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A PALAEOECOLOGICAL AND TAPHONOMIC ANALYSIS OF THE MICROMAMMALS FROM A MARINE ISOTOPE STAGE 5 LAYER AT KLASIES RIVER, SOUTHERN CAPE, SOUTH AFRICA.

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WITWATERSRAND,
JOHANNESBURG

A dissertation submitted to the Faculty of Science, University of the Witwatersrand, Johannesburg, 2020, in fulfilment of the requirements for the degree of Master of Science.

DIVISION OF ARCHAEOLOGY
SCHOOL OF GEOGRAPHY, ARCHAEOLOGY AND ENVIRONMENTAL STUDIES.

Declaration

I declare that this dissertation is my own, unaided work. It is being submitted for the Degree of Master of Science in the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination at any other University.

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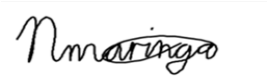

Abstract

This research investigated the palaeoecology at Klasies River main site during Marine Isotope Stage 5d by analysing the micromammal remains excavated from the BOS Three layer in Cave 1 during the 2017 excavation season. During this time, Cave 1 was inhabited by anatomically modern humans with complex modern behaviour. The taphonomic analysis shows that light and moderate digestion on the cranials and post-cranials are common, with the majority of specimens displaying moderate breakage. These modifications are associated with *Tyto alba* (Barn owl) and *Bubo africanus* (Spotted eagle-owl) as the accumulators of the assemblage. Encrustation and soil staining are the most prevalent post-depositional modifications in both cranial and post-cranial assemblages. This relates to the presence of tufa, speleothem material and the presence of water. The taxonomic analysis on the cranial elements (mandibles, maxillae and teeth) identified the most prominent species as *Otomys irroratus* (Southern African vlei rat), *Myosorex varius* (Forest shrew) and *Crocidura flavescens* (Greater red musk shrew). This indicates a strong presence of taxa that prefer densely vegetated and moisture enriched environments. However, two of the dominant taxa identified also indicate a broad habitat tolerance. The Taxonomic Habitat Indices show a strong indication of closed, grassy plains with ample precipitation. The overall indication of the environment at KRM during MIS 5d is an impression of mosaic environment with bodies of standing water such as vleis.

Key words: Palaeoecology, Palaeoenvironment, Taphonomy, Taxonomy, Micromammals, Klasies River, MIS 5.

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Chapter 1: Introduction

1.1 Introduction

This chapter serves to introduce the study site and provide the history of excavations and cultural significance (Section 1.2) and the stratigraphy of the site (Section 1.3). The research inquiry section begins with the research statement (Section 1.4), the research question (Section 1.5), aims (Section 1.6) and the rationale (Section 1.7). The introductory chapter concludes with the structure of the dissertation in Section 1.8.

1.2 Site background

Klasies River main site (KRM) (34°6'29.69" S, 24°23'25.95" E) is situated on the Tsitsikamma coast between Cape St Francis and Plettenberg Bay in the Eastern Cape Province, South Africa (Singer & Wymer 1982; Deacon 1995; Grine *et al.* 2017; Wurz *et al.* 2018).

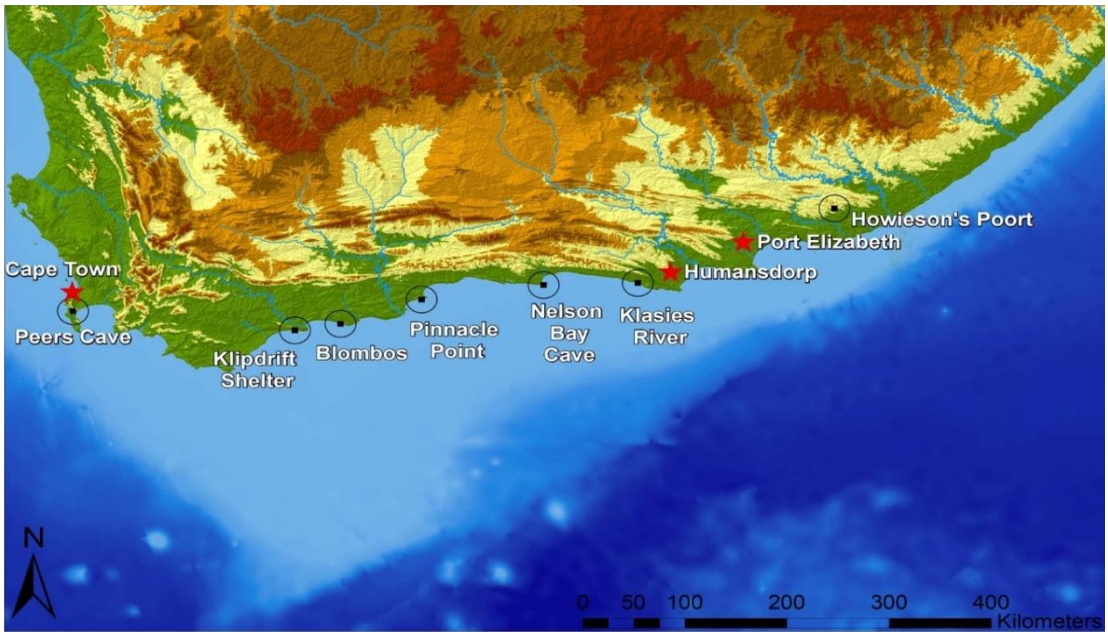


Figure 1.1: A map of the coastal sites in the southern Cape (adapted from Mosweu 2019).

KRM (Figure 1.1) site is found in the Eastern Fynbos and Renosterveld bioregions which forms part of the Fynbos biome (Mucina & Rutherford 2006). A

sampling analysis of the variety of vegetation surrounding main site (Caves 1, 1A, 1B and 2), Caves 3,4 and 5 and Klasies River was researched by Van Wijk and colleagues (Van Wijk *et al*. 2017).



Figure 1.2: A panoramic aspect of Main site. The vegetation surrounding the National Heritage cultural landscape and the proximity of the shore to the site slightly hidden by the jagged rock bench towards in the entrance of Caves 1 and 1B are shown (after Van Wijk *et al.* 2017: 14).

The vegetation types in the proximity of the site are thicket, some coastal vegetation, forest and fynbos (Figure 1.2) which represents an intricate mixture of vegetation (Van Wijk *et al*. 2017: 28).

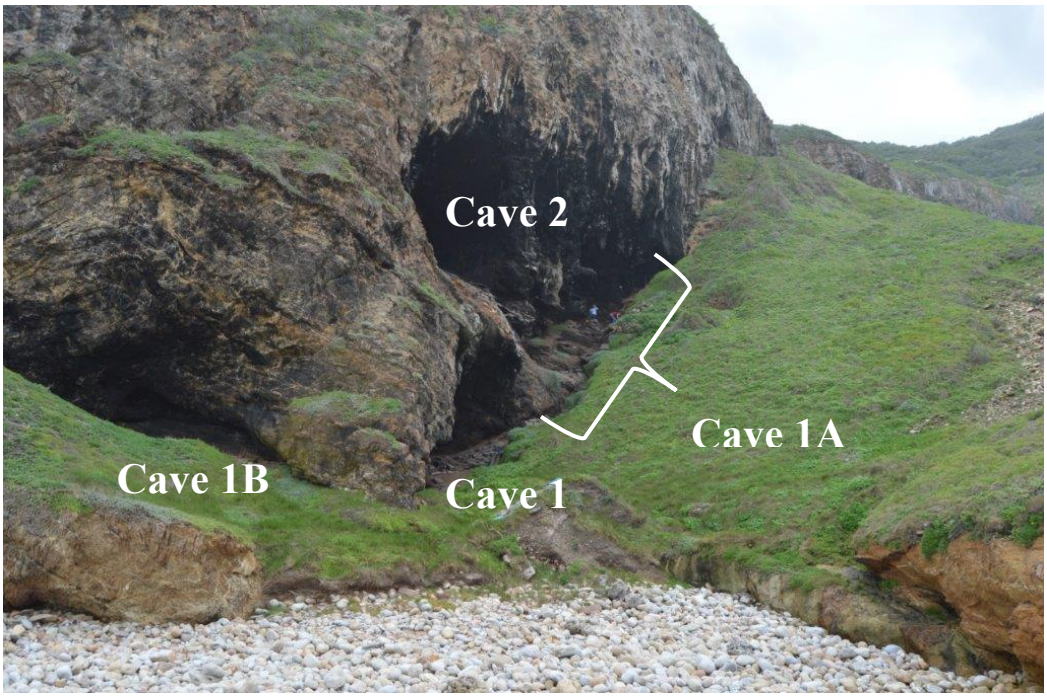


Figure 1.3: An annotated image of main site and the quartzite cobble stones that comprise Cobble/Storm Beach (Courtesy of Dr. Silje Evjenth Bentsen).

A cluster of caves (Cave 1 and 2) and closely associated overhangs (referred to as Caves 1A and 1B), formed by wave action in the cliff face, comprise the Klasies

River main site (Figure 1.3) (Singer & Wymer 1982; Wurz *et al.* 2018). Further eastwards along the coast Caves 3, 4 and 5 occur (Singer & Wymer 1982; Wurz *et al.* 2018). KRM and the surrounding landscape has been declared as a National Heritage site and this collective cultural landscape is now referred to as a National Monument (Wurz *et al.* 2018).

At Klasies River main site, during the early MIS 5 (approximately 125 ka), a sediment pile accumulated inside and in front of Cave 1 and 1B, situated 6m above sea level, to such an extent that their entrances were blocked off (Deacon 1995). By around 70 ka, this sediment pile reached the height of Cave 2, 18m above sea level, and subsequently filled this cave too (Deacon 1995). During the Holocene, the sediment pile was eroded by the rise of the sea level, opening the caves and leaving 21 metres of remnant deposits at main site (Wurz *et al.* 2018). Research at Klasies River was initiated with excavations by John Wymer (JW) in 1967-1968 (Singer & Wymer 1982). The excavation project was aimed at understanding cultural and human evolution during the Late Pleistocene and recent times in South Africa (Singer & Wymer 1982: 7). The significance of KRM was established with the discovery of human remains, well preserved shell middens and other archaeological features. The site is also suitable for geological, geographical, oceanic and ecological research (Deacon 2001). Hilary John Deacon (HJD) renewed excavations at KRM from 1985 to 1995 with the intention of conserving the deteriorating site since the last excavations by JW (Deacon 1995, 2004). Another reason for the renewal of excavations at KRM was to extend the archaeological archival record to the beginning of the Late Pleistocene (125ka) because the base of the Boomplaas sequence, the other site excavated by Deacon, dated to 80ka (Deacon 1995: 121, 2004). Together the sites would form a palaeoarchive reaching from MIS 5e into the Holocene.

A new phase of excavations began in 2015 by Professor Sarah Wurz (SW) (Wurz *et al.* 2018), with the focus on the ca.100 ka and older layers of the Witness Baulk (Wurz 2016), continuing the Deacon excavations in this area. The aims of this project include the application of new analytical methods and additional dating

analyses that could be integrated with the developments of contemporaneous MSA sites both inland and coastal (Wurz 2016). The Witness Baulk is a 12m high accumulation of sediment and archaeological material located in the middle of Cave 1, that remained after the JW excavation (Wurz *et al.* 2018). The Witness Baulk was first excavated by HJD in the 90s and subsequently by SW since 2015 (Wurz *et al.* 2018).

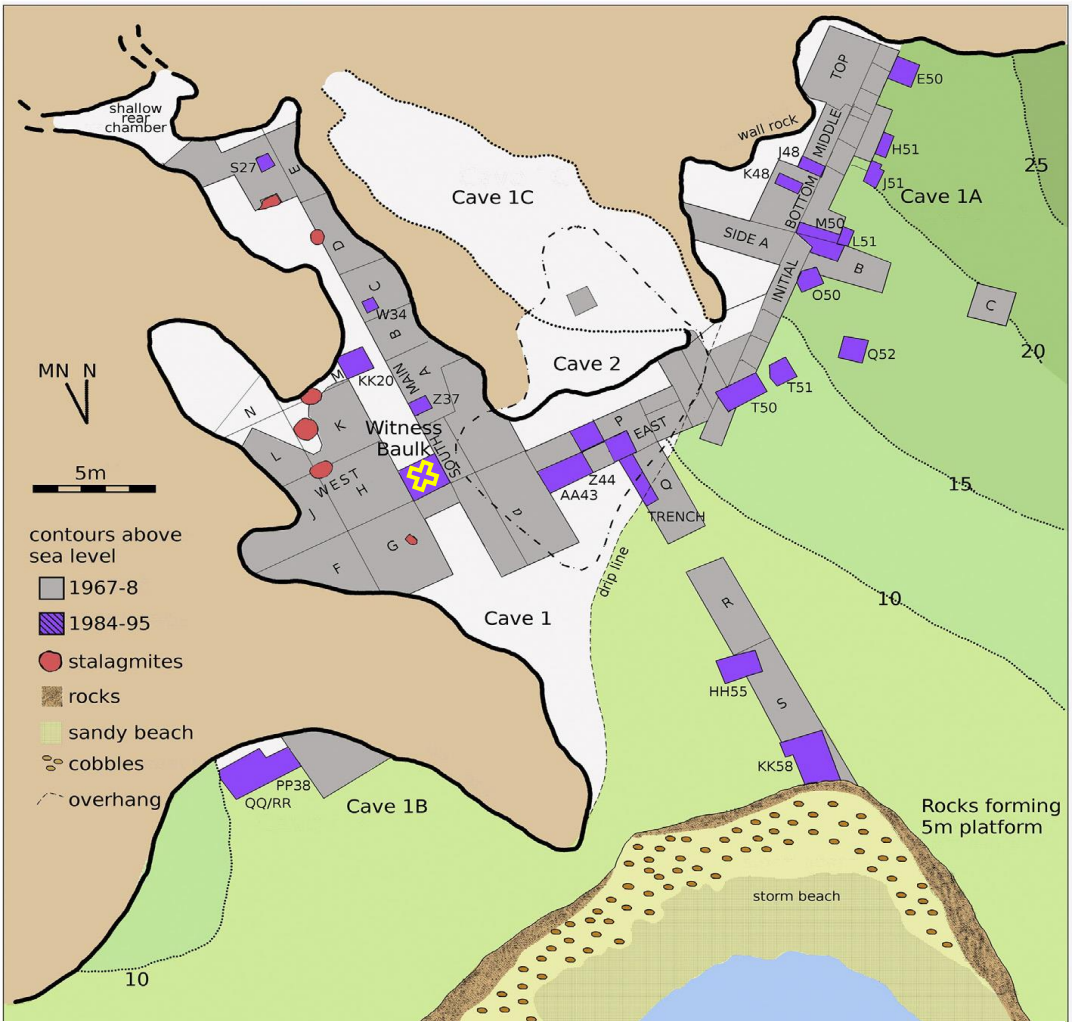


Figure 1.4: Site plan of main site. Excavations by Wymer are emphasised with the shade of grey and the Deacon excavation in purple (adapted from Wurz *et al.* 2018).

The site plan shows details of the two earliest excavations at main site are displayed in Figure 1.4. The Wurz excavation is indicated with a yellow cross indicating the excavated portion of the Witness Baulk in Cave 1. This section is divided into squares A1-3, B1-3 and C1-3. The micromammal assemblage analysed here was recovered from square C3.

1.3 Stratigraphy and cultural associations

Klasies River main site hosts a wealth of archaeological material including shell middens, faunal remains, lithics, human remains and botanical remains (Deacon & Geleijnse 1988; Deacon 2001, Grine *et al.* 2017). A series of layers of varying thicknesses indicative of human occupation and periods of non-occupation by humans occur at KRM (Deacon & Geleijnse 1988; Deacon 2001). Singer & Wymer (1982) divided the main deposits into layers and Deacon & Geleijnse (1988) classified the deposits into lithological members.

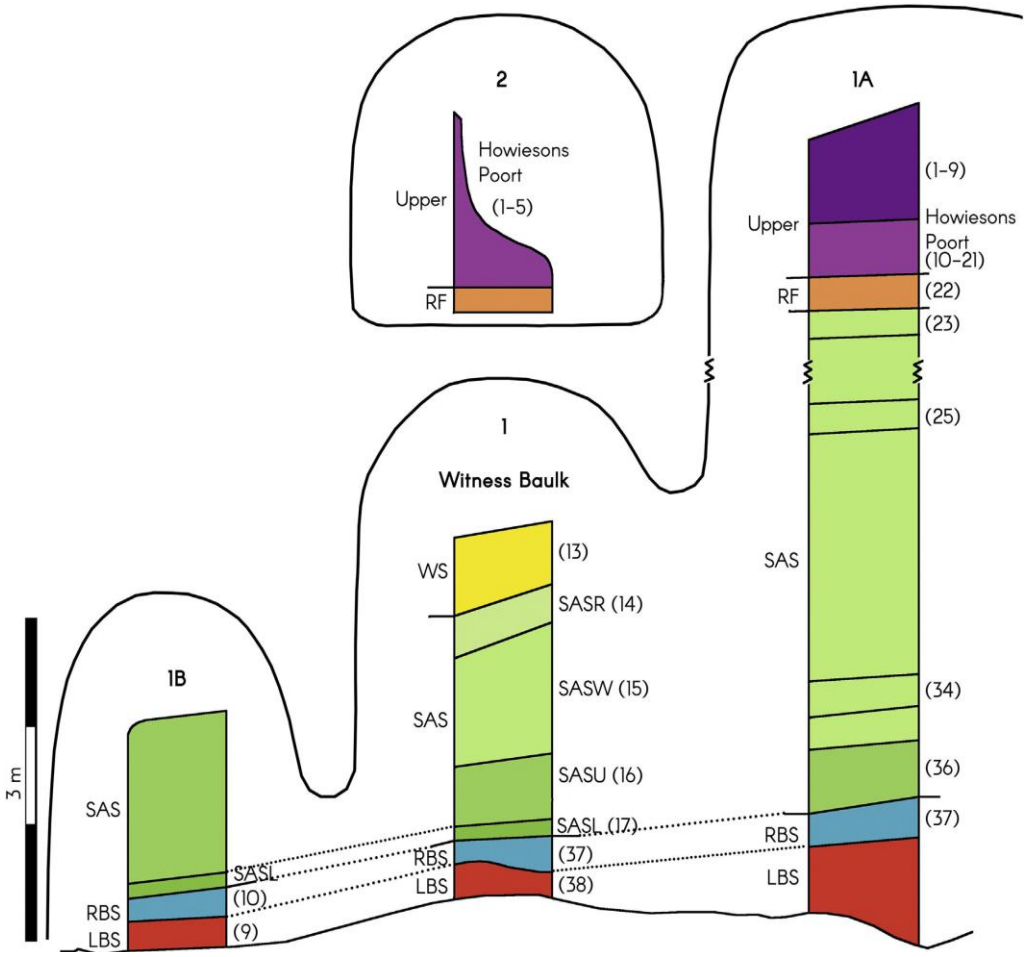


Figure 1.5: The stratigraphy of main site. The labels for each member are denoted on the left of the stratigraphy and the labelled on the right are the members and associated S-W layers shown in brackets (after Figure 4, Wurz *et al.* 2018).

There are five members (Figure 1.5) that occur at KRM, from oldest to youngest, Light Brown Sand (LBS), Rubble and Sand (RBS), Shell and Sand (SAS), White Sand (WS), Rockfall (RF) and the Upper (UPPER) (Deacon & Geleijnse 1988,

Figure 5; Brenner & Wurz 2019). The SAS member is comprised of sub members Shell and Sand Rubble (SASR), Shell and Sand Wedge (SASW), Shell and Sand Upper (SASU) and Shell and Sand Lower (SASL) (Figure 7, Deacon & Geleijnse 1988).

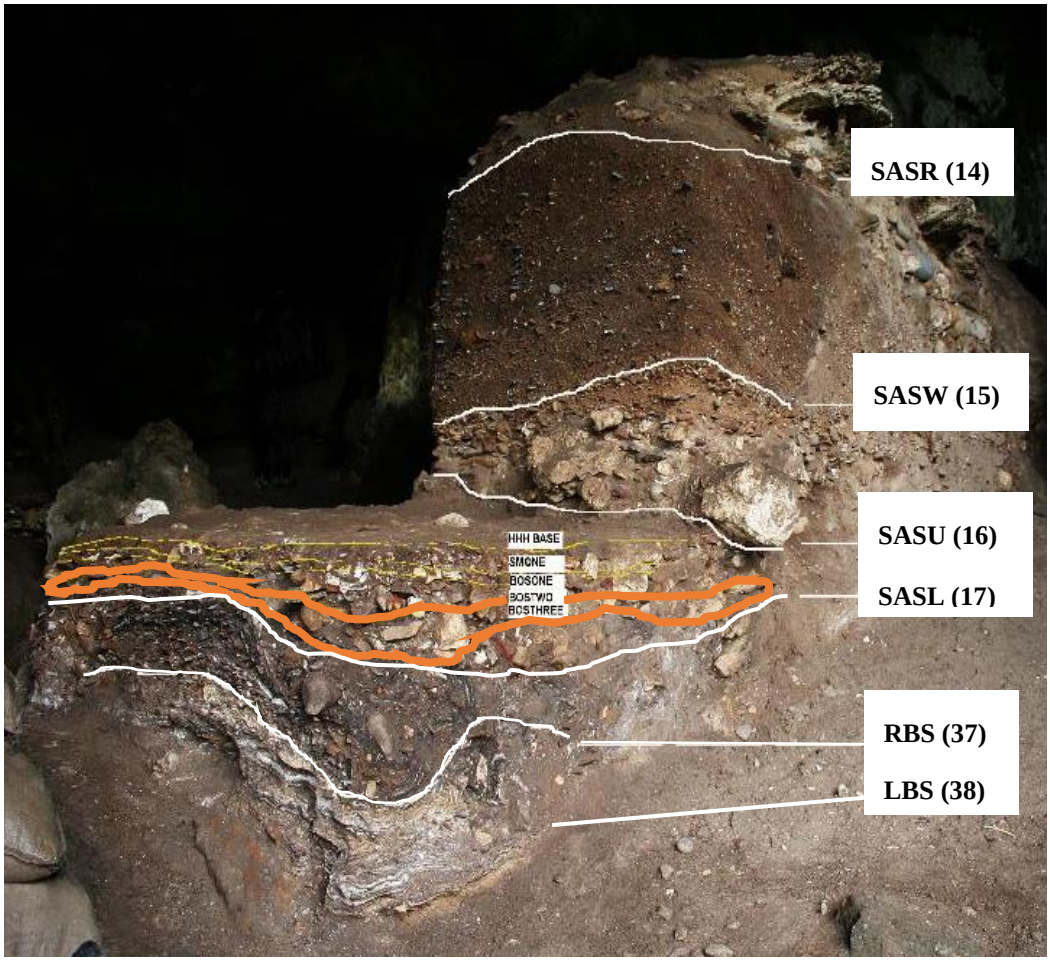


Figure 1.6: An image of the Witness Baulk with the members as labelled by Deacon & Geleijnse 1988) and the JW layers in parentheses (adapted from Wurz *et al*. 2018). The layers from the Wurz excavation are indicated in yellow and the BOS Three layer is highlighted in orange.

In Cave 1, the Witness Baulk is separated into four members, LBS, RBS, SAS and WS. The stratigraphic layers excavated by Wurz up to 2017 is shown in Figure 1.6. The layers highlighted in yellow have been excavated during previous SW excavations. The scope of this research focuses on the layer highlighted in orange. The area where Cave 1 and Cave 1A intersect is where squares AA43/Z44 where excavated by Deacon during the 1980s (Wurz *et al*. 2018). The Witness Baulk was once connected to squares AA43/Z44, the deposits joining these two separate

features was removed during the JW exvacations (Wurz *et al*. 2018).

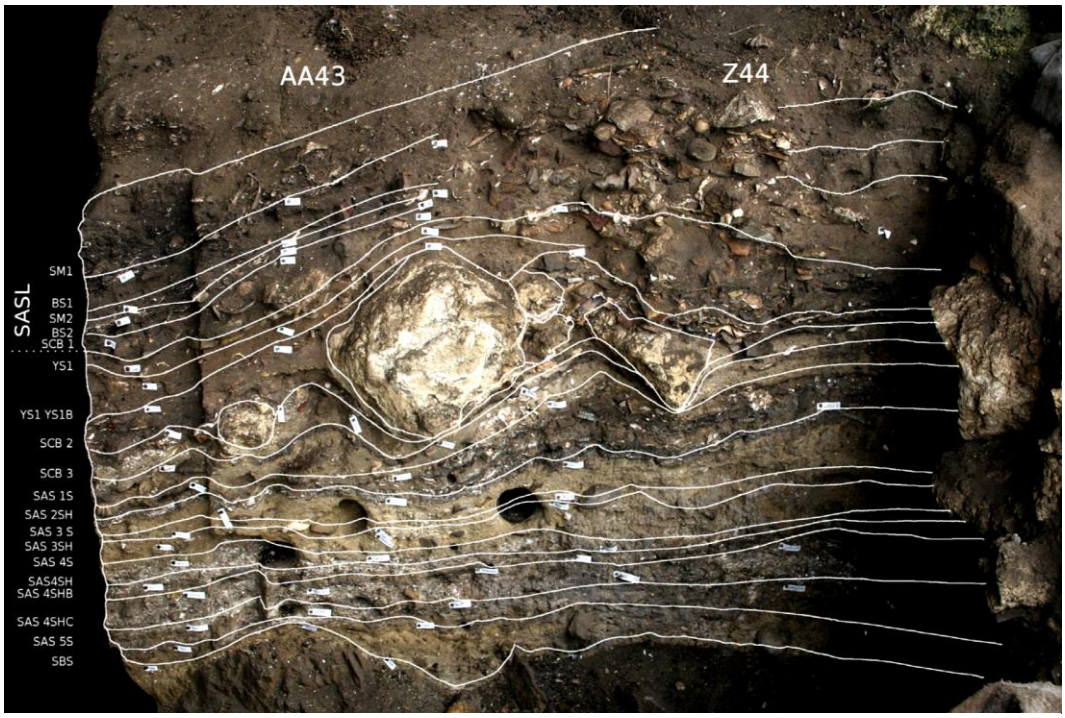


Figure 1.7: An image of squares AA43/Z44 located in Cave 1A. The stratigraphy of these two squares (layers in small font and member in large font on the left side of the image) links with the members and layers of the Witness Baulk in Cave 1 (after Figure 6, Wurz *et al.* 2018: 106).

The AA43/Z44 squares (Figure 1.7) are significant because they form part of the assemblage analysed by Avery (1987), Nel (2013) and Nel *et al.* (2018), which will be compared to the BOS Three assemblage.

Singer & Wymer (1982) identified five different lithic technocomplexes, MSA I, MSA II, the Howiesons Poort, MSA III and MSA IV. The technocomplexes that occurred during MIS 5 at KRM are MSA I (Klasies River) and MSA II (Mossel Bay) (Singer & Wymer 1982; Wurz 2002). The Klasies River technocomplex is characterised by curved and relatively thin symmetrically shaped blades and points with lengths longer than the end products of MSA II (Wurz 2002: 1005). The Mossel bay technocomplex is characterised by thick points with a prominent bulb of percussion and straight profiles on the lateral part of the product (Wurz 2002: 1008). The MSA I phase is grouped in the LBS member and the MSA II phase is grouped in the SAS member (Singer & Wymer 1982; Thackeray & Kelly 1988; Thackeray 1989). This study concerns the MSA II Lower cultural phase

(Wurz 2002).

1.4 Research Statement

Rodents, shrews, hares, bats and hedgehogs are collectively known as small mammals (Andrews 1990). Micromammals refer to rodents, bats, golden moles, shrews and some mole-rats, therefore in this context the terms ‘micromammals’ and ‘small mammals’ are not interchangeable. The study of micromammals remains from archaeological sites is a critical means of exploring palaeoenvironments, palaeoecology and site formation processes (Manthi 2008). In previous studies, micromammals have been used as Middle Stone Age environmental proxies at South African coastal and inland archaeological sites for example Avery (1987, 1988), Manthi (2008), Maringa (2017), Matthews (2004), Matthews *et al.* (2005, 2011), Nel (2013) and Nel *et al.* (2018).

Avery (1988) used a weight classification for her micromammal research, mammals smaller and equal to 150g, because they are more likely to be preyed on by owls. This research will focus on micromammals smaller than *Bathyergus suillus* (Cape Dune mole-rat) which ranges from 780g to 1000g in mass (Skinner & Chimimba 2005; Bennett *et al*. 2009). *B. suillus* is a large rodent however, due to their large mass it is included in large mammal fauna research by the following researchers Henshilwood (1997), Van Pletzen (2000) and Henshilwood *et al.* (2001). Micromammal research has the potential to provide high quality information that contributes to palaeoenvironmental proxy research, this can be done with innovative and integrated research methods and a significant sample size. This research proposes to deduce the palaeoenvironmental conditions at KRM during MIS 5d, explore predator-prey interactions and contribute knowledge with regards to the environmental context in which complex behaviour developed.

1.5 Research question

How was the micromammal assemblage from the BOS Three layer at Klasies River accumulated and which palaeoenvironmental conditions occurred during this period? In addition to the research question this study investigates three

hypotheses;

1. The assemblage was accumulated by the *Tyto alba* (Barn owl) and *Bubo Africanus* (Spotted eagle-owl).
2. The assemblage will not display evidence of human accumulation and consumption of micromammals during the stipulated time frame.
3. The environment was densely vegetated, grassy and warm with moderate moisture conditions.

1.6 Aims

1. To conduct a taphonomic analysis of the cranial and post-cranial specimens in the sample to understand the accumulation and site formation processes linked to this layer.
2. To undertake a taxonomic analysis of the cranial elements from the 2017 BOS Three assemblage.
3. To prove or disprove the hypotheses stated.
4. To infer the palaeoenvironmental conditions for the duration of the assemblage investigated at KRM.
5. To compare the inferred palaeoenvironmental conditions at KRM with that from contemporaneous coastal sites, the Pre-M3 and M3 phases from Blombos Cave (BBC) (Nel 2013) and the MIS 6 and MIS 5 layers from Pinnacle Point Cave 13B (PP13B) (Matthews *et al.* 2009).

1.7 Rationale

The southern Cape is an ideal geographical area to understand multifaceted climatic variability, modern human origins and the development of complex behaviour and the abundant fossil fauna remains because archaeological sites increased significantly during MIS 5 (Marean *et al.* 2014; Wadley 2015; Braun *et al.* 2018; Helm *et al.* 2018; Loftus *et al*. 2019). Archaeological sites along the southern Cape coast yield the longest record of modern human occupation in South Africa (Loftus *et al*. 2019). KRM is one of the southern Cape coastal sites that was intensively occupied by hunter-gatherer-fishers during the Middle Stone Age (Wurz *et al.* 2018). The occupants of the site left behind an abundant

accumulation of subsistence and cultural material remains (Wurz *et al.* 2018).

Micromammals provide higher resolution data than for example macromammals in terms of environmental research (Avery 1987; Manthi 2002; Matthews 2004; Matthews *et al.* 2005; Nel 2013). Micromammals have small habitat ranges compared to large fauna and can therefore provide more details of the environmental conditions at the site. They are also eminently suitable for palaeoenvironmental and palaeoecological reconstruction because of their characteristics such as constricted habitat ranges, large populations, diet, habitat preferences, specific predators (Avery 1987, 1988; Manthi 2002; Matthews 2004; Avery 2007; Reitz & Wing 2008; Matthews *et al*. 2011; Nel 2013). It should be noted that the micromammal assemblage is a representation of the micromammal community and they range of dispersal. Predators often hunt for prey several kilometers from their nest or roosting site (Fernández-Jalvo *et al.* 2016). This factor may be seen as a consequence because it is not a representation of the environment in the direct vicinity of the site. The hunting range of the owls provides insight on the different location from where micromammals can be found and the distribution of the habitats in which they prefer. Micromammal remains at KRM are well preserved and occur in large quantities (Avery 1988, Nel 2013). Three micromammal studies have been carried out at Klasies River main site the first by Avery (1987), second by Nel (2013) and third by Maringa (2017). The micromammal assemblages for the first two analyses originate from the Deacon 1984-1995 excavations (Avery 1987; Deacon & Geleijnse 1988; Wurz 2012a; Nel 2013). These micromammal assemblages were analysed using the lithic technocomplex phases to associate the assemblages with a time period (Avery 1987; Nel 2013; Nel *et al*. 2018). Analyses by Avery (1987) focused on micromammal assemblages from Cave 1A. Nel (2013) and Nel *et al*. (2018) focused their research on micromammal assemblages from Caves 1, 1A and 1B. The third analysis used material that originated from the BOS One layer which was recovered during the Wurz 2015 excavation season (Maringa 2017). The micromammal material investigated in this research originates from the Wurz 2017 excavation season of the BOS Three (Black Occupation Soil) layer square

C3. The new date for the BOS Three layer is 110ka obtained through radiometric uranium series dating (Brenner & Wurz 2019; Wurz *et al.* in prep). The finds are from clumped deposits in a clayey matrix. Small fauna remains were retrieved through a 2mm dry sieve of all excavated buckets followed by a 0.3mm wet sieve mesh (Wurz *et al*. 2018).

Palaeoenvironmental studies may use an ecological approach with the aid of taxonomic identification to better interprete the balance of the environment from which the faunal or floral remains were recovered. Taxonomy is the scientific study of biological nomenclature of living organisms (Kingdon 2013: 729). The study of the interrelationships between living organisms and the natural environment is known as ecology (Ricklefs 1976: 11). Avery (1987) used a taxonomic approach -identifying the taxa, their habits, habitats and diversity- to reconstruct the coastal ecology and environment for the MSA I phase through to the post Howiesons Poort phase from Cave 1A. Nel (2013) undertook a taxonomic and a taphonomic approach to reconstruct the palaeoecology and palaeoenvironment for the earlier period (dating to MIS 5b-e) for the material excavated from Caves 1, 1A and 1B. Both Avery and Nel's analyses grouped layers together to increase the assemblage size for palaeoenvironmental reconstruction (Avery 1987; Nel 2013). Interpretations made from grouped layers can potentially lead to ambiguous palaeoenvironmental inferences. Maringa (2017) conducted a taxonomic analysis of the BOS One layer micromammal assemblage, from the Witness Baulk in Cave 1, to infer the palaeoenvironmental conditions during MIS 5d at KRM.

The goal of this research is to construct a focused palaeoenvironmental reconstruction from a temporally restricted context. The context from which the micromammal sample originates is associated with rare modern human fossils (Grine *et al.* 2017; Wurz *et al.* 2018), and it is imperative to develop a refined understanding of the environment in which they lived at Klasies River. In this study I will focus on a sample from a 50 x 50cm square, C3, within the BOS Three layer (Figure 1.6), excavated in 2017 from the Witness Baulk in Cave 1.

The results of this research will contribute towards understanding the environmental setting where complex behaviour developed in anatomically modern humans at KRM during MIS 5 (McIntosh *et al.* 2015; Wurz 2016).

1.8 The framework of the dissertation

This dissertation is portioned into six chapters, where Chapter 1 is comprised of the introduction and site background. Chapter 2 is the literature review which provides more details on micromammal research at Klasies River main site and two other coastal sites, including palaeoenvironmental research. The methods applied for the analysis of the micromammal assemblage are discussed in Chapter 3. Chapter 4 presents the results of the analysis and Chapter 5 is a discussion and interpretation of the data presented in the results. The conclusion, limitations and future avenues of this project are presented in Chapter 6 followed by the last section of this dissertation, the Appendix.

