A GEOARCHEOLOGICAL ANALYSIS OF FORT CLATSOP, LEWIS AND CLARK NATIONAL HISTORICAL PARK

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ABSTRACT

Fort Clatsop, built and occupied by the Lewis and Clark expedition, served as the expedition's winter encampment in 1805-1806, following their long cross-country journey. Upon the group's departure in March, 1806, the fort rapidly decayed in the wet coastal forest of western Oregon. The National Park Service maintains a replica fort within the Lewis and Clark National Historical Park that is believed to sit on or near the site of the original fort. The original fort, however, has not been seen since the mid-19th century and, despite efforts, remains of the fort continue to elude archaeologists.

Archaeologists working at the site over the past six decades have described myriad subsurface "pit" and "lens" features, variously interpreted as fire hearths and trash or privy pits, and sometimes interpreted as evidence of Lewis and Clark. The ubiquity of such features on the landscape and the absence of corroborative artifactual evidence call into question their anthropogenic origin, and archaeologists have often failed to consider the full range of site formation processes acting on the site.

In this geoarchaeological study, several methods of investigation were employed to examine subsurface profiles and purported features, and to test the various hypotheses for the origins of the pits at Fort Clatsop. Geoarchaeological investigations consisted of controlled excavations, including re-examinations of units dug by previous researchers in hopes of observing identified features. One excavation unit was placed at distance from the fort reconstruction and served as a control; the location of this unit was chosen in an attempt to reveal relatively undisturbed litho-and pedo-stratigraphic sequences (in other words, sediments that had not been disturbed by farming, road construction, brick making, or other activities). Soil descriptions, granulometry, loss-on-ignition tests, and micromorphological analyses were done to characterize and compare "pits" with surrounding deposits. Phosphorous analysis was conducted to test the hypothesis that features were trash or privy pits. Polished sections were created to characterize one of the red lenses so common in excavation profiles. These investigations, informed by principles of forest ecology, document natural and cultural disturbances to the landform, and suggest several alternative explanations for the formation of subsurface features. There is no data to suggest an early 19th-century Lewis and Clark origin for any of these features.

ACKNOWLEDGEMENTS

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1.0 INTRODUCTION

Despite the passage of two centuries, the cross-country expedition of Meriwether Lewis and William Clark's Corps of Discovery continues to capture the imagination of the American public. The epic, two and a half year journey between 1804 and 1806 resonates in our nation's memory, observed in scores of bicentennial events. The expedition is remembered for pioneering work in exploration, natural history, and cartography, but also for its profound impact on the course of diplomacy and settlement in the American west.

Journals, letters, and other documents related to the expedition have provided fodder for generations of American historians, but archaeological evidence of the journey has been elusive. The Corps of Discovery moved quickly and lightly across the landscape, bivouacking at hundreds of sites, and rarely recording more than scant details about their location. Furthermore, the explorers closely guarded and husbanded their few possessions, so vital for trade and survival, rendering camp detritus minimal.

Archaeologists searching for traces of the expedition logically have focused their attention on the locations of the Corps' lengthier stays. The two winter encampments – Fort Mandan, North Dakota, and Fort Clatsop, Oregon – are most notable in this regard. Because Fort Mandan is currently somewhere beneath the waters of the Missouri River, physical traces of the expedition have been sought most often at Fort Clatsop, which was occupied from December 1805 to March 1806.

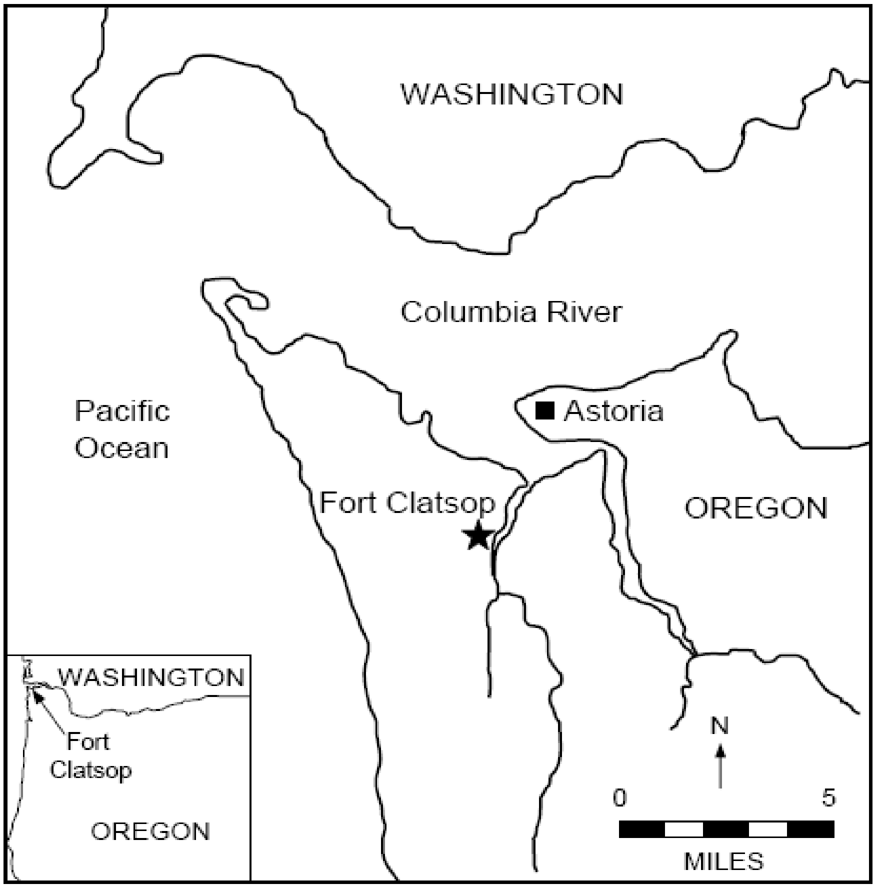

Figure 1. Location of Fort Clatsop.

Upon Lewis and Clark's departure in 1806, Fort Clatsop rapidly decayed in the wet coastal forests at the mouth of the Columbia River near present-day Astoria, Oregon (Figure 1). The National Park Service maintains a replica fort within the Lewis and Clark National Historical Park that is believed to sit on or near the site of the original fort. Archaeological excavations at Fort Clatsop have recovered a variety of historic artifacts, but most of these clearly postdate the 1805-1806 encampment, and none can be tied conclusively to the expedition. Archaeologists inclined to see Lewis and Clark's presence point to a variety of subsurface features or pits distributed across the landscape. The tendency has been to view virtually all such disturbances at Fort Clatsop as anthropogenic and ascribe them functional designations, such as fire pit, barbeque pit, and privy. Previous geoarchaeological research has also focused on the origins of these pits, testing the chemistry of presumed pit anomalies identified during magnetometer surveys, but generally ignoring the surrounding landform and site formation processes (Kiers and Stein 1998). The geoarchaeological investigation described in this report takes a more holistic approach by examining the Fort Clatsop landform within its geomorphic, environmental, and cultural setting. This study re-evaluates previously described cultural features using geoscientific methods, with the goal of distinguishing between features of anthropogenic and natural origin. This approach, informed by principles of forest ecology, broadens our understanding of disturbances to the natural landscape, and ultimately provides new insight into the ongoing search for Fort Clatsop.

2.0 ENVIRONMENTAL BACKGROUND

The Fort replica sits on a forested terrace overlooking the Lewis and Clark River, a low energy tributary of the Columbia River (Figure 2). The terrace is underlain by unconsolidated Holocene and Pleistocene alluvium comprised of clay, silt, sand, and gravel deposited in river, stream, and estuarine environments (Walsh 1987). The modern terrace has apparently emerged through a combination of subduction-related stresses and plate-boundary earthquakes occurring throughout the Pleistocene and Holocene. The local vegetation encountered by Lewis and Clark on the Fort Clatsop terrace was typical of Sitka Spruce Zone forests (Franklin and Dyrness 1973). This coastal forest experiences a variety of natural and cultural disturbances, including those due to fire, wind, and tree harvest, which have shaped the modern landform and aided in soil development. This section details the geologic development of the Fort Clatsop terrace and the natural processes that have altered the terrace sediments.

2.1 Geological Setting

Geological description of the area immediately surrounding the fort has not been well developed, and has previously been only briefly summarized by Thomas (1989). In order to understand the depositional history of the terrace upon which Fort Clatsop was built, it is important to have a broad sense of the regional geologic history of the area. Thus, while much of the information presented in this section is at a coarse resolution, it is useful in interpreting the fine scale data obtained through geoarchaeological investigations.

The region immediately surrounding Fort Clatsop National Memorial lies on Quaternary derived sediments surrounded to the north and west by the Astoria Formation (and the Columbia River Basalt) and to the south and east by the Coastal Range of Oregon. Since the formation and development of these regions has most likely strongly influenced the local geology of the Fort Clatsop region, it is important to understand their role in the overall geologic history of the area.

2.1.1 Coast Range

The Coast Range consists of many elongate ridges and narrow valleys that are approximately parallel to the coast, although the coast usually shows a more exact trend than do the ridges and valleys. It has long been recognized that the northern Coast Ranges (Oregon and northern California) have core complexes derived of eugeosynclinal and basic intrusive rocks: the so-called Franciscan complex (Stowell 1983). The Franciscan rocks have been variously labeled a series, a formation, or an assemblage; some portions have even been termed a mélange (this is especially true in Northern Oregon near the focus area; see Gates 1994). Lithilogically, the Franciscan is dominated by grayish green graywackes, generally in beds 0.3-3 meters thick (Snavely and Wells 1996). These graywackes are derived from the rapid erosion of a volcanic highland and deposited in deep marine basins, usually by turbidity currents of submarine mudflows (Williams 1985). The graywackes are composed mainly of quartz and plagioclase feldspars, with a chlorite mica matrix that is responsible for the dark green color. These rocks constitute 90 percent of the Franciscan; it is estimated that they average 25,000 feet in thickness and are exposed over 75,000 square miles on land and offshore (Snavely et al. 1980).

All of these Franciscan rocks have been intruded by ultrabasic igneous rocks, now serpentized peridotite. Sometimes the peridotites have been injected as normal intrusives, but in other cases they occur in sill-like sheets that lack the thermal alteration of enclosing rocks expected in most sills (Williams 1985).

Glaucophane, jadeite, and lawsonite occur in some Franciscan graywackes (Stowell 1983). These minerals are thought to form under low temperature (not over 300°C) and high pressure (approximately 70,000 feet of burial). Consequently, some geologists have proposed that Franciscan rocks were carried rapidly down from their depositional site on the deep sea floor along a subduction zone beneath the edge

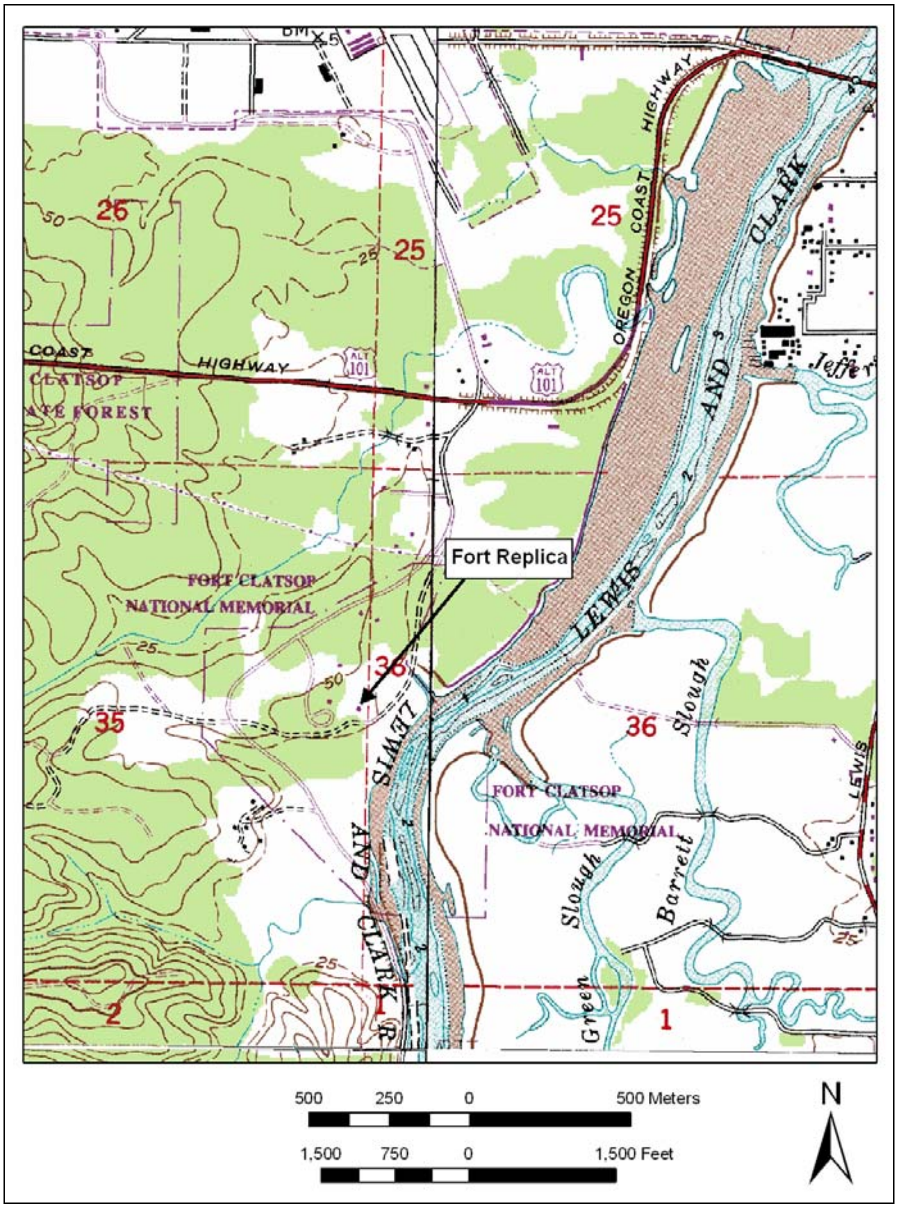

Figure 2. Location of Fort Clatsop replica. Modified from Astoria and Warrenton USGS 7.5-minute quadrangles.

of the continent where they were forced back up with equal rapidity, thus producing minerals that reflect both high pressure and low temperature (Stowell 1983).

Besides the Franciscan formation the only major pre-Cenozoic sediments in the Coast Ranges are in the Great Valley sequence. This is an enormous sequence of miogeosynclinal late Jurassic to late Cretaceous shale, sandstone, and conglomerate, generally quite unlike the contemporary Franciscan assemblage (Snavely et al. 1980; Snavely and Wells 1996). The lower part of the Great Valley sequence is the late Jurassic Knoxville Formation, a dark shale underlying lower Cretaceous sandstones (referred to as the

Shasta series by Nelson and Shearer 1969 but not used elsewhere). These sandstones are as much as 34,000 feet thick and are associated with minor conglomerate and other sedimentary rocks.

By Cenozoic times, the sediments being deposited in the Coast Ranges were primarily of continental origin. Correlation of pre-Cenozoic Coast Range rocks across structural boundaries has not yet been accomplished, the reason being that movement in most fault zones has been great enough to bring different rocks into contact (Williams 1985). On the other hand, Cenozoic rocks, being younger and less extensive originally are not so widely separated across structural breaks and so have been less affected by Coast Range tectonism.

The post-Cenozoic depositional history of the Coast Ranges has been developed, modified, scrapped, and rethought through the last fifty years of the 20th century. Most current research suggests that the Coast Ranges are made up of sediment scraped off of the floor of the ocean. Franciscan sediments and the Great Valley sequence are indeed the same except that the Franciscan rocks were jammed onto the edge of the continent while the Great Valley sequence rode undisturbed above them. "Slice" after "slice" of muddy sediment was scraped off the sea floor as it was subducted beneath the continent (Williams 1985). One under another, the slices were stuffed onto the continental margin to make the swollen welts of Franciscan rocks of the range. Present arrangement of layers bears little relationship to the original positions on the sea floor and layers of muddy sandstone and chert now exposed next to each other may well have been deposited dozens of miles apart.

It seems likely that rocks of the Coast Ranges were stuffed into a deep marginal trench offshore that was then being pulled down by the slab of sea floor sinking beneath it. After the subduction ceased, the trench no longer had anything pulling down on it and so it floated upwards. It was then that the rocks of the Coast Ranges broke to the surface as a chain of islands. Their rise separated the future Great Valley of California from the Pacific Ocean, creating an isolated inland sea that gradually filled with sediment (Stowell 1983; Williams 1985).

2.1.2 Astoria Formation

The term "Astoria Formation" is a relatively recent name relating to a sequence that has been continuously studied for over a century. The sequence was first referenced by Cope in 1880, stating: "the backbone of the Coast Range consists of argillaceous shales, which contain invertebrate and vertebrate fossils, frequently in concretions…" (in Walsh 1987, p.6). This zone was later extended to include sandstones as well as shales that are exposed on both sides of the Colombia River upstream of the city of Astoria. Geologists assigned the rocks to the Oligocene series, but separated the lower beds, which contained *Aturia sp*. fossils, as Eocene. In the 1920s researchers included the *Aturia* bearing beds in the Astoria formation and assigned the entire sequence a middle Miocene age. Some extended the usage as far north as the Grays Harbor and Puget Basins (although it is no longer applied in the latter). Snavely et al. (1980) mapped marine Miocene rocks in the Centralia-Chehalis area and stated that "the Astoria formation, as described and mapped by Etherington and Weaver, is accepted with reservation by the authors as beds of middle Miocene age in the Centralia-Chehalis area cannot be traced, without interruption, into the type section of the Astoria Formation of Oregon" (p.122).

Walsh (1987) reports that the region to the west and southwest of Astoria lies on the Youngs Bay member of the Astoria Formation. This member dates to the lower and middle Miocene (11-5 ma) and consists of laminated, carbonaceous and micaeous mudstone complexly intertongued with two thick bodies of clean, medium to coarse grained, friable feldspathic sandstone containing large mica flakes. Commonly this rock is weathered yellow, iron stained, or white to medium grey (fresh). Although generally structureless, these sandstones are laminated. Fresh mudstones are typically medium gray and contain dikes of medium grained feldspathic sandstone, bathyal formanifera, and a few graded, thin to medium bedded feldspathic sandstone beds.

Overlying the Astoria Formation near the reconstruction of Fort Clatsop, Walsh (1987) reports two varieties of Quaternary unconsolidated deposits. First, he notes a Holocene alluvium comprised of unconsolidated clay, silt, sand, and gravel deposited along rivers, streams, and estuaries. This includes sand bars and islands in major rivers and stabilized tidal flats in Willapa Bay. This type of alluvium is probably a good description of the kind of sediment found below the terrace near the Lewis and Clark River. Second, Walsh describes terraced sediments with Holocene and Pleistocene origins consisting of sand, silt and gravel that form terrace remnants along the edges of the Grays River Valley. This description partially describes the terrace upon which the Fort Clatsop reconstruction sits; however, the lack of any mention regarding clay deposits is interesting.

2.1.3 Lower Columbia River Drainage and Sediment Supply

The Fort reconstruction sits on a terrace overlooking the Lewis and Clark River; a small river in its own right, the Lewis and Clark River is part of the much larger Columbia River drainage system. Unlike the high energy depositional system created by the fast moving Columbia River, the Lewis and Clark represents one of the many low energy tributarial arms that comprises this extensive drainage system (Sherwood et al. 1984). The Columbia River is responsible for almost all of the sediment supplied to the estuarine system. According to Sherwood et al. (1984), the river drains 667,000 square kilometers of geologically varied terrain that includes igneous, sedimentary, and metamorphic rocks and "extensive alluvial and eolian surficial deposits" (p.4). Near the fort reconstruction, sediments contain increasing amounts of plagioclase and volcanic rock fragments and decreasing percentages of quartz and potassium (which characterize the extensive loess deposits of western Washington) (Whetten 1966). The overall composition of the sediment in the lower Columbia River system resembles greywacke, which is mentioned above.

Volcanism in the Cascade Range may be responsible for an important fraction of the sediment input (Sherwood 1984). The 1980 eruption of Mt. St. Helens and the subsequent debris flow down the Toutle-Cowlitz Rivers and into the Columbia River at Longview provide models for the intermittent and substantial supply of sediment to the estuary. In the absence of human interaction, an eruption of Mt. St. Helens, Mt. Hood, Mt. Adams, or other andesite volcanoes might be expected to provide airborne ash, an almost immediate influx of suspended sediment, and a longer term supply of sediment to the Columbia River system (Sherwood et al. 1984). Although cataclysmic in human terms, over geologic time these major eruptions represent a relatively constant supply of sediment to the Columbia River system. The mineralogy of the estuarine fragments, pumice, and glass mantled grains found in the estuary subsequent to the Mt. St. Helens eruption point to the importance of the volcanic contribution to the estuarine sediments (Roy et al. 1982; Sherwood et al. 1984).

Additional sediment sources include local tributaries (such as the Lewis and Clark River). Sherwood et al. (1984) suggest that sediment from local tributaries may be a locally important source near the entrance to these rivers. Slotta (1975) has suggested that most of the sediment in the upper reaches of Youngs Bay are derived from the erosion of Oligocene-Miocene sedimentary rocks in the drainages of the Young, Walluski, and Lewis and Clark Rivers. While the contribution of these tributaries to the overall estuary system is expected to be minimal (Sherwood et al. 1984), the impact of tributaries on local depositional environments is predicted to be high. Thus, it is likely that most of the sediment comprising the terrace underlying the fort reconstruction was transported from Oligocene-Miocene sedimentary rocks via the Lewis and Clark River.

2.1.4 Neo-tectonic Effects

It is widely recognized that worldwide sea levels have been rising throughout the Holocene (Bloom 1983; Gates 1994). Indeed, Bloom (1983) suggests that sea level has risen approximately 120 m globally over the last 10,000 years. Geological evidence suggests that, on average, sea level increased rapidly during the early Holocene (10 mm per year) and subsequently slowed in the middle and late Holocene to the present rate of 1-2 mm per year (Gates 1994).

Despite this overall trend, sea level has not continued to rise along the Washington and Oregon coasts in historic times. Gates (1994) suggests that modern tectonic uplift of "coastal Oregon and Washington is producing a lowering in relative sea level" (p.34). Geological data over the past 95 years suggests that sea level has been falling in the Astoria area since the turn of the century (Ando and Balazas 1979; Gates 1994; Hicks 1978). Chelton and Davis (1982) have estimated rates of sea level fall at 0.11 cm per year. Gates (1994) interprets this regional reversal in sea level trends to stem from "interseismic strain accumulation associated with interplate coupling between tectonic plates" (p.35). In other words, deformation of basement rocks caused by subduction-related stresses have led to a "ratcheting" of some local landforms in the Astoria area.

However, this general ratcheting trend cannot solely explain the recent geological developments in the region. Atwater and Hemphill-Haley (1997) have suggested that plate-boundary earthquakes occurring throughout the Pleistocene and Holocene have led to a general subsidence in the region. They note that:

> The plate boundary is the only recognizable fault common to all areas having evidence for coseismic subsidence in southern coastal Washington (Northern Oregon). Although some of these areas coincide with mapped late Cenozoic synclines, where coseismic subsistence might accompany earthquakes on faults in the North America plate, others are outside of such synclines (p.1).

Earthquakes along this boundary have lead to the development of new reverse-thrust faults along the sea floor between the continental shelf and the zone of subduction. Coseismic settling along these faults has produced a "horst and graben" effect whereby marine sediment has subsided over an area of at least 400 km. The effects of this subsistence have been radically different above the continental shelf, where Franciscan basement rocks have resisted static deformation, but have exerted enough stress on overlying layers to produce some ductile flow. Thus, the Quaternary terraces on the western coast of Oregon may show slight signs of uplifting, due to the ductile deformation of the Astoria Formation below them, despite a general trend towards subsidence throughout the region. The U.S. Geological Survey is currently studying subsidence and formation of buried soils in this region (Atwater and Hemphill-Haley 1997). Further research will be necessary to falsify or confirm this hypothesis.

This cursory overview of the major geologic histories of rocks underlying Fort Clatsop has shown that terrace formation is a complex process resulting from the interaction of numerous factors. In short, the terrace appears to have been formed first through recent Quaternary deposition of alluvial sediments followed by localized uplifting caused by off shore subduction. Thus, the creation of the terrace would appear to be a geologically recent event, dating to the last 10,000 years. Further research is warranted to refine the timing and magnitude of this event.

2.2 Forest Ecology

Lewis and Clark encountered a forest at Fort Clatsop that was typical of the Sitka Spruce Zone, which stretches from southeast Alaska to the tip of northern California (Franklin and Dyrness 1973). This forest type is often characterized as a variant of the Western Hemlock Zone, being unique in its coastal location, frequent fogs, and presence of Sitka spruce (*Picea sitchensis*). Other major tree species in this zone include western red cedar (*Thuja plicata*), Douglas fir (*Pseudotsuga menziesii*), and red alder (*Alnus rubra*). This coastal forest experiences a variety of natural and cultural disturbances, including those due to fire, wind, and tree harvest.

2.2.1 Forest Fire

In moist forest environments such as the Sitka Spruce Zone, forest fires are infrequent but intense when they occur. In such high-severity fire regimes, fires may recur only at intervals of many centuries, but they may be so intense that they kill most of the trees. Fire frequency for the Oregon Coast has been estimated at 400 years (Agee 1993).

Most forest fires spread by combustion of organic matter in contact with or part of the soil, and forest litter surface temperatures can exceed 800°C during intense fires (DeBano et al. 1979). Under such intense fire conditions, combustion can follow and consume tree root masses below ground, which can continue to smolder for many hours or days (Agee 1993). Fire may completely consume the root systems, yielding extensive voids containing charcoal and ash. Furthermore, fire may oxidize the sediments surrounding root voids. Voids gradually collapse, forming lenses of reddened sediment mixed with charcoal and ash (Figure 3).

