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The Origin of Tan Ashy Lenses in a Puget Sound Shell Midden: Results of sediment analysis

By Stephanie VanBuskirk
June 2, 2000

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HONORS THESIS

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Abstract
Excavation of a shell midden in Puget Sound, Washington, (45-SK-144) revealed tan-colored lenses full of shell fragments with an ashy feel, alternating with black lenses with abundant charcoal. Magnetic susceptibility tests, Curie tests, particle size and constituent analysis were performed to compare the two types of lenses and to determine the origin of the tan-colored samples. Sorting of the <0 phi portions of the samples showed that the tan-colored samples had a greater abundance of *Strongylocentrotus spp.* framents, while the black samples had a greater abundance of charcoal, bone, *Saxidomus spp.*, and *Mytilus edulis*. The tan-colored lenses contained far less charcoal, but had higher magnetic susceptibility values (X_0) than the black samples and contained magnetite, indicating that they are a product of burning. The differences between samples indicate tan samples were burned for longer durations or with greater intensity than black samples. Differences in shell types and clear boundaries between layers suggests they were burned at different times and possibly for different reasons.

Introduction

Archaeological excavation of a shell midden site in Puget Sound, Washington, revealed tan-colored lenses of possible ash, alternating with black lenses with abundant charcoal. The tan-colored samples range in Munsell color from 10YR 6/2 (pale yellowish brown) to 10YR 5/6 (yellowish brown), and contain many shell fragments. The formation processes of the lenses are unknown. Field observations of the lenses noted that they have many fine particles including crushed shell, and an "ashy" feel. Similar lenses have been noted in other shell middens in the Puget Sound region, and it has been suggested that they are ash lenses from fire pits (Stein 1992). Other layers within the shell midden contain both charcoal and fire-modified rock, but the tan-colored lenses do not seem to contain either of these obvious indications of fire. The purpose of this study is to analyze the tan soil samples to determine what they are composed of, and what their origin is.

The shell midden is located on the south side of Bowman Bay and the west side of Lottie Bay on Fidalgo Island, Washington (Figure 1), and is designated as an archaeological site (45-SK-144). The site was excavated by students in the 1999 Western Washington University field school. The samples analyzed are from a 1x1 meter unit designated South 22, East 0. There were five samples taken from lenses in the west wall (Figure 2). Three of these (MS1, MS3, and MS 5) are the tan-colored, probable ash samples that this paper focuses on. The other two samples (MS2 and MS4) are black samples that are used for comparison. There were 11 natural levels that were determined by the excavators as they dug down through the unit. Bulk samples that were taken from Level 6, a tan level, and Level 7, a black level, were also used for comparisons, because they were bigger samples and contained more material to work with.

Similar tan-colored lenses have been found at other sites around Puget Sound (Figure 3). Stein (1992) discusses tan-colored lenses within the British Camp shell midden in the San Juan Islands stating, "Tan facies are usually very small . . . and are described in the field as ashy, with burned bone and shell. They are particularly lacking in gravel-sized (larger than 3mm) objects" (Stein 1992: 110). Analysis of the tan facies determined they are very low in organic matter and high in calcium carbonate, indicating an abundance of shell. Stein also states, "small-sized shell (crushed and burned) often makes up 95% of the entire facies)" (Stein 1992: 149).

Many of the units in the Duwamish No.1 Site (45-KI-23) (Campbell 1981) include tan-colored lenses ranging in Munsell color from 10YR 7/3 to 10 YR 5/2 with compacted shell fragments. One large lense in unit 96N/36W is described as a "Lightly compacted burnt shell lens with fine-grained sand and silt matrix; light yellowish brown (10YR 6/4)" (Campbell 1981: 128).

Munsell colors are not given in the descriptions of stratigraphy at Cattle Point, a shell midden site in the San Juans (45-SJ-1) (King 1950), but the descriptions suggest they are very similar to the other tan lenses. The West Bluff profile is "made up of large quantities of shell and echinoderm lenses interspersed with lenses of charcoal, fire-broken rocks, and sand" (King 1950: 7). The profile map of the East Bluff area includes a lense of "Yellow ash – shell" (King 1950: 8).

McClean and Kean (1993) and Bellomo (1993) have found that the magnetic susceptibility of soil can be used to recognize fire pits or hearths within archaeological sites, especially if the site has been occupied for a long period of time. Fire reduces non-ferrimagnetic oxides present in soil to magnetite, which may also re-oxidize to maghemite as the soil is cooled (Maher 1986). The presence of magnetite and maghemite both increase the magnetic susceptibility of soil. There are other ways of forming magnetite and maghemite, but fire is the most common way (Maher 1986).

Tite and Mullins (1971) suggest that differences in the magnetic susceptibility of soils from archaeological sites is mainly due to variation in the number of fires the soil was subjected to, the reducing power of the atmosphere during the fire, and the amount of iron oxide present in the soil. Fire pits used for longer periods of time have higher magnetic susceptibility values, because of the increase in magnetic minerals each time there is a burning (McClean and Kean 1993). The tan samples from 45-SK-144 can be compared to nearby sediments within the site and to McClean and Keans' (1993) data from experimental fires to determine whether or not they are the result of fire, and possibly to estimate the length of time that they were burned. The samples should have high magnetic susceptibility if they have been burnt.

Magnetic susceptibility tests determine if there are any magnetic minerals in samples. This includes, but is not limited to, magnetite. A more specific means of identifying magnetite in soil samples is by running Curie tests. The Curie temperature of magnetite is 580° C (Mullins 1974), meaning that it loses its magnetic properties at 580°C. The magnetic susceptibility of the samples should drop near zero at about 580°C if magnetite is present in the samples.

Methods

Magnetic susceptibility tests were run on the seven samples (MS1, MS2, MS3, MS4, MS5, Level 6, and Level 7) using a Kappa Bridge machine. Samples were placed in a Kappa Bridge machine and run through a computer program that recorded a magnetic susceptibility unit, K (assuming a volume of 10 cm^3). K was normalized by volume allowing samples of different volumes to be compared directly. Additional magnetic susceptibility tests were also done on the clay-sized fraction of each sample because magnetic minerals are usually concentrated in the clay-sized fraction of soil (Mullins, 1974).

Curie tests were run on the five samples taken from lenses in the west wall (MS1, MS2, MS3, MS4, and MS5) to determine if they contained magnetite. The magnetic susceptibility was recorded as the samples were heated to 700°C and then cooled back down. Argon was used to keep oxygen levels around the sample low, so magnetic minerals would not be created while the sample was being heated. A free furnace run was so done to subtract the "noise" from the furnace.

Portions of all seven samples were sieved, for 20 minutes each, using a Rotap machine. The screen sizes used were -1ϕ, 0ϕ, 1ϕ, 2ϕ, and 3ϕ. The -1ϕ and 0ϕ sizes were sorted by component, and a count and mass for each category was recorded. Some of the 0ϕ samples were split before sorting, because of the large amount of materials in them. The 1ϕ, 2ϕ, 3ϕ, and >3ϕ portions of the samples were analyzed under a microscope for more general comparisons.

Data

There were a moderate range of magnetic susceptibility values (X_0) for the samples tested (Table 1 and Figure 4). Tan samples had higher magnetic susceptibility values (X_0) than the black samples in both sets of tests. The tests run on the clay-sized fractions of the samples resulted in higher values for all of the samples except Level 6. In the first set of tests Level 6 yielded the highest magnetic susceptibility value (X_0), 42.93 and was followed by the other tan samples: MS1, 27.97; MS3, 21.57; and MS5, 15.11. The highest value (X_0) for the black samples was MS2, 12.59, followed by Level 7, 9.85 and MS4, 6.65. In the tests run on the clay-sized fractions MS1 yielded the highest (X_0) value 40.67, followed by MS3, 34.84; MS5, 24.93; Level 6, 28.58; MS2, 20.68; Level 7, 19.75; and MS4, 13.11.

The Curie Tests show the magnetic susceptibility of all five samples dropping to zero at about 580° C (Figures 5-9). The heating curve for MS1 drops gradually until it reaches about 520° C and then it drops more rapidly, approaching zero as it nears 580° C (Figure 5). The cooling curve is similar to the heating curve, but has higher magnetic susceptibility values from about 520° C down to about 200° C, where it drops below the heating curve.

The heating curves for MS2, MS3, and MS4 (Figure 6-8) show a sudden drop in magnetic susceptibility near 580° C. They also show an increase in susceptibility just before the drop. The magnetic susceptibility values along the cooling curves are somewhat higher than the heating curves, except for a short period during the test on MS2.

The heating curve for MS5 (Figure 9) shows a more gradual drop in magnetic susceptibility. However, the curve does reach zero near 580° C. The cooling curve drops below the heating curve at about 390° C.

The grain size distributions of the samples that were screened are very different and seem to correspond with the general color of the samples (Table 2, Figure 10). The black samples that were screened: MS2, MS4, and Level 7 all have a high percentage of grains bigger than -1ϕ. The cumulative curves for the black samples start at higher percentages and increase at fairly even rates. The cumulative curves for the tan colored samples: MS1, MS3, MS5, and Level 6 show a relatively smaller percentage of grains bigger than -1ϕ, a steep increase from 0ϕ to 1ϕ, and a similar increase from 3ϕ to >3ϕ, indicating there is more material between these two size ranges.

