CHAPTER 6

THE RAVENSWORTH 3 SEDIMENT AND HEAT RETAINER ANALYSIS

6.1 INTRODUCTION

The excavations revealed detailed information about the contents of the Ravensworth 3 and Tchelery 1 mounds. However, various aspects of mound building remained unanswered, including the source and characteristics of the mound sediment, and how it related to the underlying basement. This chapter aims to delineate the history of the mound material, for example the breakdown history of the heat retainers, temperatures reached in firing processes and source of mound material. It also aims to determine whether the characteristics of the mound material are due to natural processes such as leaching or soil formation processes, or cultural processes such as burning. Particular minerals with a high magnetic susceptibility (eg. iron oxides, iron sulphates, manganese oxides) occur in different proportions in different types of sediment. Analysis of magnetic susceptibility is a method utilised to identify the mineralogical history of sediments, and differentiate sediment types (Gale and Hoare 1991:201-229). Magnetic susceptibility is particularly useful as it can also lead to an understanding of the effects of cultural practices such as firing and baking on the mineralogy of sediments (Tite & Mullins 1971:209).

The first section of this chapter examines the characteristics of the heat retainers and fragments of heat retainers that are defined as all baked clay that was retained on the 11mm and 2mm sieves. Heat retainers made from other materials (such as fire cracked rock or termite mound) were looked for but not found. The second section details an analysis of the finer sediment fractions under 2mm.

6.2 RAVENSWORTH 3 HEAT RETAINER ANALYSIS

6.2.1 Aims of the Analysis

The objective of the heat retainer analysis was to determine:

- how the heat retainers and broken up heat retainers affect the magnetic susceptibility of the sediment
- whether sizes of heat retainers and fragments changes throughout the mound
- characteristics of heat retainers and whether this reflects different sources of material and different cooking methods.

6.2.2 Laboratory Procedures

The heat retainer samples for the Colour and pH, magnetic susceptibility and baking experiment came from the same bulk samples collected during the excavation as described in 6.3.1. All sample bags were weighed and then sieved through a 2mm Endecott sieve to remove the greater than 2mm sediment fraction and cultural material such as heat retainers, pieces of bone and shell, and stone artefacts. The heat retainers were collected and bagged and used in the heat retainer analysis. The samples used to determine the sizes and types of heat retainers came from the excavation material, defined as all baked clay material that was caught by the 11mm and 2mm sieves.

1. Colour and pH

A sample of 12 red heat retainers, 12 brown heat retainers, and 12 in-between red and brown heat retainers were tested. The different colours were tested because colour reflects the different firing history that may in turn reflect the magnetic susceptibility. The colours reflect the temperature and oxidation/reduction environment of the firing of the clay.

The heat retainers were crushed in a strong plastic dish using a geological hammer. Samples were tested for colour and pH using the following methods. A Munsell colour chart was used to determine a standard colour for each sample (Appendix 6 Table 6.1). A spatula portion of sediment from each sample was placed on a perspex plate and the colour compared to the Munsell chart in good light conditions including indirect natural light from the windows. A pH test was then carried out on each sample after colour determination. A CSIRO/Inoculo Laboratory 'soil pH test kit' was used, a drop of Universal Indicator was mixed with the sediment and then the barium sulphate powder sprinkled on top. After about 2 minutes the colour was compared to the pH colour chart, thus measuring the pH of the samples.

2. Magnetic Susceptibility

Samples of the crushed heat retainers (above) were placed in capsules, weighed and tested for magnetic susceptibility using the same procedure as the sediment testing (6.3.1). As results were variable, the three colours red, brown and in-between red/brown were separated out (these colours had already been noted and marked on the capsules). Approximately 10grams of sediment from each sample was used to fill a small plastic capsule, thus giving a constant volume that was later used to determine density of the sediment. Each capsule was weighed and labelled and used for the magnetic susceptibility tests.

Volume magnetic susceptibility was measured using a Barrington Instruments model MS2 set at 1.0 resolution and Si units. Readings were taken at both high frequency (xhf, 4.6kHz), and low frequency (xlf, 0.46kHz). The meter was reset to zero between readings, and results were recorded on the spreadsheet. As the density of each sample was potentially different, the readings were converted by dividing the volume magnetic susceptibility reading by the weight of the sample and then multiplied the result by 10 to standarise the results to 10 grams of sediment. This gave a standardised calculation of mass susceptibility (Xhf and Xlf) that can be compared with other work such as Mitchell (1996) or Williams (1988). The results were then graphed.

3. The Baking Experiment

The baking experiment was designed to determine the effect of baking the underlying clay rich basement. The heat retainers from the mound showed a markedly higher magnetic susceptibility than either the mound sediment or the underlying basement, and the baking experiment was designed to determine how this change was produced. Ten similar sized balls were made from the basement material, left to dry and then baked in a furnace at controlled temperatures and times. The first five clay balls were baked in the furnace at 600 degrees C for 2 hours and left to cool for 24 hours. This was designed to replicate a heat retainer used in a ground oven once only. One ball was removed and the experiment repeated, with clay ball 5 being heated a total of

5 times. This experiment was then repeated using the remaining clay balls, this time baked at 1000 degrees C. The temperatures were determined from the previous firing experiments of Clarke and Barbetti (1982) who measured temperatures between 600 and 900 degrees C in an experimental oven. Such temperatures were also suggested by the occurrence of fused silica particles in the >2mm fraction of the sediment, indicating the ovens attained temperatures of between 600 and 900 degrees C (Mitchell 1996).

4. Heat Retainer Sizes

The initial sieving of mound material in the field included a 11mm top sieve which collected larger pieces of heat retainer, and a lower 2mm sieve. The 11mm fraction was sieved again with a 22mm sieve to further break down the heat retainer sizes to detect any trends in size. The three sizes of heat retainer for each excavation spit (>22mm, >11mm and >2mm) have been graphed to determine if there is a change is size of heat retainers throughout the mound. The > 22mm heat retainers from a randomly chosen spit were also measured and length by width graphed to show variation in size and shape.

5. Heat Retainer Types

During analysis of the excavation material the heat retainers was examined to determine if there were visible differences in texture, imprints, and shape.