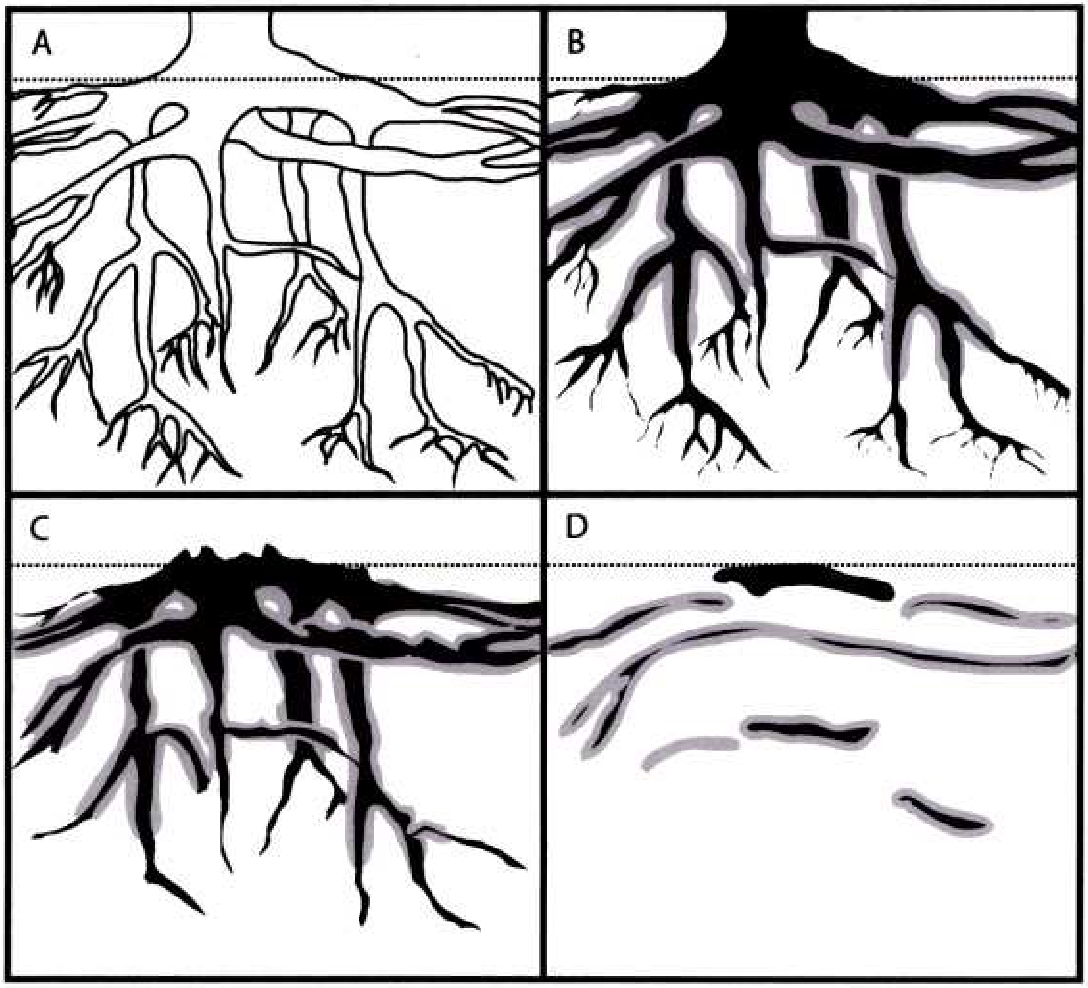

Figure 3. Schematic illustration of fire-induced subsurface oxidation lenses. A) Before combustion, intact tree trunk and root system. Ground surface represented by dotted line. B) Wood carbonizes during combustion, becoming ash and charcoal (black). High temperatures oxidize sediments around major roots, yielding burned root casts (gray). C) Months to years after combustion, structural voids in pockets of ash and charcoal begin to collapse. D) Many years after combustion, voids collapsed entirely and edaphic and biological processes disperse ash and charcoal.

Charcoal, recovered beneath centuries-old trees at Fort Clatsop, demonstrates that fire occurred in the prehistoric forest at the site (Agee 1989). The timing and recurrence of prehistoric forest fires at Fort Clatsop is unknown; however, based on the old growth forest characteristics described in Lewis and Clark's journals, the last fire likely predated the Corps of Discovery by several hundred years.

2.2.2 Wind in Coastal Forests

Wind is a more persistent disturbance factor than fire in coastal forests (Agee 1993). Along the Oregon Coast, winter storm winds from the south to southwest account for most of the wind damage. These storms create treefall and gaps in the forest. Windthrow, the uprooting of the stem and root mass of a tree due to wind, is one of the most dynamic pedoturbation processes in forest soils (Johnson and Watson-Stegner 1990).

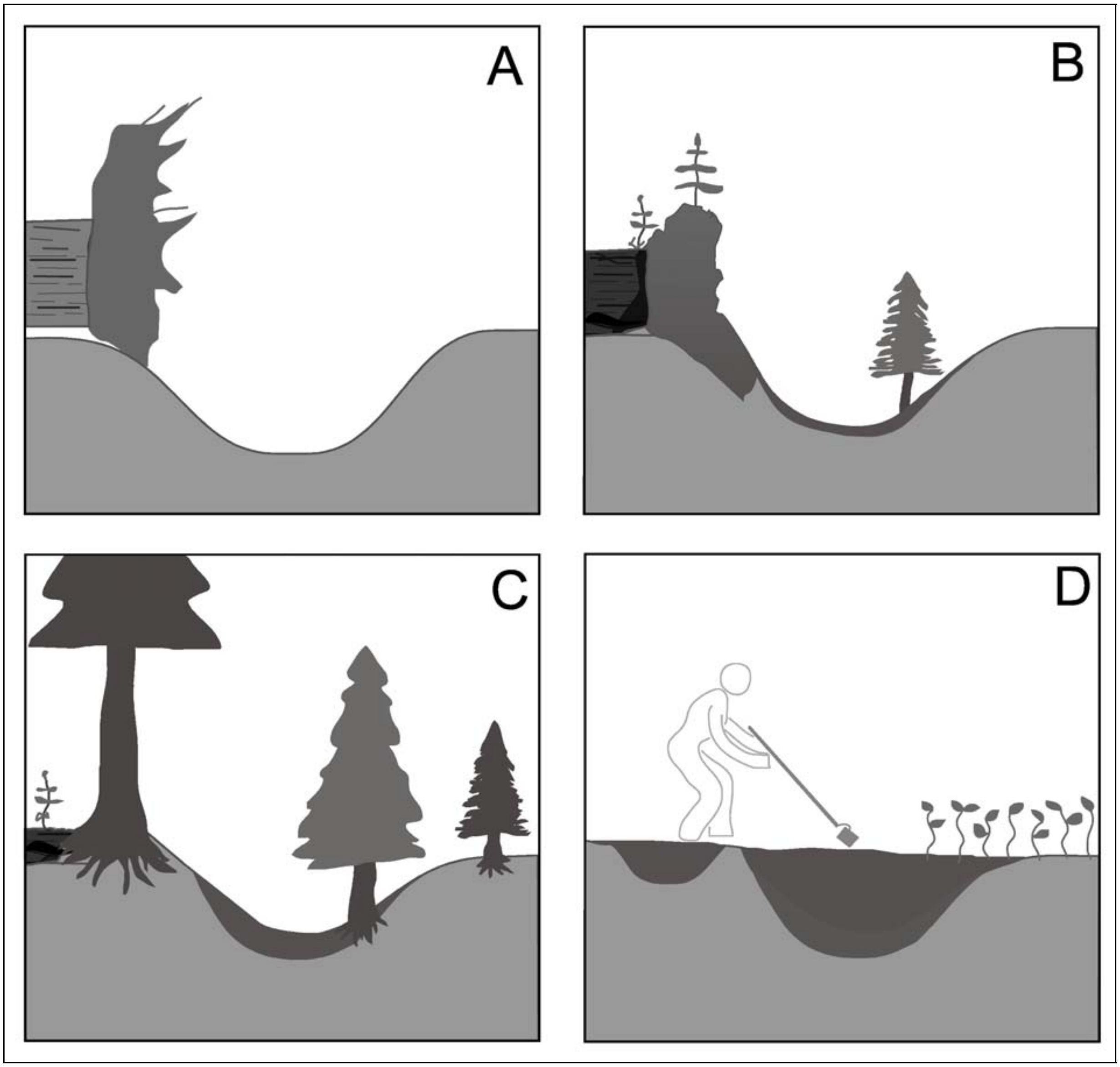

Figure 4. Tree tip illustration (after Agee 1989). A) Tree roots and pit in first year. B) Tree roots and pit after 5 years. C) Pit and mound topography after 50-100 years. D) Pit after infilling.

Tree stands that have undergone windthrow for long periods of time tend to develop "pit and mound" topography. The pit represents the area where the old root system had been, and the mound is the adjacent location where soil removed from the pit with the root mass is deposited (Figure 4). These topographic features persist unless other natural or cultural processes fill the pits and smooth the mounded topography. When infilling occurs, whether from sloughing of root ball material or redeposition of topsoil and leaf litter, the filled pit is expected to contain more organic matter at depth than the surrounding soil.

Agee (1989) cites two lines of evidence for the importance of wind in stand development at Fort Clatsop. First, several areas of the Fort Clatsop terrain contain classic "pit and mound" topography suggesting prevailing winds from the south (Agee 1989). Second, Agee examined prehistoric tree species composition by examining buried charcoal samples from the site. The absence of Douglas fir and the dominance of shade-tolerant species in these samples imply that wind was an important disturbance process in the forest, creating small gap openings as opposed to large openings created by frequent fire.

2.2.3 Forest Harvest

Cultural processes account for significant disturbance to the forest at Fort Clatsop during the past two centuries. Lewis and Clark's men did some clearing while building their fort (Gillette 1853). Homesteaders arrived in the mid-1800s and cleared land for homes and agriculture. Carlos Shane, the first homesteader at the site, recalled: "In clearing away for my house I set fire to the remains of the old cabins [of the fort] and endeavored to burn them" (Shane 1900).

By 1852, a lumber mill was in operation at the old canoe landing, being fed with timber harvested from the surrounding woods (Hussey 1957). Logging techniques of the day included harvesting large diameter trees by cutting the trunk approximately 10 feet above ground and leaving the stump. Following logging, homesteaders would likely have burned out remnants of the large diameter stumps, and either burned or dragged out smaller stumps by chain and animal. Trunk removal would cause significant ground disturbance, create pits, and contribute to the hummocky surface topography. Homesteaders would have also flattened the land through plowing, filling pits and distributing charcoal and topsoil over the entire field. Pit features resulting from these activities are expected to resemble the features created by forest fire or windthrow described above.

3.0 CULTURAL BACKGROUND

Since 1806, people have used the Fort Clatsop landscape in various ways, including logging, farming, brickmaking, and tourism. Each of these uses has had different impacts on the landscape and associated cultural resources. Some activities added artifacts and features, while others redistributed and destroyed existing artifacts and features. Some activities – logging, for example – likely did both. The history of landuse since the time of Lewis and Clark can be considered a history of cultural transformational processes that have altered the archaeological record.

This history also includes the account of the archaeological search for the fort. Multiple episodes of archaeological inquiry have not only created indelible marks on the landscape, they have also introduced multiple interpretations of the archaeological record. One of the goals of this study has been to evaluate some of these interpretations, which are outlined in Section 3.2 below.

3.1 History of Post-1805 Land Use

Soon after the Expedition's departure from the Oregon coast, the landscape likely reverted to traditional land use patterns of hunting and gathering by Clatsop Indians. Lewis and Clark presented Fort Clatsop and its "furniture" as a gift to Chief Coboway, who may have used the structure as a "hunting lodge" for 10 or 15 years thereafter (Smith 1957). "Lodge" may be a misnomer, and the Clatsops may have used the fort more like a hunting blind or field camp, visiting it infrequently for brief periods of time. These activities probably would not have caused changes to the landscape, aside from deposition of a few stone, bone, and possibly metal artifacts, and perhaps an occasional fire for warmth and cooking.

Journals and memoirs of curious American and European travelers describe sporadic sightseeing trips to Fort Clatsop beginning as early as 1811 (see, for example, Coues 1897; Cox 1831; Franchere 1904; Lee and Frost 1844; Spaulding 1953; Townsend 1905), but these brief visits had little impact on the site. The eyewitness accounts of the remains of the fort do not always agree with each other, but one report suggests that large portions of the fort may have been dismantled by 1830 (Coues 1897).

American homesteaders arrived in the mid-1800s and began to use the land in ways that clearly had a significant impact on the landscape. The first homesteader, Carlos Shane, placed a claim in 1848[1850] and built a house and probably outbuildings as well, which he relinquished to his brother, Franklin, in 1852. Precisely what the Shane brothers did to make a living at the homestead is uncertain, but they may have farmed and raised orchard crops (Trutch 1900). Depending on crops and cultivation methods, agriculture would have impacted archaeological deposits through digging, hoeing, or plowing, as well as root growth. In an affidavit sworn in 1900, Carlos Shane was definite on one point, however: "In clearing away for my house I set fire to the remains of the old cabins and endeavored to burn them" (Shane 1900). Shane's donation claim almost certainly was the site of Fort Clatsop, so Shane probably put an end to whatever remained of the fort.

By 1852, Richard Moore was operating a lumber mill at the old canoe landing, feeding his operation with timber harvested from the surrounding woods (Oregon Historical Society n.d.). Forest ecology surveys have revealed that a large forest fire swept through the area approximately 300 years ago (Agee 1989), and Lewis and Clark's men did some clearing while building their fort (Gillette 1853), so we cannot be certain of the size of the trees that existed at the site in Moore's time. Following logging, homesteaders would have burned out remnants of the large diameter stumps, and either burned or dragged out smaller stumps. Trunk removal would cause significant ground disturbance, as described above.

By the 1870s, the property passed to the William "Wade" Smith family, relatives of the Shanes. By this time, the old Shane house had burned down, so the Smiths built a new house, and set in with their own entrepreneurial ventures. In addition to being local postmaster, Smith manufactured bricks from the clayey sediments found at the site. Clay quarry pits dug first by Smith, and later by the Oregon Pottery Company, may still be seen around the property (Hussey 1957).

Between 1876 and 1879, the Joseph Stevenson family took over the property, possibly as renters. Like Smith, Stevenson also was something of an entrepreneur, and his daughter recalled that he made charcoal at the site for a period; Smith also learned to make charcoal on the property at this time (Smith 1957). Members of the Astoria Junior Chamber of Commerce (Jaycees) found large amounts of charcoal at the site in the 1940s and 1950s during groundskeeping of the property.

From the 1860s to the 1880s, the Oregon Steam Navigation Company, later the Oregon Railway and Navigation Company, maintained a wharf nearby on the Lewis and Clark River. Between 1872 and 1875, the Clatsop Plains Road, little more than a dirt trail, allowed coaches and wagons carrying passengers and cargo to go to and from the wharf. Impact from the vehicles and draught animals would have been minimal, however.

Little is known about landuse between the 1880s and 1901, when the Oregon Historical Society acquired the main land parcel that eventually would form the NPS property. After 1901, however, the site was protected from destruction while it gradually was developed into a landmark. Management of the site, first by the Oregon Historical Society, and later by the National Park Service, has involved construction of a variety of buildings and parking facilities, installation of utilities, and landscaping modifications to the vegetation.

3.2 History of Archaeology

The archaeological search for Fort Clatsop began more than fifty years ago, and the site has experienced several distinct episodes of archaeological inquiry since that time (Figure 5). In many ways, the fort search focuses on the romantic side of archaeology: it is a detective story in which a string of sleuths have tried their hand at solving the mystery. In truth, research has been sporadic, and results inconclusive. Nonetheless, a thorough understanding of previous work is prerequisite for successful future research at Fort Clatsop.

There are important reasons to know the history of archaeology at Fort Clatsop. First, archaeologists have caused significant post-depositional disturbance at the site, particularly within the circumscribed area surrounding the fort replica. Research addressing issues of landscape development and modification must account for these activities. Second, since the 1990s, the trend in archaeology at the site has been towards non-destructive (i.e., ground penetrating radar, magnetometry) and minimally intrusive (i.e., test pitting, auguring) methods. Data from previous research supplement this recent work, providing a more complete picture of site. Third, the results of previous excavations affect resource management decisions made by National Park Service personnel, including decisions about future archaeological research. For example, in 1999, a moratorium was placed on new archaeological excavations at the site. Fourth, the results of previous work may stimulate further questions or require clarifications. Indeed, much of the work described in this report is intended to reexamine interpretations proposed by previous researchers.

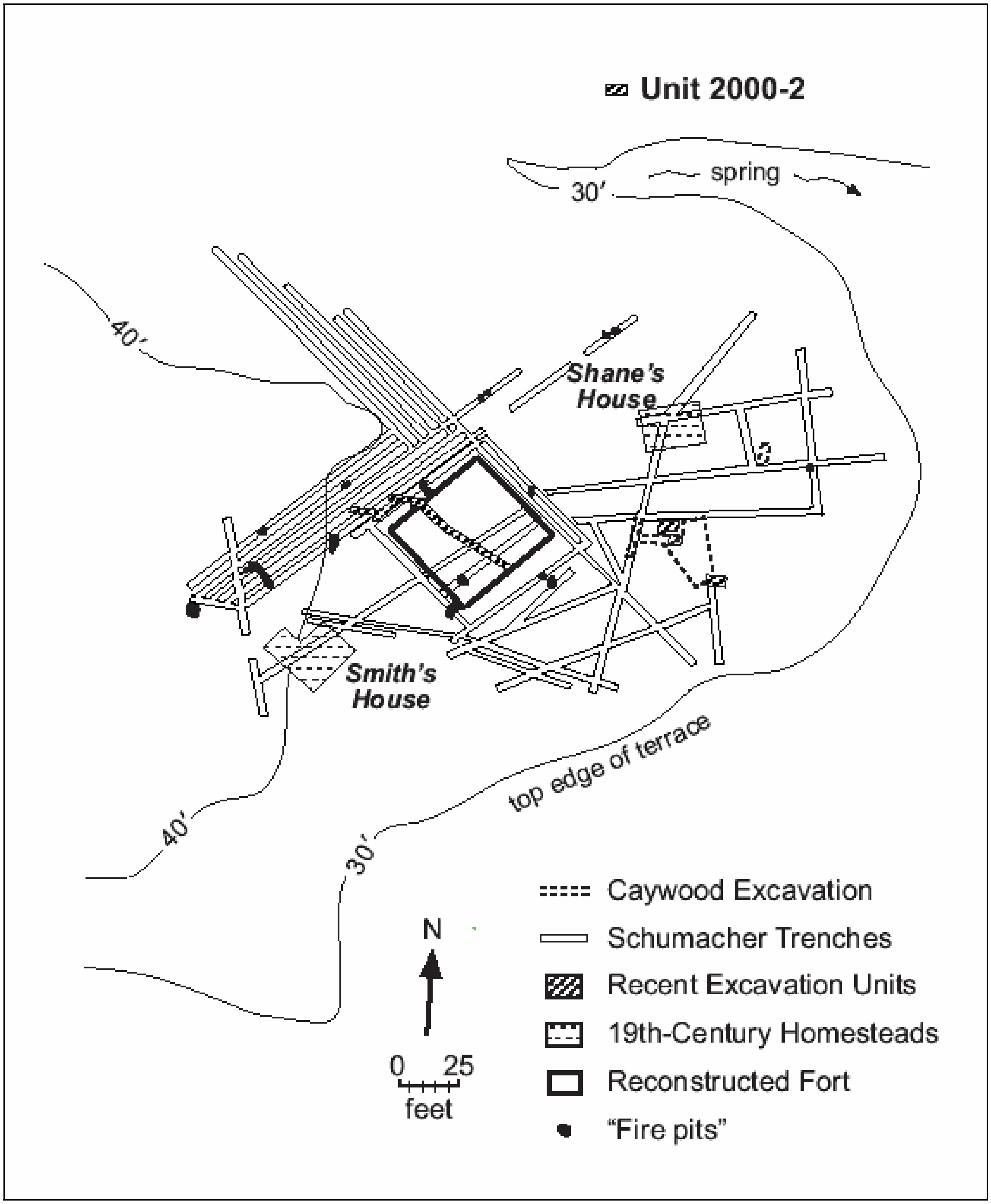

Figure 5. Fort Clatsop site map, showing fort reconstruction and excavation areas.

3.2.1 Louis Caywood: Pioneering Work

Hussey (1957) has asserted, "In pinpointing the location of Fort Clatsop, the important fact to bear in mind is that the site was never lost sight of." Whether or not this claim is entirely true, by 1948 the precise location of the fort was sufficiently obscure to impel the Oregon Historical Society (OHS) to request that the National Park Service send an archaeologist "to determine, if possible, the 1805-06 location of the Lewis and Clark winter" (Caywood 1948).

NPS archaeologist Louis Caywood worked nine days at the Fort Clatsop site, from July 9 to 17, 1948, concentrating his efforts to the east and north of the present location of the fort replica (Figure 5). Caywood's sparse excavation records do not indicate on what basis he selected the excavation area, but his site plan shows the 1928 bronze marker (subsequently removed) just to the southwest of his excavations. Karsmizki has estimated that the total area excavated may have exceeded 725 square feet (Karsmizki 1995). Caywood dug several test trenches, as well as exposing a large feature (c. 12' x 3-4') he called a "barbecue pit," based on the presence of fire modified rocks, burned earth, wood, charcoal, ash, and unburned animal bones. He recovered from this feature a piece of wood that he believed had been cut by a saw.

Caywood also uncovered several, smaller (11-18"), charcoal features – one containing "walls burned to a reddish color" – calling them "fire pits." Caywood detected the top of each of these features at approximately 10" below surface. Caywood reported finding a stick within one of these features. Caywood suggested that the stick had been whittled with a metal blade, although at least one subsequent researcher has suggested that it was a naturally occurring "staghorn" (Schumacher 1957a). The party also unearthed a piece of chipped basalt and "a piece of red coloring material such as might have been traded to Indians" (Caywood 1948).

Caywood noted that no unequivocal artifacts from the American period of occupation were uncovered, yet he attributed all features to a Euroamerican origin, asserting, "evidence is positive that white men at one time occupied this site" (ibid). Caywood confidently concluded, "[I]t can be safely stated that the excavations were done on the Lewis and Clark site of Fort Clatsop" (ibid).

3.2.2 Paul Schumacher

If not entirely conclusive, Caywood's excavations at least put the matter of Fort Clatsop to rest for several years. However, in 1955, the Astoria Jaycees, along with other local civic groups, constructed the fort replica with OHS assistance (Cannon 1995). The OHS quickly came to the realization that it lacked sufficient resources to maintain the facility, spurring yet another push for federal recognition and management. In July 1955, Oregon Senator Neuberger introduced legislation that required the Secretary of the Interior to investigate and report to Congress on the advisability of establishing Fort Clatsop as a national memorial. Signed into law on June 18, 1956, Public Law 590 forced the NPS to reconsider a 1937 ruling that the authenticity of the site was questionable due to the lack of actual physical remains, and therefore not worthy of inclusion in the National Park System.

The NPS dispatched regional archeologist Paul Schumacher to fulfill the requirements of Neuberger's bill. Schumacher reports that he reviewed various written document pertaining to "the general area and the site" and decided where to excavate (Schumacher 1957a). It is unclear which documents he had access to, but as Karsmizki (1998) suggests, he most likely viewed photographs of the region taken in 1900 and Caywood's 1948 report.

In December 1956, Schumacher, assisted by paid laborers from the neighboring community, excavated eight trenches. The excavations were inconclusive, but he acquired additional funds and conducted further excavations the following April, excavating "1543 linear feet of trenches, each three feet wide and three and one half feet deep" (Schumacher 1957b; Figure 6). Although Schumacher recovered a number of historic artifacts, none could be linked indisputably to Lewis and Clark. Nor had he located "by the widest stretch of the imagination" any feature that could have been associated with the fort (Schumacher 1957a).

Since Caywood had come to a different conclusion nine years earlier, Schumacher felt compelled to comment on some of his predecessor's findings. He argued that the lenses of burned earth and charcoal, which he too called “fire pits,” could not be associated conclusively with Lewis and Clark’s occupation of the area. Interestingly, he drew this conclusion while at the same time remarking on the depth of these lenses (eleven in all); Schumacher felt that they were deep enough to pre-date 1850 (Schumacher 1957b). Schumacher was working under the assumption that deposition at the site had been relatively constant over the previous 150 years; this was an assumption without warrant. However, it has been a common assumption by archaeologists working at Fort Clatsop that increasing depth below surface equates with greater age. Unfortunately, the concept of a “Lewis and Clark layer” that can be found at a uniform depth throughout the site is an example of archaeological mythology that has become attached to the site.

Figure 6. Schumacher’s trenches (1957). (Lewis and Clark NHP Archives, Photo H2215-247.)

Schumacher suggested also that the barbecue pit found by Caywood probably had not been created by Lewis and Clark, but by recent campers (ibid). Furthermore, a local resident had pointed out to him that a number of items that he believed to be whittled sticks were, in fact, nothing more than tree roots (ibid). Since Caywood claimed to have found similar whittled sticks, Schumacher concluded that he had been fooled by the same phenomena. In the end, Schumacher dismissed the same evidence that Caywood had used to support his conclusions, thereby casting doubt on the true location of Fort Clatsop.

Senator Neuberger reacted with disappointment to Schumacher’s results, remarking “I now understand that there is some controversy over the precise site where the original fort was erected…” (Neuberger 1956, 1957). Neuberger did not want any doubt that the Memorial that he was working to establish was in the right place. In the spring of 1961, the NPS sent Schumacher back to Fort Clatsop for three weeks. This time he employed a backhoe, cutting twelve parallel trenches to the northwest of the fort reconstruction, and uncovering numerous “fire pit” features similar in shape and depth to the ones found in 1957 (Figure 7). He placed these trenches near a group of cherry trees that appear in an early

Figure 7. Photo of one of Schumacher's men excavating a fire pit (1957). Note pedestaled fire pit in center of photo. (Lewis and Clark NHP Archives, Photo H2215-252.)

photograph of the site taken by George M. Weister in 1899 (Wheeler 1904). Based on his understanding of the location of the Smith and Shane houses, he may have believed that this was the most likely place for the fort to have been (Schumacher 1961). Although the material evidence found in the 1961 excavation was no more substantial than the remains from any of the previous digs, Schumacher wrote that, "I strongly believe these fire pits are evidence of Indian or Lewis and Clark fires or of the fort wall when it was burned" (ibid).