The different components within the different samples were much easier to determine after sieving (Tables 3-9). The components of the -1φ and 0φ sizes included mineral grains, clumps of soil that appeared burnt, fire-modified rock, charcoal, unidentifiable shell, *Stongylocentrotus spp.* (sea urchin) body parts and spines, *Cancer spp.* (crab), *Clinocardium spp.* (cockles), *Mytilus edulis* (mussel), Lepidochitonidae (chiton), *Protothaca spp.* (little neck clams), *Saxidomus spp.* (butter clams), *Thais spp.* (dye shells), *Balanuss spp.* (barnacles), and fish bones including vertebrae. Four major groups were defined including mineral grains and soil clumps, shell, bone, and charcoal (Table 10). (Count percentages were used because they more accurately represent the volume of the different components in the sample than the weights, due to the fact that shell weighs much more than bone and charcoal.) Shell was also separated and broken down into percentages for each sample (Table 11).

MS1 contained mainly shell and mineral grains in the -1φ and 0φ sieve sizes (Table 3, Figure 11). One bone was also found. Most of the shell was unidentifiable, but there was a fairly large amount of *Strongylocentrotus spp.* (sea urchin), making up 19% of the total shell (Figure 12). Other shells present included *Cancer spp.* (crab), *Clinocardium spp.*, and *Mytilus edulis* (mussel). The smaller size ranges in the MS1 sample contained mostly shell fragments. *Stongylocentrotus spp.* spines were abundant in the 1ϕ and 2ϕ sizes. Small pieces of charcoal were found under the microscope.

The -1ϕ and 0ϕ sizes from MS2 contained mostly shell (Table 4 and Figure 13). Other components were mineral grains and soil clumps, bone, and charcoal. Most of the shells were unidentifiable (Figure 14). *Mytilus edulis* was the most abundant identifiable shell, followed by *Saxidomus spp.* and *Thais spp.*. One piece each of *Protothaca spp.*, *Stongylocentrotus spp.*, and Lepidochitonidae were also present. The smaller sieved sizes contained mostly charcoal.

MS3 was dominated by mineral grains and clumps of soil that appeared to be burnt (Table 5 and Figure 15). A small amount of charcoal was present in the -1φ and 0φ sieve sizes. No shell was found in the –1φ and 0φ sieve sizes. The smaller size ranges were very similar, containing mostly mineral grains, soil clumps, and small shell fragments that were hard to distinguish from each other. Some charcoal was also present in the smaller size ranges.

In the -1ϕ and 0ϕ sieve sizes from MS4 the most abundant component was charcoal, making up 88% of the grouped components by count (Table 6 and Figure 16). There was also some shell and mineral grains. The only shell that was identifiable was mussel (Figure 17). The smaller sized particles were also dominated by charcoal.

MS5 was dominated by shell in the -1ϕ and 0ϕ sizes (Table 7 and Figure 18). Charcoal, mineral grains and soil clumps, and bone was also present. Identifiable shells in the sample included mainly *Stongylocentrotus spp.* and some *Mytilus edulis* and *Balanus spp.* (Figure 19). The smaller sized portions were dominated by shell fragments. *Stongylocentrotus spp.* spines were very abundant in the 1ϕ and 2ϕ sizes, making up about 20% of the volume of those portions.

Level 6 contained mostly unidentifiable shell and mineral grains in the -1ϕ and 0ϕ sizes (Table 8 and Figure 20). There was also one bone present. Identifiable shell was comprised mostly of *Strongylocentrotus spp.*, but also included *Protothaca spp., Saxidomus spp., Tthais spp.*, and *Mytilus edulis* (Figure 21). The smaller sizes were very similar, but with a greater abundance of *Strongylocentrotus spp.* spines at the 1ϕ and 2ϕ sizes.

The -1ϕ and 0ϕ sizes for Level 7 contained mostly mineral grains and shell, but there was also a substantial amount of charcoal and a small percentage of bone (Table 9 and Figure 22). Identifiable shells were comprised mainly of *Saxidomus spp.* (Figure 23). Other shells found in smaller amounts included, *Mytilus edulis, Clinocardium spp.*, and *Protothaca spp.*. The smaller sized particles were very similar, but the most abundant component was charcoal.

Discussion

The magnetic susceptibility values are much lower than expected. Thirteen samples from experimental fire pits tested by McClean and Kean (1993) yielded X_0 (10^{-8} m^3 kg^{-1}) values between 55 and 971, but the samples from 45-SK-144 only yielded X_0 values between 6.65 and 42.93. However there is a fairly large difference between the samples, allowing for comparison. All of the tan samples had higher magnetic susceptibility than the black samples (Figure 3), indicating that the tan-colored samples have more magnetic minerals in them, that are most likely the result of fires. The second set of tests run on only the clay-sized fraction of the samples gives a better comparison between samples, because the magnetic susceptibility values were normalized by volume. The clay-sized fraction of the sediment is where the magnetic minerals are concentrated and it does not include shell fragments, bone, and other non magnetic material that was present in the samples in varying amounts.

The Curie test results show that there was magnetite in all five of the samples taken out of the west wall, because the magnetic susceptibility of the samples approaches zero at about 580°C (Figures 5-9). The increase and then sudden drop in the heating curves for MS2, MS3, and MS4 is characteristic of magnetite. The cooling curves for all of the samples are not significantly different from the heating curves, indicating most of the magnetic minerals were present before running the tests. It is somewhat strange that the cooling curve for MS5 is below the heating curve (Figure 9). A stongly magnetic mineral like magnetite was probably converted into a weaker magnetic mineral during the test.

The grain size distributions of the samples that were sieved show a general difference between tan and black colored samples (Figure 10). Grain size is the result of different formational processes taking place at the site. The tan colored samples are more fine grained, which may be the result of different components which fracture more easily or different processing strategies. The components may have been cooked for longer periods of time, reached higher temperatures during cooking, or have been broken up more during preparation.

General differences can be seen between the grouped components of tan-colored and black samples (Table 10 and Figures 11, 13, 15, 17, 19, 20, and 22). A major difference is that charcoal is much more abundant in the black samples, but charcoal was also found in the tan colored samples, further indicating that they are ash lenses. Clumps of soil that appear to be burnt were also found in the tan colored samples, and were very abundant in MS3. Bone was more abundant in the black samples.

There was a general difference between shells from the tan and black samples (Table 10 and Figures 12, 14, 17, 19, 21, and 23). *Stongylocentrotus spp.* spines and body fragments were very abundant in the tan-colored samples, but only one piece of *Stongylocentrotus spp.* was found in any of the black samples. The black samples contained larger pieces of shell than the tan samples did, especially *Saxidomus spp.* shells. *Saxidomus spp.* was abundant in MS2 and Level 7 (both black samples) and only one piece was found in a tan sample (Level 6). The black samples also contained more *Mytilus edulis* shells, especially MS2 (18% of shells) and MS4 (21% of shells). However, *Mytilus edulis* may be a large part of the unidentifiable shell in most of the samples, but it is to weathered and fragmented to make definite identifications.

Conclusions

The higher magnetic susceptibility values and presence of magnetite and charcoal in tan-colored samples indicates they have been burnt. It is not clear whether they were intentionally cooked in a food preparation process or whether they were burnt for other reasons. The higher magnetic susceptibility values for the tan-colored samples indicates they were burnt differently than the black samples. They may have been burnt for longer periods of time, reached higher temperatures during burning, or been burnt in thinner layers allowing for more oxidation to take place.

The greater abundance of fine-sized particles in the tan-colored samples indicates different formational processes. It suggests the tan samples were burned for a longer duration or with greater intensity. One of the major points made in Stein's (1992) analysis of the British camp shell midden was that tan facies had much lower organic matter in them, further indicating a longer duration or greater intensity of burning. The difference in grain size may also be related to a difference in processing. The shell in the tan samples may have been broken up more before burning.

The tan layers appear to be created at different times than the black layers. The tan lense above the fire pit feature in the northwest corner of S22 E0 most likely resulted from later use of an existing fire pit, because it does not cover the entire pit and has distinct boundaries. The large tan lense in the southwest corner also has distinct boundaries.

The differences in composition between the two types of samples also suggests they were created at different times. The black samples contain more abundant charcoal, bone, *Mytilus edulis* and *Saxidomus spp.* shells while tan samples contained an abundance of *Stongylocentrotus spp.* Only one

Strongylocentrotus spp. fragment was found in any of the black samples. It is odd that *Strongylocentrotus spp.* is so abundant in the tan-colored samples, because in the ethnographic record they are usually eaten raw. However, sometimes they are included in the cooking of other shellfish for flavor. A variety of other shells may be present in the tan samples, but the framents are so small that they are unidentifiable. The *Strongylocentrotus spp.* are easy to identify in small fragments because they have bumps on their body and the spines are easily recognized. It is also possible that *Strongylocentrotus spp.* were not being cooked for eating, but that the shells were burnt after eating.

It is not clear exactly why or how the tan-colored lenses were burnt. Ethnographic research could be done to help explain the formation processes involved in the tan-colored lenses. Experimental archaeology could also be done to try to recreate tan lenses. There has not been much focus on tan lenses, although they seem to be common in sites around Puget Sound. More work should be done to compare tan-colored lenses between sites and determine if the constituents are similar.

