Micromammals from the Middle Stone Age (92–167 ka) at Cave PP13B, Pinnacle Point, south coast, South Africa

Thalassa Matthews^{1*}, Curtis Marean² & Peter Nilssen³

 ¹Iziko South African Museum, P.O. Box 61, Cape Town, 8000 South Africa *Author for correspondence: tmatthews@iziko.org.za
²Institute of Human Origins, School of Human Evolution and Social Change, P.O. Box 872402, Arizona State University, Tempe, AZ 85287-2402, U.S.A.
³CHARM, Mossel Bay, South Africa

Introduction

This paper presents the preliminary results of an analysis of micromammal assemblages recovered from three excavation areas in Cave 13B at Pinnacle Point (from this point referred to as PP13B), namely the 'eastern', 'western' and the 'LC-MSA' areas. The geological context of the site, dating, excavation and stratigraphy of these areas are described in detail in Marean et al. (2004, 2007) and Marean et al. (in press), and are dealt with only briefly here. All the Optically Stimulated Luminescence (OSL) dates quoted in this paper were carried out by Zenobia Jacobs at the School of Earth and Environmental Sciences, University of Wollongong, Australia. In this paper, we report age ranges as the maximum spread of all employed dating techniques, which include OSL and uranium-thorium on speleothems, with 1 sigma error added on to either side of the age. Some spreads are corrected and/or narrowed by other dating techniques. For example, a series of highly precise uranium-thorium ages shows the cave was closed to human occupation beginning ~92 ka, providing limits to the OSL age spreads.

Background

The LC-MSA area

In the northeastern area archaeological sediments are called the LC-MSA (Lightly Cemented Middle Stone Age). The LC-MSA is attached to the cave wall and is capped by a flowstone. The LC-MSA consists of multiple lenses of burning, within which are faunal bone, shellfish, lithics and ochre. The LC-MSA is divided into three stratigraphic aggregates. These aggregates are the LC-MSA Lower, LC-MSA Middle and the LC-MSA Upper, which reflect a relatively homogeneous set of formation processes. LC-MSA Lower is the oldest facies, is the archaeologically richest, and has the least cemented layers (Marean *et al.* 2007; Marean *et al.*, in press). At the bottom of the currently sampled horizons is water-rounded bedrock. The excavations in this area were limited as the amount of preserved sediment is small.

Micromammals were found throughout the LC-MSA aggregates, although, to date, sample sizes sufficient for analysis were found only in the LC-MSA Lower sediments dated by OSL to 153 to 174 ka, placing it in MIS stage 6. However, our 3D sea level model (Marean *et al.*, 2007) shows the coast was only close enough for shellfish

collection around 167 ka, and thus this further constrains the age spread for the LC-MSA Lower.

The eastern area

In the eastern area the various stratigraphic facies identified and used for analysis are depicted in Table 1 (from the bottom to the top of the sequence), along with the OSL dates obtained for that horizon, and the number of individual micromammal specimens (NISP) recovered. The Shelly Brown Sand and Upper Roof Spall were separated in excavation, however, the excavators now consider them contemporary due to the overlapping age estimates and the fact they grade into each other.

The Lower Roof Spall Facies, which represents an MSA horizon, is at the base of the excavations and rests on bedrock. Archaeological finds are scarce and tend to be concentrated towards the top of this facies. The deposits lie between the bedrock, forming a thick fill which thins out over the tops of the boulders. Cemented patches are found and are more common in the southerly parts of the excavated area. The Upper Roof Spall Facies represents a richer archaeological horizon than the Lower Roof Spall Facies and contains lithics, shellfish and fauna and grades into the Shelly Brown Sand. This facies thickens appreciably from south to north. In the southernmost area, the Upper Roof Spall Facies contains both isolated and connected burnt areas which become increasingly more complex and inter-woven towards the northern side of the facies. Within these areas stratified hearths with associated lithics and fauna are found. On top of the Upper Roof Spall Facies and Shelly Brown Sand are the Truncation Fill, the modern Redeposited Disturbance, and the Surface Sediments.

As Table 1 illustrates, micromammal assemblages of sufficient size for analysis were recovered from only the Lower Roof Spall Facies and the Upper Roof Spall Facies, although sample size was very poor in the latter.