Chapter 2: Literature Review

2.1 Introduction

The Middle Stone Age context of this research is briefly addressed in Section 2.2, followed by a description of the modern environment, sea-level and the coastal plain in the southern Cape (Section 2.3). The significance of environmental proxies for palaeoenvironmental reconstructions (Section 2.4) are mentioned relative to previous and on-going research. The use of micromammals as an environmental proxy to infer the palaeoenvironment from three sites in the southern Cape is highlighted in Section 2.5. This review chapter is then concluded with the history of taphonomy (Section 2.6) and the connection between micromammal and complex behaviour in anatomically modern humans (AMH) (Section 2.7) is explored. This review chapter concludes in Section 2.8, composed of a summary of the chapter.

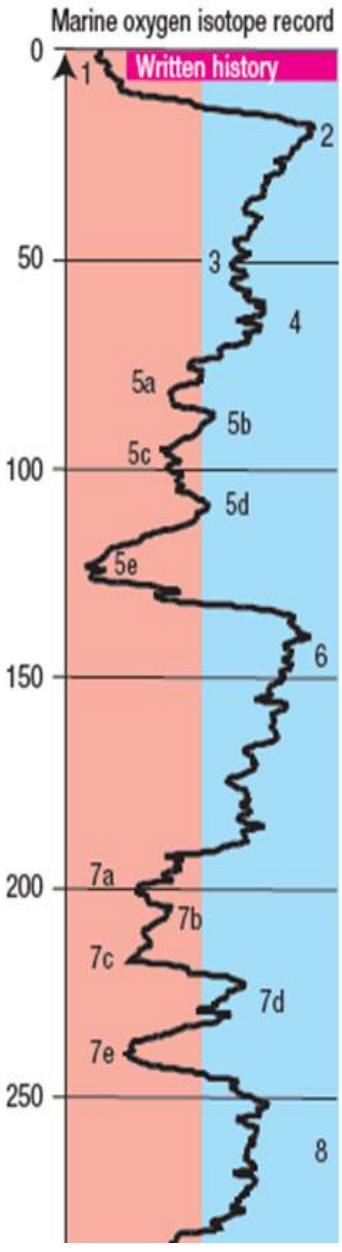
2.2 Middle Stone Age

The Middle Stone Age (MSA) is a term which refers to the description of lithic technology from Sub-Saharan Africa during the Middle and Late Pleistocene (Wurz 2018). The MSA was first introduced by Goodwin and Van Riet Lowe (1929) as a means of distinguishing between the Early Stone Age (ESA) and the Late Stone Age (LSA). Goodwin and Van Riet Lowe (1929) described the MSA assemblages as convergent flaking on prepared cores to manufacture retouched and unretouched pointed flakes with facteted platforms. Throughout the decades research on lithic technology and typology has advanced and the result of that shows variability, more notably, in MSA lithic assemblages (Wurz 2018). This emphasises that the definition for the MSA initiated by Goodwin and Van Riet Lowe is very specific (Wurz 2018).

The MSA, specifically 300-24ka, is separated into Marine Isotope Stages with the associated general temperature regime as shown in Table 2.1 (Table 2, Wadley 2015: 168). The MSA is well known for technological and cultural innovations such as composite weaponry (Wurz 2013; Wadley *et al.* 2015; Wurz 2018),

engraved ochre and ostrich eggshells (Henshilwood *et al.* 2002). These innovations first appeared in the archaeological record after 300ka when *Homo sapiens* are first documented (McBrearty & Brooks 2000; Bräuer 2008; Wadley 2015: 159). In South Africa the MSA has attracted a wide variety of research as it has been dedicated to understanding the palaeoenvironment, technological industry, cultural material and subsistence strategies concerning modern human origins.

Table 2.1: The approximated dates of the Marine Isotope stages from MIS 8-2 and the temperature regimes associated with each stage (adapted from Table 2, Wadley 2015: 168).



MIS Stage	Approximate start (ka)	Temperature regime
2	24	Cold
3	59	Cool with warm oscillations
4	73	Cool
5a	84	Warm
5b	93	Cool
5c	106	Warm
5d	115	Cool
5e	130	Warm
6	188	Cool with warm oscillations
7	241	Warm with cool oscillations
8	291	Cool

Figure 2.1: Marine Oxygen Isotope Stages and temperature fluctuations (after Compton 2016: 1).

The MSA, specifically the period coinciding with the MIS 5 (130-84ka) phase (Table 2, Wadley 2015: 168), is identified as the stage where sporadic and non-continuous episodes of behavioural complexity emerged and developed along coastal and inland sites in South Africa (Wurz 2013; Wadley 2015; Carr *et al.* 2016; Stewart & Jones 2016). Coastal sites are vital areas that harbour a rich variety of dependable and consistent resources, for example, an assortment of terrestrial and marine food sources, vegetation and habitats (Wurz 2012b). The southern Cape coast is a significant location for integrated scientific investigative research that focuses on climate mechanisms in the Southern hemisphere and human evolution (e.g. Bar-Matthews 2010; Braun *et al*.2018; Van Pletzen-Vos *et al*. 2019; Reynard & Wurz 2019). This chapter further provides the site environmental proxy research, taphonomy and palaeoenvironmental research at contemporaneous MIS 5 southern Cape sites. The link between complex behaviour and the environment that can be seen through various novel and established method is indicative for the development of complex behaviour at KRM during MIS 5d.

2.3 The modern environment, sea level and the Southern Coastal Plain

The geographical position of South Africa plays a significant role in the atmospheric and oceanic circulatory systems that influence the climatic conditions over the country (Chase & Meadows 2007; Braun *et al.* 2017). Most of the country is surrounded by two large water bodies, i.e. the Indian and Atlantic oceans, and the juncture of these oceans occurs on the southern coast (Bar-Matthews *et al.* 2010). The country is characterised as arid because of the low rainfall (less than 500mm annually) that is unequally spread over the broad landscape (King *et al.* 2011).

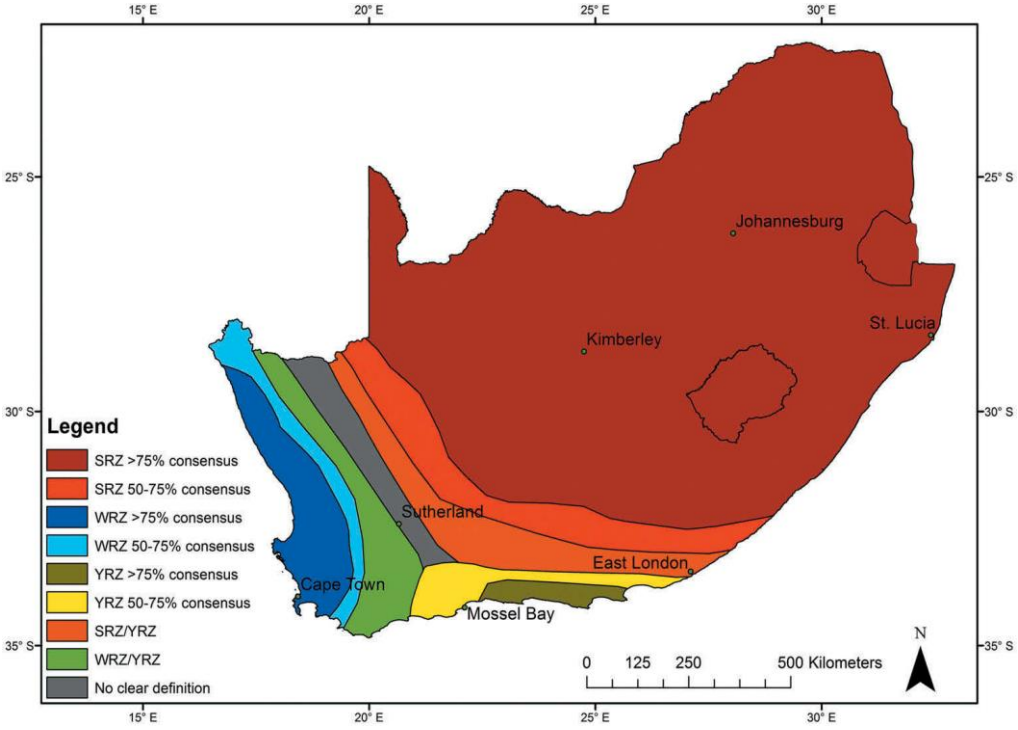


Figure 2.2: A map of South Africa indicating the three different rainfall zones. The eastern most portion indicated in the red and orange is the SRZ, the two shades of blue indicate the WRZ and the center most portion of the country highlighted in orange, yellow, green and grey encompass the YRZ. The variety of colours display the dispute and consensus between scholars on the seasonality and spatial boundaries of rainfall zones across the country (extracted from Figure 2, Roffe *et al.* 2019: 168).

The country can be divided into three seasonal rainfall zones characteristic of the times rain is expected during a certain period of the year (King *et al.* 2011), (Figure 2.2) Summer Rainfall Zone (SRZ), Winter Rainfall Zone (WRZ) and the Year-round Rainfall Zone (YRZ) (Tyson & Preston-Whyte 2000; Chase & Meadows 2007; Braun *et al.* 2017). Klasies River main site, Pinnacle Point and Blombos Cave are located within the Year-round Rainfall Zone (YRZ) (Bar-Matthews *et al*. 2010).

The Cape Floristic Region (CFR) is an area located in the southern parts of the country that hosts a variety of endemic fauna and flora (Cowling *et al.* 2003). The Greater Cape Floristic Region (GCFR) is a large region inclusive of the CFR comprised of the fynbos, sub-tropical thicket and succulent Karoo biomes (Bergh *et al.* 2014). The vegetation around main site and Caves 3, 4 and 5, as mentioned

in Chapter 1, are in the Broad Eastern Fynbos and Renosterveld bioregion within the CFR (Mucina & Rutherford 2006). The Fynbos biome is characterised as highly diverse and dominated by C3 vegetation (Braun *et al.* 2018). Significant sea level fluctuations during the Late Pleistocene caused the emergence and submergence of coastal plains, therefore affecting the distance of coastal sites from the seashore as shown in Table 2.2 (Van Andel 1989; Dor 2017). Lowering of the sea level along the southern coast would have exposed a continental shelf known as the Southern Coastal Plain (SCP) (interchangeably the Agulhas bank or the Palaeo-Aghulhas Plain) (Van Andel 1989; Fisher *et al.* 2010; Compton 2011; Helm *et al.* 2018). Exploitation of resources such as marine fauna, vegetation, terrestrial fauna by early humans would occur, especially during glacial maxima, because they would probably occupy the newly exposed land on the Southern Coastal Plain landscape. The fluctuating sea levels are demonstrated in Table 2.2 for the three southern Cape sites. The data captured for each site show that during MIS 5e-c the sites are not more than 3.5km away from the shoreline. Unfortunately, this land would be submerged during interglacial periods, thus concealing and possibly destroying archaeological material of the coastal inhabitants that is now unbeknownst to modern day communities and researchers (Compton 2011).

Table 2.2: The distance from each site (Blombos Cave M3 phase and Pinnacle Point Cave 13B) to the shore line according to the dates provided in Fisher *et al*. (2010) and Van Andel (1989) for Klasies River MSA I and MSA II phases. The MIS dates (Wadley 2015) are included in the table to provide the chronological context of the sea level fluctuations. There is no data for distances indicated with a dash (-).

<table>
<tr><th>MIS stage</th><th>Age (ka)</th><th colspan="3">BBC M3</th><th colspan="4">KRM MSA I and II</th><th colspan="2">PP13B</th></tr>
<tr><th></th><th></th><th>(Table 2, Fisher et al. 2010: 1395)</th><th>(Langejans et al. 2012: 90)</th><th>(Dor 2017: 44)</th><th>(Figure 10, Van Andel 1989: 144)</th><th>(Langejans et al. 2012: 92)</th><th>(Figure 2, Langejans et al. 2017: 65)</th><th>(Dor 2017: 44)</th><th>(Table 1, Fisher et al. 2010: 1393)</th><th>(Dor 2017: 44)</th></tr>
<tr><td rowspan="4">5c Warm</td><td>100</td><td>-</td><td>2.33km</td><td>-</td><td>-</td><td>-</td><td>3.4 km</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>101</td><td rowspan="2">2.3 km</td><td rowspan="11">-</td><td>1.0 km</td><td>0.1 km</td><td>2.3 km</td><td rowspan="7">-</td><td>1.3 km</td><td rowspan="2">0.5 km</td><td>0.9 km</td></tr>
<tr><td>102.5</td><td rowspan="3">-</td><td>-</td><td>-</td><td rowspan="4">-</td><td rowspan="5">-</td></tr>
<tr><td>105.5</td><td rowspan="8">-</td><td>2.8 km</td><td rowspan="3">-</td><td>1.7 km</td></tr>
<tr><td>106</td><td>3.0 km</td><td>-</td></tr>
<tr><td rowspan="3">5d Cool</td><td>107</td><td>3.2 km</td><td>1.7 km</td></tr>
<tr><td>110</td><td>2.3 km</td><td>-</td><td>3.2 km</td><td>2.9 km</td><td>2.2 km</td></tr>
<tr><td>114.5</td><td rowspan="5">-</td><td>0.2 km</td><td rowspan="2">2.0 km</td><td rowspan="5">-</td><td>0.5 km</td><td rowspan="5">-</td></tr>
<tr><td>115</td><td></td><td>3.0 km</td><td>-</td></tr>
<tr><td rowspan="4">5e Warm</td><td>116</td><td>0.1 km</td><td rowspan="4">-</td><td rowspan="4">-</td><td>0.5 km</td></tr>
<tr><td>120</td><td></td><td>-</td></tr>
<tr><td>121.4</td><td rowspan="2">0.0 km</td><td rowspan="2">0.1 km</td></tr>
<tr><td>123.9</td></tr>
</table>

2.4 Environmental proxies

Environmental proxies such as marine and terrestrial fauna, isotopes and botanical material are used to detect changes in the palaeoenvironment on different spatial scales. Inferring palaeoenvironments based on one proxy is not an ideal method as this can yield confusing, ambiguous or erroneous results and interpretations (Hall *et al.* 2014). This section will focus on the various environmental proxies that have been used to infer palaeoenvironmental conditions during MIS 5 in the southern Cape. The environmental changes that occurred during the Late Pleistocene (291-24ka) affected various parts of the world in terms of sea level, temperatures and vegetation (Compton 2016). Several environmental proxies have been used to reconstruct and analyse palaeoenvironments in the southern Cape during MIS 5 in order to decipher the environmental settings in which technological and cultural innovations took place.



Figure 2.3: The location of Klasies River Main site, Pinnacle Point caves and Blombos cave (Google Earth 2020a).

The focus will be on two southern Cape sites that are contemporaneous with the KRM assemblage analysed here, namely Blombos Cave and Pinnacle Point Cave 13B (Figure 2.3). The environmental proxies that will be discussed are oxygen isotopes, marine shellfish, diatoms, foraminifera, botanical remains, large and small terrestrial mammals. Three oxygen isotopes (O^{16}, O^{17} and O^{18}) are particularly useful proxies used to detect sea-level fluctuations and sea surface temperatures (Fisher *et al.* 2010). Two of these (O^{16} and O^{18}) are stable isotopes

with the former lighter than the latter (Fisher *et al.* 2010). During cooler periods the sea level lowers while the size of the ice sheets increases, which means that the ice sheets are mostly composed of O^{16} (lighter isotope) and the oceans mostly composed of O^{18} (heavier isotope) (Fisher *et al*. 2010). These changes in the isotope concentrations are connected to the global Marine Isotope Stages (Fisher *et al.* 2010). The most frequently used parameters to investigate climatic conditions is δO^{18} present in calcite in speleothems and in marine mollusc shells (Loftus *et al.* 2017). The quantity of δO^{18} found in speleothems indicates temperature and palaeoprecipitation within cave shelters (De Cisneros & Caballero 2013) and to record variations in rainfall (Braun *et al*. 2018). Speleothem samples were taken from two cave sites at Pinnacle Point, Staircase Cave and PP29, to record the rainfall changes at Pinnacle Point from 330 to 130ka and 112 to 43ka (Braun *et al*. 2018). The rainfall records for Staircase Cave during MIS 7/6 transition a relative quantity of convective rain which increases into the early stage of MIS 6 (Braun *et al*. 2018). The speleothem record for Staircase Cave ends during MIS 5e due to high sea level stands (Braun *et al*. 2018). The rainfall at PP29 was low with stratiform precipitation at the beginning of MIS 5 followed by intermediate rainfall throughout the remainder of MIS 5 (Braun *et al*. 2018).

The presence of δO^{18} in molluscan shells is ideal for sampling because the layers of growth on the shell can record the sea surface temperatures and sea-level fluctuations (Loftus *et al.* 2017). Marine molluscs are found in abundance at coastal archaeological sites and are brought in by foraging communities as a source of food, the remains of the molluscs are used for material culture purposes (symbolic accessories) or discarded into middens near the site (Langejans *et al*. 2012, 2017; Loftus *et al.* 2017). The opercula of the marine mollusc *Turbo sarmaticus* (South African turban snail) preserve well in deposits (Loftus *et al.* 2017). Samples analysed from the opercula are used to determine the palaeotemperature thus contributing to palaeoenvironmental research (Loftus *et al.* 2017). Loftus *et al.* (2017) for example analysed *T. sarmaticus* opercula from the MIS 1 and MIS 2 contexts from Nelson Bay Cave, Robberg Cave and

Byeneskranskop and the MIS 5, MIS5/4 transition from Klasies River main site and Pinnacle Point Caves 5-6 (Loftus *et al.* 2017). The minimum and maximum palaeotemperature results for KRM during MSA I (c. 115-120ka) was 12.0°C and 16.9°C, during MSA II Lower (c. 90-95ka) was 11.1°C and 16.0°C and lastly during MSA II Upper (c. 80-85ka) 10.3°C and 16.2°C (Table 2, Loftus *et al.* 2017: 78). Little change was observed with the Sea Surface Temperatures (SSTs) at KRM during the three phases which may indicate occupations during the MIS 5 interstadials (Loftus *et al*. 2017: 78). The minimum and maximum palaeotemperatures for the PP5-6 DBCS (62 ± 3 ka) could not be calculated because the only operculum was not available (Loftus *et al*. 2017: 78). The results for the other PP5-6 contexts are as follows (min and max), OBS1 (69 ± 3 ka) 9.9°C and 16.2°C, SADBS (71 ± 3 ka) 11.5°C and 16.9°C, ALBS (72 ±3 ka)12.3°C and 15.7°C, LBSR (81 ± 4 ka) 13.5°C and 18.1°C (Table 2 in Loftus *et al*. 2017: 78). The SSTs at PP5-6 declined by 2.7°C from the oldest to the youngest contexts during the MIS 5/4 transition (Loftus *et al*. 2017:78).

Isotopic analysis can also be undertaken on diatoms and foraminifera. Diatoms are single-celled algae with a siliceous frustule, they are used for sea level fluctuations reconstructions because they preserve well in marine and lake sedimentary environments (Anderson & Vos 1992; Mackay *et al.* 2003). Diatoms are found in marine, coastal and continental aquatic systems of which they occur in three main categories of life forms such as planktonic; benthic and epiphytic (Mackay *et al*. 2003). Planktonic diatoms may be used for palaeoenvironmental reconstructions however they are not always suitable because they are introduced into coastal ecosystems through tidal action (Anderson & Vos 1992). There has yet to be palaeoenvironmental research at KRM using diatoms. Marine organisms with unicellular skeletal shells, composed of calcium carbonate mineral structures, are called foraminifera (Scott & Medioli 1986; Mortyn & Martínez-Botí 2007). These organisms are sensitive to changes in their marine environment; therefore, fossil foraminiferal assemblages are ideal for proxy investigations due to factors that affect their sensitivity and habitat preferences (Scott & Medioli 1986). Foraminifera are useful for isotopic analyses because their shells reflect isotopic

values (Franco-Fraguas *et al*. 2011). This method of analysis enables palaeoenvironmental reconstructions of landscapes and sea levels (Strachan *et al.* 2014) as they are sensitive to factors such as temperature, salinity, dissolved oxygen and elevation above mean sea level (Scott & Medioli 1986; Mortyn & Martínez-Botí 2007).

Planktonic foraminifera are found in deep-sea sediments and they are generally used to monitor ocean surface temperatures because of their temperature sensitivity (Mortyn & Martínez-Botí 2007). Currently there is an ongoing palaeoenvironmental investigation using foraminifera and ostracods found at KRM for the MIS 5c-d layers (Faul *et al.* 2019). Preliminary results of the research by Faul *et al*. (2019) show one genus of benthic foraminifera (*Elphidium*) and two genera of ostracods (*Sarscypridopsis* and *Limnocythere*). The *Elphidium* foraminifera genus is found in estuarine systems (Strachan 2016), and the ostracod genus *Sarscypridopsis* occurs in permanent and temporary water systems (Martens *et al.* 1996). The *Limnocythere* ostracod genus can be found in fresh water and also in water systems with high salinity and alkalinity (Martens *et al.* 1996). The preliminary results show the presence of estuarine systems and other water systems at KRM during MIS 5c-d, however more research is required to confirm this interpretation.

Botanical remains that survive in the archaeological record are significant palaeoenvironmental indicators. Floral remains that can be analysed and used as environmental proxies are seeds, (fossilised and carbonised), charcoal, pollen and leaves (Hall *et al.* 2014). The preservation of botanical remains in the archaeological record is not always favourable, due to the inadequacy of suitable preservation conditions (Carr *et al.* 2016). This often limits the quantity and quality of palaeoenvironmental research using botanical remains. At KRM, for example, it was shown that even though charcoal from the MIS 5c-d layers (SMONE, BOS Three and SBLS) was recovered, it did not preserved well (Magubane 2019; Magubane *et al.* 2019). Despite the poor preservation a number of species such as *Grewia occidentalis* (Crossberry tree), *Nuxia florisbunda* (Forest elder), *Dovyalis caffra* (Kei-apple) and *Tarchonanthus littoralis* (Coastal

camphor bush) were identified during a preliminary study (Magubane 2019). Although these four species may co-exist, they indicate a mixture of vegetation types at KRM with an increase in moisture and warm conditions during MIS 5c-d (Magubane 2019).

Other than botanical remains, fauna can also be used as an environmental proxy. Faunal remains have a highly significant role in the reconstruction of palaeoenvironments because they are mostly well preserved in archaeological sites and they provide indications of the type of landscape and vegetation that may have existed once before (e.g. Avery 1987; Reitz & Wing 2008; Cuenca-Bescós *et al.* 2009; Matthews *et al.* 2011; Faith *et al.* 2016; Van Pletzen-Vos *et al.* 2019). Terrestrial fauna are separated into three groups, large mammals (large fauna), small mammals (small fauna) and micromammals (microfauna). Macromammals are mammals that have a weight greater and equal to 5kg during adulthood, while smallmammals are fauna that weigh less than 5kg during adulthood (Andrews 1990). In this context micromammals are defined as mammals that weigh less than 780g during adulthood, which is the minimum weight of *B. suillus* during adulthood (Skinner & Chimimba 2005; Bennett *et al*. 2009). The large fauna assemblage from Pinnacle Point Cave 13B aggregates indicates an open environment with moist conditions and open grasslands during 134-94ka (Rector & Reed 2010: 354). Klein (1976) analysed the large mammal fauna remains at KRM from the Wymer excavation. The large fauna assemblages for the MSA I phase in Cave 1 investigated by Klein (1976: 78), Van Pletzen (2000) and Van Pletzen-Vos *et al*. (2019) identified the higher appearance of grazers (*Raphicerus* and *Tragelaphus*) than browsers in the layer 37 (directly above 38 and 39) indicating an open environment. The transition from the MSA I phase to the MSA II phase shows a decrease in open environments to an increase in closed vegetation based on the decline of grazers (Klein 1976: 78; Van Pletzen-Vos *et al*. 2019). The large mammal taxa from the MSA II phase suggest closed environments (Wurz *et al.* 2018). At Blombos Cave the large fauna indicates moist conditions based on the presence of hedgehogs and open grassy vegetation due to the presence of grazers during the M3 phase (Henshilwood *et al.* 2001:

438; Badenhorst *et al*. 2016: 50).

Micromammals have been used as proxies to reconstruct the palaeoecology and palaeoenvironment from a South African archaeological context (Avery 1987; Andrews 1990, Fernández-Jalvo 1995, 1996; Manthi 2002; Matthews 2004; Avery 2007; Matthews *et al.* 2011; Nel 2013; Nel *et al.* 2018). In previous studies micromammals have been used to infer palaeotemperatures at Klasies River main site (KRM), Border Cave (BC) and other Southern African archaeological sites (Thackeray 1987; Thackeray & Avery 1990). Thackeray (1987) undertook an analysis of 124 micromammal assemblages from nine southern African Late Pleistocene and Holocene sites, to infer temperature changes. The nine assemblages were composed of 16 taxa (Table 2, Thackeray 1987: 288). The modern ecology, distribution and climatic data associated with the 16 taxa were used to infer the palaeotemperatures. Multivariate and Factor Analysis statistical analyses were used (Thackeray 1987: 289). The KRM micromammal assemblages were recovered from the Cave 1A MSA II phase and the Howiesons Poort (HP) (Thackeray 1987). The temperatures inferred for the KRM1A assemblages are 15.5°C for MSA II and 14.3°C for the HP (Table 4, Thackeray 1987: 297). The estimated temperatures show that MSA II was relatively warmer than the HP (Thackeray 1987). Thackeray's 1987 study was extended to infer the palaeotemperatures for 37 samples from KRM (MSA I, MSA II, HP and MSA III) and 11 samples from BC (Early MSA, Howiesons Poort and Late MSA) (Thackeray & Avery 1990: 312). The average palaeotemperatures for the KRM assemblages is 14°C and the BC assemblages is 17.8°C, this shows that KRM was relatively cooler than BC. More specifically the estimated mean palaeotemperature for MSA II is 14.5°C (Table 1, Thackeray & Avery 1990: 314).

Recent research conducted by Faith *et al.* (2019) has shown that micromammals can be used as proxies for seasonality and moisture availability in terms of climate record research. This research was undertaken from three southern Cape sites and their respective time ranges being investigated are Byeneskranskop 1 (BNK1) (~65ka to 12ka), Boomplaas (BPA) (Last Glacial Maximum (LGM) to the earliest

Holocene) and Nelson Bay Cave (NBC) (LGM) (Faith *et al*. 2019). Data was extracted from 123 modern and fossil micromammal assemblages using a global climate database (WorldClim) and a Global Aridity Index database (Faith *et al*. 2019). The results for the three archaeological sites are as follows, pronounced winter rainfall in BNK1 with a slight influence of a summer rainfall trend more or less similar to the modern summer rainfall pattern (Faith *et al*. 2019: 854). The winter rainfall is intensified for NBC during the LGM (Faith *et al*. 2019: 853). Arid conditions dominate the LGM and early Holocene based on the higher occurrence of summer rainfall results for BPA (Faith *et al*. 2019: 853). These three southern cape sites investigated by Faith *et al*. (2019) are not the same as the three sites investigated in this research, however their research provides significantly valuable information regarding the rainfall seasonality and moisture availability in the southern Cape during the specified time frame.

The preservation of micromammals is usually much better than the preservation of large fauna remains because large fauna have a higher chance of being hunted and consumed by humans (Deacon 1995). Whereas, micromammals are less likely to be consumed by humans, but further investigation is required to confirm this. An example of micromammals as indicators of specific environments are *Otomys irroratus* that favour closed environments with dense vegetation and wet conditions (De Graaf 1981), and *Micaelamys namaquensis* (formerly known as *Aethomys namaquensis*) that prefers dry and semi-arid conditions with an open environment and more sandy substrates than vegetation (Kesner *et al.* 2013). However, both species are found in MSA sites within the southern Cape and may co-exist with each other in different microhabitats, as will be discussed further in the palaeoenvironmental reconstruction in section 2.5 below.

Apart from their usefulness as palaeoenvironmental indicators, the taphonomy of micromammals can also be used to infer the post-depositional processes that acted on assemblages (Avery 1987; Andrews 1990; Fernández-Jalvo 1995). The modifications on the bones are also indicators of the agents that accumulated the micromammals (Andrews 1990, 1995; Manthi 2002; Matthews 2004; Manthi 2008). For example, micromammals are accumulated by non-human mammalian

carnivores (Avery 2007; Nel 2013), floods and through natural death (Nel 2013). In archaeological contexts, micromammal species are predominantly recovered in predatory animal pellets, for example *Tyto alba* (barn owl) and *Bubo Africanus* (Spotted eagle-owl), which have also been identified as micromammal accumulators at KRM by Avery (1987), Nel (2013) and Nel *et al.* (2018). These two owl species are commonly identified as the accumulators of micromammal assemblages because the processes of digestion and breakage minimally alter the bones (Andrews 1990), hence their good preservation. This links to the first hypothesis, stated in chapter 1, where *Tyto alba* and *Bubo Africanus* are the prospective accumulators of the BOS Three micromammal assemblage. Although these two owl species have a history of being the accumulators of micromammal assemblages at KRM, there is a bias associated with the predator and prey interactions.

A limited amount of research is dedicated to the different predators and accumulators of micromammal assemblages in the archaeological record (Avery 2002), especially in a South African context. Andrews (1990) provided a brief explanation on the different levels of breakage and digestion associated with birds of prey and small mammalian carnivores, but human and reptilian predators are not included. It is understandable that human and reptilian predators may consume and leave minimal evidence of micromammal remains due to breakage and digestion. Moreover, the remains expelled from either of the predators' system may not survive in the archaeological record because of its diminished state. Therefore, the promotion of taphonomic actualistic studies dedicated to investigating predator bias and unfamiliar modifications found on specimens caused by predator groups other than predatory birds and small mammalian carnivores would produce insightful knowledge. The integration of taphonomic analysis, coupled with taxonomic analysis enables perceptive interpretations, therein strengthening inferences and reconstructions of the palaeoecology and palaeoenvironment.

2.5 Palaeoenvironmental reconstruction of southern Cape coastal sites using micromammals

Micromammal remains are incorporated into the human social and ecological archaeological record because they are accumulated by predators that nest or reside nearby the archaeological sites (Andrews 1990; Reitz & Wing 2008). Micromammal assemblages have been investigated to reconstruct palaeoenvironmental conditions in MIS 5 southern Cape sites such as Pinnacle Point Cave 13B (PP13B), Blombos Cave (BBC) and KRM (Avery 1987, 1988; Thompson 2010; Matthews *et al.* 2011; Nel 2013; Nel & Henshilwood 2016; Nel *et al.* 2018). For each of these palaeoenvironmental reconstructions, either a taxonomic or a combination of taxonomic and taphonomic analyses were conducted on cranial and post-cranial elements (Avery 1987, 1988; Matthews *et al.* 2011; Nel 2013). In the discussion for each site, the taphonomy is discussed first, followed by the results from the taxonomic identification and ecological analyses, the accumulator and the palaeoenvironmental conditions.

a) Pinnacle Point Cave

Preliminary results of a taxonomic and a taphonomic analyses for the Pinnacle Point Cave 13B (PP13B) micromammal assemblage was undertaken by Matthews *et al*. (2009). The micromammal assemblages were recovered from stratigraphic layers from three areas in the cave (Matthews *et al*. 2009). The three areas are as follows; the Lightly Cemented Middle Stone Age (LC-MSA) dates to 153-174ka in MIS 6, the Eastern area the Western area both have stratigraphic facies with varying dates (Matthews *et al*. 2009). The Eastern area facies are Roof Spall Upper and Shelly Brown Sand (110-91ka) and the Roof Spall Lower (116-107ka) (Table C3, Matthews *et al*. 2019: 22-23). The Western area facies are Light brown (LB) Sand 2 (121-91ka), Dark brown (DB) Sand 3 (121-91ka) and Light Brown Grey Sand 1 (LBG1) (121-91ka) (Table C3, Matthews *et al*. 2019: 22-23). The taphonomic analysis for PP13B was employed to identify the accumulator and the palaeoenvironmental implications (Matthews *et al*. 2019). The intensity of digestion on the incisors was the main focus of the study therefore, other taphonomic modifications were not included in this study (Matthews *et al*. 2019).

The incisor digestion from all three areas ranged from light to moderate digestion (Matthews *et al*. 2009). Therefore, the predators associated with the accumulation of the micromammal assemblages were most likely *Tyto alba* (Barn owl) and *Bubo africanus* (Spotted eagle-owl) (Matthews *et al*. 2009).

The assemblage for the LC-MSA was dominated by *Otomys irroratus* (Southern African vlei rat), *Otomys saundersiae* (Saunders vlei rat) and *Myosorex varius* (Forest shrew) (Figure 3, Matthews *et al*. 2009: 115). The most frequent taxa in the Eastern area assemblage are *Otomys saundersiae* (Saunders vlei rat), by *Otomys irroratus* (Southern African vlei rat) and *Suncus varilla* (Lesser dwarf shrew) (Figure 4, Matthews *et al*. 2009: 115). The most prevalent taxa in the Western area units are *Otomys irroratus* (Southern African vlei rat), *Otomys saundersiae* (Saunders vlei rat) and *Rhabdomys pumilio* (Four-striped grass rat) (Figure 5, Matthews *et al*. 2009: 116). Palaeoenvironmental inferences were extrapolated for the Eastern and Western areas but not for the LC-MSA because the micromammal assemblage was not large enough (Matthews *et al*. 2009). The high occurrence of *O. saundersiae* in the LC-MSA deposits indicate dry conditions, and the strong presence of *O.* irroratus in the Western and Eastern area indicates moist conditions (Matthews *et al*. 2009). These two species may co-exist in the same areas, however they may occupy different microhabitats which may result in variable changes in the environment and rainfall (Matthews *et al*. 2009). The taxa present in the Western area are more indicative of open vegetation than in the Eastern area which favour closed vegetation (Matthews *et al*. 2009). The Shannon-Wiener index displayed a higher heterogeneity for the Western area, when compared to the low index values for the Eastern area and the LC-MSA showing low heterogeneity (Matthews *et al*. 2009). The Western and Eastern area facies micromammal assemblages are from a similar time frame as the KRM MSA I assemblage and will be compared to the 2017 BOS Three assemblage.

b) Blombos Cave

The micromammal assemblage from BBC Pre-M3 layer MIS 5d (118 140ka – 97 550ka) (Table 2, Jacobs *et al.* 2019: 8). The pre-M3 layer from BBC will be compared with the BOS Three 2017 assemblage from KRM as they are from

broadly similar periods. Nel (2013) undertook a taphonomic analysis on both cranial and post-cranial elements and a taxonomic analysis on the cranial elements from BBC and KRM. The taphonomic analysis consisted of recording the following modifications; digestion (gastric etching), breakage, post-depositional modifications and the Skeletal Element Abundance (SEA) (Nel 2013). The assemblage was dominated by light digestion on the isolated and *in situ* incisors, humeri and femurs (Nel 2013). A relatively high level of limb bone fragmentation was recorded for the M3 phase (Nel 2013). In terms of post-depositional modifications etching (not related to digestion or root etching) did not occur frequently, but pitting, not related to digestion or corrosion, was abundant (Nel 2013). The most recurring skeletal elements for this phase were incisors, humeri and tibiae. Their preservation was attributed to their robustness (Nel 2013). The level of fragmentation could have indicated a mammalian carnivore (e.g. genet) as the predator, however the degree of digestion is light indicating an avian predator (Andrews 1990). *Tyto alba* (African barn owl) was identified as the most likely accumulator of the micromammal assemblage (Nel 2013).