3.2.3 Karsmizki and the Fort Clatsop Archaeological Project

In 1995, in anticipation of the bicentennial of the successful arrival of the Corps of Discovery on the Oregon coast, the National Park Service began to discuss the possibility of reopening Fort Clatsop to archaeological investigation. During the previous decade only limited testing had been accomplished, notably Bell's ground penetrating radar survey (Bell 1990, 1996). The NPS consulted with Kenneth Karsmizki, then curator of the Museum of the Rockies at Montana State University, who was well known for his work at other Lewis and Clark sites, including the Lower Portage Camp Archaeological Project near Great Falls, Montana. Upon his recommendation, magnetic surveying (Weymouth 1997, 1998, 1999) and cartographic survey (Garnett 1995) were implemented in the area surrounding the fort.

Karsmizki felt strongly that Caywood and Schumacher had relied too heavily on local oral tradition and not enough on maps, drawings, and written accounts left by the Corps of Discovery. Karsmizki was cautious of secondhand historical accounts, but attempted to "squeeze every drop of information from historical data" (1998:20). In investigating the history of the region, Karsmizki discovered that the historical accounts were often conflicting.

In 1996, Karsmizki was named principal investigator of the Fort Clatsop Archaeological Project and permitted to conduct several test excavations, including a small test pit situated near the location of the 1856 County Surveyor's field tie for the Shane House, a second test pit just to the east of this location (1996-Q2), and a small trench under the west wall of the fort reconstruction (Figure 5). In the Shane House Field Tie unit, Karsmizki discovered a possible "hearth." This feature was described as a burned stone surrounded by charcoal located at a depth Karsmizki believed to be consistent with an occupation by Lewis and Clark. Karsmizki also recovered a musket ball that would have been used during the early to mid 1800s.

Perhaps the most potentially significant discovery was a soil feature identified in the 1996-Q2 unit excavated to the east of the Shane House Field Tie unit. This feature appeared to be a man-made pit, possibly the remains of a privy dug during the Corps of Discovery's stay at Fort Clatsop. Military regulations required placing privies at certain distances from living areas, suggesting that it might be possible to extrapolate the location of the fort along the perimeter of a circle with the privy at the center point. However, flotation analysis revealed that the pit contained only limited amounts of vegetable and animal remains. Stephanie Toothman of the NPS reasoned that a privy used by the Corps could be identified and distinguished from homesteader privies by the presence of mercury. Since ill members of the Expedition were treated with a patent medicine containing mercury, which passes through the body and remains in the soil for years, elevated mercury levels in the soil would suggest use of the privy by the members of the Corps. Mercury analysis returned results that did not corroborate Karsmizki's interpretation of the pit feature (Kiers and Stein 1998).

Several seasons of magnetic survey were also conducted at Fort Clatsop during the late 1990s. Although these surveys were unable to identify remains of the fort, they did reveal many subsurface features that were interpreted as possible pits. Roger Kiers and Julie Stein of the University of Washington offered an affordable and relatively non-invasive technique for examining the nature of these magnetic anomalies (Kiers and Stein 1998; Kiers 1999). Magnetic anomalies interpreted as potential pits were augered and sampled for chemical analyses. Their results led them to conclude that none of the anomalies sampled were trash or privy pits. Although Caywood, Schumacher, and Karsmizki each supported the notion that the "pits" at Fort Clatsop were culturally produced, it was becoming apparent that many of the "pits" might have natural origins. Explanation of these abundant "features" would require a more detailed examination of the natural and cultural formation processes occurring on the landscape.

4.0 RESEARCH DESIGN

The Fort Clatsop landform has a long and complex natural and cultural history that has shaped, and continues to shape, the land surface and subsurface. The Fort Clatsop landscape is today dominated by Sitka spruce, western hemlock, western red cedar, red alder, and Douglas fir, all of which are susceptible to blow downs in extreme wind situations and to burning in extremely hot and dry conditions. Wind disturbances uproot trees creating pits and mounds that form hummocky topography, which dominates the landscape around Fort Clatsop today. Forest fires burn canopies, trunks, and even root systems if weather conditions are dry enough to allow fires to reach maximum temperatures. Historic activities, from field clearing and agriculture by homesteaders, to forest harvest, brick manufacturing and charcoal production by entrepreneurs, have also altered the landscape, above and below the ground.

Pits and burned features identified by archaeologists as cultural could have been produced by disturbance processes described above. Pits created by tree throws are likely to have diffuse boundaries if the tree fell long ago, and abrupt boundaries if it fell recently. The resulting pits would contain sparse charcoal within the sediment filling the interior. These pits could reach depths of over one meter, depending on the age, ground water conditions, and species of tree that fell. Pits created by burning root masses below ground would have diffuse or abrupt boundaries depending on the age of the burn. They would differ from tree throws in the concentration of charcoal, ash and the undisturbed lenses of burned sediment adjacent to charcoal. Recently burned roots would contain charcoal still aligned in the shape of a root and oriented to the trunk and other roots in growth position.

This study aims to test the various hypotheses for the origins of pit or burned features by closely examining their structure and composition. Attributes of features, as well as the natural soil profile, are characterized through geoarchaeological investigation and compared to the expectations for various cultural and natural pits described above.

5.0 METHODS

Section 5.1 describes the geoarchaeological field methods employed at Fort Clatsop during Autumn 2000. Sections 5.2 through 5.8 describe the laboratory methods, which were conducted at the University of Washington in Seattle during Winter and Spring Quarters, 2001.

5.1 Field Methods

Geoarchaeological investigations at Fort Clatsop consisted of three separate controlled excavations performed over six total workdays (three days in October 2000 and three in November 2000). Two of the three excavations consisted of re-examinations of earlier units dug by previous researchers; specifically, 1996-Q2 and the Shane House Field Tie units. The third unit (2000-2) served as a control unit excavated away from the Fort reconstruction; the location of this unit was chosen in the hopes that it would reveal relatively undisturbed litho- and pedo-stratigraphic sequences (in other words, sediments that had not been heavily disturbed by farming, road construction, brick making, or other activities). In this section, the excavation, recording, and sampling methods employed in each of these three units are described.

5.1.1 Unit 2000-2 Methods

The 2000-2 test unit was excavated between October 27 and 29, 2000, in a forest opening north of the spring (Figure 5). The designation of this excavation refers to the fact that it was the second unique excavation undertaken at Fort Clatsop during the year 2000 (it was unique in that it did not involve previously excavated regions and it was second following excavations at the flagpole earlier in the year: see Cromwell 2001). The unit consisted of a 1.0 by 1.5-meter trench (3.275 by 4.925 feet) (Figure 8). The unit was oriented forty-five degrees east of north (azimuth 045) to avoid roots and to provide greater exposure parallel to the slope grade; as a result, no wall is aligned in a northerly direction (true or magnetic).

Figure 8. Unit 2000-2, view to south.

The unit was excavated in 10 cm arbitrary levels by shovels, mattocks, and trowels. All sediment was screened through ¼ inch mesh. The unit was excavated to a depth of 95 cm in the eastern half and 130cm in the western half of the trench. The 30 cm extension in the west half of the unit was created in order to expose a portion of the profile from the north and west walls. This addition was not removed in arbitrary levels but rather *en masse* (this was due to the coherence of the sediment with high clay content); however, all sediment was screened.

Artifacts from each level were bagged, labeled, and mapped on plan schematic drawings depicting each arbitrary level. The elevation below surface was recorded at the base of each level in all corners and in the center of the unit. Measurements and observations were recorded by layer on individual unit forms.

Profiles of all four walls of the unit were illustrated depicting major color and texture changes in sediments as well as disturbances caused by plant and animal activity. Sediment from each layer was analyzed in the field for color, texture, and soil structure. Soil descriptions of representative sections of profiles were completed in the field, following methods advocated by Dr. Charles Hallmark, Department of Agronomy, Texas A&M University (Hallmark, pers. comm., 1998). Relevant characteristics recorded include horizonation, depth, boundary conditions, textural class (Soil Survey Staff 1999:583), Munsell color, reduction-oxidation (redox) features, soil structure (type and grade), soil consistence, and special features (e.g., slickensides, charcoal, biocasts).

Munsell color designations consist of hue, value and chroma and a verbal description (10YR 3/4 brown, for example). Color can often be an indication of differences in mineral content and quantity of organic matter present, as well as the occurrence of chemical activities such as oxidation. It is important to note that Munsell soil color determinations can be particularly subjective due to variations in moisture, lighting, and observer abilities. Color determinations reported in this document reflect the soil appearance at the time that the determination was recorded. Because several determinations were made on exposed soil profiles within each unit over a period of minutes, we note that there is variability in our determinations within and between strata and that this variability reflects the constantly changing conditions of observation. For this reason, dry and wet soil color was also measured in the lab under controlled conditions. Dry samples were air-dried and wet samples were saturated with deionized water. Comparisons to the color charts were done under florescent lighting. Moist colors were recorded in the field with samples taken from the profile using natural, available light.

A total of 20 micromorphology samples (MS-16 – MS-35) were recovered from the north, east, and west walls of the unit (Appendix D). Fourteen rectangular "mouse step" sediment samples were also taken from the north corner of the west wall; these samples were taken in 10 cm increments, beginning at the surface and continuing to 130 cm below surface. The exact locations of where these samples were removed from are indicated on the profile drawings. Charcoal samples were also collected throughout the unit; a total of 6 samples were removed and bagged. The profiles and the floor of the unit were photographed with digital and manual cameras. Given the weather and forested setting of all excavation units, the quality of most photographs was less than ideal.

The excavation unit was reopened for further examination from November 16 to 19, 2000. The backdirt was removed using shovels and the GeoTextile was taken out. Re-evaluation of the test unit consisted of the following actions. First, an unusual rock that was projecting from the north wall, which had been discovered during the original excavation, was removed and bagged for petrographic analysis. Second, fourteen additional rectangular sediment samples were taken from the southern corner of the west wall; these samples were taken in 10 cm increments, beginning at the surface and continuing to 130 cm below surface. Third, twenty-six samples were removed from the western corner of the south wall in 5 cm increments. These samples were designated for wet-screening in order to collect charcoal. Unlike the "mouse-step" sediment samples, no spaces were left vertically between samples. Instead, the entire column of sediment was removed. Fourth, augering was performed in the center of the unit to a final depth of 376 cm below surface. Color and texture changes in the sediment were recorded. No additional artifacts were collected; however, a rock was removed from the auger unit at the final depth of 376 cm below surface. It was also at this depth that water was encountered.

The locations of all sample removals were illustrated on the existing wall profiles. Upon completion of these activities, the unit was lined with GeoTextile cloth and filled in with industrial grade sand.

5.1.2 Unit 1996-Q2 Methods

The 1996-Q2 unit consisted of a 5-x-5-ft. test unit originally excavated in 1996 by Ken Karsmizki. At the time of its original excavations, the north profile of the unit was believed to have transected a feature that was widely interpreted to be a privy related to historical occupations, potentially used by Lewis and Clark themselves. The unit was re-excavated during the 2000 field season in order to expose stratigraphic profiles for sampling purposes.

Since Karsmizki's report on the 1996 field season was not available, the location of the unit was determined through reference to Keith Garnett's map of the region and by talking with personnel who had participated in the 1996 excavation. Once located, the gravel and wood chips laid down by the National Park Service were removed, as was the industrial grade sand that was used to fill in the unit after the original excavation.

Once the sand had been removed from the unit, profiles of each wall were drawn. Following this step, soil samples were taken from the unit. Two varieties of samples were collected, following the procedures outlined for Unit 2000-2 above. Equal volume soil samples were taken in vertical columns at 10 cm increments and micromorphology samples were collected using tin cans.

A total of 15 micromorphology samples (MS-1 – MS-15) were removed from north, south, and west walls of the unit. Eighteen rectangular sediment samples were removed from the unit; nine from the north wall representing depths from 30 cm below surface to 110 cm below surface, seven from the north corner of the west wall at depths from 50 cm to 110 cm below surface, and two from the northwestern balk at depth of 30 cm and 40 cm below surface. Samples were taken from the balk because the western wall had been truncated at a depth of 45cm below surface by earlier excavations. No samples were taken above a depth of 30 cm because industrial grade sand comprised the profiles above this depth. The location of all samples was recorded on the site profiles, as were roots and crotovina burrows. The soil from the profiles was then characterized using the field methods described above in order to assess boundaries, texture, color, redox, structure, and consistency.

Photographs of the wall profiles and the sample removals were taken using digital and manual cameras. Following this step the unit was relined with GeoTextile and filled with sand. Gravel and wood chips were added on the surface to minimize disturbance.

5.1.3 Shane House Field Tie Methods

Karsmizki also excavated the Shane House Field Tie unit during the 1996 field season. He reported discovering a "hearth" at a depth consistent with "Lewis and Clark age" deposits. Like unit 1996-Q2, this unit had been lined with GeoTextile cloth and filled in with industrial grade sand. This unit was re-excavated in order to examine the supposed hearth feature.

In order to accomplish this, the sand was removed from the unit, and the "hearth" was exposed. Charcoal samples were taken from the region of supposed feature and the "hearth rock" was removed and transported to storage at Ft. Vancouver. Profiles of the unit walls were drawn and rectangular sediment samples were extracted from the west wall in 10 cm increments from the surface to 50 cm below surface.

The location of these removals and of root and crotovina disturbances was illustrated on the profile drawings. Finally, the nature of the soil from the profiles was examined in the same manner mentioned above. Once these tasks were completed, the unit was re-lined with GeoTextile and filled in with sand.

5.2 Soil pH

The pH of sediment is important to understanding the chemical activity occurring in sediment. The measurement indicates the amount of hydrogen ion activity occurring in the solutions surrounding the mineral and organic particles of the sediment. A pH ranging from 0 to 6 is considered acidic and a value from 8 to 14 is considered alkaline. A reading of 7 is neutral, indicating little chemical activity. To measure pH, a 1:1 soil to water ratio was made by gently mixing 20 grams of sample with 20 ml of deionized water with a glass rod for one minute in a glass beaker. After sitting for one hour, a pH electrode connected to an Orion 720A meter was lowered into the sample for readings. Readings, to one decimal place, were taken until they stabilized, as indicated by three successive measurements of the same value (rounded to a whole number).

5.3 Granulometry Methods

The textural properties of a sedimentary unit and surrounding units can be important to understanding the overall deposition and disturbance processes of an area. Archaeologists traditionally determine the textural properties of sediments by employing either the pipette or hydrometer method of grain size analysis. Both methods rely upon Stokes' Law to relate particle diameter to settling velocity. The settling velocity (v) is a function of particle density (ρ_x), liquid density (ρ_l), acceleration due to gravity (g), particle diameter (X), and fluid viscosity (η), as described by the following equation:

$$v = g(\rho_x - \rho_l)X^2/(18\eta)$$

The pipette method is the most standard method of particle size analysis, but it requires significantly more time to complete than the hydrometer method. The hydrometer method was employed here because the Fort Clatsop project entailed testing over sixty samples and because many analysts suggest that there are negligible differences between pipette and hydrometer results (Gee and Bauder 1986; Liu et al. 1966; Walter et al. 1978). The procedure used here follows the hydrometer method of grain size analysis outlined in Gee and Bauder (1986).

5.3.1 Sample Pretreatment and Dispersion

Sample pretreatment removes organic matter, iron oxides, soluble salts, and carbonate coatings that may inhibit aggregate dispersal. Samples chosen for pipette analysis are often subjected to these methods of pretreatment. The Fort Clatsop samples were not pretreated, as the hydrometer method does not require it (Gee and Bauder 1986).

Sample dispersion can be accomplished by both chemical treatment and physical dispersion. In the method used here, the samples were chemically treated with "peptizing agent," or a 5-g/L sodium hexametaphosphate solution. Physical dispersion was accomplished by mechanically agitating the samples with a wrist-action shaker for 15 minutes.

5.3.2 Hydrometer Method

In order to split the samples and evenly distribute the grain sizes, each sediment sample was air-dried and then quartered by hand. Ten grams of each sample was placed in a drying oven overnight at 105° C. The oven dry weight was calculated by recording the weight change between wet and dry weights.

A control cylinder full of 1000 ml of peptizing agent was prepared and the temperature and hydrometer scale reading (R_L) taken prior to running each sample analysis. ASTM no. 152 H hydrometers with a Bouyoucos scale in grams per liter were used.

Forty grams of sample was placed in a 250 ml flask. Between 100 and 150 ml of peptizing agent was added to each flask. Each sample was mechanically shaken and then checked to ensure deflocculation. The solution was washed into a cylinder by a stream of peptizing agent and filled up to the 1000 ml mark with more peptizing agent. The solution was mixed with a plunger and the temperature measured. After vigorously stirring the solution, the clock was set to zero and measurements were taken at 0.5, 1, 3, 5, 10, 30, 90, 270, and 720 minutes. The hydrometer remained in the cylinder between the 0.5, 1, 3, and 5-minute readings and was removed after each subsequent reading. Some samples were measured at the 1440-minute mark, after it became apparent that 720 minutes of settling time might not capture all of the clay particles. After the last reading, the solution was poured through a 4-phi screen. The sediment in the screen was washed with tap water to flush out the fine-grained material. The remaining coarse-grained material was washed into a small beaker and placed in a 105˚ C drying oven overnight. The dry sediment was sorted in a nested sieve shaker for 15 minutes, and the sand fractions remaining on the −1, 0, 1, 2, 3, and 4-phi screens were weighed.

5.3.3 Calculations and Particle Size Distribution Curves

Calculations follow the Gee and Bauder (1986) method for hydrometer analysis. The concentration of soil in suspension (C) is represented by the difference between the uncorrected hydrometer reading (R) and the hydrometer reading of the control cylinder (R_L): $C=R-R_L$. Each timed reading is characterized by a cumulative percentage of total sample (P), where $P=C/C_o*100$ and C_o is the oven-dry weight of the sample. The mean particle diameter in (X) is calculated by $X=\theta t^{-1/2}$, where θ is the sedimentation parameter and time (t) is measured in minutes. The phi-size for fine grains is calculated by $Phi = -(\log(X/1000)/\log(2))$. For the sand fraction, the cumulative percentage is calculated by dividing the sample weight by the oven dry weight (C_o) and summing the individual percentages.

A particle size distribution curve was constructed for each sample by graphing the cumulative percent concentration by weight against the particle diameter size, or phi size. Straight lines were drawn between data points. Cumulative percents for the fine fractions (5-phi through 9-phi) were then determined by interpolating between the graphed data points. The individual percent composition of each phi-size was graphed in a series of histograms (Appendix C, Figures C.1 to C.7), in order to more accurately describe each sample.

5.3.4 Wet Screening for Charcoal

As discussed above, 26 sediment samples were removed from the western corner of the south wall of Unit 2000-2 in 5 cm increments. This column of sediment, from 0 to 130 cm below surface, was removed from the area of the pit feature, and the samples were designated for wet-screening in order to collect charcoal. The samples were processed on January 7, 2001 on the University of Washington campus. Charcoal was collected by laying fine mesh cloth over a rigid screen, placing the sediment sample on the mesh, and spraying the sample with a garden hose. The charcoal was then collected in the mesh and allowed to air dry. Charcoal percentages were calculated by dividing the weight of the charcoal by the weight of the bulk sample.

5.4 Thermal Analysis

Thermal analysis refers to a variety of techniques in which a physical parameter (e.g., weight, energy, plasticity, etc.) of a given material is measured as a function of temperature change within a controlled environment. Sediment (and soil) constituents undergo various thermal reactions at different temperatures permitting qualitative and quantitative characterization of such constituents (Tan, Hajek, and

Barshad 1986). *Thermogravimetric analysis* refers to techniques in which the physical parameter of interest is the weight of the sample material.

Two types of thermogravimetric analysis – manual loss-on-ignition (LOI) and automated thermogravimetric analysis (TGA) – were utilized to provide better understanding of the excavation profiles exposed. Although both LOI and TGA measure changes in weight as a function of temperature, the techniques obtain these measurements in different ways. TGA is a *continuous* technique in which the sample is weighed automatically every few seconds concurrent with changes in temperature; the readings are then used to construct a thermogravimetric curve (Mackenzie et al. 1972). A sample curve is provided in Figure 9. In LOI, weight measurements are *discontinuous*, made only after the sample has reached the desired temperature. Compared to manual LOI, automated TGA provides more accurate assessment of weight loss (Brown 1988; Speyer 1994; Wendtlandt 1986).

At low temperatures (< 200° C), adsorbed water is evaporated, which results in dehydration. At intermediate temperatures (200-550° C), oxidation of organic compounds and metallic ions in a reduced state occurs. At high temperatures (700-850° C), loss of crystal-lattice water and evolution of CO_2 from $CaCO_3$ occurs. Raising samples to these temperature thresholds, then, results in weight losses corresponding to the reactions mentioned above.

5.4.1 Loss-On-Ignition

Methods used for loss-on-ignition follow those devised by Dean (1974), as adapted by Stein (1984). Two, 4-7 g aliquots from each stratigraphic layer were ground, dehydrated in a drying oven at 90-100° C for approximately one hour, and weighed. Aliquots were placed in a muffle furnace preheated to 550° C for one hour, removed and cooled to room temperature, and reweighed. Aliquots then were returned to the muffle furnace, preheated to 1000° C, for one hour, removed and cooled to room temperature, and reweighed. Percentage weight loss after heating to 550° is taken to represent combustion of organic matter, while weight loss after heating to 1000° C is taken to represent combustion of $CaCO_3$.

There are several, potential sources of experimental error to be considered when interpreting LOI results. Manual weight measurements create the potential for observer error and spillage during transport of samples to and from the scale; a digital scale was used to minimize observer error, and crucible racks were examined before and after transport for evidence of spilling. Another potential source of significant error is incomplete removal of moisture from samples prior to initial combustion and failure to maintain dehydrated conditions during the experiment. Past experience has shown that combined use of the drying oven and dessicator, as outlined above, provides adequate dehydration of samples. Accordingly, the level of experimental error is anticipated to be between 3 and 5%.

5.4.2 Automated Thermogravimetric Analysis

A 0.05-0.12 g aliquot of sediment was ground and placed in a Perkin Elmer TGA 7H thermogravimetric analyzer controlled by Pyris thermoanalytical software. This equipment is housed in the Thermal Analysis Laboratory, Department of Material Science and Engineering, University of Washington, and is supervised by Dr. Brian Flinn.

Testing protocol called for a two-step sequence: a 10-minute period of isothermal acclimatization at 30° C followed by a period of increasing temperature from 30 to 1000° C at a rate of 15° C/minute. The atmosphere of combustion consisted of air introduced at a flow rate of 20 ml/minute. The Pyris software is designed to modify continually the rate of temperature change to avoid extreme divergence from target temperature values, but it is prone to underheat at higher temperatures when temperature climb rates in excess of approximately 5° C/minute are used. Therefore, most samples obtained a maximum temperature of 900-950° C, still in excess of the upper threshold for carbonate combustion (850° C), suggesting that all carbonates were combusted.

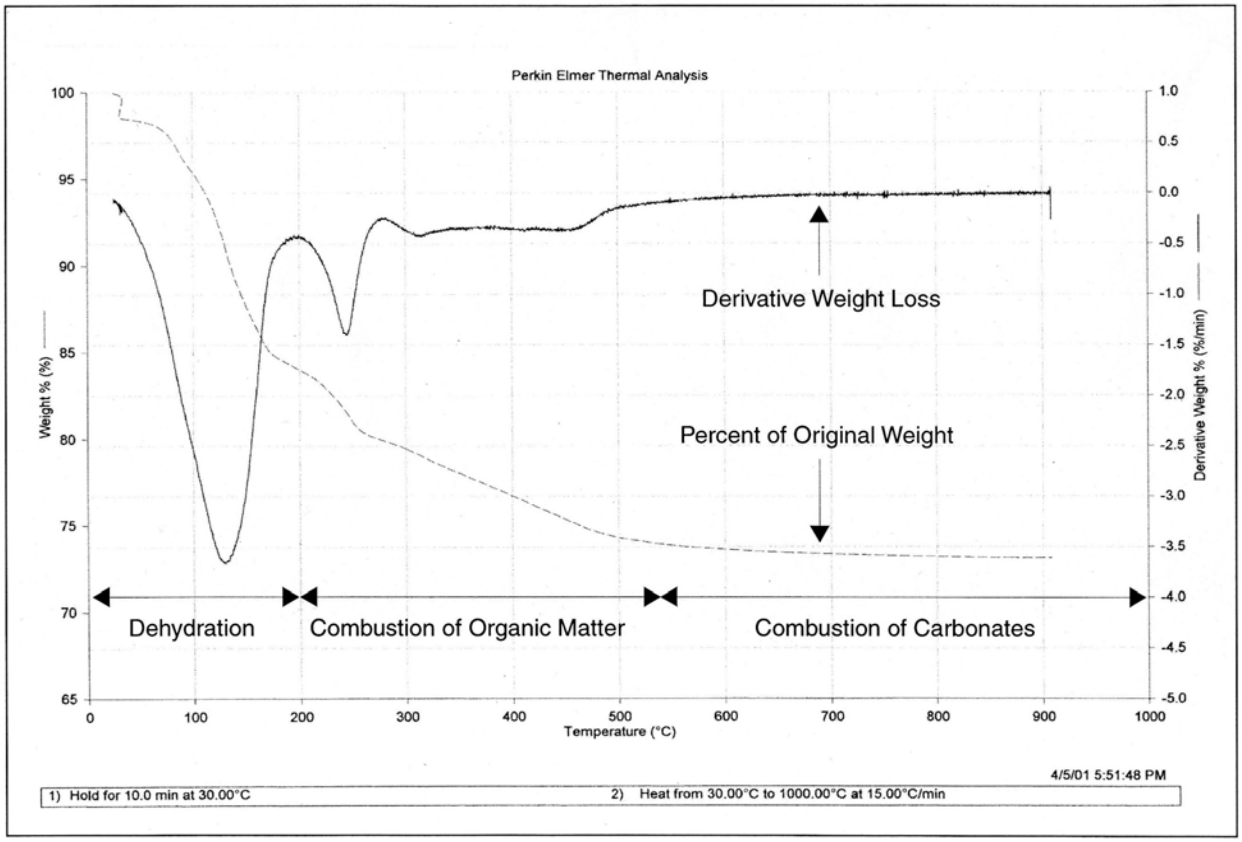

Figure 9. Sample TGA curve, showing the temperature ranges at which dehydration, combustion of organic matter, and combustion of carbonates occur. This curve was generated from the sample from Unit 2000-2, 20 cm below surface, inside the pit feature.

