet Colour
Dionisio Point	DgRv-003	149/116	2	A3	F10	97M44	10YR3/2	10YR2/1
Dionisio Point	DgRv-003	145/116	2	C2	F9	97M46	10YR2/1	10YR2/1
Dionisio Point	DgRv-003	149/116	2	A3	F11	97M47	10YR3/2	10YR2/1
Dionisio Point	DgRv-003	144/116	2	C2	F9	97M49	10YR2/1	10YR2/1
Dionisio Point	DgRv-003	144/116	2	C2	F9	97M51	10YR2/1	10YR2/1
Dionisio Point	DgRv-003	144/116	2	C2	F9	97M52	10YR2/1	10YR2/1
Dionisio Point	DgRv-003	149/116	2	C1		97M53	10YR2/1	10YR2/1
Dionisio Point	DgRv-003	149/116	2	C2		97M54	10YR2/1	10YR2/1
Dionisio Point	DgRv-003	115/106	5	C		97M55	10YR2/1	10YR2/1
Dionisio Point	DgRv-003	115/106	5	C		97M56	10YR2/1	10YR2/1
Dionisio Point	DgRv-003	111/106	5	C		97M57	10YR2/1	10YR2/1
Dionisio Point	DgRv-003	149/116	2	A3		97M58	10YR2/1	10YR2/1
Dionisio Point	DgRv-003	142/116	2	B2	F16	PEB06	10YR2/1	10YR2/1
Dionisio Point	DgRv-003	142/116	2	B2	F16	PEB07	10YR2/1	10YR2/1
Dionisio Point	DgRv-003	140/116	2	C1	F16	PEB30	10YR2/1	10YR2/1
Dionisio Point	DgRv-003	141/109	2	B4	F24	PEB35	10YR2/1	10YR2/1

Ball test	HCl test	Organic Content	Bone Content	Rock Content	Aggregate Content	Charcoal
Negative	Strong	< 5% fine roots	None	< 25% gravel	Positive	Negative
Slight	Negative	< 5% fine roots	None	< 15% gravel	Negative	Positive
Slight	Negative	< 5% fine roots	None	< 25% gravel	Positive	Negative
Slight	Negative	< 5% fine roots	None	< 10% gravel	Negative	Positive
Slight	Negative	< 5% fine roots	None	< 25% gravel	Negative	Positive
Slight	Negative	< 5% fine roots	None	< 25% gravel	Negative	Positive
Negative	Negative	< 5% fine roots	None	< 15% gravel	Positive	Negative
Negative	Negative	< 5% fine roots	None	< 15% gravel	Positive	Negative
Negative	Negative	< 5% fine roots	None	< 25% gravel	Positive	Negative
Slight	Negative	< 5% fine roots	None	< 25% gravel	Positive	Negative
Slight	Negative	< 5% fine roots	None	< 25% gravel	Negative	Negative
Negative	Negative	< 5% fine roots	None	< 25% gravel	Negative	Negative
Negative	Negative	< 5% fine roots	None	< 15% gravel	Positive	Negative
Negative	Negative	< 5% fine roots	None	< 15% gravel	Positive	Negative
Negative	Negative	< 5% fine roots	None	< 15% gravel	Positive	Negative
Negative	Negative	< 5% fine roots	None	< 15% gravel	Positive	Negative

Project	Site	Unit (N/E)	House No.	Layer/ Level	Feature	Sample	Dry Colour	Wet Colour
Dionisio Point	DgRv-003	149/122	2	B	F28	PEB44	10YR2/1	10YR2/1
Dionisio Point	DgRv-003	149/122	2	B	F28	PEB46	10YR2/1	10YR2/1
Dionisio Point	DgRv-003	149/122	2	C2	F28	PEB49	10YR2/1	10YR2/1
Dionisio Point	DgRv-003	149/120	2	C3	F34	PEB52	10YR2/1	10YR2/1
Dionisio Point	DgRv-003			Natural		SS200701	2.5Y4/4	10YR3/3
Dionisio Point	DgRv-003			Natural		SS200702	10YR5/6	7.5YR4/6
Dionisio Point	DgRv-003			Natural		SS200703	10YR4/2	10YR2/2
Dionisio Point	DgRv-003			Natural		SS200704	10YR3/3	5YR2.5/2
Dionisio Point	DgRv-003			Natural		SS200705	10YR3/3	10YR3/2
Dionisio Point	DgRv-003			Natural		SS200706	2.5Y5/4	10YR3/6
Dionisio Point	DgRv-003			Natural		SS200707	2.5Y5/4	10YR3/6
Dionisio Point	DgRv-003			Natural		SS200708	10YR3/1	10YR2/1

Ball test	HCl test	Organic Content	Bone Content	Rock Content	Aggregate Content	Charcoal
Negative	Negative	< 5% fine roots	None	< 15% gravels	Positive	Negative
Negative	Negative	< 5% fine roots	None	< 15% gravels	Positive	Negative
Negative	Negative	< 5% fine roots	None	< 15% gravels	Positive	Negative
Negative	Negative	< 1% fine roots	None	< 40% gravels	Negative	Negative
Negative	Negative	10% fine roots	None	< 40% gravels	Negative	Negative
Negative	Negative	< 1% fine roots	None	< 40% gravels	Negative	Negative
Negative	Negative	< 5% fine roots	None	< 40% gravels	Negative	Negative
Negative	Negative	10% fine roots	None	< 40% gravels	Negative	Negative
Negative	Negative	< 1% fine roots	None	< 25% gravels	Negative	Negative
Negative	Negative	< 5% fine roots	None	< 25% gravels	Negative	Negative
Negative	Negative	< 1% fine roots	None	< 25% gravels	Negative	Negative

Appendix C: Laser Particle Size Analyzer Data

Appendix C: Laser Particle Size Analyzer Data

		97M05	97M07	97M09	97M16	97M26	97M46	97M49	97M53
		33.936	32.992	30.332		31.174	24.171	27.128	
		5.128	4.763	4.064		2.3	1.714	2.427	
		29.881	28.913	25.601		19.954	18.562	19.322	
		68.179	66.821	62.685		65.857	54.973	59.365	
texture class	**µm**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**
clay (colloid)	0.054	0.009	0.016	0.013	-	0.019	0.026	0.03	-
clay (colloid)	0.063	0.019	0.033	0.028	-	0.039	0.052	0.058	-
clay (colloid)	0.073	0.031	0.05	0.043	-	0.061	0.079	0.082	-
clay (colloid)	0.085	0.046	0.07	0.061	-	0.086	0.107	0.105	-
clay	0.099	0.066	0.094	0.082	-	0.116	0.138	0.125	-
clay	0.116	0.092	0.121	0.109	-	0.152	0.173	0.147	-
clay	0.135	0.128	0.155	0.143	-	0.198	0.216	0.172	-
clay	0.157	0.176	0.196	0.187	-	0.256	0.267	0.205	-
clay	0.183	0.238	0.246	0.244	-	0.329	0.33	0.249	-
clay	0.213	0.312	0.303	0.313	-	0.418	0.404	0.304	-
clay	0.249	0.389	0.36	0.385	-	0.512	0.478	0.364	-
clay	0.29	0.44	0.399	0.437	-	0.588	0.534	0.412	-
clay	0.337	0.446	0.41	0.451	-	0.626	0.558	0.433	-
clay	0.393	0.422	0.401	0.441	-	0.639	0.56	0.438	-
clay	0.458	0.396	0.391	0.432	-	0.657	0.568	0.45	-
clay	0.533	0.371	0.383	0.426	-	0.682	0.583	0.471	-
clay	0.621	0.337	0.367	0.409	-	0.693	0.591	0.485	-
clay	0.724	0.317	0.359	0.405	-	0.719	0.617	0.514	-
clay	0.843	0.315	0.358	0.407	-	0.74	0.651	0.545	-
clay	0.982	0.317	0.358	0.412	-	0.763	0.689	0.581	-
clay	1.145	0.322	0.358	0.416	-	0.781	0.724	0.616	-
clay	1.333	0.33	0.359	0.419	-	0.795	0.756	0.65	-
clay	1.553	0.334	0.359	0.418	-	0.806	0.784	0.683	-
clay	1.81	0.34	0.363	0.42	-	0.827	0.816	0.724	-
clay	2.108	0.362	0.383	0.441	-	0.882	0.876	0.793	-
clay	2.456	0.406	0.428	0.491	-	0.99	0.977	0.903	-
clay	2.862	0.481	0.506	0.577	-	1.165	1.128	1.063	-
clay	3.334	0.589	0.62	0.706	-	1.414	1.336	1.279	-
clay		8.031	8.446	9.316	1.84	15.953	15.018	12.881	2.97
vf silt	3.884	0.732	0.771	0.881	-	1.731	1.596	1.547	-
vf silt	4.525	0.906	0.954	1.098	-	2.101	1.895	1.858	-
vf silt	5.271	1.107	1.167	1.355	-	2.503	2.219	2.2	-
vf silt	6.141	1.334	1.407	1.651	-	2.914	2.556	2.562	-
vf silt		4.079	4.299	4.985	0.53	9.249	8.266	8.167	0.7
f silt	7.154	1.597	1.683	1.993	-	3.32	2.902	2.944	-
f silt	8.335	1.904	2.003	2.387	-	3.7	3.255	3.337	-
f silt	9.71	2.269	2.379	2.836	-	4.04	3.614	3.736	-
f silt	11.312	2.714	2.833	3.352	-	4.336	3.988	4.141	-
f silt	13.178	3.254	3.376	3.933	-	4.584	4.377	4.544	-
f silt		11.738	12.274	14.501	3.21	19.98	18.136	18.702	3.67
m silt	15.353	3.897	4.017	4.571	-	4.783	4.775	4.933	-