6.2.3 Results of the Heat Retainer Analysis

1. Colour and pH

The colour of the heat retainers varied from red to brown to an in-between red/brown (Appendix 6 Table 6.3). There is no clear pattern in the colour of the heat retainers throughout the mound, or any distinct layers of similar coloured heat retainers. No patterns between colour and size were identified. This suggests that there was a range of oxidation/reduction firing environments that occurred throughout the history of the mound. The pH varies from 7 in Spit 3 and quickly becomes more alkaline with a trend similar to the pH of the sediment samples (6.3.3). The similar trend in pH between the heat retainers and the sediment suggests a relationship, i.e. much of the sediment is derived from heat retainer. There is no identifiable relationship between the three colour groups and pH of heat retainers.

2. Magnetic Susceptibility

The heat retainers have a magnetic susceptibility that averages out as nearly twice the value for the sediment (Figure 6.1, Appendix Table 6.3). Initial recordings were very variable, which suggested that the baking history including temperatures, time, and oxidation/reduction environment, affects the magnetic susceptibility and colour. To try and define the cause of the variability, the colours were separated out and twelve samples of red heat retainers, twelve of brown, and twelve of in-between red/brown were tested. This test showed that the magnetic susceptibility of the in-between red/brown heat retainers is higher than that of either the red or brown, but in particular the red (Figure 6.1). A possible explanation for this is that heat retainers that have been used only once, and fired in an oxidising environment, have lowest magnetic susceptibility. Following from this, heat retainers that have been reheated in the bottom of pits in a reducing environment would have higher readings. However, this does not explain why the red/brown heat retainers had higher readings than the brown heat retainers.

3. The Baking Experiment

The baking experiment produced unexpected and puzzling results, except for the change in colour which is as expected. Both the 600 degree C and 1000 degree C baking brought about a progressive change in colour (Appendix Table 6.4). The clay was a light yellow/red 7.5yr5/4 before cooking. In the 600 degree C oven the balls reddened and ranged from 5yr5/1 to 7.5yr6/6. In the 1000 degree C oven the colours were much redder and stayed at 2.5yr4/8. The clear crystals visible in the uncooked material became white on baking, these are probably gypsum. The dark stains in the uncooked material appeared to stay the same after baking.

The uncooked balls had a pH of 8.5 and the balls baked at 600 degrees C were all pH 6, which is acidic. The clay balls baked at 1000 degrees C ranged between pH 7.5 to 8.5, or neutral to slightly alkaline. There was no obvious trend over time for the balls heated at 1000 degrees, the pH appeared to vary randomly. This is an unexpected result, as the baking of the balls did not increase the pH so that they matched the heat retainers from the mound (which ranged from pH 7 to 10, mostly pH 10), and in fact tended to reduce pH, especially at the lower temperature.

Figure 6.1 Ravensworth 3 Mean Magnetic Susceptibility of Heat Retainers by Colour

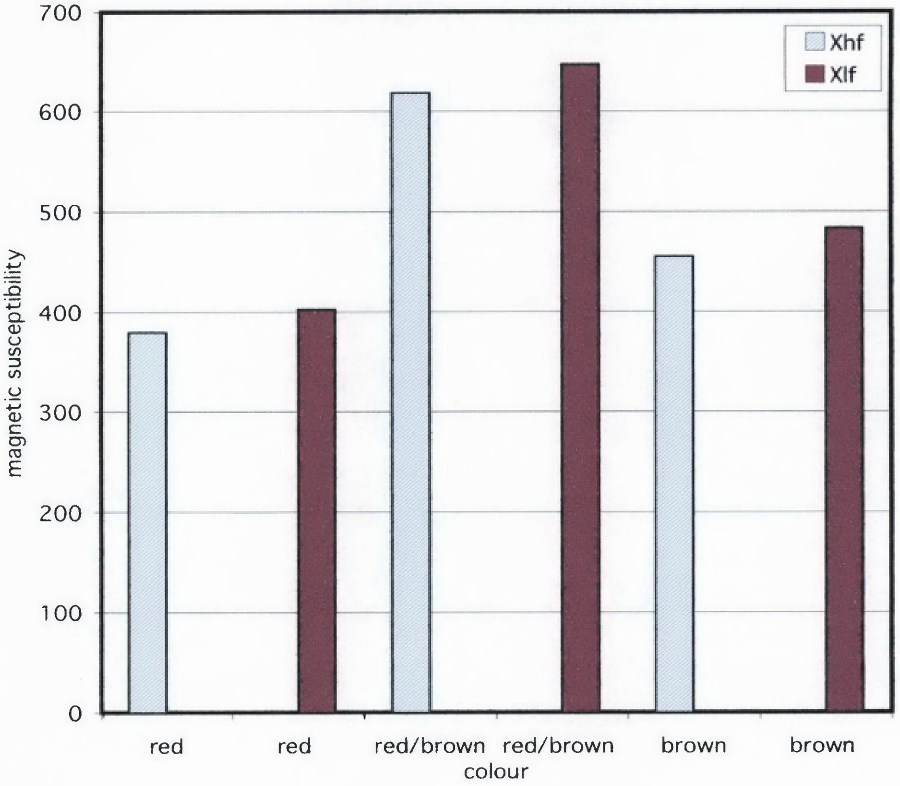
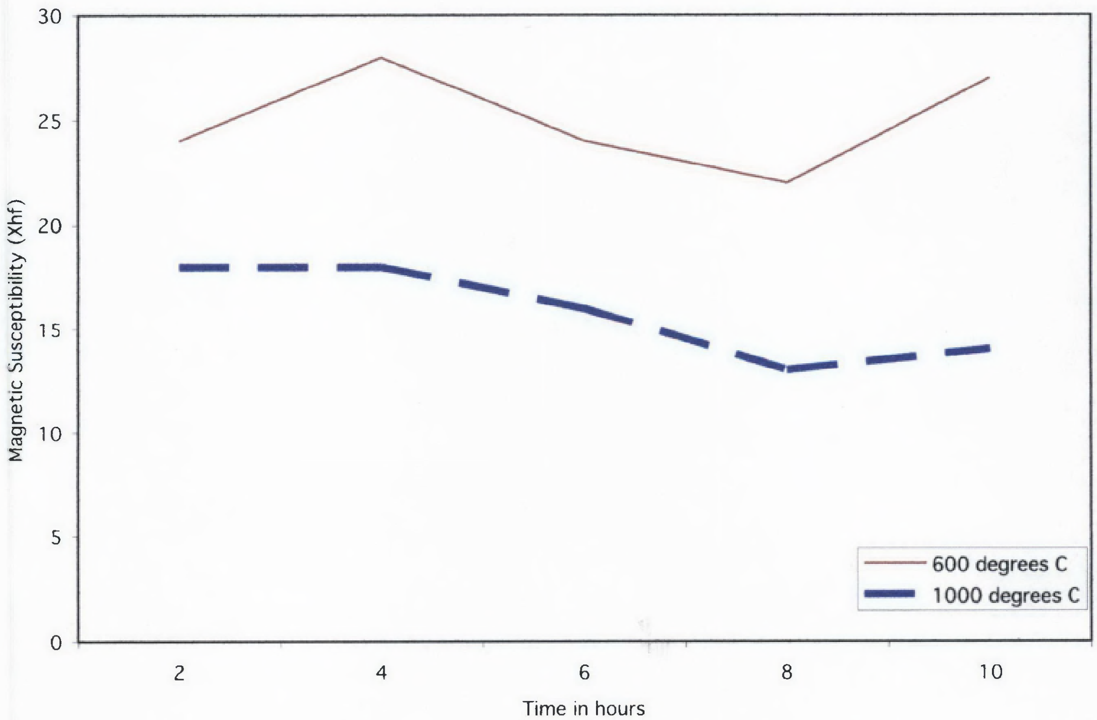