5.5 Phophorous

Phosphorous analysis was previously conducted at Fort Clatsop in order to test potential privy features identified during the magnetometer survey of the site (Kiers and Stein 1998). The researchers hoped that high levels of phosphorous in the soil would indicate that the magnetometer features were anthropogenic, and thus possibly trash or privy pits. In the present study, phosphorous was used to distinguish chemical differences between an observed pit feature and the surrounding sediments. It was hoped that phosphorous levels might indicate something about the origin of the pit feature. Phosphorous has often been used by archaeologists to indicate human occupation or disturbance at a site.

Phosphorous (P) is present in the soil in organic and inorganic forms, normally in conjunction with four oxygen atoms, forming a phosphate ion. Phosphorous is originally released in the soil by the weathering of parent material, and is taken up in plants in the form of orthophosphate. When the plant dies, the phosphorous in its tissues returns to the soil in the organic form. Organic P may remain in the soil or may be converted into inorganic forms. Inorganic P may undergo various combinations with iron or aluminum in acid soils to form insoluble phosphorous complexes that are not immediately available to plants.

A second source of phosphorous is human or animal residues, being one of the basic ingredients of the DNA molecule and other organic cellular material. Human occupation of an area generally increases phosphorous content, through excreta, dead tissues, bones, organic detritus, or the application of fertilizer (Cook and Heizer 1965). Phosphorous, as opposed to other chemical elements, is unique in that it is not generally removed by normal oxidation, reduction, or leaching processes (Eidt 1977). The failure of phosphorous to be removed with percolation water is due to its tendency, mentioned above, to form insoluble compounds. This failure is exaggerated in soils of high or low pH.

5.5.1 Sample Digestion

Analysis of total phosphorous in a sediment sample requires a homogenous solution as the test medium. Given the nonhomogenous nature of the samples collected, elemental analysis of those samples could only be conducted after bringing the samples into solution. This is done through acid digestion.

The digestion procedure used was a modified version developed by the Oceanography Chemistry laboratory at the University of Washington, and was used previously on sediments from Fort Clatsop (Kiers and Stein 1998). Though developed for oceanic sediments, the procedure was adaptable to terrestrial sediments. The procedure was carried out in the sediment lab of the Anthropology Department at the University of Washington.

Samples were initially air-dried for several weeks. Samples were then finely crushed with a mortar and pestle and placed in a drying oven at 80° C for 24 hours in order to remove any remaining water.

A 0.075 gram portion of the crushed sediment was transferred to a Teflon digestion vessel. Then, 2 mL of reagent grade Nitric acid (HNO_3) was added to the vessel and swirled. After 10 minutes, 5.0 mL of Hydrofluoric acid (HF) was added. After 10-15 minutes, the vessel was capped with a Teflon cap, double-sealed with Teflon tape to insure a tight seal, and tightened with a wrench. The vessels were placed in a Rubbermaid container with Saran Wrap covering as a gasket, and then sealed with a Rubbermaid lid. The container was placed in a microwave oven and heated for 1 minute on high power (level 10) and then for 60 minutes on low (level 1). The container was checked for leaking fumes and then reheated for another 60 minutes on low. Following heating, the samples were allowed to cool and were left to sit overnight.

Each bottle was emptied into a Teflon beaker and place on a hot plate, which was set to low. After the solution had evaporated, 4.0 mL of HNO_3 were added. The beakers were put back on the hot plate, their contents dried, and then 3.0 mL of Hydrochloric acid (HCl) and 1.0 mL of HNO_3 were added. After the contents of the beakers were dried again, 2.0 mL of HNO_3 were added, and placed on the hot plate again to dry. Next, 2.5 mL of HNO_3 were added. After drying for the final time, 2.0 mL of 30% Hydrogen peroxide (H_2O_2) were added. After the H_2O_2 effervesced, 4.0 mL of HNO_3 were added and the samples were allowed to sit overnight. Each sample was then transferred to a High Density Polyethylene bottle. Enough 1% HNO_3 was added to bring the sample to a total solution weight of 75 grams.

In addition to the samples being digested, a PACS-1 Standard Reference Material (P_2O_5) of known phosphorous concentration was also digested. This reference material was used to test the success of the digestion procedure and the accuracy of the phosphorous measurements.

5.5.2 Total Phosphorous Determination

To determine the total amount of phosphorous in the sample, the sample solution was allowed to react with a composite reagent containing a molybdic acid solution, an ascorbic acid solution, sulfuric acid, and antimony potassium tartrate. The resulting complex yields a blue solution. The absorbance of this solution was measured with a Milton Roy Spectronic 501 spectrophotometer at 880 nm. This method is taken from Murphy and Riley (1962) and has been widely used in soil research (see also Kuo 1996).

The phosphorous concentration of each sample was determined by comparing the measurement of each sample with a standard curve. The standard curve was generated by measuring the absorbance of several solutions of potassium dihydrogen phosphate (KH_2PO_4) with known phosphorous concentrations. The absorbance of each sample was divided by the slope of the standard curve in order to determine phosphorous concentrations.

5.6 Micromorphology

In addition to the macro-level analyses implemented in this project, soil micromorphology was utilized to help better interpret soil and subterranean pit feature formation in the area. First applied to archaeology in 1981 (Goldberg 1983), soil micromorphology has become a powerful contributor to the understanding of geomorphic and anthropomorphic processes involved in site formation (e.g. Barham and Macphail 1995; Davidson et al. 1992). Instead of focusing on the overall geomorphological setting more traditional to geoarchaeological analyses, soil micromorphology may confirm landscape evaluations and identify the anthropogenic activities that modified them by analyzing intact deposits microscopically (Macphail and Cruise 2001). More than any other geoarchaeological method, soil micromorphology is capable of recognizing subtle textural or chemical variations between soil layers (Goldberg 1992). By analyzing samples of archaeological sediments that have been stabilized and preserved in their original position through the use of hardening resins, soil micromorphology has two powerful advantages: first, it allows intact soil profiles to be studied outside of the field; second, it allows researchers to develop solid descriptions and interpretations concerning interfaces between soil boundaries. Since this project involved specific questions regarding the formation of subterranean features that were relatively compact, displayed clear boundaries with surrounding deposits, and were of potential anthropogenic origin, soil micromorphology was an ideal addition to the geoarchaeological repertoire.

A total of 35 samples were recovered from two excavation units: 1) the 2000-2 control unit, and 2) Karsmizki's unit 1996-Q2 (Appendix D). Samples were taken from all four walls of the 2000-2 test unit at the interface between facies and from relevant exposures of the other units. The sampling strategy involved driving empty tuna cans into the profile using a rubber mallet; these were then removed from the wall, wrapped in paper towels and sealed using masking tape. A total of 20 samples were submitted to Spectrum Petrographics in Portland, Oregon where they were impregnated with resin, cut into thin sections 30 microns thick, and subsequently mounted onto glass slides.

Soil thin sections were analyzed under a petrographic microscope and described using the methods outlined in Bullock et al. (1985). Particular attention was paid to describing and interpreting those thin sections that pertained to the origins of the ubiquitous subterranean features found throughout the region surrounding the fort.

5.7 Polished Section Analysis

Excavations of the control pit (2000-2) revealed the presence of a large mass of reddish-brown earthy material loosely held together near the southern wall at a depth of approximately 30 cm below surface. Initially the mass was believed to be oxidized sediment caused by intensive burning in the region, most likely through a tree fire. However, the absence of a major disturbance (typical in tree burnings) or further discoveries of "burned earth" made such a conclusion questionable. Further, it has been documented that 19th century occupants of the surrounding region routinely produced bricks by firing clay located in the immediate vicinity (Wilcox 1935; Bell 1938). Wilcox (1935:31) described the collection of "buff-firing clay" that was removed from the Astoria region, shipped to Portland, and used in the manufacture of stoneware. Interestingly, both Wilcox (1935) and Bell (1938) report that firebrick from this area was not of high enough quality to sustain any corporate endeavor for longer than a few years.

According to geological surveys of the time, clay-bearing deposits of the region were probably Eocene in origin (Wilcox 1935). More recent surveys suggest that these clays derive from the Astoria shales, implying an Oligocene origin (Walsh 1987). An example of such brick was recovered from test excavations and identified on the following characteristics: 1) reddish burned appearance, 2) strong cementation, and 3) sharply angular (i.e. human modified) appearance.

Based on this information, it was hypothesized that the reddish-brown mass might in fact represent the remains of a similar brick that has been broken down through some unknown process. In order to test this hypothesis, polished sections were created using both the brick (hereafter PolSec1) and the "burned mass" (PolSec2) (Figure 10). The two polished sections were produced using procedures outlined by Dr. James Feathers (personal communication) of the University of Washington. Sample preparation involved cutting, impregnation, and grinding/polishing of the samples. The polished sections were then analyzed under a microscope for compositional differences.

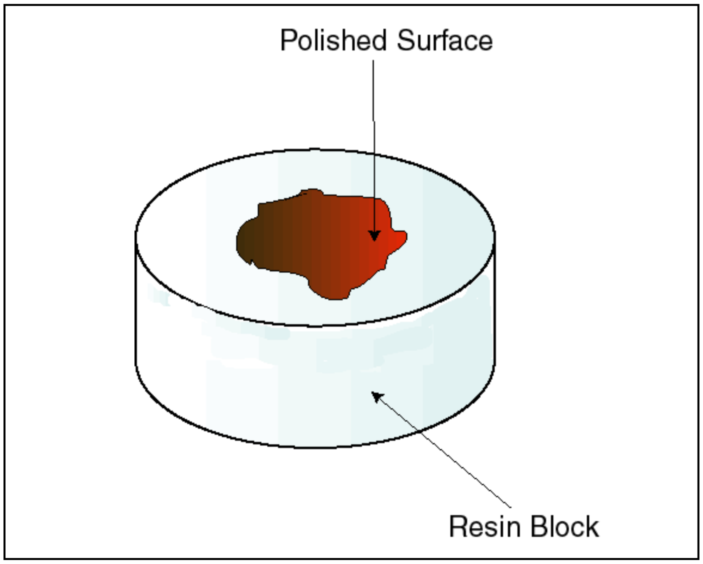

Figure 10. Schematic of a Polished Section like those used in the study. One surface of the block is ground and polished to reveal a flat cross section of the material held by the resin.

5.7.1 Cutting

The creation of polished sections requires a sample size of approximately 1cm^3; as a result, the existing material required modification. The hardness of PolSec1 necessitated the use of a diamond bladed saw to cut an appropriate amount. Only one cut was made; the surface of the cut was later used as the viewable portion of the polished section. PolSec2 was too poorly cemented to require cutting; instead a small portion was carefully pulled away from the mass. Since this method did not result in a clean, flat viewing surface, more extensive grinding was required. This is addressed below.

5.7.2 Impregnation

Both samples were placed in cylindrical plastic cups measuring 2 cm in diameter and 5 cm in height. The samples and their respective plastic cups were then placed within a small vacuum pump and left to sit while resin was prepared. Approximately 15 mg of resin and 2 mg of hardener were mixed in a paper cup using a wooden stir rod for 5 minutes. The cup was then placed in the vacuum pump with the samples for impregnation. Before the resin/hardener mixture was added to the samples, the vacuum was activated and de-pressurized to –25mm Hg for three minutes. Following this, the pump was deactivated and air was allowed to re-enter the chamber. This procedure was followed three times in order to remove most of the air bubbles in the hardener. Once this was accomplished the resin mixture was poured into the cups using a metal swivel arm on the outside of the mechanism. The fully coated samples were left to sit in the vacuum overnight.

5.7.3 Grinding

Once it seemed that the polished sections had sufficiently hardened, they were ground and polished using the Portable Polishing Table provided by the University of Washington's Department of Anthropology. Each sample was ground with the viewable side down on spinning segments of sandpaper with various grits. The use of the roughest grit sandpaper (120 grit) was employed to remove superfluous resin from above the viewing area of each sample. Since the sample PolSec2 did not have a clean viewable surface to begin with, it was ground down until such a surface was exposed. At this point, the 120-grit sandpaper was replaced with 240 grit (finer) paper and samples were reground orthogonal to their original position. This rotation insured that all scratches made by the earlier paper were removed. This procedure was repeated with 500 and 600 grit paper and then finally with a buffing cloth. Each grinding session required about five minutes per sample per sandpaper sheet. End results were excellent with the known brick sample. Unfortunately, the resin surrounding PolSec2 was not sufficiently hardened; as a result, the heat caused by grinding friction melted the resin enough to prevent the removal of all grinding scars. While these did not ultimately hamper the ability to analyze the mineral composition, these scars made the resultant photographs less clear.

5.7.4 Microscopy

Once samples were fully ground, they were analyzed under a transmitted light microscope at magnifications ranging from 10x to 500x. The presence and abundance of various visible minerals were noted and compared between both samples for similarities. After inspection, both samples were photographed using Tungsten chromatic film with a 35mm Nikon manual camera. Photographic processing was performed by the Health Sciences Department of the University of Washington.

5.8 Petrographic Analysis

During the course of excavating Unit 2000-2, a single well-weathered rock (FS #2; hereafter referred to as Petrographic Sample 1 or Pet1) was discovered protruding from the north wall at a depth of 62 cm below surface. While Pet1 did not initially appear to be modified by human activity, its discovery was unusual in that it was the only large unmodified stone present in the matrix of the excavation unit. Although it appeared to be heavily weathered, Pet1 superficially resembled local sedimentary nodules that are common on the surface and at the water table in the immediate vicinity (Brian Harrison, personal communication). In an attempt to better understand the deposition activity related to Pet1, it was decided that petrographic analysis of the sample was in order. Moreover, petrographic analysis was also performed on a weathered nodule (hereafter Pet2) taken by auger from the water table zone 3+ meters below the surface in Unit 2000-2. Analysis of this second piece was performed in order to have a comparison sample for Pet1.

Petrographic thin sections were created and analyzed using the procedures outlined in Gribble and Hall (1992). All thin sections were prepared in the Thin Section Laboratory located in the Geology department at the University of Washington with the assistance of David McDougall. Sample preparation involved a number of steps which are summarized here as 1) initial preparation and mounting, 2) grinding and polishing, and 3) microscopy.

5.8.1 Initial Preparation and Mounting

The initial step in thin section production involved sampling a small segment of each rock whose cross section was approximately the size of a standard glass slide. This was accomplished by cutting both samples with a table saw and attached diamond blade. Once cut, the smaller sections were retained and ground using a mixture of water and industrial grit of varying coarseness levels. The purpose of this step was to smooth the freshly cut surface and to remove any imperfections caused by initial cutting. Each sample was subjected to coarse and fine grit for approximately one hour each. Once the surfaces of both samples were sufficiently ground, they were removed from the grit, washed and dried, and set upon a hot plate at 80º Celsius. In this environment the samples were covered in a mixture of resin/hardener. This mixture was added to prevent spalling during later grinding of the samples. After the samples were completely covered, they were allowed to dry overnight. Once hardened, the samples were affixed to standard glass slides (exposed cross sectional surface down) using a clear epoxy. Samples were again left alone for 24 hours to allow for drying.

5.8.2 Grinding and Polishing

Once the samples were firmly affixed to the slides, excess rock was removed from the thin section. This was accomplished by two methods: first, the slide was attached to a vertical grinding wheel by means of a vacuum (see Freile and Devore 2000 for a description) and a diamond saw was then used to remove most of the remaining sample. After this step was completed, the sample consisted of a slide and a rectangular section of rock approximately 2 cm thick. Following this, the saw blade was replaced with a carbide-grinding wheel. Using minimal pressure, the sample was ground against the carbide in 10-micron increments until the measured thickness of the slide approximated 30 microns. At this point, grinding cycles proceeded in 2 μm increments. After each cycle, the slide was removed from the apparatus and studied under a petrographic microscope.

Since petrographic analysis is dependent upon the ability to note color changes (bi-refringence) among minerals, and since mineral color varies according to sample thickness, it is important to ensure that the sample is ground to the correct size. In this case, it was determined that the first appearance of gray colored minerals would indicate the appropriate thickness (roughly 30 μm). Once this thickness was attained, the samples were removed from the machine and again placed in a mixture of water and fine grit. Submersion in this mixture was performed to remove any remaining irregularities from the surface of the slides. Finally, a thin cover slip was attached to the top of the sample to protect it from damage.

5.8.3 Microscopy

Prepared slides were observed and analyzed under a transmitted-light petrographic microscope using both polarized and crossed polar light. Samples were analyzed for general mineralogical composition and inter-sample similarities. After both samples had been analyzed, samples were photographed with Tungsten chromatic film using a 35mm Nikon manual camera. Processing was performed by the Health Sciences Department at the University of Washington.

6.0 RESULTS

6.1 Excavation Results

6.1.1 Unit 2000-2 Results

Unit 2000-2 was placed in an area believed to have been relatively undisturbed by human activities and where anthropogenic subsurface features were not expected, in an effort to identify a "natural" profile that could be compared to the "cultural" profiles of previous excavations. Interestingly, the stratigraphy of this control unit revealed profiles similar to those described from other parts of the landscape. A pit-shaped feature was clearly visible in the west profile (Figure 11). This pit extends from the surface to a depth of 110 cm. The feature was difficult to discern within the A-horizon but became visible in the lower B-horizon below a depth of 70 cm. At this depth, the feature was identified by an abundance of charcoal, and by a clear color and texture boundary between the feature and the adjacent B-horizon. Samples were collected from "inside the pit" and "outside the pit", and are discussed in the sections below.

A detailed soil description of the west profile is provided in Table A.2 in Appendix A. The general profile as observed in the west wall of the unit consists of an upper 7 cm of dark brown humus or O horizon, above a very dark brown sandy loam A horizon, which extends to a depth of 14 cm. A transitional AB horizon, consisting of dark brown clay loam, is found between 18-28 cm. A series of dark brown to very dark grayish brown clay loam Bw horizons extend to a depth of 91 cm. The bottom of the unit consists of a pair of firm silty clay Bt horizons to 130 cm.

The bottom of the unit was augered to a depth of 3.76 m. Deposits consisted of silty clay, with varying amounts of silt, mottling, and occasional charcoal, to a depth of 3.25 m. Some sand and gravel was present below 3.25 m, and augering was terminated at 3.76 m due to large gravel.

The north and east profiles of Unit 2000-2 contained two yellowish red (5YR 4/6) lenses with charcoal, similar in depth and appearance to the "fire pits" described by Schumacher (Figure 12). The lenses are found at depths between 20-30 cm below the surface, within the A-horizon, and range from one to five cm thick. A 1-2 cm thick charcoal lens was found immediately beneath one of the red lenses.

A list of the artifacts uncovered by the geoarchaeological investigations of Unit 2000-2 is provided in Table 1. These consisted primarily of brick fragments, dispersed between 0 and 40 centimeters below surface. There is some question of whether or not all of the fragments are pieces of actual bricks, or whether some may be naturally burned earth. Several of them are certainly brick fragments, as evidenced by perpendicular flat surfaces.

Table 1. Artifacts from Unit 2000-2.

Depth (cm)	Description
0-10	2 brick fragments
10-20	2 lithic flakes
10-20	brick fragments (~18)
20-30	brick fragments (bag)
30-40	brick fragments (~22)
38-43	biface

The relatively abundant brick fragments in Unit 2000-2 may indicate that brick-making activities, which have been documented in other parts of the Memorial, were taking place in this area, or that a few isolated bricks were dropped or placed here. They do not appear to be part of any structure.

In addition to the brick fragments, three lithic artifacts were recovered from the unit. Two lithic flakes were encountered between 10 and 20 centimeters below surface. The smaller flake is 1 centimeter in length, and is made of a reddish cryptocrystalline silicate material. The other flake is more questionable, and may be a piece of road gravel. It is 3 centimeters long and is made of a fine-grained volcanic rock.

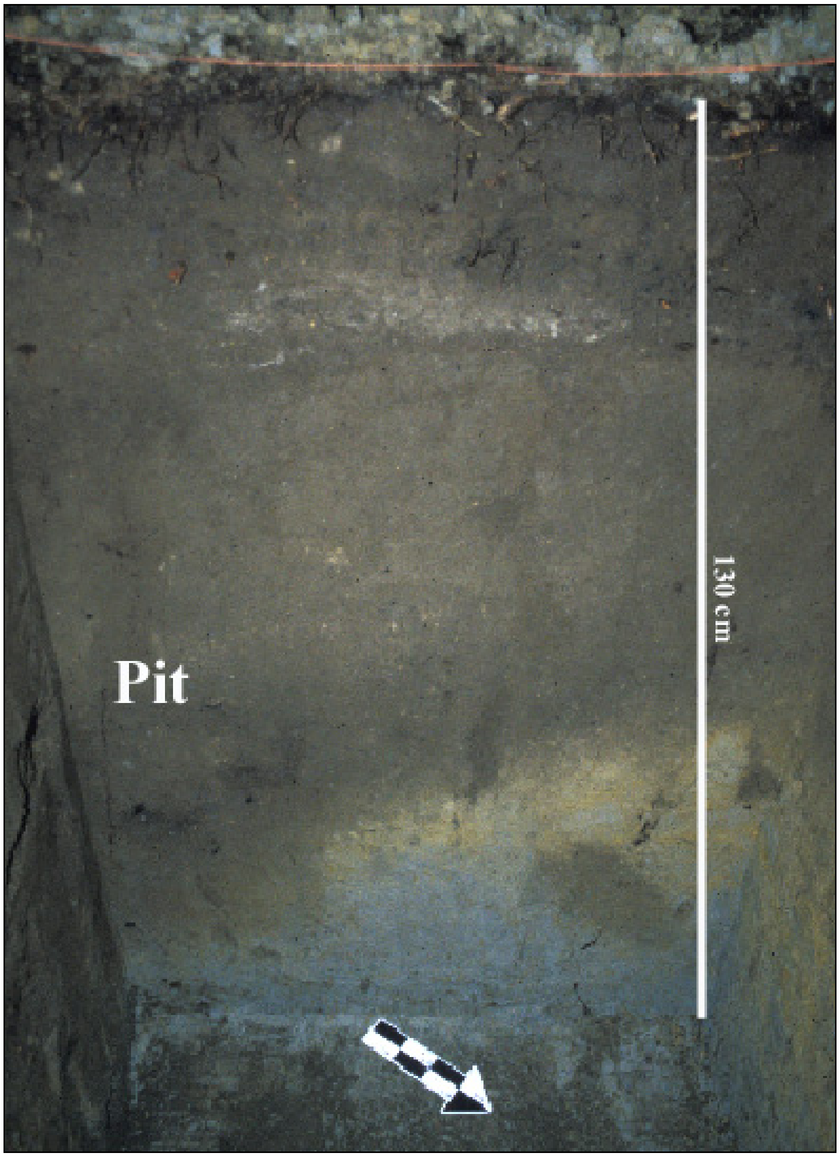

Figure 11. West profile of Unit 2000-2.

Figure 12. East profile of Unit 2000-2.

The third lithic artifact is the basal half of a broken biface made on a fine-grained volcanic rock similar to basalt (Figure 13). The biface was found between 38 and 43 cm below surface, and the base of the biface was pointed straight up. The orientation of the biface at this angle probably represents the influence of regressive soil formation processes that have acted to redistribute artifacts vertically. The biface is 4.5 cm at its widest point, and is 5 cm long. The extrapolated length, if the biface was complete, is approximately 10 cm. The biface has a convex base and convex lateral margins. There is no cortex present. The biface is made on a flake, and one face retains approximately 50 percent of the remnant ventral surface. The other face has complete, covering retouch.

The presence of lithic artifacts in 2000-2 provides additional evidence of Native American use of the site, although the antiquity of these artifacts is not clear. Unfortunately, no temporally diagnostic tools were recovered.

Figure 13. Biface from Unit 2000-2.

6.1.2 Unit 1996-Q2 Results

The 1996-Q2 unit consisted of a 5-x-5-ft. test unit originally excavated in 1996. At the time of its original excavations, the north profile of the unit transected a feature that was interpreted to be a privy related to historical occupations, potentially used by Lewis and Clark themselves. The unit was re-excavated during the 2000 field season in order to expose stratigraphic profiles for sampling purposes.

The south wall of the excavation unit had the least evidence of disturbance. The upper 46 cm consists of of very dark brown silt loam A_1 and A_2 horizons, with weak granular structure, common fine faint to distinct redox, very friable consistence, and charcoal. A gradual wavy boundary separates the A_2 horizon from a Bw horizon, which extends to 105+ cm below surface and is characterized as dark yellowish brown (10YR 4/6) silt loam, with few fine faint redox, medium subangular blocky structure, and friable consistence.

The pit feature identified by Karsmizki in 1996 was clearly visible in the west profile of the unit, and is hereafter referred to as Feature 1 (Figure 14). A second, larger pit-shaped feature, referred to as Feature 2, was observed in the north profile, and is adjacent to Feature 1 (separated by the balk and mottling in the northwest corner of the unit), but is less distinct and more mottled than Feature 1 (Figure 14). Feature 2 appears as an area in the profile where darker sediments extend to depth of 110 cm.

Four artifacts were found during the re-excavation of Unit Q2. The provenience for most of these artifacts is poor, since they were recovered while the walls of the unit were being cleaned in preparation for drawing. A brick fragment and a lamp chimney glass fragment were found in the 1/4-inch screen material from the south wall of the unit. An additional brick fragment was found while cleaning the east wall, and another lamp chimney glass fragment was found at a depth of 10 cm in the east wall.