The western area

In the western area of the site the deposits appear to resemble a midden or dump. However, micromorphological evidence is somewhat contradictory as combustion features appear to be in situ, but do not appear to be hearths, as seen in the eastern area and LC-MSA (Karkanas & Goldberg, in press). Some of the sediments have strong anthropogenic signatures, whereas others appear to be geogenic in origin. There are areas with substantial geogenic disturbance as a result of faulting, slippage, or subsidence, and there were at least two events of erosion or anthropogenic cutting of MSA sediments.

Table 1. OSL dates and NISP for the eastern area facies.

	Dates	NISP
Surface sediment	Modern	2
Re-deposited Disturbance	Modern	1
Truncation Fill	No OSL dates available, but possibly dates between 35-39 ka	7
Shelly Brown Sand	92–98 ka	1
Upper Roof Spall Facies	92–98 ka	17
Lower Roof Spall Facies	106–114 ka	27

Table 2. Sequence of stratigraphic relationships of the western area fa	cies
in sequence of formation (after Marean <i>et al.</i> , in press).	

Facies name		Age of horizons within facies
Boulder Beach		-
Laminated Facies		375–451 ka, probably MIS 11
Light Brown Silt Facies (abbreviation: LB Silt)		153–375 ka, maybe MIS 11 or just after
Dark Brown Sand Facies (abbreviation: DB Sand)	DB Sand 2 DB Sand 3 DB Sand 4	92–102 ka 92–102 ka 117–375 ka – probably just postdates the LC-MSA Lower in MIS 6
Light Brown Grey Sand Facies (abbreviation: LBG Sand)	LBG Sand LBG Sand 2 LBG Sand 3	94–134 ka 117–166 ka 152–375 ka (Note: LBG Sand 2 and 3 also probably just postdate LC-MSA Lower in MIS 6)
Light Brown Sand Facies (abbreviation: LB Sand)		92–94 ka
South Pit Fill		Modern
North-east Fill		Modern
Surface Sediments		Modern

There has also been a modern disturbance in at least one area. Maximum and minimum age spreads have been developed and Table 2 illustrates a simplified sequence of the various western area facies. The Laminated Facies is composed of a thick series of sediments which lie at the base of archaeological deposits. The Dark Brown Sand Facies contains series 4a to 4c. DB Sand 1 was later identified as representing the same horizon as DB Sand 2 and was eventually grouped with it.

Materials and methods

Stratigraphic Units (lenses, features, and other discrete sedimentary units) were initially identified during excavation, and then later verified by projecting 3D total station shots of the units onto section drawings and photographs, by generating 3-D point clouds, and lastly using micromorphological observations to develop reconstructions of the sequence of deposition, alteration, and erosion of the various facies. The stratigraphic units were grouped into larger stratigraphic aggregates, which reflected a homogeneous set of formation processes. The micromammal assemblages from each stratigraphic aggregate were analysed as a unit.

The use of the methodology initially proposed by Andrews (1990) and Fernandez-Jalvo & Andrews (1992) for the analysis of micromammal assemblages has become more or less standardized (e.g. Manthi 2002; Matthews 1999, 2002, 2006; Matthews *et al.* 2006; Dewar & Jerardino 2007) and was used for recording the breakage and taphonomy of the PP13B assemblages. Only selected results from the taphonomic analysis of the PP13B assemblages, pertaining directly to the identity of the accumulating agent/s are presented in this paper, which concentrates on the paleoenvironmental implications of the micromammals in PP13B.

From this point onwards, the three molars of the murid mandible will be referred to as the M_{1-3} , and the three maxillary molars, as the M^{1-3} , respectively.

Taphonomy

Identifying the predator/s or agents responsible for accumulating a fossil micromammal assemblage is essential if reliable palaeoenvironmental information is to be extracted (Matthews 1999; Matthews *et al.* 2006). Variation within a fossil micromammal assemblage over time may be attributable to changes in the identity of the predator responsible for the accumulation, rather than environmental change. Also, different predator species have different requirements for selecting prey species from the available local micromammal population.

A most useful tool for identifying the predator/s involved in a micromammal accumulation is the pattern of digestion on enamel and dentine of incisors. The following categories describe and record incisor digestion on both isolated and *in situ* incisors. Incisors that suffered damage and that could not be properly assessed were excluded.

Class 0: No visible digestion on the incisor. The early stages of digestion may not be detectable with a light microscope and it is possible that some incisors falling into this category sustained very light, but indiscernible digestion.