m silt	17.886	4.634	4.743	5.24	-	4.931	5.169	5.288	-
m silt	20.837	5.43	5.516	5.901	-	5.021	5.537	5.584	-
m silt	24.276	6.228	6.279	6.514	-	5.049	5.867	5.798	-
m silt		20.189	20.555	22.226	2.51	19.784	21.348	21.603	3.21
c silt	28.281	6.974	6.977	7.063	-	5.024	6.165	5.933	-
c silt	32.947	7.642	7.584	7.567	-	4.967	6.14	6.015	-
c silt	38.384	8.247	8.118	7.504	-	4.675	5.844	5.715	-
c silt	44.717	8.077	7.886	7.023	-	4.239	5.258	5.179	-
c silt	52.095	7.381	7.159	6.146	-	3.685	4.427	4.438	-
c silt		38.321	37.724	35.303	5.3	22.59	27.834	27.28	6.39
total silt		74.327	74.852	77.015	11.55	71.603	75.584	75.752	13.97
vf sand	60.691	6.239	6.022	4.985	-	3.066	3.596	3.568	-
vf sand	70.705	4.836	4.653	3.713	-	2.444	2.765	2.677	-
vf sand	82.371	3.39	3.256	2.503	-	1.87	1.934	1.867	-
vf sand	95.963	2.089	2.01	1.485	-	1.375	1.103	1.207	-
vf sand					10.72				11.63
f sand	111.797	1.058	0.763	0.73	-	0.971	0	0.729	-
f sand	130.243	0.027	0	0.256	-	0.667	0	0.428	-
f sand	151.733	0	0	0	-	0.472	0	0.274	-
f sand	176.769	0	0	0	-	0.38	0	0.213	-
f sand	205.936	0	0	0	-	0.358	0	0.187	-
f sand					15.47				16
m sand	239.915	0	0	0	-	0.351	0	0.149	-
m sand	279.501	0	0	0	-	0.297	0	0.07	-
m sand	325.619	0	0	0	-	0.164	0	0	-
m sand	379.346	0	0	0	-	0.03	0	0	-
residual >silt		17.639	16.704	13.672	26.19	9.379	9.398	11.369	27.63

Appendix C: Laser Particle Size Analyzer Data

	PEB 52	PEB 30	SS200701	SS200702	SS200705	SS200706	SS200707	SS200708
	25.187	36.69	16.898	30.673	24.37			21.452
	1.363	6.266	0.613	3.902	0.945			0.853
	19.985	32.573	10.832	24.553	19.108			14.428
	55.767	73.109	42.382	65.295	55.235			52.378
texture class	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**
clay (colloid)	0.028	0.01	0.003	0.009	0.011	-	-	0.006
clay (colloid)	0.057	0.02	0.007	0.019	0.024	-	-	0.015
clay (colloid)	0.089	0.032	0.013	0.031	0.041	-	-	0.027
clay (colloid)	0.126	0.045	0.026	0.046	0.066	-	-	0.047
clay	0.169	0.061	0.05	0.067	0.102	-	-	0.077
clay	0.22	0.082	0.093	0.094	0.155	-	-	0.124
clay	0.28	0.109	0.166	0.13	0.229	-	-	0.194
clay	0.351	0.145	0.283	0.177	0.33	-	-	0.293
clay	0.433	0.194	0.457	0.237	0.462	-	-	0.423
clay	0.521	0.255	0.696	0.309	0.623	-	-	0.585
clay	0.606	0.319	0.976	0.382	0.79	-	-	0.758
clay	0.663	0.363	1.217	0.435	0.912	-	-	0.897
clay	0.681	0.371	1.336	0.449	0.948	-	-	0.963
clay	0.672	0.353	1.357	0.436	0.922	-	-	0.974
clay	0.662	0.337	1.372	0.424	0.893	-	-	0.985
clay	0.656	0.323	1.386	0.412	0.866	-	-	1.002
clay	0.642	0.299	1.351	0.391	0.818	-	-	0.999
clay	0.645	0.287	1.352	0.383	0.8	-	-	1.025
clay	0.661	0.284	1.361	0.385	0.808	-	-	1.064
clay	0.68	0.286	1.384	0.391	0.825	-	-	1.11
clay	0.699	0.289	1.413	0.4	0.844	-	-	1.155
clay	0.715	0.293	1.44	0.412	0.86	-	-	1.193
clay	0.728	0.293	1.441	0.424	0.861	-	-	1.212
clay	0.747	0.292	1.435	0.444	0.858	-	-	1.228
clay	0.794	0.305	1.473	0.488	0.879	-	-	1.28
clay	0.88	0.337	1.563	0.565	0.936	-	-	1.379
clay	1.017	0.399	1.727	0.683	1.044	-	-	1.54
clay	1.208	0.494	1.961	0.847	1.206	-	-	1.76
clay	15.63	6.877	27.339	9.47	18.113	2.58	2.46	22.315
vf silt	1.445	0.625	2.249	1.057	1.42	-	-	2.027
vf silt	1.716	0.787	2.565	1.308	1.672	-	-	2.316
vf silt	2.006	0.98	2.876	1.594	1.947	-	-	2.6
vf silt	2.302	1.199	3.163	1.911	2.233	-	-	2.861
vf silt	7.469	3.591	10.853	5.87	7.272	0.63	1.83	9.804
f silt	2.604	1.451	3.426	2.263	2.53	-	-	3.099
f silt	2.913	1.741	3.659	2.653	2.836	-	-	3.31
f silt	3.238	2.079	3.864	3.081	3.155	-	-	3.502
f silt	3.595	2.487	4.056	3.555	3.501	-	-	3.695
f silt	3.995	2.984	4.238	4.073	3.882	-	-	3.9
f silt	16.345	10.742	19.243	15.625	15.904	3.34	2.82	17.506
m silt	4.443	3.587	4.415	4.625	4.299	-	-	4.125

m silt	4.926	4.302	4.59	5.188	4.747	-	-	4.369
m silt	5.411	5.104	4.76	5.722	5.21	-	-	4.622
m silt	5.866	5.945	4.823	6.183	5.673	-	-	4.875
m silt	20.646	18.938	18.588	21.718	19.929	2.1	3.71	17.991
c silt	6.268	6.754	4.759	6.536	6.133	-	-	5.128
c silt	6.62	7.461	4.532	6.78	6.32	-	-	5.207
c silt	6.442	8.03	4.123	6.951	6.208	-	-	5.083
c silt	5.868	8.473	3.529	6.535	5.734	-	-	4.7
c silt	4.954	7.989	2.798	5.797	4.916	-	-	4.057
c silt	30.152	38.707	19.741	32.599	29.311	3.45	2.91	24.175
total silt	74.612	71.978	68.425	75.812	72.416	9.52	11.27	69.476
vf sand	3.829	6.981	2.011	4.814	3.857	-	-	3.226
vf sand	2.691	5.605	1.276	3.722	2.729	-	-	2.329
vf sand	1.708	4.229	0.68	2.66	1.697	-	-	1.495
vf sand	0.979	2.853	0.272	1.738	0.875	-	-	0.818
vf sand						7.04	8.86	
f sand	0.51	1.478	0	1.017	0.315	-	-	0.34
f sand	0.041	0	0	0.522	0	-	-	0
f sand	0	0	0	0.249	0	-	-	0
f sand	0	0	0	0	0	-	-	0
f sand	0	0	0	0	0	-	-	0
f sand						11.1	11.34	
m sand	0	0	0	0	0	-	-	0
m sand	0	0	0	0	0	-	-	0
m sand	0	0	0	0	0	-	-	0
m sand	0	0	0	0	0	-	-	0
residual >silt	9.758	21.146	4.239	14.722	9.473	18.14	20.2	8.208