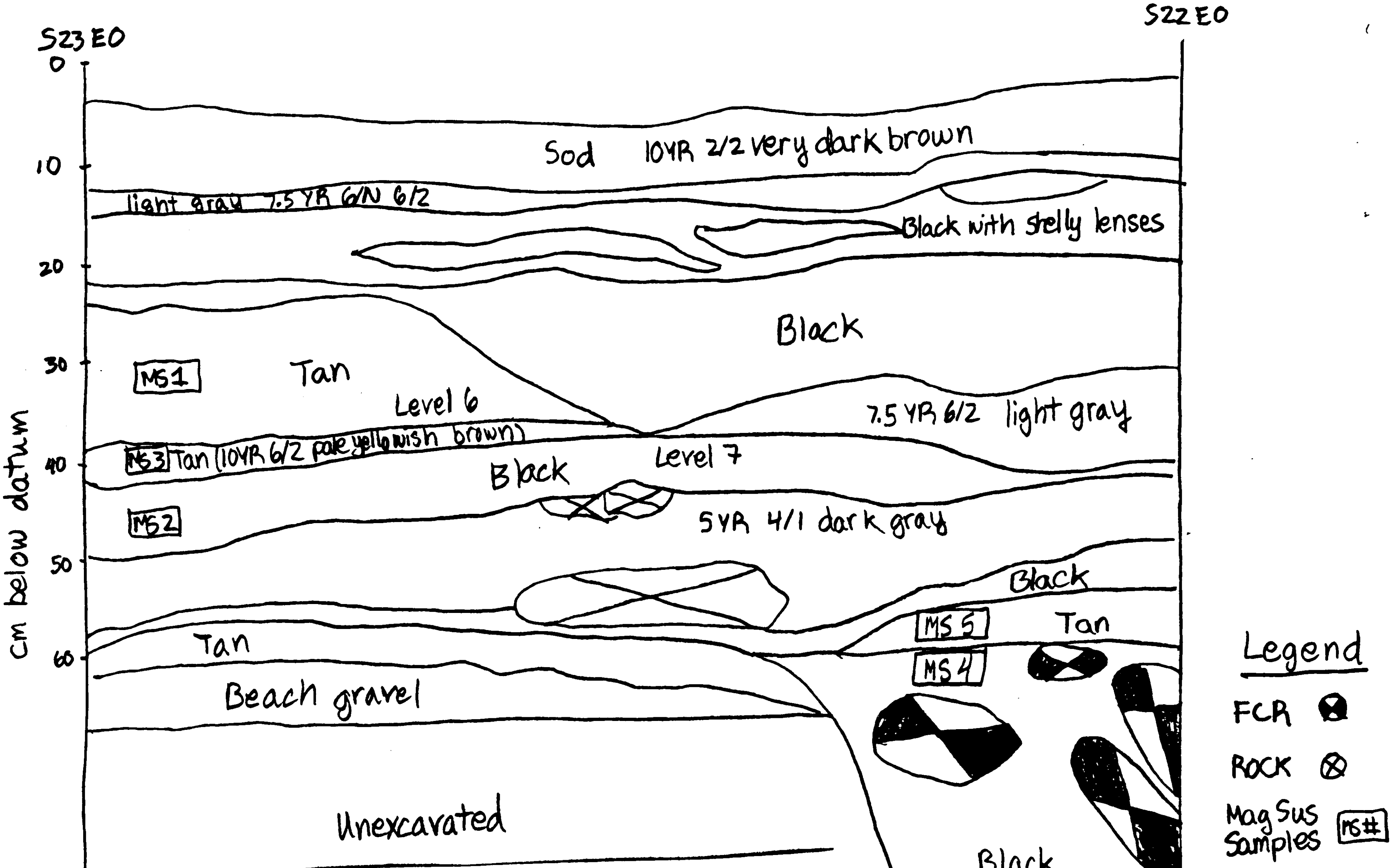

Figure 2: Profile of the west wall, S22 E0, showing alternating black and tan layers. Munsell colors are 10 YR 5/6 (brownish yellow) for the tan layers and 5 YR 2/1 for the black layers unless otherwise noted. The approximate locations of magnetic susceptibility samples are shown. Levels 6 and 7 are also

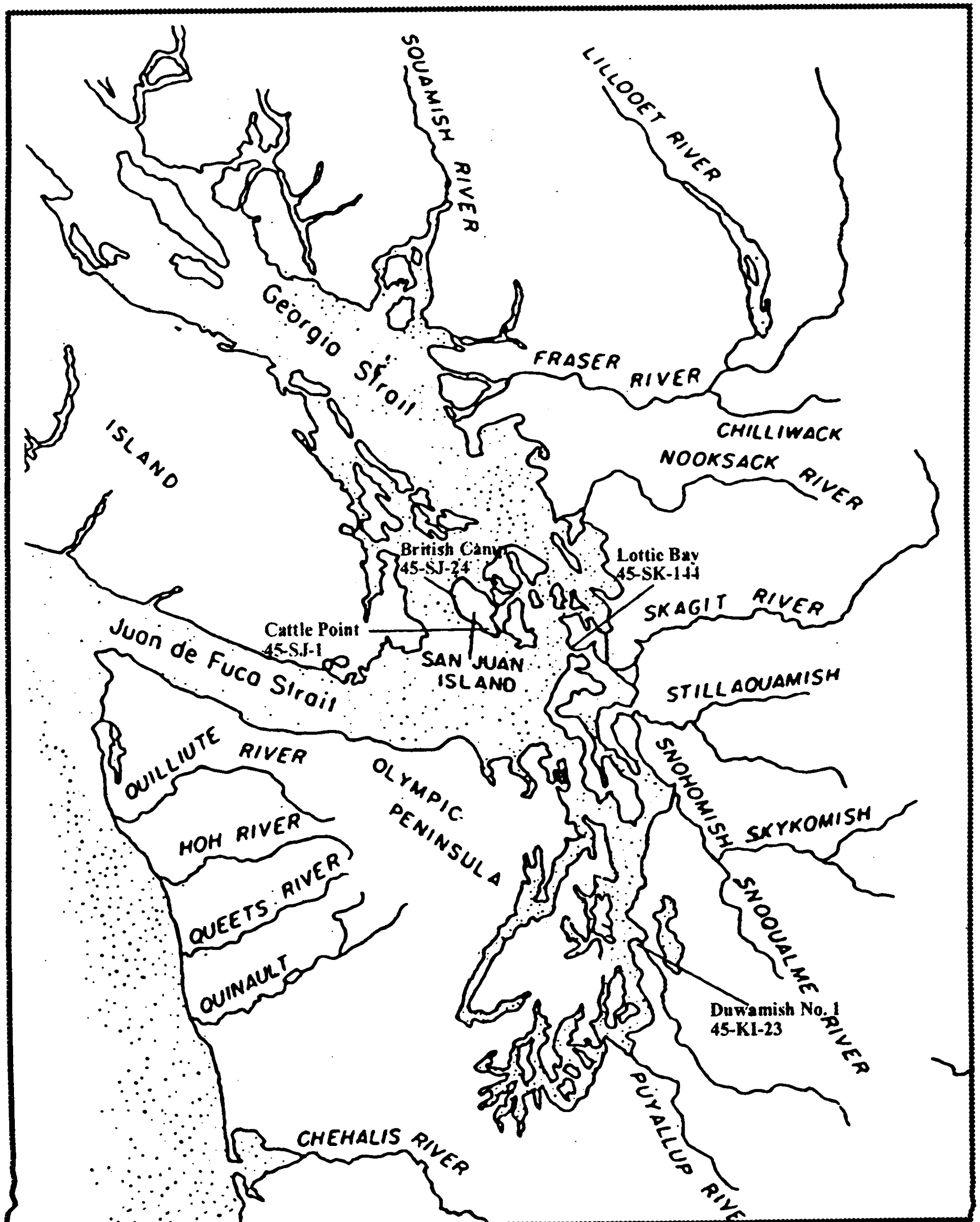

Figure 3: Map of Puget Sound showing 45-SK-144, 45-SJ-24, 45-SJ-1 and 45-KI-23. All four sites have tan shelly lenses.