Class 1 (light): Light etching and removal of the upper layers of small areas of enamel and/or dentine.

Class 2 (moderate): The area of digestion may not be much greater than Class 1, but the digestion has penetrated much deeper through enamel layers, down to, or very close to dentine. The dentine shows a deeper degree of penetration and loss.

Class 3 (heavy): The area of digestion is more extensive than Class 2 digestion, with complete removal of enamel in areas, and digestion and removal of underlying dentine.

Class 4 (extreme): Extreme digestion of both enamel and dentine, with some teeth having all enamel removed and much dentine removed. The edges of dentine or enamel may be collapsing in on themselves.

Samples of incisors from modern barn owl and spotted eagle owl pellets were examined to provide a comparative database.

Identification

Murid M^1 and M_1 teeth (*in situ* and isolated) were identified to species whenever possible, and these were used to quantify the different species present in the fossil assemblages. An exception was made in the case of Otomyinae (the vlei rats), where the more diagnostic M^3 rather than the M^1 was used to quantify this murid subfamily. Occasionally, breakage, wear or digestion of the tooth precluded identification. Teeth of uncertain identification were not used for analysis.

Differentiating between *Otomys saundersiae* and *Otomys irroratus* was frequently difficult due to great variability in size and shape of the laminate teeth of these two species. Some specimens could not be allocated with certainty to either species and were thus recorded simply as *O. saundersiae/O. irroratus*.

General diversity

The Shannon Wiener index of general diversity was used to assess diversity of the fossil micromammal assem-



Figure 1. Incisor digestion patterns of modern spotted eagle owl and barn owl pellet assemblages from the south coast.

blages. This index accounts for both the number of taxa present, and relative frequency (evenness of representation) of each taxon (Cruz-Uribe 1988). The Shannon Wiener index is calculated using the equation:

 $H = -\Sigma P_i \log P_i$,

where $P_i = n/N$, that is, the proportion of the total sample represented by each species.

Results

Taphonomy

Figure 1 shows the incisor digestion patterns typical of modern barn owl (*Tyto alba affinis*) and spotted eagle owl (*Bubo africanus*) pellet assemblages. The characteristic incisor digestion patterns of spotted eagle and barn owls were verified by studying several modern comparative assemblages (Matthews, unpubl. report). The results from two barn owl, and three spotted eagle owl pellet assemblages are averaged in Figure 1 to facilitate comparisons with the fossil assemblages. These owl species roost on the floor or on ledges of caves and rocky overhangs, and are thus the most likely contributors to the fossil micromammal assemblages in PP13B. The only small carnivore likely to build up an accumulation of scats in a cave is the small-spotted genet (*Genetta genetta*), which frequently uses caves and rocky overhangs as midden areas, however, this predator was excluded on the basis of incisor digestion patterns.

The barn owl assemblages were distinguished from those of the spotted eagle owl on the basis that a far higher proportion of incisors showed no digestion, and very few incisors fell into the 'moderate' digestion category. Neither the barn or spotted eagle owl assemblages contained incisors that showed heavy or extreme digestion, although incisors with these advanced degrees of digestion do occasionally occur in pellet assemblages from both owl species (T.M., pers. obs.).

Figure 2 shows the incisor digestion patterns found in various fossil assemblages from the western, eastern and northeastern areas of PP13B. The number of incisors in each facies is shown above the individual bar graphs. Facies which contained very few or no incisors are omitted.

Incisor digestion patterns in the LC-MSA Lower suggests that a barn owl was responsible for the accumulation of the micromammal assemblages. The sample of incisors in the LC-MSA Upper is too small for comment. In the eastern



Figure 2. Incisor digestion patterns in the east, western and northeastern areas of PP13B.



Figure 3. The micromammalian population from the LC-MSA Middle and Lower Facies.

area poor incisor sample size precludes identification of the predator, although digestion patterns are closer to the barn owl than the spotted eagle owl. in the western area barn owl predator activity is clearly suggested by incisor digestion patterns in all facies. LB Silt differs slightly in the high percentage of incisors showing moderate digestion, but this will be discussed later.

