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Sediment Analysis of Two Archaeological Sites in the Deception Pass Area, Fidalgo Island, Washington: A Geoarchaeological Approach

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Abstract

The Western Washington University's Field School (1999 and 2000 seasons) excavated two prehistoric shell midden sites located on Lighthouse Point in the Deception Pass area, Washington. A geoarchaeological approach was taken in studying site depositional processes; grain size analysis and study of sedimentary structures present in excavation profiles provided information about both natural and cultural deposition at site SK-144 and SK-46. Grain size analysis shows that angular, unconsolidated and poorly sorted colluvial sediments compose the lower beds of SK-46. While it is thought that colluvial sediments also underlie SK-144, difficulty relocating where samples were taken from makes testing this impossible. Regressing beach berms evident in excavation profiles of SK-144 show that changing sea level most likely altered the sedimentation rate and tombolo formation at SK-144; the surface area of the tombolo and therefore the site was larger in the past than it is today. A recent rise in local sea level and possible subsidence of the tombolo has caused erosion of the site evident today.

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INTRODUCTION

Archaeological investigations of two prehistoric shell midden sites carried out by the Western Washington Field School for the last two years (1999 - 2000) at Lighthouse Point in Deception Pass State Park (Figures 1), has raised many questions about site formation processes. Excavation of sites 45-SK-144 and 45-SK-46 reveals a complex geologic and depositional history taking place in a relatively small geographic area. Study of coastal, geologic and cultural depositional processes taking place on Lighthouse Point will clarify the complex processes of site formation. Such information will contribute to construction of site chronologies and interpretations of site use.

Methods include grain size analysis and examination of excavation profiles for sedimentary structures, as well as consideration of the geologic history of the area in an attempt to synthesize empirical data.

SITE DESCRIPTION

Both prehistoric shell midden sites SK- 46 and SK-144 are located on Fidalgo Island, just north of Deception Pass on a small peninsula called Lighthouse Point (Figures 1 and 2).

SK-46

Site SK-46 is perched about 10 to 15 feet above the beach on bedrock overlain by beds of Pleistocene clays and gravels (Figure 3). Six 1 x 1 meter units were excavated during the 2000 field season (Figure 4); excavation stopped when clay beds were reached at the bottom of the units. Above these clay beds are several yellowish-brown (10 YR 4/4 to 4/6 and 10 YR 5/6 to 5/8) poorly sorted and unconsolidated sediment beds. Beds of darker sediment, shell, and cultural material overlie the yellowish-brown sediments. Based on the presence of diagnostic artifacts, the site has been loosely dated to the Locarno Beach Phase, 800 to 1200 BC (Campbell, personal communication, 2001).

The site location at the base of a slope suggests three hypotheses for the sediment's origin. It is possible that the sediment layers are colluvial deposits weathered from a nearby hill and transported by gravity to the site area. In this case one expects the sediment to be poorly sorted, angular and present on a smaller, more local scale than deposits created by other processes. A second explanation for the origin of these sediments is that of ancient, uplifted beach deposits. Some structures indicative of beach deposits should be evident in profile, as well as better sorted and more rounded grains than in colluvial sediment (Boggs 2001). A third explanation for the sediment's origin is that some sort of cultural activity contributed to sediment formation. This hypotheses can be tested by sampling areas outside the site where natural depositional processes can be recognized and compared to site sediments (Stein 1985).

<u>SK-144</u>

SK-144 is located to the north of SK-46 on the east side of the tombolo that connects Lighthouse Point to the mainland, separating Lottie and Bowman Bays (Figure 2). The site is on the vegetated stable portion of the tombolo and extends from the steep hillslope to the active beach on the Lottie Bay side of the tombolo where it is currently being eroded by wave action (Figure 5). Seven 1 x 1m units were excavated during the 1999 field season; six of these units were excavated down to culturally sterile beds of beach gravel. Excavation of the seventh unit, S22 E0, terminated when a bed of yellowish-brown probable colluvial sediments were encountered. Comparison of these beds to those at SK-46 also thought to be colluvial will help in confirming this hypothesis.

It is thought that deposits at this site are composed of alternating beds of beach and colluvial deposits mixed with cultural material (Campbell and Koetje 2001). Cultural deposition or alteration includes the creation of stone pavements and digging of fire pits, as well as the formation of tan ashy lenses, the origin of which is most likely shell burning activity (VanBuskirk 2000). Several of the excavated units, S21 E1 and S22 E1, straddle the actively eroding modern beach berm, and artifacts were found eroding out of the berm during excavation. The beach on the Lottie Bay side of the tombolo is composed primarily of gravel size grains and slopes steeply down to a flat, muddy low tide terrace. In contrast, the Bowman Bay side of the tombolo is more gradually sloping and composed of finer grains (mostly medium and fine-grained sand) than the Lottie Bay beach.

It appears that the site area was larger in the past. There are several possible explanations for modern erosion of this surface. Gradual subsidence of the tombolo could cause erosion of the tombolo's surface; a rise in local sea level would also cause erosion of the site. These two hypotheses are not mutually exclusive. The past extent of the tombolo can be determined by looking at the coarsest beach material as determined by grain size analysis. This coarse material should indicate the location of past and present beach berms (Komar 1998), and the past extent of the tombolo.

A GEOARCHAEOLOGICAL APPROACH

A geoarchaeological approach has been useful in other studies of coastal shell middens (Minor 1991; Rapp and Hill 1998; Stein 1985; Stein 1992). Combining geologic techniques such as grain size analysis with archaeological methods allows for quantitative study of site sediments and depositional processes. In this approach, individual artifacts, features and shells are treated as grains. Transport and deposition or alteration of such "grains" is the result of human rather than natural processes, but by considering them grains, the same methods of analysis can be employed in this context as in a geologic study.

Sediment analysis was used to study transport mechanisms and post-depositional processes of archaeological shell deposits at the British Camp shell midden on San Juan Island (Stein 1992). Sediment analysis has also been used at this site to study microartifact manufacture (Madsen 1992), fire-cracked rock (Latas 1992) and the grain size of shell, which reflects both the shell species present at a site and the post-deposition/mechanical weathering of the shell following deposition by human activity (Ford 1992).

METHODS

The units dug during the 1999 and 2000 WWU Archaeological Field School were excavated along natural beds the excavators could see as they removed soil and cultural material from the unit. Bulk soil samples were left untouched in the corner of each unit and removed only when that bed was completely excavated and a new natural or cultural bed encountered. I separated the bulk soil samples from several of these excavation units, N4W8 at SK-46, S22 EO and S21 E1 at SK-144, into phi size fractions by sieving so that the excavation samples could be compared with control samples taken from test pits dug outside of site boundaries.

Test pits were dug outside site areas where it was believed no cultural deposition had occurred. These were samples of the natural sedimentary processes taking place in the site area and could therefore be used as control samples for comparison with site sediments (Stein 1985). At SK-46 the test pit (test pit #4) was located several meters east of the site at a slightly higher elevation than that of the site (Figure 4). Sample 1 was taken from the bottom layer of the pit at 40 cm and additional samples were taken at 5 cm intervals up from the bottom of the test pit (the humus layer was not processed). Three test pits were also dug in the vicinity of SK-144 (Figure 5). Test pit #1 was dug northwest of the site at the base of the hillslope in hopes of sampling the non-cultural sediments found in units S22 E0 and S21 E1. However, after digging through almost 70 cm of sand, shell midden deposits were encountered and excavation of the test pit stopped. Samples were collected at 10 cm intervals starting directly above the midden deposit and continuing up to the modern sod layer. Test pit # 3 was dug on the modern beach berm, and test pit #2 about half a meter behind it. Both test pits were excavated to a depth of about 50 cm. Since these pits contained beach gravel that quickly collapsed when sampling was attempted, samples were taken only from the bottom and the top of these pits. Samples were bagged, dried, and sieved in the same manner as the bulk samples from the excavation units.

When sieving, a one phi sieve size interval was used from -5.0 to -1.0ϕ. A 0.5ϕ sieve size interval was used to sort the finer grain sizes from -1.0 to 4.0ϕ. None of the samples contained any grains larger than –5.0 ϕ. Tables 1 and 2 show the results of central tendency calculations for the samples from SK-144 and SK46. Weight percent frequencies of each sample were graphed to illustrate phi size distribution and other sample trends (Figures 7, 8, 9, 10, 11 and 12). A scatter plot of skewness versus standard deviation illustrates the sorting and skewness of each sample (Figure 13). The -2.0ϕ size samples for N4W8, S22 E0, S21 E1, and test pits #3 and #4 were sorted according to composition and the weight % for each sample graphed (Figures 14, 15 and 16). Appendices A and B contain the raw data and central tendency calculations.

Visual examination of all samples to assess grain angularity and composition, as well to estimate shell, plant, and bone content, was done after the samples were sieved. A microscope was used to examine the smaller size fractions (Tables 2 and 3) and a Munsell soil chart was used prior to sieving to consistently identify the color of sediment samples. In addition to grain size analysis, drawings of excavation profiles were examined for stratigraphic relationships and any possible sedimentary structures (Figures 17, 18 and 19). A south facing profile of grid line South 22 was constructed by linking excavation profiles from several units (Figure 20). Connecting the walls of units S21 E1, S22 E0 and S21 W1, this profile stretches from the beach to the base of the talus slope that the tombolo abuts.

GEOLOGIC HISTORY OF THE DECEPTION PASS AREA

Local sea level change and tectonic events

Fidalgo Island is a geologically diverse and tectonically active area; two faults have been mapped on Lighthouse Point alone (Brown and Gusey 1978) (Figure 21). It is likely that the record of local sea level change and past tectonic activity in this area is complex, and would certainly have an effect on site formation. Tectonic events initiate depositional events, and isostatic rebound or lowering of local sea level increases the aerial exposure of glacial sediments, which commonly serve as a sediment source for tombolo formation (Farquhar 1967; Schwartz et al. 1989).

At least six glaciations of the Puget Lowland occurred during the Pleistocene. Double Bluff Drift, Possession Drift, Vashon Drift, Everson Glaciomarine Drift and Sumas Drift overly bedrock across much of Fidalgo and Whidbey islands (Carlstad

1992). About 13,000 years ago following periods of glaciation, eustatic sea level rose to approximately 60 to 70 meters below the present sea level in the Whidbey Island area due to the melting of ice sheets worldwide. Although sea level continued to rise following this period, relative sea level dropped in the Deception Pass area due to isostatic rebound. By 8,000 years ago sea level in this area was still below modern sea levels. Tectonic fluctuations have played a part in sea level fluctuations of this area as well, interacting with eustatic sea level change and isostatic rebound to create a complex geologic record of local sea level change (Carlstad 1992).

The tectonic complexity of the Puget Sound area has, to a certain extent, limited the relative sea level research done in the Puget Sound area. While many archaeologists in the past have recognized the impact of changing sea levels and tectonic activity on shoreline sites (Grabert and Larsen 1975; Grebmeier 1983; Larsen 1971; Mathews et al. 1970), geological and archaeological research in these areas is very recent. Discovery of the West Point site near Seattle did much to illustrate the complexity of Puget Sound's tectonic past, and to fuel interest in prehistoric seismic activity. Discovered during the construction of a sewage treatment plant, the landform at West Point is the result of glacial consolidation, isostatic rebound, land subsidence, and eustatic sea level rise (Larson and Lewarch 1995).

Evidence of abrupt uplift in the southern Puget Sound has also been discovered along one or several of the major faults in the Seattle area, likely due to the same earthquake activity that caused the subsidence of West Point (Bucknam et al. 1992). Evidence from a raised wave cut platform at Restoration Point, combined with marsh and tidal flat deposit data from across the southern Puget Sound indicate this abrupt uplift occurred between 500 and 1700 years ago. To complicate matters, peat deposits in several marshes and lack of uplift near the town of Winslow show that the amount of uplift was variable along the fault (Bucknam et al. 1992). Possibly associated with the same tectonic event is the presence of tsunami sand deposits in overrun tidal marshes, both at West Point near Seattle, and at Cultus Bay on Whidbey Island (Atwater and Moore 1992).

Tombolo Formation

Tombolos are structures that link offshore islands to the mainland, essentially the result of two spits joining together. Spits and tombolos are created by the interplay of bedrock geology, postglacial rebound, and coastal processes (Schwartz et al. 1989). The role of wave diffraction and refraction in tombolo formation varies depending on the geomorphology of the coastline, prevailing winds and currents, and sediment supply in the area (Farquhar 1967; Flinn 1997; Schwartz et al. 1989). The tombolo at SK-144 was most likely created by the refraction of offshore waves around the island as waves encountered the shallow shelf surrounding the island. Waves then met head on behind the island, interrupting longshore drift processes and forming an environment conducive to sediment accumulation (Flinn 1997).

Sediment is usually derived from longshore drift or previously eroded beach sediment carried back to shore by waves and coastal currents (Farquhar 1967; Komar 1998). Tombolos are particularly common in areas that were glaciated at one time, as drumlins and other glacial features provide good source material and are usually unconsolidated and easily eroded sediment beds (Farquhar 1967; Schwartz et al. 1989). This is certainly the case in the Deception Pass area where bluffs of unconsolidated glacial material line the shore (Carlstad 1992; Keuler 1979) and are present on Lighthouse Point underlying SK-46 and in a bank exposure near SK-144. Isostatic rebound, which took place 13,000 to 8,000 years ago in the Deception Pass area, can bring glacial and sedimentary deposits into higher subaerial relief, increasing erosion rates and therefore sediment supply (Schwartz et al. 1989).

RESULTS OF GRAIN SIZE ANALYSIS

In grain size analysis, measures of central tendency describe the general qualities of a sample (mean, median and mode), as well as the sorting (standard deviation) and skewness. Skewness is a measure of a sample's deviation from a normal curve in either a positive or negative direction and is an important measure when determining different source areas (Komar 1998; Friedman 1979). Negative skewness indicates either the addition of coarse material or the subtraction of fine material, while positive skewness implies the opposite.