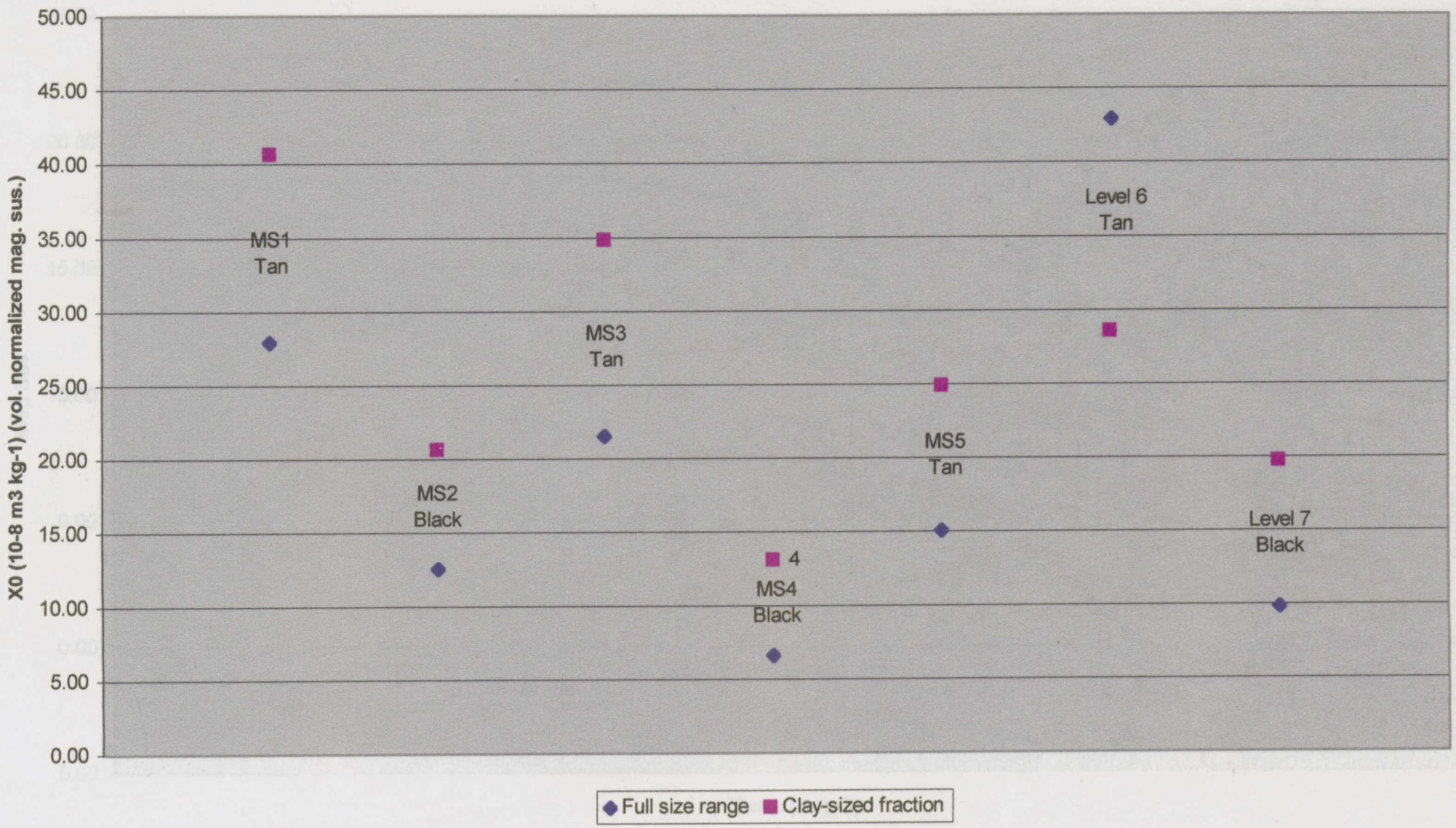

Figure 4: The volume normalized magnetic susceptibility is shown for all samples. The first tests run are shown with blue diamonds and the clay-sized fractions are shown with pink squares. The tan samples have higher values than the black samples.

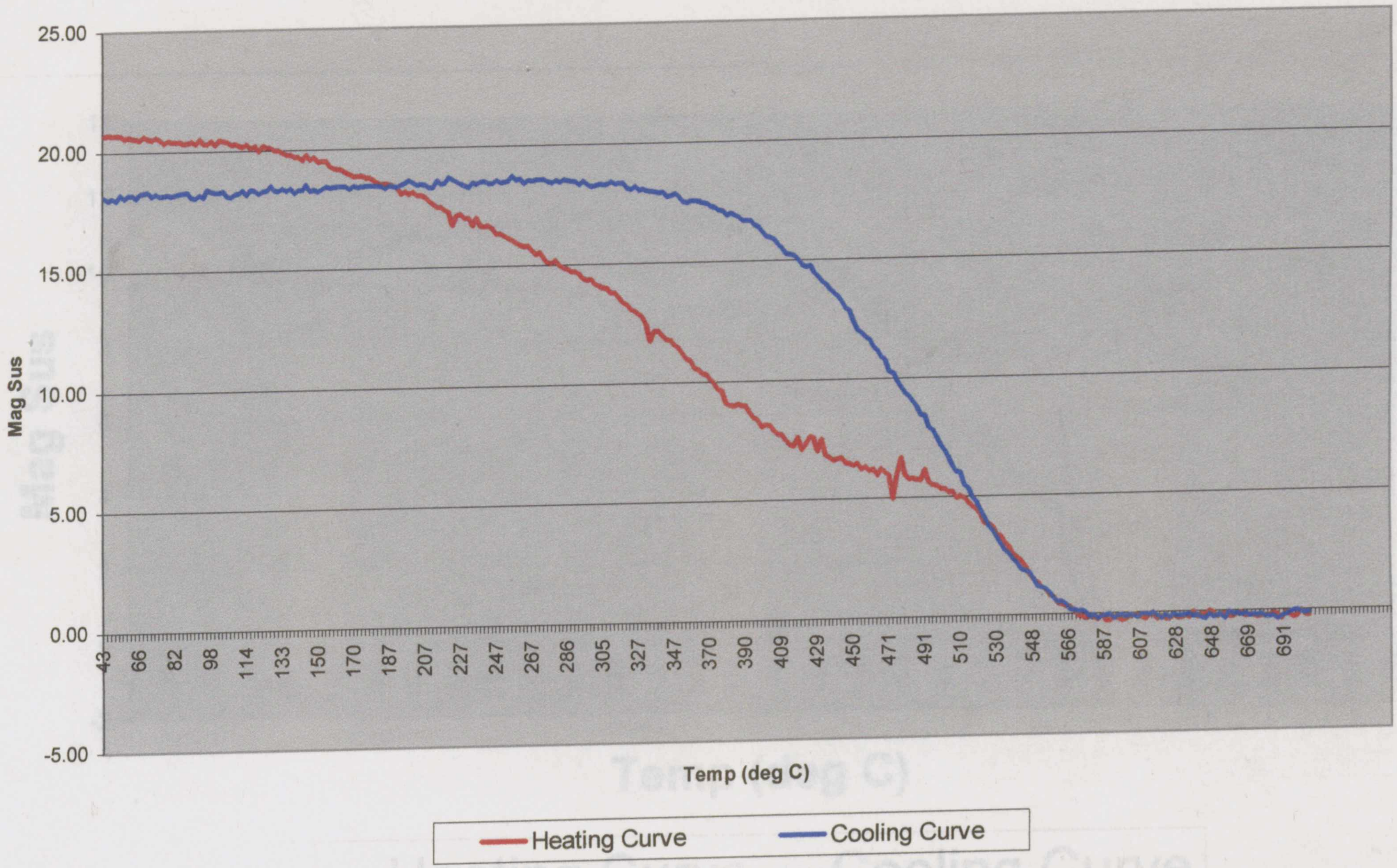

Figure 5: The Curie test for MS1 shows a drop in magnetic susceptibility, along the heating curve, to zero at about 580 degrees C, indicating the presence of magnetite. The cooling curve is close to the heating curve.

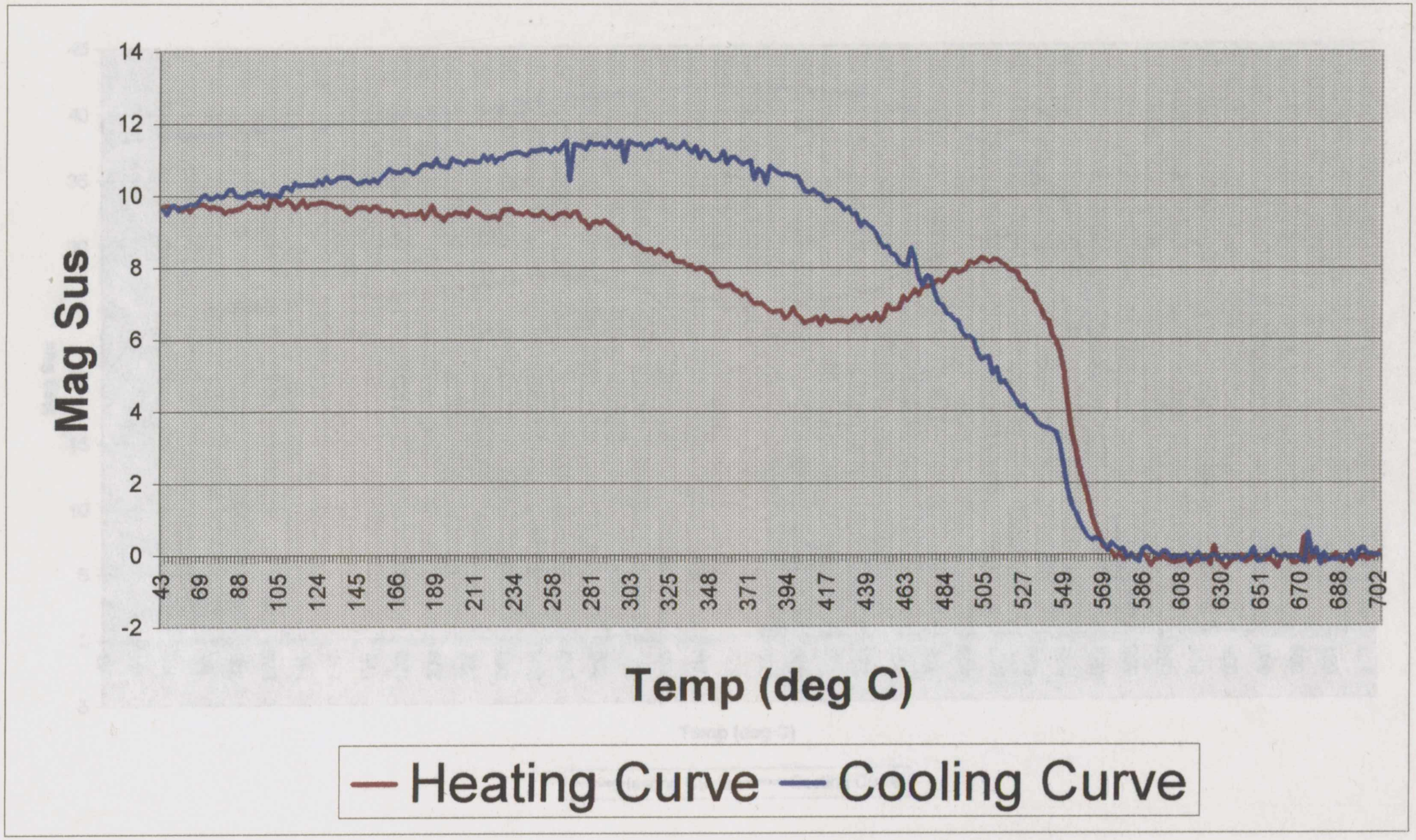

Figure 6: The Curie test on MS5 shows a rise and then fall in the heating curve just before 580 degrees C, indicating magnetite is present in the sample. The cooling curve is relatively close to the heating curve.