Appendix D: Hydrometer Raw Data

Sample	Time	R	Temp	Temp Corr. R	RL	C	Co	X	P
97M01	1	23	18	21.7	2.7	19	18.99	52.06	100.08
	3	21	18	19.7	2.7	17	18.99	30.45	89.54
	12	17	18	15.7	2.7	13	18.99	16.30	68.47
	30	15	18	13.7	2.7	11	18.99	9.99	57.94
	61	14	17	12.05	2.05	10	18.99	7.11	52.67
	91	13	17	11.05	2.05	9	18.99	5.84	47.40
	270	12	16.5	9.725	1.725	8	18.99	3.39	42.14
97M02	1	18	18.5	17.025	3.025	14	14.29	53.74	97.97
	3	16	18.5	15.025	3.025	12	14.29	31.41	83.98
	12	12	18	10.7	2.7	8	14.29	16.07	55.98
	31	10	18	8.7	2.7	6	14.29	10.28	41.99
	61	9	18	7.7	2.7	5	14.29	7.31	34.99
	90	8	17.5	6.375	2.375	4	14.29	6.00	27.99
	270	8	16.5	5.725	1.725	4	14.29	3.47	27.99
97M03	1	18	20	18	4	14	14.22	53.74	98.43
	3	15	20	15	4	11	14.22	31.59	77.34
	12	10	20	10	4	6	14.22	16.26	42.18
	31	8	19	7.35	3.35	4	14.22	10.40	28.12
	61	7	19	6.35	3.35	3	14.22	7.39	21.09
	90	7	18	5.7	2.7	3	14.22	6.04	21.09
	270	7	17.5	5.375	2.375	3	14.22	3.48	21.09
97M04	1	17	20	17	4	13	14.16	52.74	91.79
	3	15	20	15	4	11	14.16	31.59	77.67
	12	10	20	10	4	6	14.16	16.17	42.36
	31	8	19	7.35	3.35	4	14.16	10.40	28.24
	61	7	19	6.35	3.35	3	14.16	7.29	21.18
	90	7	18	5.7	2.7	3	14.16	6.04	21.18
	270	7	17.5	5.375	2.375	3	14.16	3.48	21.18
97M06	1	19	18.5	18.025	3.025	15	14.17	53.41	105.87
	3	17	18.5	16.025	3.025	13	14.17	31.22	91.75
	12	12	18.5	11.025	3.025	8	14.17	16.07	56.46
	31	9	18.5	8.025	3.025	5	14.17	10.17	35.29
	61	8	18	6.7	2.7	4	14.17	7.35	28.23
	90	8	18	6.7	2.7	4	14.17	6.00	28.23
	270	7	17	5.05	2.05	3	14.17	3.48	21.17

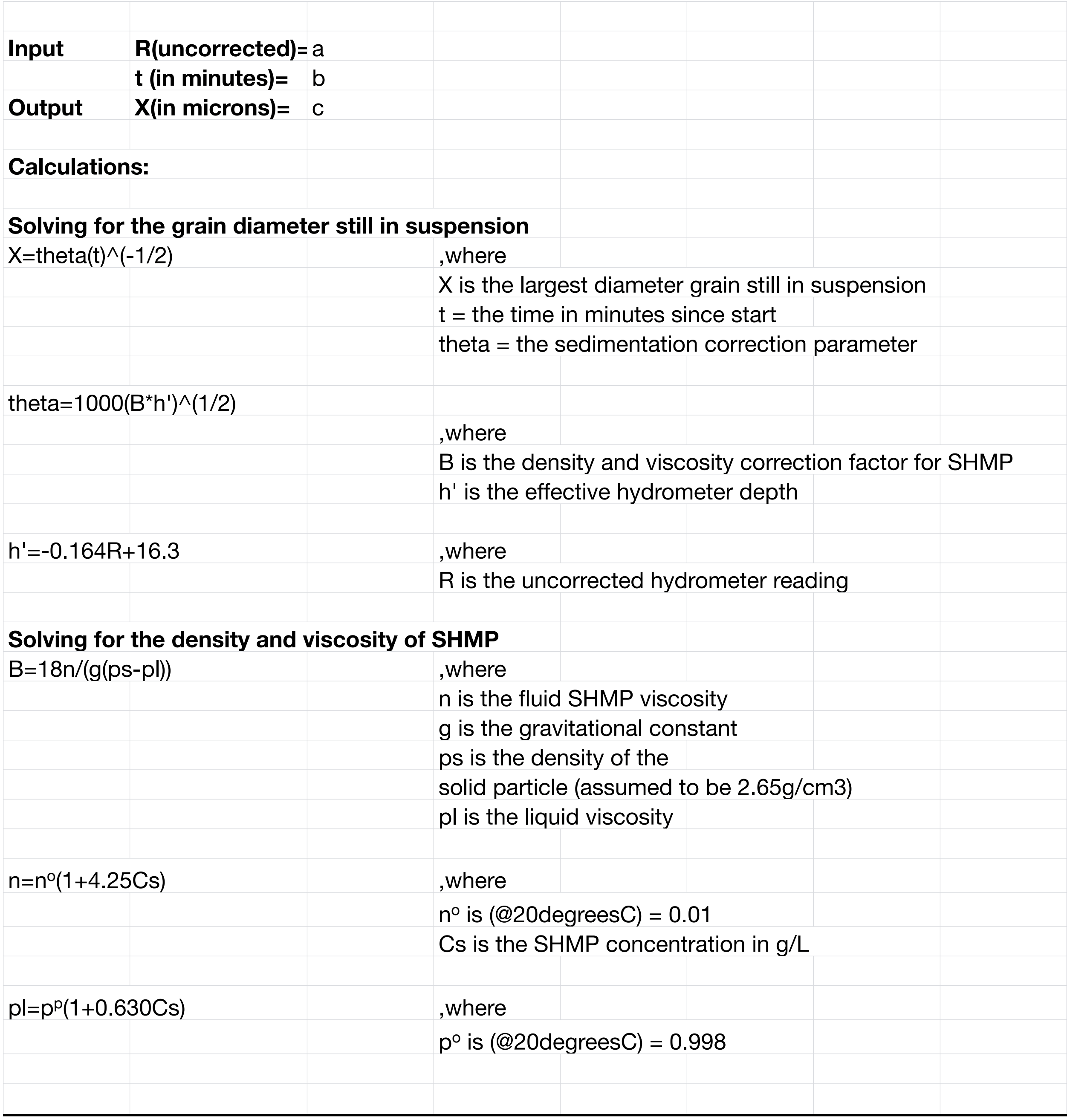
Sample	Time	R	Temp	Temp Corr. R	RL	C	Co	X	P
97M10	1	18	20	18	4	14	14.21	53.74	98.51
	3	14	20	14	4	10	14.21	31.78	70.36
	12	11	19.5	10.675	3.675	7	14.21	17.71	49.25
	31	8	19	7.35	3.35	4	14.21	10.40	28.15
	61	7	19	6.35	3.35	3	14.21	7.33	21.11
	90	7	18	5.7	2.7	3	14.21	6.04	21.11
	270	7	17.5	5.375	2.375	3	14.21	3.48	21.11
97M11	1	19	18	17.7	2.7	15	14.30	53.41	104.90
	3	17	18	15.7	2.7	13	14.30	31.22	90.91
	12	13	18	11.7	2.7	9	14.30	15.98	62.94
	31	11	18	9.7	2.7	7	14.30	10.22	48.95
	61	10	18	8.7	2.7	6	14.30	7.27	41.96
	90	9	18	7.7	2.7	5	14.30	5.97	34.97
	270	8	17	6.05	2.05	4	14.30	3.47	27.97
97M14	1	18	19	17.35	3.35	14	14.32	53.74	97.78
	3	17	19	16.35	3.35	13	14.32	31.22	90.79
	12	13	18	11.7	2.7	9	14.32	14.30	62.86
	31	11	18	9.7	2.7	7	14.32	10.22	48.89
	61	10	18	8.7	2.7	6	14.32	7.27	41.90
	90	9	18	7.7	2.7	5	14.32	5.97	34.92
	270	8	17	6.05	2.05	4	14.32	3.47	27.94
97M15	1	20	18	18.7	2.7	16	14.31	53.08	111.82
	3	18	18	16.7	2.7	14	14.31	31.03	97.84
	12	13	18	11.7	2.7	9	14.31	16.69	62.90
	30	10	18	8.7	2.7	6	14.31	10.28	41.93
	61	9	18	7.7	2.7	5	14.31	7.31	34.94
	91	9	17	7.05	2.05	5	14.31	5.97	34.94
	270	8	16	5.4	1.4	4	14.31	3.47	27.96
97M17	1	18	20	18	4	14	14.20	53.74	98.62
	3	14	20	14	4	10	14.20	31.78	70.44
	12	12	20	12	4	8	14.20	16.07	56.35
	31	9	19	8.35	3.35	5	14.20	10.17	35.22
	61	8	19	7.35	3.35	4	14.20	7.29	28.18
	90	8	18.5	7.025	3.025	4	14.20	6.00	28.18
	270	7	17	5.05	2.05	3	14.20	3.48	21.13