Figure 6.2 Change in Magnetic Susceptibility in Clay Balls with Baking Time



The mass magnetic susceptibility of the cooked balls changed very little from that of the basement material from which they were made (Figure 6.2). The balls cooked at 600 degrees C showed an slight initial increase after being baked for four hours, and a slight decrease after being baked for 8 hours, increasing slightly again after 10 hours. However, these changes are so slight compared with the high reading obtained from the mound heat retainers it is clear that the baking of the underlying basement did not have any significant effect on the magnetic susceptibility. The balls heated at 1000 degrees showed almost no change over time, and the magnetic susceptibility readings were even lower then those for the balls baked at 600 degrees. This is in direct contradiction to literature indicating that baking increases the magnetic susceptibility (Mitchell 1996). This suggests two possibilities:

- The underlying basement material is not the source of the heat retainers (confirmed by the particle analysis) and has some property that prevents baking from increasing magnetic susceptibility.
- Or some other process yet to be determined has affected the magnetic susceptibility of the mound heat retainers, such as higher temperatures or the oxidation/reduction environment.

4. Heat Retainer Sizes

The >22mm heat retainers from one spit chosen randomly were measured and graphed to show variation in size and shape (Figure 6.3). This shows that even the largest heat retainers in the mounds are relatively small and probably reduced in size by reuse and post-use breakdown. The sieve weights are variable throughout the mound but the difference between the gross weights and the amount of heat retainers and heat retainer fragments > 2mm indicate the <2mm sediment is consistently the dominant fraction (Figure 6.4) which has implications for the suggestion that mounds were re-used partly because they were a supply of heat retainer (Klaver 1998). This graph indicates there are relatively few large heat retainers throughout the mound.

The three fractions of heat retainer from the excavation spits (>22mm, >11mm and >2mm) have been graphed separately to determine if there is a change is size of heat retainer throughout the mound (Figure 6.5 and Appendix Table 6.6). The large numbers of small heat retainer fragments (<11mm and >2mm) in the first two spits are also noted in the excavation section drawing. This may indicate that a process of deflation and heat retainer breakdown has occurred on top of the mound, consistent with it having been abandoned as an active oven making area for a long period of time. Apart from the increase of small heat retainers at the top and the sharp reduction at the base of the mound, the heat retainer weights are variable from spit to spit and between Square A and Square B, but if the graph is smoothed over there is little change throughout. Some of the variation in the graph is the result of clustering of heat retainers reflecting the existence of heat retainer features.

5. Heat Retainer Types

During analysis of the excavation material, heat retainers were examined to determine if there were visible differences in texture, or material type. In the Ravensworth 3 mound the majority of heat retainers are irregular to rounded pieces of baked sediment that have similar particle sizes to the mound sediment. Other materials frequently used for heat retainers in adjacent areas including termite mound, calcrete from dune cores, and stone, are not available on the plains and not found in these mounds. The heat retainers do not appear to have been moulded carefully by hand leaving the imprints of fingers, a characteristic that is occasionally found in the Murray River mounds and ovens (Coutts et al. 1979).

Some of these heat retainers have imprints on them, or have been moulded around something, but because of the rather coarse and weathered material it is not easy to determine what this might have been. However, there are less common heat retainer pieces which are very hard and made up of very fine sediment. These can easily be mistaken for stone, and are often tabular rather than chunky. They can have imprints on one or more sides and some appear to have imprints of fish. It is suggested that these are the result of oven baking of foods encased in the fine mud from the lake. An account from 1864 of cooking on the Murray River floodplain to the south of the Hay Plain describes cooking ‘by covering the bird or animal in soft clay and placing it in a hole in the ground which has been made red hot’ (Matthews 1901:45). The mud used to encase food would have to be clay rich and therefore may be different to that used for heat retainers, and would not be dried before baking, as the usual heat retainers may have been.