SK-144

Generally, the sediment samples from excavation units S21 E1 and S22 E0 at SK-144 are poorly sorted and strongly fine skewed, with modal values of –3.0ϕ and –4.0ϕ (Table 3). The only major deviations from this are level 2 in S22 E0, which has a modal value of –1.0ϕ, and level 11b in S22 E0, which is coarsely skewed. Mean values for unit S22 E0 range from 0.18ϕ to –2.67ϕ, while values for unit S21 E1 range from-1.34ϕ to –3.41ϕ. Smooth line graphs of weight percent versus phi size show that samples from both excavation units have peak/modal values between –4.0ϕ and –3.0ϕ (Figures 7, 8, 9 and 10). However, while samples from S21 E1 have low frequency sloping tails following this peak, samples from S22 E0 have a second, smaller mode following the first around –1.0ϕ (Figures 7 and 8). A third peak is visible as well at 1.0ϕ and 2.0ϕ for samples 6 and 3 and 11b respectively (Figure 8).

All of the test pit samples collected in the vicinity of SK-144 are either very poorly sorted or poorly sorted. All of the samples are strongly fine skewed with the exception of samples 4, 5, and 7 in test pit #1 (Table 1). Modal values for samples from test pits #2 and #3 are all –3.0ϕ, while those from test pit #1 are more varied, ranging from 0.5ϕ to 2.5ϕ. Mean values for Test pits #2 and #3 are between –2.88ϕ and –3.62ϕ. Mean values for test pit #1 are more varied, and reflect a fining-up sequence, ranging from 0.91ϕ to 1.53ϕ (Table 1). Graphs of weight percent versus phi size for test pits #2 and #3 show peaks at –4.0 and –3.0, with a second small rise at 1.5 for sample #2 from test pit #2 and sample #2 from test pit #3 (Figure 10). A similar graph for test pit #1 (Figure 11) shows much more variation, modal values are grouped around 1.0ϕ and 2.0ϕ, reflecting a greater sand component in these samples.

In the excavation units, grains are either rounded or subrounded for the most part, and either equant or disc shaped (Table 1). Sediment colors are mostly dark grayish browns (10 YR 3/1) to black (10 YR 2/1). The only deviation from this is the yellowish brown (10 YR 4/4) sediments in S22 E0, level 6. In unit S21 E1 an increase in gravel content from level 2 down to level 8 is accompanied by a color change from black soil/midden (10 YR 2/1) to a sandier grayish-brown matrix (10 YR 4/2). The amount of shell increases in levels 5, 6, and 7. It is difficult to see any general trends in color change or shell content for unit S22 E0, which can be characterized only as variable.

Grains in test pit #1 were predominantly subrounded and disc-shaped (Table 2). Color was difficult to characterize for most of the samples in this test pit because there was little soil present. Sample 5 differed from the other samples in this test pit in both color (10 YR 2/1 Black) and content, containing considerable organic material and possibly some charcoal fragments. Sample 7 also contained more organic debris than the other samples and the coarser grain sizes were coated with a black soil or substance. Clay concretions are present in the smaller phi sizes. Samples from test pits #2 and #3 were black to grayish-brown in color (5 YR 2.5/1 to 10 YR 4/2), with subrounded, disc-shaped grains (Table 1). More organic material and shell was present in the upper levels than the lower, but little shell was present overall.

SK-46

All of the levels from excavation unit N4W8 are very poorly sorted based on the standard deviation of each sample from its mean (Table 2). Most of the beds are also strongly finely skewed (skewness greater than 0.30ϕ), with the exception of level 3, which is only finely skewed (skewness is 0.15ϕ) and level 5.2, which is strongly coarsely skewed (skewness equals –0.86ϕ). Mean sample values range from –1.94ϕ to 0.24ϕ, and modal values range from –4.0ϕ to –1.0ϕ (Table 2).

The samples obtained from test pit #4 are also all very poorly sorted, but have more varied skewness values than samples from the excavation unit (Table 2). Samples 1 and 2 are strongly finely skewed, while sample 3 is finely skewed. Samples 4 through 7 are coarsely skewed. Mean grain size ranges from -0.73ϕ for sample 3, up to 0.96ϕ for sample 7, while sample modes show more variation in values ranging from –1.0ϕ to >4.0ϕ (Table 2). The skewness of the test pit samples is generally lower than those of N4W8, ranging in value from -0.23ϕ to 0.38ϕ. Skewness values for N4W8 range from –0.86ϕ to 0.85ϕ (Table 2)(Figure 13).

Visual examination of the samples from each bed showed that all of the beds sampled in N4W8 are subangular, with the exception of level 5.3 in which the grains are subrounded, and level 8, which are angular (Table 4). The grains from levels 3, level 3 feature 3, level 5.2 and level 5.3 are all equant in shape, while levels 4, 6, 7, and 8 are disc-shaped. All of the beds contain a variety of shell, bone, and plant matter except for level 8, which contains no shell or organic matter. Level 8 also contains a small percentage (roughly 15%) of granitic grains comprised of feldspar and hornblende. The rest of the samples are composed of basalt grains, most likely derived from the surrounding bedrock. The upper beds are all shades of brown (10 YR 4/2 to 10YR5/3, level 5.3 is Gley 12.5/N), with the exception of feature 3, which is the same yellowish-brown color as the lower beds 6, 7, and 8 (10 YR 4/6 to 10 YR 5/6).

Samples from test pit #4 are much more consistent in their texture and composition than site samples from N4W8 (Table 4). All of the samples are subrounded and equant in shape, and are composed of clay accretions and basalt pebbles. These samples range in color from light brownish-gray (10YR 6/2) to a light yellowish brown (10 YR 6/4), with the exception of level 1, which is light gray (2.5 Y 7/2) and level 7, which is a dark grayish brown color (2.5 YR 4/2). Plant material is present in all of the samples.

Figures 14, 15, and 16 show the results of sorting the -2.0ϕ samples from several units and test pits (N4W8, S21 E1 and S22 E0) according to composition. Unit S22 E0 at SK-144 shows the most fluctuation over time in amount of shell, the content of which increases with depth. These increases in shell content (mostly fragmented) occur in samples from level 5, 7, and 10 (Figure 15). The same increases over time in shell content is found in excavation units S21 E1 and N4W8 at SK-46 (Figures 14 and 16), although neither of these show as much fluctuation in amount of shell over time as in S22 E0. N4W8 at SK-46 contains less shell overall than units from SK-144. Increased shell content is evident in samples from level 3 and 7 in S21 E1 at SK-144 (Figure 14), and in samples from levels 5.2 and 6 at SK-46 (Figure 16).

DISCUSSION

Grain size analysis

SK-46

The coastal location of SK-46 and the sandy nature of some of the upper levels in the site lends credence to the hypothesis that the lower sediment beds of SK-46 (levels 6, 7, and 8) are beach deposits uplifted by tectonic activity along one of the landform's faults (Brown and Gusey 1978) (Figure 21). Beach deposits are characteristically well sorted, have a subrounded or rounded grain shape; grain sizes range from fine sand to gravel depending upon where in the beach or nearshore zone the sediments are deposited (Boggs 2001). The grains from levels 6, 7, and 8 are subangular to angular with a rough surface texture. None of these characteristics indicate transport by water. Despite being uplifted, beach deposits should retain their original depositional structures such as parallel or cross-bedded laminae, dipping either land ward or seaward depending on the zone of deposition (Boggs 2001; Goldbery 1980). None of these structures characteristic of beach deposits are present in profiles of the poorly sorted, coarse to very coarse beds (6, 7, and 8) from N4W8 (Figures 19 and 22).

Beds 6, 7, and 8 from N4W8 have many of the characteristics of colluvial sediments, which are generally poorly sorted and unconsolidated deposits that may contain some grading in the form of increased gravel content towards the base of the deposits (Reneau et al. 1990). Colluvial deposits are created by landslides, soil slumps or creeps that entrain a wide range of grain sizes and carry them down slope where they are redeposited. Episodes of colluvial deposition can take place over thousands of years, leaving layered colluvial deposits with younger beds down slope from older beds (Reneau et al. 1990). The angularity of grains from beds 6, 7, and 8 and the fact that the grains are composed primarily of the local bedrock supports the colluvial deposit hypothesis as well. Bedrock in this area is composed primarily of foliated and deformed pillow basalts, as well as ribbon chert, graywacke, argillite and undifferentiated plagiogranite (Gusey 1978).The granite present in bed 8 is likely derived from the undifferentiated plagiogranite deposits about a mile north of the site (Figure 21).

If the lower sediment layers from SK-46 are of a colluvial origin, I expected there to be some correlation between the sediments at the site and those taken from the nearby test pit. Initially, this did not seem to be the case. The samples from the test pit contained a much greater fine component overall, which could not be separated into phi size fractions because of the sieving method used. Use of a settling tube or sedigraph to separate these finer particles would improve grain size analysis. The grains from the test pit are more rounded than those from SK-46 and the sediments from the two areas are drastically different colors. Despite these differences, closer examination of the grain size frequency graphs (Figures 11 and 12) and the scatter plots of skewness versus standard deviation (Figure 13) show that the two sample areas are not that different.

The overall shapes of the weight percent graphs for N4 W8 and test pit #4 are similar, with peaks between - 5.0 ϕ and - 0.5 ϕ and then a gradual slope from around –0.5 ϕ to 4.0 ϕ. If the unsorted fine component is ignored, the samples from the test pit appear to be bimodal, with an initial peak at –3.0 ϕ and then another at –1.0 ϕ of –0.5 ϕ. These peaks could be the due to a small sample size (less than 500g). Level 8 from N4W8 also has two peaks, one at – 4.0 ϕ and the next at –1.0 ϕ.

The scatter plot of skewness versus standard deviation (Figure 13) shows that although there are differences in skewness values for the two sample areas, the standard deviation values are between 2.0 ϕ and 3.0 ϕ for both sample areas. Overall, the samples from the site and the test pit are similarly sorted and skewed. There appears to be almost as much variation in sample characteristics within a sampling area as there is between the two sample areas. Further statistical tests of significance would clarify the nature of the relationship between the site sediments and those from the test pit.

There are several hypotheses for the presence of a greater fine component in the samples taken from test pit #4; colluvial sediments may contain some grading, with larger grain sizes toward the base of the deposit (Reneau et al. 1990). The test pit is located several meters up-slope from the site. This distance may be enough for grading to have occurred, which would explain the greater fine component in the up-slope test pit samples. The test pit is located in a wooded area and extensive root activity was evident during sampling. These test pit samples may therefore have undergone chemical changes, such as ion exchange or hydrolysis, or other soil forming processes that the site samples have not.

A third hypothesis for the lesser fine component in the site samples may be that some human activity has altered the sediments from SK-46. This hypothesis is not clearly supported or refuted by the findings of this study. The variations between the site sediments and the test pit sediments are too great for the test pit sediments to be used as control samples. Samples from the bank exposure outside of the site area may provide better control samples than test pit #4 as it is already apparent in profile that the sediments here are similar to those in the site (Figure 21).

<u>SK-144</u>

Studies have shown that grains are often coarsest at the beach berm where high energy waves deposit the largest grains (Komar 1998). My expectations were that the samples from the unit nearest the modern beach berm (S21 E1) would have coarser mean grains sizes than those from units further away from the modern beach (S22 E0). Results of grain size analysis show this to be the case, with mean grain sizes for S21 E1 closely approximating those from test pits #2 and 3 dug which were dug in the modern berm (Table 1). Mean grain sizes for S21 E1 range from -1.34ϕ to -3.41ϕ, while further away from the berm mean grain sizes are lower, ranging from 0.18ϕ to -2.67ϕ for S22 E0 (Table 1). A profile along the South 22 grid line cuts across the site from the beach to the slope and shows several possible beach berm structures (Figure 20). These structures are also evident in a photo of the south wall of unit S21 E1 (Figure 23) where it is evident that they slope upwards to a crest and then back down towards the hillside. Grain size frequency curves for S21 E1 and test pits #2 and 3 are similar in shape and distribution (Figures 7 and 9). Graphs for these samples show a peak around -4.0ϕ to -3.0ϕ, with a drop and then gradual tail of fine material all the way out to $>4.0\phi$. The "interference" of cultural material in the beach deposits of S21 E1 are evident as peaks around -0.5ϕ (Figure 7).

Little can be determined about the probable colluvial sediments at the base of S22 E0 because of difficulty determining where bulk samples were taken from during excavation. It is interesting however that the bottom beds of both SK-46 and SK-144 are potentially composed of colluvial sediments. Perhaps some tectonic event in the past along one of the small faults that run across Lighthouse Point initiated mass movements of sediment. Comparison of artifacts or radiocarbon dates from these sediment beds could show whether or not the depositional events are contemporaneous.

Visual examination of the sediment samples also showed that sample 6 from S22 E0 noticeably differs in shape and roundness from the other site samples. The grains are well rounded, disc-shaped, and have a very smooth, polished surface texture in comparison to the other lithic grains from SK-144, which usually have a pitted or rough surface texture. The smaller grain sizes ($> 4.0\phi$) have a greasy feel similar to that of midden sediments. It is possible that this sample represents another feature, but it is not possible to determine this based on the profile (Figure 18). Sample six appears to have been taken in proximity to a bed labeled "sandy loam" on the field profiles, but as this does not really describe the sample characteristics the true location of the sample and possible feature is not known at this point.

Almost all of the samples taken from SK-144 and SK-46 are positively skewed (Tables 1 and 2). These results are contrary to expectations for beach sediments, which are commonly coarsely skewed beaches because the fines are removed by nearshore turbulence leaving the coarse material behind on the beach (Komar 1998). Positive skewness can occur in beach environments, but this is usually inherited from the source, in this case possibly nearby Pleistocene clay cliffs. The positive skewness of site samples may also reflect cultural depositional mostly in the form of shell, although this cannot be determined without further analysis.

Sorting of -2.0ϕ samples for the excavation units and several of the test pits does show several episodes of increased shell content within the site (Figures 14, 15 and 16). With better stratigraphic control these episodes of increased shell deposition could be used in constructing a chronology and may indicate periods of intensified site use. Sorting more samples by composition would also provide more information about shell species present at different points in time, depositional and post-depositional processes at both SK-144 and SK-46 (Ford 1992).