Sample	Time	R	Temp	Temp Corr. R	RL	C	Co	X	P
97M19	1	18	19	17.35	3.35	14	14.04	53.74	99.72
	3	15	19	14.35	3.35	11	14.04	31.59	78.35
	12	12	18.5	11.025	3.025	8	14.04	16.07	56.98
	31	9	18.5	8.025	3.025	5	14.04	10.17	35.61
	61	8	18	6.7	2.7	4	14.04	7.35	28.49
	90	8	18	6.7	2.7	4	14.04	6.00	28.49
	270	7	17.5	5.375	2.375	3	14.04	3.48	21.37
97M21	1	21	20	21	4	17	14.49	52.74	117.32
	3	15	20	15	4	11	14.49	31.59	75.91
	12	11	19	10.35	3.35	7	14.49	16.17	48.31
	31	8	19	7.35	3.35	4	14.49	10.40	27.60
	61	8	19	7.35	3.35	4	14.49	7.29	27.60
	90	7	19	6.35	3.35	3	14.49	6.04	20.70
	270	7	17.5	5.375	2.375	3	14.49	3.48	20.70
97M22	1	18	20	18	4	14	14.37	53.74	97.42
	3	16	20	16	4	12	14.37	31.41	83.50
	12	12	19	11.35	3.35	8	14.37	16.07	55.67
	31	8	19	7.35	3.35	4	14.37	10.23	27.83
	61	7	19	6.35	3.35	3	14.37	7.33	20.88
	90	7	19	6.35	3.35	3	14.37	6.04	20.88
	270	7	17.5	5.375	2.375	3	14.37	3.48	20.88
97M24	1	18	19	17.35	3.35	14	14.43	53.74	97.04
	3	17	19	16.35	3.35	13	14.43	31.22	90.11
	12	13	19	12.35	3.35	9	14.43	16.69	62.38
	31	9	19	8.35	3.35	5	14.43	10.17	34.66
	61	8	18.5	7.025	3.025	4	14.43	7.29	27.73
	90	8	18.5	7.025	3.025	4	14.43	6.00	27.73
	270	7	17	5.05	2.05	3	14.43	3.48	20.79
97M27	1	20	20	20	4	16	14.43	53.08	110.90
	3	17	20	17	4	13	14.43	31.22	90.10
	10	11	20	11	4	7	14.43	17.71	48.52
	30	10	19	9.35	3.35	6	14.43	10.28	41.59
	60	9	19	8.35	3.35	5	14.43	7.31	34.66
	90	9	19	8.35	3.35	5	14.43	5.97	34.66
	270	8	18	6.7	2.7	4	14.43	3.47	27.72

Sample	Time	R	Temp	Temp Corr. R	RL	C	Co	X	P
97M32	1	18	18	16.7	2.7	14	14.31	53.74	97.86
	3	16	18	14.7	2.7	12	14.31	31.41	83.88
	12	13	18	11.7	2.7	9	14.31	15.98	62.91
	30	10	18	8.7	2.7	6	14.31	10.28	41.94
	61	9	18	7.7	2.7	5	14.31	7.31	34.95
	91	9	17	7.05	2.05	5	14.31	5.97	34.95
	270	7	16	4.4	1.4	3	14.31	3.48	20.97
97M38	1	19	18	17.7	2.7	15	18.69	53.41	80.28
	3	17	18	15.7	2.7	13	18.69	31.22	69.57
	12	13	18	11.7	2.7	9	18.69	16.69	48.17
	30	11	18	9.7	2.7	7	18.69	10.06	37.46
	61	9	17.5	7.375	2.375	5	18.69	7.31	26.76
	91	8	17	6.05	2.05	4	18.69	6.00	21.41
	270	8	16.5	5.725	1.725	4	18.69	3.47	21.41
97M41	1	19	18	17.7	2.7	15	14.43	53.41	103.99
	3	16	18	14.7	2.7	12	14.43	31.41	83.19
	12	11	18	9.7	2.7	7	14.43	16.17	48.53
	31	10	18	8.7	2.7	6	14.43	10.28	41.59
	61	8	17.5	6.375	2.375	4	14.43	7.35	27.73
	90	8	17.5	6.375	2.375	4	14.43	6.00	27.73
	270	8	16.5	5.725	1.725	4	14.43	3.47	27.73
97M47	1	21	20	21	4	17	14.63	52.74	116.19
	3	19	20	19	4	15	14.63	30.84	102.52
	10	15	20	15	4	11	14.63	17.30	75.18
	30	12	19	11.35	3.35	8	14.63	10.17	54.68
	60	10	19	9.35	3.35	6	14.63	7.27	41.01
	90	10	19	9.35	3.35	6	14.63	5.94	41.01
	270	9	18	7.7	2.7	5	14.63	3.45	34.17
PEB 06	1	19	19	18.35	3.35	15	14.32	53.41	104.74
	3	16	19	15.35	3.35	12	14.32	31.41	83.79
	15	10	19	9.35	3.35	6	14.32	14.46	41.89
	30	9	19	8.35	3.35	5	14.32	10.34	34.91
	60	8	19	7.35	3.35	4	14.32	7.35	27.93
	90	8	18.5	7.025	3.025	4	14.32	6.00	27.93
	270	7	17.5	5.375	2.375	3	14.32	3.48	20.95

Sample	Time	R	Temp	Temp Corr. R	RL	C	Co	X	P
PEB 07	1	22	20	22	4	18	14.31	52.40	125.82
	3	17	20	17	4	13	14.31	31.22	90.87
	12	13	20	13	4	9	14.31	15.98	62.91
	30	10	19	9.35	3.35	6	14.31	10.28	41.94
	61	9	19	8.35	3.35	5	14.31	7.21	34.95
	91	9	19	8.35	3.35	5	14.31	5.94	34.95
	270	8	18	6.7	2.7	4	14.31	3.47	27.96
	270	8	18	6.7	2.7	4	14.20	3.47	28.16
PEB 44	1	21	20	21	4	17	14.59	52.74	116.52
	3	19	20	19	4	15	14.59	30.84	102.81
	10	16	20	16	4	12	14.59	17.20	82.25
	30	12	19	11.35	3.35	8	14.59	10.17	54.83
	60	11	19	10.35	3.35	7	14.59	7.23	47.98
	90	10	19	9.35	3.35	6	14.59	5.94	41.12
	270	9	18	7.7	2.7	5	14.59	3.45	34.27
PEB 46	1	19	19	18.35	3.35	15	14.48	53.41	103.56
	3	17	19	16.35	3.35	13	14.48	31.22	89.75
	10	12	19	11.35	3.35	8	14.48	17.61	55.23
	30	10	19	9.35	3.35	6	14.48	10.28	41.42
	60	9	18.5	8.025	3.025	5	14.48	7.31	34.52
	90	8	18	6.7	2.7	4	14.48	6.00	27.62
	270	7	17.5	5.375	2.375	3	14.48	3.48	20.71
PEB 49	1	17	18	15.7	2.7	13	14.51	54.07	89.61
	3	16	18	14.7	2.7	12	14.51	31.41	82.72
	12	11	18	9.7	2.7	7	14.51	16.17	48.25
	31	10	18	8.7	2.7	6	14.51	10.28	41.36
	61	9	18	7.7	2.7	5	14.51	7.31	34.47
	90	8	17.5	6.375	2.375	4	14.51	6.00	27.57
	270	7	16.5	4.725	1.725	3	14.51	3.48	20.68

Calculations used in hydrometer analysis:



Input **R(uncorrected)=** a
t (in minutes)= b
Output **X(in microns)=** c

Calculations:

Solving for the grain diameter still in suspension

X=theta(t)^(-1/2) ,where
X is the largest diameter grain still in suspension
t = the time in minutes since start
theta = the sedimentation correction parameter

theta=1000(B*h')^(1/2)
,where
B is the density and viscosity correction factor for SHMP
h' is the effective hydrometer depth

h'=-0.164R+16.3 ,where
R is the uncorrected hydrometer reading

Solving for the density and viscosity of SHMP

B=18n/(g(ps-pl)) ,where
n is the fluid SHMP viscosity
g is the gravitational constant
ps is the density of the
solid particle (assumed to be 2.65g/cm3)
pl is the liquid viscosity

$n=n^o(1+4.25Cs)$,where
n^o is (@20degreesC) = 0.01
Cs is the SHMP concentration in g/L

$pl=p^p(1+0.630Cs)$,where
p^o is (@20degreesC) = 0.998

Appendix E: Hydrometer Results

Appendix E: Hydrometer Results

Sample	Held on:						
	Mesh	mm	phi	Individual Weight	Cumulative Weight	Individual Percentage	Cumulative Percentage
97M01	10	2	-1	52.5			
	18	1	0	19.7	19.7	0.08	0.08
Total Wt.	35	0.5	1	35.8	55.5	0.15	0.23
300g	60	0.25	2	57.6	113.1	0.23	0.46
	120	0.1625	3	46.8	159.9	0.19	0.65
	230	0.0625	4	33.1	193	0.13	0.79
	Pan	<0.0625	>4	52.6	245.6	0.21	1.00
		Total		245.6			
		Fine Wt.					
		Sand				0.79	
		Silt				0.12	
		Clay				0.09	
Sample	Held on:						
	Mesh	mm	phi	Individual Weight	Cumulative Weight	Individual Percentage	Cumulative Percentage
97M02	10	2	-1	141.9			
	18	1	0	37	37	0.18	0.18
Total Wt.	35	0.5	1	32.6	69.6	0.16	0.34
350g	60	0.25	2	42.7	112.3	0.21	0.54
	120	0.1625	3	35.4	147.7	0.17	0.71
	230	0.0625	4	24.2	171.9	0.12	0.83
	Pan	<0.0625	>4	35.6	207.5	0.17	1.00
		Fine Wt.					
		Sand				0.83	
		Silt				0.12	
		Clay				0.05	
Sample	Held on:						
	Mesh	mm	phi	Individual Weight	Cumulative Weight	Individual Percentage	Cumulative Percentage
97M03	10	2	-1	201.9			
	18	1	0	47.4	47.4	0.19	0.19
Total Wt.	35	0.5	1	35.3	82.7	0.14	0.34
450g	60	0.25	2	49.6	132.3	0.20	0.54
	120	0.1625	3	39.6	171.9	0.16	0.70
	230	0.0625	4	31.1	203	0.13	0.83
	Pan	<0.0625	>4	41.8	244.8	0.17	1.00
		Total		244.8			
		Fine Wt.					
		Sand				0.83	
		Silt				0.13	
		Clay				0.04	
Sample	Held on:						

Appendix E: Hydrometer Results

	Mesh	mm	phi	Individual Weight	Cumulative Weight	Individual Percentage	Cumulative Percentage
97M04	10	2	-1	211.4			
	18	1	0	39.1	39.1	0.17	0.17
Total Wt.	35	0.5	1	33	72.1	0.14	0.31
450g	60	0.25	2	47.6	119.7	0.20	0.51
	120	0.1625	3	39.6	159.3	0.17	0.68
	230	0.0625	4	31	190.3	0.13	0.81
	Pan	<0.0625	>4	44.6	234.9	0.19	1.00
		Fine Wt.					
		Sand				0.81	
		Silt				0.15	
		Clay				0.04	
Sample	Held on:						
	Mesh	mm	phi	Individual Weight	Cumulative Weight	Individual Percentage	Cumulative Percentage
97M06	10	2	-1	152.4			
	18	1	0	48.6	48.6	0.18	0.18
Total Wt.	35	0.5	1	41.5	90.1	0.15	0.34
425g	60	0.25	2	56.4	146.5	0.21	0.55
	120	0.1625	3	38.9	185.4	0.15	0.69
	230	0.0625	4	31.7	217.1	0.12	0.81
	Pan	<0.0625	>4	50.7	267.8	0.19	1.00
		Fine Wt.					
		Sand				0.81	
		Silt				0.15	
		Clay				0.04	
Sample	Held on:						
	Mesh	mm	phi	Individual Weight	Cumulative Weight	Individual Percentage	Cumulative Percentage
97M08	10	2	-1	35.4			
	18	1	0	21.1	21.1	0.08	0.08
Total Wt.	35	0.5	1	47	68.1	0.18	0.26
300g	60	0.25	2	66.9	135	0.26	0.52
	120	0.1625	3	49.5	184.5	0.19	0.71
	230	0.0625	4	30.8	215.3	0.12	0.83
	Pan	<0.0625	>4	45	260.3	0.17	1.00
		Fine Wt.					
		Sand				0.83	
		Silt				0.17	
		Clay					
Sample	Held on:						
	Mesh	mm	phi	Individual Weight	Cumulative Weight	Individual Percentage	Cumulative Percentage
97M10	10	2	-1	197.6			
	18	1	0	34.9	34.9	0.18	0.18

Appendix E: Hydrometer Results

	35	0.5	1	26.4	61.3	0.13	0.31
	60	0.25	2	41.1	102.4	0.21	0.51
	120	0.1625	3	33.3	135.7	0.17	0.68
	230	0.0625	4	24.7	160.4	0.12	0.80
	Pan	<0.0625	>4	38.9	199.3	0.20	1.00
		Fine Wt.					
		Sand				0.80	
		Silt				0.16	
		Clay				0.04	
Sample	Held on:						
	Mesh	mm	phi	Individual Weight	Cumulative Weight	Individual Percentage	Cumulative Percentage
97M11	10	2	-1	201.1			
	18	1	0	30.6	30.6	0.16	0.16
Total Wt.	35	0.5	1	34.7	65.3	0.18	0.33
400g	60	0.25	2	43.1	108.4	0.22	0.55
	120	0.1625	3	32.5	140.9	0.16	0.71
	230	0.0625	4	22.1	163	0.11	0.83
	Pan	<0.0625	>4	34.2	197.2	0.17	1.00
		Fine Wt.					
		Sand				0.83	
		Silt				0.13	
		Clay				0.05	
Sample	Held on:						
	Mesh	mm	phi	Individual Weight	Cumulative Weight	Individual Percentage	Cumulative Percentage
97M13	10	2	-1	187.5			
	18	1	0	36.5	36.5	0.17	0.17
Total Wt.	35	0.5	1	29.6	66.1	0.14	0.31
400g	60	0.25	2	45.1	111.2	0.21	0.53
	120	0.1625	3	33.2	144.4	0.16	0.69
	230	0.0625	4	24.2	168.6	0.12	0.80
	Pan	<0.0625	>4	41.3	209.9	0.20	1.00
		Fine Wt.					
		Sand				0.80	
		Silt				0.20	
		Clay					
Sample	Held on:						
	Mesh	mm	phi	Individual Weight	Cumulative Weight	Individual Percentage	Cumulative Percentage
97M14	10	2	-1	140.3			
	18	1	0	28.7	28.7	0.14	0.14
Total Wt.	35	0.5	1	37.2	65.9	0.18	0.32
350g	60	0.25	2	47	112.9	0.23	0.54
	120	0.1625	3	34.6	147.5	0.17	0.71
	230	0.0625	4	23.1	170.6	0.11	0.82