Figure 6.3 : Variation in Size and Shape of Heat Retainer Sample

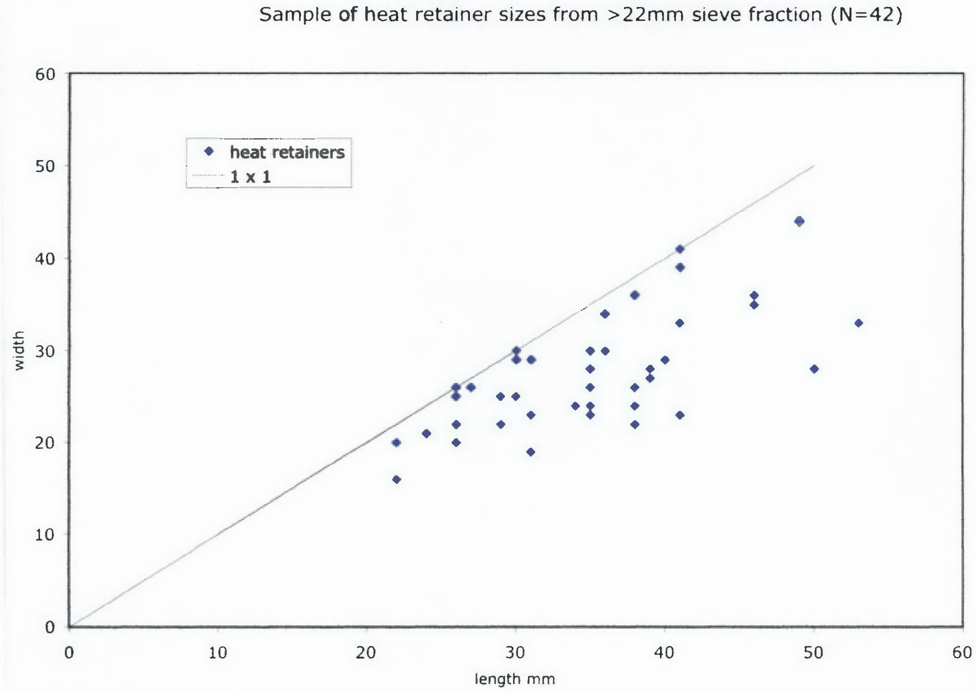
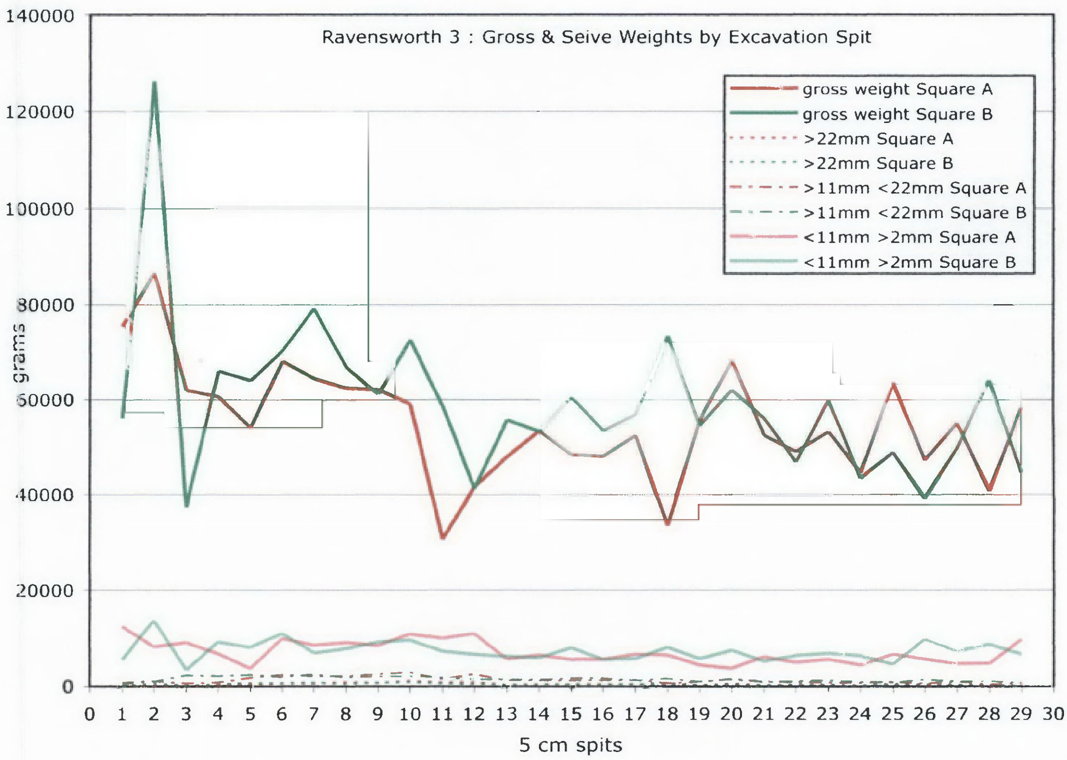


Figure 6.4 Ravensworth 3 Gross & Sieve Weight Trends by Excavation Spit



6.3 RAVENSWORTH 3 SEDIMENT ANALYSIS

6.3.1 Introduction

Sediment samples taken from the Ravensworth 3 excavation pit column sample were used for the sediment analysis. The excavation was carried out in 5cm spits and an upper and lower sediment sample was taken from each spit, that is a sample was taken every 2.5 cm. The samples were removed from the north-east corner of Square A, and each sample was between 1.5-2 kg. A total of 29 spits were excavated throughout the mound, plus a sample of the underlying clay rich basement. The samples were labelled according to spit number and 'a' for the top 2.5 cm and 'b' for the lower 2.5cm (hence 3a, 3b, 4a, 4b etc). Spits 1 and 2 were not analysed because they consisted of uneven humic layers which were full of roots and cow manure as cattle had been camping on the mound.

The aims of the sediment analysis are to provide information on the Ravensworth mound, particularly about the mound formation processes. Specific objectives that are addressed in the analysis include:

- Determining the characteristics of the mound sediment and underlying basement.
- Determining whether the mound sediment changes throughout the mound.
- Comparing any changes in mound sediment defined by the analysis with the stratigraphy recorded in the field or the analysis of mound contents such as faunal remains, stone artefacts, charcoal, pollen.
- To try and determine the source of the mound sediment.
- To delineate the history of the mound material, for example the breakdown history of the heat retainers, temperatures reached in firing processes.
- To determine whether the characteristics of the mound material are due to natural processes such as leaching or soil formation processes, or cultural processes such as burning, or addition of cultural materials.
- To determine how mounds were constructed, what sort of technology was involved and how this technology might affect the sediments.