The taxonomic analysis consisted of identifying the dominant species and their habitat preferences according to diversity indices (Shannon-Wiener and Simpson's diversity indices). The most abundant species in the M3 phase were *Myosorex varius* (Forest shrew), *Rhabdomys pumilio* (Four-striped grass rat) and *Otomys irroratus* (Southern African vlei rat) (Nel 2013: 149). *Rhabdomys pumilio* and *Otomys irroratus* share a preference of dense vegetation and moist conditions while *Myosorex varius* has a wide habitat tolerance (Nel 2013: 208). The high frequency of *Suncus varilla* (Lesser dwarf shrew) and *Myosorex varius* indicates high precipitation and temperatures during the summer months as this is when these soricids breed (Nel 2013: 212). The environmental conditions associated with the soricid breeding season is only valid if it can be demonstrated that high numbers of young animals occur in the samples (Avery, pers comm. 2020), however this information was omitted. The MIS 5e-d (CR-CQ layers in the Pre-M3 phase) palaeoenvironmental conditions were inferred as arid and warm with seasonal precipitation, while the MIS 5c (CPA-CH in the M3 phase)

palaeoenvironment experienced a decrease in warm conditions towards the end of this period (Nel 2013: 212-215). The palaeoenvironmental conditions for MIS 5c, higher in the M3 sequence, were not consistent as they vary from warm with seasonal rain to colder conditions towards the end of this period as indicated by the increase in vlei rats and the decrease in shrews (Nel 2013: 213).

c) Klasies River main site

A palaeoenvironmental reconstruction based on a taxonomic analysis of the Cave 1A micromammal assemblage was undertaken by Avery (1987). Only the lowermost unit analysed by her (sample number 41) from AA43 is relevant to this study. The ecological research conducted by Avery (1987) did not record the most abundant taxa for each individual sample, but the most frequently occurring species from the KRM 1A assemblage as a whole were *Otomys irroratus* (Southern African vlei rat), *Otomys laminatus* (Laminate vlei rat), *Otomys saundersiae* (Saunders vlei rat), *Chlorotalpa duthiae* (Duthie's golden mole), *Crocidura cyanea* (Reddish-grey musk shrew), *Myosorex varius* (Forest shrew), *Rhabdomys pumilio* (Four-striped grass rat) and *Georychus capensis* (Cape mole-rat) (Avery 1987). These species represent a variety of vegetation densities, vegetation and substrate types and climatic conditions (Avery 1987). *Otomys irroratus* (which does not reach below 15% in any sample) is particularly abundant throughout the sequence. Denser vegetation was inferred for the beginning of the KRM 1A sequence, representing MSA II, because of the high occurrence of *Otomys irroratus* in sample 41 (Avery 1987: 414). The predator was identified as *Tyto alba* (African barn owl) based on the abundance of its preferred prey *Rhabdomys pumilio* (Avery 1987) and *Otomyinae* (Matthews *et al*. 2011).

A taxonomic analysis was conducted on the cranial assemblage originating from the C2 square in the BOS One layer (~110ka) located in Cave 1 (Maringa 2017). The purpose of the study was to undertake an ecological approach to infer the palaeoenvironmental conditions at Klasies River main site during MIS 5d (Maringa 2017). The most abundant taxa for the BOS One assemblage are *Otomys irroratus/Otomys saundersiae* (Southern African vlei rat/Saunders vlei rat),

Crocidura cyanea (Reddish-grey musk shrew) and *Crocidura flavescens* (Greater red musk shrew) (Maringa 2017). These taxa reflect a broad range of habitat preferences with mosaic features, dense vegetation and moist conditions (Maringa 2017).

Nel (2013) and Nel *et al*. (2018) subsequently undertook a taphonomic and taxonomic analysis of the layers pre-dating those analysed by Avery, encompassing MSA I (MIS 5e/d) and MSA II Lower (MIS 5c/b). Nel (2013) analysed these phases which originated from the Light Brown Sand (LBS) and Shell and Sand (SAS) members from Cave 1, 1A and 1B (Deacon & Geleijnse 1988). Her taphonomic and ecological analyses are discussed in the same manner as the Blombos assemblage above. Most of the MSA I assemblage demonstrated moderate digestion on the incisors, humeri and femora, but the MSA II Lower, broadly contemporaneous to the sample analysed here, had light digestion, only visible on the incisors (Nel 2013). Breakage of the elements from the MSA I assemblage was recorded as extensive, whereas the MSA II Lower had moderate breakage (Nel 2013; Nel *et al.* 2018). The most frequent post-depositional modification for the MSA I phase was etching (not gastric or root), while low frequencies of modifications like rounded breaks, burning, desquamation, weathering, pitting, black traces, cracking and flaking occurred in both assemblages (Nel 2013; Nel *et al.* 2018).

In terms of the SEA for the MSA I assemblage high frequencies for tibiae, femurs, mandibles, maxillae, incisors and humeri occurred (Nel 2013). The SEA for MSA II Lower also reflected high percentages for humeri, femurs, tibiae and incisors but, differently from MSA I, a low percentage for maxillae and mandibles (Nel *et al.* 2018). The taphonomic modifications were used to determine the most likely accumulator of the micromammal assemblage (Nel 2013; Nel *et al.* 2018). The extent of breakage on the robust elements and the presence of fragile elements exclude mammalian carnivores as the predators because of the destruction of the bones during mastication (Andrews 1990; Nel 2013; Nel *et al.* 2018). It was deduced that *Tyto alba* (African barn owl) and *Bubo africanus* (Spotted eagle-owl) were the most likely accumulators of the Klasies River MSA I and MSA II

Lower micromammal assemblage (Nel 2013; Nel *et al.* 2018).

For the ecological analysis, diversity indices (Shannon-Wiener and Simpson's diversity indices) were used to suggest environmental conditions. The most frequently occurring taxa for MSA I phase were *Myosorex varius* (Forest shrew), *Crocidura flavescens* (Greater red musk shrew) and *Rhabdomys pumilio* (Four-striped grass rat) (Nel 2013; Nel *et al.* 2018). *Myosorex* has a wide habitat tolerance, but the greater red musk shrew and four-striped grass rat prefer both open and closed vegetation, with high moisture availability (Nel 2013; Nel *et al.* 2018). *Crocidura flavescens* and *Rhabdomys pumilio* also occur in MSA II Lower, with the addition of *Otomys irroratus* (Southern African vlei rat) and *Otomys laminatus* (Laminate vlei rat) (Nel 2013; Nel *et al.* 2018). The high prevalence of the greater red musk shrew and the four-striped grass mouse indicate that some habitats in MSA II Lower were similar to those occurring in MSA I. However, the presence of the southern African vlei rat and the laminate mouse shows that conditions were more dense and wet (Nel 2013; Nel *et al.* 2018) in MSA II Lower.

The Shannon-Wiener and Simpson's diversity indices for the MSA I demonstrated higher species heterogeneity than MSA II Lower (Nel 2013; Nel *et al.* 2018). The THI_{tvod}(Taxonomic Habitat Index for topography, vegetation, openness and dryness) suggests that the MSA I phase was moist with relatively dense vegetation (Nel 2013: 332), with more seasonal rainfall while more dense vegetation and less seasonal precipitation occurred during MSA II Lower (Nel *et al.* 2018). This inference is supported by the abundance of *Rhabdomys pumilio*, soricids and vlei rats (Nel 2013: 338) for the MSA II Lower as discussed above. The results of the 2017 BOS Three assemblage will be compared to the equivalent layers from other parts of main site (Cave 1A and 1B) from Nel (2013) and Nel *et al.* (2018). A similar palaeoenvironmental inference as concluded for the MSA I and MSA II Lower phases is hypothesised for the BOS Three micromammal assemblage. This is because similar taxa identified from previous micromammal research at KRM are expected to be identified. While a small possibility of unfamiliar taxa, i.e. taxa that have not been identified at KRM, being present in

this assemblage.

2.6 Taphonomy

Taphonomy is defined as the process where faunal remains transition from the biosphere to the lithosphere (Efremov 1940). The term taphonomy was coined by I.A Efremov, it is derived from the Greek word *taphos* (burial) and *nomos* (laws) (Efremov 1940). The study of taphonomy is used to identify the nature of the changes that acted on the animal remains after death as they were accumulated (Efremov 1940: 85). The processes and agents that acted on the bone can be detected through systematically recording and describing the modifications (Gifford 1981; Reitz & Wing 2008). The study of taphonomy is useful in disciplines such as Archaeology and Palaeontology, where transformations of faunal remains provide insight on prehistoric and present-day processes (Gifford 1981; Reitz & Wing 2008). For example, taphonomy is useful for zooarchaeological, archaeobotanical and palaeoecological research because the alterations on the faunal or floral remains are indicators associated with early human or hominid subsistence patterns and interactions between animals, plants and the environment (Gifford 1981; Lyman 1994b).

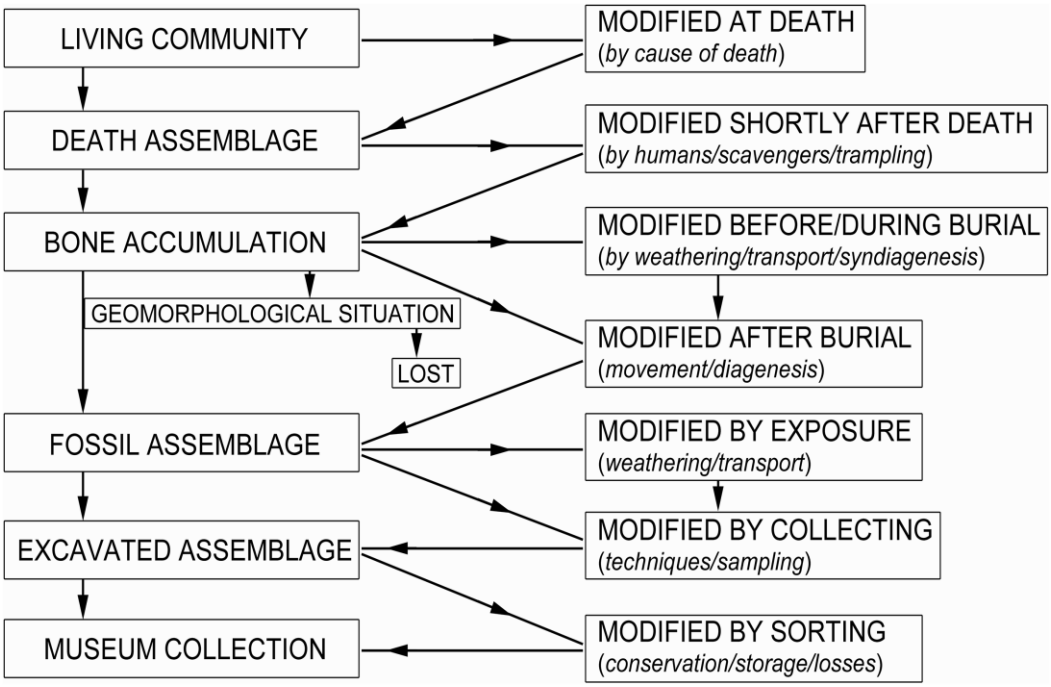


Figure 2.4: The chronological stages of assemblage formation and the agents and processes that act on the different components (after Figure 1.1, Fernández-Jalvo & Andrews 2016: 2). The first four stages (on the left) demonstrate the formation of the fossil assemblage and the last two stages refer to the different changes that occur from the recovery to storage of the assemblage (after Figure 1.1, Fernández-Jalvo & Andrews 2016: 2). The information on the right refers to the agents and processes that occur during the relevant stages as indicated by the arrows (after Figure 1.1, Fernández-Jalvo & Andrews 2016: 2).

The sequence of taphonomic modifications (Figure 2.4) expands our knowledge of past events that occurred, thus improving interpretations of accumulation and palaeoecology (Fernández-Jalvo & Andrews 2016). Although, taphonomy is aimed at identifying modifications on components as a result of agents and processes there are some constraints that may affect interpretations. For example, the superimposition of modifications like manganese staining and burning (blackened bones) produce similar types of discolouration, brown and black, on faunal remains (Rhodes *et al.* 2016). Another example of different processes causing similar results is digestion and microorganism (bacterial or fungal) attack may cause perforations on faunal remains (Fernández-Jalvo & Andrews 2016). In some cases, microorganism attacks may blacken the bone surface creating a similar modification as manganese staining (Fernández-Jalvo & Andrews 2016). These processes may cause confusion during the taphonomic analysis especially

when both modifications are present, therefore more in-depth research dedicated to differentiating the alterations on the faunal remains is required. Taphonomy is also used to determine human subsistence behaviours, such as hunting, scavenging and processing of faunal remains (Reitz & Wing 2008; Fernández-Jalvo & Andrews 2016). Furthermore, it can be used to distinguish modifications caused by hunting and alterations caused by scavenging on large faunal remains. However, this is rarely translated to microfaunal remains. This is because modifications made by the primary predator (hunter) may be superimposed and similar to the modifications caused by a secondary predator (scavenger) (Andrews 1990). The link between human subsistence and micromammals will be discussed further in section 2.7.

2.7 The connection between complex behaviour and the environment at KRM

Klasies River main site is a MSA site that is generally known for its rich archaeological deposit of human occupation (Wurz 2016; Wurz *et al*. 2018), and the contribution to understanding the emergence of "modern" cognition and behaviour (Deacon & Wurz 2005) or "symbolically mediated behaviour" (Henshilwood & Marean 2003). Initially, the debate focused on whether humans at KRM were cognitively and behaviourally "modern" or behaved in "symbolic" ways. However, recently the focus has shifted to understanding the development of complex cognitive behaviour (Wadley 2013). Complex cognitive behaviour is defined as "*The capacity for abstract thought, analogical reasoning, cognitive fluidity, innovative thought, complex goal-directed actions, flexibility in problem-solving, multi-tasking, task switching, response inhibition and planning over long distances or time*." Wadley (2013: 163). A key issue encountered by researchers is analysing the relationship between palaeoclimate and complex behaviour (Carr *et al*. 2016: 40), but investigating this relationship is complicated. The difficulty lies in detecting a relationship between the occurrence of complex behaviour and the fluctuations in climatic conditions that might have affected resources (Carr *et al.* 2016: 39). Nevertheless, the analysis of this relationship is important because it allows us to explore the context in which complex behaviour emerged and

developed. Human behaviour is influenced by the distribution of spatial resources on a temporal scale (Kelly 1995). Environmental change affects the availability of stationary resources (such as water bodies), movement of faunal populations and vegetation which in turn is linked to affect the subsistence patterns (Carr *et al*. 2016: 40).

One avenue to begin exploring complex cognitive behaviour in relation to micromammals is to investigate their capture and consumption by humans. The capture of micromammals requires forethought as they are not easily caught by hand. An elaborate plan to create an object, i.e. a snare, that can capture small animals is an indication of complex behaviour. This is an area of research that has not been explored at KRM, nor any other MSA site in South Africa. This type of investigation would require taphonomic evidence to support the hypothesis that micromammals have been hunted and consumed by humans. This section aligns with the hypothesis which explores the possibility of human subsistence of micromammals at KRM during MIS 5d. A way of ascertaining if humans hunted large mammal fauna is by investigating the intensity of tool-assisted bone marrow processing, bone charring and butchery on faunal remains (Henshilwood 1997; Stiner *et al.* 2000). Microfauna on the other hand, especially mice and rats, would be too small to have been processed in the aforementioned ways. Furthermore, methods of capturing small and microfauna may vary depending on the type of prey. Tortoises, hares, rodents and birds would either be captured by hand or trapped in snares because they are not regarded as high-risk prey (Stiner *et al.* 2000). In this context the term high-risk refers to fauna that would rather retaliate than escape from a predator. The method of capture has the potential to be identified if the bones of the small and microfauna prey are altered (broken) during the process of capture and consumption. It would be interesting to investigate the behaviour of taphonomic modifications caused by snares on micromammal remains through experimentation; however due to time constraints it will be excluded from this research. The capture of small fauna by human predators requires abstract thought and response inhibition (Wadley 2013: 167).

In Central Africa, for example, contemporary nomadic foraging groups, namely

the Bofi and the Aka, employ a variety of hunting techniques that are dependent on the size and aggressiveness of the prey (Lupo & Schmitt 2005). One of the methods they use is woven snares that are set out to trap small rodents. Snares are commonly used to capture a variety of small and fast prey, such as mice and rats (*Muridae*). The rodents get trapped in the woven fibres of cone-shaped snares, and the hunter will then kill the prey or recover the carcass after the prey has succumbed to starvation (Lupo & Schmitt 2005). There is no direct evidence for the use of snares on small prey in the MSA, however it is possible to detect through circumstantial evidence, such as butchery marks on the bones (Wadley 2015). The innovation of constructing a mechanism that can successfully capture small fauna, such as a snare, requires strategic planning and forethought which is a characteristic of complex behaviour. This avenue of research provides a way to explore a relationship between micromammals and complex behaviour. If the small fauna had been snared, this may indicate complex cognition in anatomically modern humans during MIS 5d at KRM.

As discussed above in the taphonomy section, the taphonomic analysis provides insight on post-depositional modifications caused by a variety of agents and processes. These modifications can be used to determine site formation processes, predator accumulation patterns and the factors that affect the assemblage (in terms of preservation and quantity) (Fernandez-Jalvo & Andrews 2016). It should be noted that not all post-depositional alterations will be evident on the bones and this could be attributed to the size and the fragility of the bone (Andrews 1990). Simply put, some taphonomic modifications that alter large faunal remains can be completely destructive on small and microfauna remains. An example of such a process is trampling. Trampling may leave linear striations and/or fragment large fauna bones (depending on the weight and force exerted by the agent). If the same agent acts on micromammal remains, then the bones could potentially be crushed into small fragments or destroyed. Also, some modifications may result in the exclusion of taphonomic modifications on small mammal bones. For example, modifications caused by butchery (i.e. cut marks, percussion marks and perforations) may not occur on small rodents because they were not processed for

marrow (Badenhorst 2008) and their bones can easily be broken or torn apart. Butchery marks have yet to be reported on small mammal remains, with regards to *Muridae*, which may infer human consumption.

Badenhorst (2008) argues that the absence of taphonomic modifications such as butchery marks and fragmented long bones, on small mammal remains does not eliminate the possibility of human predation and consumption. Badenhorst (2008) also states that small mammals, more specifically rodents, can be considered as an intentional food source acquired by humans and are not always natural intrusions as some researchers tend to conclude. It is understandable that small mammals such as rodents would be a regularly sought-after food source because of their significantly high abundance in areas where they thrive (Stiner *et al.* 2000; Lupo & Schmitt 2005). An example of human consumption of small fauna such as rodents and lagomorphs (hares and rabbits) comes from the American Southwest Farming communities (Badenhorst 2008). The remains of these small mammals where found in human coprolites and showed evidence of digestion (Badenhorst 2008). An additional example of human consumption of small mammals is the capture and consumption of the *B. suillus* (Cape dune mole-rat).

Limitations identified from both case studies will be addressed, especially with regards to interpretations that lead to conclusions to demonstrate human subsistence of small mammal fauna and the taphonomic modifications associated with it. The patterns of charring observed on the Cape dune mole-rat remains as a result of processing and consumption by humans will be used as a reference of burning recorded in the BOS Three assemblage. The two Central African foraging groups discussed above used snares to capture small fauna, but their snares neither killed the animals, nor did it modify their bones upon entrapment (Lupo & Schmitt 2005). The way the hunter killed the animal is not specified because it was not the main focus of the research and thus excluded from the research (Lupo & Schmitt 2005). The research conducted by Badenhorst (2008) on the South American Farming communities and their consumption of small fauna required emphasis on the analysis of the small fauna assemblage. However, a thorough elucidation of how the taphonomic modifications suggested human consumption

is needed, because the taphonomic archaeozoological methods used to analyse large and small faunal remains are different. The correct methods of taphonomic analysis should be used with respect to the two fauna size groups to minimize erroneous interpretations.

The alternative methods of analyses suggested in his research would be suitable as supporting evidence of human consumption of small fauna. These methods include the analysis of butchery marks on long bones (to determine marrow processing), ethological methods (which tackles the clusters of rodent remains vs individual skeletal remains), digestion, burning on the extremities, small fauna remains in human coprolites, and fresh vs sun-bleached remains (Badenhorst 2008). Henshilwood (1997) conducted an ethnographic study to investigate the patterns of charring on *B. suillus* (Cape dune mole-rat) carried out by local farm labourers in the Still Bay area. The mole-rats were captured from the entrance from their burrows, killed then roasted whole on hot coals for 30 minutes (Henshilwood 1997). The remains affected by burning are the upper and lower incisors, premaxillae and post-cranial extremities (Henshilwood 1997). This charring pattern is the same as demonstrated by the Blombos assemblage (units 2-6) (Henshilwood 1997). Although the Cape dune mole-rat is excluded from the BOS Three micromammal assemblage the method used to capture and process them could have been used on smaller mammals.

The following case studies are a demonstration of the methods of analysis used to ascertain human subsistence of micromammals in two Later Stone Age sites in South Africa. Dewar & Jerardino (2007) conducted research investigating the possibility of micromammals being consumed by Later Stone Age people at a Namaqualand Later Stone Age site, KV502, in South Africa. The site was radiocarbon dated, using a marine shell from a single occupation layer, to 2490 ± 45 years BP (Dewar & Jerardino 2007: 3). The micromammal assemblage consisted mostly of crania and very few post-crania. These remains were identified as the *Elephantulus edwardii* (Cape rock elephant shrew), *Rhabdomys pumilio* (four-striped field mouse), *Parotomys brantsii* (Brant's whistling rat),

Otomys unisulcatus (Karoo bush rat), and *Gerbillurus paeba* (hairy-footed gerbil) (Dewar & Jerardino 2007: 9). These micromammal remains were found near a hearth and some of the bones were burnt and it is suggested that roasting of the small mammals took place (Dewar & Jerardino 2007). The dominance of crania is assumed to be the undesired part of the carcass that was discarded while the rest is consumed by the predator (Dewar & Jerardino 2007). The proximity of the burnt micromammal bones and the presence of material culture, such as a single ostrich eggshell bead and retouched lithics, further identifies humans as the primary predators of the micromammal assemblage at KV502 (Dewar & Jerardino 2007).

Groen River Mouth 5 (GRM5) is a shell midden Later Stone Age site, located 150 km south from KV502, that also relates to the possible consumption of micromammals by humans. The site consists of a single human burial (a mostly complete and articulated skeleton) that was eroding on the north river bank. The collagen from the ribs of the human remains yielded a radiocarbon date of 2720 ± 60 BP (Jerardino *et al.* 1992). Artefacts associated with the human burial were a single paired and intact shell of a black mussel (*Choromytilus meridionalis*) found in the proximity of the pelvis (Jerardino *et al*. 1992: 78). Two individuals of the genus *Parotomys*, whistling rats, were found in the stomach and intestinal region of the human remains (Jerardino *et al*. 1992: 78; Dewar & Jerardino 2007). The taphonomic modifications on the micromammals, including acid etching, breakage and relative abundance, were analysed to investigate the effect of possible human consumption on the micromammal remains (Dewar & Jerardino 2007). The post-crania displayed a high level of breakage, a high degree of acid etching and the assemblage displayed a low relative abundance of skeletal elements (Dewar & Jerardino 2007). The high frequency of breakage from the GRM 5 assemblage was interpreted as an indication of mastication which was inferred to be a direct indicator of human consumption of the micromammals (Dewar & Jerardino 2007:11). The taphonomic modifications can be associated best with Category 5 in Andrews' (1990) classification of predator modification (Dewar & Jerardino 2007).

The exploration of alternative proxies for complex behaviour may exist where a

relationship between micromammals and anatomically modern humans can be determined. This relationship has the potential to be investigated by focussing on the predator-prey interactions and prey capture techniques executed by the predators. It is crucial to use taphonomy and taxonomy for this type of investigation to further advance scientific research in the presence of complex behaviour and micromammal research. The implications related to discerning if humans at KRM, during MIS 5d, captured and consumed micromammals would indicate the presence of complex behaviour. This approach would be an alternative to recognising complex behaviour in the archaeological record apart from the evidence provided from techno-complexes (Wurz 2000), shell beads, ochre (Henshilwood *et al*. 2004, 2011) and rock art (Sterelny & Hiscock 2014). It would require a series of experimentation and elaborate research on predator-prey interactions and taphonomic modifications to test the viability of this type of relationship.

2.8 Summary

This chapter has provided a literature review to provide the background of this research. It has shown that the significance of the MSA is represented by the cultural and technological innovations. The environmental setting for these innovations is somewhat known, however the advancement of palaeoenvironmental research contributes to decreasing that gap. Environmental changes are detected through proxies such as oxygen isotopes, botanical remains and faunal remains. It shows that a combination of environmental proxies reinforces palaeoenvironmental inferences. A variety of environmental proxy research has been undertaken at MSA sites in South Africa. These studies contribute to a better understanding of the palaeoenvironments that occurred during this opportune time. Palaeoenvironmental research from Blombos, Klasies River and Pinnacle Point using micromammal remains were mentioned. The additional use of taphonomy aids the understanding of site formation processes and predators. The topic of humans as predators of micromammals is reviewed as a link to complex behaviour.

Chapter 3: Methodology

3.1 Introduction

The methods chapter provides and explanantion of the materials and the methods (Section 3.2) employed to perform the analyses. The methods used to quantify the specimens (Section 3.3) and the limitations associated are reviewed (Section 3.4). The taphonomic protocol (3.5) is explained with emphasis on the surface (Section 3.6) and shape (Section 3.7) modifications. The various calculations are explained (Sections 3.8-3.12), subsequent to that is the explanation of the taxonomic protocol in Section 3.13. The method used to quantify loose teeth (Section 3.14) for the micromammal taxa and the diversity indices (Section 3.15), followed by a section 3.16 a summary concluding this chapter.

3.2 Methods and materials

The micromammal assemblage originates from square C3 from the BOS Three layer excavated from the Witness Baulk in 2017. The excavated micromammal materials are curated and temporarily stored at the University of the Witwatersrand, Johannesburg. The micromammal assemblage from the BOS Three layer was previously sorted into cranial and post-cranial elements, while fish, reptilian, amphibian and avian skeletal elements were excluded from the analyses (Avery 1987, Andrews 1990, Nel 2013, Nel *et al*. 2018). Fragmented micromammal elements that have retained their diagnostic features are included in both the taxonomic and taphonomic analyses (Nel 2013, Nel *et al.* 2018). It is a challenge to taxonomically identify micromammal post-crania (Andrews 1990) because they do not have diagnostic features specific for each taxon; therefore, post-cranial elements have only been recorded according to element. The equipment used for both analyses are a 10x magnification hand lens, a sorting tray, a digital caliper, a Geo-Xplore Store colour chart, needle tipped pinchers, an Olympus Zeiss Stemi 305 stereo microscope and a portable illuminating lamp. The taxonomic and taphonomic procedures followed in this methodology are based on the methods proposed by Andrews (1990) and Fernández-Jalvo & Andrews (2016) and supplemented with research by Avery (1987), Manthi

(2002), Matthews (2004), Nel (2013) and Rhodes *et al.* (2016).

3.3 Quantification methods

The specimens in this assemblage are divided into three groups which are identifiable specimens (ID), unidentifiable specimens (UnID) and non-micromammal (Nn-Mm). All specimens are counted using a simple method of quantification, N, which is defined here as a unit to tally a single specimen irrespective of articulated features. An example of this method is as follows; a maxilla with an articulated incisor is counted as one specimen. This tally method only applies to registering the number of faunal remains that occur in each of the three groups. This is not to be confused with the methods of calculating NISP which is stated in section 3.3b. The standard calculations such as the Number of Specimens (NSP), Number of Identified Specimens (NISP), Minimum Number of Individuals (MNI) and Minimum Number of Elements (MNE) are used to quantify the taxonomically identifiable specimens in the assemblage (Lyman 1994a, 1994b, 2008). These quantifications are also used to maintain homogeneity in archaeozoological research to ensure ease when comparing results. Each quantification is defined followed by an explanation on the manner in which the value is calculated. The limitations relative to the primary quantification methods (NISP, NSP, MNI and MNE) are also discussed in more detail in the subsequent section.

a) Number of Specimens

A similar unit of quantification to NISP is the number of specimens (NSP) which includes all specimens – both identifiable and non-identifiable skeletal elements and fragments – recovered from an assemblage (Lyman 2008). Each specimen is counted as an individual, for example, one mandible *with in situ* teeth, one loose incisor or loose molar would each be counted as an individual. NSP is used to obtain the total quantity of micromammal specimens within the assemblage.

b) Number of Identified Specimens

The NISP is a primary quantitative unit which tallies the abundance of identifiable elements. Following Lyman (2008) and Reitz & Wing (2008), articulated

elements are counted separately. For example, one left mandible with three *in situ* molars would produce a NISP value of four. NISP can also be used to investigate site formation processes, recovery techniques and laboratory procedures (Lyman 2008: 203).

c) Minimum Number of Individuals

The MNI is defined as the highest frequency of a skeletal element that would make up a single individual (Lyman 1994a, 2008). Simply put, MNI is used to account for the abundance of individuals within an assemblage. For example, if one right tibia and two left femurs of a taxon are present in the assemblage, then the MNI will be two because each faunal specimen only has one left femur.

d) Minimum Number of Elements

The minimum number of elements (MNE) is defined as the lowest quantity of skeletal elements to account for a single individual in the sample (Lyman 1994a, 2008; Reitz & Wing 2008). This unit of quantification, similar to MNI, accounts for the least number of individuals (Lyman 2008; Reitz & Wing 2008). The MNE quantification unit takes fragmentation of an individual specimen into account and acknowledges it as a complete skeletal element. For example, if there are three humeri (two right and one left), where one left and one right are distal fragments and the remaining right is a proximal fragment, the MNE value will be two because the two right fragments can be refitted and represent a complete humerus that fragmented into two pieces. If the two right fragments could not be refitted, then the MNE will be three.

3.4 Limitations of quantification methods

The taxonomic quantifications highlighted in the previous section are commonly used for large and small faunal analysis, however, some scholars namely; Marshall & Pilgram (1993), Badenhorst (2008), Lyman (2008) and Reitz & Wing (2008) have noted the limitations associated with these methods. The limitations of these quantifications are discussed further below.

a) Number of Specimens (NSP)

The Number of Specimens is a straight forward count of all the specimens within the assemblage regardless of their identifiability. A disadvantage associated with this quantitative method is that it has the potential to inflate the total quantity of specimens in the assemblage. For example, an assemblage has 33 specimens, but if one specimen (for example a femur) fragments into three pieces during the analysis then the total number of specimens in that assemblage is 36.

b) Number of Identified Specimens (NISP)

Fragmentation of faunal specimens due to cultural or non-cultural processes and the survival of robust elements (teeth, vertebrae, pelves) influence the element count, thus inflating the number of specimens within the sample (Lyman 2008; Reitz & Wing 2008). It is also subject to biases related to predators and other animals, site formation processes, recovery techniques during excavation and preparation and analyses procedures conducted in the lab (Reitz & Wing 2008). NISP is an example of a primary count that inflates the number of individuals found in an assemblage because the fragmentation of an identifiable specimen is not acknowledged (Lyman 2008; Reitz & Wing 2008). Additionally, not all faunal skeletal elements occur in similar quantities which means the quantification methods need to be adapted according to the different fauna (Lyman 2008). The following example demonstrates this issue. The forest shrew, *Myosorex varius*, has 32 teeth while the four-striped grass mouse, *Rhabdomys pumilio*, has 16 teeth. Therefore, using NISP would overestimate the presence of the forest shrew and underestimate the presence of the grass mouse. This emphasises the importance of using suitable methods for quantifying faunal specimens with different elements (Lyman 2008).

Also, the anatomical elements not only differ in some animals as explained above, these elements occur in different quantities in different types of animals. An example of this is comparing the skeletal elements of a snake and a rodent, a snake consists of a skull, vertebrae and ribs, while rodents consist of a variety of skeletal elements (humeri, femurs, vertebrae etc.). This means that snake skeletal

elements could possibly be under represented relative to rodent skeletal elements because rodents have a variety of robust skeletal elements that would preserve well. Although, NISP has these limitations it is used in this research because the NISP is routinely used in faunal research. NISP has been used in previous micromammal research at KRM (Nel 2013; Nel *et al*. 2018) and contemporaneous coastal MSA sites such as Blombos Cave (Nel 2013) and Pinnacle Point Cave 13B (Matthews *et al*. 2009). This enables a comparison of statistical analyses from these assemblages.

c) Minimum Number of Individuals (MNI)

MNI was introduced as a solution that accounts for the fragmentation of bones and avoids counting specimen's multiple times, however, it too has its disadvantages (Marshall & Pilgram 1993). MNI is affected by elements distributed unevenly within sites and sample size which adds to the challenge of calculating the MNI value of an assemblage (Marshall & Pilgram 1993). The basis of MNI is using the principle of symmetry, in which pairs of elements account for a single individual and not a matching pair of elements that originate biologically from the same individual (Reitz & Wing 2008). Determining the age of the individual (juvenile or adult) plays a role when symmetry is used. The evidence of fused elements indicates adults; while unfused elements indicate juvenile individuals, which increases the MNI value because the epiphyses of unfused elements can potentially be counted separately (Reitz & Wing 2008). Thus, this leads to accounting for more juvenile individuals than actually present in the assemblage. When using symmetry, the age of the individuals must be considered, so if two humeri (left and right) are found they should both be fused or unfused to represent one individual from a known taxon. MNI is also affected by the same biases as NISP such as the consumption and displacement caused by predators or other animals, site formation processes, excavation and laboratory techniques and procedures (Reitz & Wing 2008).

d) Minimum Number of Elements (MNE)

The limitations associated with MNE are like that of MNI in that it is subjective to

the analysts' protocol (Lyman 2008; Reitz & Wing 2008). The method utilized by the analyst is biased because of subjectivity. This creates a disadvantage in terms of comparative analysis because a researcher will not be able to analyse trends efficiently because different methods were used to calculate the MNE values. In some publications the methods for quantifying the MNI and MNE are not disclosed or stated clearly (Lyman 2008; Reitz & Wing 2008). This then allows for incorrect interpretations to be made when the MNE values from different studies are compared. MNE is affected by the way it is calculated (some scholars calculate it in the same manner as they would MNI), the sample size, aggregation and the age (when refitting elements) of the specimen (Reitz & Wing 2008). The method used for this research to calculate MNE in the assemblage is to count refitted elements as one specimen (two right and one left femur fragments, one proximal and two distal, result in an MNE value of two). The methods of tallying anatomical elements can be subjective, and the variability in the different tallying methods may inflate the frequency of faunal specimens within the assemblage (Lyman 2008). Therefore, it is imperative for the methods used to calculate the NSP, NISP, MNI and MNE to be stated explicitly to avoid confusion (Lyman 2008).

In some cases, certain elements may survive in the deposits based on their robustness, while other elements do not survive due to physical and chemical processes (Lyman 2008). For instance, the micromammal assemblage at KRM has high frequencies of vertebrae, maxillae, mandibles and loose teeth, while ribs and phalanges occur in low frequencies (Nel 2013). Another factor affecting faunal remains is the recovery techniques used during the excavation process and in the field laboratory. Appropriate equipment could be used to recover as much archaeological material with techniques that are less destructive. Dry sieving sediment may cause abrasion and fragmentation of some remains (Pearsall 2000). Also, using a sieve with a mesh size larger than 1mm will result in the loss of small remains such as rodent molars, sesamoids, vertebrae and other skeletal elements. At KRM in layer BOS Three the recovered material was wet sieved to counteract the loss of bone and decrease the extent of broken bones during field

laboratory procedures.

3.5 Taphonomic methodology

Taphonomy is helpful in deducing the palaeoenvironment by understanding site formation and predator accumulation processes, irrespective of faunal size divisions, or agents and processes that modify osseous remains (Gifford 1981; Andrews 1990; Matthews 2004; Fernández-Jalvo & Andrews 2016). In terms of micromammal remains it provides a detailed account of biases associated with the accumulation of micromammal remains (Matthews *et al.* 2005). It also provides a representation of the micromammals within the assemblage relative to the initial micromammal community (Matthews *et al.* 2005). Taphonomic investigation includes surface and shape modifications of the micromammal bones (Andrews 1990, Nel & Henshilwood 2016).