Appendix E: Hydrometer Results

	Pan	<0.0625	>4	37	207.6	0.18	1.00
		Fine Wt.					
		Sand				0.82	
		Silt				0.13	
		Clay				0.05	
Sample	Held on:						
	Mesh	mm	phi	Individual Weight	Cumulative Weight	Individual Percentage	Cumulative Percentage
97M15	10	2	-1	210.1			
	18	1	0	38.3	38.3	0.20	0.20
Total Wt.	35	0.5	1	28.5	66.8	0.15	0.36
400g	60	0.25	2	39.6	106.4	0.21	0.57
	120	0.1625	3	25.7	132.1	0.14	0.70
	230	0.0625	4	17.9	150	0.10	0.80
	Pan	<0.0625	>4	37.4	187.4	0.20	1.00
		Fine Wt.					
		Sand				0.80	
		Silt				0.15	
		Clay				0.50	
Sample	Held on:						
	Mesh	mm	phi	Individual Weight	Cumulative Weight	Individual Percentage	Cumulative Percentage
97M17	10	2	-1	61.8			
	18	1	0	26	26	0.09	0.09
Total Wt.	35	0.5	1	56.2	82.2	0.20	0.29
350g	60	0.25	2	72.7	154.9	0.26	0.54
	120	0.1625	3	59	213.9	0.21	0.75
	230	0.0625	4	32.2	246.1	0.11	0.87
	Pan	<0.0625	>4	38.4	284.5	0.13	1.00
		Fine Wt.					
		Sand				0.87	
		Silt				0.10	
		Clay				0.03	
Sample	Held on:						
	Mesh	mm	phi	Individual Weight	Cumulative Weight	Individual Percentage	Cumulative Percentage
97M18	10	2	-1	181.2			
	18	1	0	44.2	44.2	0.21	0.21
Total Wt.	35	0.5	1	37.2	81.4	0.18	0.39
400g	60	0.25	2	47.1	128.5	0.23	0.62
	120	0.1625	3	27.5	156	0.13	0.76
	230	0.0625	4	20.7	176.7	0.10	0.86
	Pan	<0.0625	>4	29.8	206.5	0.14	1.00
		Fine Wt.					
		Sand				0.86	
		Silt				0.14	

Appendix E: Hydrometer Results

		Clay					
Sample	Held on:						
	Mesh	mm	phi	Individual Weight	Cumulative Weight	Individual Percentage	Cumulative Percentage
97M19	10	2	-1	241.6			
	18	1	0	38.3	38.3	0.20	0.20
Total Wt.	35	0.5	1	29.2	67.5	0.15	0.35
450g	60	0.25	2	41	108.5	0.21	0.56
	120	0.1625	3	20.5	129	0.11	0.66
	230	0.0625	4	22.6	151.6	0.12	0.78
	Pan	<0.0625	>4	43	194.6	0.22	1.00
		Fine Wt.					
		Sand				0.78	
		Silt				0.17	
		Clay				0.05	
Sample	Held on:						
	Mesh	mm	phi	Individual Weight	Cumulative Weight	Individual Percentage	Cumulative Percentage
97M21	10	2	-1	1.3			
	18	1	0	38.6	38.6	0.20	0.20
Total Wt.	35	0.5	1	36.6	75.2	0.19	0.39
195g	60	0.25	2	50.8	126	0.26	0.65
	120	0.1625	3	21	147	0.11	0.76
	230	0.0625	4	14.7	161.7	0.08	0.84
	Pan	<0.0625	>4	30.9	192.6	0.16	1.00
		Fine Wt.					
		Sand				0.84	
		Silt				0.13	
		Clay				0.03	
Sample	Held on:						
	Mesh	mm	phi	Individual Weight	Cumulative Weight	Individual Percentage	Cumulative Percentage
97M22	10	2	-1	118.6			
	18	1	0	53.5	53.5	0.21	0.21
Total Wt.	35	0.5	1	41.3	94.8	0.16	0.37
450g	60	0.25	2	53.1	147.9	0.21	0.58
	120	0.1625	3	40.4	188.3	0.16	0.74
	230	0.0625	4	26.2	214.5	0.10	0.84
	Pan	<0.0625	>4	41	255.5	0.16	1.00
		Fine Wt.					
		Sand				0.84	
		Silt				0.12	
		Clay				0.03	
Sample	Held on:						

Appendix E: Hydrometer Results

	Mesh	mm	phi	Individual Weight	Cumulative Weight	Individual Percentage	Cumulative Percentage
97M43	10	2	-1	154.3			
	18	1	0	30.7	30.7	0.21	0.21
Total Wt.	35	0.5	1	16.7	47.4	0.11	0.32
300g	60	0.25	2	36.2	83.6	0.25	0.57
	120	0.1625	3	30.2	113.8	0.21	0.78
	230	0.0625	4	12.9	126.7	0.09	0.87
	Pan	<0.0625	>4	19.4	146.1	0.13	1.00
		Fine Wt.					
		Sand				0.87	
		Silt				0.10	
		Clay				0.03	
Sample	Held on:						
	Mesh	mm	phi	Individual Weight	Cumulative Weight	Individual Percentage	Cumulative Percentage
97M24	10	2	-1	253.8			
	18	1	0	50	50	0.26	0.26
Total Wt.	35	0.5	1	34.4	84.4	0.18	0.44
383g	60	0.25	2	40.3	124.7	0.21	0.65
	120	0.1625	3	20.1	144.8	0.10	0.75
	230	0.0625	4	14.4	159.2	0.07	0.83
	Pan	<0.0625	>4	33.7	192.9	0.17	1.00
		Fine Wt.					
		Sand				0.83	
		Silt				0.14	
		Clay				0.04	
Sample	Held on:						
	Mesh	mm	phi	Individual Weight	Cumulative Weight	Individual Percentage	Cumulative Percentage
97M27	10	2	-1	182.6			
	18		0	53.4	53.4	0.20	0.20
Total Wt.	35		1	37	90.4	0.14	0.34
450g	60		2	59.6	150	0.22	0.56
	120		3	48.3	198.3	0.18	0.75
	230		4	30.2	228.5	0.11	0.86
	Pan	<0.0625	>4	37.4	265.9	0.14	1.00
		Fine Wt.					
		Sand				0.86	
		Silt				0.11	
		Clay				0.04	
Sample	Held on:						
	Mesh	mm	phi	Individual Weight	Cumulative Weight	Individual Percentage	Cumulative Percentage
97M32	10	2	-1	101.7			
	18	1	0	33.8	33.8	0.17	0.17

Appendix E: Hydrometer Results

Total Wt.	35	0.5	1	36.6	70.4	0.19	0.36
300g	60	0.25	2	41.1	111.5	0.21	0.57
	120	0.1625	3	33.5	145	0.17	0.73
	230	0.0625	4	20.8	165.8	0.11	0.84
	Pan	<0.0625	>4	31.5	197.3	0.16	1.00
		Fine Wt.					
		Sand				0.84	
		Silt				0.12	
		Clay				0.03	
Sample	Held on:						
	Mesh	mm	phi	Individual Weight	Cumulative Weight	Individual Percentage	Cumulative Percentage
97M37	10	2	-1	69			
	18	1	0	31.2	31.2	0.14	0.14
Total Wt.	35	0.5	1	48.8	80	0.21	0.35
300g	60	0.25	2	51.4	131.4	0.22	0.57
	120	0.1625	3	40.6	172	0.18	0.75
	230	0.0625	4	22.8	194.8	0.10	0.85
	Pan	<0.0625	>4	34.4	229.2	0.15	1.00
		Fine Wt.					
		Sand				0.85	
		Silt				0.15	
		Clay					
Sample	Held on:						
	Mesh	mm	phi	Individual Weight	Cumulative Weight	Individual Percentage	Cumulative Percentage
97M38	10	2	-1	168.3			
	18	1	0	43	43	0.26	0.26
Total Wt.	35	0.5	1	41.5	84.5	0.25	0.51
335g	60	0.25	2	32	116.5	0.19	0.70
	120	0.1625	3	14.8	131.3	0.09	0.79
	230	0.0625	4	10.8	142.1	0.07	0.86
	Pan	<0.0625	>4	23.6	165.7	0.14	1.00
		Fine Wt.					
		Sand				0.86	
		Silt				0.11	
		Clay				0.03	
Sample	Held on:						
	Mesh	mm	phi	Individual Weight	Cumulative Weight	Individual Percentage	Cumulative Percentage
97M41	10	2	-1	151.7			
	18	1	0	53.3	53.3	0.18	0.18
Total Wt.	35	0.5	1	40.8	94.1	0.14	0.32
450g	60	0.25	2	68.2	162.3	0.23	0.55
	120	0.1625	3	56	218.3	0.19	0.74
	230	0.0625	4	35.3	253.6	0.12	0.86