<u>Test Pit #1</u>

The shell midden and buried soil horizons encountered in test pit #1 at SK-144 raise questions about site extent and depositional rates. The presence of cultural material indicates that the extent of the site is greater than previously thought, while the depth at which midden was encountered (about 66cm) shows that depositional rates are drastically different on either side of the tombolo (Figure 25). A possible buried soil horizon roughly 40 cm below the surface of test pit #1 may indicate cultural deposition as soil development serves as a record of periods of landscape stability (Gerrard 1992; Rapp and Hill 1998).

Phosphorous and pH are both good indicators of the presence of cultural sediments; both are related to increased amounts of organic debris due to human presence at a site (Gerrard 1992; Rapp and Hill 1992; Stein 1987). Soil chemistry analysis of sedimentary beds at Yaquina Head on the Oregon Coast (Minor 1991) showed that increased levels of phosphorus is an accurate predictor of human presence and can be used to differentiate depositional events. Soil pH is also useful in determining cultural versus natural sediments, particularly in shell middens where the dissolution of shells causes pH changes in the surrounding soil and affects artifact preservation (Minor 1991; Campbell 1981).

Chemical testing of pH or phosphorous concentrations in soil from test pit #1 is necessary for the nature of this soil horizon to be determined, but at the very least the thickness of this soil horizon is evidence of a long period of landform stability when vegetation could be established. No cultural material was encountered when test pits were dug a meter deep during the 1999 field season to the east of the witness post and near the datum (Figure 5). The discovery of cultural material nearly a meter deep in test pit #1 indicates that future test pits dug at this site will have to be much deeper. Only further investigation at SK-144 can establish the site boundaries.

The tombolo formation at SK-144

The tombolo formation at SK-144 serves as a partial record of wave action and wind conditions in the past (Farquhar 1967). Past beach berms associated with the tombolo indicate earlier levels of sea level, as evident in site profiles (Figures 17 and 20). The regression of past beach berms may be due to a drop in local sea level or to episodes of increased sedimentation, which would cause the tombolo to build outwards into Lottie and Bowman Bays. Until the site is more securely dated and more study of fluctuations in local sea level occurs, the timing of these regressions cannot be determined. I am curious about the cause of the depression in the tombolo terrace to the east of the site. It may be an indication of landform subsidence, which may have occurred more recently and may be associated with the rise in local sea level and modern erosion of the site. Knowing what lay beneath the tombolo would perhaps aid in interpreting this feature of the landform. At the present time this feature is labeled simply as Quaternary deposits on a geologic map (Figure 21). Investigations of this site with ground penetrating radar may help in determining whether or not the tombolo is built on top of bedrock. A better understanding of the tectonic history in this area would also aid in interpretations of subsidence and sea level change.

Tombolo formation and size fluctuations over time have the potential to change the local ecology (Farquhar 1967). Today Lottie Bay is a gravel/pebble beach with a muddy intertidal zone; a typical beach in Skagit County due to the glacial sediment supply in the area (Keuler 1979). A search for clam species on this beach turned up nothing but *macoma nasuta* (bent-nosed clams), a species that prefers muddy sediment and is an indicator of low oxygen concentrations (Flora 1982). This species features little in the archaeological shell deposits, which contains *Protothaca stamina* (Pacific Littleneck), *Saxidomus giganteus* (Butter Clam) and *Strongylocentrotus droebachiensis* (Green Sea Urchin) to name a few species. Both *Protothaca* and *Saxidomus* can live in either muddy or rocky sediments, but *Strongylocentrotus* prefer rocky shores and tide pools (Flora 1982). Of course the archaeological shellfish could simply have been collected from Bowman Bay or any of other nearby yet environmentally different tidal zones, but it is interesting to consider how fluctuations in sea level and landform size can affect the local ecology and perhaps site use.

Future investigations

Determining sample locations in unit profiles was a problem in this investigation; discrepancies in the profiles and field notes made it difficult to accurately locate samples.

The result is that it is difficult to interpret the grain size results or to say anything definitive about a particular level in relationship to the stratigraphic profiles. Problems such as these are common when using field data not collected for a specific purpose or research question. If one entered excavation with the idea of doing sediment of beach berm deposits, it is likely that more sediment samples would have been collected from specific structures and stratigraphic control tighter.

I also had difficulty applying the results of grain size analysis to any specific archaeological features or events. Even after all of the samples were sieved, I could not say anything quantitative specifically about the archaeological material within the sediment. Although I sorted the -2.0ϕ samples for this project so that I could talk about shell content of different beds, sorting of all possible material would provide more information and allow more interpretation of sedimentary processes. If grain size analysis is to be used, samples should be sieved and then separated into different components such as bone, shell, and rock. Grain size frequencies for these components would provide information about increases and decreases in site use over time and allow for study of changing subsistence strategies employed at a site. Post-depositional processes affecting cultural deposits could be studied further as well.

I believe many of the problems encountered here are inherent to the geoarchaeological approach; geological techniques are developed for deposits on a much larger scale than what is commonly encountered in an archaeological site. Beach structures take place on too large of a scale to be visible in a 1x1 m excavation profile and it is difficult to truly study tombolo formation and beach processes over time on such a small scale. To understand more about how stable the tombolo landform is one would need to trench across the entire structure to see features in profile. This would be counterproductive however as it would disrupt beach processes and destroy the tombolo formation.

CONCLUSIONS

The coarse, poorly sorted sediments layers 6, 7, and 8 of SK-46 do not contain any of the sedimentary structures characteristic of beach deposits. The angular grains, coarse grain size frequency distributions and poor sorting of the sediments suggest they are of colluvial nature. Comparison of the site sediments to samples collected from a test pit outside the site show that the test pit contained a much greater fine component than the site sediments. This difference in grain size distribution may be due to soil formation processes in the test pit area, grading of colluvial deposits, or a sediment component in the site introduced by human activity that is not present in the test pit.

Grain size analysis at SK-144 shows that beach berm deposits are present in the unit closest to the beach, S21 E1, and structures evident in the excavation profile show that the tombolo landform has been building outward over time, possibly due to a drop in local sea level. Recent subsidence of the landform or a rise in local sea level most likely caused erosion of the site that can be seen today.

Future investigations of depositional processes at both SK-46 and SK-144 should involve chemical analysis of sediments to determine boundaries and help in distinguishing cultural from natural sediments. This would be particularly interesting if done on the buried soil horizon encountered in test pit #1. Following sieving, samples should be sorted according to composition and analysis of these separate constituents done. If further sediment analysis is to be done, site samples should be collected with this in mind and better stratigraphic control maintained.

Table 1. Central Tendency Calculations for Sediment Samples from SK-144 (Values in Phi).

S22 E0

Level #	Mode	Mean	Standard Deviation	Skewness
2	-3.0	-2.06	2.62	0.92
3	-1.0	-0.08	2.05	-0.07
5	-4.0	-2.64	2.31	1.26
6	-3.0	-1.29	1.90	0.07
7	-3.0	-2.67	2.43	1.53
8	-4.0	-1.39	2.43	0.33
9	-3.0	-1.32	2.23	0.95
10	-4.0	-1.88	2.67	0.6
11	-3.0	0.18	2.35	0.29
11b	-4.0	-0.15	3.01	-0.15

S21 E1

Level #	Mode	Mean	Standard Deviation	Skewness
2	-3.0	-1.78	2.62	0.81
3	-3.0	-1.34	2.27	0.29
4	-4.0	-3.37	1.76	2.44
5	-3.0	-3.41	1.88	2.15
6	-4.0	-3.32	1.88	2.25
7	-4.0	-3.06	2.26	1.62
8	-3.0	-2.47	2.59	0.97

Test Pit #1

Sample #	Mode	Mean	Standard Deviation	Skewness
2	2.5	1.53	3.27	1.14
3	2.5	1.32	2.86	1.16
4	0.5	0.18	2.04	-0.29
5	1.0	0.22	1.64	-0.13
6	0.5	0.40	1.53	1.25
7	2.0	0.91	1.31	-0.94

Test Pit#2

Sample #	Mode	Mean	Standard Deviation	Skewness
1	-3.0	-3.62	1.31	3.24
2	-3.0	-3.08	1.78	1.52

Test Pit #3

Sample #	Mode	Mean	Standard Deviation	Skewness
1	-3.0	-3.39	1.03	4.35
2	-3.0	-2.88	1.91	1.3

Table 2. Central Tendency Calculations for Sediment Samples from SK-46 (Values in Phi).

N4W8

Level #	Mode	Mean	Standard Deviation	Skewness
3	-2.0	-0.15	2.67	0.15
F3	-3.0	-0.93	2.71	0.35
4	-2.0	-0.99	2.64	0.46
5.2	-3.0	0.24	3.06	-0.86
5.3	-2.0	-0.37	2.48	0.31
6	-4.0	-1.94	2.5	0.85
7	-1.0	-1.23	2.53	0.49
8	-4.0	-1.76	2.31	0.49

Test Pit #4

Sample #	Mode	Mean	Standard Deviation	Skewness
1	-1.0	-0.2	2.34	0.38
2	-3.0	0.21	2.36	0.33
3	-4.0	-0.73	3.08	0.13
4	>4.0	0.83	2.49	-0.19
5	-4.0	0.1	2.88	-0.21
6	>4.0	0.39	2.72	-0.23
7	>4.0	0.96	2.53	-0.21

Table 3. Sediment Color and Texture Descriptions for SK-144.

S21 E1

Level #	Comments
2	5 Y 2.5/1 Black. Shell present, subrounded grains with rough surface texture, disc-shaped.
3	2.5 Y 2.5/1 Black. Disc-shaped subangular grains with rough surface texture. Shell fragments present.
4	2.5 Y 2.5/1 Black. Subrounded grains with slightly smoother surface texutre than other levels. Shell present.
5	2.5 Y 3/1 Very dark grey. Increased shell content, fish bone. Subangular grains with rough/pitted surface texture. Disc-shaped.
6	10 YR 3/2 Very dark grayish-brown. Shell. Subrounded disc-shaped grains with rough/pitted surface texture. Possible historic artifact.
7	10 YR 3/1 Dark gray. Subrounded disc-shaped grains with rough surface texture. Lots of shell.
8	10 YR 4/2 Dark grayish-brown. Subangular grains with mix of disc and blade-shapes. Rough surface texture. Less shell than 5, 6, and 7.

S22 E0

Level #	Comments
2	Sand, no soil. Subangular pebbles equant in shape with rough/pitted surface. Minimal shell and no bone.
3	10 YR 2/1 Black. Mix of subrounded/polished and angular/rough grains, equant in shape. Very little shell. Glass fragments.
5	10 YR 2/1 Black. Subangular, mix of blade and disc-shaped grains. More small shell fragments than previous levels.
6	10 YR 4/4 Dark yellowish-brown. Lots of sea urchin. Subrounded, polished, equant shaped grains.
7	10 YR 3/1 Very dark gray. Lots of larger beach gravel and shell gragments. Subrounded and equant with rough/pitted surface texture.
8	10 YR 2/1 Black. Rounded, equant pebbles. Shell fragments present.
9	10 YR Grayish-brown. Subrounded, disc shapped grains. Very little shell fragments.
10	10 YR 2/1 Black. Lots of shell fragments, subrounded pebbles.
11	10 YR 3/1 Very dark gray. Subrounded grains with rough surface texture. Clay concretions present. Very few shell fragments.
11b	10 YR 3/1 Very dark gray. Large clay concretions and subrounded grains, very rough surface texture. Few shell fragments.

Test Pit #1

Sample #	Comments
2	Multi-color sand matrix, no soil but lots of organic material. No shell. Grains subangular and equant.
3	Multi-color sand matrix, no soil, no organic material or shell. Subrounded, disc-shaped grains.
4	2.5 YR 3/1 Very Dark Gray matrix of sand, soil, and organic material. No shell. Grains subrounded and disc-shaped.
5	10 YR 2/1 Black. Lots of organic material and possibly some charcoal. Grains subrounded and disc-shaped.
6	Multi-color sand matrix, no soil, shell, or organic material. Subrounded, disc-shaped grains.
7	Multi-color sand matrix. Organic debri and some charcoal present. Grains subrounded and equant, with some clayey concretion and a black substance present on coarse sand size grains.

Test Pit #2

Sample #	Comments
1	5 YR 2.5/1 Black matrix. Organic material present, some shell. Grains subangular, disc-shaped with rough surface texture.
2	10 YR 4/2 Dark grayish-brown matrix of sand and soil. Shell present. Grains subangular and disc-shaped with rough surface texture.

Test Pit #3

Sample #	Comments
1	7.5 YR 5/1 Black soil matrix. Lots of organic material and shell present. Grains subangular and blade-shaped with rough surface texture.
2	10 YR 4/1 Dark gray sand matrix. Very little shell present, some fragments in smaller phi sizes. Grains subangular and mix of disc-shaped and equant grains.

Table 4. Sediment Color and Texture Descriptions for SK-46.

N4W8

Level #	Comments
F 3	10 YR 5/4Yellowish Brown, Bimodal mix of angular/rough and subrounded/polished grains, roughly equant in shape. Shell, bone, and plant material present.
3	10 YR 5/3 Brown, angular with rough surface and disc-shape. Most plant debri for unit, shell and fish bone also present.
4	10 YR 4/3 Brown, angular, disc-shaped. Shell, fish bone, and plant material present.
5.2	10 YR 4/2 Dark Grayish Brown, mix of angular/rough and subrounded/smooth grains with disc-shape. Shell, plant material, and bone (fish vertebrae) present.
5.3	Gley 12.5/N Black, angular and disc-shaped. Level has most shell for unit. Plant material and bone also present
6	10YR 5/6 Yellowish Brown, angular and disc-shaped with rough surface texture. Bone, plant material, and shell present.
7	10YR 5/4 Yellowish Brown, angular, disc-shaped, with rough surface texture. Shell, bone, and plant material present.
8	10 YR 4/6 Dark Yellowish Brown, angular, disc-shaped, and rough surface texture. No shell, bone or plant material present.

Test Pit #4

Level #	Comments
1 (-40 cm)	2.5Y 7/2 Light Gray, subangular and equant. Plant material present.
2 (-35 cm)	10YR 6/2 Light Brownish Gray, subrounded and equant. Plant material present.
3 (-30 cm)	10YR 6/2 Light Brownish Gray, subrounded and equant. Plant material present.
4 (-25 cm)	10YR 6/3 Pale Brown, subrounded and equant. Plant material present.
5 (-20 cm)	10YR 6/3 Pale Brown, subrounded and equant. Plant material present.
6 (-15 cm)	10 YR 6/4 Light Yellowish Brown, subrounded and equant. Plant material present.
7 (-10 cm)	2.5YR 4/2 Dark Grayish Brown, subrounded and equant. Has the most plant material for STP.