Identification

The proportional representation of micromammalian taxa found in the LC-MSA Middle and LC-MSA Lower Facies is shown in Fig. 3, and those of Roof Spall-Upper and Roof Spall-Lower (eastern area) in Fig. 4. The values pertaining to these figures may be seen in Appendix A. The NISP in all the following figures was calculated by counting the number of upper and lower first molars (isolated and *in situ*). Figure 5 illustrates micromammal percentage representation in the western area assemblages containing a NISP of 28 or more, namely LB Sand 1, DB Sand 3, LBG Sand 1 and LB Silt.

Table 3 shows the number of each micromammal species present in the western area facies, including those depicted in Fig. 5.

General diversity (H)

Table 4 gives micromammal diversity for the various facies of PP13B and, for the purposes of comparison, Table 5 shows the general diversity in several micromammal- bearing south and east coast archaeological sites (after Avery, 1986).

Discussion

Sample size in the LC-MSA Middle Facies is too small for paleoenvironmental analysis and species which are present are catholic in their ecology. Otomyinae dominate the micromammal assemblages, a feature seen in the majority of facies throughout the western area as well. Sample size in the LC-MSA Lower is larger, but once again no clear pattern of environmental conditions emerges from the ensemble of species represented. Incisor digestion patterns suggest that a barn owl was responsible for the accumulation of this facies. Barn owls are generalist feeders and produce pellet assemblages that provide a broad sample of the micromammal population living within the hunting range of the owl (Andrews 1990; Avery *et al.* 2005) so predator bias with regard to selection of prey species should not be affecting the suite of species to any marked



Figure 4. The micromammalian population from the Upper Roof Spall and Lower Facies.



Figure 5. The micromammalian population in larger (NISP \geq 28) samples from the western area facies.

degree. The fact that all the species present are species found in a variety of habitats and are thus presumably adaptable to changing conditions may in itself be significant, but this must be substantiated by further research into micromammal assemblages from other Pinnacle Point cave sites.

The fact that O. saundersiae dominates in the LC-MSA Lower Facies, and O. irroratus throughout most of the western area facies, may indicate relatively drier conditions in the LC-MSA, but this interpretation is tentative as both these Otomys species are frequently found together in modern comparative barn owl assemblages from the south coast (Avery et al. 2005; Matthews, unpubl. report). This suggests that these two species can occupy the same areas simultaneously, although they may inhabit different microhabitats. Changes in relative proportions of the two species may thus have little to do with changes in rainfall/environment over time. The presence of Otomys unisulcatus, albeit in very low frequencies (this species was represented by one mandible and one isolated M_1 , does lend some credence to the suggestion that conditions were somewhat drier in the LC-MSA as O. unisulcatus is known to shun damp situations (De Graaff 1981). It is not found along the southern coast today, but is distributed some distance inland from the coast. During the formation of the LC-MSA Lower and Middle the coastline was further away than it is today, but still within several kilometres of PP13B. However, species which might be expected to reflect drier, more sparsely vegetated or sandier environments, such as S. krebsii, A. namaquensis and G. afra are not found in greater abundance in these older facies, so the picture is not clear. In addition, the soricid, Crocidura flavescens, which is generally associated with dense vegetation and reportedly shows a preference for relatively moist environments, appears only in the older facies of all three areas (i.e. the LC-MSA Lower in the northeastern, the Roof Spall Lower sediments in the eastern, and in LB Silt in the western area). The absence of this species during later periods at Pinnacle Point was confirmed by the micromammal assemblages from PP9C (PP9C lies along the coast approximately 100 m north of PP13B) which are currently undergoing analysis. The implications of this are presently uncertain.

There are a couple of species not found in the LC-MSA Lower that the eastern and western areas hold in common. These are the woodland mouse, T. dolichurus and the chestnut climbing mouse, D. mystacalis. T. dolichurus provides evidence for the presence of a woodland/forest/thicket environment in the vicinity over 114 ka up until at least 92 ka (as indicated from its appearance in the eastern area in the Roof Spall Lower Facies at 114 ka, and in the western area in LBG Sand 1 and DB Sand 4a). Today this species is found on the eastern coast in Albany thicket, and may indicate that this biome extended further down the south coast in the past. D. mystacalis requires a habitat of tall grasses and rank vegetation. Such grasses could be provided by both a fynbos, or more typically grassland, habitat. This suggests that vegetation was denser during MIS 5 than the preceding MIS 6 (as represented by the LC-MSA Lower Facies).