Taphonomic modifications were identified with the aid of published literature with a variety of images and detailed descriptions of the modifications published by academics, for example Reitz & Wing (2008), Lyman (1994b) and Fernández-Jalvo & Andrews (2016). The methods used in this research are a combination of the methods used by Andrews (1990), Fernández-Jalvo & Andrews (2016) and Rhodes *et al.* (2016). A chromatic scale used by Rhodes *et al.* (2016) and a Munsell colour chart were used to ensure consistency in identifying the colours of each specimen. Modifications that alter the original shape of the osseous material were classified as shape modifications in this research, for example breakage and corrosion (Fernández-Jalvo & Andrews 2016).

The crania and post-crania (long bones, pelves, scapulae, vertebrae, sesamoids, astragali, phalanges) were analysed for taphonomic modifications. Fragmented bones that can be identified to element along with complete bones were included in the taphonomic analysis. Fragmented bones that do not retain their diagnostic features were labelled as unidentifiable and were not included in the taphonomic analysis. Long bones that retained either the proximal or distal articular ends were included in the assemblage (Andrews 1990). Complete vertebrae and fragmented

vertebrae that retained at least 50% of bone or the central body were included in the taphonomic analysis (Nel 2013). A description of the taphonomic modifications recorded is provided in the surface modification section below.

3.6 Surface modifications

Surface modifications are chemical or physical changes that alter the osseous material (Fernández-Jalvo & Andrews 2016) and include linear marks, perforations, pits, discolouration, weathering, encrustation, crystallisation and abrasion (Reitz & Wing 2008; Lyman 1994b; Fernández-Jalvo & Andrews 2016). The variety of surface modifications are described below.

a) Linear marks

Linear marks are defined as marks where the length is four times greater or more than the breadth (Andrews & Fernández-Jalvo 2012: 192; Fernández-Jalvo & Andrews 2016: 25). They can be identified as parallel lines, uneven or sporadic striations, elongated linear indentations or grooves. These marks are caused by fauna (trampling), cut marks, tooth marks, beak marks, root etching, claw marks and other natural agents (water and wind) (Andrews & Fernández-Jalvo 2012: 192; Fernández-Jalvo & Andrews 2016: 25).

Trampling is a destructive taphonomic agent especially with regards to small and micromammal bones due to their fragility (Fernández-Jalvo 1995). It is characterised by polish, concoidal flake scars and striations (Fisher 1995). This process is likely to be caused by human or larger animals passing through an area where a collection of small mammal bones have been deposited or avian predators trampling on pellets while in their nests or roosting areas (Andrews 1990).

Cut marks and tooth marks are differentiated by their cross-sectional profile. The cross-sectional profile of a cut mark is v-shaped, where the cross-sectional shape of a tooth mark is u-shaped (Andrews & Fernández-Jalvo 2012: 193; Fernández-Jalvo & Andrews 2016). It is most likely to find cut marks on large mammal bones rather than on small mammal bones, because small mammal bones may break easily during the butchery process (Fernández-Jalvo & Andrews 2016: 30).

The presence of cut marks is used as a proxy for human activity (butchery or bone tool manufacture), scavenging or hunting by human and fauna predators (Andrews 1990; Reitz & Wing 2008; Andrews & Fernández-Jalvo 2012; Fernández-Jalvo & Andrews 2016).

Tooth marks are an indication of human or carnivore action on bones that occur during the process of hunting or scavenging (Fisher 1995). The definition of tooth marks is often subjective, a definition suggested by Brain (1981: 143) is the presence of striations, puntures and ragged edges on the bones as a result of predatory action. Another definition of tooth marks employed in the taphonomic analysis is the unbranched linear marks that vary in length (Andrews & Fernández-Jalvo 2012: 197).

Plant roots secrete chemicals which slightly discolour and etch the bone surface (Nel 2013; Fernández-Jalvo & Andrews 2016). The shape of plant root etching on bone may vary depending on the way root contacts the bone; however, they are mostly linear in shape or they meander or they branch out (Fisher 1995; Fernández-Jalvo & Andrews 2016: 33). Root etching on bone may vary in colour such as dark red or brown in colour (Fernández-Jalvo & Andrews 2016).

b) Perforations

Perforations are indentations that occur on bone and their size, shape and penetrative depth are dependent on the agent (Andrews & Fernández-Jalvo 2012: 197; Fernández-Jalvo & Andrews 2016: 101). Perforations with a cone-shaped profile -wide on the surface and narrowed into the periosteum- are attributed to organic processes (such as carnivore chew marks or gripping and penetration caused by insects) (Fernández-Jalvo & Andrews 2016: 101-102). Conversely, perforations with a broad base and irregular profiles are attributed to inorganic processes (such as trampling caused by fauna and abrasion caused by water or wind) (Fernández-Jalvo & Andrews 2016: 101).

c) Pits (Pitting)

Pits are superficial marks that occur on the surface of a bone and are like

perforations in that their size and depth is an indication of the agent responsible for the modification (Andrews & Fernández-Jalvo 2012: 197; Fernández-Jalvo & Andrews 2016: 101). The shape of pitting is inconsistent and varies depending on the taphonomic agents (carnivore chewing) and the area of the bone in which the modification is found (Fernández-Jalvo & Andrews 2016: 101-102). Pits also occur on the bone surface while perforations penetrate the periosteal surface (Fernández-Jalvo & Andrews 2016: 101). The difference between pits and perforations depends on the shape; where perforations occur in two distinct shapes, as mentioned above, pits have an inconsistent shape (Fernández-Jalvo & Andrews 2016: 101). The likely agents responsible for pitting include human and animal tooth marks, beak or claw marks, wind and sand abrasion and trampling (Fernández-Jalvo & Andrews 2016: 101).

d) Punctures

Punctures are described as deep inverted conical depressions commonly accompanied by crushed bones along the margins of the hole (Horwitz & Smith 1988: 474; Andrews & Fernández-Jalvo 2012: 198). The may occur as deep depressions on the bone surface or they may penetrate the bone (Fisher 1995). They are usually associated with carnivore action on large or small fauna, for example hyaenas preying on human remains, cattle, goats, sheep and pigs (Horwitz & Smith 1988).

e) Digestion (gastric/acid etching)

Digestion is a taphonomic aspect that identifies the most likely predator responsible for the accumulation of micromammals in the assemblage (Rhodes *et al*. 2016). Digestion is also used to identify any biases regarding the presence or absence of skeletal elements and the preferred prey species of the predator (Rhodes *et al*. 2016). The digestion of bone in avian predators takes place in the stomach whereas, in mammalian carnivores, the digestion process occurs in the stomach and continues in the intestines (Andrews 1990). This continued process of digestion leads to more intense modification on the bones and teeth. Evidence of digestion commonly occurs on teeth and it is recognised by the exposure of

enamel and dentine, polish, pitting and rounded edges of teeth (Andrews 1990). The initial categories formulated by Andrews (1990) have been adapted following Matthews (2004), Matthews *et al.* (2009, 2011) and Nel (2013). Overall the evidence of gastric etching on rodent molars, incisors, maxillae and mandibles and post-cranial elements is grouped into five categories (Andrews 1990; Matthews 2004, Matthews *et al.* 2009, 2011; Nel 2013). The extent of damage measured in these five stages are associated with the digestion and breakage characteristic of avian or mammalian predators (Andrews 1990). The intensity of gastric etching increases with the progression of each stage where stage zero has no digestion and breakage of the bone. Stage four consists of an extreme degree of digestion where a few elements are still identifiable and partially intact.

f) Etching (unknown source)

This type of etching is not a result of gastric or root action due its differential appearance. Nel (2013: 99) defined this type of etching as "characterised by penetration of the bone surface extending into deep grooves or even holes, some spreading over large parts of the elements, and others more confined in an area".

g) Weathering

Weathering on vertebrate bone is defined as the process of decomposition of the bone as a whole or just the cortical surface as it is deposited on the ground surface for long periods of time (Behrensmeyer 1978: 150). Weathering is characterised by cracking, disintegration and splitting of the bone (Fisher 1995: 31). The destructive properties of weathering directly affect the preservation of the bone and may cause bias in some assemblages (Behrensmeyer 1978). Behrensmeyer (1978) formulated a guide to determining the stages of weathering by assessing the intensity and rate of the weathering process on bones in different environments. There are six stages of weathering where stage 0 has no weathering evident on the bone surface (no peeling or flaking) and stage 5 is where the bone has undergone extreme weathering and the bone splinters and disintegrates when handled (Behrensmeyer 1978: 151). This guide for weathering is mostly used for fauna larger than 5kg. As an alternative a combination of weathering

characteristics have been gathered from the works of Andrews (1990: 10-16), Matthews (2004: 73-74), Nel (2013: 101) and Fernández-Jalvo & Andrews (2016: 201-205) to assess weathering conditions on micromammals.

h) Crystallization

The crystallization of salts on bone surfaces is likely to occur in soils with high alkalinity (Behrensmeyer 1978). The continued growth of salt crystals (e.g. gypsum) and calcium carbonate precipitate (tufa) on the bone surfaces causes the bone to weather, more specifically, the surface splits and flakes (Behrensmeyer 1978).

i) Encrustation

In this context, the term 'encrustation' is the accumulation of compacted sediment, minerals (calcium carbonate) or other substances that coats and solidifies a section or the entire bone (Bao *et al*. 1998). The substance that encrusts the bone might be either compacted sediment, charcoal, or a mixture of other substances (like dissolved shell material or ash adhered to the bone surface as observed in the assemblage). Where possible the encrustation was gently removed from the bone surface, however, if it could not be removed from the bone it was recorded as such in the Excel spreadsheet during the analysis.

j) Discolouration

Discolouration is the change in colour of the entire bone to either a dark or light hue relative to its original colour. Discolouration may only occur on the surface of bone or it may penetrate deep within the mineralized bone tissue (Fernández-Jalvo & Andrews 2016: 155). It appears as localised patches, a cluster of small spots, stripes and complete discolouration of the remains (Turner *et al.* 2018). In some cases, more than one colour can be observed on the bone as this could be attributed to taphonomic agents such as heat exposure (burning), sun bleaching, soil, fungal or manganese staining (López-González *et al*. 2006; Marín-Arroyo *et al*. 2008; Fernández-Jalvo & Andrews 2016: 155). A method of categorising this colour change on the bone would be to identify the most prominent colour thus making it easier to determine the taphonomic agents (Fernández-Jalvo & Andrews

2016). A colour chart was used as a guide for consistency in differentiating the variety of colours that appear on the bones. Additional methods and techniques i.e. Scanning Electron Microscopy (SEM) and X-Ray Diffraction (XRD) are used to distinguish the agents of discolouration (Stathopoulou *et al.* 2019). These methods and techniques, except the colour chart, are not within the scope of this research and therefore will not be used.

k) Staining

Staining of bones is an indication of the organic and inorganic processes that occur within the environment that the bone was deposited (Fernández-Jalvo & Andrews 2016). Osseous material staining caused by the presence of mineral oxides is very common in several archaeological contexts (Marín-Arroyo *et al*. 2008). The most common colours that occur on bone that have been chemically stained are brown, red and black (Fernández-Jalvo & Andrews 2016: 157-158). Iron (Fe) oxides present in clay cause an orange-yellow, reddish-brown or dark chocolate brown discolouration and manganese causes a dark brown and black discolouration on the bone (Marín-Arroyo *et al*. 2008, 2014; Stathopoulou *et al.* 2013; Stathopoulou *et al.* 2019). The presence of ochre in the deposits may also be an agent of bone staining (López-González *et al*. 2006). Staining can also be indicated by a greyish black discolouration caused by a fungal attack, which is most likely to occur in an environment with an abundance of organic matter, moisture and availability of air (Marín-Arroyo *et al*. 2008; Fernández-Jalvo & Andrews 2016: 157). In a South African context, taphonomic analyses have been conducted on several micromammal assemblages (e.g. Pinnacle Point Cave 13B (Matthews 2004), Saldanha Bay Yacht Club (Manthi 2002), KRM (Avery 1987, Nel 2013, Nel *et al.* 2018), BBC (Nel & Henshilwood 2016). Unfortunately very little emphasis has been placed on investigating the different processes of staining on micromammal remains.

l) Burning

The exposure of osseous material to fire modifies the material by causing the object to peel, crack and change its original pigmentation. The more time osseous

materials are exposed to a thermal influence, the higher the probability of bone disintegration. Rhodes *et al.* (2016) associated colour or chromatic stages along with the different temperature stages and physical modifications based on the experimental research by Shipman *et al*. (1984). The six stages describe the thermal discolouration and the degrees associated with that pigmentation (Rhodes *et al*. 2016). Stage zero indicates no burning, therefore no colour change is observed, whereas stage five displays calcination, ash white colour, of the bone associated with temperatures less than 950°C (Shipman *et al.* 1984; Rhodes *et al*. 2016). The colour scale grades from stage 1 to stage 5 (yellow, red, dark brown, black, grey and white) (Rhodes *et al*. 2016). If a certain area of the bone has been affected by burning, then it is classified as localised burning and the colour of the burned area will be determined according to the colour scale grades mentioned above. The colour scales used for recording the degree of burning on large fauna vary per researcher. For example, Costamagno *et al.* (2005) created a colour scale for burnt bones where numerical values are used as a code for each colour. The codes from zero to four and associated colours are as follows; zero is the natural colour of the bone, one is localised burning, two is black, three is grey and four is white (calcined) (Table 6.1, Costamagno *et al.* 2005: 53).

m) Exfoliated surface/Water logging

Water logging is a taphonomic modification that causes discolouration of osseous material (brown or black) (Marín-Arroyo *et al*. 2014; Turner *et al*. 2018; Stathopoulou *et al.* 2019). It is the submergence of bones in soils saturated with water over long periods of time, it also known as “ponding” in cave environments (Marín-Arroyo *et al*. 2014: 3). In addition it may result in a roughened and dull surface of the cortical surface and in extreme cases it may intermittently alter the shape of the bone itself.

3.7 Shape modifications

Shape modifications are physical or chemical alternations of osseous material caused by breakage or corrosion (Fernández-Jalvo & Andrews 2016). The two types of shape modifications breakage and corrosion are described below.

a) Breakage

Breakage of bone is a common taphonomic aspect that may provide insight on the depositional and post-depositional actions that modified the bone. Post-depositional breakage occurs due to contact of the remains with solid materials or a natural force (i.e. gravity) and may be a result of excavating, screening, sorting and analysing small and microfaunal remains (Andrews 1990, Avery 2007). Breakage of the crania and post-crania have been recorded according to the methods formulated by Andrews (1990). A complete skull is defined as the preservation of at least half of the cranial vault, the frontal bones and the maxilla (Andrews 1990). In most cases the maxilla detaches from the rest of the skull thus disqualifying the element as a complete skull (Andrews 1990). The zygomatic process may still be attached to the maxilla after the maxilla has been detached from the rest of the skull (Andrews 1990). A complete mandible is defined as the entire mandibular body with the presence of a complete ascending ramus for each mandibular body (Andrews 1990). The presence or absence of some of the teeth in the mandible does not affect the definition of a complete mandible or maxilla (Andrews 1990).

The types of bone breakages were adapted from Andrews (1990) criteria and combined with the types of bone breakage observed in the micromammal assemblage (Figures A.1-A.2). The types of cranial breakage locations are categorised into six classes; complete (Co), proximal (Px), proximal and middle (PxMe), distal (Ds), distal and middle (DsMe) and diaphysis/middle fragments (Me) (Andrews 1990). The post-cranial bone breakage locations are categorised into six classes; complete (Co), proximal (Px), proximal and shaft (PxSf), distal (Ds), distal and shaft (DsSf) and diaphysis/shaft fragments (Sf) (Andrews 1990). Bones that retain all three segments with breakage to the epiphyses, or the absence of the greater trochanter of the femur and the distal articulation of the humerus are still considered as complete (Andrews 1990). In the case, of identifiable elements that do not follow either of these breakage portions they will be recorded as incomplete (InCo) or Indeterminate (InD). Bone fracture patterns are usually studied on large fauna long bones to identify the difference between

anthropogenic marrow extraction and natural breakage (Villa & Mahieu 1991). Bone fracture patterns such as spiral and transverse breaks will be difficult to discern from natural fractures on micromammal remains because they are small and possibly easy to break without the aid of a tool. It is unlikely that micromammals would have been butchered for marrow extraction, therefore, bone fracture patterns will not be included in this research.

b) Corrosion

Corrosion is the chemical, biological or geochemical activity that erodes the bone tissues away altering the original shape of the bone (Fernández-Jalvo & Andrews 2016). Corrosion is distinguished from weathering based on the type of environment that allows each process to thrive. Corrosion occurs in a chemically reactive environment with no exposure to air, while weathering occurs when the bones are exposed to the natural environment (Fernández-Jalvo & Andrews 2016). The agent responsible for corrosion is unknown, however it is possible that corrosion is caused by acids present in the soil at the site (Andrews 1990). The difference between corrosion and digestion is the location of the modifications, where digestion is concentrated on a localised area and is a surface modification (Fernández-Jalvo & Andrews 2016). Corrosion does not focus on a localised area of the bone and is more sporadic in its modifications on the bone (Fernández-Jalvo & Andrews 2016).

3.8 Skeletal Element Abundance (SEA)

The representation of prey skeletal elements found in predator assemblages can aid the processes of distinguishing the different types of predators (Andrews & Nesbit-Evans 1983, Andrews 1990). The number of skeletal elements are represented as proportions to provide an indication of the amount of individuals present in an assemblage (Andrews 1990). The relative abundance is calculated as follows:

$$R = \frac{Ni}{(MNI \times Ei)}$$

R = The relative abundance of element *i*

N = The number of element *i* in the assemblage

MNI = The Minimum Number of Individuals

E*i* = The number of elements present in an individual prey skeleton

3.9 Mortality pattern

Mortality pattern is defined as the age-frequency distribution of a faunal population (Lyman 1994b). There are two types of mortality patterns, the first is known as attritional, alternatively "normal", mortality and the second is catastrophic, also referred to as "mass" mortality (Voorhies 1969; Lyman 1994b; Discamps & Costamagno 2015: 62). Attritional mortality is defined as a higher proportion of juvenile and old individuals and a lower proportion of prime adults (Discamps & Costamagno 2015: 62). This type of mortality profile is selective in terms of the susceptibility of young and old individuals to predation and the unlikely probability to escape traps and survive unfavourable environmental conditions (Lyman 1994b: 118). Catastrophic mortality is defined as the stable living population where the representation of older individuals is much less than that of the younger individuals (Lyman 1994b: 118). This mortality profile is non-selective and the proportion of prime adult mortalities is higher than attritional mortality profiles (Voorhies 1969: 46-47). These two mortality patterns are beneficial as they provide significant information, however due to time constraints it will not be used for this research. A less complex method and codes following Driver (2005) will be used to record the age of the specimens in the assemblage. The age profile is recorded based on the presence or absence of epiphyses on post-crania bones and the presence or absence of fusion of the sutures on the crania. The following codes are used to record the different age profiles according to Driver (2005), Juvenile (JUV), Adult (AD) and Unknown (UN).

3.10 Distal element loss

The preferential destruction or the loss of distal limb elements is a feature of several predatory assemblages (Andrews 1990: 50). Distal limbs are easily recognisable whereas distal foot bones are not, as due to their small size they are

often lost during the excavation process or disregarded (Andrews 1990: 50). The distal element loss proportion highlights a trend associated with different micromammal predators according to Andrews' (1990: 90) five category system. The lowest proportion of distal element loss is associated with category 1 and the highest proportion of distal element loss is associated with category 5 (Andrews 1990: 90).

$$\text{Distal element loss } = \frac{\text{tibia+radius}}{\text{femur+humerus}}$$

3.11 Post-cranial and cranial proportions

The proportion of cranial to post-cranial elements is calculated to estimate the level of damage to either skeletal element group (Nel 2013). The cranial and post-cranial proportions are used to account for the number of elements in predator assemblages (Andrews 1990). The proportion of cranial elements to post-cranial elements would correspond in an assemblage with no breakage, however, this is not the case with all predatory assemblages (Andrews 1990). Two indices, the proportion of post-crania to crania and the proportion of distal limbs, are used to compare preservation of the two skeletal element groups (Andrews 1990). The cranial elements used in these ratios are the mandible, maxillae and molars (articulated and loose) a total of (16 elements) and the post-crania; humerus, radius, ulna, femur and tibia (10 elements) (Andrews 1990: 49). The formula for the post-crania to crania proportion is given below (Andrews 1990: 49):

$$Ratio = \frac{\text{post} - \text{crania}}{\text{crania}} \times \frac{5}{8} \times 100$$

The formula for the preferential loss of elements is given below (Andrews 1990: 49):

$$Ratio = \frac{\text{femur} + \text{humerus}}{\text{mandible} + \text{maxilla}} \times 100$$

This ratio provides an estimate of preferential loss of the cranial or post-cranial elements (Andrews 1990). These proportions provide information about the

predator responsible for the accumulation of the assemblage because some predators decapitate and dispose the head of the prey before consuming the rest of the carcass (Andrews 1990).

3.12 Statistical analysis

Chi-squared tests can be used to explore whether certain taphonomic variables are associated. A Chi-squared test is used to indicate the degree of difference between the counts in the sample and the counts that would be expected should there be no relationship between the variables in the sample (cf. Barceló 2018). The null hypothesis is that there is no association between the variables. When the probability (p) is greater than 0.05, it indicates that the differences between the variables is not significant and the null hypothesis is accepted. The null hypothesis can be rejected when p is smaller than 0.05, indicating that the result of the test is significant. Social Science Statistics is a free online statistical website, and it was used to undertake the statistical calculations for this research.

3.13 Taxonomic protocol

The cranial elements of the micromammal assemblage consist of maxillae, mandibles, and teeth (*in situ* and isolated molars and incisors). Complete skulls rarely survive in the archaeological record, owing to their fragile nature, and it is thus challenging to taxonomically identify fragments with undiagnostic features with a high level of certainty (Andrews 1990; Matthews *et al*. 2011). The unidentifiable cranial elements were counted and weighed for each square and no further analysis was conducted on them. Loose rodent incisors that retain their proximal and distal tips are included in the taxonomic identification because they could be provenanced to either the mandible or maxilla. Teeth articulated to maxillary or mandibular bone are categorised as maxillae with -molars, - incisor or -teeth. Loose molars that have retained their cusps are included in the taxonomic analysis. However, molars that retain their roots but not the occlusal portion (cusp) are classified as *Rodentia*. Diagnostic micromammal specimens are taxonomically identified to species level and in more complex cases the specimens have been identified to higher taxonomic levels (e.g. order, sub-order,

genus). Reference material including comparative samples at the Ditsong National Museum of Natural History (former Transvaal Museum) and literature (e.g. Avery 1979; Avery 1982; Skinner & Chimimba 2005; Happold 2013a; Happold & Happold 2013) were used to taxonomically identify and to verify the side (left or right) of the specimens.

Additional factors such as the size and shape of the maxillae, mandibles and molars were identified with the aid of illustrations from Avery (1979, 1982) identification plates and reference collections. Some of the specimens from the reference collection at Ditsong did not have partially or completely exposed alveoli which complicate the identification process. The BOS Three assemblage has cranial specimens with articulated teeth, loose teeth, mandibles and maxillae with exposed alveoli. The characteristics of the alveoli have been used to taxonomically identify the specimens with the aid of identification keys by Avery (1979). The identification keys include as much detail as possible relative to the mandibles, maxillae and teeth of certain micromammal species (upper and lower tooth row measurements, dental formula etc.) (Avery 1979). The identification keys are also useful for identifying the alveoli characteristics in the absence of *in situ* teeth, provided research has been done for each species. The disadvantages of using identification keys are that they can be relevant only to a restricted specific geographical location (e.g. ecological region) or there may be issues with the species identification. There may also be an insufficient amount of research available on rare or problematic micromammals.

3.14 Quantification of the loose teeth

Only taxonomically identifiable *in situ* and loose teeth were included in the taxonomic calculations for this research when their provenance could be determined (either originating from either the upper or lower jaw). Loose molars were identified as M1, M2 or M3 for the mandible or maxilla (Nel 2013). Loose incisors, that have retained their distal ends, were included in the taxonomic analysis and were classified as *Rodentia* due to the challenge of further identification of loose incisors to species (Hillson 1986). Teeth that could not be

provenanced or where the molar identification could not be determined were categorised as indeterminate and were not included in any quantification or taxonomic indices calculations (cf. Matthews 2004; Matthews *et al*. 2011). Loose teeth are included in the NISP calculation, however only loose teeth that could be sided are included in the MNI calculation.

3.15 Diversity indices

Statistical indices for taxonomic biodiversity such as the Shannon-Wiener and Simpson's Indices were used to measure the diversity of the assemblage. The most abundant taxa and their habitat preferences were used to formulate inferences of the palaeoenvironment. The taxonomic indices that were used are: species richness (S) alternatively the number of taxa (NTAXA), the Shannon-Wiener Indices (evenness and diversity), the Simpson's Indices (diversity and dominance) and the Taxonomic Habitat Index (THI) (Nesbit-Evans *et al.* 1981; Magurran 1988; Andrews 1990; Hammer & Harper 2006; Lyman 2008). All the taxonomic indices mentioned above, with the exception of the THI, were calculated using the Paleontological Statistics (PAST) software program (Hammer *et al.* 2001). The diversity indices are calculated using the MNI values for each taxon as the input values. The indices were calculated using the PAST software programme, where the lower percentile 2.5% and the upper percentile 97.5% display the bootstrap intervals of the assemblage (Hammer & Harper 2006). These indices have also been used by Matthews (2004), Nel (2013), Maringa (2017) and Nel *et al.* (2018).

a) Species Richness

Species richness (S) is a diversity index often defined as the number of taxa (NTAXA) identified in an assemblage (Hammer & Harper 2006; Lyman 2008). This diversity index is proportional to the sample size; simply put, as the sample size increases so does species richness (Lyman 2008). However, this is true only to a certain extent because the relationship between sample size and NTAXA is logarithmic (Magurran 1988).

b) The Shannon-Weiner Index

The Shannon Weiner Index estimates the abundance of species diversity found in a faunal assemblage or community (Lyman 2008). This index relies on the number of taxa and the relative abundances of the sample (Hammer & Harper 2006). The index values generally range between 1.3 and 3.5 where low values indicate fewer taxa and high values indicate more than one taxon present in the assemblage (Hammer *et al*. 2001: 156; Lyman 2008). The equation for the Shannon-Weiner Index is:

$$H = -Pi(ln\mathrm{P}i)$$

Where H is the general diversity or heterogeneity (also denoted as H') and P*i* is the proportion of taxon *i* in the assemblage.

c) The Shannon-Weiner Index of evenness

The Shannon-Weiner Index of evenness – also known as equitability – is used to determine if the assemblage has an even distribution of taxa (Magurran 1988). The index values for this equation range between zero and one; where values close to zero indicate an uneven assemblage and values close to one indicate an even assemblage (Magurran 1988: 37). The equation for equitability is:

$$J = \frac{H'}{Hmax}$$

Where J is the taxonomic evenness, H' is the Shannon-Wiener Index and, H_{max} is the natural log of species richness (lnS).

d) Simpson's Index for dominance

The Simpson's index for dominance (D) calculates the probability that two individuals selected at random are of the same species (Magurran 1988: 39). The equation for the Simpson's Index is:

$$D = \sum(Pi)^2$$

where D is dominance and P$i = \frac{ni}{n}$ (the proportion of species *i*).

The values range from zero to one, if the index value is close to one then there is a single taxon that dominates the assemblage (Hammer & Harper 2006: 188).

e) Simpson's Index for diversity

The Simpson's index for diversity calculates the biodiversity estimate of a past community in an assemblage (Hammer & Harper 2006). The equation for calculating this diversity index is:

$$1 - D \text{ or } 1 - \sum(Pi)^2$$

There is an inverse relationship experienced between Simpson's dominance and diversity; if the value of D is high (i.e. close to 1) then the diversity should be low (Magurran 1988). Therefore, Simpson's Index can also be expressed as 1-D or 1/D due to this inverse relationship (Magurran 1988: 39). However, in this case, the diversity index will be determined as the complement of D in accordance with the statistical software used to calculate all the diversity indices (Hammer *et al.* 2001). The Simpson's index will have its minimal value of Σ (1/S)2= 1/S when all the taxa within the assemblage are equal (Hammer *et al.* 2001: 189).

f) Taxonomic Habitat Index

The taxonomic habitat index (THI) is a cumulative index which combines the habitat preferences of all taxa present in an assemblage, but it is based on extant taxa niches (Nesbit-Evans *et al*. 1981; Andrews 1990; Nel 2013; Nel *et al*. 2018). Extinct taxa require a different approach however that method is not discussed because none of the identified taxa in the assemblage are extinct. This index provides a more specific ecological range for each taxon present in an assemblage, because the habitat preferences of higher taxon or genus groups are generally understood in a broad sense (Nesbit-Evans *et al.* 1981). In southern African micromammal research conducted by the following scholars Fernández-Jalvo *et al.* (1998), Avery (2001) and Manthi (2006), applied broad habitat types. This however demonstrates a broad description of the habitats in the region of interest.

Matthews *et al*. (2005) suggested that a broad habitat description would result in smaller habitat types being overlooked therefore a less detailed palaeoenvironment will be the result. Two methods of THI were employed, one focused on the general vegetation as described by Acocks (1988) and the other focused on local regions (Nel 2013). Nel (2013) adapted this approach by following the first THI method according to Matthews *et al.* (2005) where microhabitats are used instead of broad vegetation types denoted as THI_{veg}. The second THI method is an adaptation from Avery (1995) where the vegetation, openness, topography and dryness are used to acquire more detail of the palaeoenvironment (denoted as THI_{tvod}) (Nel 2013: 112).

The Taxonomic Habitat Index for vegetation (THI_{veg}) for KRM is analysed using the method adapted by Matthews *et al.* (2005) and Nel (2013). The geographical boundary of South Africa is used as the spatial parameter for the preferential niches of the extant taxa. The THI_{veg} scores are calculated using a qualitative method whereby the researcher estimates the values for the preselected vegetation components based on the habitat preferences of each taxon. Each taxon was given a score between 0 and 1, which is dependent on the number of habitats in which that taxon is found (Nesbit-Evans *et al.* 1981). Each habitat is given a score based on the abundance of each taxa in that niche, for example if a species is found in one habitat it is given the value of 1 (Nesbit-Evans *et al*. 1981). If the species occurs equally in different niches, then each habitat is awarded the same value and the summation of those values must be equivalent to 1 (Nesbit-Evans *et al.* 1981). If the taxon is found in a variety of habitats, then the habitat it prefers most is given a high value and the habitat it least prefers is given a low value (Nesbit-Evans *et al.* 1981). For example, The THI_{veg} for *Myosorex varius* (forest shrew) can be found in grassland (0.25), woodland and forest (0.15), savanna (0.05), riverine and wetland (0.35), scrub (0.05) and fynbos (0.10) (Skinner & Chimimba 2005: 237; Baxter & Dippenaar 2013c). An example of a taxon that is found in fewer habitat ranges is *Suncus varilla*, it is found in riverine and wetland (0.05), grassland (0.80) and woodland and forest (0.15) (Skinner & Chimimba 2005). The summation for each habitat type is acquired then divided by the number of taxa in

the assemblage to achieve the cumulative index.

The second approach is the Taxonomic Habitat Index for topography, vegetation, openness and dryness (denoted THI_{tvod}) will be used to continue the palaeoenvironmental record of KRM as initiated by Avery (1995) and continued by Nel (2013). The methodology adapted by Nel (2013: 112) is as follows; the vegetation is described as scrub, trees/bushes and grass; topography as waterside, hillside and plains. Openness is described as either open or closed and dryness is characterised by moist or dry (Nel 2013: 112). For example, *Steatomys krebsii*, is given the following values based on its habitat characteristics; grass 0.7, trees/bushes 0.15 and scrub 0.15 for vegetation; plains 1 for topography; closed 0.1 and open 0.9 for openness, dry 0.9 and moist 0.1 for dryness. The cumulative index for the THI_{tvod} is acquired in the same manner as the THI_{veg}. The benefit of using THI is to assess the increase or decrease of a habitat type, the introduction of a new habitat, changes in the current habitat over time and the disappearance of habitat types (Cuenca-Bescós *et al.* 2009). It also prevents the use of broad descriptions of the distribution of habitat types in micromammal research. This double THI approach enhances the amount of detail extracted from the analysis of the micromammal assemblage.

3.16 Summary

This chapter has provided descriptions of the different methods used to analyse the micromammal materials recovered from the BOS Three layer at KRM. The benefits and limitations for the various quantification methods have been thoroughly discussed. The taphonomic modifications were divided into two categories, surface and shape modifications, where each modification is described clearly with the aid of several sources. Taphonomic calculations in the form proportions of skeletal elements and statistical analysis were explained. These calculations are beneficial for providing significant insight on site formation processes and the identification of the potential accumulators. The taxonomic protocol provided information of how the micromammal materials were recovered, sorted, quantified and identified to species (where possible). A

description of the diversity indices and their relevance was addressed inorder to provide great detail for the interpretation of the palaeoenvironmental conditions at Klasies River main site during MIS 5d.

Chapter 4: Results

4.1 Introduction

This chapter presents the results of the analyses of the BOS Three micromammal sample. The data is presented in a variety of graphs, tables and charts with interpretations. The chapter starts off with a summary of the assemblage in Section 4.2. The results of the taphonomic analysis (Section 4.3) of the cranial and post-cranial elements are presented, followed by the taxonomic analysis (Section 4.4) which only focuses on the cranial elements. The last two sections, palaeoenvironmental indicators (Section 4.5) and the deduction of the results (Section 4.6) conclude this chapter.

4.2 Sample

A total of 140 specimens identified as non-micromammal (reptile, fish, bird and frog) have been excluded from the sample. The sample from square C3 consists of a total of 5909 micromammal specimens (number of specimens, NSP) of which 2649 are identifiable (ID) (1200.0g) and 3260 are non-identifiable (Non-ID) (248.9g) (Table 4.1). The ID and Non-ID values are not used further in this research as they are utilised as a primary count of the specimens in the C3 assemblage. The cranial (498.8g) and post-cranial (701.2g) skeletal elements are presented separately in the taphonomy section to determine if there is a significant difference in the appearance and frequency of taphonomic modifications on the cranial and post-cranial skeletal elements. The NISP for the cranial assemblage is 1367 and for the post-cranial assemblage is 1456.

Table 4.1: Units of quantification of the micromammal specimens in the sample.

Units of Quantification	Number (N=)
Non-ID	3260
ID	2649
NSP	5909
NISP (cranial)	1367
NISP (post cranial)	1456

The taphonomy is also discussed in relation to Skeletal Element Abundance (SEA). SEA is used to represent the number of elements recovered from the assemblage. The representation of skeletal elements in the assemblage is shown in Figure 4.1 and Table A.1 (Appendix) which displays the tabulated NISP and R values for each skeletal element.