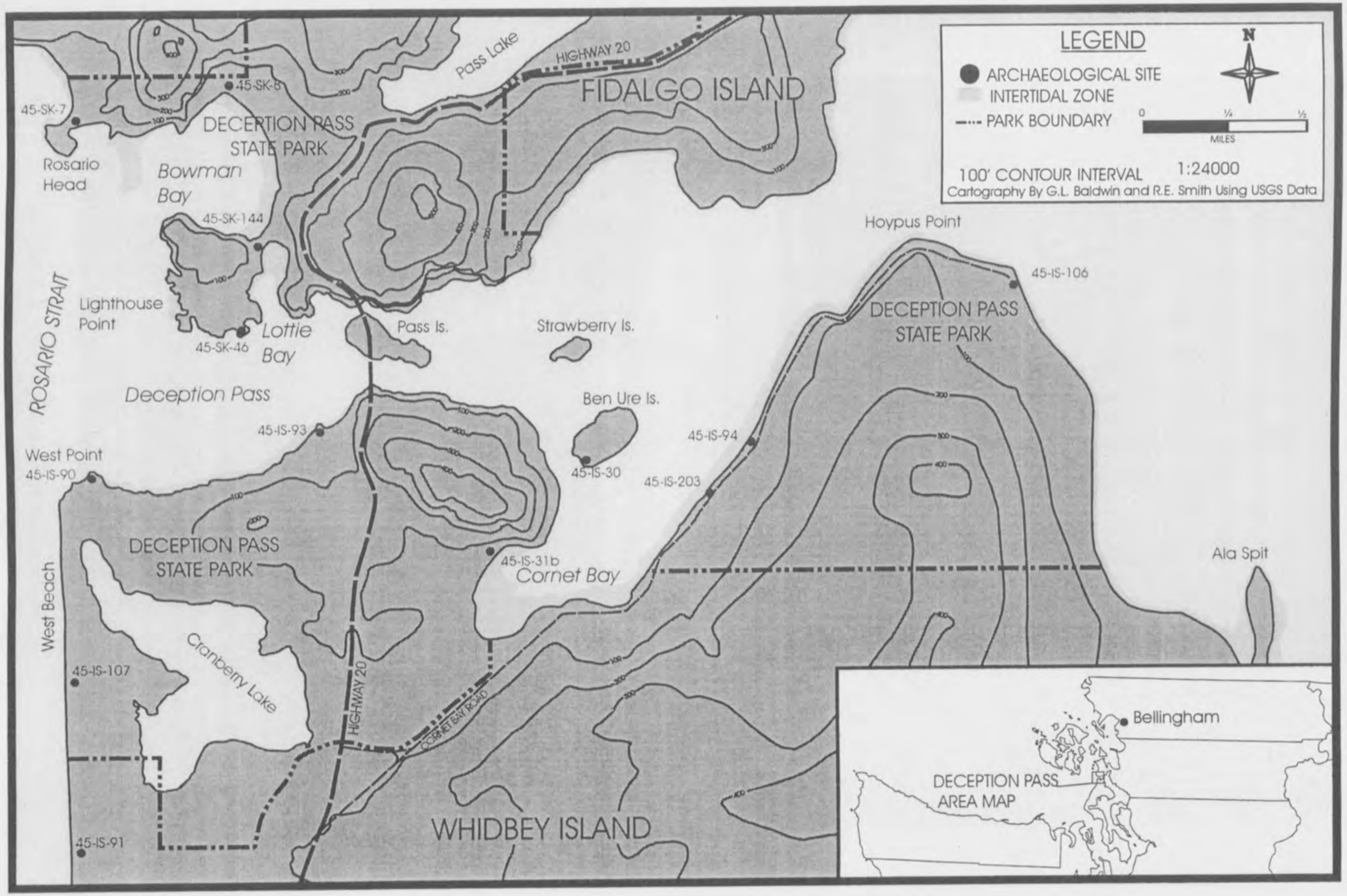

Figure 1. Map of Deception Pass study area.

Figure 2. Aerial photo of Lighthouse Point with site locations marked.

Figure 3. Photo of SK-46 excavation.

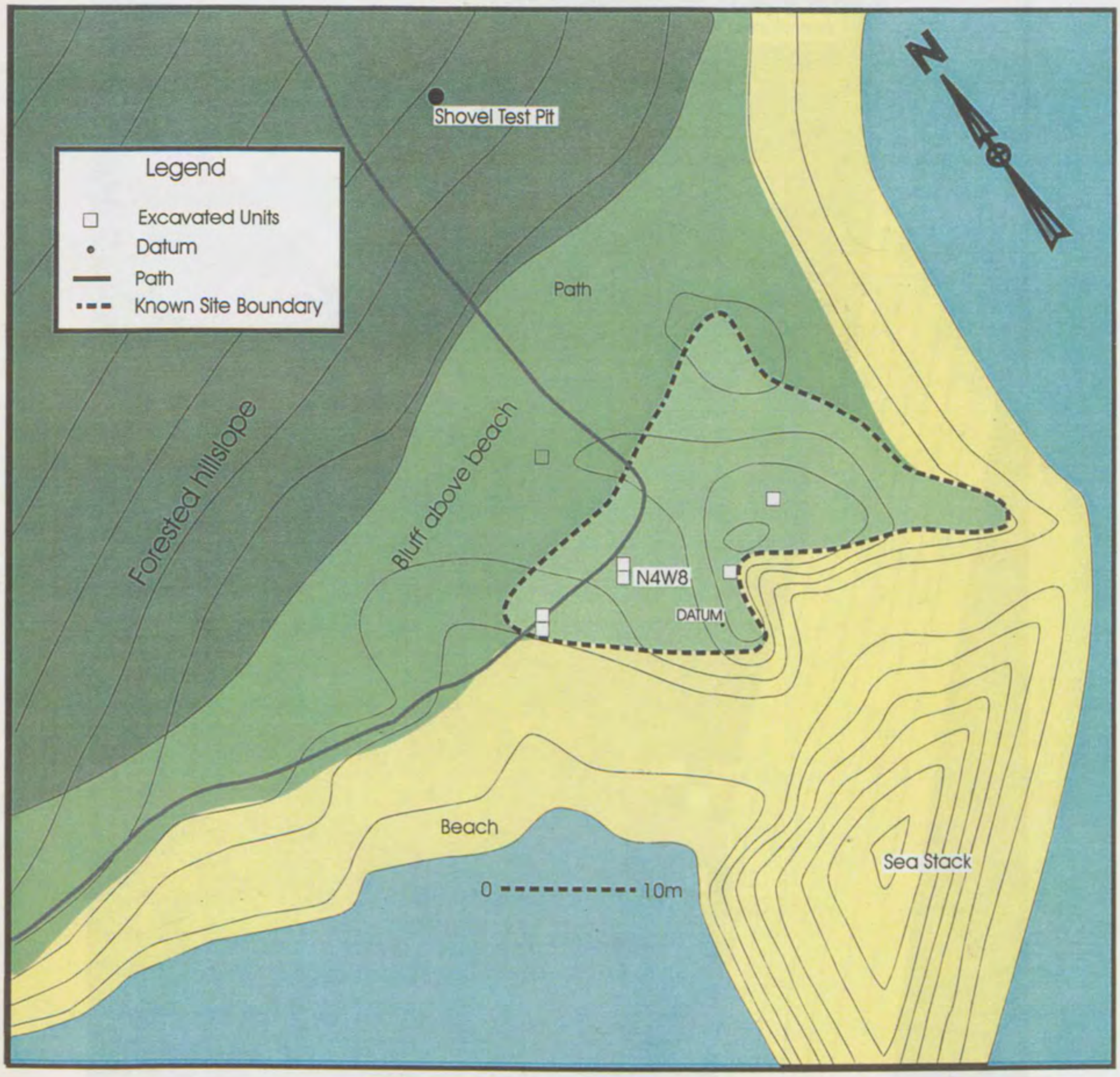

Figure 4. Map of SK-46 site area with excavation units and test pit location marked.

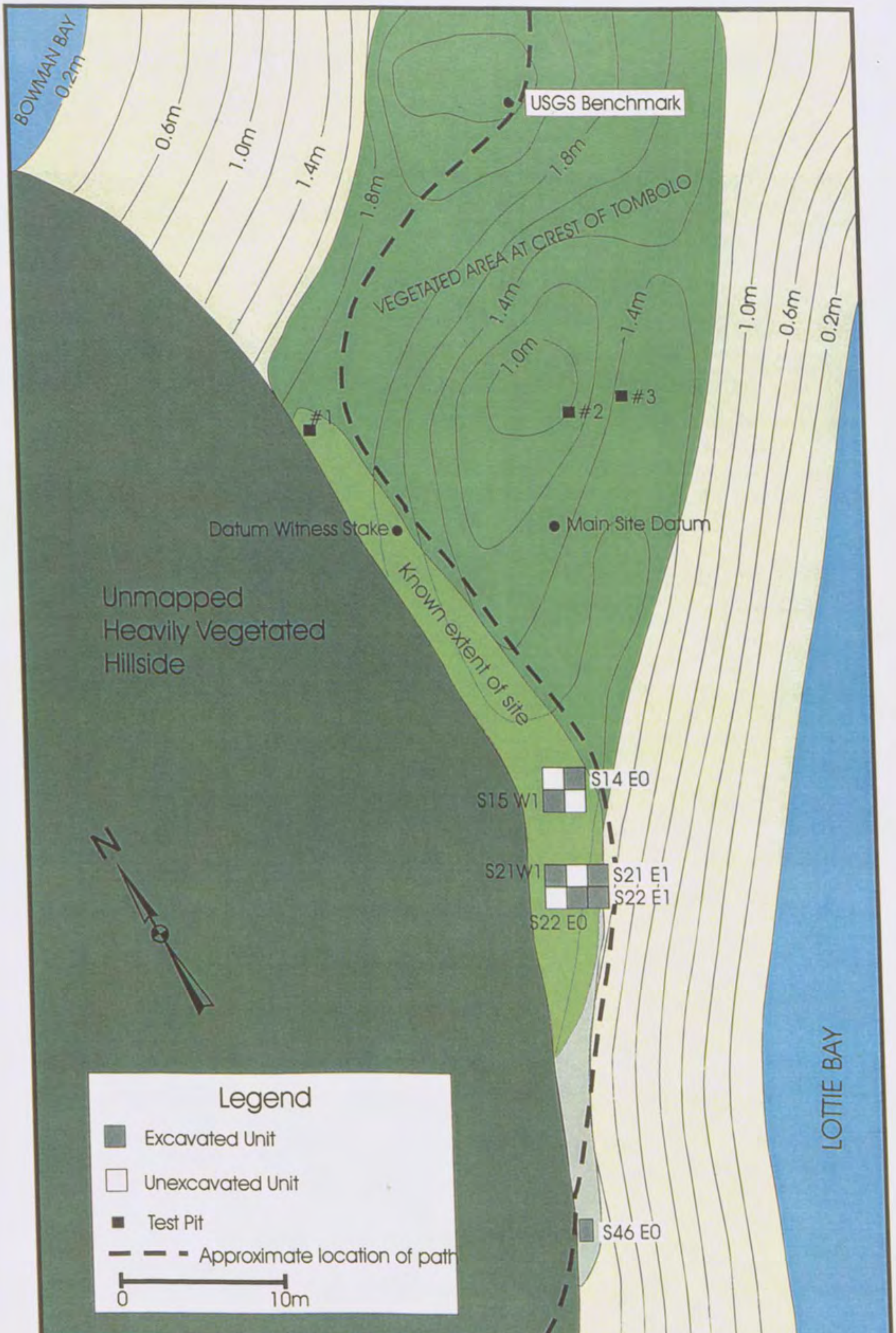

Figure 5. Map of SK-144 site area with excavation units and test pit locations marked.

Figure 6. Photo of excavation at SK-144. Lottie Bay is to the left of the photo.

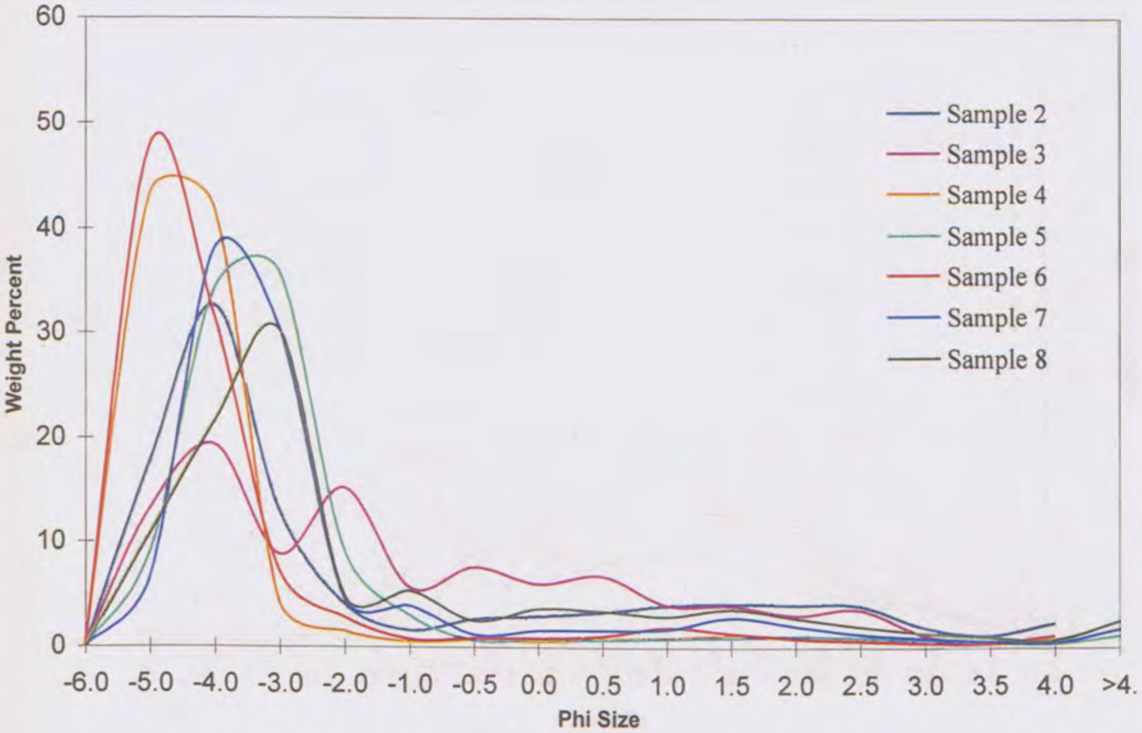

Figure 7. Graph of weight percent versus phi size for S21 E1, SK-144.