Appendix E: Hydrometer Results

	Pan	<0.0625	>4	42.2	295.8	0.14	1.00
		Fine Wt.					
		Sand				0.86	
		Silt				0.10	
		Clay				0.04	
Sample	Held on:						
	Mesh	mm	phi	Individual Weight	Cumulative Weight	Individual Percentage	Cumulative Percentage
97M47	10	2	-1	201.3			
	18		0	45.3	45.3	0.23	0.23
Total Wt.	35		1	25.3	70.6	0.13	0.36
400g	60		2	39.5	110.1	0.20	0.56
	120		3	35	145.1	0.18	0.73
	230		4	19.3	164.4	0.10	0.83
	Pan	<0.0625	>4	33.5	197.9	0.17	1.00
		Fine Wt.					
		Sand				0.83	
		Silt				0.12	
		Clay				0.05	
Sample	Held on:						
	Mesh	mm	phi	Individual Weight	Cumulative Weight	Individual Percentage	Cumulative Percentage
97M51	10	2	-1	195.7			
	18	1	0	48.1	48.1	0.21	0.21
Total Wt.	35	0.5	1	32.2	80.3	0.14	0.35
430g	60	0.25	2	52.6	132.9	0.23	0.57
	120	0.1625	3	42.3	175.2	0.18	0.75
	230	0.0625	4	23.1	198.3	0.10	0.85
	Pan	<0.0625	>4	34.2	232.5	0.15	1.00
		Fine Wt.					
		Sand				0.85	
		Silt				0.15	
		Clay					
Sample	Held on:						
	Mesh	mm	phi	Individual Weight	Cumulative Weight	Individual Percentage	Cumulative Percentage
97M52	10	2	-1	139.8			
	18	1	0	53.8	53.8	0.21	0.21
Total Wt.	35	0.5	1	40.4	94.2	0.16	0.37
400g	60	0.25	2	56	150.2	0.22	0.58
	120	0.1625	3	44.8	195	0.17	0.76
	230	0.0625	4	26.3	221.3	0.10	0.86
	Pan	<0.0625	>4	35.8	257.1	0.14	1.00
		Fine Wt.					
		Sand				0.86	
		Silt				0.14	

Appendix E: Hydrometer Results

		Clay					
Sample	Held on:						
	Mesh	mm	phi	Individual Weight	Cumulative Weight	Individual Percentage	Cumulative Percentage
97M55	10	2	-1	184			
	18	1	0	33.5	33.5	0.20	0.20
Total Wt.	35	0.5	1	25.5	59	0.16	0.36
350g	60	0.25	2	32.6	91.6	0.20	0.56
	120	0.1625	3	24.8	116.4	0.15	0.71
	230	0.0625	4	17.6	134	0.11	0.82
	Pan	<0.0625	>4	30	164	0.18	1.00
		Fine Wt.					
		Sand				0.82	
		Silt				0.13	
		Clay				0.05	
Sample	Held on:						
	Mesh	mm	phi	Individual Weight	Cumulative Weight	Individual Percentage	Cumulative Percentage
PEB 06	10	2	-1	109.1			
	18		0	41.1	41.1	0.17	0.17
Total Wt.	35		1	34.6	75.7	0.14	0.32
350g	60		2	55.6	131.3	0.23	0.55
	120		3	44.9	176.2	0.19	0.73
	230		4	28.8	205	0.12	0.85
	Pan		>4	35.1	240.1	0.15	1.00
		Fine Wt.					
		Sand				0.85	
		Silt				0.12	
		Clay				0.03	
Sample	Held on:						
	Mesh	mm	phi	Individual Weight	Cumulative Weight	Individual Percentage	Cumulative Percentage
PEB 07	10	2	-1	98.7			
	18	1	0	46.1	46.1	0.18	0.18
Total Wt.	35	0.5	1	36.8	82.9	0.15	0.33
350g	60	0.25	2	56.3	139.2	0.23	0.56
	120	0.1625	3	45.5	184.7	0.18	0.74
	230	0.0625	4	29.7	214.4	0.12	0.86
	Pan	<0.0625	>4	34.8	249.2	0.14	1.00
		Fine Wt.					
		Sand				0.86	
		Silt				0.11	
		Clay				0.03	
Sample	Held on:						

Appendix E: Hydrometer Results

	Mesh	mm	phi	Individual Weight	Cumulative Weight	Individual Percentage	Cumulative Percentage
PEB 35	10	2	-1	109.1			
	18	1	0	30.9	30.9	0.13	0.13
Total Wt.	35	0.5	1	25.8	56.7	0.11	0.23
350g	60	0.25	2	57	113.7	0.24	0.47
	120	0.1625	3	57.6	171.3	0.24	0.71
	230	0.0625	4	30.6	201.9	0.13	0.84
	Pan	<0.0625	>4	39.5	241.4	0.16	1.00
		Fine Wt.					
		Sand				0.84	
		Silt				0.16	
		Clay					
Sample	Held on:						
	Mesh	mm	phi	Individual Weight	Cumulative Weight	Individual Percentage	Cumulative Percentage
PEB 44	10	2	-1	136.8			
	18		0	41.8	41.8	0.20	0.20
Total Wt.	35		1	28	69.8	0.13	0.33
350g	60		2	43.2	113	0.20	0.53
	120		3	37.1	150.1	0.17	0.71
	230		4	23	173.1	0.11	0.82
	Pan	<0.0625	>4	39.1	212.2	0.18	1.00
		Fine Wt.					
		Sand				0.82	
		Silt				0.13	
		Clay				0.05	
Sample	Held on:						
	Mesh	mm	phi	Individual Weight	Cumulative Weight	Individual Percentage	Cumulative Percentage
PEB 46	10	2	-1	134.6			
	18	1	0	38.1	38.1	0.18	0.18
Total Wt.	35	0.5	1	27	65.1	0.13	0.30
350g	60	0.25	2	47.1	112.2	0.22	0.52
	120	0.1625	3	41.3	153.5	0.19	0.72
	230	0.0625	4	24.6	178.1	0.11	0.83
	Pan	<0.0625	>4	36	214.1	0.17	1.00
		Fine Wt.					
		Sand				0.83	
		Silt				0.14	
		Clay				0.03	
Sample	Held on:						
	Mesh	mm	phi	Individual Weight	Cumulative Weight	Individual Percentage	Cumulative Percentage
PEB 49	10	2	-1	169.9			
	18	1	0	35.4	35.4	0.1969	0.1969

Appendix E: Hydrometer Results

Total Wt.	35	0.5	1	23	58.4	0.1279	0.3248
350g	60	0.25	2	40.8	99.2	0.2269	0.5517
	120	0.1625	3	34.4	133.6	0.1913	0.7430
	230	0.0625	4	18.1	151.7	0.1007	0.8437
	Pan	<0.0625	>4	28.1	179.8	0.1563	1.0000
		Fine Wt.					
		Sand				0.8570	
		Silt				0.1100	
		Clay				0.03	

Appendix F: Loss-On-Ignition Data

Appendix F: Loss-on-Ignition Data

Sample	Crucible #	Crucible W	Sample wt	105C wt.	**105C wt.**	550C wt	950C wt	wt. CO2 **OM**	% CO2 **OM**	wt. CaCO3 **IC**	% CaCO3 **IC**
97M01	-	14.9030	10.0000	24.3958	9.49	22.7792	22.698	1.62	17.03	0.08	0.86
97M02	35	9.9879	10.0000	19.5144	9.53	18.1151	18.039	1.40	14.69	0.08	0.80
97M03	35	9.9875	10.0000	19.4696	9.48	17.9706	17.8839	1.50	15.81	0.09	0.91
97M04	33	10.3493	10.0000	19.7913	9.44	18.2122	18.1187	1.58	16.72	0.09	0.99
97M06	-	15.8020	10.0000	25.3318	9.53	24.2997	24.2263	1.03	10.83	0.07	0.77
97M08	31	10.8375	10.0000	20.2805	9.44	18.4552	18.3998	1.83	19.33	0.06	0.59
97M08	-	15.8987	10.0000	25.4098	9.51	23.5259	23.4677	1.88	19.81	0.06	0.61
97M09	34	10.7400	10.0000	20.3300	9.59	19.5300	19.4300	0.80	8.34	0.10	1.04
97M10	VI	10.5157	10.0000	19.9903	9.47	18.5266	18.4207	1.46	15.45	0.11	1.12
97M11	12	10.9823	10.0000	20.5152	9.53	19.0508	18.9696	1.46	15.36	0.08	0.85
97M14	-	14.8006	10.0000	24.3462	9.55	22.9668	22.9037	1.38	14.45	0.06	0.66
97M15	25	11.3505	10.0000	20.8896	9.54	19.7495	19.6597	1.14	11.95	0.09	0.94
97M16	-	-	-	-	-	-	-	-	8.99	-	0.56
97M17	30	10.5634	10.0000	20.0273	9.46	18.061	17.9761	1.97	20.78	0.08	0.90
97M17	-	14.8667	10.0000	24.287	9.42	22.0281	21.9309	2.26	23.98	0.10	1.03
97M18	27	10.7558	10.0000	20.2782	9.52	18.5392	18.4721	1.74	18.26	0.07	0.70
97M19	-	15.8311	10.0000	25.1906	9.36	23.836	23.7444	1.35	14.47	0.09	0.98
97M20	-	14.9138	10.0000	24.4976	9.58	23.4726	23.3932	1.03	10.70	0.08	0.83
97M21	27	10.7576	10.0000	20.4196	9.66	19.8971	19.8364	0.52	5.41	0.06	0.63
97M22	10	10.8096	10.0000	20.3903	9.58	19.6073	19.5443	0.78	8.17	0.06	0.66
97M23	26	10.3693	10.0000	19.8927	9.52	18.3612	18.2838	1.53	16.08	0.08	0.81
97M24	-	15.8198	10.0000	25.4375	9.62	24.4939	24.4198	0.94	9.81	0.07	0.77
97M25	26	10.3695	10.0000	19.9729	9.60	18.9077	18.8324	1.07	11.09	0.08	0.78
97M26	26	14.7400	10.0000	24.1774	9.44	22.7620	22.6722	1.42	15.00	0.09	0.95