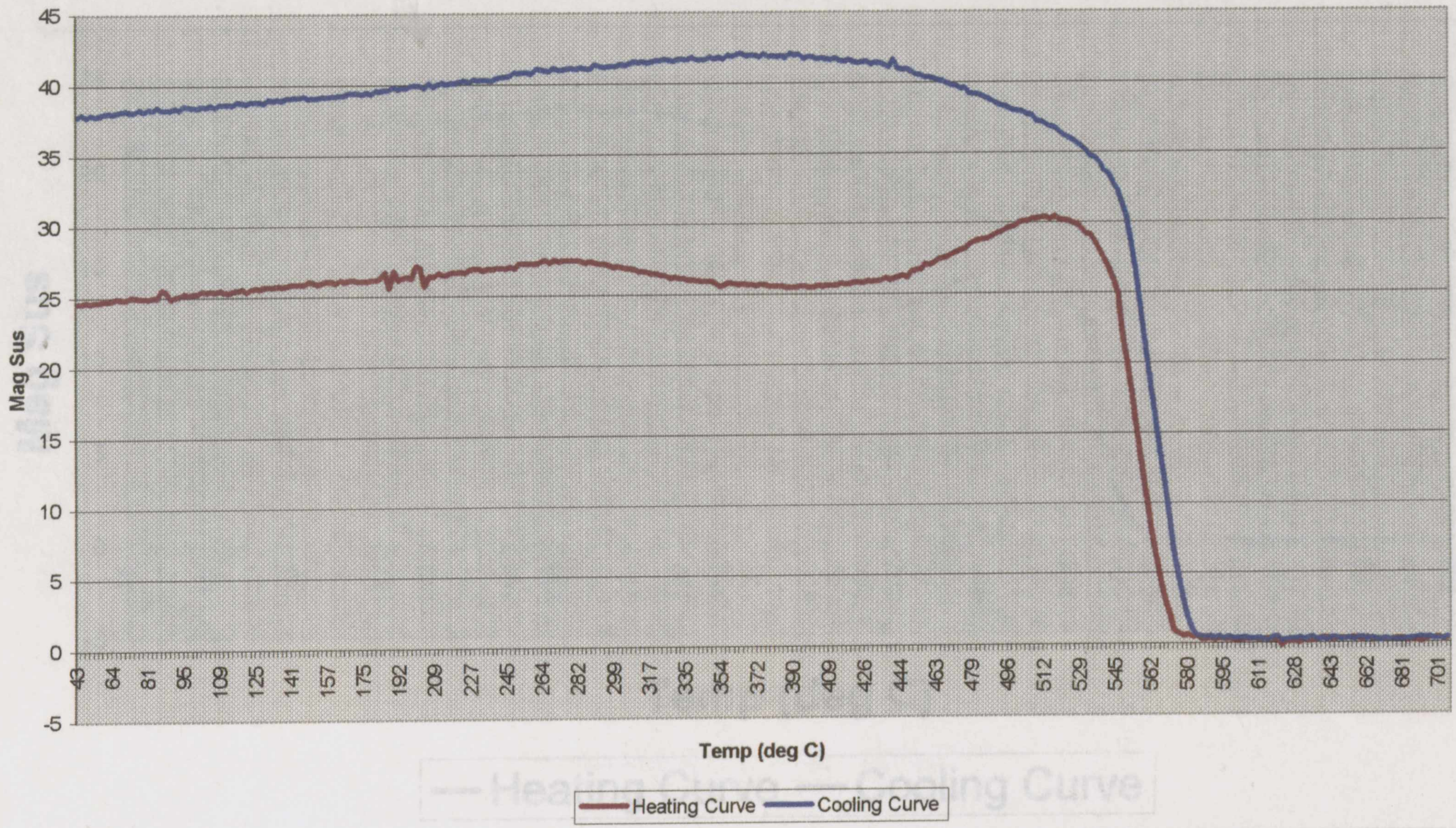

Figure 7: The Curie test for MS3 shows a rise and then fall in the heating curve just before 580 degrees C. The cooling curve is relatively close to the heating curve

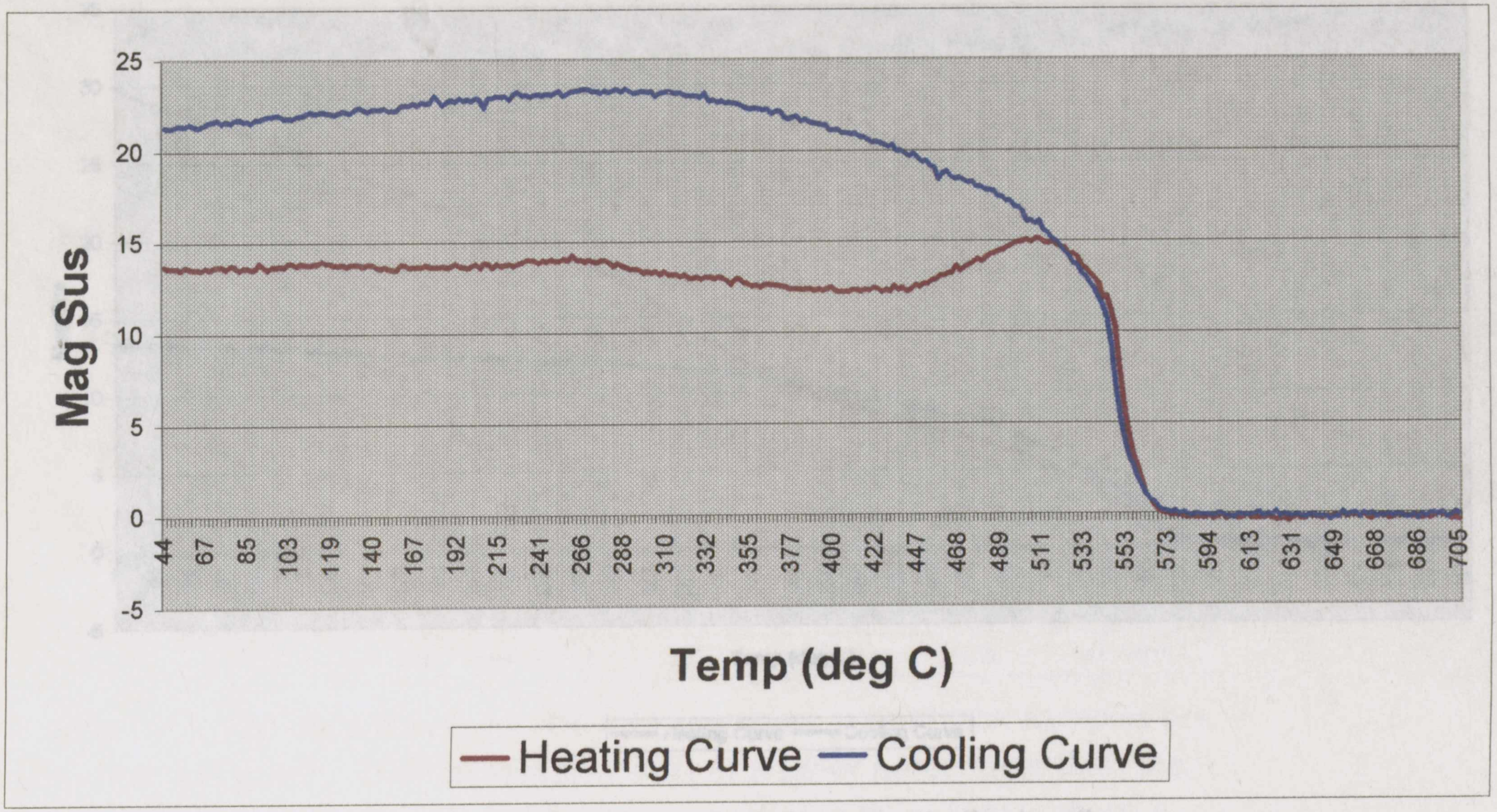

Figure 8: The Curie test on MS4 shows a rise and then fall just before 580 degrees C. along the heating curve. The cooling curve is relatively close to the heating curve.