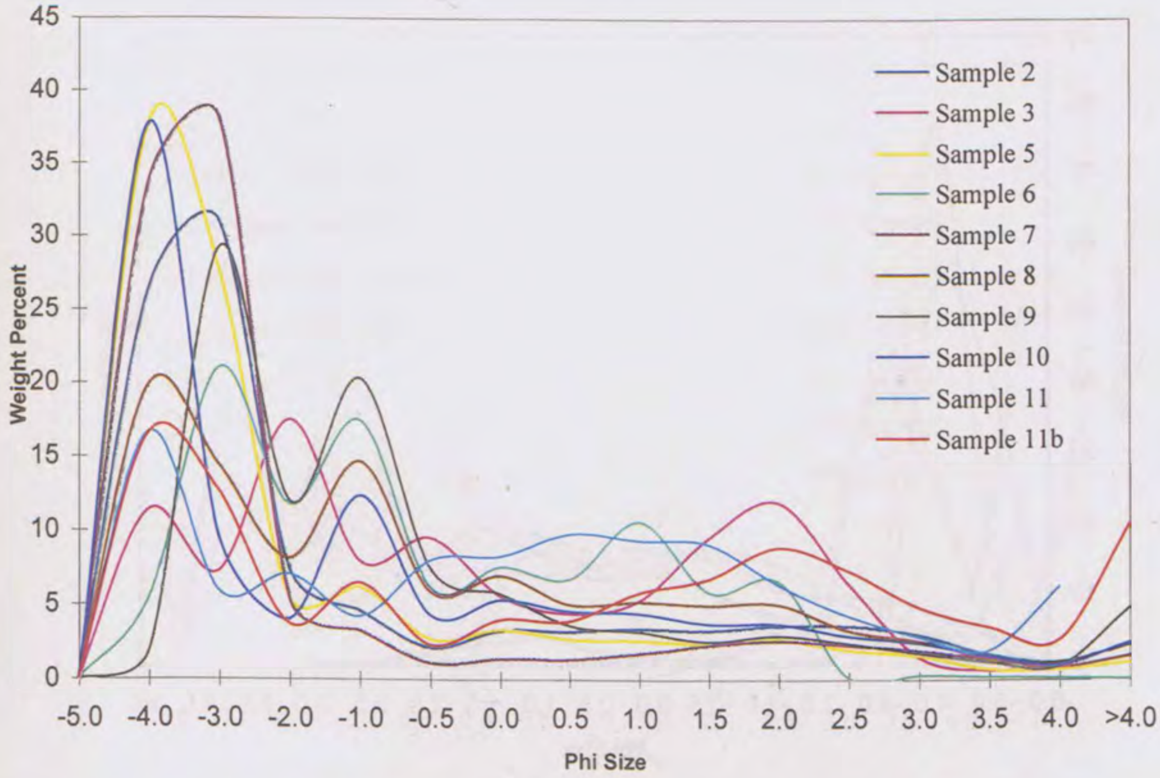

Figure 8. Graph of weight percent versus phi size for S22 E0, SK-144.

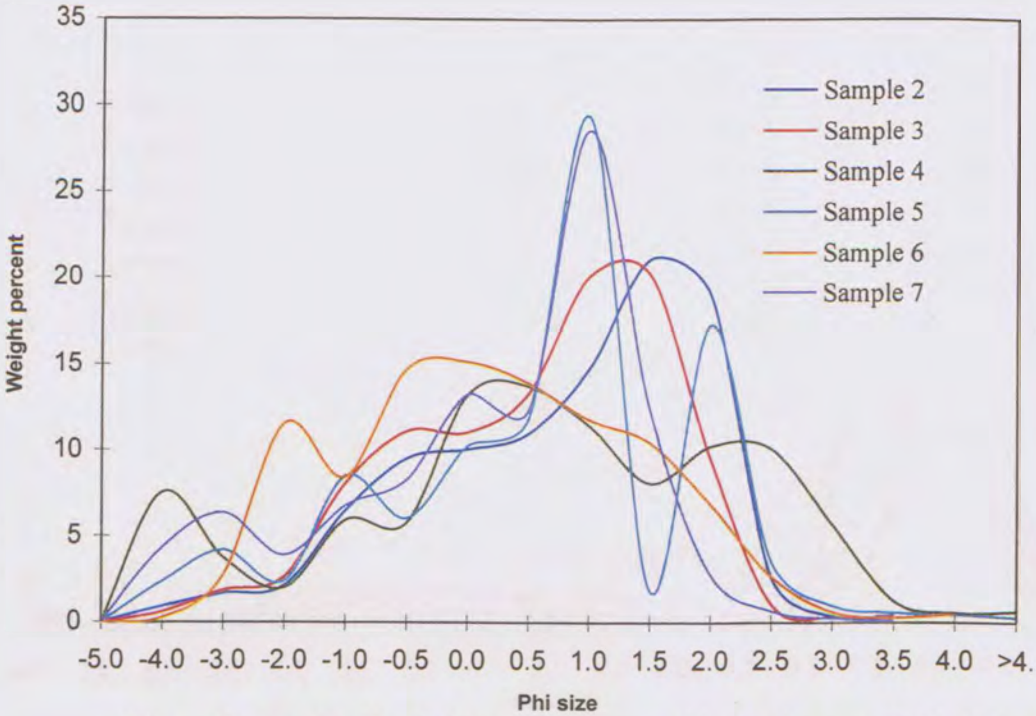

Figure 9. Graph of weight percent versus phi size for test pit #1, SK-144.

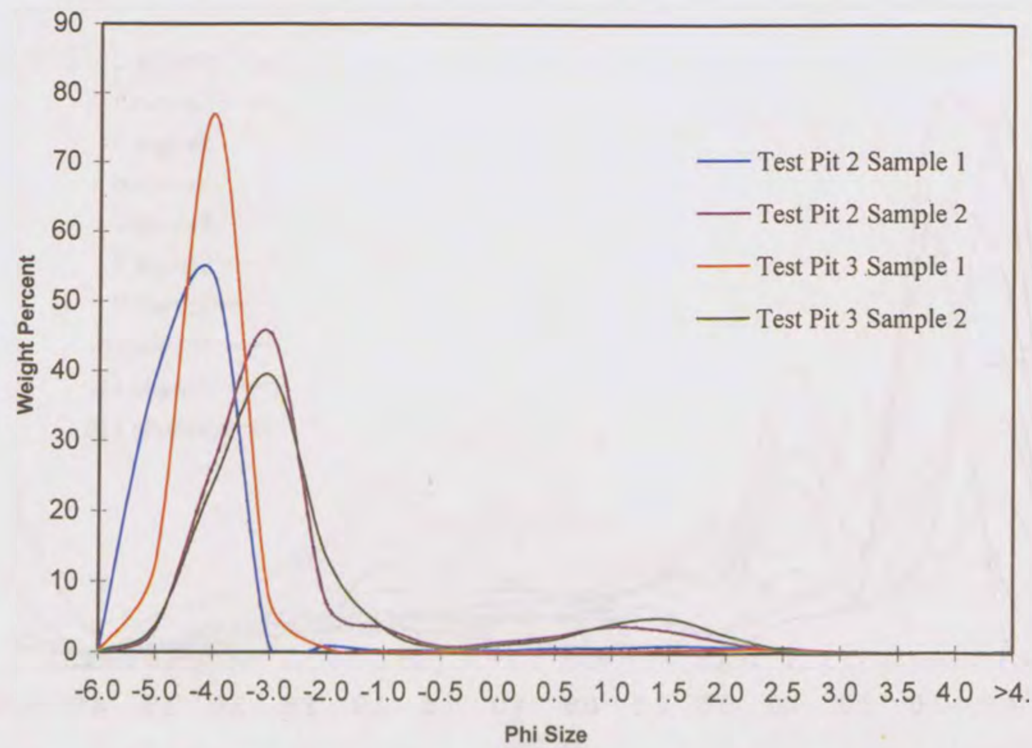

Figure 10. Graph of weight percent versus phi size for test pits #2 and #3, SK-144

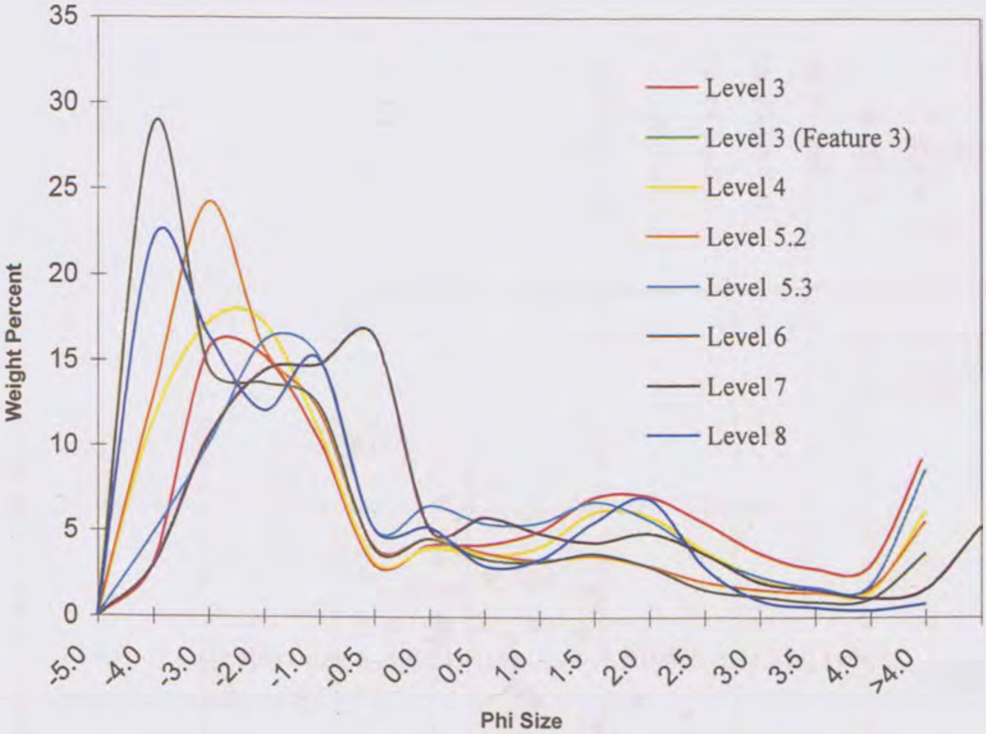

Figure 11. Graph of weight percent versus phi size for N4W8, SK-46.

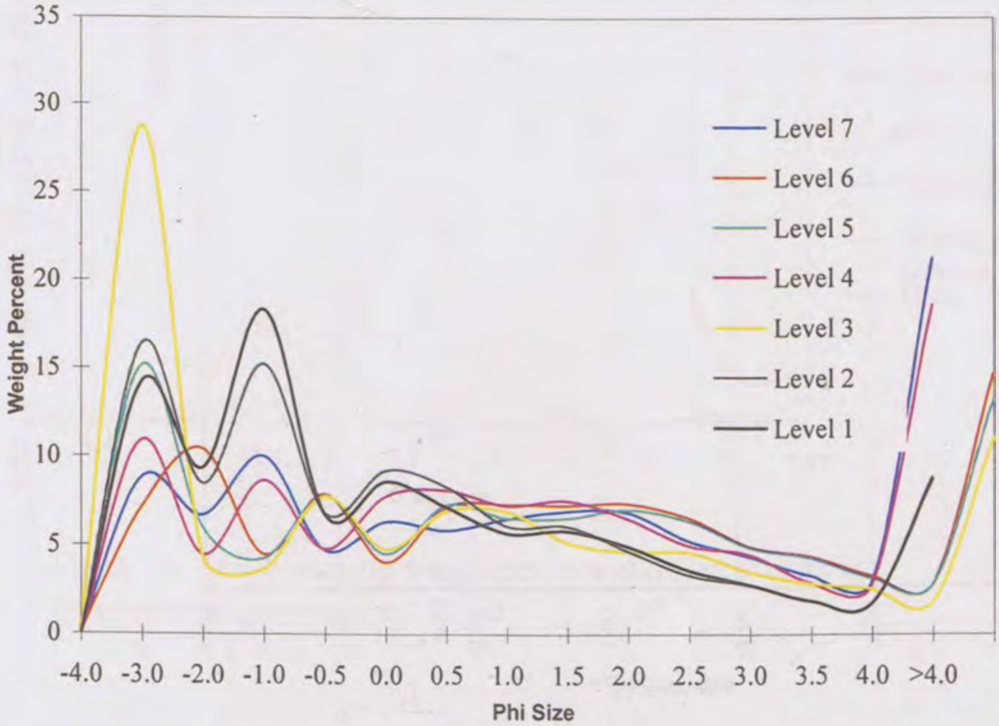

Figure 12. Graph of weight percent versus phi size for test pit #4, SK-46.