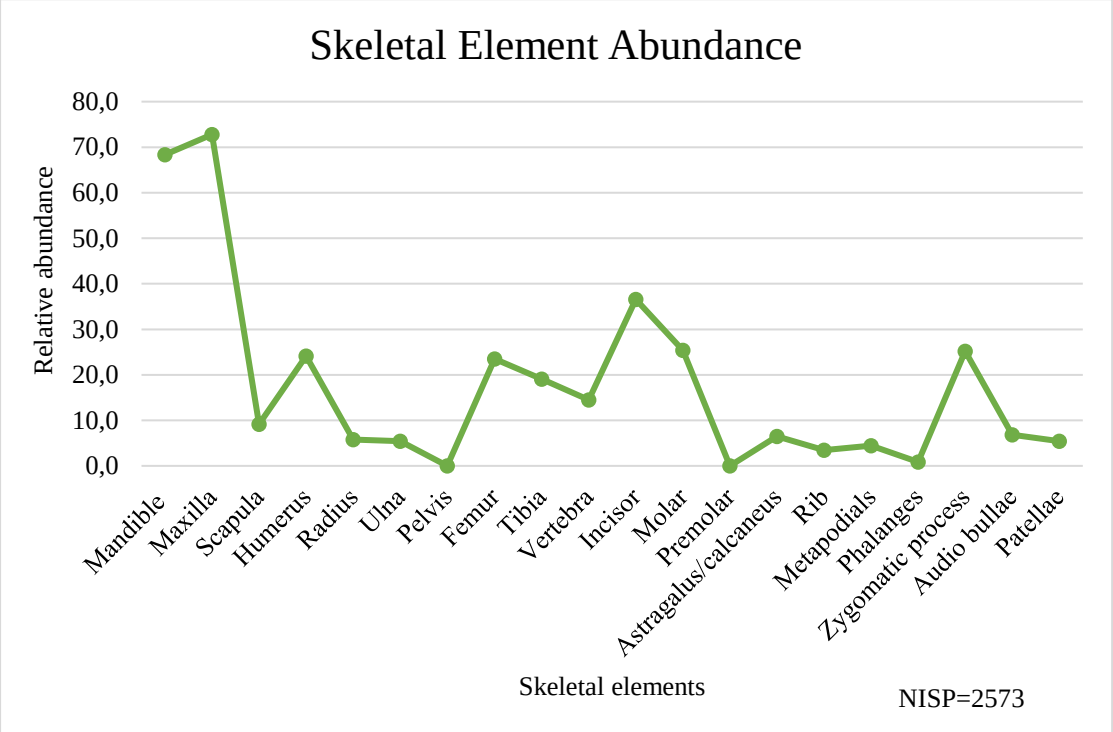


Figure 4.1: The Skeletal Element Abundance for the C3 micromammal assemblage. Some elements were excluded from the SEA calculation because the exact number of those skeletal elements that occur in the murid skeleton are not known for certain. This lead to the change in the NISP value from 2823 to 2573.

The most abundant elements in the assemblage are cranial elements, maxillae (72.8%, n=214), mandibles (68.4%, n=201) and loose incisors (36.6%, n=215). The least frequently abundant skeletal elements are post-cranial elements, metapodials (4.5%, n=131), ribs (3.6%, n=122) and phalanges (0.9%, n=71). It should be noted that in the BOS Three assemblage that was sampled no pelves or fibulae were recorded.

4.3 Taphonomy

The analyses of digestion and breakage patterns are presented first since these are the key characteristics of identifying the accumulator of the assemblage. Mortality profiles are then presented to determine the age profile of the prey as accumulated by the predator. Thereafter, all taphonomic modifications found on the crania and post-crania are addressed.

4.3.1 Digestion

The NISP (crania = 1367, post-crania = 1456 Table 4.1) values are used to present the intensity of digestion in the cranial and post-cranial assemblages. The five stages (0-4) which are used to measure the intensity of gastric etching on the faunal remains, as discussed in Chapter 3 section 3.6e, yielded the following results. None of the specimens in either of the assemblages display characterisitics of Stage 0 (No digestion), therefore this category is not included in the graphs and tables. Table 4.2 shows the four different intensities of digestion analysed in the cranial assemblage. The light digestion category is the most common type of gastric etching with a total of 85.3% (n=1166) present on the specimens. Over 78% of most of the cranial elements, apart from the zygomatic process, show light digestion traces. Extreme digestion is the least common category occurring at 0.22% (n=3), on only two incisors and one molar, whereas heavy digestion also occurs very infrequently (2.0%, n=27). Moderate digestion occurs on 171 specimens (12.5%).

Table 4.2: The different levels of digestion observed on the cranial elements (NISP values in **bold** and NISP% in parentheses).

Element	Light digestion	Moderate digestion	Heavy digestion	Extreme digestion	Total digestion
Cranial bone	**19** (95.0)	**1** (0.0)	**0** (0.0)	**0** (0.0)	**20** (1.5)
Maxilla	**261** (89.1)	**31** (10.6)	**1** (0.3)	**0** (0.0)	**293** (21.4)
Zygomatic process	**45** (60.0)	**28** (37.3)	**2** (2.7)	**0** (0.0)	**75** (5.5)
Mandible	**231** (78.3)	**63** (21.4)	**1** (0.3)	**0** (0.0)	**295** (21.6)
Incisor	**176** (81.9)	**26** (12.1)	**11** (5.1)	**2** (0.9)	**215** (15.7)
Canine	**1** (100.0)	**0** (0.0)	**0** (0.0)	**0** (0.0)	**1** (0.1)
Molar	**414** (92.4)	**21** (4.7)	**12** (2.7)	**1** (0.2)	**448** (32.8)
Bulla	**19** (95.0)	**1** (5.0)	**0** (0.0)	**0** (0.0)	**20** (1.5)
Total	**1166** (85.3)	**171** (12.5)	**27** (2.0)	**3** (0.2)	**1367** (100%)

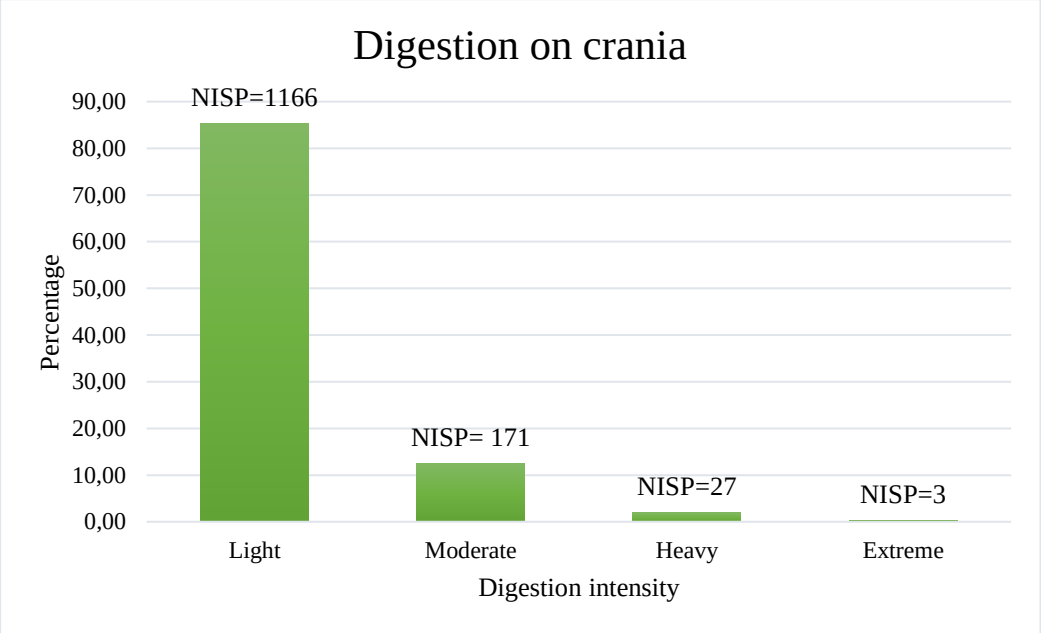


Figure 4.2: The types of gastric etching observed on the cranial elements.

Figure 4.2 shows that the least frequent types of digestion are evident only on cranial specimens and have a combined percentage of less than 3%.

a) Loose incisors

The different stages of digestion on the loose incisors is shown in Table 4.3 and the effect of digestion on a loose incisor is shown in Figure A.17 (Appendix). Most of the loose incisors (81.9%, n=176) show evidence of light digestion, and a fifth of the incisors display traces of moderate digestion (21.1%, n=26). Extreme digestion is low in the assemblage with only two incisors (0.9%) displaying these characteristics.

Table 4.3: Digestion on the loose incisors (NISP values in **bold** and NISP percentages in parentheses).

	Light digestion	Moderate digestion	Heavy digestion	Extreme digestion	Total digestion
Loose incisors	**176** (81.9)	**26** (12.1)	**11** (5.1)	**2** (0.9)	**215** (100)

b) Post-crania

Table 4.4 shows the different stages of digestion analysed in the post-cranial assemblage. Similar to the cranial assemblage, Stage 0 (No digestion) did not occur and therefore only four categories are presented. The pattern of digestion is similar to that of the cranials with light digestion as the most common type of digestion that occurs in this assemblage (75.6%, n=1100), followed by moderate digestion (18.4%, n=268). The elements mostly affected by light digestion are radii (94.1%, n=17), ribs (92.6%, n=122) and astragali (90.0%, n=20).

Table 4.4: The different levels of digestion observed on the post-cranial elements (NISP values in **bold** and NISP percentages in parentheses).

Elements	Light digestion	Moderate digestion	Heavy digestion	Extreme digestion	Total digestion
Vertebra	**542** (70.8)	**175** (22.9)	**42** (5.5)	**7** (0.9)	**766** (52.6)
Rib	**113** (92.6)	**7** (5.7)	**2** (1.6)	**0** (0.0)	**122** (8.4)
Scapula	**21** (77.8)	**5** (18.5)	**1** (3.7)	**0** (0.0)	**27** (1.9)
Humerus	**55** (77.5)	**10** (14.1)	**4** (5.6)	**2** (2.8)	**71** (4.9)
Radius	**14** (94.1)	**1** (5.9)	**0** (0.0)	**0** (0.0)	**17** (1.2)
Ulna	**13** (81.3)	**1** (6.3)	**2** (12.5)	**0** (0.0)	**16** (1.1)
Carpal	**47** (83.9)	**1** (14.3)	**1** (1.8)	**0** (0.0)	**56** (3.8)
Femur	**43** (62.3)	**16** (23.2)	**9** (13.0)	**1** (1.5)	**69** (4.7)
Patella	**6** (37.5)	**8** (50.0)	**2** (12.5)	**0** (0.0)	**16** (1.1)
Tibia	**46** (82.1)	**10** (17.9)	**0** (0.0)	**0** (0.0)	**56** (3.8)
Astragalus	**18** (90.0)	**2** (10.0)	**0** (0.0)	**0** (0.0)	**20** (1.4)
Calcaneus	**16** (88.89)	**1** (5.7)	**1** (5.6)	**0** (0.0)	**18** (1.2)
Metapodial	**104** (79.4)	**17** (13.0)	**10** (7.6)	**0** (0.0)	**131** (9.0)
Phalange	**60** (84.5)	**7** (9.9)	**3** (4.2)	**1** (1.4)	**71** (4.9)
Total	**1100** (75.6)	**268** (18.4)	**77** (5.3)	**11** (0.8)	**1456** (100.0%)

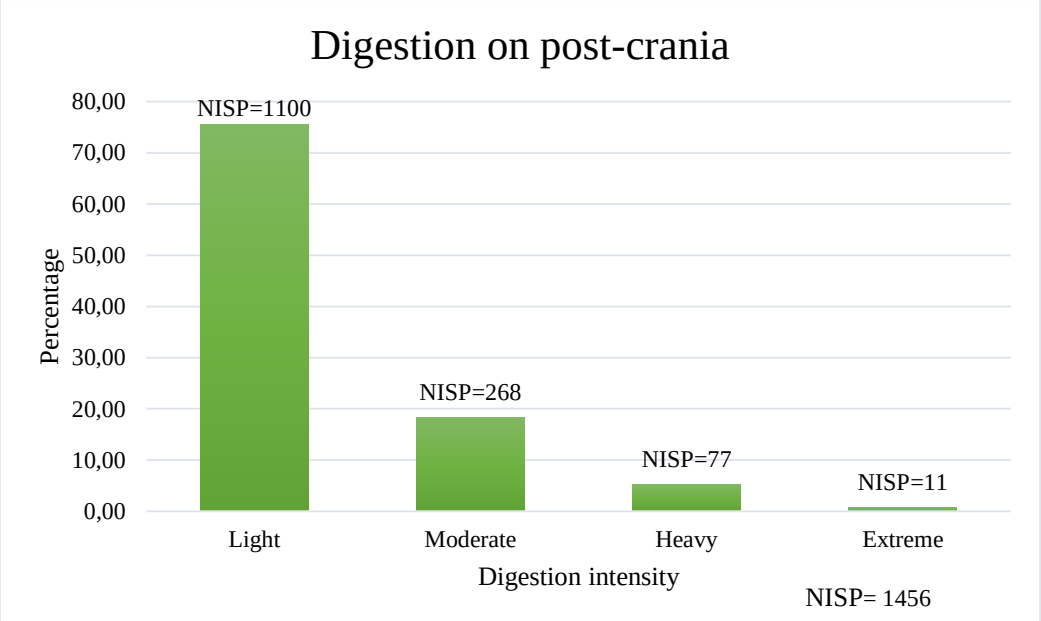


Figure 4.3: Digestion intensities on the post-cranial elements.

Figure 4.3 presents the percentage of the digestion for the stages of digestion in the post-cranial assemblage. Light digestion (75.6%, n=1100) is well represented and extreme digestion (0.8%. n=11) is the least represented category in the

assemblage. The least frequent digestion categories are heavy and extreme digestion that appear at less than 7% altogether.

c) Long bone digestion

Table 4.5 and Figures A.6-12 and Figures A.18 (Appendix) display the different levels of digestion on the long bones in the assemblage. Light digestion is the most frequent degree of gastric etching observed on the long bones (75.6 %, n=173). Light digestion occurs most commonly on radii (94.1%, n=17), tibiae (82.1%, n=56) and ulnae (81.3%, n=16). Extreme digestion is the least common category present on two humeri and one femur (1.3%).

Table 4.5: The levels of digestion on the long bones. The total number of long bones in the assemblage is 229 (The NISP values are in **bold** and the NISP percentage in parentheses).

Elements	Light digestion	Moderate digestion	Heavy digestion	Extreme digestion	Total digestion
Humerus	**55** (77.5)	**10** (14.5)	**4** (5.6)	**2** (2.8)	**71** (31.0)
Radius	**16** (94.1)	**1** (5.9)	**0** (0.0)	**0** (0.0)	**17** (7.4)
Ulna	**13** (81.3)	**1** (6.3)	**2** (12.5)	**0** (0.0)	**16** (7.0)
Femur	**43** (62.3)	**16** (23.2)	**9** (13.0)	**1** (1.5)	**69** (30.1)
Tibia	**46** (82.1)	**10** (17.9)	**0** (0.0)	**0** (0.0)	**56** (24.5)
Total	**173** (75.6)	**38** (16.6)	**15** (6.6)	**3** (1.3)	**229** (100.0)

A chi-squared test was used to determine whether light and moderate digestion levels on the loose incisors and long bones are statistically significant (Table 4.6).

Table 4.6: Cross-tabulation of the frequencies (NISP) of the degree of digestion and body parts (NISP values in **bold**).

	Light digestion	Moderate digestion	Total
Loose incisors	**176**	**26**	**202**
Long bones	**173**	**38**	**211**
Total	**349**	**64**	**413**

The chi-square statistic (X^2[df =1, N= 354] = 2.0807; p= 0.149) indicates that

there is no significant association between the two dominant digestion categories in the cranial and post-cranial assemblages.

4.3.2 Breakage

The breakage of micromammal remains is recorded to provide an indication of predator action and site formation processes. Table 4.7 shows the different breakage locations in the cranial assemblage. The bullae, canine, cranial bones and the zygomatic processes are the most fragile as none of these specimens are complete. Most of the cranial elements are broken (61.0%, n=834), with the most frequent fragment being the distal-medial (DsMe) (19.8%, n=270) portion. The most complete skeletal elements in the assemblage are loose molars (77.9%, n=349) and loose incisors (61.4%, n=132). Many of the zygomatic processes are distal-medial fragments (50.7%, n=38).

Table 4.7: The type of fracture portions for cranial elements (NISP values in **bold** and NISP% in parentheses).

Elements	*Co	Ds	DsMe	Ind	Me	Px	PxMe	Total
Cranial bone	**0** (0.0)	**0** (0.0)	**0** (0.0)	**19** (95.0)	**1** (5.0)	**0** (0.0)	**0** (0.0)	**20** (1.5)
Maxilla	**14** (4.8)	**51** (17.4)	**117** (39.9)	**2** (0.7)	**87** (29.7)	**12** (4.1)	**10** (3.4)	**293** (21.4)
Zygomatic process	**0** (0.0)	**34** (45.3)	**38** (50.7)	**0** (0.0)	**2** (2.7)	**1** (1.3)	**0** (0.0)	**75** (5.5)
Mandible	**38** (12.9)	**28** (9.5)	**91** (30.9)	**2** (0.7)	**86** (29.2)	**3** (1.0)	**47** (15.9)	**295** (21.6)
Incisor	**132** (61.4)	**21** (9.8)	**20** (9.3)	**11** (5.1)	**28** (13.0)	**1** (0.5)	**2** (0.9)	**215** (15.7)
Canine	**0** (0.0)	**0** (0.0)	**0** (0.0)	**1** (100.0)	**0** (0.0)	**0** (0.0)	**0** (0.0)	**1** (0.1)
Molar	**349** (77.9)	**0** (0.0)	**4** (0.9)	**94** (21.0)	**1** (0.2)	**0** (0.0)	**0** (0.0)	**448** (32.8)
Bulla	**0** (0.0)	**0** (0.0)	**0** (0.0)	**1** (5.0)	**19** (95.0)	**0** (0.0)	**0** (0.0)	**20** (1.5)
Total	**533** (39.0)	**134** (9.8)	**270** (19.8)	**130** (9.5)	**224** (16.4)	**17** (1.2)	**59** (4.3)	**1367** (100%)

*The code for each breakage location are as follows: Co= Complete, Ds= Distal, DsMe= Distal-medial, Ind= Indeterminate, Me= Medial, Px = Proximal, PxMe= Proximal-medial.

Table 4.8 displays the location of breakage frequencies in the post-cranial assemblage. The post-cranial assemblage has a higher occurrence of complete

skeletal elements (58.3%, n=849) than the cranial elements (39.0%, n=533). The elements with the highest occurrence of completeness are the astragali (100.0%, n=20), carpals (96.4%, n=56), calcanei (94.4%, n=18) and the phalanges (90.1%, n=71). The post-cranial assemblage has a lower frequency of fragmented specimens (41.7%, n=607) than the cranial assemblage specimens (61.0%, n=834). The highest frequency of fragment portion in the assemblage is the proximal fragments (9.3%, n=135). The least frequent fragment is the distal shaft portion (2.0%, n=29).

Table 4.8: The fragment portions of each post-cranial specimen (NISP values in **bold** and NISP% in parentheses).

Elements	*Co	Ds	DsSf	Ind	Sf	Px	PxSf	Total
Vertebra	**571** (74.5)	**0** (0.0)	**0** (0.0)	**195** (25.5)	**0** (0.0)	**0** (0.0)	**0** (0.0)	**766** (52.6)
Rib	**9** (7.4)	**0** (0.0)	**0** (0.0)	**4** (3.3)	**13** (10.7)	**40** (32.8)	**56** (45.9)	**122** (8.4)
Scapula	**0** (0.0)	**0** (0.0)	**0** (0.0)	**1** (3.7)	**2** (7.4)	**4** (14.8)	**20** (74.1)	**27** (1.9)
Humerus	**1** (1.4)	**21** (29.6)	**6** (8.5)	**2** (2.8)	**9** (12.5)	**29** (40.9)	**3** (4.2)	**71** (4.9)
Radius	**2** (11.8)	**0** (0.0)	**0** (0.0)	**0** (0.0)	**1** (5.9)	**8** (47.1)	**6** (35.3)	**17** (1.2)
Ulna	**0** (0.0)	**1** (6.3)	**1** (6.3)	**0** (0.0)	**0** (0.0)	**6** (37.5)	**8** (50.0)	**16** (1.1)
Carpal	**54** (96.4)	**0** (0.0)	**0** (0.0)	**2** (3.6)	**0** (0.0)	**0** (0.0)	**0** (0.0)	**56** (3.8)
Femur	**6** (8.7)	**13** (18.8)	**1** (1.5)	**12** (17.4)	**1** (1.5)	**26** (37.7)	**10** (14.5)	**69** (4.7)
Patella	**14** (87.5)	**0** (0.0)	**0** (0.0)	**2** (12.5)	**0** (0.0)	**0** (0.0)	**0** (0.0)	**16** (1.1)
Tibia	**5** (8.9)	**12** (21.4)	**8** (14.3)	**3** (5.4)	**4** (7.1)	**17** (30.4)	**7** (12.5)	**56** (3.8)
Astragalus	**20** (100)	**0** (0.0)	**0** (0.0)	**0** (0.0)	**0** (0.0)	**0** (0.0)	**0** (0.0)	**20** (1.4)
Calcaneus	**17** (94.4)	**0** (0.0)	**1** (5.6)	**0** (0.0)	**0** (0.0)	**0** (0.0)	**0** (0.0)	**18** (1.2)
Metapodial	**86** (65.7)	**3** (2.3)	**12** (9.2)	**0** (0.0)	**2** (1.5)	**5** (3.8)	**23** (17.6)	**131** (9.0)
Phalange	**64** (90.1)	**1** (1.4)	**0** (0.0)	**6** (8.5)	**0** (0.0)	**0** (0.0)	**0** (0.0)	**71** (4.9)
Total	**849** (58.3)	**51** (3.5)	**29** (2.0)	**227** (15.6)	**32** (2.2)	**135** (9.3)	**133** (9.1)	**1456** (100.0)

* The code for each breakage location are as follows: Co= Complete, Ds= Distal, DsSf= Distal shaft, Ind= Indeterminate, Sf= Shaft, Px = Proximal, PxSf= Proximal shaft.

4.3.3 Post-cranial and cranial proportions

The values of the post-cranial proportions as explained in chapter 3, section 3.10 and section 3.11 are shown in Table 4.9. The post-cranial/cranial ratio is low (13.8%) which means the proportion of post-crania to crania is not equal. The preferential loss of elements (Fem+Hum/Mand+Max) also shows a low result (23.8%) indicating an unbalanced proportion.

Table 4.9: Post-cranial and cranial proportions (NISP value in **bold** and the proportions in parentheses (%)).

	NISP	Distal Element Loss	Post-Crania/ Crania	Fem+Hum/ Mand+Max
Proportions	**2823**	(52.1)	(13.8)	(23.8)

*NISP values are used as the input values to calculate the proportions.

4.3.4 Mortality pattern

Age (adult, juvenile and unknown) was recorded on all skeletal elements. The skeletal elements from both the cranial and post-cranial assemblages where age could be determined are shown in Table 4.10. There is a high number of specimens in the Unknown age category (54.63%, n=2041), possibly due to the breakage of the specimens. Table 4.10 shows that juvenile specimens make up 32.0% (n=652) of the assemblage and the adult specimens compose 13.4% (n=274) of the assemblage.

Table 4.10: The estimated age of the specimens in the cranial and post cranial assemblage for adults, juveniles and specimens of unknown age (NISP values in **bold** and NISP percentage in parentheses).

Elements	Adult	Juvenile	Unknown	Total
Cranial bone	**0** (0.0)	**19** (95.0)	**1** (5.0)	**20** (1.0)
Maxilla	**3** (1.0)	**45** (15.4)	**245** (83.6)	**293** (14.4)
Molar	**0** (0.0)	**0** (0.0)	**100** (100.0)	**448** (22.0)
Vertebra	**69** (9.0)	**480** (62.7)	**217** (28.3)	**766** (37.5)
Scapula	**18** (66.7)	**3** (11.1)	**6** (22.2)	**27** (1.3)
Humerus	**3** (4.2)	**40** (56.3)	**28** (39.4)	**71** (3.5)
Radius	**15** (88.2)	**1** (5.9)	**1** (5.9)	**17** (0.8)
Ulna	**0** (0.0)	**0** (0.0)	**100** (100.0)	**16** (0.8)
Carpal	**0** (0.0)	**1** (1.8)	**55** (98.2)	**56** (2.7)
Femur	**6** (8.7)	**19** (27.5)	**44** (63.8)	**69** (3.4)
Tibia	**9** (16.1)	**38** (67.9)	**9** (16.1)	**56** (2.7)
Metapodial	**91** (69.5)	**3** (2.3)	**37** (28.2)	**131** (6.4)
Phalange	**60** (84.5)	**3** (4.2)	**8** (11.3)	**71** (3.5)
Total	**274** (13.4)	**652** (32.0)	**1115** (54.6)	**2041** (100.0)

A chi-square test (Table 4.11) was conducted to determine whether there is an association between mortality profile (adults and juveniles) and body parts (cranial and post-cranials) preserved.

Table 4.11: A cross-tabulation of the fequencies (NISP values in **bold**) of adults and juveniles and cranials and post-cranials.

	Adult	Juvenile	Total
Cranial	**3**	**64**	**67**
Post-cranial	**271**	**588**	**859**
Total	**274**	**652**	**926**

The chi-squared test (X^2[df =1, N= 926] = 21.8615, p< 0.00001) shows that the null hypothesis of no association between the mortality profile and the body parts preserved can be rejected as p is <0.05. It is thus highly probable that crania and post-crania preserve to different degrees in juveniles and adults.

4.3.5 Additional Taphonomic modifications

The taphonomic modifications are presented in this section which include encrustation, weathering, pits, perforations and root etching as shown in Figures A.3-A.26 (Appendix). It should be noted that the type of etching described in section 3.6f was not observed in this micromammal assemblage. The taphonomic modifications for the cranial assemblage are presented first followed by the post-cranial assemblage. The taphonomic modifications for the cranial elements are shown in Table 4.12. The post-cranial modifications are displayed in Table 4.13.

Gastric etching, soil staining (99.8%, n=1364) and encrustation (66.3%, n=906) (Table 4.12) are prevalent on cranial elements. No instances of crystal formation (gypsum) was recorded on the cranial elements. The modifications that have a moderate occurrence in the sample are burning, manganese staining, perforations and root etching. Burning is more prevalent on the canine, cranial bones, molars and maxillae. The bullae (95.0%, n=20), zygomatic processes (48.0%, n=75), mandibles (30.8%, n=295) have the highest occurrence of manganese staining. It should be noted that none of the discoloured specimens in the assemblage (i.e. burning, soil or manganese staining) left residue upon contact. The least frequent modifications occurring below 7% are pits, exfoliated surfaces, weathering, punctures, crystallisation and tooth marks. Weathering is very infrequent in this assemblage (1.7%, n=23), and is mostly found on the zygomatic processes and mandibles. Pits occur mostly on the cranial bones and bullae and infrequently on the incisor. Tooth marks (0.3%, n=4) are the least common modification in the assemblage and occur in low frequencies on the mandibles, maxillae and molars.

The taphonomic modifications present on the post-cranial specimens are presented in Table 4.13. The most prominent taphonomic modifications observed on the post-cranial skeletal elements, as discussed in detail in section 4.3.1, is gastric etching (100%, n=1456). Soil staining (99.7%, n=1451) and encrustation (92.5%, n=1346) are also highly prevalent (Table 4.13). The trend observed with the three most prominent modifications in the cranial assemblage also occurs in the post-cranial assemblage. However, there is some difference between the trends for the moderate and least occurring modifications of the two assemblages.

The modifications that occur at a moderate frequency are perforations pits and manganese staining. Perforations are common on the patellae, carpals and scapulae. Pits occur mostly on the patellae, carpals, calcanei, metapodials and vertebrae. The patellae and carpals show some trend with these modifications that are linked to digestion. The least occurring modifications are root etching, burning, punctures, possible cut marks, gnaw marks, trampling, weathering, crystallisation, tooth marks and exfoliated surfaces. There were two instances of possible cut marks, but this needs further investigation. Trampling is only observed in the post-cranial assemblage.

Table 4.12: A table displaying the taphonomic modifications observed on the cranial elements (NISP values in **bold** and the NISP% in parentheses).

Elements	*GE	BN	PT	PF	PC	TM	Total
Cranial bone	**20** (100.0)	**8** (40.0)	**12** (60.0)	**4** (20.0)	**0** (0.0)	**0** (0.0)	**20** (1.5)
Maxilla	**293** (100.0)	**102** (34.8)	**25** (8.5)	**96** (32.8)	**0** (0.0)	**1** (0.3)	**293** (21.4)
Zygomatic process	**75** (100.0)	**21** (28.0)	**4** (5.3)	**4** (5.3)	**0** (0.0)	**0** (0.0)	**75** (5.5)
Mandible	**295** (100.0)	**75** (25.4)	**35** (11.9)	**113** (38.3)	**5** (1.7)	**2** (0.7)	**295** (21.6)
Incisor	**215** (100.0)	**57** (26.5)	**4** (1.9)	**1** (0.5)	**0** (0.0)	**0** (0.0)	**215** (15.7)
Canine	**1** (100.0)	**1** (100.0)	**0** (0.0)	**0** (0.0)	**0** (0.0)	**0** (0.0)	**1** (0.1)
Molar	**448** (100.0)	**177** (39.5)	**2** (0.4)	**3** (0.7)	**0** (0.0)	**1** (0.2)	**448** (32.8)
Bulla	**20** (100.0)	**1** (5.0)	**10** (50.0)	**7** (35.0)	**5** (25.0)	**0** (0.0)	**20** (1.5)
Total	**1367** (100.0)	**442** (32.3)	**92** (6.7)	**228** (16.7)	**10** (0.7)	**4** (0.3)	**1367** (100.0)

*Modification abbreviations: GE= Gastric etching, BN=Burining, PT= Pits, PF= Perforations, PC= Punctures and TM= Tooth marks.

Table 4.12: (Continued) A table displaying the taphonomic modifications observed on the cranial elements (NISP values in **bold** and the NISP% in parentheses).

Elements	*RE	MgSt	SS	EnCr	CrYs	WT	ExSf	Total
Cranial bone	**7** (35.0)	**2** (10.0)	**20** (100.0)	**20** (100.0)	**0** (0.0)	**0** (0.0)	**0** (0.0)	**20** (1.5)
Maxilla	**56** (19.1)	**55** (18.8)	**293** (100.0)	**258** (88.1)	**2** (0.7)	**8** (2.7)	**10** (3.4)	**293** (21.4)
Zygomatic process	**23** (30.7)	**36** (48.0)	**75** (100.0)	**63** (84.0)	**2** (2.7)	**3** (4.0)	**5** (6.7)	**75** (5.5)
Mandible	**58** (19.7)	**91** (30.8)	**295** (100.0)	**248** (84.1)	**3** (1.0)	**10** (3.4)	**19** (6.4)	**295** (21.6)
Incisor	**47** (21.9)	**58** (27.0)	**215** (100.0)	**75** (34.9)	**0** (0.0)	**0** (0.0)	**1** (0.5)	**215** (15.7)
Canine	**0** (0.0)	**0** (0.0)	**1** (100.0)	**1** (100.0)	**0** (0.0)	**0** (0.0)	**0** (0.0)	**1** (0.1)
Molar	**22** (4.9)	**26** (5.8)	**445** (99.3)	**221** (49.3)	**1** (0.2)	**2** (0.4)	**11** (2.5)	**448** (32.8)
Bulla	**2** (10.0)	**19** (95.0)	**20** (100.0)	**20** (100.0)	**0** (0.0)	**0** (0.0)	**0** (0.0)	**20** (1.5)
Total	**215** (15.7)	**287** (20.1)	**1364** (99.8)	**906** (66.3)	**8** (0.6)	**23** (1.7)	**46** (3.4)	**1367** (100.0)

*Modification abbreviations: RE= Root etching, MgSt= Manganese staining, SS= Soil staining, EnCr= Encrustation, CrYs= Crystallisation, WT= Weathering, and ExSf= Exfoliated surface.

Table 4.13: The taphonomic modifications observed on each post-cranial specimen with the percentage of each modification reflecting the frequency of its occurrence in the assemblage (NISP values in **bold** and the NISP% in parentheses).

Elements	*GE	BN	PT	PF	PC	PCM	TP	ExSf	Total
Vertebra	**766** (100.0)	**28** (3.7)	**463** (60.4)	**487** (63.6)	**3** (0.4)	**1** (0.1)	**2** (0.3)	**29** (3.8)	**766** (52.6)
Rib	**122** (100.0)	**4** (3.3)	**20** (16.4)	**27** (22.1)	**0** (0.0)	**0** (0.0)	**3** (2.5)	**1** (0.8)	**122** (8.4)
Scapula	**27** (100.0)	**1** (3.7)	**4** (14.8)	**21** (77.8)	**0** (0.0)	**0** (0.0)	**0** (0.0)	**0** (0.0)	**27** (1.9)
Humerus	**71** (100.0)	**1** (1.4)	**17** (23.9)	**39** (54.9)	**6** (8.5)	**0** (0.0)	**4** (5.6)	**2** (2.8)	**71** (4.9)
Radius	**17** (100.0)	**0** (0.0)	**4** (23.5)	**2** (11.8)	**0** (0.0)	**0** (0.0)	**0** (0.0)	**0** (0.0)	**17** (1.2)
Ulna	**16** (100.0)	**0** (0.0)	**7** (43.8)	**6** (37.5)	**0** (0.0)	**0** (0.0)	**0** (0.0)	**0** (0.0)	**16** (1.1)
Carpal	**56** (100.0)	**1** (1.8)	**35** (62.5)	**50** (89.3)	**18** (32.1)	**2** (3.6)	**2** (3.6)	**1** (1.8)	**56** (3.8)
Femur	**69** (100.0)	**1** (1.4)	**31** (44.9)	**43** (62.3)	**28** (40.6)	**0** (0.0)	**2** (2.9)	**0** (0.0)	**69** (4.7)
Patella	**16** (100.0)	**2** (12.5)	**11** (68.8)	**15** (93.8)	**0** (0.0)	**0** (0.0)	**0** (0.0)	**0** (0.0)	**16** (1.1)
Tibia	**56** (100.0)	**4** (7.1)	**23** (41.1)	**30** (53.6)	**0** (0.0)	**0** (0.0)	**4** (7.1)	**0** (0.0)	**56** (3.8)
Astragalus	**20** (100.0)	**1** (5.0)	**7** (35.0)	**9** (45.0)	**1** (5.0)	**0** (0.0)	**0** (0.0)	**0** (0.0)	**20** (1.4)
Calcaneus	**18** (100.0)	**0** (0.0)	**11** (61.1)	**8** (44.4)	**4** (22.2)	**0** (0.0)	**0** (0.0)	**0** (0.0)	**18** (1.2)
Metapodial	**131** (100.0)	**5** (3.8)	**80** (61.1)	**47** (35.9)	**0** (0.0)	**0** (0.0)	**3** (2.3)	**7** (5.3)	**131** (9.0)
Phalange	**71** (100.0)	**2** (2.8)	**22** (31.0)	**29** (40.8)	**3** (4.2)	**0** (0.0)	**0** (0.0)	**1** (1.4)	**71** (4.9)
Total	**1456** (100.0)	**50** (3.4)	**735** (50.5)	**813** (55.8)	**63** (4.3)	**3** (0.2)	**20** (1.4)	**41** (2.8)	**1456** (100.0)

*Modification abbreviations: GE= Gastric etching, BN=Burining, PT= Pits, PF= Perforations, PC= Punctures, PCM= Possible cut marks, TP= Trampling and ExSf= Exfoliated surface.

Table 4.13: (Continued) The taphonomic modifications observed on each post-cranial specimen with the percentage of each modification reflecting the frequency of its occurrence in the assemblage (NISP values in **bold** and the NISP% in parentheses).