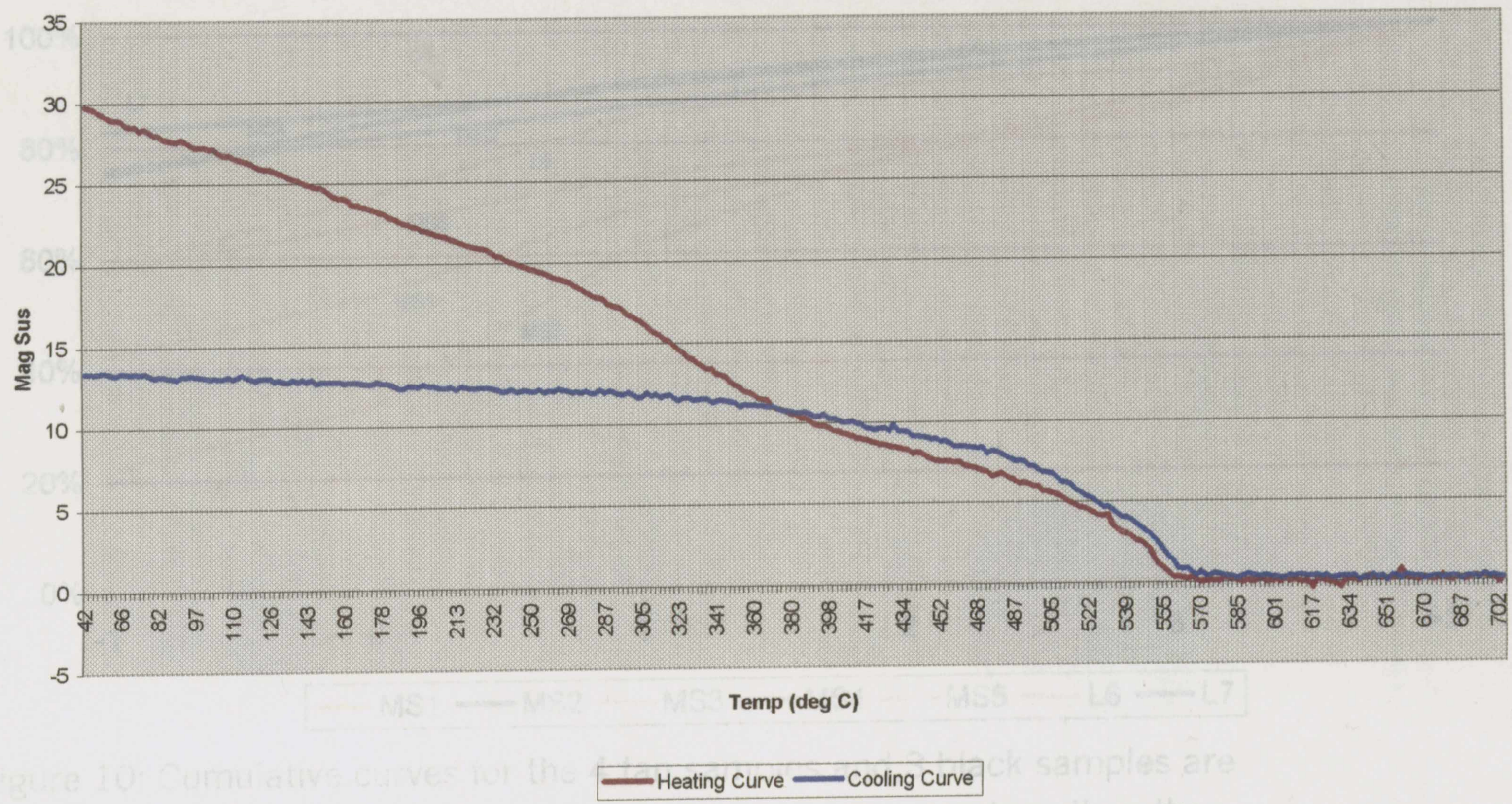

Figure 9: The Curie test on MS5 shows a gradual decrease in the heating curve until it reaches zero at about 580 degrees C. The cooling curve falls below the heating curve.

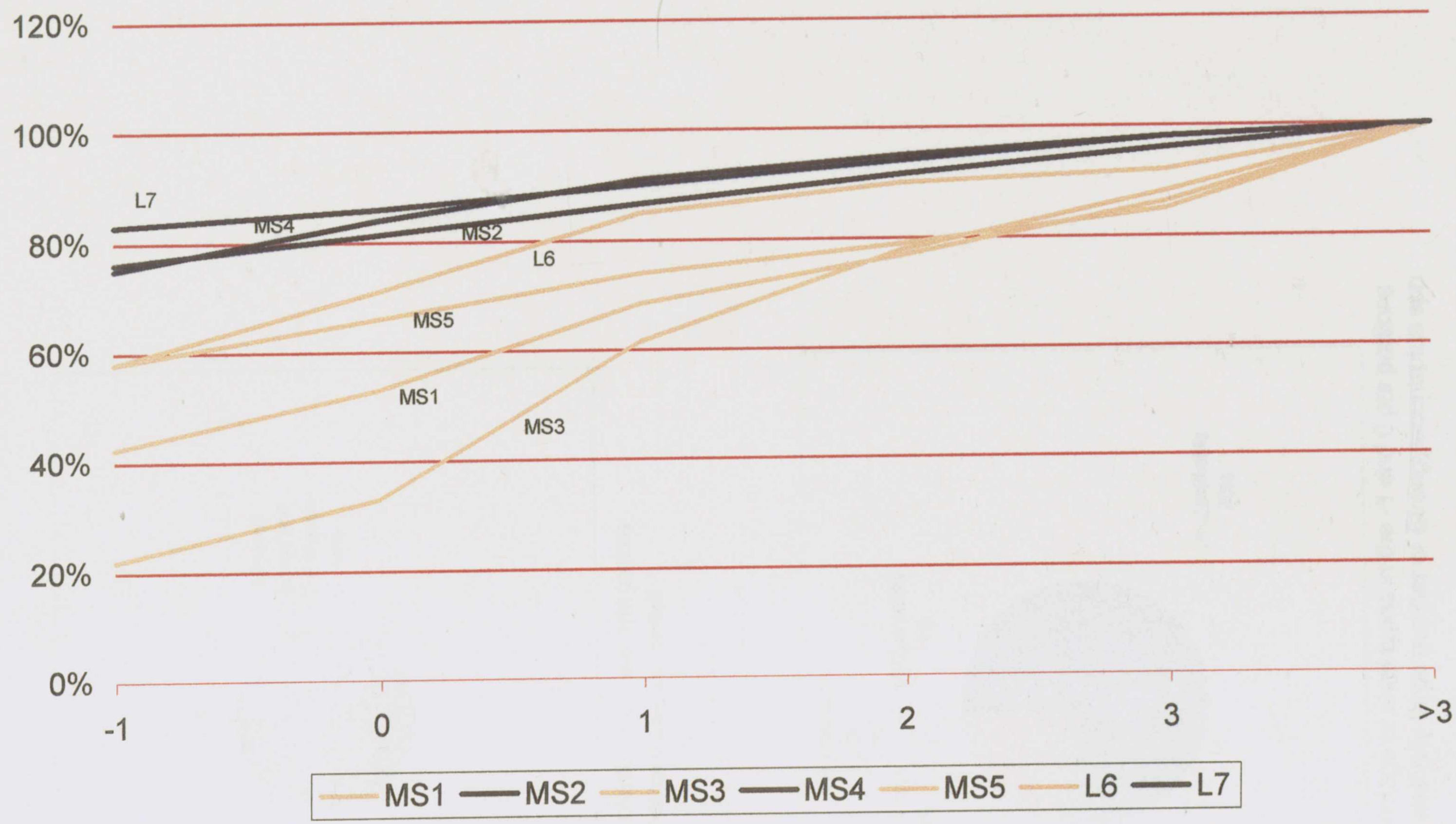

Figure 10: Cumulative curves for the 4 tan samples and 3 black samples are shown on the graph. The tan samples start at a lower percentage than the black samples do, because they have less material in them bigger than -1 phi. Most of the tan samples show a large increase from 0 to -1 phi and from from 3 to >3 phi. The tan samples vary much more than the black samples do.

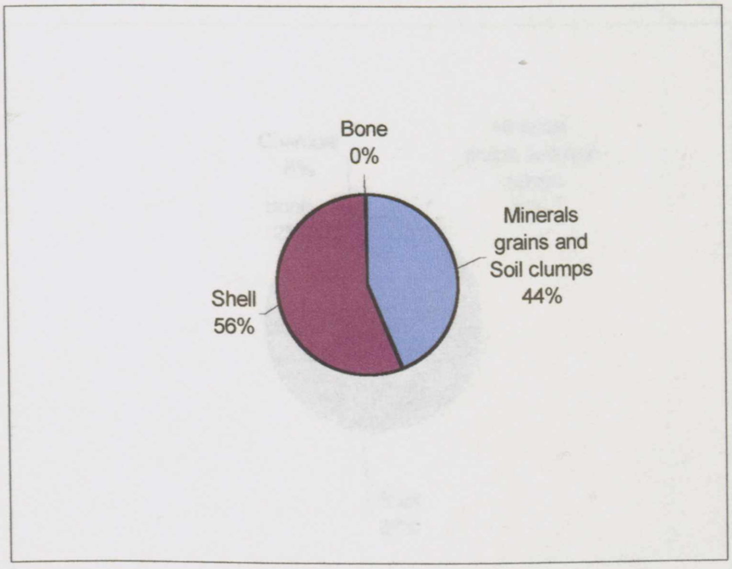

Figure 11: Grouped components in the -1 and 0 phi portions from MS1. Note the abundance of shell and mineral grains and soil clumps.

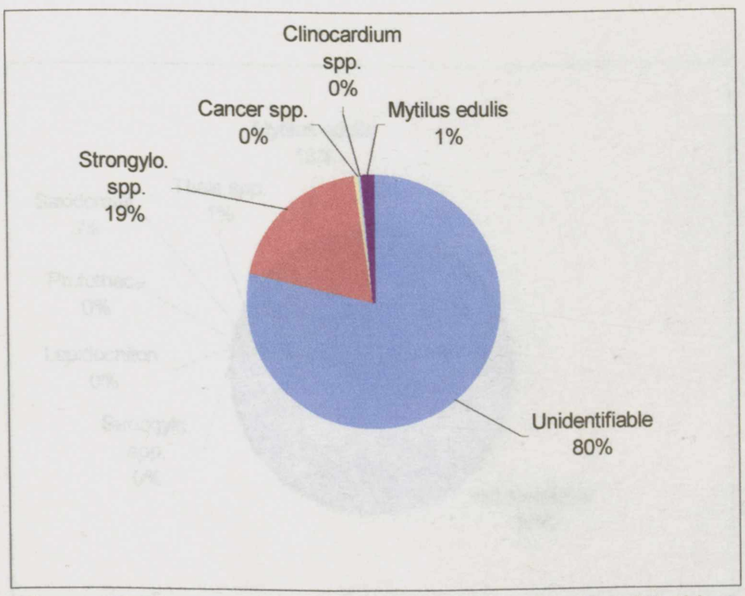

Figure 12: The percentage of shell types in the -1 and 0 phi portions from MS1 shows a relatively large number of Strongylocentrotus spp.