Steatomys krebsii is found only in the western area of PP13B, in surface sediments. In the fossil sediments only one specimen was recovered from LB Sand 1. Avery (1977) noted that on the basis of fossil evidence from Boomplaas A, *S. krebsii* arrived at the south coast at the onset of the Holocene. The appearance of *S. krebsii* in the western area suggests that this species was present in the Mossel Bay area around 100 ka.

In the eastern area, two horizons dated from 92–98 ka (Upper Roof Spall) and 106–114 ka (Lower Roof Spall)

Table 3. The micromammals from the western area factes.	Table	3 . The	micromammals	from	the western	area facies.
----------------------------------------------------------------	-------	----------------	--------------	------	-------------	--------------

Genus and species	South Pit Fill	Northeast Fill	LB Sand 1	DB Sand 2	LB Sand 2	DB Sand 3	LBG Sand 3
S. varilla M. varius		1	1	1	2	2 1	1
C. judescens Crocidura sp.			1	1			
Zelotomys sp.			1			1	
G. afra			3	2		2	
M. albicaudatus			4		2	1	
S. krebsu			1		1		
D. mysiucuiis R numilio			1 4	4	1	2	
O. irroratus	1		13	8	3	17	
O. saundersiae	-		7	4	1	1	
M. verreauxi			2		1		
M. minutoides			2			1	
Indet. chrysochlorid	1		1	1			
Indet. bathyergid			1				
Muotis sp			2 1				
NISP	2	1	39	20	11	28	1
Genus and species	DB Sand 4a	LBG Sand 1	LBG Sand 2	DB Sand 4b	DB Sand 4c	LB Silt and LB Silt G	Laminated Facies
Suncus sp.		1				1	
S. varilla		10					1
M. varius		13				1	
Indet soricid						1	
T. dolichurus	1	2				1	
Zelotomys sp.		2				2	
G. afra		6				5	
D. mysticalis		1			2	_	
R. pumilio	2	41	4	1	2	.7	1
O saundersiae	4	92 33	4	1	11 4	13	1
O. saundersiae/O. irroratus	1	7	3		т	15	
M. verreauxi		3	-				2
M. minutoides		4					
Indet. chrysochlorid		1					
Myotis sp.		1					
Indet. bathyergia		1			1		
Elephantulus sp		1			1		2
Indet. Chiroptera		1					-
Rhinolophus sp.		1				?1	
NISP	8	210	7	1	18	59	6

contained micromammals, but only the latter horizons contained a sample size sufficient for analysis. The pattern of incisor digestion is closer to that of the spotted eagle owl rather than the barn owl, although incisor sample size is unsatisfactorily small and the identity of the predator/s is uncertain. The diversity of species is high considering the relatively small sample, and suggests that the predator/s took a broad selection of prey species. The pattern of species representation of the Roof Spall Lower was unusual in that it shows none of the peaks and dominance of 1–3 taxa commonly seen in barn and spotted eagle owl pellet assemblages. Roof Spall Lower shows a pattern of low percentage representation from a number of different species, and a diversity which is relatively high compared to other areas in PP13B.

Incisor digestion patterns indicate that a barn owl was responsible for deposition of micromammals in all western area facies containing larger samples. LB Silt contains more incisors in the moderate digestion category than observed in modern barn owl assemblages, but a high percentage of undigested incisors suggests the predator is also a barn owl. This is supported by the fact that the frequency of micromammal species found in LB Silt is similar to those in the surrounding facies. It may be that a young barn owl was contributing to the assemblage as

Table 4. Micromammal diversity in the various facies of PP13B.

	Н	No. of species	NISP
Western area			
Surface sediments	2.15	11	20
LBG Sand 1	1.78	17	207
LB Silt	1.57	9	57
LB Sand 1	2.13	12	39
DB Sand 3	1.46	9	28
DB Sand 2	1.54	9	20
Eastern area			
Upper Roof Spall	1.76	7	17
Lower Roof Spall	2.58	13	27
LC-MSA area			
LC-MSA Lower	1.98	12	63

Table 5. Diversity *H* in fossil micromammal assemblages from south and east coast archaeological assemblages (values after Avery (1986) unless otherwise indicated).