Elements	*RE	MgSt	SS	GM	EnCr	CrYs	WT	TM	Total
Vertebra	**31** (4.0)	**179** (23.4)	**765** (99.9)	**1** (0.1)	**728** (95.0)	**1** (0.1)	**2** (0.3)	**1** (0.1)	**766** (52.6)
Rib	**12** (9.8)	**18** (14.8)	**122** (100.0)	**0** (0.0)	**94** (77.0)	**1** (0.8)	**0** (0.0)	**0** (0.0)	**122** (8.4)
Scapula	**3** (11.1)	**10** (37.0)	**27** (100.0)	**0** (0.0)	**27** (100.0)	**0** (0.0)	**0** (0.0)	**0** (0.0)	**27** (1.9)
Humerus	**20** (28.2)	**33** (46.5)	**71** (100.0)	**0** (0.0)	**64** (90.1)	**0** (0.0)	**1** (1.4)	**0** (0.0)	**71** (4.9)
Radius	**1** (5.9)	**6** (35.3)	**16** (94.1)	**0** (0.0)	**15** (88.2)	**1** (5.9)	**0** (0.0)	**0** (0.0)	**17** (1.2)
Ulna	**3** (18.8)	**6** (37.5)	**16** (100.0)	**0** (0.0)	**15** (93.8)	**0** (0.0)	**0** (0.0)	**0** (0.0)	**16** (1.1)
Carpal	**1** (1.8)	**11** (19.6)	**56** (100.0)	**2** (3.6)	**55** (98.2)	**0** (0.0)	**0** (0.0)	**0** (0.0)	**56** (3.8)
Femur	**11** (15.9)	**26** (37.7)	**68** (98.6)	**0** (0.0)	**66** (95.7)	**0** (0.0)	**0** (0.0)	**0** (0.0)	**69** (4.7)
Patella	**3** (18.8)	**2** (12.5)	**16** (100.0)	**0** (0.0)	**10** (62.5)	**0** (0.0)	**0** (0.0)	**0** (0.0)	**16** (1.1)
Tibia	**9** (16.1)	**8** (14.3)	**56** (100.0)	**0** (0.0)	**47** (83.9)	**0** (0.0)	**2** (3.6)	**1** (1.8)	**56** (3.8)
Astragalus	**2** (10.0)	**3** (15.0)	**19** (95.0)	**0** (0.0)	**20** (100.0)	**0** (0.0)	**0** (0.0)	**0** (0.0)	**20** (1.4)
Calcaneus	**0** (0.0)	**3** (16.7)	**18** (100.0)	**0** (0.0)	**18** (100.0)	**1** (5.6)	**0** (0.0)	**0** (0.0)	**18** (1.2)
Metapodial	**7** (5.3)	**35** (26.7)	**131** (100.0)	**0** (0.0)	**131** (100.0)	**0** (0.0)	**2** (1.5)	**0** (0.0)	**131** (9.0)
Phalange	**8** (11.3)	**41** (57.7)	**71** (100.0)	**0** (0.0)	**56** (78.9)	**0** (0.0)	**1** (1.4)	**0** (0.0)	**71** (4.9)
Total	**111** (7.6)	**381** (26.2)	**1451** (99.7)	**3** (0.2)	**1346** (92.5)	**4** (0.3)	**8** (0.6)	**2** (0.1)	**1456** (100.0)

*Modification abbreviations: RE= Root etching, MgSt= Manganese staining, SS= Soil staining, , GM= Gnaw marks, EnCr= Encrustation, CrYs= Crystallisation, WT= Weathering and TM= Tooth marks.

It is evident that post-depositional alterations occur in both cranial and post-cranial assemblages, where some occur more than others. The issue of discoloured specimens will be investigated further to identify its significance in the assemblage. In chapter 3 section 3.6, discolouration, weathering, staining and burning are described because these processes can change the original colour of osseous materials. Table 4.14 demonstrates the range of colours perceived in the micromammal sample. Light yellow brown is the most prevalent and occurs on 1514 specimens (53.6%), while Dark yellow brown is the second most common colour with 714 specimens (25.3%). The least common colours in the assemblage

are Light brown (0.1%, n=2) and Medium grey (0.0%, n=1).

Table 4.14: The different colours observed in the sample (NISP values in bold and NISP percentage in parentheses).

*Discolouration	NISP %
Black	**6** (0.2)
Dark brown	**68** (2.4)
Dark green brown	**367** (13.0)
Dark green grey	**3** (0.1)
Dark yellow brown	**714** (25.3)
Dark yellow grey	**3** (0.1)
Light brown	**2** (0.1)
Light yellow	**6** (0.2)
Light yellow brown	**1514** (53.6)
Medium brown	**139** (4.9)
Medium grey	**1** (0.0)
Total	**2823** (100.0)

*Discolouration recorded as the overall colour of the bone.

The occurrence of weathering in the micromammal assemblage is low (1.7%, n=1367 crania Table 4.12 and 8%, n=1456 post-crania Table 4.13). The majority of specimens display characteristics of stage zero weathering while the remaining specimens show evidence of stage one and stage two weathering. The extent of weathering observed in the sample did not affect the colour of the bones in an extreme manner (e.g. sun-bleached). Manganese staining appears on the bones as small black spots and large patches on the bone, and it rarely blackens the bone completely in this assemblage (Figure A.23 and 26). Most of the specimens appeared to be stained by the brown clay matrix from which they were recovered. Due to the overlap of agents and processes that could could be responsible for the discolouration of the specimens further investigation is recommended.

Burning displays an inconsistent trend in the micromammal assemblage where it

has an intermediate occurrence in the cranial assemblage (32.3%, n=1367) and a low occurrence in the post-cranial assemblage (3.4%, n=1456). The percentage of burning according to the different stages (as discussed in chapter 3 section 3.6l) is shown in Table 4.15 and Figures A.19-A.26 (Appendix). The occurrence of burning is higher in the cranial assemblage (32.3 %, n=442) and very minimal as seen in the post-cranial assemblage (3.4%, n=50). Most of the bones 82.6% (N=2823) are classified in Stage 0 indicating no exposure to extreme temperatures. Stage 3 (Brown) is the second most common stage with 455 specimens (16.1%, N=2823). None of the specimens display characteristics for Stage 1 and Stage 5.

Table 4.15: The different stages and color indications of fire exposure (NISP values in **bold** and NISP percentage in parentheses).

Intensity	Colour	NISP (%)
Stage 0	Original (bone colour)	**2332** (82.6)
Stage 1	Yellow	**0** (0.0)
Stage 2	Red	**1** (0.0)
Stage 3	Brown	**455** (16.1)
Stage 3/4	Brown/Black	**7** (0.25)
Stage 4	Black	**6** (0.2)
Stage 4/5	Black/Grey	**1** (0.0)
Stage 5	Grey	**0** (0.0)
Localised	-	**21** (0.7)
Total		**2823** (100.0)

Unburnt bones seem to dominate the assemblage. To test whether there is a significant difference between the burnt and unburnt samples in the cranial and post-cranial assemblages, a chi-squared test was performed (Table 4.16). The chi-square statistic (X^2[df =1, N= 2823] = 409.18; p<0.00001) shows that there is a significant degree of difference between the two populations. The reason for this needs further investigation.

Table 4.16: A cross-tabulation of burnt and unburnt specimens and the cranial and post-cranial assemblages (NISP values in **bold**).

	Burnt	Unburnt	Total
Cranial	**442**	**925**	**1367**
Post-cranial	**50**	**1406**	**1456**
Total	**492**	**2331**	**2823**

Some modifications are more prevalent on post-crania than on crania, for example trampling, breakage, burning, possible cut marks and tooth marks. This emphasises the significance of analysing all skeletal elements because they provide vital information towards accumulation and site formation processes. The amount of breakage can be indicative of predation it is also subjected to fragmentation caused by trampling and compression after deposition in addition to predatory action. The other taphonomic modifications aid with site formation and post-depositional processes, which informs on the environmental conditions that occured.

4.4 Taxonomic composition

The units of quantification used to present the taxonomic data are shown in Table 4.17, for ease of reference see also Table 4.1. The micromammal assemblage consists of mice and rats (*Muridae*), shrews (*Soricidae*), bats (*Rhinolophidae*), golden moles (*Chrysochloridae*) which altogether make up 85% (n=1156) of the assemblage. The *Bathyergidae* specimens exclude the *Bathyergus suillus* (Cape dune mole-rat) as they are larger than 750g and it is usually included in the category of large mammal fauna (Skinner & Chimimba 2005; Bennett *et al*. 2009).

Table 4.17: Units of quantification (see also Table 4.1).

Units of Quantification	Number (N=)
MNE	2184
MNI	147
NISP	1367

The remaining analysed specimens that could not be taxonomically identified to

species are classified as unknown and comprise 15.1% (n= 206) of the assemblage. These specimens are loose incisors, bullae, skull bone fragments and zygomatic processes. Table 4.18 presents the NISP values of the families present in the assemblage.

Table 4.18: The taxonomic composition of the BOS three C3 micromammal crania assemblage (NISP in **bold** and the NISP% in parentheses). The families are listed according to Wilson & Reeder (2005).

Family	*Chrysochloridae*	*Muridae*	*Bathyergidae*	*Soricidae*	*Rhinolophidae*	Unknown	Total
NISP	**3** (0.2)	**925** (67.7)	**5** (0.4)	**209** (15.3)	**19** (1.4)	**206** (15.1)	**1367** (100.0)

The NISP and MNI values and percentages of the micromamamal species found in the assemblage are shown in Table 4.19. None of the *Chrysochloridae* specimens where identified to genus or species therefore they are excluded from the results of the taxonomic analysis. The most abundant species, using MNI values, are *Otomys irroratus* (26.5%, n=39), *Myosorex varius* (19.7%, n=29), *Crocidura flavescens* (12.2%, n= 18) and *Otomys laminatus* (8.2%, n =12). The least occurring taxa in the assemblage are *Georychus capensis, Mastomys coucha/natalensis, Mus minutoides*, *Otomys sp., Rhinolophus capensis* and *Suncus varilla* all of which occur at the same frequency (0.7%, n=1). The other taxa such as *Rhabdomys pumilio* (6.1%, n=9), *Rhinolophus clivosus* (4.8%, n=3), *Steatomys krebsii* (4.1%, n=6), *Suncus varilla/Crocidura cyanea* (4.1%, n=3) and *Otomys saundersiae* (3.4%, n=5) are present in the assemblage at a moderate to low frequency. Displaying both values also gives an indication of the significant differences observed when using the standard units of quantification. This is evident in the quantities of the vlei rats and the grand totals, where the NISP is 731 and the MNI is 147.

Table 4.19: The taxonomic composition of the assemblage (NISP and MNI values in **bold**, NISP% and MNI% in parentheses). The taxa are organised according to Wilson & Reeder (2005).

Taxa	Common Name	NISP (%)	MNI %
Mastomys coucha/natalensis	Southern multimammate mouse/Natal multimammate mouse	**2** (0.3)	**1** (0.7)
Myomyscus verreauxii	Verreaux's mouse	**14** (1.9)	**3** (2.0)
Mus minutoides	Pygmy mouse	**1** (0.1)	**1** (0.7)
Rhabdomys pumilio	Four-stripped grass mouse	**35** (4.8)	**9** (6.1)
Steatomys krebsii	Kreb's fat mouse	**8** (1.1)	**6** (4.1)
Acomys subspinosus	Cape spiny mouse	**9** (1.2)	**4** (2.7)
Otomys irroratus	Southern African vlei rat	**257** (35.2)	**39** (26.5)
Otomys saundersiae	Saunder's vlei rat	**62** (8.5)	**5** (3.4)
Otomys laminatus	Laminate vlei rat	**97** (13.3)	**12** (8.2)
Otomys sp.	Vlei rats	**31** (4.2)	**1** (0.7)
Georychus capensis	Cape mole-rat	**1** (0.1)	**1** (0.7)
Crocidura flavescens	Greater-red musk shrew	**59** (8.1)	**18** (12.2)
Crocidura cyanea	Reddish-grey musk shrew	**5** (0.7)	**3** (2.0)
Myosorex varius	Forest shrew	**124** (17.0)	**29** (19.7)
Suncus varilla	Lesser dwarf shrew	**1** (0.1)	**1** (0.7)
Suncus varilla/ Crocidura cyanea	Lesser dwarf shrew/ Reddish-grey musk shrew	**6** (0.8)	**6** (4.1)
Rhinolophus capensis	Cape horseshoe bat	**2** (0.3)	**1** (0.7)
Rhinolophus clivosus	Geoffroy's horseshoe bat	**17** (2.3)	**7** (4.8)
Total	-	**731** (100.0)	**147** (100.0)

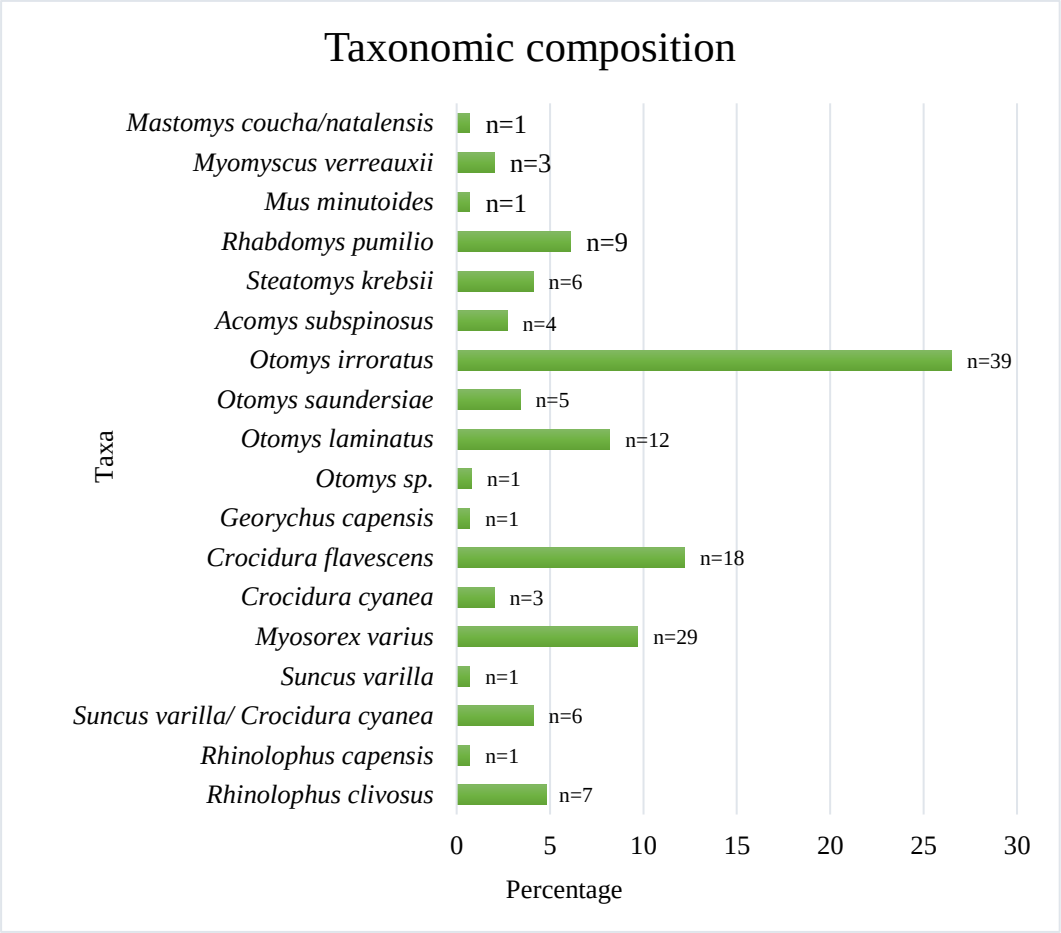


Figure 4.4: The taxonomic composition of the BOS Three micromammal assemblage (MNI%). The taxa are listed according to Wilson & Reeder (2005).

The taxonomic composition of the C3 assemblage is displayed in Figure 4.4. The MNI percentage values are used in Figure 4.4 which represents the presence of each taxon in the assemblage. This figure demonstrates the dominance of three taxa, *O.irroratus*, *M. varius* and *C. flavescens* and the least frequent taxa, *G. capensis, S. varilla, Otomys sp., Mus minutoides, R. capensis* and *M.coucha/natalensis*. Most of the taxa within the assemblage could be identified to species except for *Mastomys coucha/natalensis, Otomys sp.* and *Suncus varilla/Crocidura cyanea*. Some difficulties were encountered during the process of these species precluding identification with a high level of certainty. For example, although the size differences between the three vlei rats (*O. irroratus*, *O. laminatus* and *O. saundersiae*) are noticeable it is not the best criterion for recognising taxa. Another factor that added to the difficulty in distinguishing between the species is fragmentation. A few molars and single laminate teeth

were found to be fragmented that did not allow the estimation of the complete size. *Suncus varilla*/*Crocidura cyanea* were grouped together because they are similar in size and the absence of distinguishing features due to the fragmented nature of the four specimens from the BOS Three assemblage they could not be taxonomically distinguished. The challenge encountered with *Mastomys coucha*/*natalensis* is that these two species have very similar features (size, alveoli and dentition) and, as they are found in similar habitats (Skinner & Chimimba 2005), these species were grouped together.

4.5 Palaeoenvironmental indicators

The results pertaining to the palaeoenvironmental indicators are presented in this section. The habitat preferences of the taxa found in the C3 assemblage are presented first followed by the results and interpretations of the palaeoenvironmental indices. The results present in this section are used to understand what the palaeoecology was like during MIS 5d.

4.5.1 Habitat preference for recovered taxa

The taxa have been clustered into their family groups and ordered according to Wilson & Reeder (2005). Their abundance, habitat preferences and additional information are discussed in this section.

a) Muridae

There are nine species from the family *Muridae* present in the BOS Three micromammal assemblage namely, *Acomys subspinosus* (Cape spiny mouse), *Mastomys coucha* (Southern multimammate mouse)/*Mastomys coucha* (Southern multimammate mouse), *Mus minutoides* (Pygmy mouse), *Myomyscus verreauxii* (Verreaux's mouse), *Otomys irroratus* (Southern African vlei rat), *Otomys laminatus* (Laminate vlei rat), *Otomys saundersiae* (Saunders'vlei rat), *Rhabdomys pumilio* (Four-stripped grass mouse) and *Steatomys krebsii* (Krebs's fat mouse).

Acomys subspinosus (Cape spiny mouse) are found in areas with high altitudes and rocky areas with mountain slopes and ledges. They are a nocturnal species, as

they are active from sunset to just before dawn (Skinner & Chimimba 2005: 126; Dempster 2013: 233). *Mastomys coucha* (Southern multimammate mouse) are found in grasslands, savanna, fynbos and woodland, fields and human dwellings (Smithers 1983: 254; Leirs 2013a: 463; Cassola 2016). *Mastomys* natalensis (Natal multimammate mouse) occur in moist areas while *Mastomys coucha* prefers drier regions, therefore regions with more than 700mm of rainfall annually will rarely have *Mastomys coucha* present (Skinner & Chimimba 2005). These two species occur together (overlap) in the same habitats, thus it is difficult to tell the difference between the two (Leirs 2013a: 463). *Mastomys natalensis* have a broad habitat range and they are found in grasslands, thickets, with or without scrubs, trees and disturbed patches (Smithers 1983: 254; Leirs 2013b: 469). *Mus minutoides* are a small mouse species with a wide habitat range and are found in Grassland, Savanna and Fynbos biomes (Smithers 1983: 251; Skinner & Chimimba 2005: 145). They prefer vlei areas, grasslands, fallowlands, plantations, rocky habitats, riverine, suburban areas and grasslands that have been recently burned (Skinner & Chimimba 2005: 145; Monadjem 2013b: 484-485). They occur in regions with high elevations up to 2400m, and with rainfall ranging from 100mm to 1000m in the south west and Drakensberg and they are nocturnal (Smithers 1983: 252; Skinner & Chimimba 2005: 145). *Myomyscus verreauxii* are a taxon found in forests in the Knysna area, vlei areas with grass cover, damp meadows and take shelter in fallen trees (De Graaf 1981; Happold 2013b: 506). They have been found in forest margins, scrub on grassy hillsides and in riverine forests (Rautenbach & Nel 1980) and they are also nocturnal species (Skinner & Chimimba 2005: 154).

Otomys irroratus are a vlei rat that appears in broad habitat range i.e. on the fringes of swamps, damp soil vlei areas, grasslands, fynbos and along river beds (Davis 1973; Smithers 1983: 227). They are also found on ridge tops and grass covered hillsides near water sources in montane and sub-montane regions (Rowe-Rowe & Meester 1982; Taylor 2013a: 584). They are a crepuscular species however they can vary with their nocturnal and diurnal activity (Skinner & Chimimba 2005: 173). They are mostly terrestrial, but they are semi-aquatic, only

entering the water when it has no other choice (Skinner & Chimimba 2005: 173). *Otomys laminatus* are a vlei rat species present in coastal, grassland and submontane areas (Smithers 1983: 224; Skinner & Chimimba 2005: 169; Taylor 2013b: 586). Their habits are unknown except that they co-exist with *O. irroratus* and *O. angoniesis* (Skinner & Chimimba 2005: 169). *Otomys saundersiae* is a vlei rat species found on the drier upper slopes on hilly terrain and open grassland areas (Taylor 2013c: 588). *Rhabdomys pumilio* are a mouse species that occur in grassland areas with a lot of grass cover and has a broad habitat range and they are a crepuscular species (active during the day or night) (Skinner & Chimimba 2005: 131-132). They prefer habitats with forest, savanna, high grassveld, bush/scrub, dry river beds, karoo, succulent karoo and woodlands (Happold 2013c: 546). *Steatomys krebsii* is a mouse species that favours dry, sandy alluvium and sandy grassland and they are nocturnal (Smithers 1983: 295; Skinner & Chimimba 2005: 207). It has a broad range for habitats on loamy and sandy soils (Monadjem 2013a: 197).

b) Bathyergidae

Only one Bathyergid species was found in this assemblage, *Georychus capensis* (Cape mole-rat). This taxon is found in coastal sand dunes, savanna grasslands, sandy soils, montane and coastal fynbos, montane areas in the Eastern and Western Cape, forests sandy alluvium along rivers systems (Smithers 1983: 185; Skinner & Chimimba 2005: 89; Bennett 2013 663-664).

c) Soricidae

The four *Soricidae* taxa, *Crocidura cyanea* (Reddish-grey musk shrew), *Crocidura flavescens* (Greater red musk shrew), *Myosorex varius* (Forest shrew) and *Suncus varilla* (Lesser dwarf shrew) occur in the assemblage. *Crocidura cyanea* are a species found in a variety of habitats, showcasing its wide habitat range (Skinner & Chimimba 2005: 247). They occur in dry terrain with low rainfall, approximately less than 500mm (Meester 1963), in addition to areas with grass cover and wet vlei areas (Skinner & Chimimba 2005: 247; Baxter & Dippenaar 2013a: 69). They are found in fynbos and karroid scrub and savanna

within rocky landscapes (Skinner & Chimimba 2005: 247; Baxter & Dippenaar 2013a: 69). In KwaZulu Natal they are found in dry bushveld habitats and moist dense grassy habitats (Skinner & Chimimba 2005: 247). They are also found in montane forests (Rautenbach 1982) and in dense grass and scrub, in hedges near farmlands and damp areas (Meester 1963). This species is sporadically active during the day and at night and it is commonly found in *Tyto alba* pellets (Skinner & Chimimba 2005: 247).

Crocidura flavescens are a shrew species that can survive in a wide variety of vegetation types such as temperate and subtropical grassland, fynbos and montane, Afromontane, savanna, tropical forest and woodland (Skinner & Chimimba 2005: 248-249; Baxter & Dippenaar 2013b: 76). They prefer regions with high rainfall and moist conditions with a significant amount of vegetation cover (Skinner & Chimimba 2005: 249; Baxter & Dippenaar 2013b: 76) and they are also found in disturbed habitats (near buildings and infrastructure/built up areas) (Meester 1963; Baxter 1997; Taylor 1998b). This species is mostly active at night with sporadic incidences of activity during sunset and just before dawn (Baxter *et al*. 1979). *Myosorex varius* are a shrew species with a wide habitat range and are found in densely vegetated and moist environments (Smithers 1983: 5; Skinner & Chimimba 2005: 237). In the Western Cape, Northern Cape and Eastern Cape they are found in the coastal mountains with drier conditions, low rainfall and vegetation cover consisting of low succulent bushes (Skinner & Chimimba 2005: 237). They are diurnal during midwinter and during summer they are nocturnal (Brown *et al.* 1997). They remain less active during the cold periods of the night (Skinner & Chimimba 2005: 237). They occur in moist and dense grasslands, Savanna (Baxter & Dippenaar 2013c: 161) and forest (Rautenbach 1982). *Suncus varilla* (Lesser dwarf shrew) are a small shrew species found in open grassland regions (Lynch 1986), open savanna, coastal forests and suburban regions (Taylor 1998b).

d) Rhinolophidae

Two *Rhinolophidae* taxa, *Rhinolophus capensis* (Cape horseshoe bat) and

Rhinolophus clivosus (Geoffroy's Horseshoe bat) occur in the C3 micromammal assemblage. *Rhinolophus capensis* occupy a wide range of habitats, for example savanna, South West cape fynbos, Afromontane and coastal forests (Bernard 2013: 315). They are found in coastal caves in the Eastern and Western Cape of South Africa and their abundance is most probably dependent on the availability of food sources and shelter (Skinner & Chimimba 2005: 343; Bernard 2013: 315). They are also found in mine adits and caves and they can simultaneously occupy the same shelters as *Rhinolophus clivosus* (Skinner & Chimimba 2005: 343). They are nocturnal feeders because they leave their caves or shelters just before sunset and return just before sunrise (Skinner & Chimimba 2005: 343). The species *Rhinolophus clivosus* are also found in many habitats, such as deserts, forest fringes and mostly in savanna woodlands, montane forests, open grasslands, desert and semi-desert areas (Smithers 1983: 126; Skinner & Chimimba 2005: 339; Bernard & Happold 2013: 317). In Kwa Zulu Natal they are found in open grasslands and wooded habitats (Taylor 1998a). These bats are found roosting in mine adits, caves (favorably sandstone caves) and rock crevices (Skinner & Chimimba 2005: 339). They are nocturnal feeders because they leave their caves or shelters 30 minutes before sunset and return just before sunrise (Skinner & Chimimba 2005: 339).

4.5.2 Habitat preference summary

The strong presence of *Otomys irroratus* (that prefers densely vegetated regions with damp vlei areas), *Myosorex varius* and *Crocidura flavescens* (that both have a broad habitat range) provides an indication that the environment during MIS 5d had plenty of water, and that a mosaic of vegetation occurred close to the site. The presence of other taxa such as *Steatomys krebsii*, *Georychus capensis* and *Suncus varilla* (that prefer more open, dry and sandy substrate areas) indicate that the KRM region was dotted with small sections of different habitats creating a complex mosaic environment.

a) Diversity Indices

The Shannon-Wiener and Simpson's diversity indices are presented in Table 4.20

below. These indices are used to provide insight with regards to the micromammal community and the type of environment that may have existed during MIS 5d at KRM.

Table 4.20: The diversity indices for the C3 micromammal assemblage.

Indices	B	Lower	Upper
Species richness (S)	17	17	17
Individuals	146	146	146
Shannon-Wiener Index (H)	2.3	2.1	2.4
Shannon-Wiener Index of Evenness (J)	0.8	0.8	0.8
Simpson's Index for Dominance (D)	0.1	0.1	0.2
Simpson's Index for Diversity (1-D)	0.9	0.8	0.9

The species richness (S) –interchangeably NTAXA- for the micromammal assemblage is 17. This is the number of taxa present from the 146 specimens taxonomically identified in the cranial assemblage. The Shannon-Wiener diversity index is an estimation of the species abundance with values that lies between the range of 1.3 and 3.5 (as stated in Chapter 3 section 3.15b). The Shannon-Wiener index value is 2.3 which is a relatively moderate score for the sample. This means that the taxa heterogeneity is neither high nor low in relation to the sample size (Hammer *et al.* 2001: 156; Lyman 2008). The value for the Shannon-Wiener Evenness Index -Equitability Index- (0.8), being so close to one, means the assemblage has an even distribution of taxa. The Simpson's Dominance index is low with a value of 0.1. This suggests that there is no single taxon that dominates the sample, as shown in Figure 4.4, where there are three prominent taxa. An assemblage with a high dominance value is indicative of a stressed environment, because only one habitat type will thrive. The Simpson's Index for Diversity is

high (0.9) because it is very close to one. This value indicates that there is a high level of diversity in the assemblage. The diversity indices for the micromammal assemblage shows that the taxa in the sample are diverse and relatively evenly distributed. This correlates with the high number of taxa in the assemblage and the different vegetation types in which they thrive in.

b) The Taxonomic Habitat Index vegetation

The Taxonomic Habitat Index vegetation (THI_{veg}) is used to estimate values designated according to their preferred habitat ranges as shown in Table 4.21, as explained in Chapter 3 section 3.15f. The *Chiroptera* (*R. capensis* and *R. clivosus*) are excluded from the THI calculation in the research carried out by Nel (2013), because their habitats are not dependent on vegetation and substrate types like the other taxa (Skinner & Chimimba 2005). Specimens that could not be identified to species were not included in the THI calculation, such as *Otomys sp*. and those classified as unknown. The grouped taxa, i.e. *Mastomys coucha/Mastomys natalensis* and *Suncus varilla/Crocidura cyanea* were included in the THI calculation because they are identified to species but the similarities between species could not be distinguished. The THI_{veg} shows that grassland (0.27) is the most prominent vegetation type. As indicated by the THI_{veg}, savanna (0.10), rocky substrate (0.10), scrub (0.09) and sandy substrate (0.08) are the least prominent vegetation and substate types.

Table 4.21: The cumulative index values for each taxon identified in the assemblage according to the variety of vegetation and substrate types that are found near KRM (MNI values in **bold**). The taxa are listed according to Wilson & Reeder (2005).

MNI	Taxa	Fynbos	Grassland	Riverine/ Wetland (grass)	Rocky substrate	Sandy Substrate	Scrub	Woodland/ Forest	Savanna
1	*Mastomys coucha/ Mastomys natalensis*	0.05	0.35	-	-	-	0.10	0.20	0.30
3	*Myomyscus verreauxii*	-	0.25	0.25	-	-	0.25	0.25	-
1	*Mus minutoides*	0.10	0.30	0.30	0.10	-	0.05	0.05	0.10
9	*Rhabdomys pumilio*	-	0.35	0.20	-	-	0.30	0.10	0.05
6	*Steatomys krebsii*	-	0.15	-	-	0.35	0.20	-	0.30
4	*Acomys subspinosus*	0.15	-	-	0.60	0.25	-	-	-
39	*Otomys irroratus*	0.30	0.30	0.30	-	-	-	0.10	-
5	*Otomys saundersiae*	0.15	0.20	-	0.50	-	0.15	-	-
12	*Otomys laminatus*	0.10	0.40	0.40	-	-	-	0.10	-
1	Georychus capensis	0.20	0.20	-	-	0.30	-	0.10	0.20
18	*Crocidura flavescens*	0.25	0.25	-	-	-	-	0.25	0.25
3	*Crocidura cyanea*	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
29	*Myosorex varius*	0.15	0.25	0.35	-	-	0.05	0.15	0.05
1	*Suncus varilla*	-	0.80	0.05	-	-	-	0.15	-
6	*Suncus varilla/ Crocidura cyanea*	0.11	0.19	0.13	0.11	0.11	0.11	0.13	0.11
138	Column Total	1.69	4.12	2.11	1.44	1.14	1.34	1.71	1.49
Cumulative Index		0.11	0.27	0.14	0.10	0.08	0.09	0.11	0.10

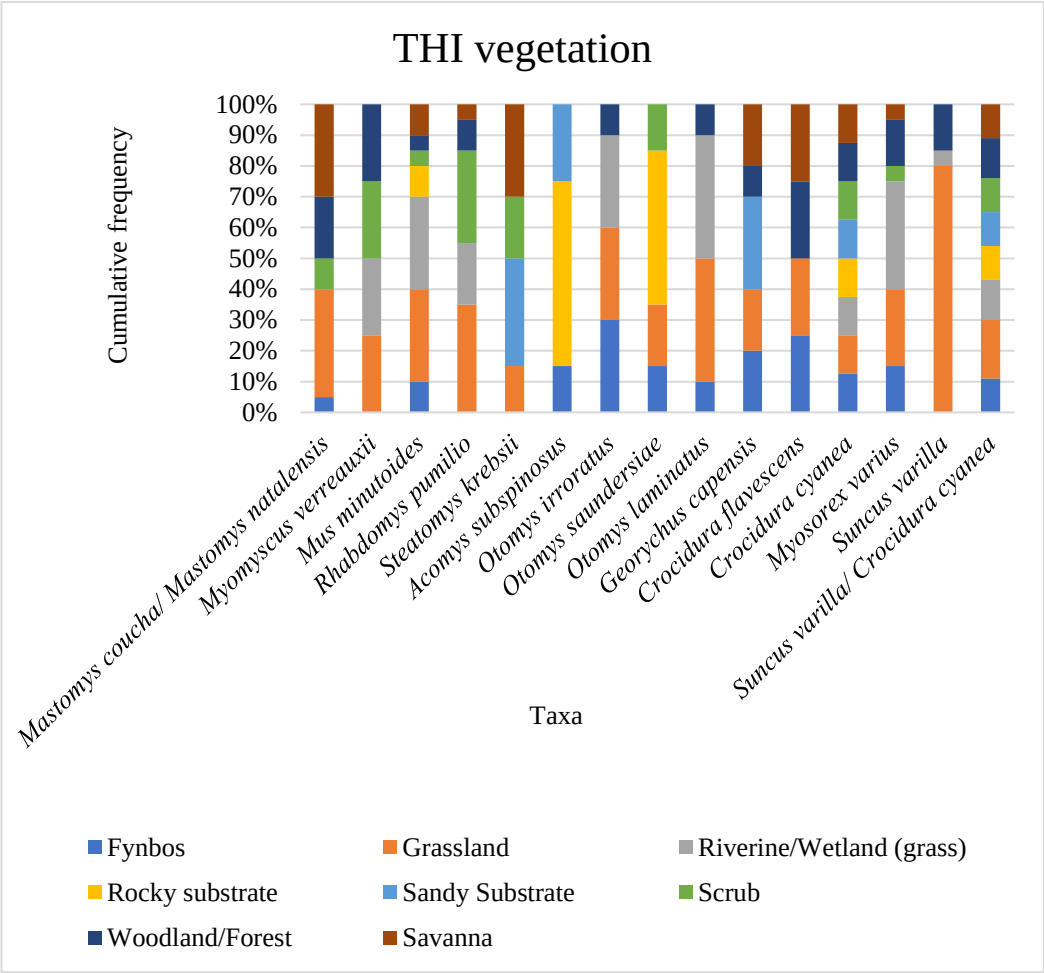


Figure 4.5: A graphical representation of the cumulative frequencies of the vegetation types according to each taxon. The taxa are organised according to Wilson & Reeder (2005).

Figure 4.5 demostrates the varieties of vegetation types preferred by each taxon in the assemblage. This representation shows that most of the species have broad habitat ranges. The most common habitat types are grassland, riverine/wetland (grass), woodland forest, scrub and savanna. The least common vegetation types preferred by the taxa are rocky substrate, savanna and sandy substrate. Although this is an indication of an environment composed of varieties of vegetation types over varying spatial ranges.