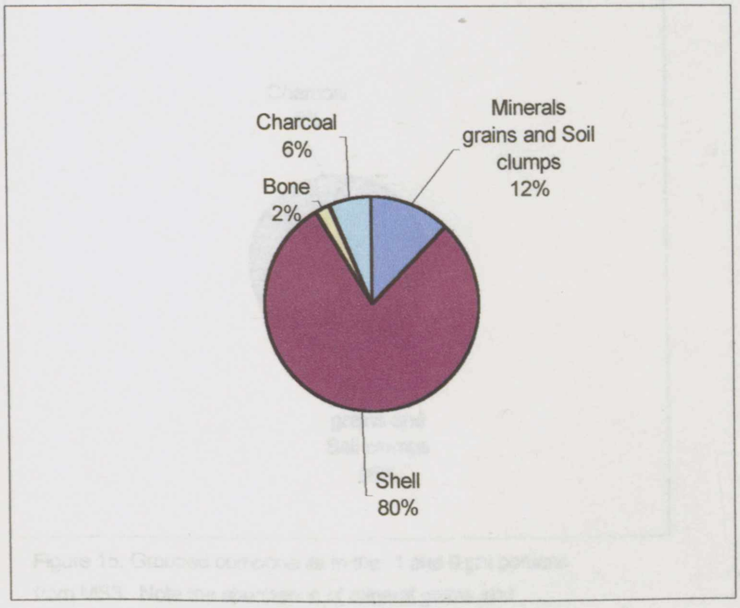

Figure 13: Grouped components of the -1 and 0 phi portions from MS2. Note the abundance of shell and presence of charcoal.

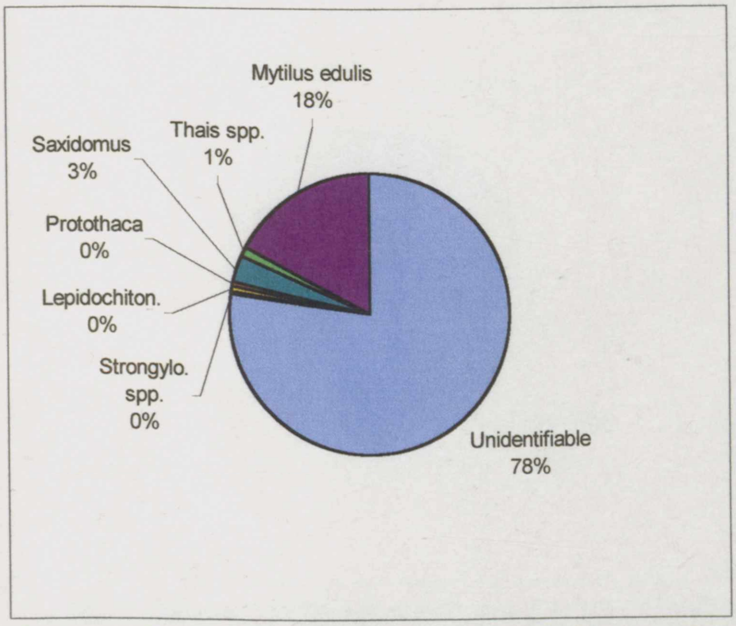

Figure 14: Percentages of shells from the -1 and 0 phi portions of MS2 show a relative abundance of Mytilus edulis and a very small percentage of Stronglyocentrotus spp.

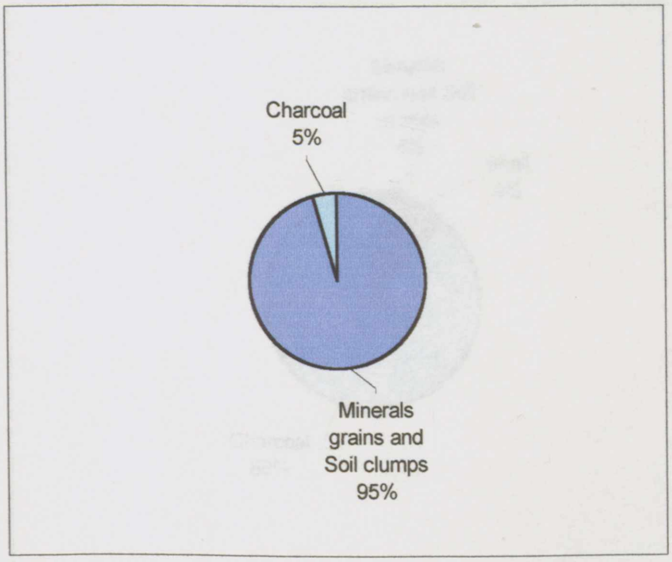

Figure 15: Grouped components in the -1 and 0 phi portions from MS3. Note the abundance of mineral grains and soil clumps and the presence of charcoal.

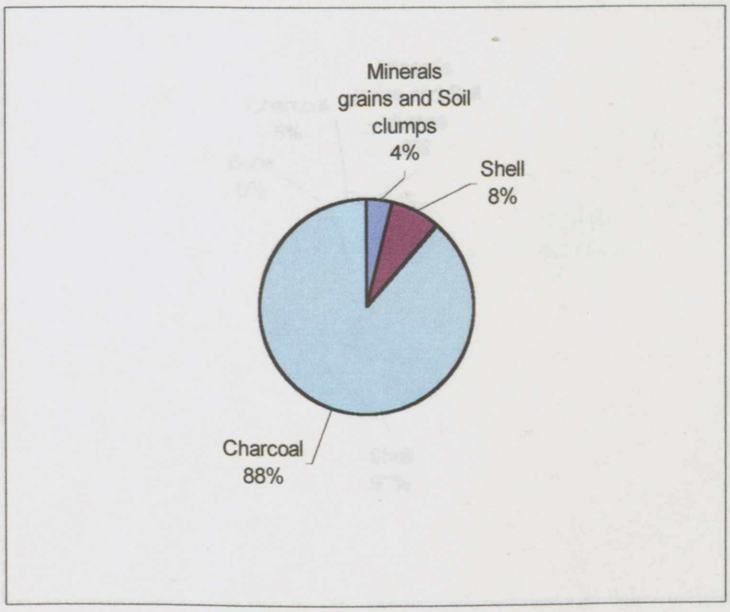

Figure 16: Grouped components of the -1 and 0 phi portions of MS4. Note the abundance of charcoal.

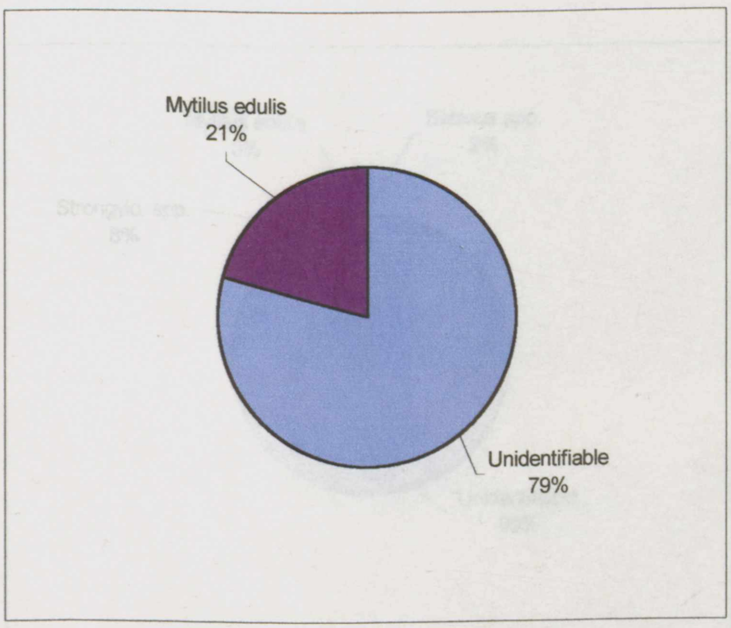

Figure 17: The only identifiable shell in the -1 and 0 phi portions of MS4 is Mytilus edulis.

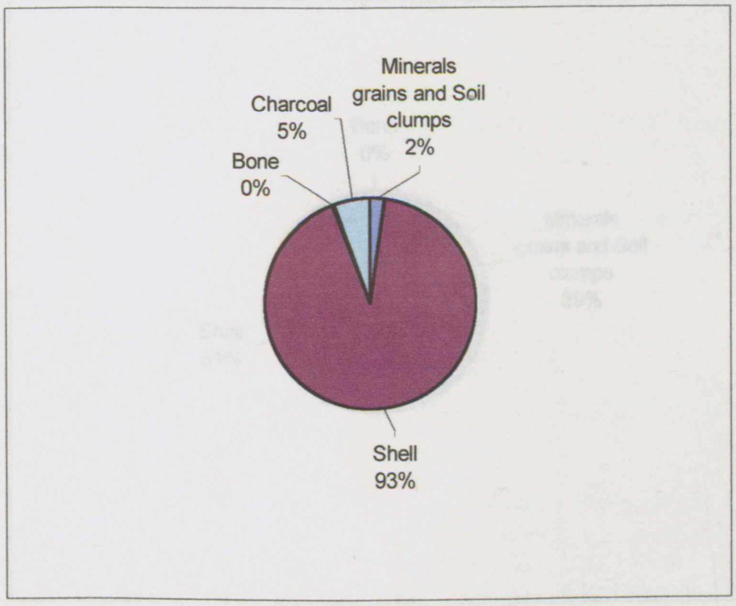

Figure 18: Grouped components of the -1 and 0 phi portions of MS5. Note the abundance of shell and the presence of charcoal.