Unit Q2 is near the former location of the Shane house, a known 19th Century homestead, so the artifacts recovered in this unit may relate to that period of occupation. No artifacts potentially dating to the Lewis and Clark occupation of the site were recovered.

Figure 14. Unit Q2, view to west. Feature 1 can be seen in the west profile. Feature 2 is in the north profile. The cans in the profiles are micromorphology samples.

6.1.3 Shane House Field Tie Unit Results

Karsmizki excavated the Shane House Field Tie unit during the 1996 field season, and reported discovering a "hearth" at a depth consistent with "Lewis and Clark" age deposits. This unit was re-excavated in order to examine the supposed hearth feature and associated deposits.

The generalized soil profile consists of an upper 6 cm of black humus O horizon above A_1 and A_2 horizons, which reach a depth of 41 cm. The A horizons are very dark brown loam, with weak subangular block structure, very friable consistence, and clear wavy boundaries. The A_2 horizon also has common fine distinct redox. A Bt horizon extends to a depth of 63+ cm, and is dark yellowish brown sandy clay loam, with subangular blocky structure and friable consistence.

The "hearth" feature did not appear to be unique from other subsurface pits or features observed in the other excavation units, and its function as a cultural hearth seems questionable.

Figure 15. West profile of the Shane House Field Tie Unit.

6.2 Soil pH Results

The pH values for all samples taken fall within the range of 3.8 to 5.4, which is considered very strongly acidic using USGS Soil Survey criteria. Appendix B provides all pH values measured for each sample. In general, the pH is consistent throughout the individual soil profiles and between all units. In unit 2000-2, values range from 4.1 to 5.1 outside the pit and inside the pit values range from 3.8 to 5.0. Unit Q2 pH ranges from 4.3 to 5.3 in the southwest balk, in Feature 1 the pH is 4.6 to 5.4, and in Feature 2 the pH is 4.8 to 5.3. The sand fill in unit Q2 has a pH of 5.8. The Shane House Field Tie unit profile yielded pH values ranging from 4.1 to 5.4, and the sand fill is also acidic with a pH of 5.4. The pH values found in this analysis are consistent with those listed for the Walluski Series of soils, which typify this area of Clatsop County. The acidic nature of the sediments may explain the lack of bone and wooden artifacts at Fort Clatsop.

6.3 Granulometry Results

Summaries of the textural composition for each sample are presented in Table 2, in terms of gross sand, silt, and clay percentages, unmeasured sediment and USDA textural nomenclature. Bar graphs of the detailed grain size distributions by phi-fraction for each sample can be found in Appendix C.

6.3.1 Unit 2000-2 Granulometry Results

Unit 2000-2 served as the control unit for this analysis. Sediment samples were removed from the west wall of the unit and avoided the boundaries of an apparent pit feature (referred to as 'outside the pit'). Samples from 2000-2, outside the pit, should reflect a natural soil profile unaffected by cultural activities. The hydrometer results for this unit (see Appendix C) reflect very low sand content throughout the profile: coarse fractions range between 3% and 7%. Silt content, between 47% and 77%, generally decreases with depth. Clay content fluctuates between 4% and 12%, but no clear pattern is apparent. It is significant, however, that the percentage of unmeasured sediment increases as depth increases. This phenomenon most likely results from a very high clay content in the lower depths combined with the inability of the hydrometer analyses to measure the extremely fine clay fractions in the allotted time. If the unaccounted fractions are assumed to represent clay, the clay fraction outside the pit (denoted as %clay + %unmeasured) then leaps to between 18% and 50%.

Table 2. Summary of textural compositions for all units.

Unit	Depth (cm)	%Sand -1 to 4 Phi	%Silt 5 to 8 Phi	%Clay 9 to 12 Phi	%Unmeasured*	%Clay + %Unmeasured	Textural Classification
2000-2 Outside Pit	10	5.3	68.7	10.0	16.0	26.0	Silty Clay Loam
2000-2 Outside Pit	20	5.4	77.1	4.3	13.2	17.5	Silt Loam
2000-2 Outside Pit	30	4.6	69.5	10.1	15.9	26.0	Silty Clay Loam
2000-2 Outside Pit	40	3.6	74.4	11.5	10.5	22.0	Silt Loam
2000-2 Outside Pit	50	3.6	71.5	12.0	13.0	25.0	Silty Clay Loam
2000-2 Outside Pit	60	6.7	71.3	11.7	10.3	22.0	Silty Clay Loam
2000-2 Outside Pit	70	4.6	71.4	11.3	12.7	24.0	Silty Clay Loam
2000-2 Outside Pit	80	5.5	62.5	8.9	23.1	32.0	Silty Clay Loam
2000-2 Outside Pit	90	5.3	51.7	9.1	33.9	43.0	Silty Clay
2000-2 Outside Pit	100	2.7	47.3	9.5	40.6	50.0	Silty Clay
2000-2 Outside Pit	110	3.3	51.2	12.2	33.3	45.5	Silty Clay
2000-2 Outside Pit	120	3.9	55.7	6.9	33.6	40.5	Silty Clay
2000-2 Outside Pit	130	3.2	55.8	9.3	31.7	41.0	Silty Clay
2000-2 Inside Pit	0	57.0	35.0	4.6	3.4	8.0	Sandy Loam
2000-2 Inside Pit	10	50.0	23.0	0.0	27.0	27.0	Sandy Clay Loam
2000-2 Inside Pit	20	32.9	34.1	6.6	26.4	33.0	Clay Loam
2000-2 Inside Pit	30	24.9	46.1	6.8	22.2	29.0	Clay Loam
2000-2 Inside Pit	40	18.5	49.5	12.0	20.0	32.0	Silty Clay Loam
2000-2 Inside Pit	50	12.9	48.1	11.2	27.8	39.0	Silty Clay Loam
2000-2 Inside Pit	60	27.3	67.3	2.9	2.6	5.5	Silt Loam
2000-2 Inside Pit	70	21.9	56.1	11.1	10.9	22.0	Silt Loam
2000-2 Inside Pit	80	14.2	63.8	11.0	11.0	22.0	Silt Loam
2000-2 Inside Pit	90	13.4	64.6	11.4	10.6	22.0	Silt Loam
2000-2 Inside Pit	100	7.6	65.4	7.0	20.0	27.0	Silty Clay Loam
2000-2 Inside Pit	110	6.1	59.9	9.2	24.8	34.0	Silty Clay Loam
2000-2 Inside Pit	120	3.2	55.9	9.3	31.8	41.0	Silty Clay
2000-2 Inside Pit	130	3.3	59.7	10.8	26.2	37.0	Silty Clay Loam
Q2-SW Quad	0	38.5	50.5	2.8	8.2	11.0	Silty Loam
Q2-SW Quad	10	19.0	66.0	6.8	8.2	15.0	Silty Loam
Q2-SW Quad	20	18.7	66.3	6.7	8.3	15.0	Silty Loam
Q2-SW Quad	30	23.8	66.2	4.6	5.4	10.0	Silty Loam
Q2-SW Quad	40	23.1	62.9	3.5	10.5	14.0	Silty Loam
Q2-SW Quad	50	44.3	47.7	5.4	2.6	8.0	Loam

Q2-SW Quad	60	8.8	58.2	4.2	28.8	33.0	Silty Clay Loam
Q2-SW Quad	70	5.5	59.5	4.0	31.0	35.0	Silty Clay Loam
Q2-SW Quad	80	5.4	58.6	5.3	30.8	36.0	Silty Clay Loam
Q2-SW Quad	90	5.0	58.0	3.7	33.3	37.0	Silty Clay Loam
Q2-SW Quad	100	4.9	64.1	2.7	28.3	31.0	Silty Clay Loam
Q2-Feature #1	Sand Fill	97.4	2.6	0.0	0.0	0.0	Sand
Q2-Feature #1	30	21.5	65.5	7.5	5.5	13.0	Silty Loam
Q2-Feature #1	40	15.2	71.3	8.0	5.5	13.5	Silty Loam
Q2-Feature #1	50	21.2	66.8	9.3	2.7	12.0	Silty Loam
Q2-Feature #1	60	11.1	74.9	11.3	2.7	14.0	Silty Loam
Q2-Feature #1	70	11.2	73.8	9.7	5.3	15.0	Silty Loam
Q2-Feature #1	80	8.0	75.0	11.7	5.3	17.0	Silty Loam
Q2-Feature #1	90	18.4	67.6	8.7	5.3	14.0	Silty Loam
Q2-Feature #1	100	13.3	70.7	7.9	8.1	16.0	Silty Loam
Q2-Feature #1	110	21.5	62.5	8.1	7.9	16.0	Silty Loam
Q2-Feature #2	30	25.4	55.1	5.7	13.8	19.5	Silty Loam
Q2-Feature #2	40	20.5	65.5	5.9	8.1	14.0	Silty Loam
Q2-Feature #2	50	20.4	68.6	5.3	5.7	11.0	Silty Loam
Q2-Feature #2	60	15.0	76.5	5.4	3.1	8.5	Silty Loam
Q2-Feature #2	70	13.1	73.4	5.6	7.9	13.5	Silty Loam
Q2-Feature #2	80	13.3	75.3	8.7	2.8	11.5	Silty Loam
Q2-Feature #2	90	11.7	71.3	6.4	10.6	17.0	Silty Loam
Q2-Feature #2	100	13.3	70.7	10.8	5.2	16.0	Silty Loam
Q2-Feature #2	110	15.4	71.1	8.3	5.3	13.5	Silty Loam
Shane House	Sand Fill	96.4	3.6	0.0	0.0	0.0	Sand
Shane House	0	32.5	56.1	2.9	8.6	11.5	Silt Loam
Shane House	10	17.9	64.1	6.4	11.6	18.0	Silt Loam
Shane House	20	23.7	59.3	4.6	12.4	17.0	Silt Loam
Shane House	30	24.0	58.0	3.6	14.4	18.0	Silt Loam
Shane House	40	9.4	61.6	7.4	21.6	29.0	Silty Clay Loam
Shane House	50	6.9	61.1	10.3	21.7	32.0	Silty Clay Loam

*Unmeasured sediment refers to the difference between 100% and the sediment captured by the hydrometer method for each sample.

A second series of samples from the west profile were collected from within the boundaries of the apparent pit feature. Individual percent compositions of these samples, referred to as “inside the pit,” show a bimodal distribution for the first 90 centimeters (Table 2; Appendix C). In this section, the sand fraction (–1 to 4 phi) ranges from 13% to 57%, the silt fraction from 23% to 65%, and the clay fraction from 0% to 12%. There is a large spike of silt at 60 cm below surface, as indicated by the 5-phi fraction. Below 90 centimeters, the soil is characterized by a unimodal distribution dominated by silt and clay. There is no clear pattern in the percentages of unaccounted sediment as they relate to depth.

When textural profiles from inside and outside the pit are compared (Appendix C, Figure C.3), the most obvious difference is the significantly higher sand content (-1 to 4 phi) inside the pit. One possible explanation for this difference became apparent upon inspection of the sand fraction under a microscope.

These sand-sized grains appear to be small charred and fired clumps of clay possibly associated with root burning (Figure 16). Severe heating in forest fires has been shown to cause such fusion of clay particles elsewhere (Donaghey 1969, Dyrness and Youngberg 1957). Another difference is that percentages of sand, silt, and clay inside the pit are much more uniform than those outside. This pattern could result from turbation or sediment mixing resulting from natural or cultural disturbances.

Figure 16. Sand-sized grains from within the 2000-2 west profile pit feature. These grains appear to be small charred and fired clumps of silt and clay.

6.3.2 Unit Q2: SW Balk, Feature #1, and Feature #2 Granulometry Results

Unit Q2 SW Balk (Table 2; Figure C.4) is characterized by a large silt fraction that generally decreases with depth until 60 cm, when it starts to rebound. The sand fraction in the Q2 SW Balk decreases with increasing depth, and falls off dramatically at 60 cm below surface. This decrease in sand probably reflects the upper limit of the B-horizon. The percentage of unaccounted sediment in Q2-SW Balk increases drastically with depth, and may represent clay particles that did not have time to settle in the experiment, as discussed in section 6.3.4 below. Q2 Feature #1 (Figure C.5) has a less clear pattern in terms of sand, silt, and clay fractions than does the SW Balk. The fractions do not seem to vary, directly or indirectly, with depth and may indicate mixing. Q2 Feature #2 (Figure C.6) exhibits a more regular pattern, as the sand fraction has an inverse relationship with depth and silt has a direct relationship with depth, however it is not as clear as Q2 SW Balk. Nevertheless, Feature #2 does not appear as heavily mixed as Feature #1.

6.3.3 Shane House Unit Granulometry Results

Following a previous excavation of the Shane House unit, construction-grade sand fill was used to refill the hole and to clearly mark archaeological activity. Grain-size analysis on the sand fill was conducted in order to assess whether this sediment was responsible for any patterns observed in the Shane House granulometry results. The sand fill consisted primarily of 3-phi sand fraction and may have contributed to the pattern observed in the 0 cm sample, but did not infiltrate further down the column (Table 2; Figure C.7). As a result, the sand fill is not included in the following discussion.

The Shane House hydrometer analyses show roughly uniform silt content at all depths, ranging from 56% to 64% (Table 2; Figure C.7). Clay content, between 3% and 10%, increases with depth. The sand content fluctuates between 7% and 33%, but generally decreases with depth. An interesting pattern is the increasing percentage of unmeasured sediment with depth. As discussed below, this trend may result from large clay concentrations in deeper samples and the inability of the hydrometer analyses to capture these very fine fractions.

6.3.4 Sources of Potential Error

Systematic error may have been introduced by the hydrometers themselves. The hydrometers are not uniform in their reflection of R_L and the six hydrometers used here vary in their control cylinder reading, ranging between 6 and 7 grams per liter. One hydrometer remained in the control cylinder for the duration of the sampling schedule, while a different hydrometer was used to measure the settling velocities of the sample. Most samples, however, were tested with the same hydrometer for the duration of the measuring schedule, rendering them internally consistent.

Another source of error, albeit a minor one, is the sediment lost when the hydrometers were removed from the cylinders between readings. The decision to remove the hydrometer after the five-minute reading was made in order to reduce the disturbance caused to the suspended sediments. Meriaux (1952) documents such a disturbance and recommends that it can be avoided by restirring the solution after each measurement. However, this procedure adds significant time to the analysis. Instead, the hydrometer was removed and any adhering sediment was washed off, which usually resulted in a very small amount of sediment loss.

Most of the sampling schedules ended after the 720-minute reading. Upon initial calculation of the percentage of captured sediment (by weight), less than the recommended 95% capture volume had been achieved. It was postulated that, due to the very fine-grained nature of our samples, the clay and silt fractions were not given enough time to settle. A 1440-minute reading was recorded on subsequent samples in an attempt to compensate for the low retention rates. Even after a 1440-minute reading, many samples maintained a high percentage of unmeasured sediment. This fraction, ranging between 3% and 40%, is most likely clay that did not have sufficient time to settle and was lost when the cylinders were poured through a 4-phi screen.

In some cases, the sand fraction is characterized by many aggregates, presumably composed of clay particles, which are most likely cemented by iron oxide or magnesium oxide. These aggregates were not dispersed by the peptizing agent or mechanical mixing. These aggregates could increase the clay fraction by five to ten percent, and could account for the apparently low clay fraction.

6.3.5 Field Correlation

Textural classification in the field closely matches textural classifications determined by the hydrometer analyses. This independent support for the hydrometer results mean that experimental errors were not so great as to significantly affect the interpretation. Where field classifications and hydrometer classifications do differ, they are along classification boundaries and are within the range of reasonable error.

6.3.6 Wet-Screening (Charcoal) Results

The charcoal percentages for the column sample from Unit 2000-2 are provided in Table 3. Charcoal percentages are low throughout the column, and there are no clear patterns in the distribution.

Table 3. Charcoal percentage by depth, Unit 2000-2.

Sample #	Depth (cm)	Weight w/ bag (g)	Bag Weight (g)	Sediment Weight (g)	Charcoal Weight (g)	% Charcoal
0	0-5	257.4	10.8	246.6	0.0597	0.02%
0.5	5-10	411.7	12.3	399.4	0.4948	0.12%
1	10-15	641.3	11.2	630.1	2.0609	0.33%
1.5	15-20	993.9	10.5	983.4	2.1511	0.22%
2	20-25	949.3	11.0	938.3	0.6872	0.07%
2.5	25-30	1205.4	21.9	1183.5	0.9129	0.08%
3	30-35	1070.7	10.9	1059.8	0.8448	0.08%
3.5	35-40	974.8	11.7	963.1	0.3428	0.04%
4	40-45	940.8	10.7	930.1	0.3419	0.04%
4.5	45-50	1053.4	11.1	1042.3	0.6097	0.06%
5	50-55	949.3	12.2	937.1	0.6107	0.07%
5.5	55-60	975.0	10.6	964.4	0.6686	0.07%
6	60-65	1039.7	10.9	1028.8	0.6313	0.06%
6.5	65-70	867.3	10.9	856.4	3.5646	0.42%
7	70-75	1075.7	11.3	1064.4	0.4980	0.05%
7.5	75-80	908.7	11.4	897.3	0.7182	0.08%
8	80-85	907.3	21.7	885.6	1.8053	0.20%
8.5	85-90	1166.4	11.1	1155.3	0.8700	0.08%
9	90-95	967.2	12.4	954.8	0.4712	0.05%
9.5	95-100	979.8	10.2	969.6	0.3502	0.04%
10	100-105	924.2	10.7	913.5	0.4253	0.05%
10.5	105-110	1021.4	21.8	999.6	0.5971	0.06%
11	110-115	1064.5	11.3	1053.2	2.2941	0.22%
11.5	115-120	1115.7	11.3	1104.4	0.3542	0.03%
12	120-125	1186.2	11.0	1175.2	0.0540	0.00%
12.5	125-130	971.8	10.9	960.9	0.2329	0.02%

6.4 Thermal Analysis Results

LOI results are presented in Table 4 and Table 5, and shown graphically in Figure 17, Figure 18 and Figure 19. Organic matter and carbonate levels observed are consistent with those expected in a temperate, deciduous forest. Due to variations in disturbance and accumulation of leaf litter, it is anticipated that organic matter may vary widely in samples within 10 to 20 cm of the surface, and that these variations have no bearing on the archaeological questions being addressed. The validity of this expectation is illustrated in Table 4, which shows organic matter ranging between 28 and 88% at 0 cm, and between 18 and 24% at 10 cm.

Table 4. Percent Organic Matter, all units.

Depth (cmbs)	2000-2 Inside Pit	2000-2 Outside Pit	Shane House Field Tie	Q2 SW Balk	Q2 Feature 1	Q2 Feature 2
0	27.13	88.31	41.23	18.95	Sand Fill	Sand Fill
10	23.54	22.19	21.46	18.17	Sand Fill	Sand Fill
20	16.99	17.52	19.95	16.93	Sand Fill	Sand Fill
30	16.48	17.57	19.16	17.22	16.54	16.30
40	17.81	13.97	12.51	17.00	15.08	13.83
50	16.73	11.48	9.37	10.95	16.60	11.78
60	13.34	9.95	N/A	8.65	15.01	9.94
70	11.71	9.03	N/A	8.41	13.16	9.94
80	9.96	8.26	N/A	7.93	12.21	9.93
90	9.37	8.08	N/A	7.42	12.99	10.41
100	10.39	7.59	N/A	7.51	11.72	8.79
110	8.97	7.17	N/A	N/A	9.81	8.94
120	7.88	6.49	N/A	N/A	N/A	N/A
130	7.36	5.98	N/A	N/A	N/A	N/A

Table 5. Percent Carbonate, all units.

Depth (cmbs)	2000-2 Inside Pit	2000-2 Outside Pit	Shane House Field Tie	Q2 SW Balk	Q2 Feature 1	Q2 Feature 2
0	2.48	0.76	2.00	1.58	Sand Fill	Sand Fill
10	2.06	3.95	2.93	1.78	Sand Fill	Sand Fill
20	1.98	2.57	1.95	1.77	Sand Fill	Sand Fill
30	1.82	2.60	1.93	1.69	2.49	2.16
40	1.97	2.78	2.25	1.61	2.21	2.12
50	2.16	2.88	2.67	2.21	1.98	2.23
60	2.74	3.41	N/A	3.20	2.78	2.33
70	2.52	3.30	N/A	2.84	2.11	2.33
80	2.44	3.20	N/A	2.66	2.47	2.35
90	2.42	2.91	N/A	2.71	2.60	2.36
100	2.47	3.11	N/A	2.60	2.37	3.27
110	2.58	2.94	N/A	N/A	2.46	2.51
120	3.37	3.19	N/A	N/A	N/A	N/A
130	2.62	3.45	N/A	N/A	N/A	N/A

In samples from 20 cm depth and below, all profiles show a similar pattern of declining organic matter content with increasing depth (Figure 17, Figure 18, and Figure 19). This suggests that the primary source of organic matter in pedogenesis derives from plant and animal matter accumulating at the surface, rather than through subsurface plant root growth and animal burrowing. In several profiles, there are slight increases in organic matter (e.g., Unit 2000-2 (Inside Pit) at 40 cm and 100 cm). While these subsurface increases could be interpreted as buried paleosols (once-stable land surfaces, which accumulated organic matter and subsequently were buried), the slight increases are within the range of experimental error and are dismissed as statistically insignificant. Similarly, slight differences between features within the same units, and between units themselves, are within the range of experimental error. All profiles show a general pattern of declining organic matter content with increasing depth. This decline suggests that the primary source of organic matter is forest organic matter derived from plant and animal litter accumulating at the surface, and not from pit-fill deposited by people.

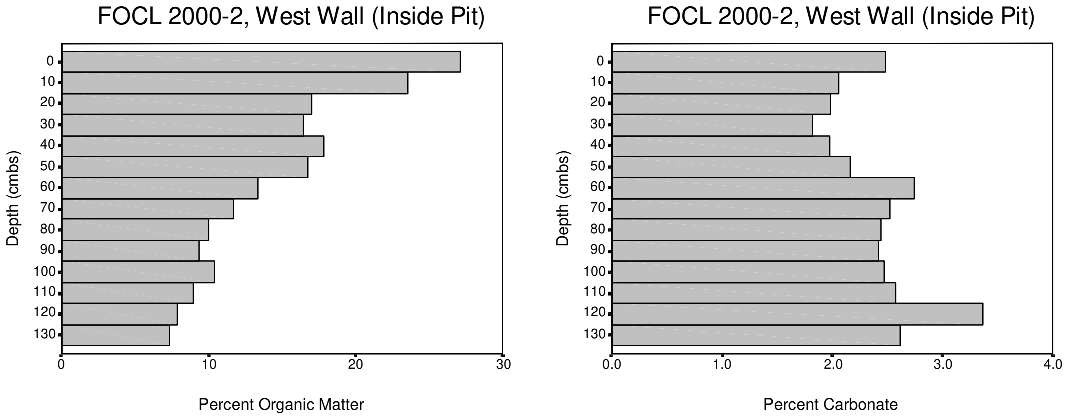

Figure 17. Percent organic matter and carbonate, Unit 2000-2, inside and outside the pit.

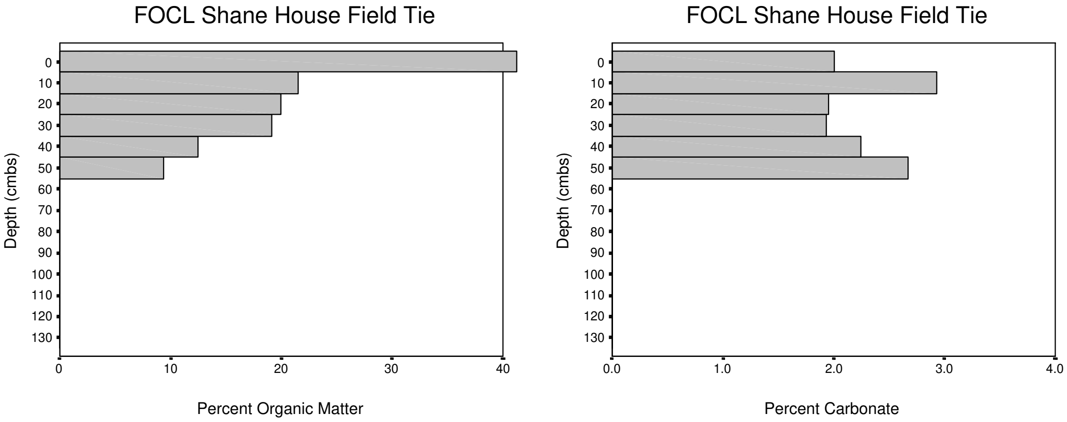

Figure 18. Percent organic matter and carbonate, Shane house field tie unit.