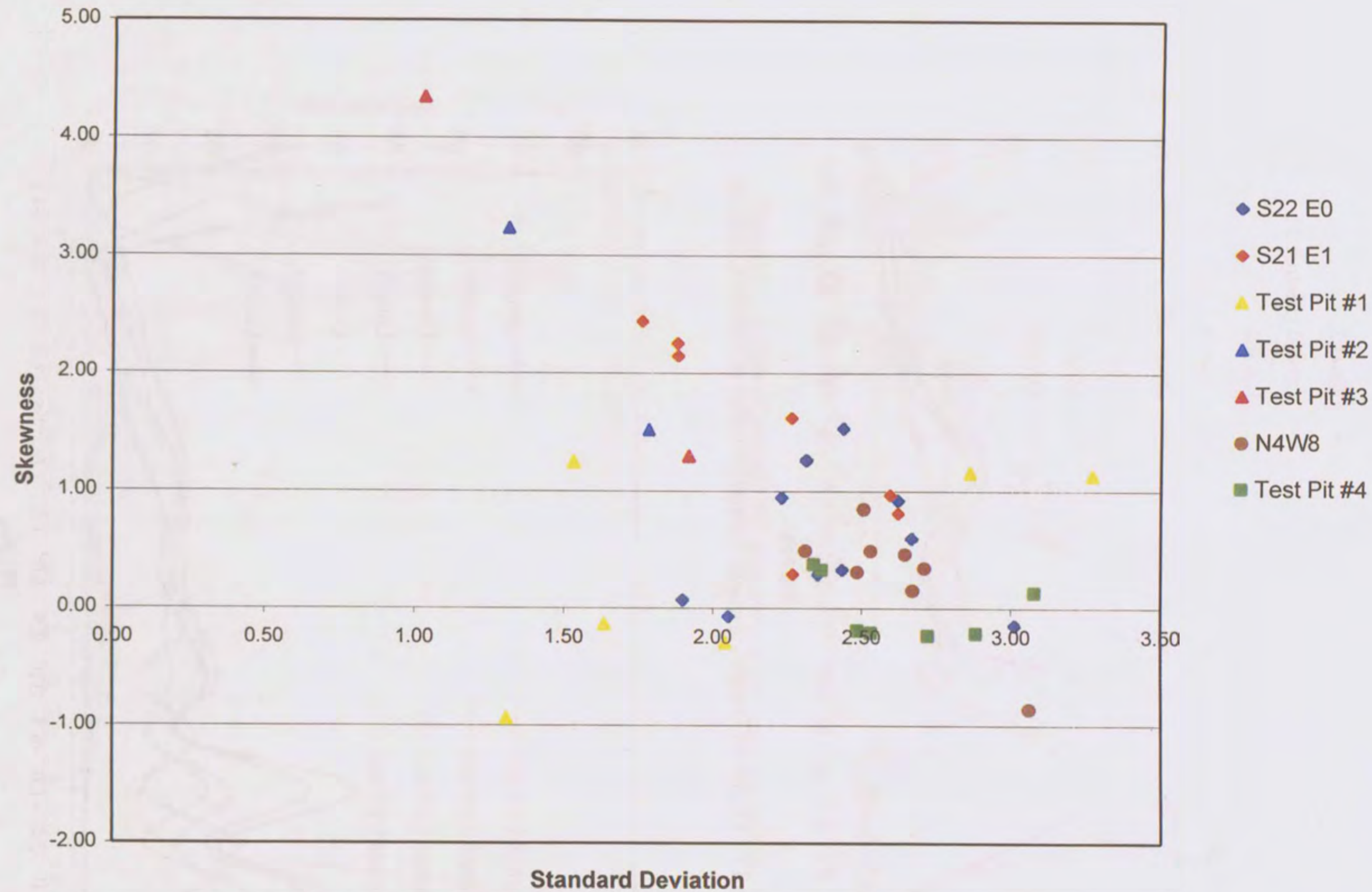

Figure 13. Scatter plot of skewness versus standard deviation for all samples.

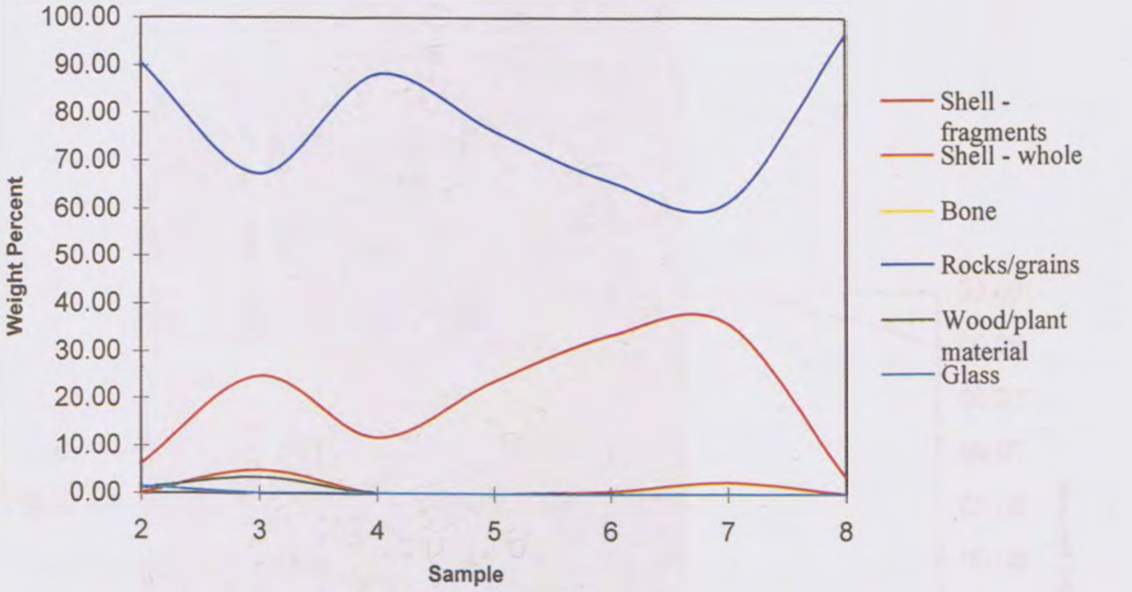

Figure 14. Graph showing weight percents of different material types according to levels of S21 E1.

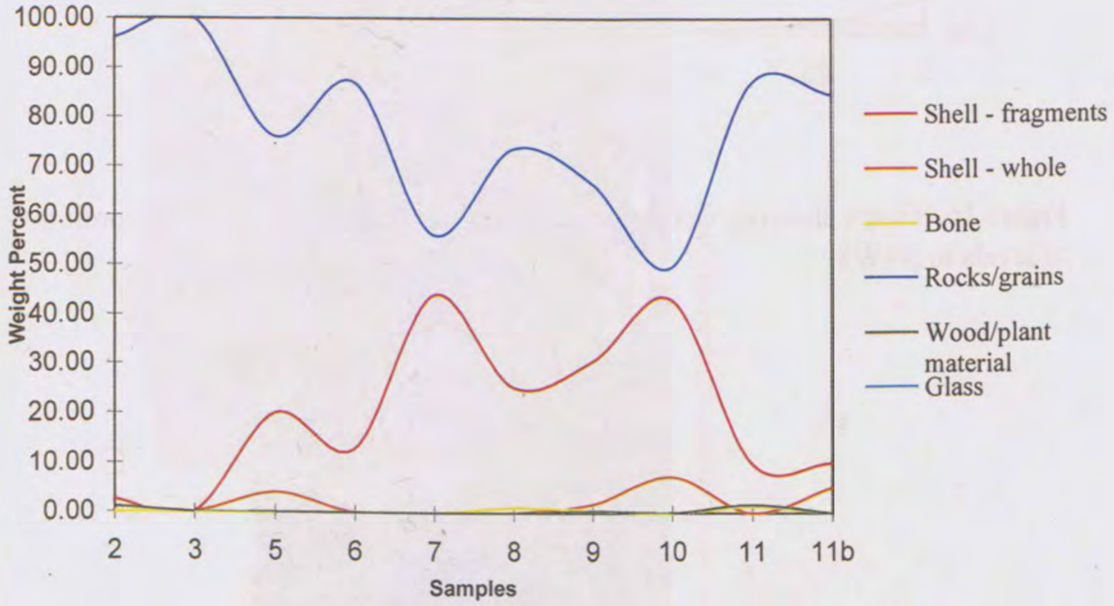

Figure 15. Graph showing weight percents of different material types according to levels in S22 E0

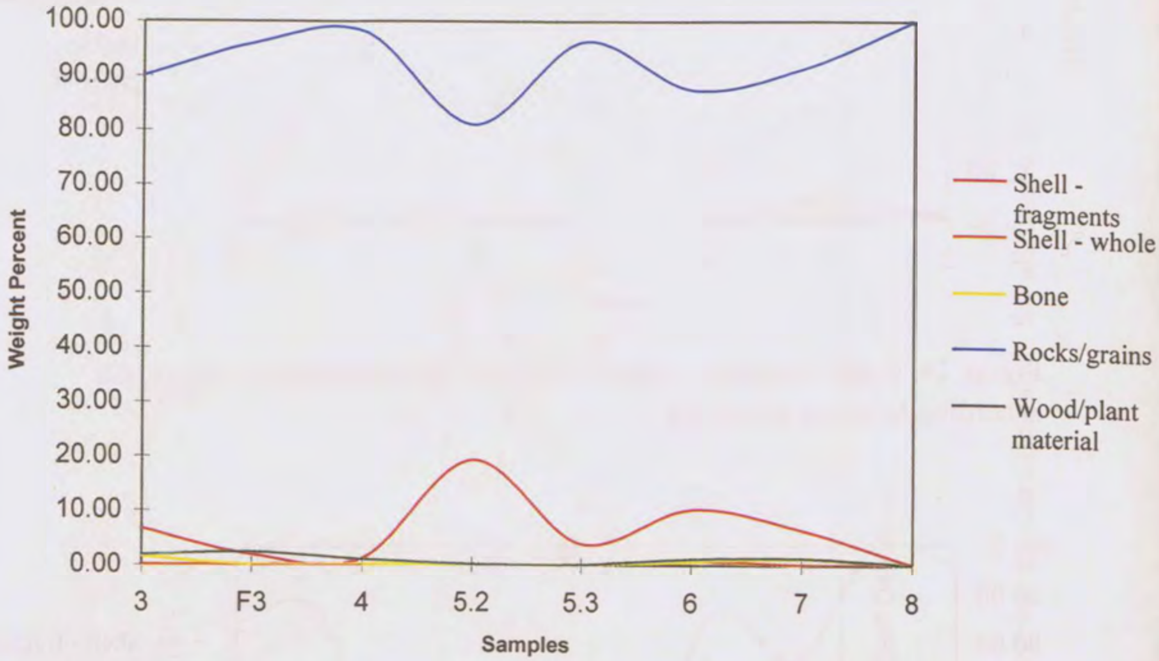

Figure 16. Graph showing weight percents of different material types according to levels in N4W8

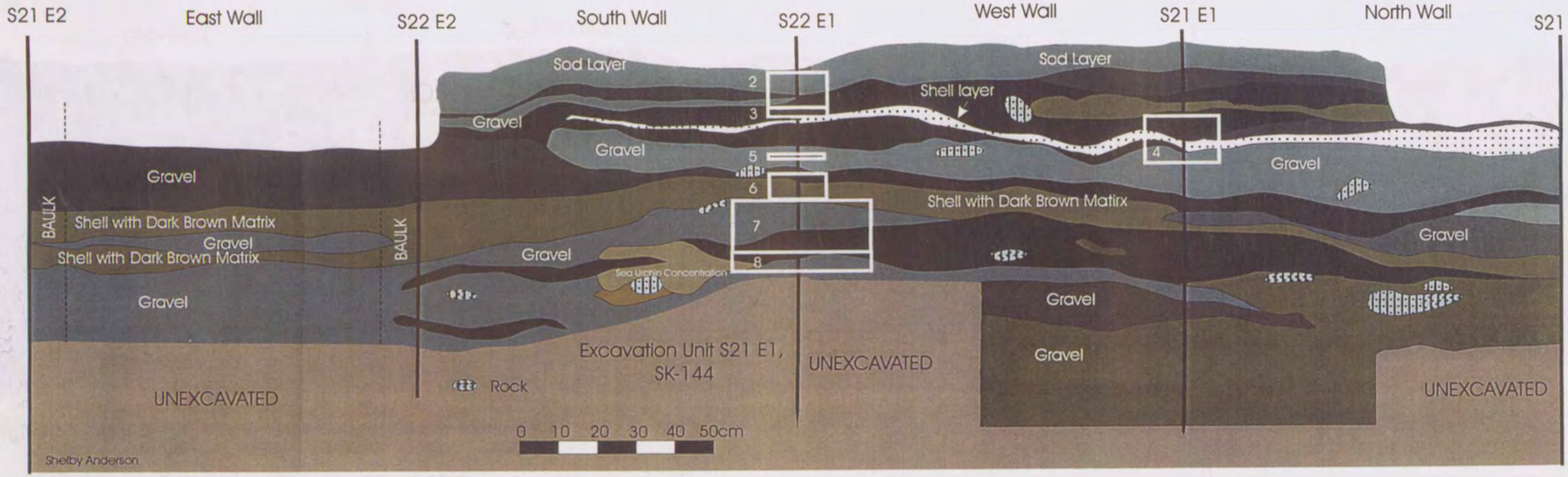

Figure 17. Profile of S21 E1, SK-144, with sample locations indicated.

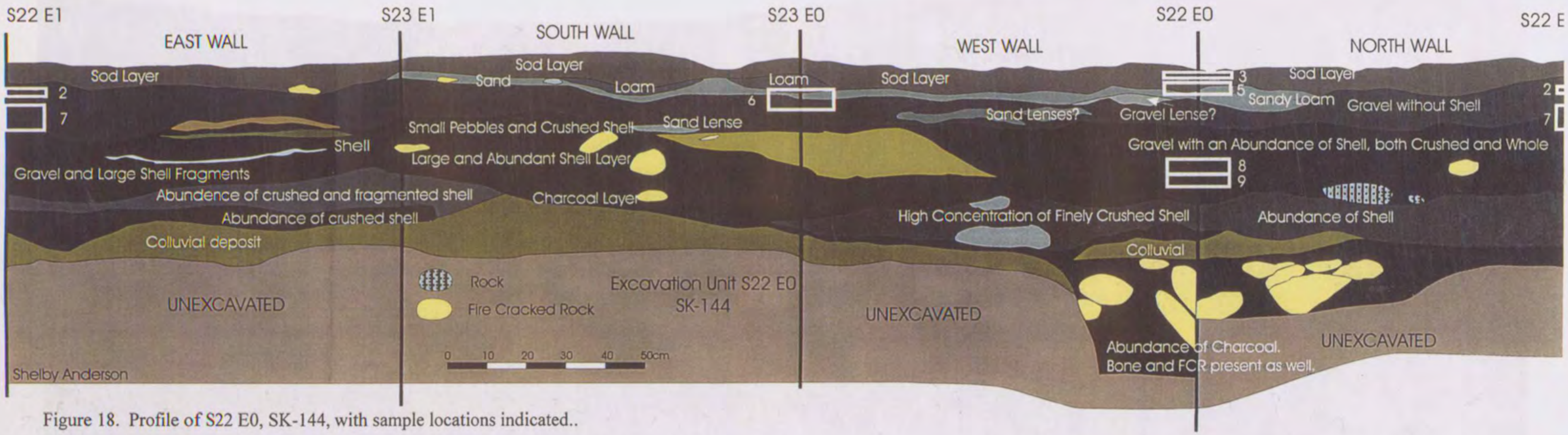

Figure 18. Profile of S22 E0, SK-144, with sample locations indicated..