6.3.2 Laboratory Procedures

Data entry forms in the Microsoft Excel spreadsheet format were used (Appendix 6). All sample bags were weighed and then sieved through a 2mm Endecott sieve to remove the greater than 2mm sediment fraction and cultural material such as heat retainers, pieces of bone and shell, and stone artefacts. The weights of the greater than 2mm fraction were recorded. The bone, stone and shell was removed, bagged and labelled and later included in the excavation analysis. The heat retainers were collected and bagged and some of these were used in the heat retainer analysis. Excavation spit 29 was a mixture of fine sediment from the mound and material from the underlying basement. The basement material formed clay rich lumps which would not go through the 2mm sieve, these lumps were picked out and included in the sediment analysis as a separate sub-spit (29a>2mm and 29b>2mm). The <2mm fraction was kept for the sediment analysis.

The following tests were carried out on the sediments;

1. Colour and pH

A Munsell colour chart was used to determine a standard colour for each sample (Appendix 6.1). A spatula portion of sediment from each sample was placed on a perspex plate and the colour compared to the Munsell chart in good light conditions including indirect natural light from the windows. A pH test was then carried out on each sample after colour determination. A CSIRO/Inoculo Laboratory 'soil pH test kit' was used, a drop of Universal Indicator was mixed with the sediment and then the barium sulphate powder sprinkled on top. After about 2 minutes the colour was compared to the pH colour chart, thus measuring the pH of the soil.

2. Magnetic Susceptibility

Particular minerals with a high magnetic susceptibility (eg. iron oxides, iron sulphates, manganese oxides) occur in different proportions in different types of sediment. Analysis of magnetic susceptibility is a method utilised to identify the mineralogical history of sediments, and to differentiate sediment types (Gale and Hoare 1991:201-229). From the <2mm fraction 500 grams of each sample was weighed and then put through a 'Riffle box' which randomly separates the sample by splitting it into 2 halves. This was done 5 times for each sediment sample. Approximately 10grams of sediment from each sample was used to fill a small plastic capsule, thus giving a constant volume which was later used to determine density of the sediment. Each full capsule was then weighed and labelled and used for the magnetic susceptibility tests.

Volume magnetic susceptibility was measured using a Barrington Instruments model MS2 set at 1.0 resolution and Si units. Readings were taken at both high frequency (xhf, 4.6kHz), and low frequency (xlf, 0.46kHz). The meter was reset to zero between readings, and results were recorded on the spreadsheet. As the density of each sample was potentially different, the readings were converted by dividing the volume magnetic susceptibility reading by the weight of the sample and then multiplied the result by 10 to standarise the results to 10 grams of sediment. This gave a standardised calculation of mass magnetic susceptibility (Xhf and Xlf) which was then graphed (Figures 6.6).

3. Particle Size

Particle size analysis is used to understand soil formation processes and sources of sediment found in sites. By looking at the relative proportion of particle sizes in each sample, it is possible to determine changes through the mound which may relate to either natural or cultural processes. Natural processes include transport of sediment by wind and soil profile formation. Cultural processes include the inclusion of clay heat retainers and their breakdown components, and deposition by people of sediment from sources other than the immediate vicinity of the mound.

A further 500 grams of sediment was removed from each sample and placed in a nest of sieves of mesh size 1mm, .5mm, and .25mm. The sieves were placed in a sediment shaker for about 50 minutes. However, during sieving of the first sample the sediment was clogging the finer sieves and caking around the edges, and a test run with oven dried material indicated that moisture was causing this problem. Each sample was then oven dried for 3 hours at 38-40 degrees C before sieving, resulting in a 10% weight loss. It is recommended that sediment not be dried at over 40 degrees C as it may affect the magnetic susceptibility measurements (Gale & Hoare 1991). After one third of the samples had been sieved the shaker broke down and the remaining two thirds were sieved by hand, which was a more efficient and quicker method (and resulted in a10% weight loss from me).

6.3.3 Results of the Sediment Analysis

1. Colour and Ph

Colour changes throughout the mound are quite subtle variations of yellow-red (Appendix Table 6.1). There are slight changes at Spit 4a, 10a, 15a and 21a which correspond to the changes seen in the stratigraphic section (Figures 5.6 & 5.7). The apparently distinctive colour variation in the section between Layer 3 and Layer 4 only shows up in the Munsell chart as variation from 10yr4/2 to 10yr3/2. Obviously texture plays a part in what is seen in a section. The underlying basement has a distinctly different colour to the mound material, being much more yellow (the basement fine fraction is 2.5y5/2).

The pH of the mound shows a change from neutral to alkaline to very alkaline, and back to alkaline. Spit 3a is neutral with pH 7, Spit 4 had pH 8.5, Spit 5 has pH 9, and Spits 6 to 28 are all pH 10 (Appendix Table 6.1). Spit 29 and the basement have pH 8.5. The top acidic layer is surprising but it may relate to the humic layer above it or farming practices. It may however be the result of soil formation processes and the leaching of cultural material including ash, charcoal, bone, shell and possibly minerals from top layers.

2. Magnetic Susceptibility

The volume magnetic susceptibility of the mound sediment (Spits 2-28) is in the order of 10 times higher then the underlying basement and 5 times higher than Spit 29 just above the basement (Figure 6.6 and Appendix Table 6.2). The change at Spit 29 is sudden and reflects the incorporation of basement sediment. The mound sediment 29a (which has some admixture of basement) plunges to 100 from 218 at 28b. Spit 29a >2mm (which is the fraction consisting largely of clay rich lumps of basement) is only 48, 29b is lower than 29a at 66, 29b>2mm is very low at 19, similar to the basement which is 25. This shows that the magnetic susceptibility value rapidly plunges as mound sediment is replaced by basement sediment. The mound sediment shows very little variation in volume magnetic susceptibility, with a slight decrease in Spit 3 and an overall very slight decrease from Spit 4 to Spit 28.