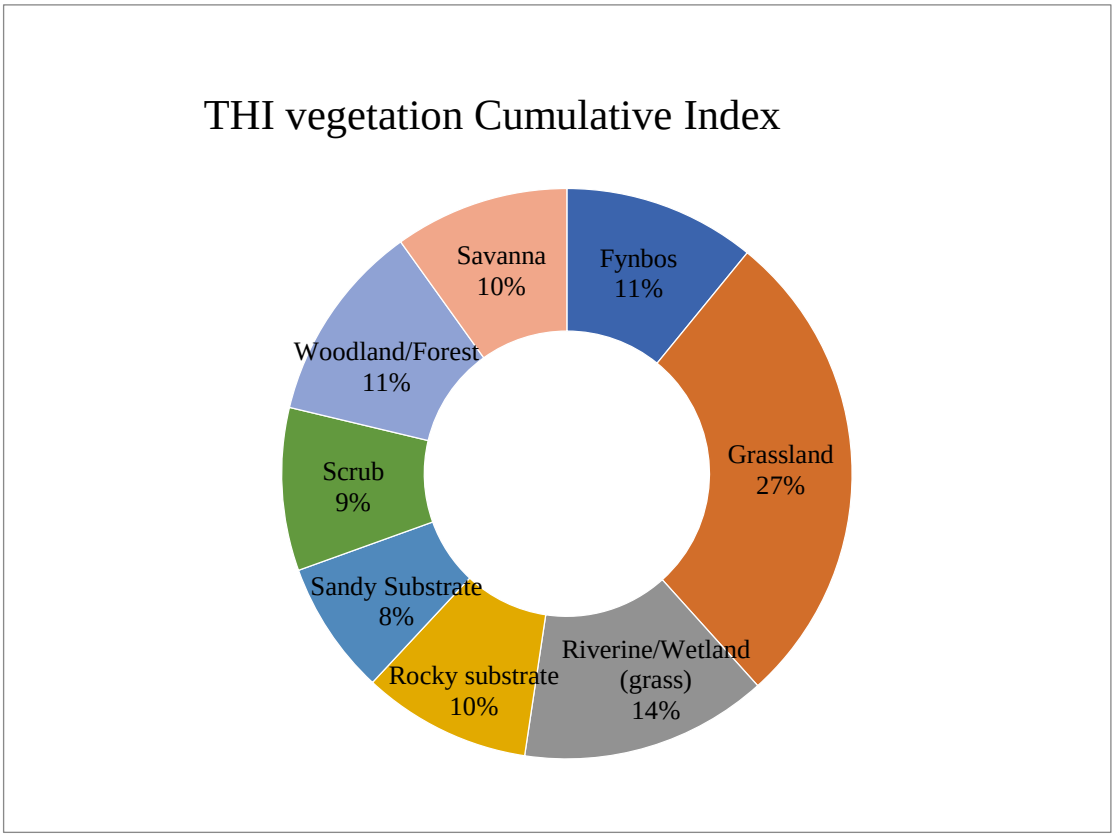


Figure 4.6: The distribution of habitat types according to the THI_{veg}.

Figure 4.6 shows the best represented vegetation types, where grassland (27%), woodland/forest (11%) and savanna (10%) are the most common. Grassland and woodland/forest have a pronounced distribution because a significant number of taxa can survive in these vegetation types, such as *O. irroratus, M. varius. C, flavescens* and *O. saundersiae* to name a few. The least represented habitat types are fynbos (11%), rocky substrate (10%), scrub (9%) and sandy substrate (8%). These habitat types are represented by taxa such as *G. capensis, S. krebsii* and *A. subspinosus*.

c) Taxonomic Habitat Index topography, vegetation, openness and dryness

The Taxonomic Habitat Index for topography, vegetation, openness and dryness (THI_{tvod}) is used to enhance the amount of detail extracted from the THI_{veg}. The values and cumulative index for the THI_{tvod} is shown in Table 4.22. The values for the THI_{tvod} are adapted from Nel (2013).

Table 4.22: The Cumulative Index values for the Taxonomic Habitat Index$_{tvod}$ (MNI values in **bold**). The taxa are listed according to Wilson & Reeder (2005).

		Topography			Vegetation			Openness		Dryness	
MNI	Species	Plains	Hillside	Waterside	Grass	Scrub	Trees/ bushes	Closed	Open	Dry	Moist
1	*Mastomys coucha/ Mastomys natalensis*	0.5	0.5	-	0.34	0.33	0.33	0.5	0.5	0.5	0.5
3	*Myomyscus verreauxii*	0.3	0.7	-	0.5	0.1	0.4	0.7	0.3	0.2	0.8
1	*Mus minutoides*	0.5	-	0.5	0.5	0.25	0.25	0.4	0.6	0.5	0.5
9	*Rhabdomys pumilio*	0.5	-	0.5	0.7	0.15	0.15	1	-	0.1	0.9
6	*Steatomys krebsii*	1	-	-	0.7	0.15	0.15	0.1	0.9	0.9	0.1
4	*Acomys subspinosus*	-	1	-	-	0.5	0.5	0.5	0.5	0.6	0.4
39	*Otomys irroratus*	-	0.5	0.5	0.8	0.2	-	1	-	-	1
5	*Otomys saundersiae*	-	1	-	0.5	0.5	-	0.2	0.8	0.7	0.3
12	*Otomys laminatus*	0.7	-	0.3	0.7	0.3	-	1	-	-	1
1	*Georychus capensis*	0.7	-	0.3	0.33	0.33	0.34	0.2	0.8	0.5	0.5
18	*Crocidura flavescens*	-	1	-	0.33	0.34	0.33	1	-	0.2	0.8
3	*Crocidura cyanea*	0.5	-	0.5	0.5	0.5	-	1	-	0.5	0.5
29	*Myosorex varius*	0.3	0.3	0.34	0.5	0.24	0.26	1	-	0.1	0.9
1	*Suncus varilla*	1	-	-	0.8	-	0.2	0.2	0.8	-	1
6	*Suncus varilla/ Crocidura cyanea*	1	-	-	0.34	0.33	0.33	0.5	0.5	0.5	0.5
138	Total	7	5	2.94	7.54	4.22	3.24	9.3	5.7	5.3	9.7
	Cumulative index	0.47	0.33	0.20	0.50	0.28	0.22	0.62	0.38	0.35	0.65

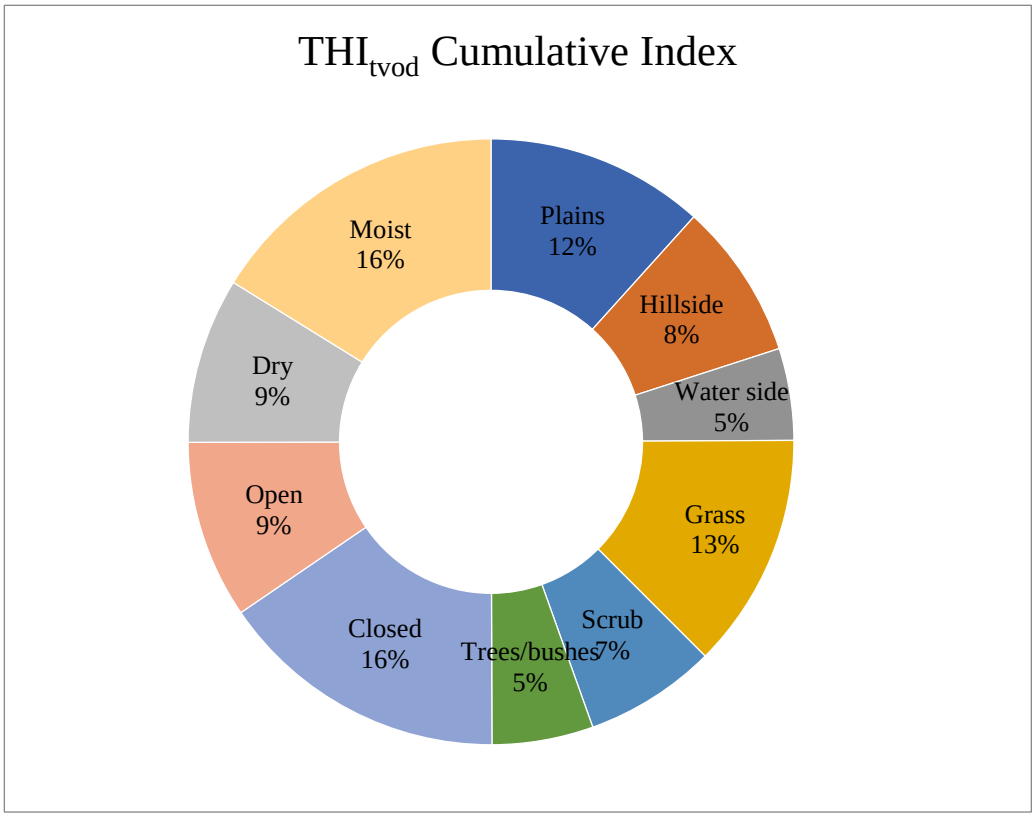


Figure 4.7: The characteristics of the environment according to the THI_{tvod}.

Figure 4.7 shows the distribution of environmental characteristics according to the THI_{tvod}. In the category of topography, plains (12%) and hillside (8%) are commonly favoured. In terms of vegetation, grass (13%) is a highly favoured vegetation type as opposed to the least frequent trees/bushes (5%) in the vegetation category. The last two categories openness and dryness show that the environment was closed (16%) with high levels of moisture (16%) (precipitation). This index demonstrates that the environment at KRM had moist conditions with densely vegetated areas mostly covered with grass along the gentle gradient.

4.6 Summary of results

In this chapter it has been shown that all of the micromammal specimens show evidence of light and moderate digestion. Breakage in the assemblage is moderate with most of the complete specimens being crania and post-crania being the least

complete. The proportions of crania and post-crania in the assemblage suggest *T. alba* and *B. africanus* as the accumulators. Encrustation and soil staining are the types of modifications occurring most frequently. This shows a high occurrence of water, which enabled the processes of staining and calcium carbonate precipitate to alter bones. Even though the occurrence of burning is low (stage 3 (brown) and localised burning), the chi-square test suggests that its presence in the assemblage is significant. The most frequent taxa in the assemblage include *O. irroratus, M. varius and C. flavescens*. This finding indicates a strong presence of taxa that prefer densely vegetated and moisture enriched environment. However, two of the dominant taxa identified also indicate a broad habitat tolerance. The diversity indices indicate an evenly distributed heterogenous micromammal community with a variety of vegetation types. The Taxonomic Habitat Indices show a strong indication of closed, grassy plains with ample precipitation. The overall indication of the environment at KRM during MIS 5d is an impression of mosaic environment with bodies of standing water such as vleis.

Chapter 5: Discussion

5.1 Introduction

This chapter consists of interpretations of the findings presented in chapter 4, a discussion of the findings in relation to Blombos Cave and Pinnacle Point Cave 13B as it addresses the aims and hypotheses stated in Chapter 1. The research question in this study involved identifying the accumulator of the micromammal assemblage from the BOS Three layer at Klasies River. The research question also entailed which palaeoenvironmental conditions occurred during the deposition of the BOS Three layer dated to ~110ka (MIS 5d). Five aims were set to answer the research question; to undertake a taphonomic analysis of the cranial and post-cranial specimens; to carry out a taxonomic analysis of the cranial elements; to prove or disprove the hypotheses; to use taxonomic results and indices to infer the palaeoenvironmental conditions at KRM and to compare the inferred palaeoenvironmental conditions at KRM with those from the contemporaneous coastal assemblages at Blombos Cave and Pinnacle Point Cave 13B. The interpretation and discussion of the results begins with identifying the accumulator of the assemblage (Section 5.2) and the post-depositional modifications indicative of the site formation processes in Cave 1 (Section 5.3). The palaeoenvironmental conditions at main site (Section 5.4) are discussed then the palaeoenvironmental implications relative to the southern Cape (Section 5.5) are addressed. The discussion chapter concludes with a brief summary of the interpretations drawn from the study and implications of the environment (Section 5.6) during MIS 5d.

5.2. Accumulator of the BOS Three assemblage

The first hypothesis states that the assemblage was accumulated by *Tyto alba* (Barn owl) and *Bubo Africanus* (Spotted eagle-owl). These two owl species have been suggested as the accumulators of the micromammal assemblage based on the analysis of the ecology, broad distribution (in southern Africa) and diet breadth of the potential accumulators and the taphonomic analysis of the micromammal assemblages (Avery 1982, 1987; Andrews 1990; Hockey *et al.* 2005; Nel 2013;

Nel *et al.* 2018). These predators cause the least amount of modification on the micromammal remains (Table A.2). These owl taxa are co-occuring and territorial of their nested sites towards other predators and they are known to roost in the same place throughout their lifespan (Andrews 1990; Avery 2002; Kopij *et al.* 2014). *T. alba* are known to have a broad dietary range, of varying sizes and availability but mostly preying on the most abundant micromammal species (Andrews 1990; Kopij *et al.* 2014). They may roost in areas close to humans (Andrews 1990); therefore it is likely that they roosted at KRM while it was occupied by AMH. The dietary breadth of *B. africanus* is similar to that of *T. alba* with the inclusion of non-murid rodents, insects and birds (Andrews 1990; Kopij *et al.* 2014). The hypothesis is confirmed, as the BOS Three assemblage showed a significant number of specimens displaying light digestion and a considerable amount with moderate digestion. The heavy and extreme digestion categories only occurred on a small number of specimens. This trend was observed in the cranial and post-cranial assemblage. A few punctures were recorded in both assemblages and these could be associated with predatory action. Depending on the predator the modifications could be caused by teeth (mammalian carnivores) and beak or claw marks (predatory birds) (Horwitz & Smith 1988; Andrews & Fernández-Jalvo 2012). Tooth marks are infrequent and appear on one tibia and one vertebra and they may be the result of a small mammalian carnivore. Tooth marks on micromammals are not common unless inflicted on by a small carnivores, anything larger would disintegrate the bone (Andrews 1990).

Specimens with light and moderate digestion preserve well in the archaeological record when compared to specimens with heavy and extreme digestion. This is because specimens with higher levels of digestion are weakened by gastric acid, thus compromising the original strength which makes the bones more susceptible to breakage. The presence of heavy and extreme digestion may suggest different predators (like Kestrels and mammalian carnivores) had occupied the site at some point (Table A.2). Andrews' (1990) notes that micromammals consumed by juvenile owls (or just *Tyto alba*) display extreme digestion. Therefore, it might also be that the presence of a few specimens with extreme and heavy digestion

were introduced by juvenile owls and not other raptors or mammalian carnivores.

The incisors and long bones show similar patterns of digestion (light and moderate digestion). The chi-squared test shows that there is no significant difference between light and moderate digestion on the loose incisors and on the long bones. This confirms that both long bones and loose incisors are ideal for digestion analyses because they reflect the same trend throughout the assemblage (Andrews 1990). *Tyto alba* (Barn owl) is associated with light digestion and *Bubo africanus* (Spotted eagle-owl) is associated with moderate digestion.

Breakage is more prevalent in the cranial assemblage than in the post-cranial assemblage. A substantial number of specimens in the cranial assemblage are fragmented and correlate with category three modifications (Table A.2). None of the most fragile cranial elements (bullae, cranial bones and zygomatic processes) are complete. Loose molars and incisors are the most commonly complete cranial elements in the assemblage. These elements are most likely to preserve well in deposits because they are the most robust elements. The post-cranial assemblage has more complete specimens than the cranial assemblage. This higher degree of breakage of the cranial assemblage is most probably caused but the hunting behaviour of the predator. Birds of prey deliver a fatal blow to the head of their prey before consumption (Andrews 1990). The impact of the deathblow and consumption of the prey increase the degree of damage to the cranial elements. The level of breakage in the assemblage may not only be attributed to damage caused by the predator but also due to other post-depositional processes (Fernández-Jalvo *et al.* 2016).

SEA data show that crania are the most abundant skeletal elements in the assemblage and post-crania are the least abundant elements. The predators associated with post-cranial digestion are the same as those associated with the cranial elements. Where *T. alba* is associated with light digestion and *B. africanus* is associated with moderate digestion (Table A.2). The low ratio of the post-cranial/cranial proportion reflects the same results as the SEA proportion where there are more crania in relation to post-crania. The preferential loss of elements is low as well which reiterates the proportion of the post-cranial to cranial elements.

The value of the distal element loss is moderate; this is an indication of the overall breakage of the remains. These proportions are a representation of the hunting behaviour of the accumulators and post-depositional preservation of the skeletal elements. In this regard, if predators prefer to decapitate their prey and consume the rest of the carcass then the value of post-crania would be higher than the crania and it would reflect in the SEA calculation as well. The distal element loss shows that preservation is still fairly good because breakage is present. The BOS Three assemblage shows a trend of predators consuming the prey whole instead of discarding the head of the prey. These proportions substantiate the characteristics of the BOS Three sample being a predatory assemblage because the characteristics of the assemblage correlate with the predator modifications in Table A.2.

The mortality profile reflects a high prevalence of juvenile micromammals and a low frequency of adult micromammals in the assemblage. This can be attributed to the predator's choice of prey, because juvenile micromammals are most likely to be more vulnerable than adults (Longland & Jenkins 1987; Wolff 2007). The mortality profile of a large percentage of the specimens in the sample could not be determined due to the level of fragmentation of the remains. A chi-squared test was undertaken to determine whether cranials and post-cranials preserve differently with respect to adults and juveniles. The test showed a significant association between these variables. This confirms that the accumulators were selective of younger more vulnerable prey, rather than adult micromammals that are more aware of predator risk (Longland & Jenkins 1987; Wolff 2007).

The degrees of digestion present on the incisors, humeri and femurs from KRM, BBC and PP13B (where available) are compared to discern trends of the identified accumulators. The levels of digestion on the isolated incisors from the MIS 5 levels from KRM from the previous micromammal study undertaken by Nel (2013) and at BBC (Nel 2013) are shown in Table A.3 (Appendix). All the isolated incisors from the BOS Three assemblage show evidence of digestion, while the other assemblages from KRM and BBC have specimens that do not have gastric etching. Most of the isolated incisors do not exhibit digestion in the

MSA I and MSA II Lower units at KRM and in the Pre-M3 and M3 phases at BBC.

The articulated incisors shown in Table A.4 (Appendix) show the same trend, but it should be noted that articulated incisors will hardly show a high frequency of digestion because they are protected by the mandibular and maxillary bones. There is an observed difference in the frequency of the absence of digestion and light digestion. This could be a result of the different modifications that are used to recognise gastric etching on skeletal elements. Another reason for this could be that identifying the magnitude of digestion is subjective even though the standard criteria are used (Andrews 1990). It is evident that the most common stages of gastric etching in the KRM and BBC units are light and moderate digestion. Heavy and extreme digestion are the least common digestion categories in all KRM and BBC units. This trend shows that it is most likely that the accumulators (*T. alba* and *B. africanus*) from both southern Cape coastal sites are the same.

Table 5.1 shows digestion on all incisors (articulated and loose) from the KRM, BBC and PP13B units. The incisors from the PP13B units show mostly light digestion, with some moderate and very few with heavy digestion. A small portion of the incisors display no evidence of digestion and none of the incisors in either of the PP13B units display extreme digestion. The BBC units demonstrate a different pattern from PP13B, where most of the incisors do not have gastric etching. Light digestion is common in the BBC units followed by moderate digestion and a few specimens with heavy and extreme digestion. The KRM MSA II Lower units have more incisors with no gastric etching and few displaying heavy and extreme digestion. The most common categories of digestion are light and moderate which occurs on all incisors. The MSA I and BOS Three assemblage show similarities with light digestion being the most frequent type of digestion present. There are no incisors in the MSA I units that exhibit traces of moderate or extreme digestion. The BOS Three layers show moderate digestion as a common category and fewer specimens with extreme digestion. Overall, the most prevalent degrees of gastric etching on all of the incisors are light and moderate and the least frequent are heavy and extreme digestion. The presence of

extreme digestion suggests that other than owl species, raptors were also present and consuming micromammals. In terms of incisor digestion, it is most likely that all three coastal sites share the same predator species, i.e. *T. alba* (light digestion) and *B. africanus* (moderate digestion). The low occurrence of specimens with higher degrees of gastric etching is attributed to further post-depositional breakage and poor preservation.

Table 5.1: The degrees of digestion on all incisors from KRM, BBC and PP13B units (NISP values in **bold** and NISP% in parentheses).

	KRM MSA I	KRM MSA II Lower			KRM BOS Three	BBC Pre-M3 and M3 phase			PP13B				
Digestion	Z44 SCB & SAS	Y44 SM5	Y44 CL & BS	Y45 YS1	C3	CPA	CQ	CR	LB Sand 1	DB Sand 3	LBG Sand 1	Roof Spall Upper	Roof Spall Lower
None	-	**62** (62.0)	**30** (48.4)	**45** (51.7)	**0** (0.0)	**93** (42.9)	**180** (60.2)	**180** (63.5)	**11** (32.0)	**10** (30.0)	**50** (33.0)	**4** (44.4)	**1** (4.5)
Light	**8** (18.2)	**26** (26.0)	**24** (38.7)	**38** (43.7)	**189** (78.8)	**76** (35.0)	**84** (28.1)	**45** (26.5)	**21** (62.0)	**20** (61.0)	**83** (55.0)	**3** (33.3)	**21** (95.5)
Moderate	**0** (0.0)	**12** (12.0)	**6** (9.7)	**3** (3.4)	**38** (15.8)	**40** (18.4)	**18** (6.0)	**10** (5.9)	**1** (3.0)	**3** (9.0)	**15** (10.0)	**0** (0.0)	**0** (0.0)
Heavy	**1** (2.3)	**0** (0.0)	**2** (3.2)	**0** (0.0)	**11** (4.6)	**5** (2.3)	**10** (3.3)	**6** (3.5)	**1** (3.0)	**0** (0.0)	**3** (2.0)	**2** (22.2)	**0** (0.0)
Extreme	**0** (0.0)	**0** (0.0)	**0** (0.0)	**1** (1.1)	**2** (0.8)	**3** (1.4)	**7** (2.3)	**1** (0.6)	**0.0** (0)	**0** (0.0)	**0** (0.0)	**0** (0.0)	**0** (0.0)
Total digested	**9** (20.5)	**38** (38.0)	**32** (51.6)	**42** (47.1)	**240** (100.0)	**124** (55.8)	**119** (37.5)	**62** (35.9)	**23** (68.0)	**23** (70.0)	**101** (67.0)	**5** (55.5)	**21** (95.5)
Number analysed	**44** (100.0)	**100** (100.0)	**62** (100.0)	**87** (100.0)	**240** (100.0)	**217** (100.0)	**299** (100.0)	**170** (100.0)	**34** (100.0)	**33** (100.0)	**151** (100.0)	**9** (100.0)	**22** (100.0)

The digestion on the humeri and femurs for the KRM and BBC units are shown in Table 5.2. The categories, “presence and absence of digestion” is used following Nel (2013) to maintain comparative consistency. The MSA I units show higher frequencies of humeri with digestion and lower frequencies of humeri with no digestion. The MSA II Lower units show a similar trend where the majority of the humeri do not have digestion and a small percentage of the species display gastric etching. The BOS Three assemblage has digestion present on all humeri.

Most of the BBC units have a higher occurrence of digested humeri than non-digested humeri. This is a similar trend to the MSA I sample. Digestion on the femurs for the KRM and BBC post-cranial assemblages is also displayed in Table 5.2. The femurs from all the KRM and BBC units show a higher occurrence of digestion than non-digestion which is a different trend demonstrated by the dental assemblage. A better assessment of digestion on the humeri and femurs and the predators responsible for the accumulation could have been undertaken if the digestion categories were included in the table. However based on the data presented in Table 5.2, digestion is more evident on the femurs than on the humeri. This could suggest that femurs are more sensitive to digestion damage than humeri. The total number of digestion on crania is high with a few incisors showing evidence of non-digestion. The post-crania almost show an unwavering trend of digestion. This shows that humeri and femurs are ideal for identifying traces of digestion in a micromammal assemblage.

Table 5.2: A comparison of the presence and absence of digestion observed on humeri and femurs from the KRM and BBC units (NISP values in **bold** and NISP% in parentheses). The data for PP13B humeri is unavailable.

	KRM MSA I		KRM MSA II Lower						KRM BOS Three		BBC Pre-M3 and M3 phase					
Units	Z44 SCB & SAS		Y44 SM5		Y44 CL & BS		Y45 YS1		C3		CPA		CQ		CR	
Elements	HM	FM	HM	FM	HM	FM	HM	FM	HM	FM	HM	FM	HM	FM	HM	FM
No digestion	**11** (29.0)	**10** (25.0)	**22** (59.5)	**13** (41.9)	**7** (53.9)	**3** (42.9)	**8** (34.8)	**7** (23.3)	**0** (0.0)	**0** (0.0)	**17** (22.4)	**9** (12.7)	**60** (41.1)	**10** (11.1)	**31** (41.3)	**4** (6.5)
Digested	**27** (71.0)	**30** (75.0)	**15** (40.5)	**18** (58.1)	**6** (46.2)	**4** (57.1)	**15** (65.2)	**23** (76.7)	**71** (100.0)	**69** (100.0)	**59** (77.6)	**62** (87.3)	**86** (58.9)	**80** (88.9)	**44** (58.7)	**58** (93.5)
Number analysed	**38** 100.0)	**40** (100.0)	**37** (100.0)	**31** (100.0)	**13** (100.0)	**7** (100.0)	**23** (100.0)	**30** (100.0)	**71** (100.0)	**69** (100.0)	**76** (100.0)	**71** (100.0)	**146** (100.0)	**90** (100.0)	**75** (100.0)	**62** (100.0)

*Codes used in the table: HM= Humeri and FM= Femurs.

5.3 The taphonomy of the BOS Three assemblage and site formation processes

The second hypothesis referring to site formation states the following: The assemblage will not demonstrate human accumulation and consumption of micromammals during the stipulated time frame. This hypothesis was based on previous research of KRM where AMH are more likely to pursue large fauna rather than micromammals. Although human subsistence of micromammals (<750g) has not been investigated at KRM or in the southern Cape. It may be an interesting venture to pursue as it will validate the exploitation of other fauna resources.

The post-depositional modifications recorded in the assemblage indicative of site formation processes are encrustation, discolouration, burning, weathering, root etching, water logging and possible cut marks and tooth marks. It was found that encrustation and soil staining are the most prevalent post-depositional modifications in both cranial and post-cranial assemblages. The type of encrustation that occurred frequently is that of compacted sediment and tufa (calcium carbonate precipitate) strongly adhered to the bones. There is a high concentration of speleothem material in this layer (Wurz, pers comm. 2019). Crystal formation on deposited bones is a result of a chemical reaction (calcium carbonate precipitate and gypsum) of the bone with the minerals in the soil (Behrensmeyer 1978). No gypsum formation was observed on the crania, but it was present in the post-cranial assemblage. This could be an indication of alkaline soil at the site, but the level of alkalinity might be low. This is because only a few specimens have gypsum formed on the bone surface. The presence of acidic soil would result in low preservation of the deposited archaeological material.

Soil staining is a very common modification; the bones show a high level of discolouration, mostly shades of brown, in both cranial and post-cranial assemblages. The types of discolouration in the assemblages are caused by burning, manganese staining and soil staining and none caused by weathering. The agents of staining are related to the minerals present in the soil matrix in

which the remains were deposited, the presence of water and perhaps also the presence of ochre (Marín-Arroyo *et al*. 2008, 2014; Stathopoulou *et al.* 2013; Stathopoulou *et al.* 2019). The colours of the two ochre pieces recovered from the BOS Three layer are brown-red and bright red, and they could be the agents of discolouration on the micromammal remains (Culey *et al*. 2019). The soil matrix in which the archaeological materials were deposited is clay, which suggests high levels of saturation. The presence of water is most likely the main agent of discolouration in the assemblage. There are a few specimens that have surfaces associated with water logging (exfoliated surface). This modification, as observed in the assemblage, shows cortical surfaces which are slightly dull and rough with some distortion. In some cases, a small portion of the bone would exhibit an exfoliated surface while the rest of the cortical surface is unaffected. The type of modification suggests that only some parts of the bones were exposed to water (Marín-Arroyo *et al*. 2014). The presence of some bones with this type of modification further suggests the significance of water present at the site. The discolouration of the bones in the assemblage occurs as follows; small black spots or light black patches on the cortical surface and complete brown discolouration of the entire bone. Only a few specimens have complete manganese staining (black) Figure A.23 and A.26 (Appendix). The cause of different variations of brown (dark and light) is not known for certain. It can be suggested that a discolouration present on the remains could be caused by a combination of manganese, iron (Fe), waterlogging and ochre staining, because these modifications are superimposed on some specimens. Furthermore, remains that do not exhibit staining and those that do could be an indication of different depositional microenvironments (Turner *et al.* 2018).

Some of the brown colouration is related to burning. Burning is mostly present on the mandible, maxillae, molars and incisors in the C3 assemblage. This correlates with the pattern of burning found on micromammals that are captured and roasted over a fire or baked in hot coals (Henshilwood 1997; Badenhorst 2008). The post-cranial extremities such as phalanges are expected to display the most heat damage because they are the bony parts and have thin skin and fur coverage (Henshilwood 1997; Badenhorst 2008). In the BOS Three post-cranial assemblage

a low degree of burning occurs on the vertebra, metapodials and ribs (Table 4.13). This trend does not correlate with the pattern of scorched extremities as stated by Henshilwood (1997) and Badenhorst (2008). It is possible that extremities could be lost during the recovery process, and if they were extremely burnt then the preservation of those elements could be the issue. The recovery methods used during Wurz excavations at KRM are suitable for retrieving micromammal remains where the remains are water screened (2mm and 0.3mm sieve sizes) and gently agitated to release the materials from the dense clay matrix (Wurz *et al.* 2018). The ethnographic observation followed through by Henshilwood (1997) indicated that none of the post-cranial elements exhibit scorching. Therefore, it is possible that AMH's consumed micromammals because of the presence of burnt cranial bones (after Henshilwood (1997) and Badenhorst (2008)). On the other hand, all elements displayed some degree of gastric etching and bone fragmentation which closely relates to birds of prey (Andrews 1990) being the predators, rather than humans.

If some of the micromammal remains were consumed by AMH's, then two possible scenarios would occur. The humans would process the micromammals and discard the bones after consuming the flesh. Which would display some taphonomic modifications (i.e. burning, tooth marks). The other scenario is if these humans consumed the flesh and bones, gastric etching and bone breakage would occur. In this case, destructive modification such as burning, digestion and fragmentation would be extreme (category 4 digestion and category 5 predators associated with raptors and mammalian carnivores) (Table A.2) (Andrews 1990). Evidence of predators with destructive processes (mastication, digestion and breakage) may not be visible in the archaeological record. Further research dedicated to actualistic investigations of the chaîne opératoire of AMH's subsistence of micromammals smaller than *B. suillus* is required. As well as deciphering the differences of faunal remains consumed and (where possible) digested by humans. If it turns out that humans did consume micromammals, further inferences on complex behaviour may be made, as discussed in Chapter 2. The occurrence of possible cut marks in the post-cranial assemblage occurs on two carpals and one vertebra (Table 4.13) this too requires further research in this

regard.

The last few taphonomic modifications, weathering, trampling and root etching are interpreted as they occurred the least in the assemblage. The first two stages of weathering occur in the assemblage, but it occurs in low frequencies. The low occurrence of weathering in the assemblage could be associated with the bones being encased in owl pellets, therefore shielding the remains from weathering conditions (Andrews 1990). Weathering would occur once the bones are exposed due to the disintegration of the owl pellet (Andrews 1990). This is an indication of the bones not being exposed to the natural elements for extended periods of time. Trampling is only observed in the post-cranial assemblage at low frequencies and probably occurred when owls walked over the pellets whilst in the nest (Andrews 1990). Alternatively, other micromammals may have trampled over the scattered remains because larger fauna would further fragment or destroy the bones upon impact. Root etching is moderately common in the cranial assemblage and this is an indication of plant activity. The type of root etching observed is mostly individual linear marks as opposed to a cluttered network etched onto the bone surface. This suggests that the soil was not densely vegetated, or that the bones remained on the ground surface for a short duration before being covered in soil with active vegetation (Andrews 1990).

The taphonomic modifications presented on the BOS Three micromammal assemblage draw on different aspects. The published materials from BBC and PP13B present data focusing on digestion to determine the accumulator and the variety of taxa to make inferences on the palaeoenvironment. Additional information from these two sites with regards to site formation processes have probably been conducted but not published. This limits the scope of comparisons that could be made between all three coastal southern Cape sites.

5.4 The palaeoenvironment at KRM during MIS 5d

The third hypothesis regarding the palaeoenvironment at KRM states that the environment was densely vegetated, grassy and warm with moderate moisture conditions. Micromammal research at KRM has been undertaken on materials

recovered from different excavations and cave locations at main site (Avery 1987; Nel 2013; Maringa 2017; Nel *et al*. 2018). Nel (2013: 332) found that for deposits broadly contemporaneous with the BOS Three assemblage studied here, the palaeoenvironment for the MSA I units was open with drier conditions compared to the MSA II Lower and Upper units. The MSA II units increased in vegetation density and moisture availability (Nel 2013: 387). The palaeoenvironment as indicated by the contemporaneous micromammal assemblages (Nel *et al.* 2018: 17) showed a grassy environment with warm and dry conditions. These palaeoenvironmental inferences correspond to the palaeoenvironmental conditions inferred by Avery (1987). Applying similar research methods with some additions, as discussed in chapter 3, empowers high quality research and a continuation of palaeoenvironmental inferences can be attained.

A total of 17 taxa were recovered from the BOS Three assemblage, where the prevalence for one vlei rat species, *O. irroratus*, with specific habitat range and two shrew species, *M. varius* and *C. flavescens*, that have broad habitat ranges is observed. These dominant taxa are indicative of grasslands, forests and dense vegetation. The dominance of single taxa in the assemblage would directly reflect a simple environment and very low diversity (Cuenca-Bescós *et al*. 2009), however this is not the case in the BOS Three assemblage. The diversity indices show that micromammal communities are generally heterogeneous, stated simply the different variety of taxa are evenly distributed within the micromammal community. Therefore, the BOS Three assemblage exhibits a diverse micromammal community with a complex combination and distribution of vegetation structures (Cuenca-Bescós *et al*. 2009) in the KRM region.

The distribution of vegetation as demonstrated by the THI_{veg} reflects the estimated distribution of recovered taxa. The common trend in the habitat preferences of the recovered taxa shows that these taxa successfully co-existed within the Klasies River landscape (Figure 4.5). *O. irroratus, M. varius* and *C. flavescens* are the dominant species and their habitat preferences reflect the prominence of grasslands, wetland and fynbos vegetation in the KRM region. Other taxa such as *O. laminatus, C. cyanea, M. minutoides* and *R. pumilio* reinforce the dominance of

the three main vegetation types. Most of the least frequent taxa, *G. capensis, S. varilla, M. coucha/natalensis* and *M. minutoides* can exist in some of the dominant habitat types but they prefer the least prevalent vegetation and substrate types. The least frequent taxa may suggest that their preferential vegetation types were declining while taxa that thrive in closed and water rich environments expanded. This could suggest a transition from warm, sandy and dry environmental conditions associated with MIS 5e, as indicated by Nel *et al*. (2018) for the MSA I deposits, to the cooler, more closed wet environmental conditions associated with MIS 5d. At particular times aseasonal precipitation was inferred for the lower layers near the base of the sequence at KRM (Avery 1987: 416). In addition, Avery (1987) found that a closed environment occurred during the early and late samples from the MSA II and MSA III phases and an open environment during the MSA I and Howieson's Poort phases. The vegetation density stated by Avery (1987) correlates with the vegetation patterns indicated by the large fauna analysed by Klein (1976).

Micromammal taxa with more restricted habitat preferences like *A. subspinosus* and *S. varilla* are suitable for identifying the variations in the environment as opposed to the general range of habitats indicated by the generalist taxa. Trends between taxa with general habitat ranges and taxa with special habitat ranges can demonstrate the expansion or decline of habitat types (Cuenca-Bescós *et al*. 2009). Therefore changes found in the micromammal community can be correlated with changes in the environment and used alongside alternative environmental proxies (Cuenca-Bescós *et al*. 2009). It can be inferred that the vegetation for the BOS Three assemblage was dense with a significant presence of water and diverse vegetation structures.