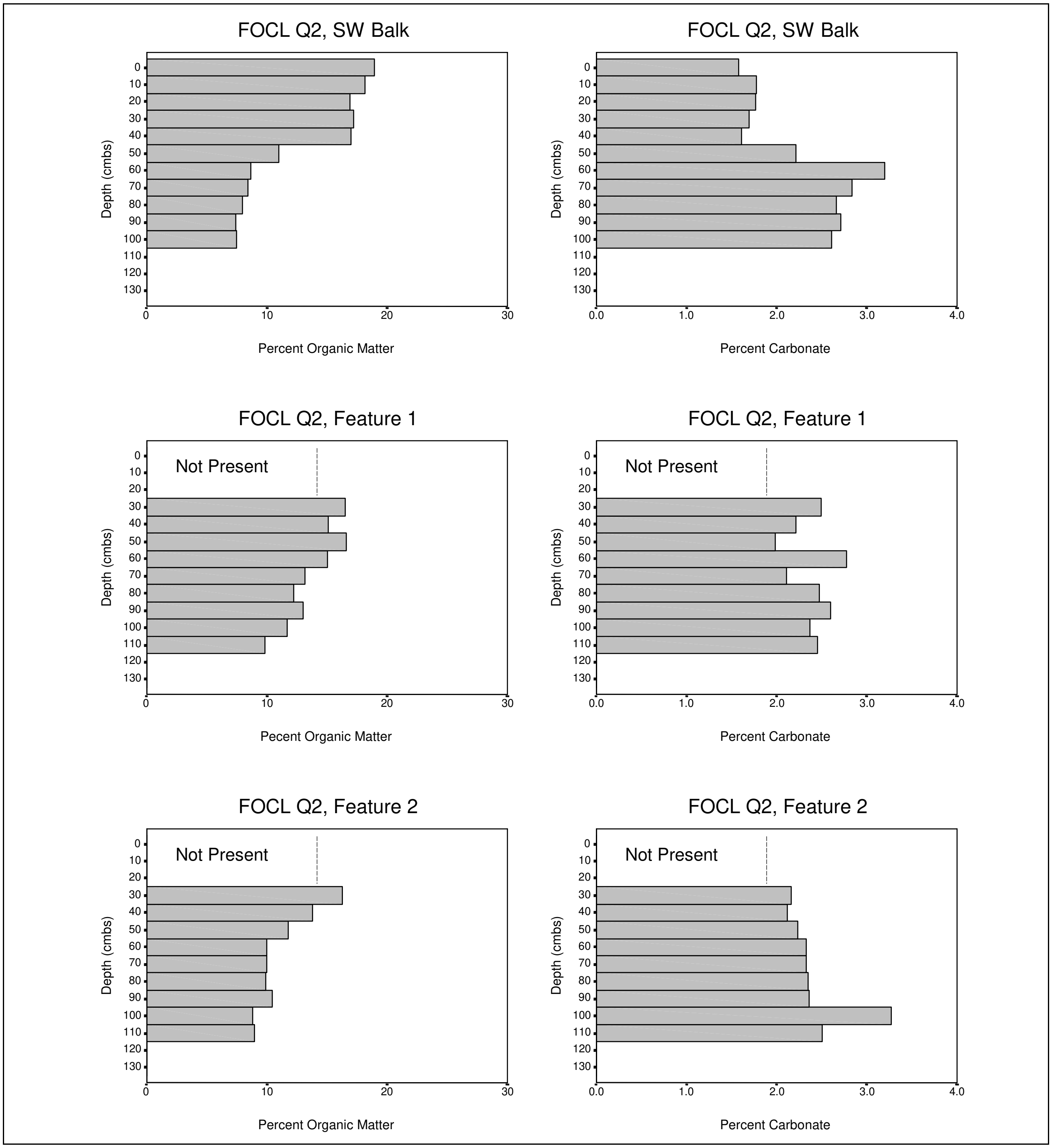

Figure 19. Percent organic matter and carbonate, Unit Q2 SW Balk, Feature 1, and Feature 2.

In so far as LOI tests the chemical composition of the profiles in question, the pit in Unit 2000-2 is chemically identical to adjacent sediments from outside of the pit. In Unit Q2, Features 1 and 2 are indistinguishable chemically from one another, as well as from surrounding sediments (SW Balk).

Examination of TGA curves (Figure 20) corroborates the LOI results for Unit 2000-2.

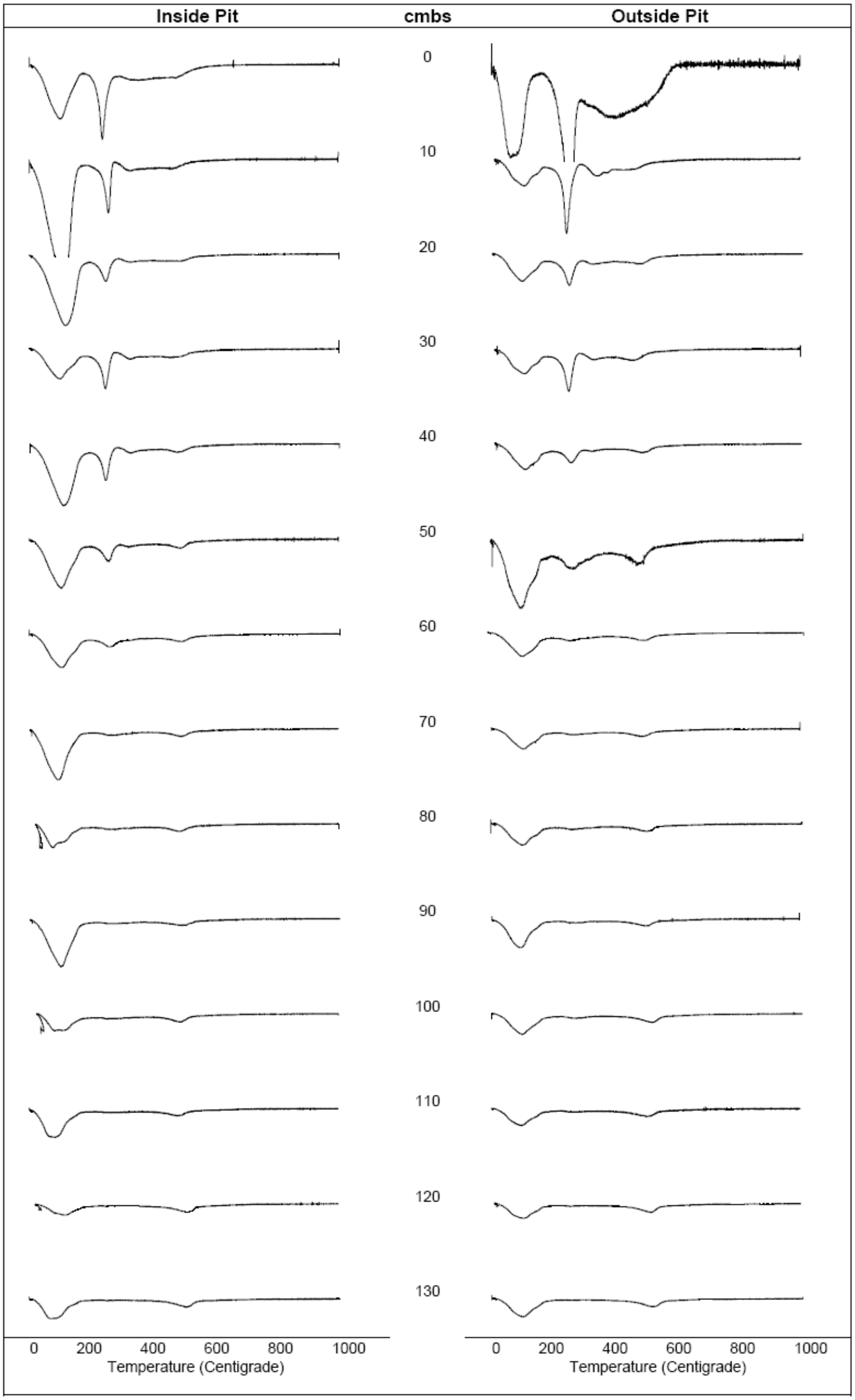

Figure 20. TGA curves for Unit 2000-2, inside and outside the pit, arranged by depth.

6.5 Phosphorous Results

Phosphorous results for Unit 2000-2 are shown in Figure 21, which is a plot of the total phosphorous concentrations vs. depth below surface, showing the data for samples inside and outside the pit. Total phosphorous levels range from as low as 52 ppm to as high as 672 ppm. As might be expected, the lowest P values generally occur at greater depths while the higher values are found near the surface. Phosphorous enrichment occurs at the ground surface, where P sources such as plant debris and fertilizer may be present. Thus, P levels are expected to be the highest at the surface and should decrease down the profile.

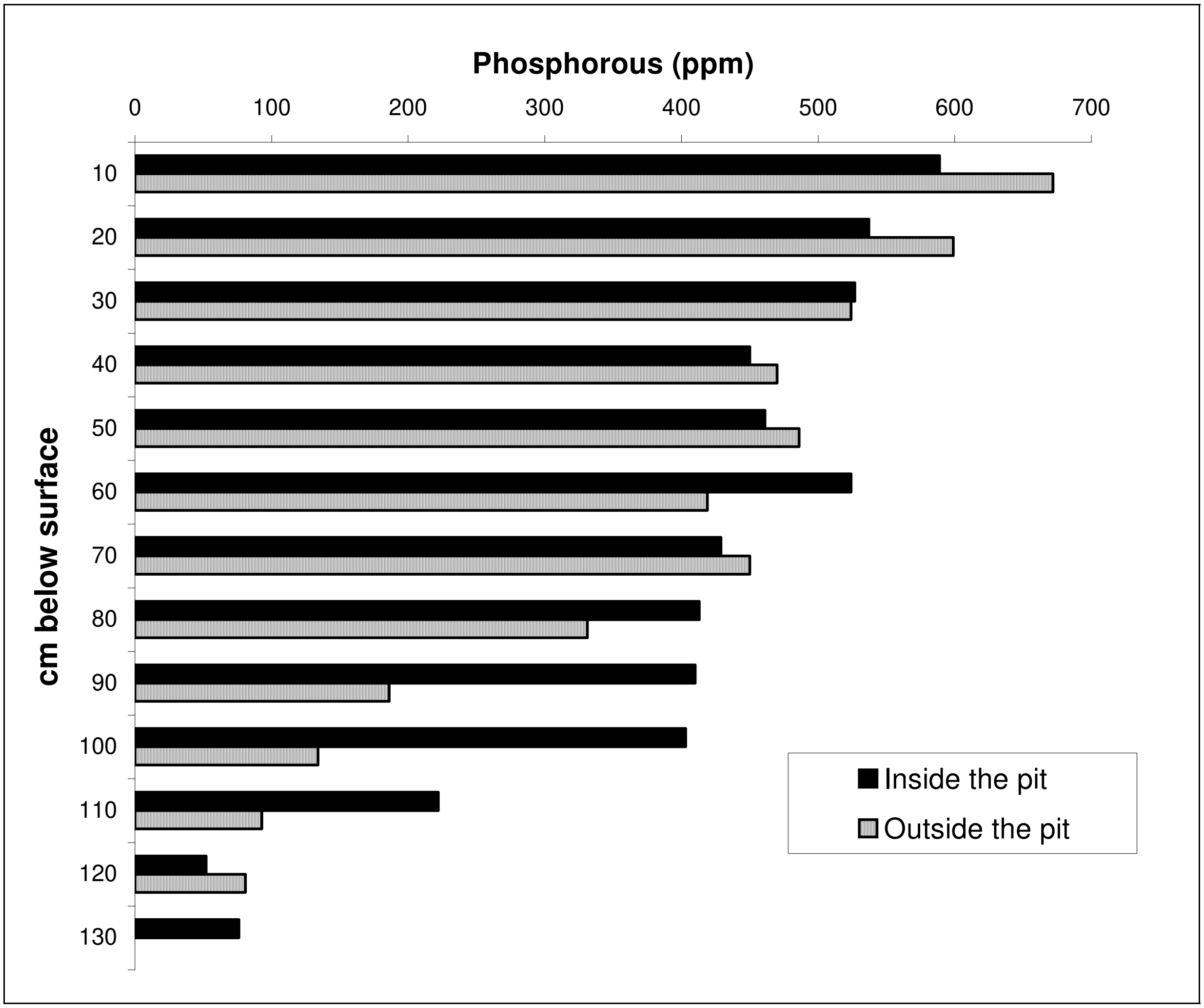

Figure 21. Total phosphorous concentrations (ppm) for Unit 2000-2, inside and outside the pit.

Phosphorous levels inside and outside the pit are generally similar. It can be noted, however, that phosphorous levels inside the pit are significantly higher than the P levels outside the pit between 90 and 110 centimeters below the surface. As the stratigraphic profiles of this unit show, the pit extends to a depth of about 110 centimeters, so the greater P levels at this depth are detecting the bottom of this pit. However, P levels as a whole are not higher inside the pit than they are outside the pit, so the feature was probably not an anthropogenic pit filled with organic waste.

It is also interesting to note that the phosphorous levels measured at this location are lower than P levels measured in other parts of the landscape (Kiers and Stein 1998). The location of this excavation unit was selected because it was thought to be on a relatively undisturbed area of the landscape. The elevated P levels detected in the previous study, then, are possibly due to agriculture and the application of fertilizer. It appears that the area around unit 2000-2 was not farmed, or that fertilizer was not used.

6.6 Micromorphology Results

A total of 35 micromorphology samples were collected. Twenty samples were mounted onto slides for analysis. Results of the micromorphological analysis lend support to the hypothesis that the subterranean features in the project area are not anthropogenic in nature. A selected number of micromorphological samples are described in detail below.

Micromorphological analysis of a dark red lens identified 30 cm below surface in the east profile of Unit 2000-2 revealed a combination of minerals (quartz, plagioclase, and muscovite) and heavily rubified organic components (Figure 22). Importantly, many of the quartz grains are deformed, indicating that they have been exposed to high temperatures. Further, the organic components are extremely friable and clumped into aggregates, suggesting that they were burned. However, no evidence of wood–ash is present in any part of the sample, suggesting that the temperature of the fire was greater than 600°C. Such a high temperature is more consistent with subterranean root burning than with a localized surface burning such as a hearth. Further, voids (hollow spaces between soil aggregates) are filled with smaller grains of quartz and plagioclase; this infilling suggests that the sediment had been disturbed following oxidation, possibly as the void caused by root burning collapsed under the weight of overburden. In any event, the morphology and composition of the dark red lens shows no evidence of an anthropogenic origin.

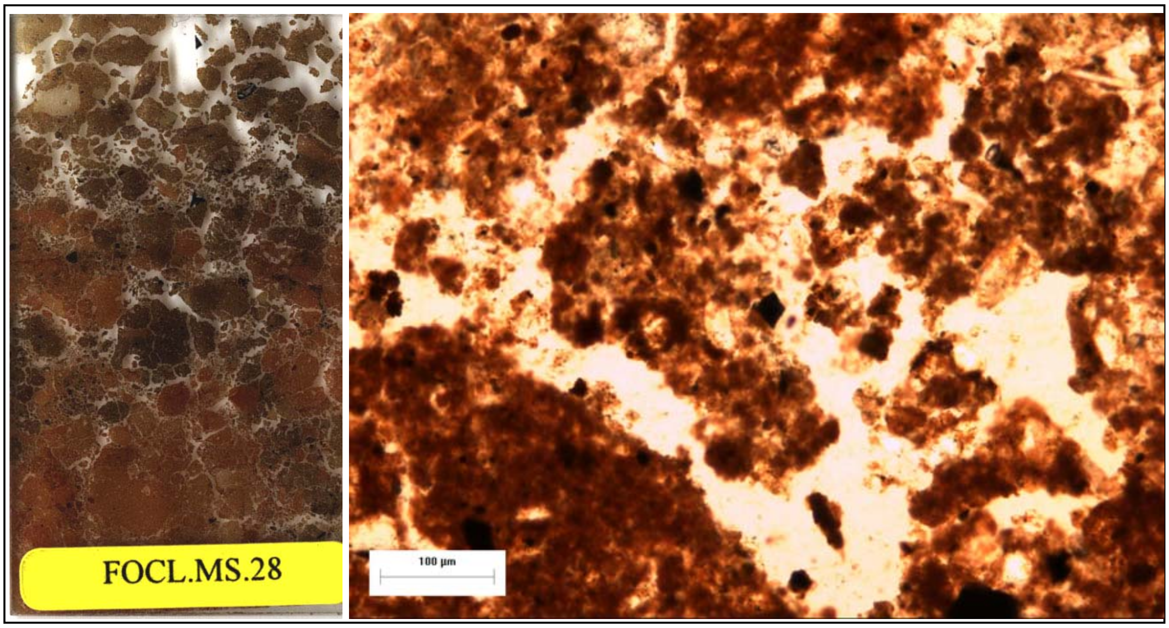

Figure 22. Micromorphology slide MS.28 (left), and at 100X magnification (right). MS.28 is from the east profile of Unit 2000-2, from 23-31 cm below surface. Note that the top of the slide is unburned while bottom of slide is reddened. The photomicrograph at right shows extent of rubification in the bottom third of the slide. The scale at lower left is 100 microns.

In contrast to slide MS.28, micromorphological slide MS.27 shows an undisturbed sample from Unit 2000-2 (Figure 23). The sample, from the west profile at a depth of 118-126, reveals higher amounts of clay and silt sized particles at this depth. Most importantly, the sediment is massive; there are very few voids and nearly no planes or channels, indicating that there has been little to no disturbance. Evidence of burning or charcoal is also lacking.

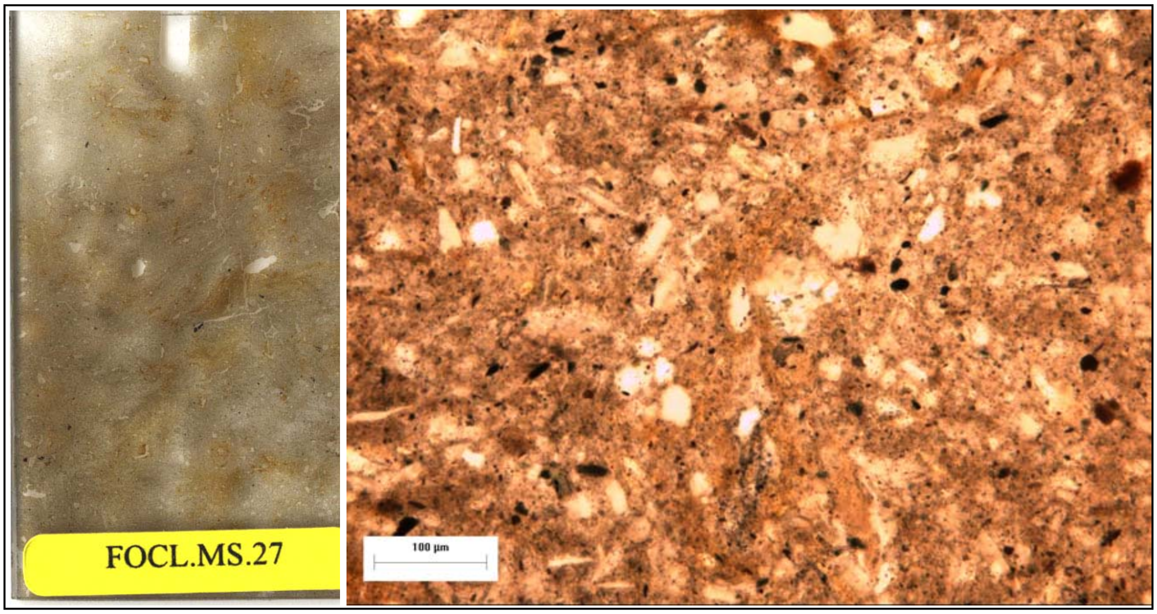

Figure 23. Micromorphology slide MS.27 (left), and at 100X magnification (right). MS.27 is from the west profile of Unit 2000-2, from 118-126 cm below surface. The photomicrograph shows lack of voids and lack of burning. Darker nodules are unburned organic matter. The scale at lower left is 100 microns.

Similarly, micromorphological samples from both within and without Feature 1 in excavation unit Q2 suggest a non–human origin. Under the petrographic microscope sediment from within the pit feature shows clear signs of turbation in the form of clumping and channel infilling, as seen in slide MS.9 from the pit feature at a depth of 58-64 cm (Figure 24). The sediment is composed of quartz, plagioclase, and micas interspersed with what appears to be aggregates of grey and yellow rip–up clasts. Despite the evidence for turbation, there is no microscopic evidence to support the hypothesis that the pit represents an historic privy. There is no evidence of micro–artifacts, faunal remains, or diatoms (which tend to be prolific in such settings). Additionally, there is no evidence of fecal material, although groundwater movement and bacterial action in the region could have largely removed such evidence. Analysis of sediment outside of the pit feature, as seen in sample MS.5 (Figure 25), shows little to no evidence of turbation and indicates the presence of slaking crusts, which tend to form as the structural elements of soils are destroyed by the mechanical force of precipitation (Jongerius 1983). Comparison of sediments from both within and without the pit feature suggests that the feature has been significantly disturbed and does indeed represent a pit; however, no evidence is present that suggests an anthropogenic origin.

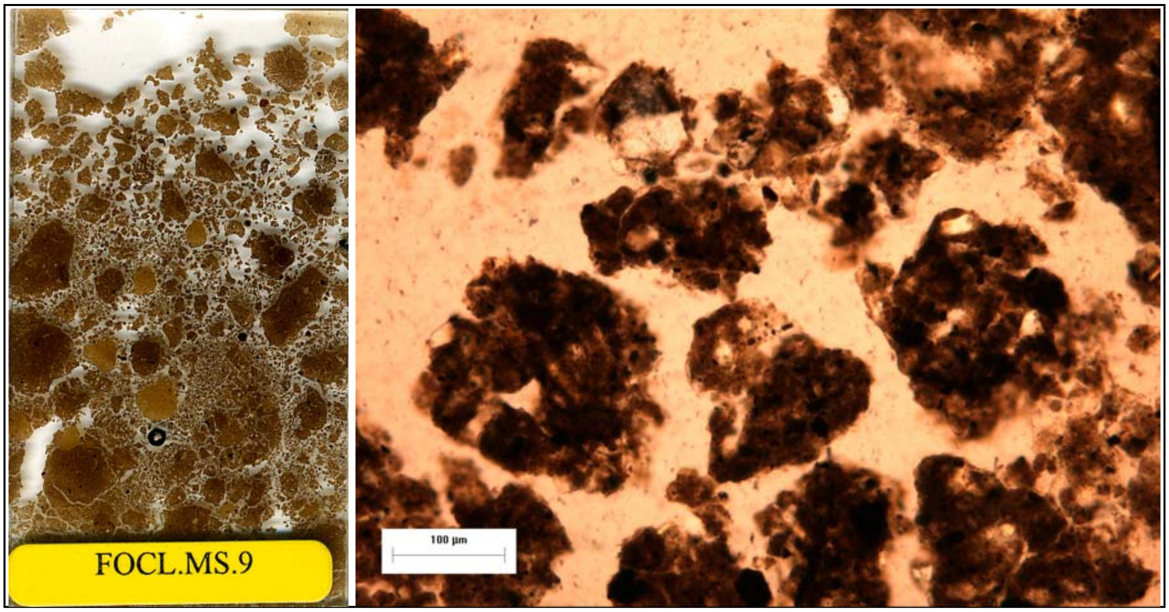

Figure 24. Micromorphology slide MS.9 (left), and at 100X magnification (right). MS.9 is from Unit Q2, Feature 1, at a depth of 58-64 cm. Note the mixing of darker, spodzoic soil with lighter sediments. The sediment is clumpy, and clumps are surrounded by channels filled with silica. The scale at lower left is 100 microns.

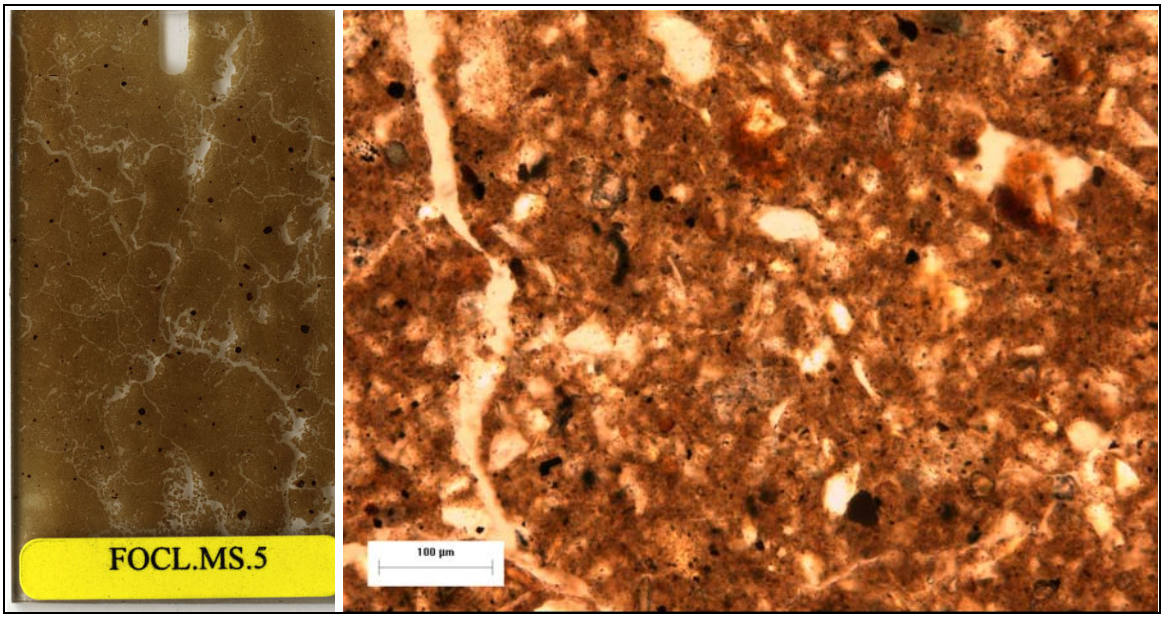

Figure 25. Micromorphology slide MS.5 (left), and at 100X magnification (right). MS.5 is from Unit Q2, SW Balk, from outside the pit feature at a depth of 78-86 cm. Note the massive sediment and lack of mixing. Planar voids are likely root disturbances. Reddish nodules are clay aggregates. The scale at lower left is 100 microns.

6.7 Polished Section Results

6.7.1 PolSec1 Results

In cross section the brick appears to be fully oxidized (as indicated by the uniform red color) (Figure 26). This is consistent with subjection to extreme temperatures. Mineralogically, the sample is composed mainly of clay and silt sized grains, some of which are stained with hematite (FeO). This staining may be due to the makeup of the minerals within the brick or may have been deposited through water movement while *in situ*. The sample also contains a number of identifiable and unidentifiable minerals, most notably smoky quartz (SiO_2) and biotite. Interestingly, a number of voids are visible on the surface. These may indicate either organic elements inherent in the brick that were destroyed during burning; alternatively, they could represent impressions left by minerals that were removed during cutting. In total, observable minerals comprise approximately 5-10% of the visible surface area. (Note: this figure was based on gross approximations of mineral size under the microscope to the exposed cross-section. No quantifying method was employed.) The most notable characteristic of the brick sample was its degree of compaction and cementation. As noted above, the brick was extremely hard and could only be broken using a saw. This is characteristic of typical fired brick ware and is not unusual.