Figure 6.5 Ravensworth 3 Heat Retainer Sieve Fraction Weight Trends by Excavation Spit

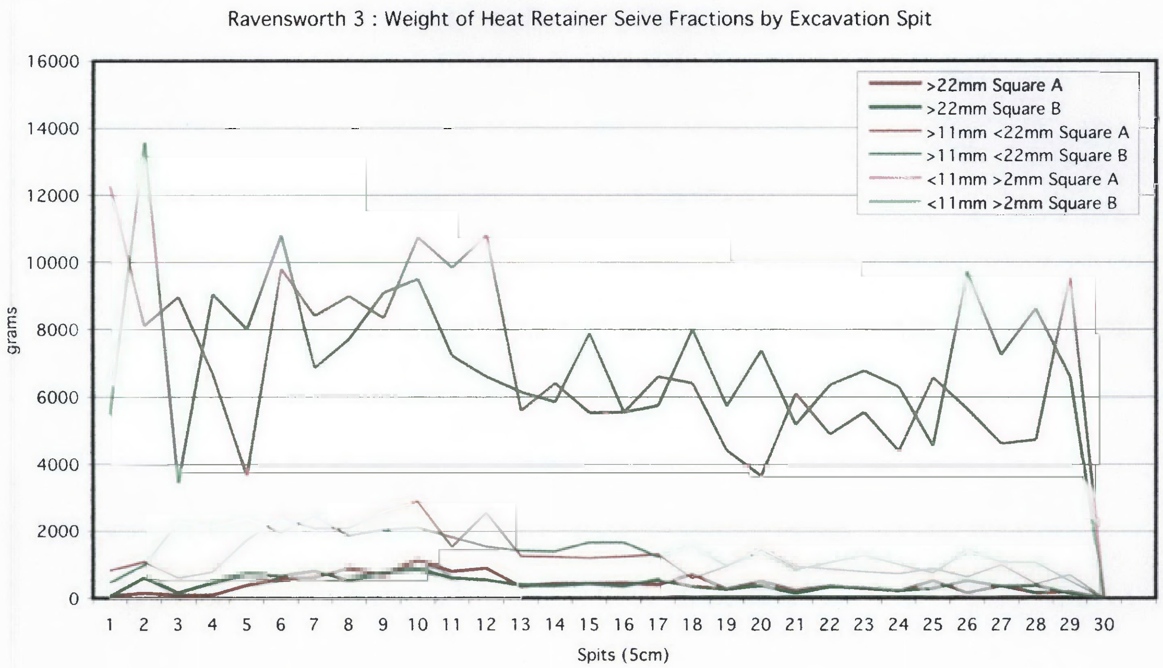
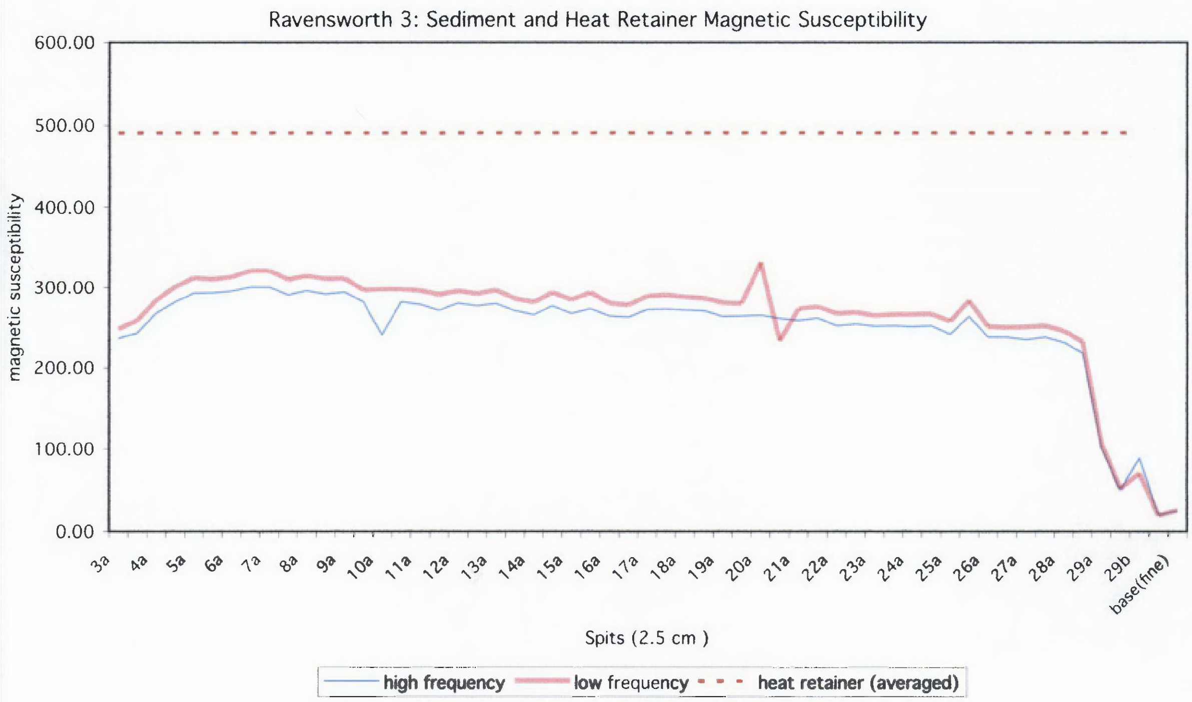


Figure 6.6 Sediment and Heat Retainer Magnetic Susceptibility



3. Particle Size Analysis

The particle size analysis of the sediments (Figure 6.7 and Appendix Tables 6.1) indicates that there is a very sudden change at Spit 29 where the percentage of very fine material (<.25mm) suddenly drops and the percentage of the coarser fractions (<2mm and <1mm) correspondingly increase. The underlying basement also has a much lower percentage of very fine material, indicating that the decrease in fine sediment in Spit 29 is due to an admixture of basement material. Throughout the majority of the mound (except for Spit 29) the percentage of the four fractions remains relatively stable, except for a minor variation between Spits 3-9. The overall trend in particle size is a lack of change throughout the mound except for a distinct change at Spit 29 which reflects admixture of the coarser basement material. This indicates that the material for the mound sediment was sourced from a sediment with a higher percentage of very fine material than the basement, and therefore did not come from the underlying lunette material.