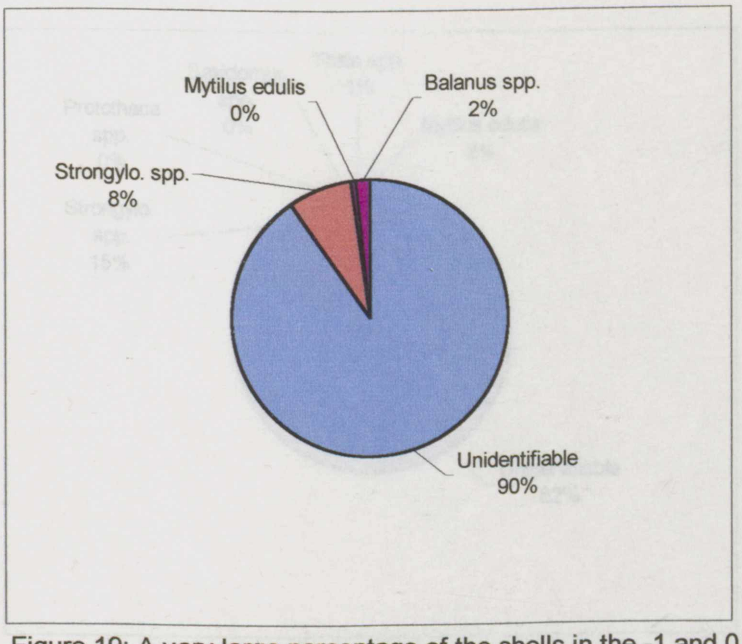

Figure 19: A very large percentage of the shells in the -1 and 0 phi portions from MS5 are unidentifiable. Stronglylocentrotus spp. is the most abundant identifiable shell.

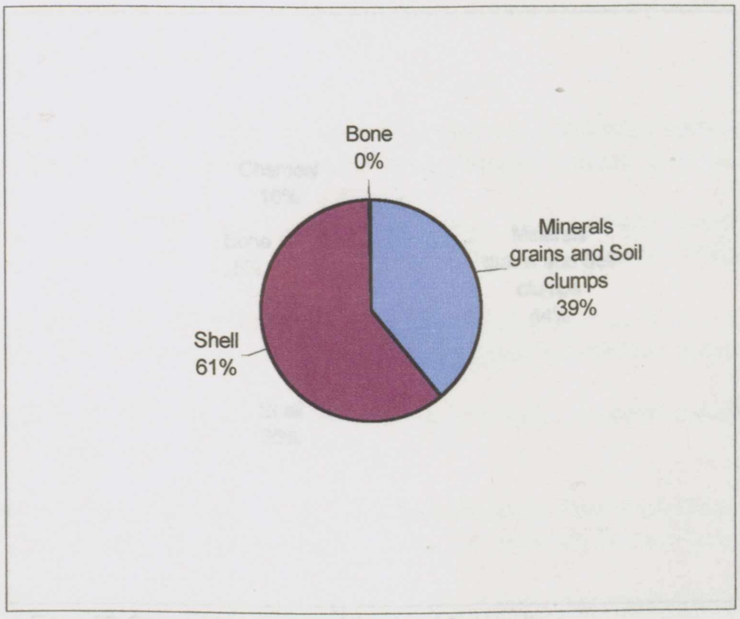

Figure 20: Grouped components of the -1 and 0 phi portions of the samples from Level 6. Note the abundance of shell and mineral grains and soil clumps.

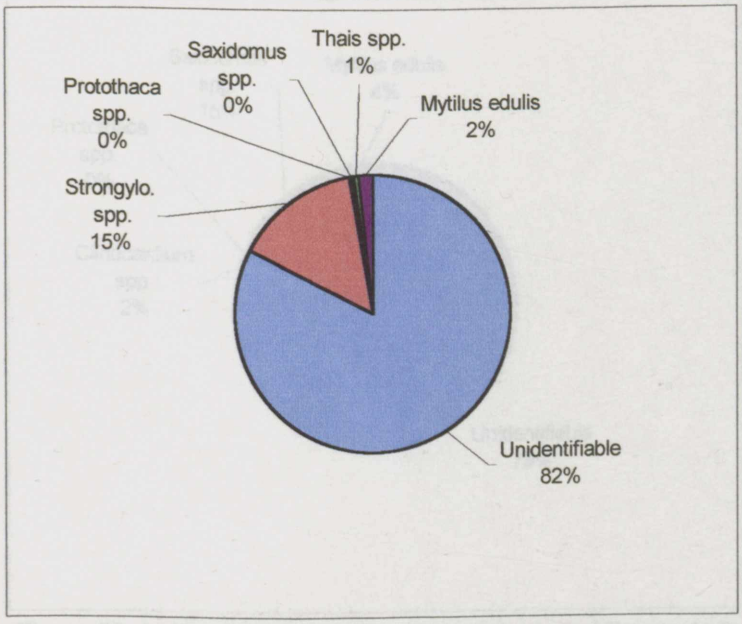

Figure 21: The percentages of shell types from the -1 and 0 phi portions of Level 6 shows a relative abundance of Strongylocentrotus spp.

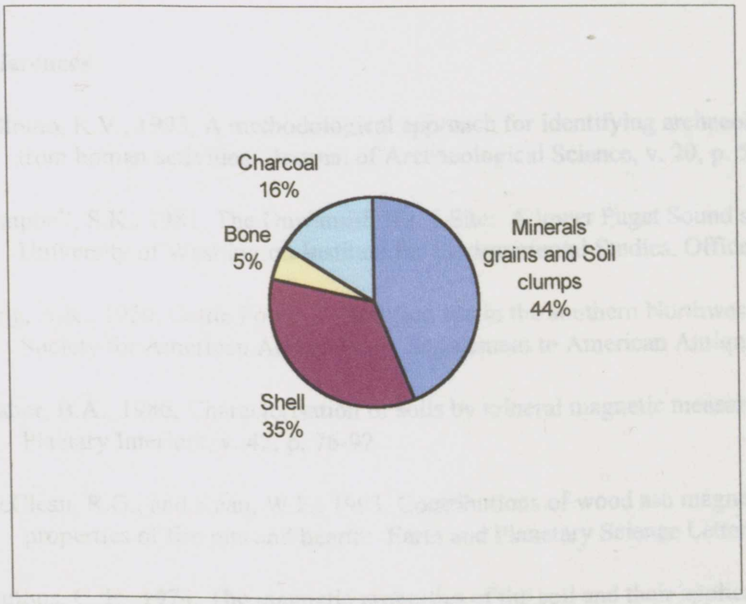

Figure 22: Grouped components of the -1 and 0 phi portions of the sample from Level 7. Note the relative abundance of charcoal and bone compared to other samples.

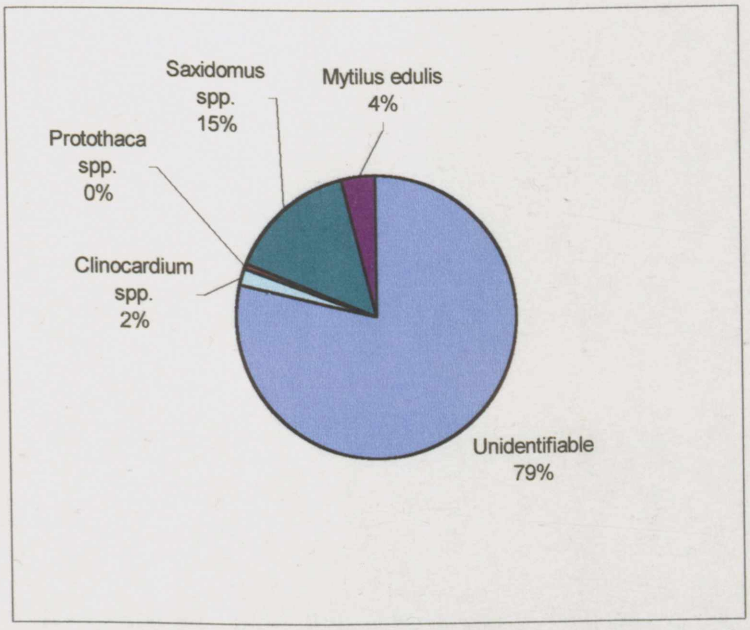

Figure 23: In the -1 and 0 phi portions of the Level 7 sample the most abundant identifiable shell is Saxidomus spp.

References

Bellomo, R.V., 1993, A methodological approach for identifying archaeological evidence of fire resulting from human activities: Journal of Archaeological Science, v. 20, p. 525-553.1

Campbell, S.K., 1981, The Duwamish No. 1 Site: A lower Puget Sound shell midden: Seattle, WA, University of Washington Institute for Environmental Studies, Office of Public Archaeology.

King, A.R., 1950, Cattle Point: A stratified site in the southern Northwest Coast region: Memoirs of the Society for American Archaeology, Supplement to American Antiquity, v. 15, no. 4, part 2.

Maher, B.A., 1986, Characterisation of soils by mineral magnetic measurements: Physics of the Earth and Plaetary Interiors, v. 42, p. 76-92.

McClean, R.G., and Kean, W.F., 1993, Contributions of wood ash magnetism to archaeomagnetic properties of fire pits and hearth: Earth and Planetary Science Letters, v. 119, no. 3, p. 387-394.

Mullins, C. E., 1974, The magnetic properties of the soil and their application to archaeological prospecting: Archaeo-Physika, p. 143-347

Stein, J.K., ed., 1992, Deciphering a Shell Midden: San Diego, California, Academic Press, Inc., 375 p.

Tite, M.S. and Mullins, C., 1971, Enhancement of the magnetic susceptibility of soils on archaeological sites: Archaeometry, v. 13, no. 2, p. 209-219.