Appendix F: Loss-on-Ignition Data

Sample	*Crucible #*	*Crucible Wt.*	*Sample wt.*	*105C wt.*	***105C wt.***	*550C wt*	*950C wt*	*wt. CO2 /**OM***	*% CO2 **OM***	*wt. CaCO3 **IC***	*% CaCO3 **IC***
97M27	30	10.5634	10.0000	20.1819	9.62	19.0434	18.9642	1.14	11.84	0.08	0.82
97M32	25	11.3502	10.0000	20.8831	9.53	19.0481	18.9572	1.84	19.25	0.09	0.95
97M34	-	14.5588	10.0000	24.0795	9.52	22.8883	22.7912	1.19	12.51	0.10	1.02
97M36	27	10.7598	10.0000	20.2441	9.48	18.8488	18.7475	1.40	14.71	0.10	1.07
97M37	-	15.6171	10.0000	25.074	9.46	23.0197	22.8082	2.05	21.72	0.21	2.24
97M38	-	15.2168	10.0000	24.8985	9.68	24.2182	24.1412	0.68	7.03	0.08	0.80
97M39	34	10.7351	10.0000	20.3592	9.62	19.3505	19.2268	1.01	10.48	0.12	1.29
97M41	32	10.7055	10.0000	20.3222	9.62	19.1653	19.0940	1.16	12.03	0.07	0.74
97M43	31	10.8368	10.0000	20.5047	9.67	19.6688	19.5601	0.84	8.65	0.11	1.12
97M44	X	10.6041	10.0000	20.2722	9.67	19.1500	18.7298	1.12	11.61	0.42	4.35
97M46	27	10.7662	10.0020	19.8810	9.11	18.6979	18.5867	1.18	12.98	0.11	1.22
97M47	XII	10.8204	10.0000	20.5746	9.75	19.9250	19.6124	0.65	6.66	0.31	3.20
97M49	X	14.9128	10.0000	24.4082	9.50	22.9844	22.9276	1.42	14.99	0.06	0.60
97M51	34	10.7329	10.0000	20.2564	9.52	18.5566	18.4690	1.70	17.85	0.09	0.92
97M52	36	10.3583	10.0000	19.7623	9.40	17.3923	17.2584	2.37	25.20	0.13	1.42
97M53	-	-	-	-	-	-	-	-	9.44	-	0.63
97M54	-	16.0604	10.0000	25.5735	9.51	24.0715	24.0127	1.50	15.79	0.06	0.62
97M55	VIII	10.9030	10.0000	20.3728	9.47	18.7765	18.6915	1.60	16.86	0.08	0.90
97M56	10	10.8035	10.0000	20.3111	9.51	18.7732	18.6886	1.54	16.18	0.08	0.89
97M57	12	10.9842	10.0000	20.5793	9.60	19.5774	19.4893	1.00	10.44	0.09	0.92
97M58	10	10.8082	10.0000	20.4482	9.64	19.3766	19.305	1.07	11.12	0.07	0.74
PEB 6	26	10.3690	10.0000	19.9168	9.55	18.5473	18.4675	1.37	14.34	0.08	0.84
PEB 7	10	10.6045	10.0000	20.1419	9.54	18.7513	18.6778	1.39	14.58	0.07	0.77
PEB 30	30	16.3400	10.0000	25.9603	9.62	24.8321	24.7597	1.13	11.73	0.07	0.75
PEB 35	34	10.7339	10.0000	20.3470	9.61	19.2790	19.1901	1.07	11.11	0.09	0.92

Appendix F: Loss-on-Ignition Data

Sample	*Cruc. #*	*Crucible Wt.*	*Sample wt.*	*105C wt.*	***105C wt.***	*550C wt*	*950C wt*	*wt. CO2 /**OM***	*% CO2 **OM***	*wt. CaCO3 **IC***	*% CaCO3 **IC***
PEB 44	8	10.9037	10.0000	20.6303	9.73	19.8211	19.2057	0.81	8.32	0.62	6.33
PEB 46	10	10.8032	10.0000	20.4596	9.66	19.5060	19.2289	0.95	9.88	0.28	2.87
PEB 49	31	10.8377	10.0000	20.5092	9.67	19.6903	19.5682	0.82	8.47	0.12	1.26
PEB 52	X	15.7043	10	25.3111	9.61	24.4486	24.172	0.86	8.98	0.28	2.88
SS200701	12	10.9808	10.0000	20.8072	9.83	20.2580	20.2051	0.55	5.59	0.05	0.54
SS200702	35	9.9848	10.0000	19.5415	9.56	17.7935	17.7264	1.75	18.29	0.07	0.70
SS200703	27	10.7050	10.0000	20.0622	9.36	19.5331	19.4800	0.53	5.65	0.05	0.57
SS200704	12	10.9800	10.0000	20.9200	9.94	20.5900	20.5400	0.33	3.32	0.05	0.50
SS200705	26	10.3600	10.0000	20.1400	9.78	19.7200	19.6600	0.42	4.29	0.06	0.61
SS200706	1003	15.5457	10.0074	25.3199	9.77	25.0484	24.9792	0.27	2.78	0.07	0.71
SS200707	-	-	-	-	-	-	-	-	3.57	-	0.21
SS200708	X	15.8023	10.0000	25.4300	9.63	*24.7036*	24.6597	0.73	7.54	0.04	0.46

Appendix G: Electrical Conductivity and pH Data

Appendix G: Electrical Conductivity and pH Data

Sample	EC (µS/cm)	pH
97M01	145.80	5.90
97M02	150.30	5.60
97M03	96.6	5.73
97M04	83.8	5.92
97M05	194.60	6.21
97M06	126.20	6.00
97M07	188.40	6.21
97M08	227.10	5.50
97M09	160.10	6.00
97M10	84.5	5.85
97M11	142	5.92
97M14	155.10	5.50
97M15	94	5.98
97M16	145.20	6.20
97M17	149.20	5.80
97M18	182	5.4
97M19	68.20	6.20
97M20	99.60	6.10
97M21	105.20	5.98
97M22	241	5.9
97M23	682	6.01
97M24	189.10	5.90
97M25	160.90	6.20
97M26	114.00	6.20
97M27	94.7	5.79
97M32	150.1	5.57
97M36	185.90	5.80
97M37	218.20	6.60
97M38	443.00	6.40
97M39	148.2	6.05

Sample	EC (µS/cm)	pH
97M39	148.2	6.05
97M41	70.1	5.72
97M43	155.6	6.68
97M44	139.7	6.94
97M46	125.00	5.90
97M47	114.2	6.97
97M49	134.40	6.07
97M51	85.8	5.58
97M52	81.7	5.61
97M53	151.20	6.10
97M54	97.30	5.60
97M55	151.6	5.67
97M56	132.6	5.7
97M57	84.4	5.99
97M58	184.40	6.30
PEB 06	126.5	5.66
PEB 07	82.3	6.12
PEB 30	104.40	6.06
PEB 35	84.7	6.17
PEB 44	209	6.94
PEB 46	99.6	6.91
PEB 49	103.6	6.77
PEB 52	197.20	7.32
SS200701	51.80	5.68
SS200702	78.60	5.81
SS200703	77.40	5.82
SS200704	64.6	6.23
SS200705	108.20	5.90
SS200706	109.30	5.60
SS200707	100.30	5.50
SS200708	43.60	6.15

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