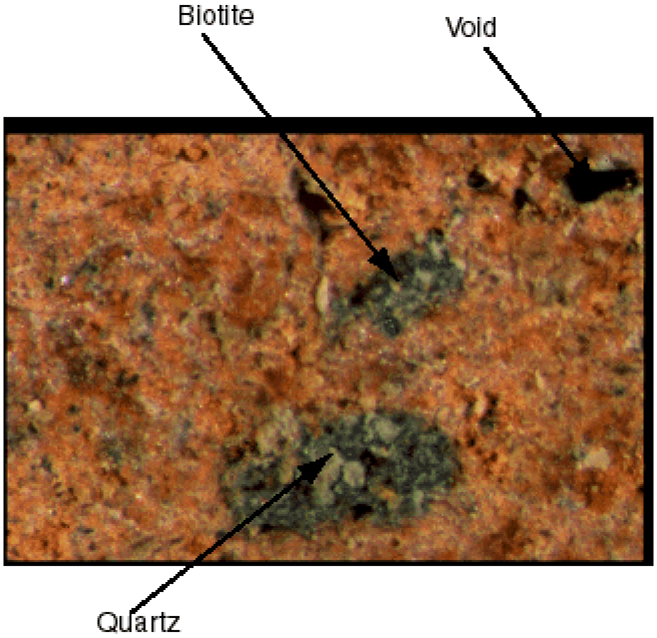

Figure 26. PolSec1 at 30x magnification. At this resolution, individual grains of biotite and quartz can be discerned. The orange-ish grains are burned sediment. Voids in the cross-section may be the result of minerals breaking off of the surface during sawing.

6.7.2 PolSec2 Results

In cross section the sample appears to be fully oxidized (Figure 27). Mineralogically, the unknown sample strongly resembles the brick sample. It is comprised mainly of clay to silt sized particles that have been burned, interspersed with visible minerals including smoky quartz and biotite. Even a gross estimate of the amount of visible minerals observable is difficult due to the lack of compaction evident in the sample; however, approximately 5% of the surface area seems to be comprised of these minerals. Voids are not observable in the sample; again, this is probably the result of compaction. Degree of compaction is a defining characteristic of this sample; compaction and cementation is minimal, and the mass easily falls apart when touched.

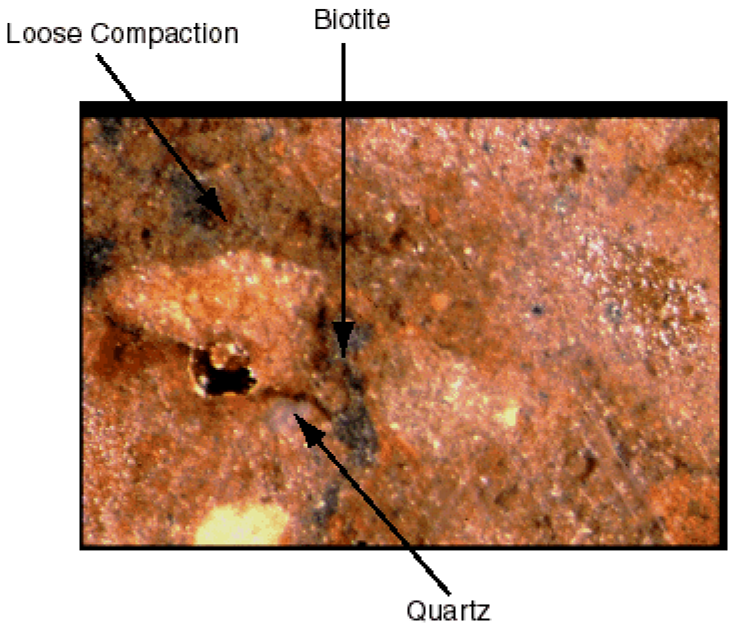

Figure 27. PolSec2 at 30x magnification. As in PolSec1, biotite and quartz are visible. Voids are present throughout the sample; in this case, loose compaction of the sediment may be the likely cause.

Given this information, it is possible that both samples were derived from the same parent material. Further, both appear to have been exposed to high temperatures. If the first sample truly is a brick, is it fair to say that the reddish-brown mass is as well? Two obstacles stand in the way of this comparison. First, the lack of compaction evident in the PolSec2 sample must be explained. What, if any, processes could break down the bonds holding this mass together while leaving the brick untouched? Moreover, the size of the mass is at issue. The burned mass itself seems too large to be a brick, although it is not so large as to be non-portable. Based on the petrographic results alone, it is unclear how this mass should be treated. However, the analyses of the surrounding matrix described above suggest burning not associated with brick manufacture may explain the origin of this material.

6.8 Petrographic Results

6.8.1 Pet1 Results

The sample can be divided into two distinct zones: the unweathered interior and the weathered rind. Mineralogically, both zones are similar, but also have some noticeable differences. Both regions are predominantly composed of numerous euhedral prismatic crystals that seem to be aligned along two axes (in this case, x and y; visual inspection shows that all visible crystals are lying on their sides, so to speak; the thin section truncates none vertically). The shape and size of the crystals suggest that they could either be quartz (SiO_2) or feldspar ($CaAl_2Si_2O_8$). When the sample is rotated under the microscope using the analyzer the minerals display a clear twinning property, meaning that differing extinction orientations within the same mineral have planar contacts (Figure 28). This is observable in the sample with the alternating blue and yellow-orange color of the minerals. However, the failure of some crystals to demonstrate this property suggests that quartz is also likely to be present in the sample. Based on the available information, the twinning mineral is probably a plagioclase feldspar ($CaAl_2Si_2O_8$) or an alkali feldspar (microcline) ($KalSi_3O_8$). If the latter is the case, the development of clay in the region may partly be explained as a result of microcline alteration, given the following equation:

3 microcline + 2 $H_2O \rightarrow$ illite + 6 silica + 2 potash

or, if excess water is present:

2 microcline + 3 $H_2O \rightarrow$ kaolin + 4 silica + 2 potash

Seen in polarized light, the feldspar crystals exhibit a first order color of gray (Figure 29).

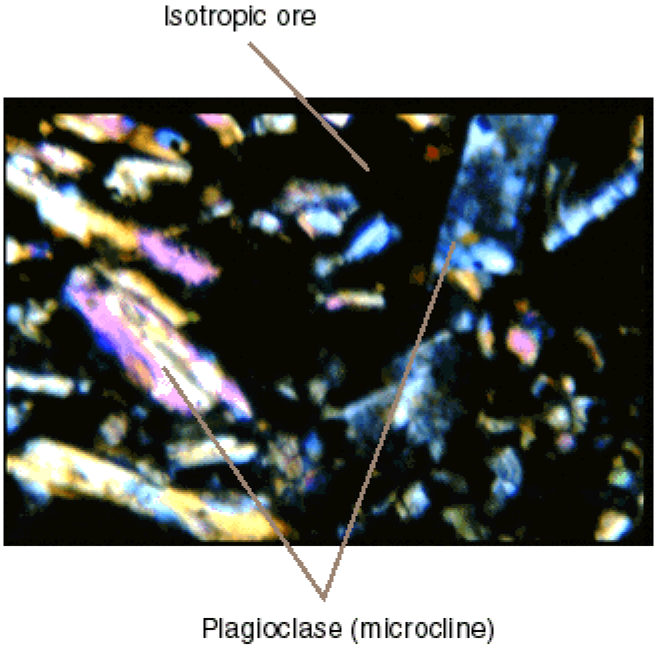

Figure 28. Pet1 shown with tint plate (analyzer in) at 20x. Plagioclase minerals appear to change color from yellow to pink to blue as they are rotated on the slide. Isotropic ore, which by its nature does not transmit light, appears black throughout the photograph. The use of the tint plate allows interference colors to be seen.

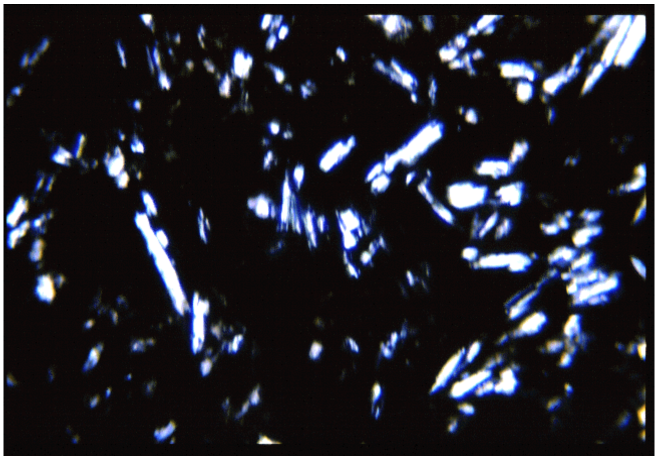

Figure 29. Pet1 shown without analyzer at 20x. The same photograph as above, but without the tint plate. Plagioclase is clearly the most dominant anisotropic mineral in the cross section.

Surrounding the feldspar crystals throughout the rock is (1) biotite and (2) some sort of isotropic mineral. Due to its isotropic properties, light is not transmitted through the ore and therefore has no bi-refringence (Craig and Vaughan 1981). Exact identification of the isotropic component was not established; however, evidence suggests that this mineral may contain hematite (Fe_2O_3). The reason for this supposition is that the primary difference between the weathered and non-weathered zones of the sample (mineralogically speaking) was the existence of hematite exsolvents. Exsolvated hematite is abundant throughout the outer rind of the rock. Exsolvation refers to the fact that non-hematite crystals (i.e. feldspar) have been coated with hematite. Nowhere in the thin section is there evidence for fully formed hematite (which generally appears as hexagonal and tabular crystals with no cleavage). Thus, it may be the case that the hematite is being derived from the isotropic component of the sample upon exposure to water.

6.8.2 Pet2 Results

This sample is identical to Pet1 in many regards, but is very different from Pet1 in the degree of weathering. Pet2, which was extracted from a position at or below the water table, has possibly been exposed to inundation with water for a longer period than Pet1. This is evident in that the weathering rind of the sample encompasses most of the rock, leaving a thin, figure-8 shaped non-weathered interior. The non-weathered section looks mostly identical to the corresponding area of Pet1; the only observable difference is that the abundance of feldspar seems to be slightly less in Pet2. This could be due to alteration of the minerals, but formational processes should not be ruled out. Again, the feldspar is surround by an isotropic component, most likely some sort of hematite ore.

The weathered region of the rock appears to be comprised mostly of feldspar. There appears to be heavy hematite exsolvation. Moreover, there is some evidence of quartz in the outer rind. A significant amount of this quartz has been hematite stained as well (Figure 30). The appearance of sparse amounts of quartz in the outer rind is not surprising given the equations mentioned above.

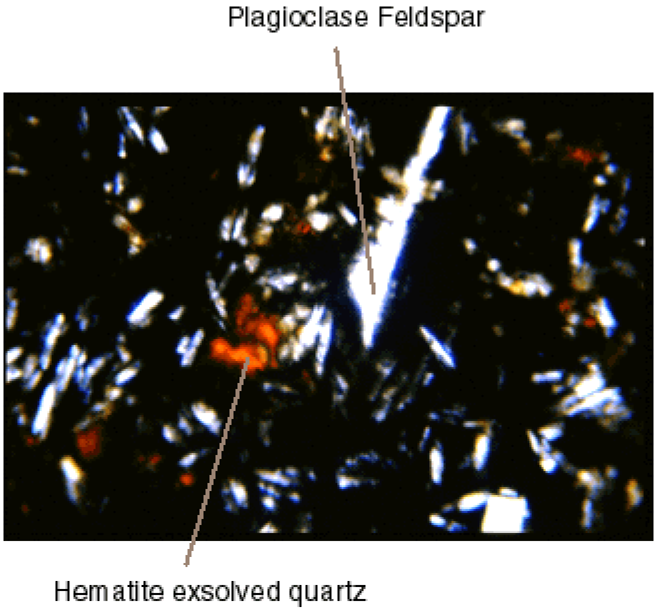

Figure 30. Pet2 without analyzer at 20x. Even without the use of a tint plate the orange-ish color of the hematite can be seen. Hematite does not exist as independent crystals within the rock itself, but rather as coating on the quartz crystals.

Possibly the most interesting feature of the outer rind is the appearance of a tabular, greenish mineral (not pictured). Based on available data, this mineral is most likely some variety of covellite (CuS) (Gribble and Hall 1992). Covellite appears as an idiomorphic greenish hexagonal crystal, often as a secondary mineral in a zone of alteration. The appearance of this mineral could indicate that either the isotropic component is partially comprised of copper or that copper is present in the groundwater of the region.

It seems likely that both Pet1 and Pet2 represent roughly identical materials subjected to different degrees of physical and chemical weathering. Neither of these rocks appears to have been modified by human agents; moreover, human transportation of these rocks is not likely. Based on the petrographic description of these samples, it is likely that they represent graywackes derived from the Youngs Bay Miocene formation (after Walsh 1987). The fact that such seismically produced rocks are common in the region sheds some light on the influence of regional subduction on local geology. Finally, it is suggested that much of the clay found in the terrace underlying Fort Clatsop is derived from alkali feldspar alteration of the abundant graywackes.

7.0 CONCLUSIONS

The results of these excavations and analyses offer compelling, alternative, natural explanations for features that have been commonly attributed to cultural processes. The study reveals a pattern of natural disturbance extending across the entire terrace landform on which Fort Clatsop rests. The data suggest several possibilities for the origins of the variety of "pits" described by previous archaeologists searching for the fort.

Grain-size analyses highlighted the presence of sand-sized concretions of clay and silt. Although the origin of these concretions is unknown, it is possible that they were created during high-temperature burning of sediments. Some of the concretions have a charred appearance. In Unit 2000-2, these concretions were significantly more abundant inside the observed pit feature than they were outside the pit. Charcoal was abundant across the entire landscape, but this pit feature contained a relatively high amount of charcoal. Taken together, these data suggest that forest fires may be responsible for some of the pit features on the Fort Clatsop landform.

The red lenses of oxidized sediments observed in Unit 2000-2 seem to be ubiquitous across the landscape. The micromorphological data indicate that the reddened sediment lenses had been subjected to high temperatures. Thomas (1989) was the first to suggest that these oxidized sediments may be due to root fires, and our data support this. The discussion of the landform on which the fort is situated also calls into question cultural explanations for the origin of the burned lens-shaped features. These features are consistently found at depths of at least 20 cm below surface. If these features are historic hearths, there would need to be a significant sediment source for them to be buried to such depths within the past 200 years. No such sediment source exists, since the fort rests on an elevated ancient terrace well above the modern floodplain. Explanations for the formation of these features requires some process by which they may form through *in situ* burning, such as the burning of tree roots.

Some of the pit features were most likely created by subsurface disturbances besides, or in addition to, burning, as evidenced by the structure of some observed features. The mottled and mixed nature of these sediments suggests that pits were created and then filled back in. The phosphorous analysis suggests that the previous interpretation of these features as trash or privy pits is unlikely. An alternative mechanism for the creation of these pits is by windthrow or forest harvest and subsequent infilling.

The "pits" excavated and described by archaeologists at Fort Clatsop have commonly been interpreted as cultural features such as fire hearths or privies. The historical and geoarchaeological research presented here suggests several alternatives for the origin of these pits. There is no data to suggest an early 19th-century Lewis and Clark origin for any of these features. Rather, the evidence suggests that fires and tree disturbances may have created these ubiquitous "pits." These could be natural fires or windthrow occurring several decades before Lewis and Clark's arrival at the site, or the activities of homesteaders and loggers burning and removing trees several decades after Lewis and Clark left for St. Louis.

The widespread disturbance of the landform has important implications for the continuing search for the remains of the original fort, and it is critical that archaeologists attempting to decipher the evidence have an understanding of the dynamic nature of this landscape.

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Appendix A: Soil Profile Description Forms

Table A.1

Unit: FOCL Q-2 Wall: South Page: 1 of 1 Date:11/18/2000 Archaeologist(s): Chris Lockwood

Horizon	Depth (note in/cm)	Boundary distinctness	Boundary topography	Texture Sand Clay Class	Color Hue Value Chroma	Redox Abun. Size Cont.	Structure Type/Grade	Consistence (moist)	Special Features
A_1	0-17	clear	smooth	silt loam	10YR2/2 very dark brown	common fine distinct	granular weak	very friable	charcoal
A_2	17-46	gradual	wavy	silt loam	10YR2/2 very dark brown	common fine faint	granular weak	very friable	charcoal
Bw	46-105+	--	--	silt loam	10YR4/6 dark yellowish brown	few fine faint	subangular blocky medium	friable	none

Site Characteristics

A. Landform

______ floodplain
__ x__ stream terrace
______ upland

B. Parent Material

__x__ alluvium
______ colluvium
______ residuum

C. Erosion

__x__ none to slight
______ moderate
______ severe

D. Slope

______ 0-1% level/nearly level
__x__ 1-3% gently sloping
______ 3-5% moderately sloping
______ 5-8% strongly sloping
______ 8-12% steep
______ 12%+ very steep

Soil Classification

A. Epipedon

______ mollic
______ ochric
______ none

B. Subsurface horizons/features

______ argillic
______ cambic
  ______ calcic
______ slickensides
______ lithic contact
______ paralithic contact
______ none

C. Order ____

Table A.2

Unit: FOCL 2000-2 Wall: West Page: 1 of 1 Date: 11/18/2000 Archaeologist(s): Chris Lockwood

Horizon	Depth (note in/cm)	Boundary		Texture Sand Clay Class	Color Hue Value Chroma	Redox Abun. Size Cont.	Structure Type/Grade	Consistence (moist)	Special Features
		distinctness	topography						
O	0-7	clear	smooth	humus	7.5YR3/2 dark brown	N/A	granular structureless	loose	none
A	7-14	clear	smooth	sandy loam	10YR2/2 very dark brown	N/A	subangular blocky weak	very friable	none
AB	18-28	abrubt	smooth	clay loam	10YR3/3 dark brown	N/A	subangular blocky weak-medium	very friable	none
Bw$_1$	28-68	abrupt	wavy	clay loam	10YR3/3 dark brown	N/A	subangular blocky medium	very friable – friable	none
Bw$_2$	68-78	abrupt	wavy	clay loam	10YR3/2 v dark grayish brown	N/A	subangular blocky medium	friable	charcoal
Bw$_3$	78-91	clear	smooth	clay loam	10YR3/2 v dark grayish brown	N/A	subangular blocky weak-medium	friable	none
Bt$_1$	91-103	abrupt	wavy	silty clay	10YR5/3 brown	common fine distinct	(sub)angular blocky medium	firm	none
Bt$_2$	103-130+	--	--	silty clay	10YR5/1 grey	common fine-medium distinct	angular blocky medium	firm	none

Site Characteristics

A. Landform
______ floodplain
__ x__ stream terrace
______ upland

B. Parent Material
__x__ alluvium
______ colluvium
______ residuum

C. Erosion
__x__ none to slight
______ moderate
______ severe

D. Slope
______ 0-1%
level/nearly level
______ 1-3%
gently sloping
__x__ 3-5%
moderately sloping
______ 5-8%
strongly sloping
______ 8-12%
steep
______ 12%+
very steep

Soil Classification

A. Epipedon
______ mollic
______ ochric
______ none

B. Subsurface horizons/features
______ argillic
______ cambic
______ calcic
______ slickensides
______ lithic contact
______ paralithic contact
______ none

C. Order ____

Table A.3

Unit: Shane House Field Tie Wall: SW Balk Page: 1 of 1 Date:11/18/2000 Archaeologist(s): Jennie Deo

Horizon	Depth (cm)	Boundary		Texture	Color	Redox	Structure	Consistence	Special
		distinctness	topography	Sand Clay Class	Hue Value Chroma	Abun. Size Cont.	Type/Grade	(moist)	Features
O	0-6	clear	wavy	humus	10YR2/1 black	N/A	granular structureless	loose	roots
A_1	6-33	gradual	wavy	loam	10YR2/2 very dark brown	N/A	subangular blocky weak	very friable	none
A_2	33-41	clear	wavy	loam	10YR2/2 very dark brown	common fine distinct	subangular blocky weak	very friable	none
Bt	41-63+	--	--	sandy clay loam	10YR4/4 dark yellowish brown	N/A	subangular blocky	friable	none

Site Characteristics

A. Landform
_____ floodplain
__ x__ stream terrace
_____ upland

B. Parent Material
__x__ alluvium
_____ colluvium
_____ residuum

C. Erosion
__x__ none to slight
_____ moderate
_____ severe

D. Slope
_____ 0-1% level/nearly level
__x__ 1-3% gently sloping
_____ 3-5% moderately sloping
_____ 5-8% strongly sloping
_____ 8-12% steep
_____ 12%+ very steep

Soil Classification

A. Epipedon
_____ mollic
_____ ochric
_____ none

B. Subsurface horizons/features
_____ argillic
_____ cambic
_____ calcic
_____ slickensides
_____ lithic contact
_____ paralithic contact
_____ none

C. Order ______________________________

Appendix B: pH Data Tables

Unit Q-2

Sample Location	Depth cmbs	pH
SW Bulk	0	4.3
SW Bulk	10	4.5
SW Bulk	20	4.6
SW Bulk	30	4.8
SW Bulk	40	4.6
SW Bulk	50	4.6
SW Bulk	60	5.3
SW Bulk	70	5.1
SW Bulk	80	5.0
SW Bulk	90	4.6
SW Bulk	100	5.2

Sample Location	Depth cmbs	pH
Feature 2	30	4.6
Feature 2	40	4.6
Feature 2	50	4.9
Feature 2	60	5.4
Feature 2	70	5.2
Feature 2	80	5.1
Feature 2	90	5.2
Feature 2	100	5.2
Feature 2	110	5.3

Sample Location	Depth cmbs	pH
Sand fill	0	5.8
Feature 1	30	4.8
Feature 1	40	5.0
Feature 1	50	5.2
Feature 1	60	5.2
Feature 1	70	5.3
Feature 1	80	5.3
Feature 1	90	5.1
Feature 1	100	5.2
Feature 1	110	5.1

Unit 2002-2

Sample Location	Depth cmbs	pH
Outside Pit	0	4.4
Outside Pit	10	4.1
Outside Pit	20	4.6
Outside Pit	30	4.5
Outside Pit	40	4.6
Outside Pit	50	4.8
Outside Pit	60	4.8
Outside Pit	70	4.5
Outside Pit	80	5.1
Outside Pit	90	5.1
Outside Pit	100	5.0
Outside Pit	110	4.6
Outside Pit	120	4.9
Outside Pit	130	4.8

Sample Location	Depth cmbs	pH
Inside Pit	0	3.8
Inside Pit	10	4.1
Inside Pit	20	4.5
Inside Pit	30	4.5
Inside Pit	40	4.7
Inside Pit	50	4.7
Inside Pit	60	4.9
Inside Pit	70	5.0
Inside Pit	80	4.9
Inside Pit	90	4.8
Inside Pit	100	4.9
Inside Pit	110	4.8
Inside Pit	120	5.0
Inside Pit	130	4.8

Shane House

Sample Location	Depth cmbs	pH
West Wall	0	4.1
West Wall	10	4.8
West Wall	20	4.7
West Wall	30	4.8
West Wall	40	5.3
West Wall	50	5.4
Sand Fill		5.4