The THI_{tvod} provide a more detailed description of the environment based on the taxa recovered in the assemblage. The result of the THI_{tvod} shows that MIS 5d was densely vegetated with higher levels of precipitation and stationary water bodies, with plenty of grass cover and mostly level land and few regions of steep gradient. *S. krebsii, O. saundersiae* and *A. subspinosus* are taxa that prefer open vegetation with dry environmental conditions (Table 4.22) indicating such an environment in

the near vicinity of the site. During MIS 5d, the distance from KRM to the seashore ranged from 0.1-3.2km (Van Andel 1989; Langejans *et al*. 2012, 2017). However, Dor's study indicated that at 110ka, a low sea stand occurred, and during this time Klasies River main site was 3.2 km from the shore (Dor 2017: 44). This correlates with cooler conditions during MIS 5d. The retreat of the seashore from the site exposed land on the Southern Coastal Plain, thus expanding an area of land covered with variations of vegetation. This correlates with the THI_{tvod} where plains are common. Species that prefer rocky and sandy substrates would not have thrived in these regions because temperature conditions and the increasing density of the vegetation and the increase of plains may have affected their abundance.

The variety of vegetation types at KRM is supported by results of a charcoal analysis where tree species *Dovyalis caffra* (Kei-apple), *Grewia occidentalis* (Crossberry tree), *Tarchonanthus littoralis* (Coastal camphor bush) and *Nuxia florisbunda* (Forest elder) occurred in the BOS Three layer (Magubane 2019). These tree species occur in very diverse habitats and in Afromontane and Afrotemperate forest environments in the southern Cape region (Rutherford *et al.* 2006; Mensah *et al*. 2018). These species are indicative of warm temperatures (annual mean minimum is 11.1°C and annual mean maximum is 19.2°C) and high annual rainfall (700-1230mm) (Gadow *et al*. 2016).

The BOS Three assemblage was deposited at 110ka, however the minimum and maximum palaeotemperatures for this date are not known. In order to compensate for this the closest phases, MSA I and MSA II Lower, at KRM will be used. The minimum and maximum palaeotemperatures for the MIS 5d (115-120ka) are 12.0°C and 16.9°C and for MIS 5b (90-95ka) are 11.1°C and 16.0°C (Loftus *et al.* 2017: 78). Little variation between the minimum and maximum palaeotemperatures is observed for both MSA I and MSA II Lower phases (Loftus *et al.* 2017). Therefore, it can be inferred that the palaeotemperatures during the deposition of the BOS Three assemblage remained within the same temperature range and correlate with the temperatures inferred from the botanical data. The palaeotemperatures inferred by Thackeray (1987: 297) and Thackeray & Avery

(1990: 314) for the MSA II phase at KRM1A are very similar at 15.5°C and 14.5°C. These temperatures fall with in the minimum and maximum temperature ranges of the MSA I and MSA II Lower phases as mentioned in the paragraph above (Loftus *et al*. 2017). This underscores that micromammals are valuable as a proxy for palaeotemperature. The palaeotemperatures for KRM during this period indicates relatively warm conditions.

The abundance of water is shown by the presence of water loving species, such as the *O. irroratus* (vlei areas) (Davis 1973), benthic foraminfera, *Elphidium* (estuarine systems) (Strachan 2016) and molluscs *Turritella capensis* (candle shell, mollusc), *Nassarius kraussiamus* (tick shell) and *Turbo cidaris* (turban shell) suggestive of lagoon, estuaries and tidal pools (Von den Driesch 2004; Table 3, Langejans *et al.* 2017: 65-68).

A seminal ecological study of the micromammal materials excavated by Deacon (1984-1986) was undertaken by Avery (1987: 414). The micromammals from unit 40, relating to MSA II Lower is relevant to this study, although the findings in relation to MSA II as a whole tend to be discussed. The density of vegetation was high based on the strong presence of *O. irrotatus* throughout MSA II phase (from AA43 Cave 1A) (Avery 1987: 414). However, the presence of the other taxa (*M. varius, R. pumilio* and *O. laminatus*) also point to a variety of vegetation types and densities. An increase in closed environments is also indicated for the MSA II phase (Klein 1976: 78; Van Pletzen-Vos *et al.* 2019). The MSA II phase is dominated by the strong presence of browsers suggesting closed environments (Wurz *et al.* 2018).

Nel reports that the micromammal assemblages reflect a palaeoenvironment during MSA II Lower with an increase in moisture and vegetation density in relation to MSA I due to the prevalence of *O. irroratus, C. flavescens* and *R. pumilio* (Nel 2013; Nel *et al*. 2018). A more recent micromammal analysis exhibited a dominant presence of *C. cyanea, O. irroratus/O. saundersiae* and *C. flavescens* in the BOS One assemblage (Maringa 2017). This suggests a closed environment with wet conditions and a mosaic spread of vegetation in the KRM region (Maringa 2017). The taxa from the BOS Three assemblage are indicative

of dense vegetation with mosaic characteristics, water abundance (precipitation, water bodies) and cool temperatures and a closed environment. Throughout the decades of micromammal research at KRM there are taxa that commonly occur (*C. flavescens, O. irroratus, R. pumilio, M. varius* etc.) and those that briefly appear (*C. duthiae*). Although, the abundance of the dominant taxa fluctuate somewhat, similar palaeoenvironmental conditions are indicated.

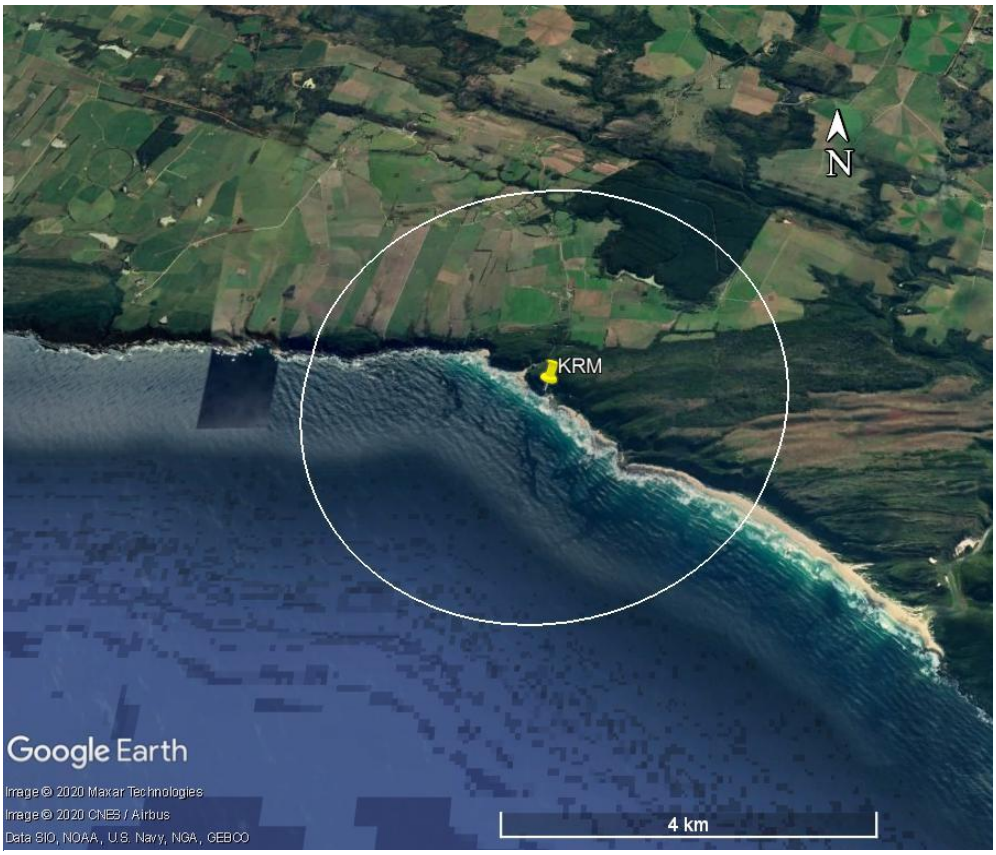


Figure 5.1: A buffered zone of the hunting range of *T.alba* relative to KRM (Google Earth 2020b).

Figure 5.1 demonstrates the hunting range of *T. alba* which is approximately 2-3km (Andrews 1990). This figure shows the large expanse of land within the buffered zone. In terms of the palaeoenvironment this zone would reflect the variety of vegetation structures characterised with mosaic features and a retreated shoreline.

5.5. Wider implications: The palaeoenvironment in the southern Cape during MIS 5d

The inferred palaeoenvironmental conditions for the southern Cape during MIS 5d are discussed in relation to the data from Blombos Cave and Pinnacle Point Cave 13B. The palaeoenvironmental inferences are based on the small and large mammal analyses from each site.

The Pre-M3 and M3 layers from the BBC micromammal assemblage have *R. pumilio, M. varius* and *O. irroratus* as the most frequent taxa (Nel 2013). This is similar to the dominant taxa in the BOS Three assemblage with the exception of *R. pumilio*. The palaeoenvironment during the MIS 5e-d phase shows warm and arid conditions with a decline in rainfall (Nel 2013: 213). Records of the distance from site to the shore are mostly unavailable for MIS 5e-d therefore a trend cannot be associated (Fisher *et al.* 2010: 1395; Langejans *et al*. 2012: 90). On the other hand, Dor (2017: 44) indicates that the shore was around 2.38 km away from the site at 110ka. Palaeotemperatures for BBC are unavailable as this site was not included in the study by Loftus and colleagues (Loftus *et al.* 2017). The large fauna from the CH-CL units in the M3 phase is relevant to this study, and the date for layer CP is 100.9 ± 4.6 ka to 90.9 ± 4.3 ka (Table 1, Jacobs *et al*. 2019: 51). The most frequent taxa from the M3 phase are *Procavia capensis* (Rock hyrax), *Bathyergus suillus* (Cape dune mole-rat) and *Raphicerus sp(p.)* (Steenbok and Grysbok) (browsers) (Henshilwood *et al.* 2001). The large mean size of the M3 phase mole-rats indicated an increase in moisture, open environment and browse with rock crevices emphasised by the prominent presence of *Raphicerus sp(p.)* and *P. capensis* (Henshilwood *et al.* 2001).

The micromammal assemblages from the three areas in PP13B exhibit the following palaeoenvironmental conditions. Closed environments were inferred for the Eastern area (MIS 5e-b) based on the strong presence of *S. varilla, O. irroratus* and *O. saundersiae* (Matthews *et al.* 2009). The environmental conditions inferred for the Western area (MIS 5e-b) demonstrated dense vegetation as indicated by the dominance of *O. irroratus* and patches of open environments as indicated by *O. saundersiae,* and *R. pumilio* (Matthews *et al.*

2009). The inconsistency with the vegetation density could be a factor of the large temporal range (MIS 5e, 5d, 5c and 5b) provided for the Eastern and Western areas. The palaeoenvironmental conditions at PP13B from MIS 5e-b thus display fluctuations of wet conditions (*O. irroratus*) throughout MIS 5e-b (Matthews *et al.* 2009). Similar to BBC the distance from site to shore is unavailable for 110ka however; Dor (2017: 44) indicates the distance as 2.23km. The palaeotemperatures for Pinnacle Point were attained for Caves 5 and 6 (Loftus *et al.* 2017) and not for Cave 13B, therefore no trends can be addressed. The large fauna remains from PP13B originate from the Western (MIS 5e-a) areas (Rector & Reed 2010; Jacobs *et al.* 2019). The fauna assemblage consists of small bovids mixed feeders and browsers, large grazing ungulates, mixed foliage specialists and a carnivore species (Rector & Reed 2010: 347). These taxa predominantly indicate vegetation with mosaic characteristics and wetter grassland conditions (Rector & Reed 2010: 354).

The palaeoenvironmental conditions for the southern Cape during MIS 5d can be inferred based on the three coastal sites. An ideal solution would be to create a solid and consistent analysis of the palaeoenvironmental record, but that is not the case. A broad inference of the southern Cape environment is as follows; a range of cool and warm temperatures, fluctuations in moisture availability, a complex distribution of heterogenic vegetation structures and slightly closed environments.

5.6 Summary

The hypotheses set regarding the accumulators; site formation processes and the palaeoenvironment at KRM were addressed. The most common types of categories of digestion are light and moderate digestion in the BOS Three cranial and post-cranial assemblages with the post-crania exhibiting most of the breakage. These taphonomic modifications are indicative of *T. alba* and *B. africanus* as the accumulators of the micromammal assemblage. The taphonomic modifications show that burning occurs in low frequencies in the overall assemblage and it does not completely follow the trends that suggest human consumption of micromammals. Discolouration of the bones may be a result of consistent water exposure. The abundance of water is validated by the presence of water loving

taxa such as *O. irroratus, O. laminatus, M. varius* and *R. pumilio*. The presence of taxa with mostly broad habitat ranges suggests mosaic vegetation, high levels of moisture and a closed environment. The retreated shoreline from the site indicates a large expansion of land that was readily exploited by AMH and fauna. The palaeoenvironmental conditions during MIS 5d are similar at KRM, BBC and PP13B showing mostly dense vegetation cover and varying levels of moisture as indicated by both macro- and micromammals. The palaeoenvironmental conditions in the southern Cape during this time is characterised by the combination of environmental conditions that occurred at all three sites.

Chapter 6: Conclusion

6.1 Introduction

This chapter concludes the findings of this research dissertation summarizing the outcomes of the three hypotheses (Section 6.2). The limitations relative to the analyses will be addressed in Section 6.3 and lastly the future avenues (Section 6.4) of micromammal research will be put forward as suggestions to improve the methods and quality of this research.

6.2 Concluding remarks

The taphonomic modifications from the BOS Three layer at KRM show that owls are the most likely accumulators of the micromammal assemblage. The accumulators of this assemblage are identified as *T. alba* and *B. africanus*. This confirms the first hypothesis as they have been identified as the main predators from previous Klasies River micromammal research. The same predators are also responsible for the accumulation of micromammal assemblages at other southern Cape sites.

The post-depositional modifications with regards to site formation processes are indicative of water abundance validated by the different agents of discolouration. The presence of burning and modifications found on micromammal remains may hint at alternative avenues into researching complex behaviour in AMH's. For the most part the second hypothesis has been confirmed, but human subsistence of micromammal remains cannot be eliminated due to the lack of information on this subject. Actualistic studies need to be conducted to investigate this subject thoroughly.

The palaeoenvironment at KRM during MIS 5d was inferred based on the taxa, their habitat preferences and palaeoenvironmental indices. The presence of *O. irroratus*, *M. varius* and *C. flavescens* confirms the third hypothesis that parts of the environment was densely vegetated with a significant abundance of water, associated with a complex distribution of heterogeneous vegetation, including grassy areas. The abundance of water at KRM is validated by the water-loving

micromammal taxa.

6.3 Limitations

During the research process some problems where encountered. The initial aim of this research was to analyse all nine squares from the BOS Three layer. This could not be achieved due to the large sample size and therefore the sample was reduced. Regarding the taxonomic analysis, differences could not be distinguished between *Suncus varilla* and *Crocidura cyanea*, the three vlei rats (*Otomys sp.*) and *Mastomys coucha* and *Mastomys natalensis* due to the level of fragmentation of some of these specimens. Futhermore, the analyses of some post-depositional modifications such as rounding and fracture patterns were omitted from the analysis due to time constraints.

6.4 Future avenues of research

The remaining squares from the BOS Three layer should be analysed using the same methods employed in this dissertation. This will ensure a very detailed inference on palaeoenvironmental conditions at KRM. It will also enable a more continuous palaeoenvironmental record at KRM. Ideally, it would be to the benefit of micromammal research if an open access online database can be created and expanded to all regions across the country.

Advanced investigations should be undertaken on the several taphonomic modifications noted in this dissertation to ensure that a high level of certainty can be achieved. More actualistic studies are required to explore taphonomic modifications caused by humans, predators and natural processes. The avenue of human subsistence of micromammals smaller than the *B. suillus* requires further investigation as it has the potential to contribute significant information. The application of ecomorphological studies (Paine *et al*. 2019) on micromammal remains will prove to be beneficial in the near future, especially because not all remains can be taxonomically identified. An alternative to that would be to use ZooArchaeology by Mass Spectrometry (ZooMS) to identify more taxa (Buckley *et al*. 2016). A large amount of information can be extracted from the micromammal assemblages using these two innovative methods.

The variety of approaches and techniques has improved over the decades and contributed to a wealth of ever-growing information with regards to palaeoenvironmental proxy research. New avenues of research open with the growth of academic inquiry and advancements of technology. Nothing should hinder the inclusion of young and up-coming researchers and collaborations with experienced researchers as it is the ideal way forward.

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Appendix

The appendix is composed of significant supplementary information in the form of Figures and Tables.

A.1 Breakage

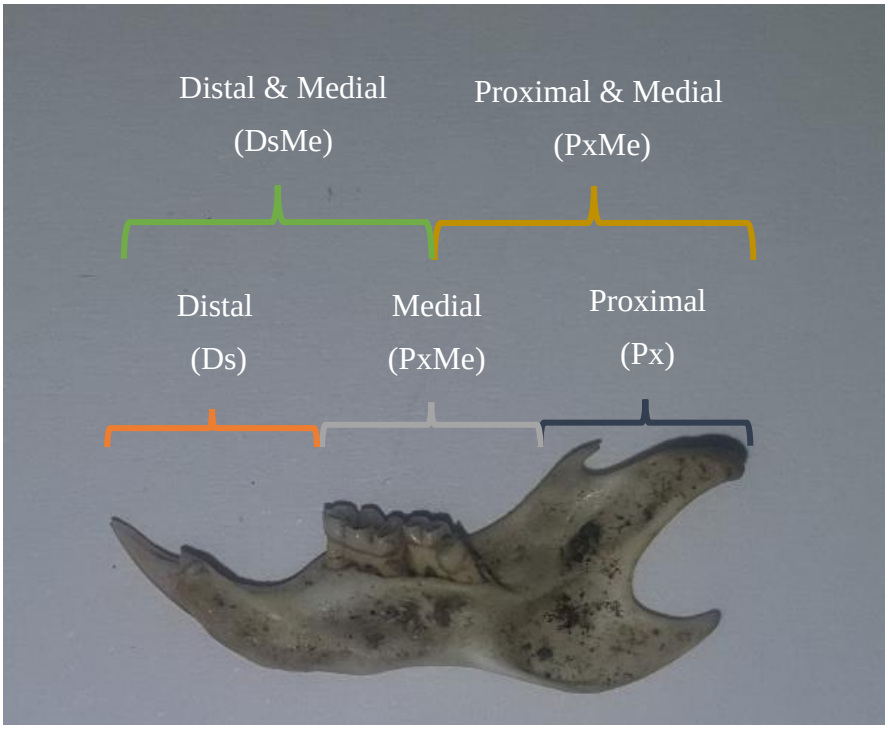

Figure A.1: The fragment portions recorded on the cranial elements.

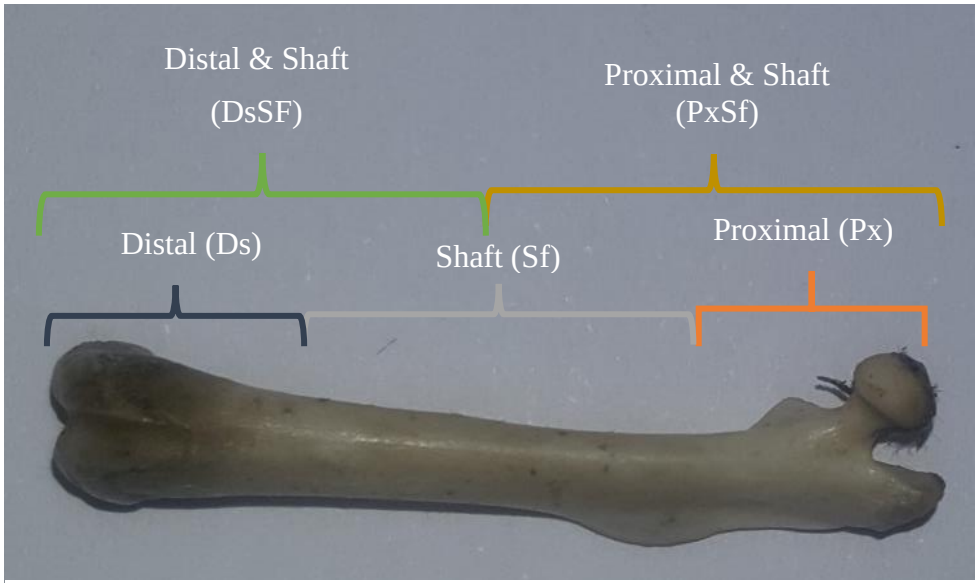

Figure A.2: The fragment portions recorded on post-cranial elements.

A.2 Skeletal Element Abundance (SEA)

Table A.1: Skeletal Element Abundance for the C3 micromammal assemblage. E_i is the amount of each skeletal element in a murid skeleton (after Rhodes *et al.* 2019), N_i is the total number of elements in the assemblage and R is the relative abundance (%).

Skeletal element	E_i	N_i	R
Mandible	2	201	68.4
Maxilla	2	214	72.8
Scapula	2	27	9.2
Humerus	2	71	24.2
Radius	2	17	5.9
Ulna	2	16	5.4
Pelvis	2	0	0.0
Femur	2	69	23.5
Tibia	2	56	19.1
Vertebra	36	766	14.5
Incisor	4	215	36.6
Molar	12	448	25.4
Premolar	-	-	-
Astragalus/calcaneus	4	38	6.5
Rib	24	122	3.5
Metapodials	20	131	4.5
Phalanges	56	71	0.9
Zygomatic process	2	75	25.5
Bullae	2	20	6.8
Patellae	2	16	5.4
Grand total	180	2573	9.7
MNI	147		

* Certain skeletal elements were not included in this table because there is uncertainty with the exact number found in a single murid skeleton, e.g. the number of carpals in a single murid skeleton is uncertain.

A.3 Predator categories

Table A.2: Predator categories (after Table 3.16, Andrews 1990: 90).

	Category 1 Light	Category 2 Intermediate	Category 3 Moderate	Category 4 Heavy	Category 5 Extreme
Skeletal element proportions	Barn owl, Snowy owl, Long-eared owl, Short-eared owl, Verreaux eagle, Great grey owl	Spotted eagle-owl, European eagle-owl	Tawny owl, Little owl	Kestrel, Hen harrier	Mammalian carnivore
Incisor digestion	Barn owl, Snowy owl, Short-eared owl	Long-eared owl, Verreaux eagle owl, Great grey owls, Bat-eared fox	European eagle, Spotted eagle-owl, Little owl, Tawny owl, Mongoose, Genet, Pine marten	Kestrel	Hen harrier, Coyote, Red fox, Arctic fox
Breakage of maxillae	Barn owl, Snowy owl, Long-eared owl, Verreaux eagle owl, Great grey owl	Short-eared owl, Spotted eagle-owl, European eagle-owl, Tawny owl	Little owl, Kestrel, Hen harrier	-	Mammalian carnivore
Breakage of mandibles	Barn owl, Long-eared owl, Verreaux eagle owl, Great grey owl	Snowy owl, Short-eared owl, European eagle-owl, Tawny owl	Spotted eagle-owl, Kestrel, Hen harrier	Little owl, Mammalian carnivores	-
Breakage of teeth	Barn owl, Snowy owl, Long-eared owl, Great grey owl	Short-eared owl, Verreaux eagle owl, Spotted eagle-owl, Little owl	European eagle-owl, tawny owl	Kestrel, Hen harrier	Mammalian carnivores
Post-cranial digestion	Barn owl, Snowy owl, Long-eared owl, Short-eared owl, Verreaux eagle-owl, Great grey owl	European eagle-owl, Spotted eagle-owl, Tawny owl	Little owl, Kestrel, Hen harrier	-	Mammalian carnivores
Breakage of post-crania	Barn owl, Great grey owl, Long-eared owl, Short-eared owl, Verreaux eagle-owl	Snowy owl, European eagle-owl	Spotted eagle-owl, Tawny owl	Little owl, Kestrel, Hen harrier, Mongoose, Genet, Bat-eared fox	Pine marten, Arctic fox, Coyote, Red fox

Table A.2: (Continued) Predator categories (after Table 3.16, Andrews 1990: 90).

	Category 1 Light	Category 2 Intermediate	Category 3 Moderate	Category 4 Heavy	Category 5 Extreme
Postcranial/ cranial proportions	Barn owl, Long-eared owl, Short-eared owl, European eagle owl, Great grey owls, Pine marten, Bat-eared fox	Tawny, Verreaux eagle, Spotted eagle-owl, Kestrel, Genet	Hen harrier, Arctic fox	Snowy owl, Little owl, Mongoose, Coyote, Red fox	-
Loss of distal elements of post-crania	Barn owl, Snowy owl, Long-eared owl, Verreaux eagle owl, Tawny owl	Short-eared owl, European eagle owl, Great grey owl, Coyote, Arctic fox	Little owl, Kestrel	Spotted eagle-owl owl, Hen harrier, Red fox	Pine marten, Mongoose, Genet, Bat-eared fox
Mandibular tooth loss	Barn owl, Snowy, long-eared, Short-eared, Great grey owl European eagle owl	Verreaux eagle owl, Spotted eagle-owl, Tawny owls	Little owl, Kestrel, Coyote, Arctic fox, Pine marten	Hen harrier, Mongoose, genet, Bat-eared fox, Red fox	-
Maxillary tooth loss	Barn owl, Snowy owl, Long-eared owl, Verreaux eagle owls	Great grey, Tawny owls	Short-eared, European eagle, Spotted eagle-owl, Bat-eared fox, Coyote	Little owl, Kestrel, Hen harrier, Genet, Mongoose, Red fox, Arctic fox, Pine marten	-
Proportions isolated teeth	Barn, Snowy owl, Long-eared, Short-eared owl, Verreaux eagle owl, European-eagle owl, Spotted eagle-owl	Great grey owl, Coyote, Mongoose	Tawny, Little owls, Bat-eared fox	Kestrel, Genet, Red fox, Pine marten	Hen harrier, Arctic fox
Loss of zygomatic	Barn owl, Long-eared owl, Snowy owl, Verreaux eagle owl, Great grey owl	Spotted eagle-owl, European eagle owl, Tawny owls	Short-eared owl, kestrel, Hen harrier, Mongoose, Genet, Bat-eared fox, Coyote	Little owl, Arctic fox, Red fox, Pine marten	-

A.4 Digestion on incisors from KRM and BBC

Table A.3: Comparison of digestion on the loose incisors from the KRM and BBC units. (NISP values in **bold** and NISP percentage in parentheses). The data for PP13B isolated incisors is unavailable.

	KRM MSA I	KRM MSA II Lower			KRM BOS Three	BBC Pre-M3 and M3 phase		
Unit	Z44 SCB & SAS	Y44 SM5	Y44 CL & BS	Y45 YS1	C3	CPA	CQ	CR
No digestion	**34** (79.1)	**57** (60.0)	**29** (49.2)	**41** (50.6)	**0** (0.0)	**74** (42.8)	**152** (60.6)	**80** (62.0)
Light digestion	**8** (18.6)	**26** (27.4)	**23** (39.0)	**36** (44.4)	**176** (81.9)	**59** (34.1)	**66** (26.3)	**35** (27.1)
Moderate	**0** (0.0)	**12** (12.6)	**5** (8.5)	**3** (3.7)	**26** (12.1)	**32** (18.5)	**16** (6.4)	**7** (5.4)
Heavy	**1** (2.3)	**0** (0.0)	**2** (3.4)	**0** (0.0)	**11** (5.1)	**5** (2.9)	**10** (4.0)	**6** (4.7)
Extreme	**0** (0.0)	**0** (0.0)	**0** (0.0)	**1** (1.2)	**2** (0.9)	**3** (1.7)	**7** (2.8)	**1** (0.8)
Total digested	**9** (20.9)	**38** (40.0)	**30** (50.9)	**40** (49.3)	**215** (100.0)	**99** (57.2)	**99** (39.4)	**49** (38.0)
Number analysed	**43** (100.0)	**95** (100.0)	**59** (100.0)	**81** (100.0)	**215** (100.0)	**173** (100.0)	**251** (100.0)	**129** (100.0)

Table A.4: The different degrees of digestion on the articulated incisors from the KRM, BBC and PP13B units (NISP values in **bold** and NISP% in parentheses). The data for PP13B articulated incisors is unavailable.

	KRM MSA I	KRM MSA II Lower			KRM BOS Three	BBC Pre-M3 and M3 phase		
Digestion	Z44 SCB & SAS	Y44 SM5	Y44 CL & BS	Y45 YS1	C3	CPA	CQ	CR
No digestion	**1** (100.0)	**5** (100.0)	**1** (33.3)	**4** (66.7)	**0** (0.0)	**19** (43.2)	**28** (58.3)	**28** (68.3)
Light digestion	**0** (0.0)	**0** (0.0)	**1** (33.3)	**2** (33.3)	**13** (52.0)	**17** (38.6)	**18** (37.5)	**10** (24.4)
Moderate	**0** (0.0)	**0** (0.0)	**1** (33.3)	**0** (0.0)	**12** (48.0)	**8** (18.2)	**2** (4.2)	**3** (7.3)
Heavy	**0** (0.0)	**0** (0.0)	**0** (0.0)	**0** (0.0)	**0** (0.0)	**0** (0.0)	**0** (0.0)	**0** (0.0)
Extreme	**0** (0.0)	**0** (0.0)	**0** (0.0)	**0** (0.0)	**0** (0.0)	**0** (0.0)	**0** (0.0)	**0** (0.0)
Total digested	**0** (0.0)	**0** (0.0)	**2** (66.6)	**2** (33.3)	**25** (100.0)	**25** (56.8)	**20** (41.7)	**13** (31.7)
Number analysed	**1** (100.0)	**5** (100.0)	**3** (100.0)	**6** (100.0)	**25** (100.0)	**44** (100.0)	**48** (100.0)	**41** (100.0)

A.5 Taphonomic modifications



Figure A.3: Mandible with *in situ* M1 molar. The mandible has vascular grooves, pits, perforations (arrow), manganese staining, soil staining and encrustation. The molar has encrustation. Light digestion is observed on the specimen.

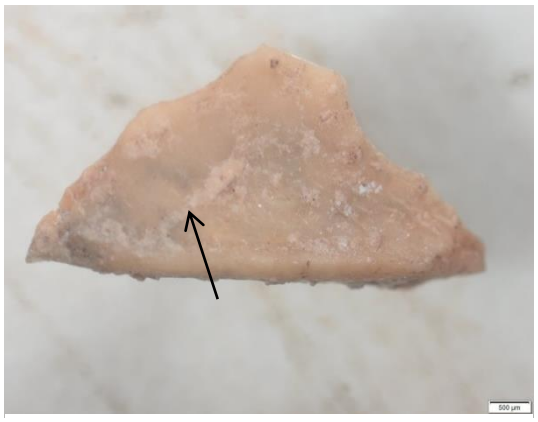

Figure A.4: A mandible fragment with manganese staining, encrustation, and possible arthritic build-up (arrow).



Figure A.5: Calcaneus with soil staining, puncture, vascular grooves, gypsum and digestion.



Figure A.6: Ulna fragment with exfoliated surface, manganese staining, encrustation.



Figure A.9: Ulna with digestion damage on the shaft, manganese staining and encrustation.

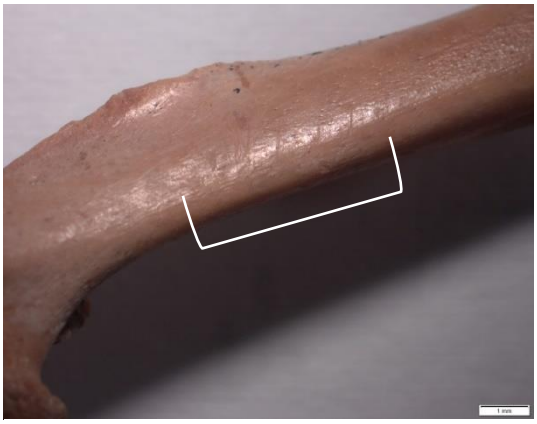

Figure A.7: Femur with polish, trampling marks (bracket), root etching, polish and vascular grooves.



Figure A.12: Proximal femur epiphysis with root etching, pits, perforations and polish.



Figure A.8: Proximal femur epiphysis with root etching, pits, polish and digestion (corrosion) encrustation.

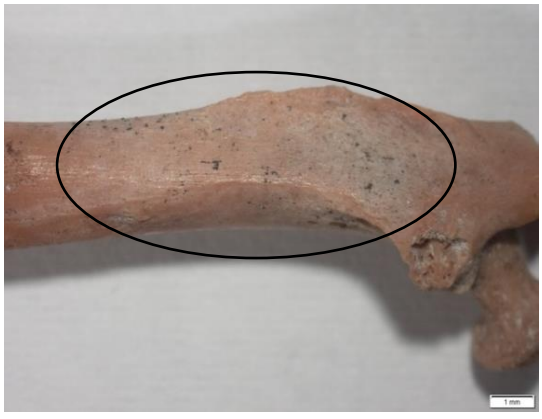

Figure A.11: Femur with a patch of light (white) discolouration (circled), polish, root etching, manganese staining, pits and vascular grooves.



Figure A.10: Proximal femur epiphysis with corrosion caused by digestion, pits, encrustation and soil staining.



Figure A.16: Caudal vertebra with polish, pits, perforations, soil staining, manganese staining, digestion damage, rounded edges, and indentation at the center of the bone that wraps around the bone (bracket).



Figure A.15: Metapodial with polish, predatory mark (bracket), soil staining and charcoal smudges.



Figure A.14: Femoral head with discolouration, manganese staining exfoliated surface.



Figure A.13: Tibia with root etching, predatory mark (arrow), encrustation and polish.

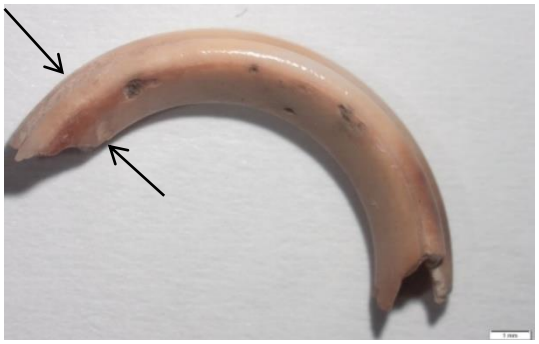

Figure A.18: Loose incisor with polish, digestion damage on the distal tip and on the dentine (arrows).

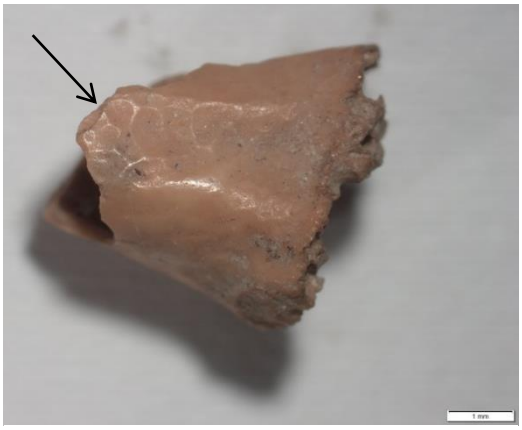

Figure A.17: Tibia fragment with a honeycomb lattice pattern on the bone shaft (arrow), polish and light encrustation.

A.6 Burning



Figure A.22: Patella with polish, localised burning (red-brown colour).



Figure A.21: Maxilla with localised burning (brown).



Figure A.19: Tibia with localised burning (red/brown colour).



Figure A.20: Single laminate tooth with burning (dark brown).



Figure A.25: Metapodial with an over-lap of burning and manganese staining.



Figure A.26: Incisor enamel fragment burnt (red/orange).



Figure A.23: Femoral head burnt (dark brown).



Figure A.24: Isolated incisor fragment burnt (black) with manganese staining.