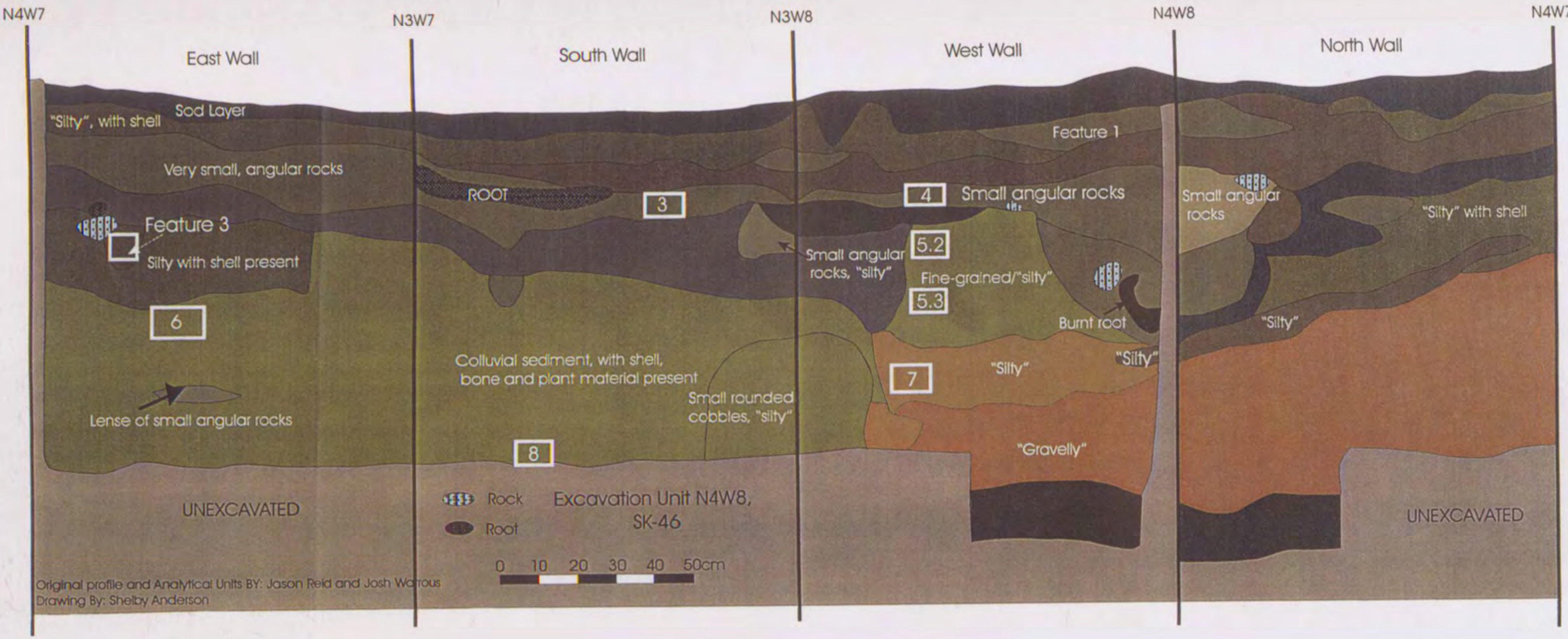

Figure 19. Profile of N4W8, SK-46, with sample locations indicated.

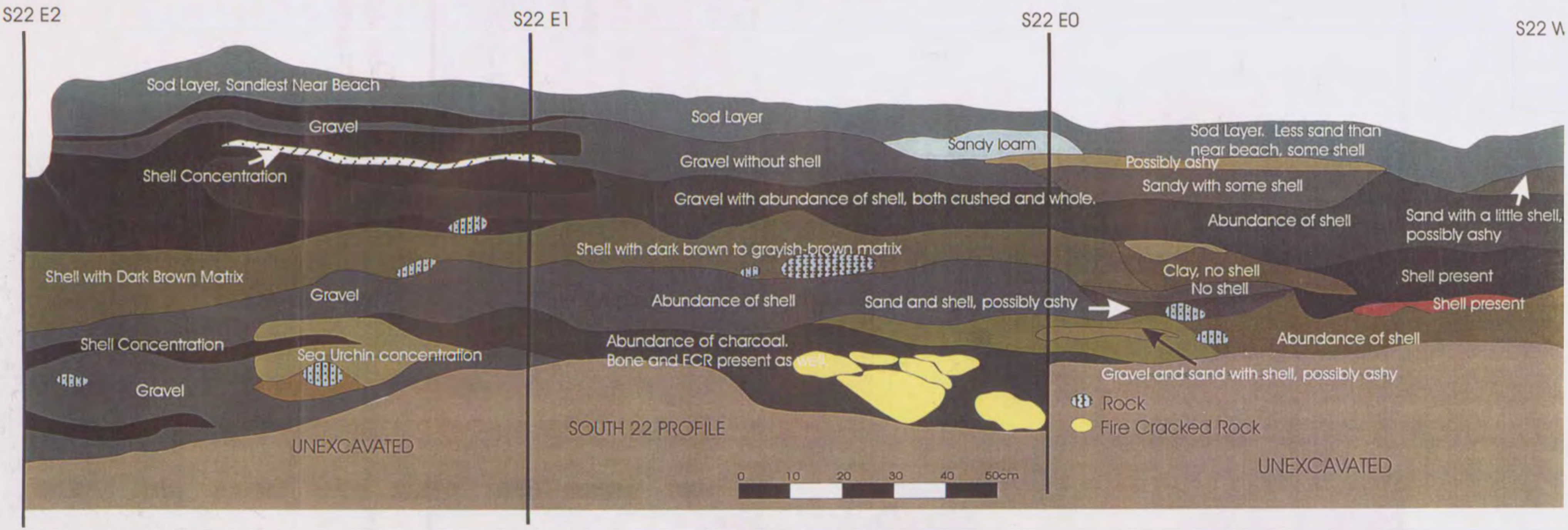

Figure 20. Profile of south 22 excavation, SK-144. Note possible beach berm structures on the east wall.

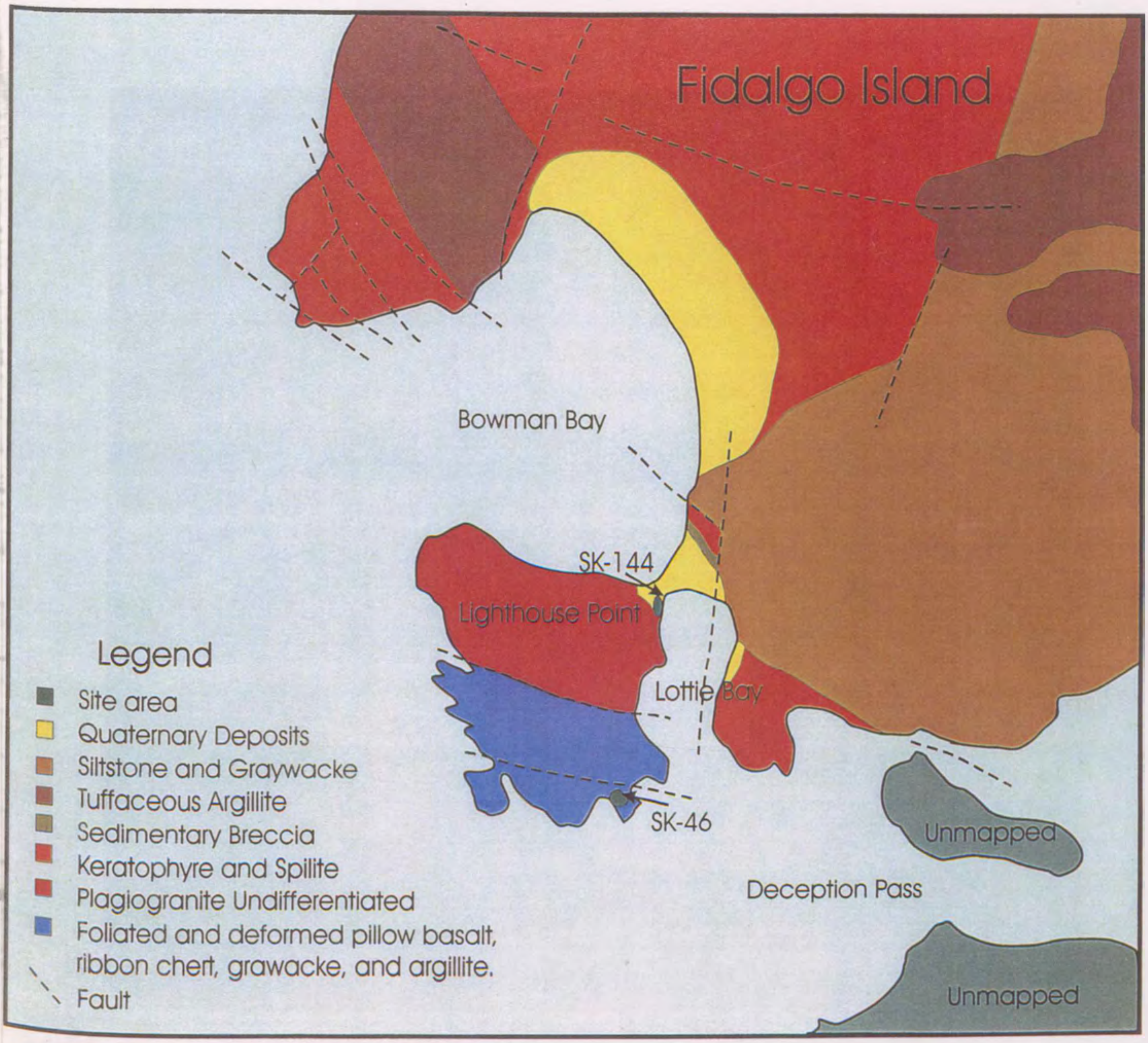

Figure 21. Geologic map of Lighthouse Point and surrounding area with site locations indicated (Adapted from Brown and Gusey 1978).

Figure 22. Photo of north wall of excavation unit N4W8, SK-46. Yellowish-brown colluvial sediments are visible at base of excavation unit.

Figure 23. Photo of south wall of excavation unit S21 E1 (the blackboard is mislabeled). Note the layers of beach gravel and berm structures.

Figure 24. Profile of bank profile at SK-46 with colluvial sediments evident above the Pleistocene bed.

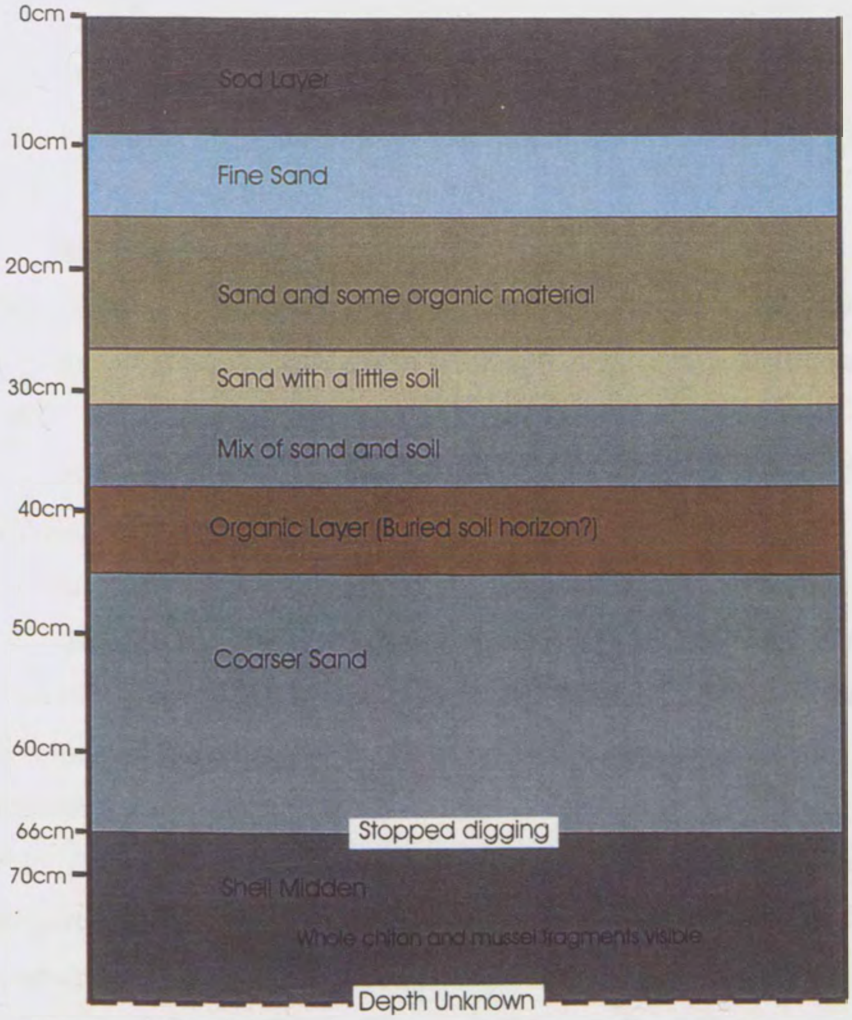

Figure 25. Profile of sediment layers in Test Pit #1

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Appendices

Appendix A. Raw Phi Size Weights for All Units and Test Pits.

Appendix B. Raw Phi Size and Weight Percent Data for –2.0ϕ Samples.