Appendix C: Granulometry Figures

Figure C.1
Hydrometer Analyses: Unit 2000-2, Outside Pit

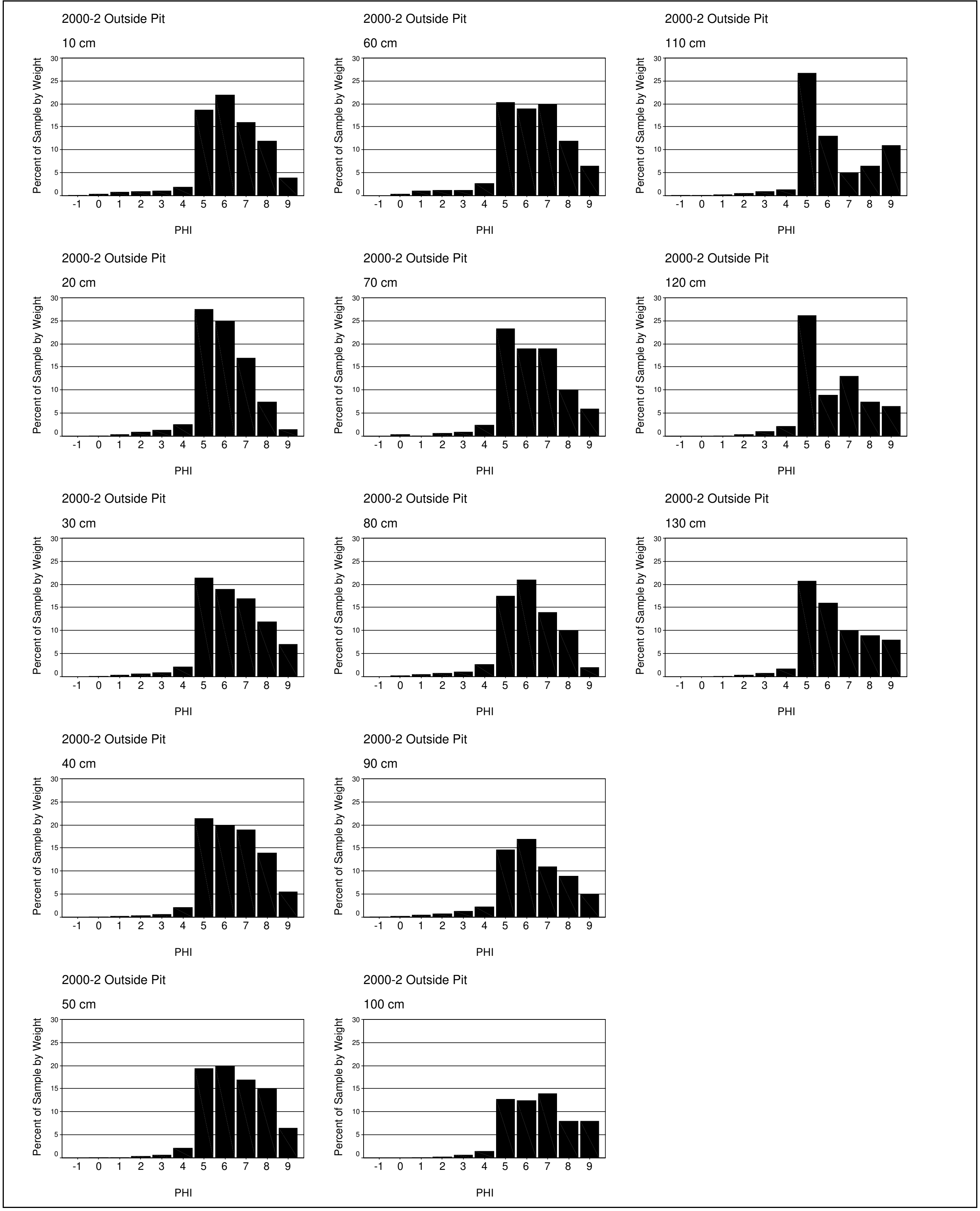
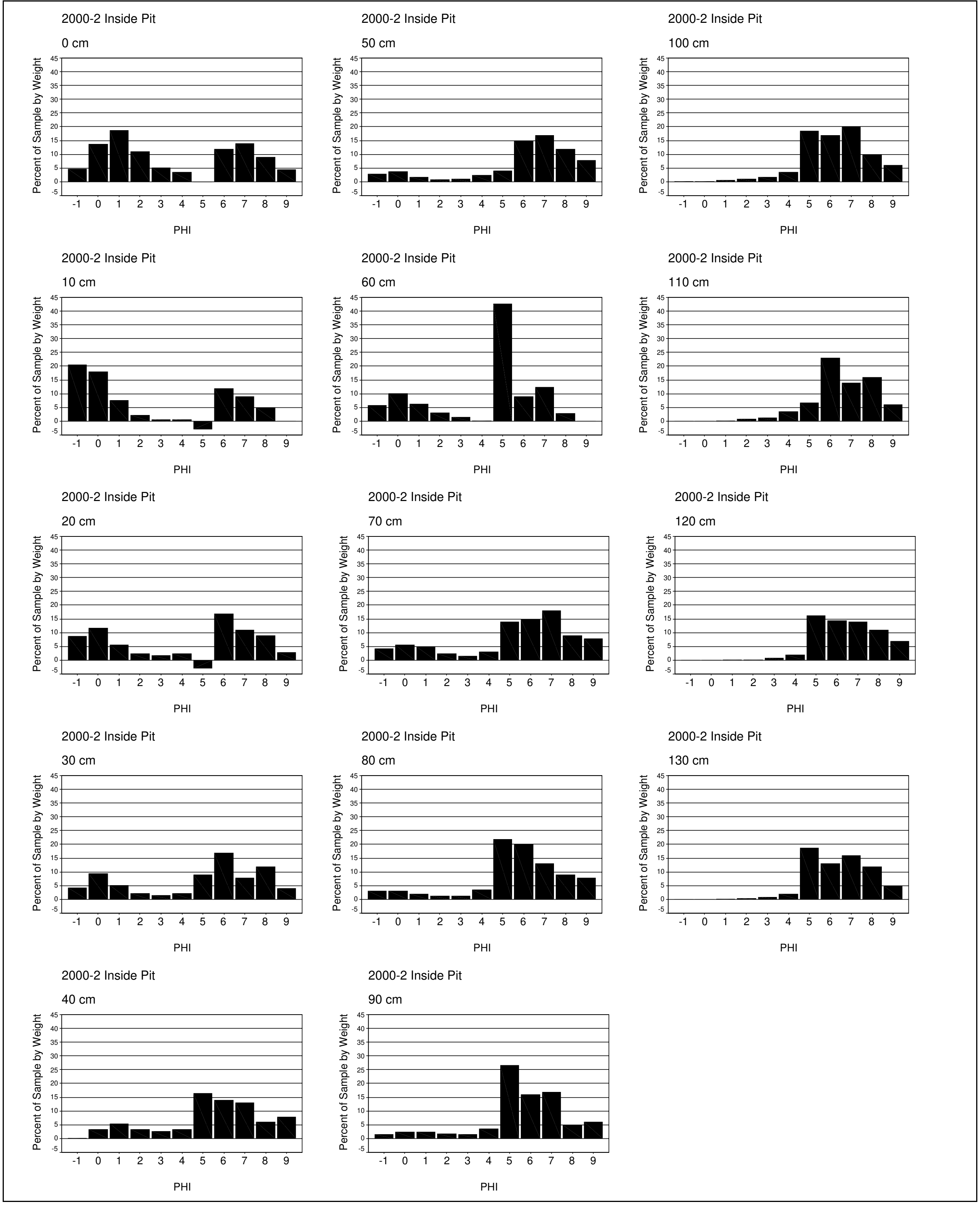


Figure C.2
Hydrometer Analyses: Unit 2000-2, Inside Pit



2000-2 Inside Pit 0 cm

2000-2 Inside Pit 50 cm

2000-2 Inside Pit 100 cm

2000-2 Inside Pit 10 cm

2000-2 Inside Pit 60 cm

2000-2 Inside Pit 110 cm

2000-2 Inside Pit 20 cm

2000-2 Inside Pit 70 cm

2000-2 Inside Pit 120 cm

2000-2 Inside Pit 30 cm

2000-2 Inside Pit 80 cm

2000-2 Inside Pit 130 cm

2000-2 Inside Pit 40 cm

2000-2 Inside Pit 90 cm

Figure C.3
Hydrometer Analyses: Unit 2000-2, Inside and Outside Pit

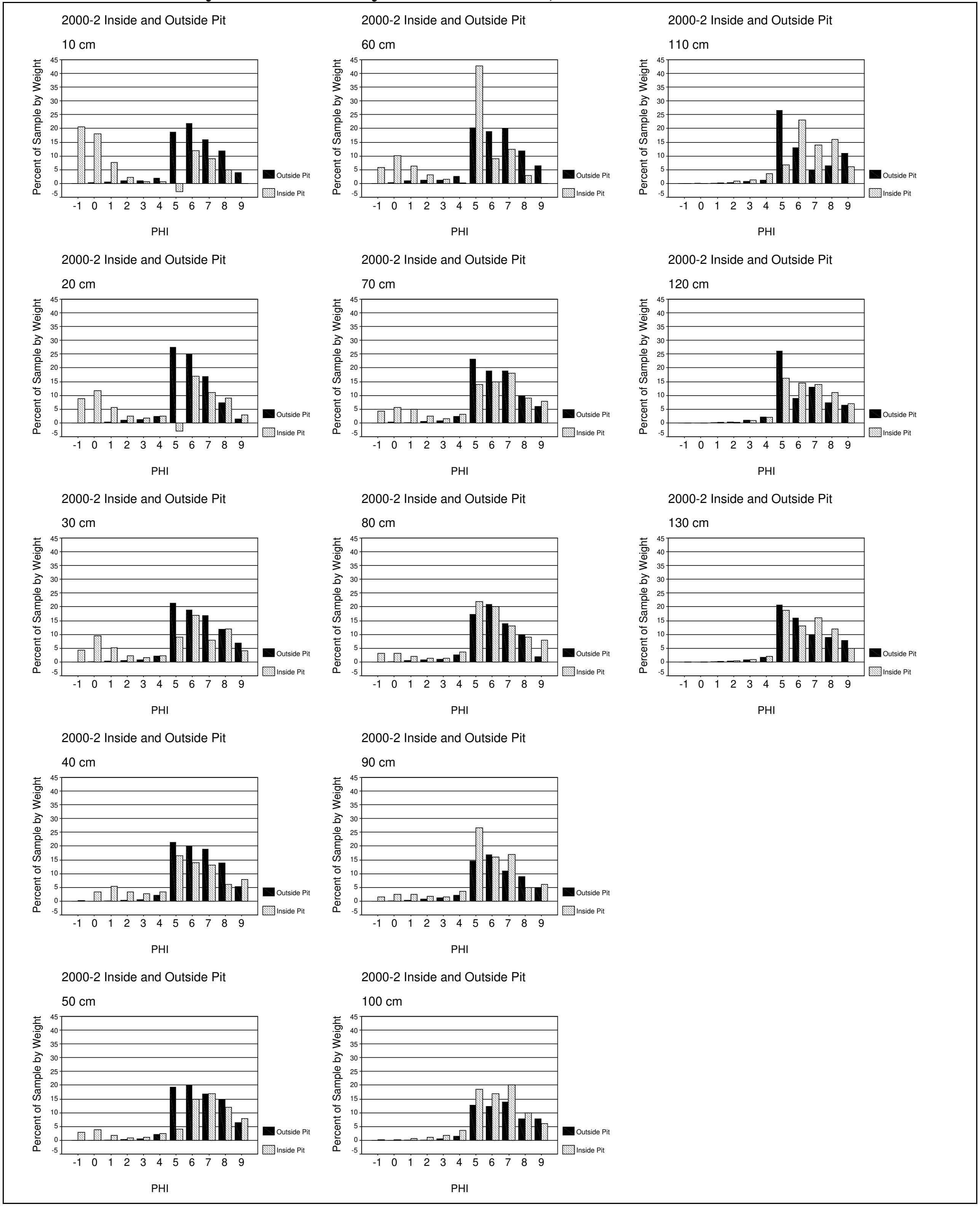


Figure C.4
Hydrometer Analyses: Unit Q2, SW Balk

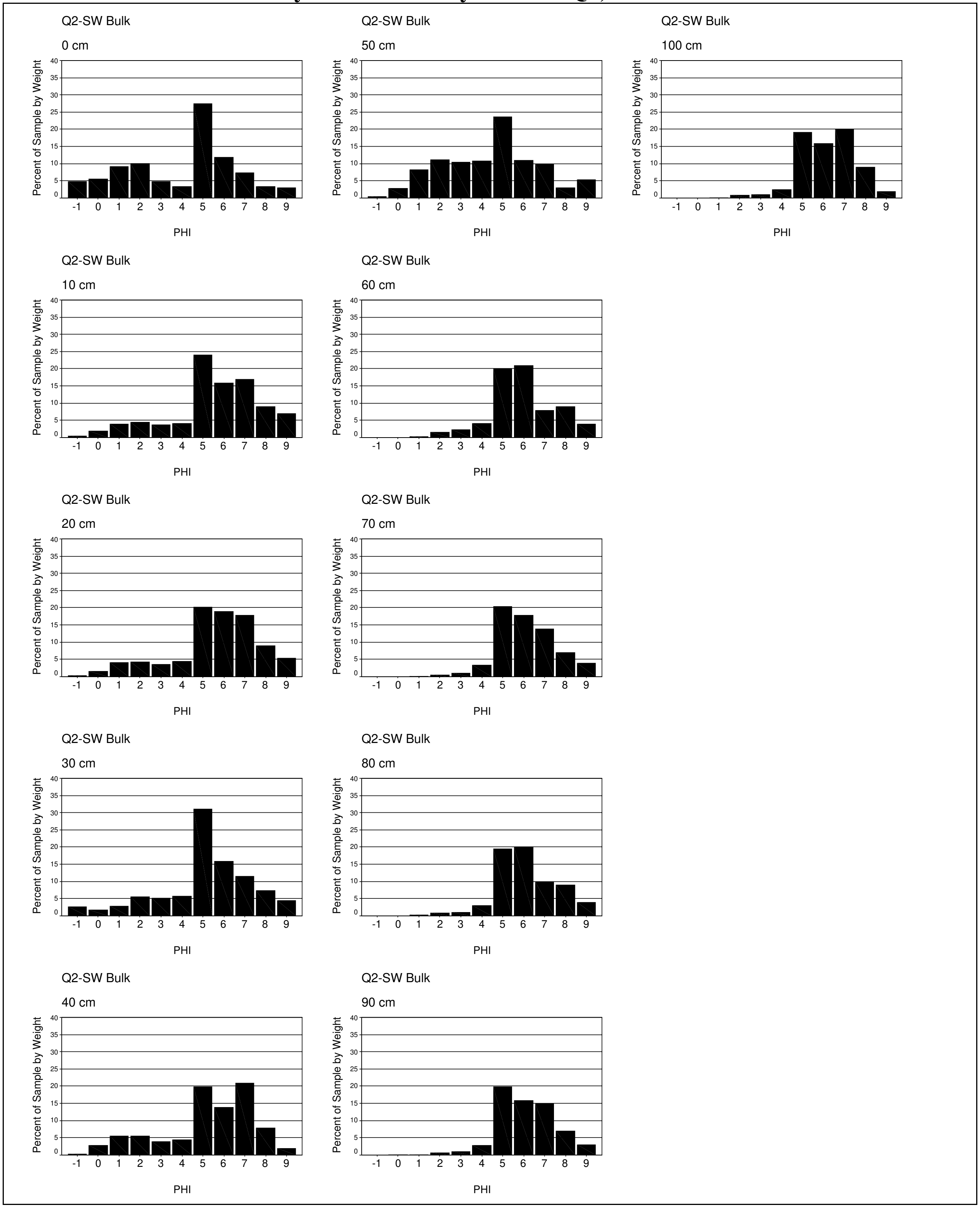
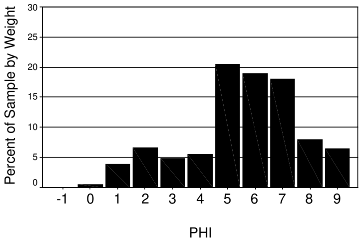


Figure C.5
Hydrometer Analyses: Unit Q2, Feature #1

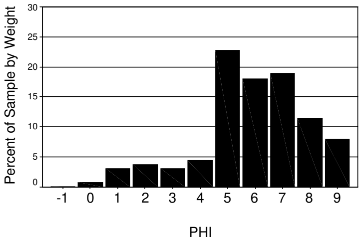
Q2-Feature 1

30 cm



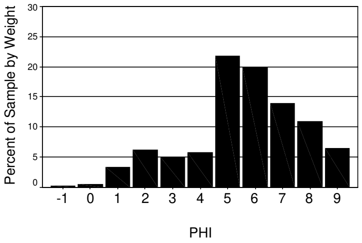
Q2-Feature 1

40 cm



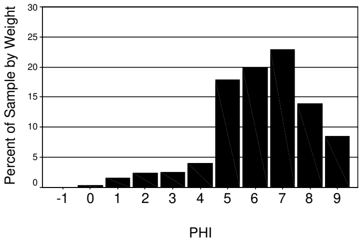
Q2-Feature 1

50 cm



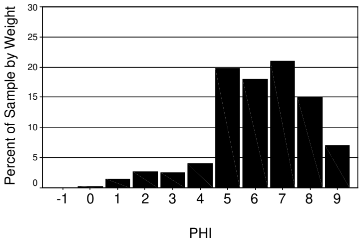
Q2-Feature 1

60 cm



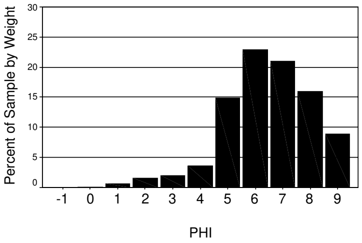
Q2-Feature 1

70 cm



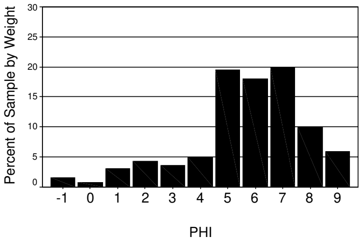
Q2-Feature 1

80 cm



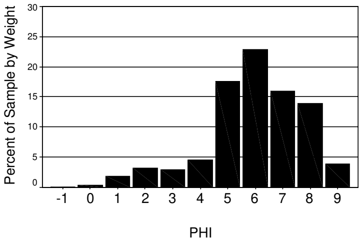
Q2-Feature 1

90 cm



Q2-Feature 1

100 cm



Q2-Feature 1

110 cm

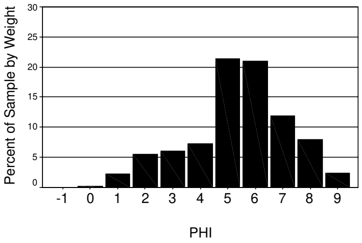


Figure C.6
Hydrometer Analyses: Unit Q2, Feature #2

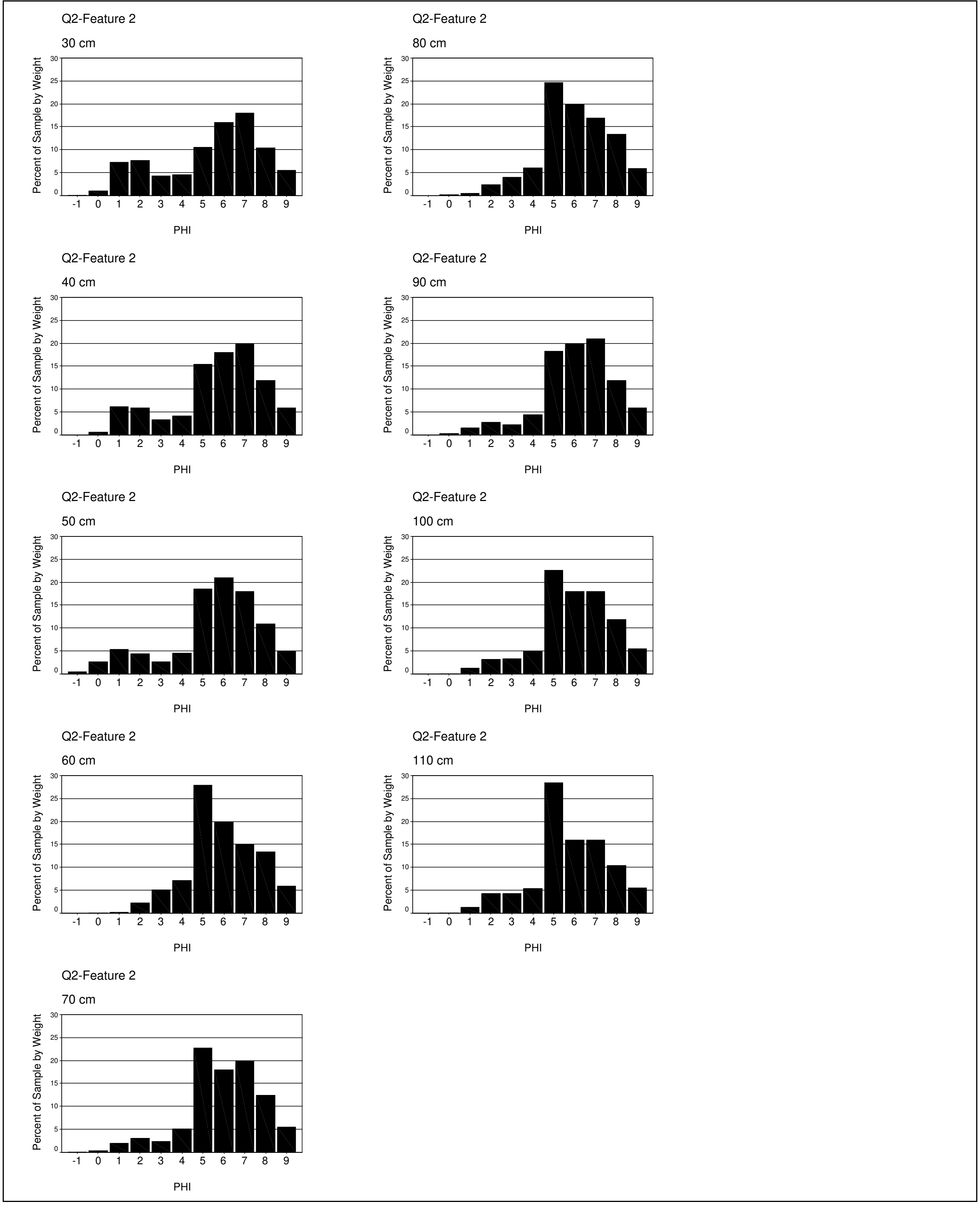
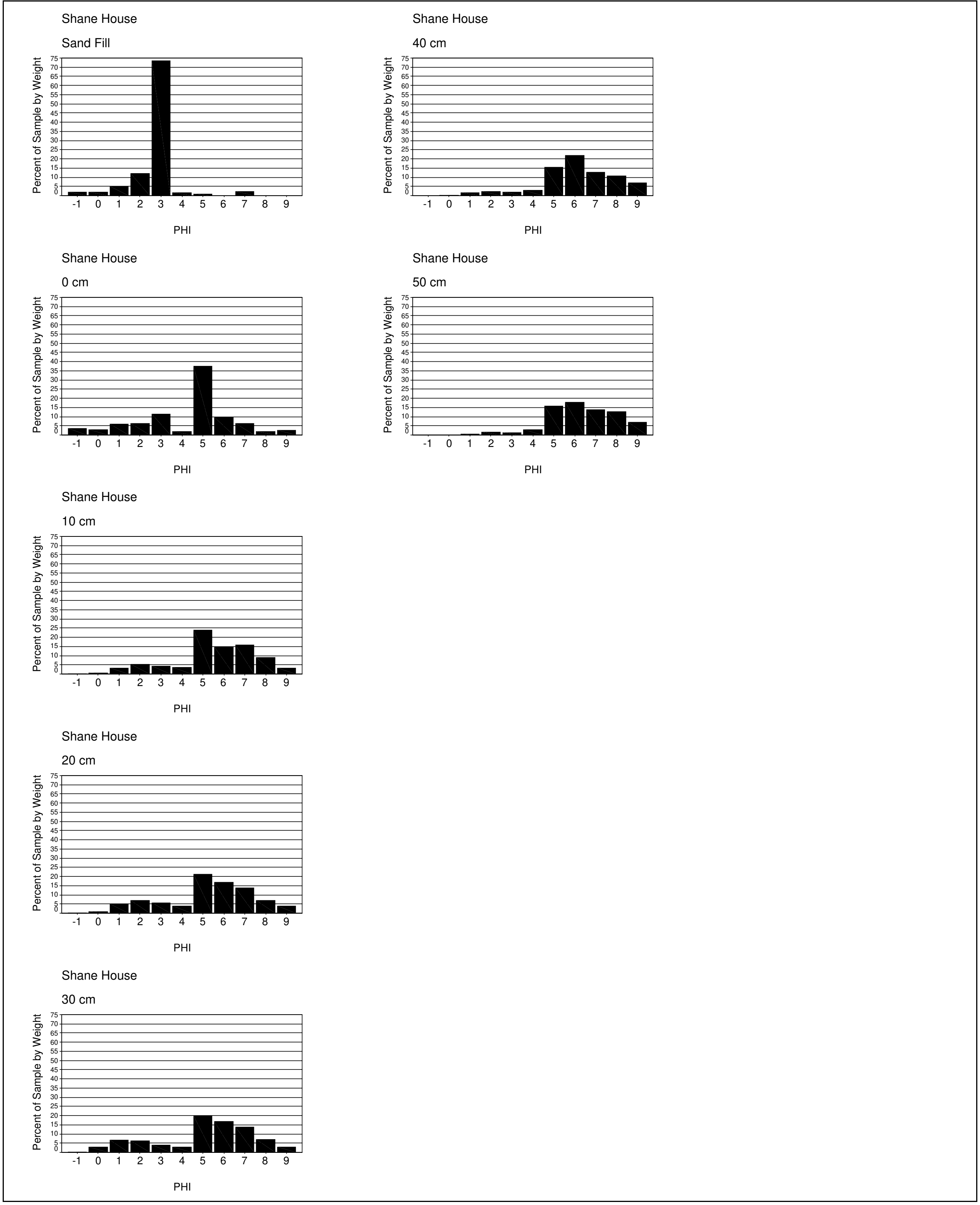


Figure C.7
Hydrometer Analyses: Shane House Field Tie Unit



Appendix D: Micromorphology Sample List

Fort Clatsop National Memorial
Micromorphology Sample Inventory

Micromorphology Sample #*	Unit	Dept Below Surface (cm)	Description
MS-1	**Q2**	**23-31**	**SW Balk**
MS-2	Q2	20-28.5	SW Balk
MS-3	**Q2**	**42-51**	**SW Balk**
MS-4	Q2	42-50	SW Balk
MS-5	**Q2**	**77.5-86**	**SW Balk**
MS-6	Q2	78-86	SW Balk
MS-7	**Q2**	**46-54**	**West Wall outside of feature**
MS-8	**Q2**	**58-64**	**Feature 1**
MS-9	**Q2**	**58-64**	**Feature 1**
MS-10	**Q2**	**73-81**	**Feature 1**
MS-11	**Q2**	**85-93**	**Feature 1 boundary**
MS-12	Q2	46-54	Boundary between feature 1 and 2
MS-13	Q2	33-41	Boundary between feature 1 and 2
MS-14	Q2	66-74	Feature 2
MS-15	Q2	18-26	Feature 2
MS-16	**2000-2**	**8-16**	**West Wall – brown, plowzone?**
MS-17	**2000-2**	**15-23**	**West Wall – brown, plowzone?**
MS-18	2000-2	90-98	West Wall – charcoal, bottom of feature
MS-19	**2000-2**	**89-97**	**West Wall – charcoal, bottom of feature**
MS-20	2000-2	22-30	West Wall – white lens
MS-21	**2000-2**	**24-32**	**West Wall – white lens**
MS-22	2000-2	53-61	West Wall – brown
MS-23	**2000-2**	**55-63**	**West Wall – brown**
MS-24	2000-2	86-94	West Wall – mottled yellow
MS-25	**2000-2**	**88-69**	**West Wall – mottled yellow**
MS-26	2000-2	115-123	West Wall – olive gray clay
MS-27	**2000-2**	**118-126**	**West Wall – olive gray clay**
MS-28	**2000-2**	**23-31**	**East Wall – red lense, FS#1**
MS-29	**2000-2**	**23-31**	**East Wall – red lense, FS#1**
MS-30	**2000-2**	**49-57**	**East Wall – boundary between mottled yellow and brown**
MS-31	**2000-2**	**53-61**	**East Wall – boundary between mottled yellow and brown**
MS-32	**2000-2**	**41-49**	**East Wall – boundary between white lens and brown**
MS-33	2000-2	37-45	North Wall – white lens
MS-34	2000-2	20-28	North Wall – red lens and charcoal
MS-35	2000-2	18-26	North Wall – red lens above charcoal

*Samples in **bold** were made into slides for analysis. All other samples were discarded.