4. Magnetic Susceptibility of Particle Size Fractions

After completion of the above tests another magnetic susceptibility test was run on the particle size fractions to determine if there is a difference in the magnetic susceptibility of the different fractions. The finest <.25mm fraction has the lowest magnetic susceptibility readings, and shows very consistent readings throughout the mound, except for a reduction in the top Spits 3 and 4, and the expected plunge at Spit 29 and the basement (Figure 6.8 and Appendix Table 6.5). The <.5mm fraction has a higher magnetic susceptibility reading and a similar trend to the finest fraction, although it is more variable. The coarser fractions (<1mm and <2mm) have higher readings again and show similar trends to the <.5mm fraction. The readings are more variable in the upper spits of the mound (above Spit 15). Throughout the mound the larger particle sizes have higher magnetic susceptibility readings. This is likely to be related to the presence of small pieces of heat retainers within the larger fractions, and suggests that the more broken down the heat retainers the lower its magnetic susceptibility. The presence of 'crumbs' of heat retainer in the larger two fractions was visible to the naked eye and was confirmed by microscope examination. This trend is the opposite for the basement and for Spit 29 which has an admixture of basement, here the coarser material has lower magnetic susceptibility which relates to the coarser sediment of the lunette rather than broken down heat retainers.

Figure 6.7 Particle Size by Percentage of Sediment Sample

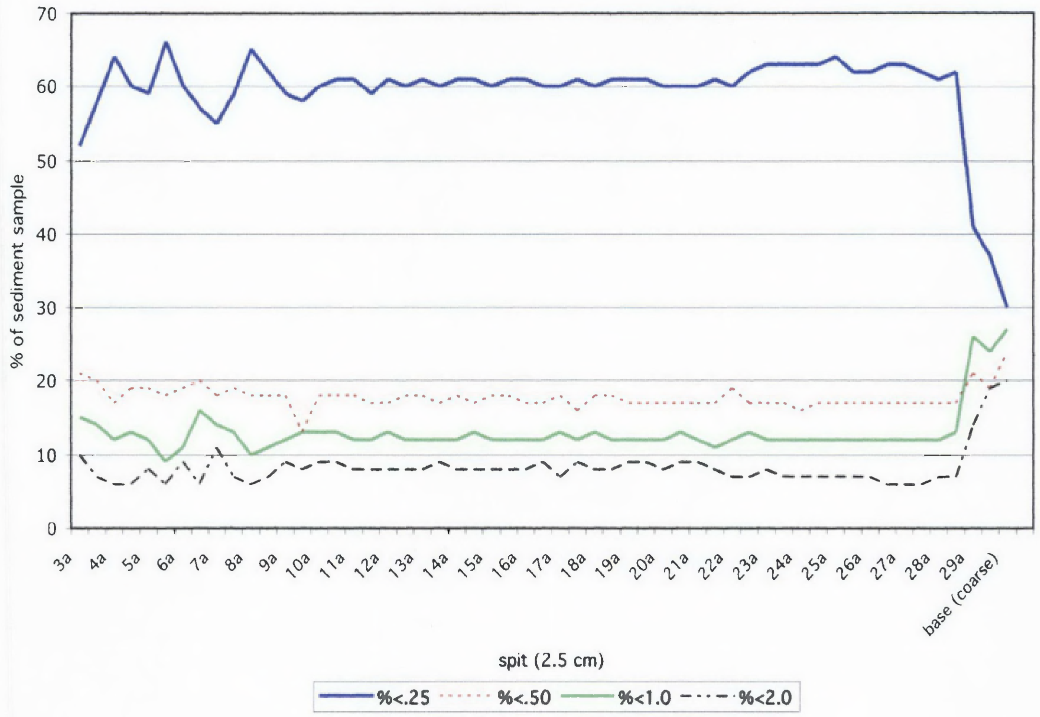
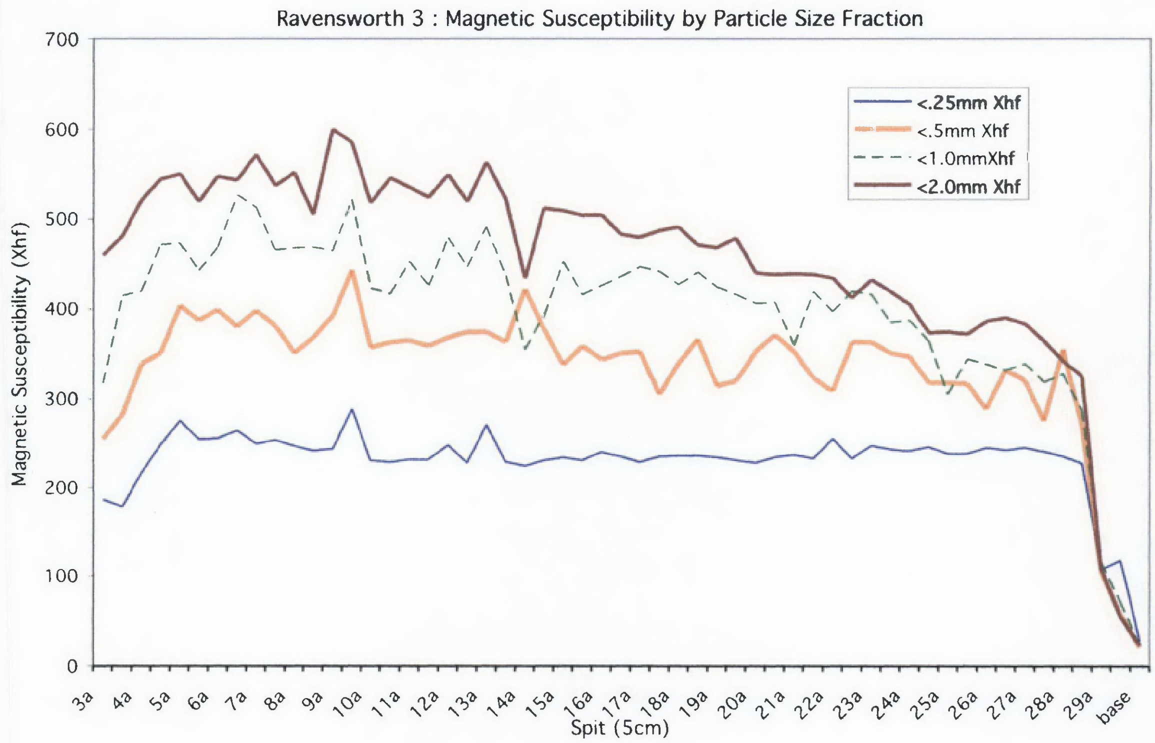


Figure 6.8 Ravensworth 3 Magnetic Susceptibility by Particle Size Fraction



6.4 CONCLUSIONS

Compared to the underlying lunette, the mound sediment:

i. is darker and redder in colour and generally much more alkaline

ii. has ten times higher magnetic susceptibility

iii. has a higher proportion of fine grained particles under 0.25mm.