Appendix C. Standard Deviation and Skewness Value Chart (Boggs 2001).

Appendix A. Raw Phi Size Data for All Units and Test Pits.

S21 E1

Level #	-5.0	-4.0	-3.0	-2.0	-1.0	-0.50	0.0	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	>4.0	Total Weight (g)
2	0	310.49	363.93	86.78	53.86	24.98	38.27	37.41	39.80	38.20	42.27	41.91	34.78	19.64	13.77	27.81	1173.90
3	0	0.00	28.77	18.22	44.35	20.08	24.18	14.26	11.17	13.40	24.12	30.15	16.24	3.77	1.66	2.67	253.04
5	0	527.75	390.31	76.78	86.39	38.17	46.50	37.75	36.89	33.62	37.31	27.84	22.46	9.96	10.21	16.52	1398.46
6	0	40.69	158.01	88.30	131.71	46.64	56.93	50.67	80.10	43.98	49.51	0.74	2.24	1.45	1.01	0.49	752.47
7	0	268.94	303.09	43.06	25.74	8.73	10.99	10.64	13.80	18.06	20.36	18.06	15.27	11.06	9.24	18.61	795.65
8	0	91.86	66.66	37.56	67.89	27.39	32.31	23.28	24.19	22.99	23.36	15.09	11.79	6.50	4.06	7.43	462.36
9	0	11.18	166.30	68.00	115.62	42.39	32.81	20.41	18.03	14.39	16.57	13.53	9.93	6.62	5.30	27.61	568.69
10	0	163.63	41.27	17.38	53.49	18.63	23.10	19.87	19.16	16.08	16.09	12.51	10.45	6.65	4.42	10.74	433.47
11	0	0.00	62.56	22.14	26.35	15.80	30.16	31.28	36.93	35.31	34.31	23.86	15.97	10.66	7.42	23.63	376.38
11b	0	61.63	47.05	13.82	24.07	8.64	14.87	14.51	21.64	25.10	33.13	27.17	18.04	13.06	9.99	39.16	371.88

S22 EO

Level #	-5.0	-4.0	-3.0	-2.0	-1.0	-0.50	0.0	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	>4.0	Total Weight (g)
2	0.00	167.73	309.59	123.40	39.02	15.29	25.74	28.34	32.13	38.41	40.16	38.89	38.11	18.18	11.28	22.50	948.77
3	0.00	50.89	74.95	34.20	59.06	22.23	29.61	23.58	26.45	15.91	15.74	12.12	14.00	4.65	2.10	2.23	387.72
4	0.00	340.24	330.67	34.74	12.00	4.23	5.64	4.43	6.43	7.37	9.19	8.59	6.81	4.94	3.92	9.27	788.47
5	90.89	348.60	364.25	93.15	31.40	7.09	8.38	7.32	8.77	9.69	11.34	9.68	7.19	4.96	4.06	11.60	1018.37
6	0.00	630.56	417.92	96.12	37.94	10.41	11.50	11.52	14.36	25.62	18.52	11.41	8.21	5.93	5.01	14.67	1319.70
7	84.51	496.94	397.55	60.71	51.87	16.12	21.01	21.61	23.17	37.89	27.13	17.06	12.30	8.21	6.59	23.14	1305.81
8	178.38	357.17	500.35	81.13	88.99	42.44	61.48	57.51	49.87	61.29	47.56	33.67	23.90	16.39	13.00	42.17	1655.30

Test Pit #1

Sample #	-5.0	-4.0	-3.0	-2.0	-1.0	-0.5	0.0	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	>4.0	Total Weight (g)
2	0	0.00	0.00	5.52	10.21	12.97	39.89	58.59	61.83	67.45	90.93	130.00	116.49	16.03	2.27	2.51	614.69
3	0	0.00	0.00	4.10	12.78	18.27	56.41	77.52	77.16	93.07	140.61	141.19	66.42	7.36	2.00	2.46	699.35
4	0	45.77	22.82	12.00	35.86	34.96	80.05	83.22	69.22	49.06	61.92	60.93	34.35	7.49	3.34	3.95	604.94
5	0	8.46	15.12	8.58	30.60	21.62	36.82	42.59	105.37	6.58	62.12	12.66	3.54	2.08	1.63	1.05	358.82
6	0	0.00	2.40	24.26	103.71	75.91	132.03	135.99	124.88	105.85	93.67	61.57	23.77	5.60	2.72	4.35	896.71
7	0	0.00	0.00	27.21	39.91	24.51	42.51	52.00	83.30	77.48	179.32	77.21	17.42	4.10	1.58	0.82	627.37

Test Pit #2

Sample #	-5.0	-4.0	-3.0	-2.0	-1.0	-0.5	0.0	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	>4.0	Total Weight (g)
1	0.00	673.69	917.38	17.06	15.87	3.58	5.60	5.45	10.14	12.22	17.18	14.75	11.90	2.23	0.53	0.30	1707.88
2	58.26	475.37	810.64	123.33	63.40	16.87	27.05	41.75	66.82	55.66	28.09	6.84	3.92	1.66	1.17	2.22	1783.05

Test Pit #3

Sample #	-5.0	-4.0	-3.0	-2.0	-1.0	-0.5	0.0	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	>4.0	Total Weight (g)
1	0.00	177.73	1119.55	109.07	8.87	1.98	2.09	1.54	2.07	2.98	6.03	7.20	8.32	3.64	1.58	1.54	1454.19
2	263.21	401.40	666.03	226.74	58.71	11.11	18.83	32.59	68.63	82.57	43.05	8.84	2.43	1.17	0.91	3.51	1889.73

N4W8

Level #	-5.0	-4.0	-3.0	-2.0	-1.0	-0.5	0.0	0.5	1.0	1.5	2.0	2.5	3.0	3.50	4.00	>4.0	Total Weight (g)
8	0.00	207.81	155.58	114.33	142.70	48.53	49.54	28.43	31.85	52.61	65.78	27.85	9.31	5.37	3.10	7.58	950.37
7	43.45	151.74	208.77	214.12	237.44	74.44	84.76	70.85	63.27	70.89	53.73	29.72	23.38	16.31	23.98	76.78	1443.63
6	0.00	437.07	221.95	208.66	188.82	60.24	69.44	51.96	49.39	56.84	45.07	24.70	18.52	13.52	16.61	57.39	1520.18
5.2	0.00	63.40	120.09	78.17	60.09	20.35	22.73	18.63	16.58	18.05	15.00	10.38	8.09	7.20	8.42	27.99	495.17
5.3	0.00	42.12	87.66	141.11	133.03	45.15	57.03	47.83	48.30	59.26	49.92	32.27	20.95	15.43	16.70	75.73	872.49
4	0.00	98.87	148.91	149.47	94.89	28.30	35.28	31.89	35.67	53.69	51.49	33.97	20.44	14.10	13.22	54.58	864.77
3	0.00	13.87	71.82	70.42	47.77	14.19	19.14	19.38	23.06	32.34	32.73	25.54	17.26	13.16	13.99	44.78	459.45
F 3	0.00	73.64	66.94	76.09	55.35	15.66	19.80	18.42	20.94	31.90	32.49	22.12	14.31	9.06	9.88	28.95	495.55

Test Pit #4

Level #	-5.0	-4.0	-3.0	-2.0	-1.0	-0.50	0.0	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	>4.0	Total Weight (g)
-40 c	0.00	0.00	27.86	18.27	35.81	13.16	16.86	14.03	11.16	11.43	9.68	7.00	5.47	3.68	3.47	17.16	195.04
-35 c	0.00	0.00	37.36	19.31	34.86	15.60	21.13	19.03	13.97	13.92	10.68	7.57	6.31	4.26	4.05	20.35	228.40
-30 c	0.00	58.29	9.01	7.45	15.76	9.82	14.12	14.13	10.56	9.49	9.40	7.17	5.81	5.20	3.91	22.60	202.72
-25 c	0.00	0.00	16.27	6.66	12.92	7.18	11.61	12.16	10.84	11.27	9.72	7.44	6.71	4.35	4.19	27.87	149.19
-20 c	0.00	20.91	8.26	5.86	10.78	6.28	10.07	9.06	9.07	9.70	8.81	6.74	5.93	4.36	3.93	18.40	138.16
-15 c	0.00	9.87	14.54	6.28	11.02	5.68	10.02	10.24	10.15	10.28	9.17	6.88	6.10	4.59	3.98	20.64	139.44
-10 c	0.00	0.00	12.08	9.17	13.80	6.52	8.73	8.06	8.95	9.56	9.44	7.23	6.01	4.53	4.12	29.36	137.56

Appendix B. Raw Weights and Weight Percent Calculations for -2.0 Phi Samples.

S22 E0

Level #	Shell - fragments	Shell - whole	Bone	Rocks/grains	Wood/plant material	Glass	Total	Shell Fragment Weight %	Shell - Whole Weight %	Bone Weight %	Lithic Weight %	Wood/plant Weight %	Glass Weight %	Total
2	2.19	0.00	0.00	83.20	0.92	0.31	**86.62**	2.53	0.00	0.00	96.05	1.06	0.36	100
3	0.00	0.00	0.00	18.22	0.00	0.00	**18.22**	0.00	0.00	0.00	100.00	0.00	0.00	100
5	15.75	3.18	0.00	60.01	0.00	0.00	**78.94**	19.95	4.03	0.00	76.02	0.00	0.00	100
6	11.32	0.00	0.00	76.06	0.00	0.00	**87.38**	12.95	0.00	0.00	87.05	0.00	0.00	100
7	18.91	0.00	0.00	24.14	0.00	0.00	**43.05**	43.93	0.00	0.00	56.07	0.00	0.00	100
8	8.25	0.00	0.38	23.87	0.00	0.00	**32.50**	25.38	0.00	1.17	73.45	0.00	0.00	100
9	20.85	1.22	0.36	45.42	0.29	0.00	**68.14**	30.60	1.79	0.53	66.66	0.43	0.00	100
10	7.57	1.29	0.00	8.74	0.00	0.00	**17.60**	43.01	7.33	0.00	49.66	0.00	0.00	100
11	2.28	0.00	0.31	19.80	0.37	0.00	**22.76**	10.02	0.00	1.36	86.99	1.63	0.00	100
11b	1.47	0.75	0.00	12.27	0.00	0.00	**14.49**	10.14	5.18	0.00	84.68	0.00	0.00	100

S21E1

Level #	Shell - fragments	Shell - whole	Bone	Rocks/grains	Wood/plant material	Glass	Total	Shell Fragment Weight %	Shell - Whole Weight %	Bone Weight %	Lithic Weight %	Wood/plant Weight %	Glass Weight %	Total
2	7.78	0.00	1.17	116.04	1.34	1.72	**128.05**	6.08	0.00	0.91	90.62	1.05	1.34	100
3	8.55	1.68	0.00	23.30	1.14	0.00	**34.67**	24.66	4.85	0.00	67.21	3.29	0.00	100
4	4.28	0.00	0.00	31.93	0.00	0.00	**36.21**	11.82	0.00	0.00	88.18	0.00	0.00	100
5	22.56	0.00	0.00	72.48	0.00	0.00	**95.04**	23.74	0.00	0.00	76.26	0.00	0.00	100
6	32.67	0.59	0.00	63.96	0.00	0.00	**97.22**	33.60	0.61	0.00	65.79	0.00	0.00	100
7	22.95	1.60	0.00	38.95	0.00	0.00	**63.50**	36.14	2.52	0.00	61.34	0.00	0.00	100
8	2.92	0.00	0.00	79.72	0.00	0.00	**82.64**	3.53	0.00	0.00	96.47	0.00	0.00	100

Test Pit #2

Level #	Shell - fragments	Shell - whole	Bone	Rocks/grains	Wood/plant material	Glass	Total	Shell Fragment Weight %	Shell - Whole Weight %	Bone Weight %	Lithic Weight %	Wood/plant Weight %	Glass Weight %	Total
1	1.48	0.00	0.00	70.00	0.30	0.00	**71.78**	2.06	0.00	0.00	97.52	0.42	0.00	100

2	1.24	0.27	0.00	120.93	0.00	0.00	**122.44**	1.01	0.22	0.00	98.77	0.00	0.00	100

Test Pit #3

1	17.07	0.59	0.00	91.30	0.00	0.00	**108.96**	15.67	0.54	0.00	83.79	0.00	0.00	100
2	4.68		0.00	223.01	0.00	0.00	**227.69**	2.06	0.00	0.00	97.94	0.00	0.00	100

N4W8

3	4.99	0.00	1.19	67.41	1.37		**74.96**	6.66	0.00	1.59	89.93	1.83	0.00	100
F3	1.45	0.00	0.00	75.80	1.81		**79.06**	1.83	0.00	0.00	95.88	2.29	0.00	100
4	1.63	0.00	0.00	149.71	1.34		**152.68**	1.07	0.00	0.00	98.05	0.88	0.00	100
5.2	15.33	0.00	0.00	64.96			**80.29**	19.09	0.00	0.00	80.91	0.00	0.00	100
5.3	5.47	0.00	0.00	137.89			**143.36**	3.82	0.00	0.00	96.18	0.00	0.00	100
6	21.53	1.56	1.47	185.70	2.34		**212.60**	10.13	0.73	0.69	87.35	1.10	0.00	100
7	14.19	0.00	2.54	204.08	2.64		**223.45**	6.35	0.00	1.14	91.33	1.18	0.00	100
8	0.00	0.00	0.00	114.33			**114.33**	0.00	0.00	0.00	100.00	0.00	0.00	100

Appendix C. Standard Deviation and Skewness Value Chart (Boggs 2001).

Standard Deviation

< 0.35 ϕ	very well sorted
0.35-0.50 ϕ	well sorted
0.50 – 0.71 ϕ	moderately well sorted
0.71 – 1.00 ϕ	moderately sorted
1.00 – 2.00 ϕ	poorly sorted
2.00 – 4.00 ϕ	very poorly sorted
> 4.00 ϕ	extremely poorly sorted

Skewness

> + 0.30	strongly fine skewed
+ 0.30 - + 0.10	fine skewed
+0.10 to - 0.10	near symmetrical
-0.10 to –0.30	coarse skewed
< -0.30	strongly coarse skewed