Thus the mound material is very different to the underlying lunette sediment. Colour, pH and magnetic susceptibility of the mound material may differ from the lunette because of its cultural history, but the higher proportion of finer sediments indicates that the mound is not derived directly from the lunette. The differences between the mound and underlying lunette also shows that the mound was not made by excavating sediment and piling it up, as some of the Western Victorian mounds have reportedly been constructed (Williams 1988). The analysis indicates that heat retainer was obtained from a source other than the underlying lunette, and carried to the mound. It is suggested that the heat retainer was obtained from the nearby lakebed as wet or damp clay, to prevent wastage of energy and breaking of digging sticks needed to dig into the very hard lunette soil (so hard that the samples taken during the excavation had to be crow-barred out).

The majority of the mound, particularly Spits 6 to 28, is characterised by uniformity in colour, pH, particle size and magnetic susceptibility. In spit 29 near the base of the mound aggregates of clay rich material from the underlying lunette are mixed with the mound sediment. The clear differences between the mound material in Spit 29 and the aggregate material confirm the different origins of these materials. The upper mound Spits 3-5 are lighter in colour and more acidic, have lower magnetic susceptibility and more variable sediment fractions than the rest of the mound. The heat retainer analysis and the excavation section drawings also show that Spits 3 and 4 have a much higher proportion of small heat retainers (>2mm <11mm) than other spits. This suggests that Spits 3 to 5 have a different history to the lower Spits, and that post-depositional processes have affected the upper part of the mound. The data seems to indicate that deflation, soil formation, and leaching have affected the top of the mound, suggesting that the mound may have been abandoned as an active heat retainer cooking place for a considerable time, which is corroborated by the date of

3,820 ±36 BP from Spit A:3 near the top.

Only three sedimentary units were strongly identified by the sediment analysis laboratory results, compared to 10 strata identified during excavation. The exception to this are slight colour variations in spit 4, 10a, 15a and 21a which appear to correspond to layers seen in the excavation sections. The overall lack of variation in sediment characteristics suggests some of the colour changes may be post-depositional, particularly in the upper spits. The 10 strata identified in the field also reflect the texture and cultural contents of the sediment, which add another layer of information that is lost in the laboratory analysis.

The heat retainers in the mound have:

i. red, red/brown and brown colour suggestive of a variety of oxidising to slightly reducing environments during firing

ii. a pH very similar to the mound sediments and following the same trends

iii. an average magnetic susceptibility of nearly twice that of the mound sediment

iv. the red/brown heat retainers have a higher magnetic susceptibility than the brown and particularly the red heat retainers.

The similar trend in pH between the heat retainers and the sediment suggests that much of the sediment is derived from heat retainers. The >2mm, <2mm and <1mm sieve fraction particles largely consist of heat retainer pieces and fragments visible to the naked eye and the higher magnetic susceptibility of these fractions compared to the finest sediment fractions also suggests that they are derived from broken down heat retainers. This combined information indicates that the source of the mound sediment is predominantly derived from breakdown of heat retainers. The consistent reduction in magnetic susceptibility from large heat retainers, to >2mm, to <2mm to <1mm and finally to <0.5mm and <0.25mm sieve fractions suggests that the mineralogical change caused by firing and resulting in increased magnetic susceptibility, gradually changes or reverts as the heat retainers break down.

The differing readings of magnetic susceptibility for the three colours of heat retainers reflects a range of different firing environments. This is difficult to interpret further as temperature, duration, oxidation/reduction environment during the firing process, and post firing positions including reuse may all affect the colours. The baking experiment clearly showed the deepening colouration of the clay balls from a light red to a darker deeper red the longer the balls were heated. At this stage it is only possible to state that the different colours with their different readings of magnetic susceptibility reflect the fact that there were a range of firing environments utilised at Ravensworth 3. This would include initial firing in an oxidising environment, reducing environments in ovens, and accidental or deliberate re-use in ovens, oven walls and floors.

The high magnetic susceptibility of the heat retainers compared to the sediment and the gradual decline throughout the smaller sieve fractions supports the literature that states that firing of sediment at high temperatures increase magnetic susceptibility. Fused silica particles found throughout the >2mm fraction indicate that the ovens attained a heat of between 600-900 degrees C (Mitchell 1996). However the baking experiment with material from the lunette sediment produced contradictory results that are difficult to explain and suggest that the use of heat retainers is more complex than anticipated. The underlying lunette material used for the baking experiment is not the source of the heat retainers (latter confirmed by the particle analysis) and it may have some property that prevents baking from increasing magnetic susceptibility. Alternatively some other process yet to be determined has affected the magnetic susceptibility of the mound heat retainers, such as higher temperatures or the oxidation/reduction environment.

The heat retainer size analysis indicates that apart from the higher proportion of small heat retainers (>2mm to <11mm) in the upper spits, the distribution of the 3 sieve fractions (>22mm, >11mm and >2mm) are variable throughout the mound but if the graph is smoothed there is little change. The small proportion of large heat retainers indicates that the mound was not a good supply of heat retainers suitable for re-use and therefore did not attract people to it for this reason, as has been suggested (Klaver 1998). In conclusion, the analysis of the sediment and the heat retainers, together with the excavation results, confirms that Ravensworth 3 mound is predominantly the result of the repeated use of the location for cooking in heat retainer ovens. Heat retainer for the ovens has been brought onto the site, probably from the nearby lake bed, and the breakdown of these heat retainer largely contribute to build up of mound sediment.