Archaeological site	Shannon Wiener index of general diversity (H)	Age/age range covered by micromammal- bearing deposits
Klasies River Mouth	1.9–2.3 (the majority of assemblages fell below 2.2) (Avery 1987)	Late Pleistocene
Die Kelders 1	2.27–1.75	MSA
Die Kelders 1	2.10	LSA
Boomplaas	2.44-1.69	Last Glacial Maximum
Nelson Bay Cave	1.62–1.42	18 000-5 000
Border Cave	1.97–2.74 (Avery 1992)	134 000-24 000
Byneskranskop I	2.48–2.14	Holocene

young owls digest bones and teeth of prey to a greater degree than adults (Andrews 1990).

In the western area there is a lower diversity of species in the facies of small samples (as would be expected), relative to the larger samples. Nevertheless, the general pattern of species representation is very similar, with *O. irroratus* dominating, and *R. pumilio* and *O. saundersiae* occurring in far lower frequencies, and representing the second or third most common species. *O. irroratus* is one of the two vlei rat species that are associated with moist and marshy habitats; however, they are also found in drier habitats such as grassy hillsides.

The western area micromammals differ from those of the other two areas in that shrews (the Soricidae), as a group, are poorly represented in the western area and make up only 6.8% of the micromammals, as opposed to 25% in the eastern area, and 13.15% in the northeastern area. The western area also contains three species which do not occur in the LC-MSA and eastern areas, namely, *Zelotomys woosnami, Elephantulus edwardi,* and *Georychus capensis*. All these species are generally associated with sandy substrates and/or rocky areas and sparse vegetation.

In terms of distribution, *Zelotomys* was the most surprising find at PP13B as this species is currently confined to arid and semi-arid areas of the subregion and in the Kalahari region of South Africa (Stuart & Stuart 2001). Levinson (1985) notes that Zelotomys is likely to have undergone a habitat change since 250 ka as this species shows very few marked desertic adaptations, such as enlarged bullae, long hind legs, or a bushy tip to the tail. The presence of this species on the south coast in PP13B deposits certainly suggests that, in the past, this species lived in very different environments compared to its modern habitat. Zelotomys was found in DB Sand 3, LBG Sand 1, and LB Silt, indicating its presence in the area from early in MIS 6, to around 92 ka. A cf. Zelotomys woosnami was identified in the late Middle Pleistocene site of Hoedjiespunt 1 (Saldhana, west coast, Western Cape Province), but this find was less surprising as it is still found in the west coast region today, albeit several hundred kilometres to the north (Matthews et al. 2005).

Some features common to all PP13B micromammal assemblages were noted. The gerbilline, *Gerbilliscus afra*, appears in consistently low frequencies in many facies in all three areas of PP13B. This species is known to be associated with sandy soil rather than any particular type of vegetation and suggests the presence of a sandy component in the surrounds of PP13B over a long period of time,

with a surprising lack of variation in the proportion of G. afra in the landscape. In a study made of modern barn owl roost collections throughout the western cape, G. afra was frequently found to be one of the top two best represented species and occurred in percentages which ranged from 20.1–80.9% (Avery et al. 2005). In several of the west coast fossil sites dating from Late Pleistocene to Holocene, two species of gerbilline (G. afra and Gerbillurus paeba), four soricid species, and three species of Otomyinae were always represented, although one particular gerbilline or otomyine species usually dominated in terms of overall numbers (Matthews et. al. 2005). The pattern at PP13B is very different, and G. afra is the only gerbilline represented, and appears in very low frequencies of 4-9% in various areas of PP13B. The fact that it is common in modern, but not fossil, barn owl assemblages may be related to the fact that it thrives in environments anthropogenically modified by farming. G. afra was not found in the Klasies River assemblages, but was found in similarly low levels in LSA levels of De Kelders at 4.1% (Avery 1979).

In absolute terms the western area of PP13B contained the highest number of micromammalian taxa with some twenty species represented, the eastern area contained 16, and the LC-MSA yielded 12 species. General diversity is highest in the eastern area in Lower Roof Spall, in the western area in LB Sand 1, and in the LC-MSA in LC-MSA Lower. Small sample size hampers the interpretation of diversity in some of the smaller assemblages (diversity and richness of a fossil sample are highly correlated with sample size (see Cruz-Uribe 1988; Denys 1999; Manthi 2002; Matthews 2004) but low general diversity appears to be a real feature of LB Silt, and possibly DB Sand 3. It is uncertain how to interpret this as, in a study by Avery (1999b), proportions of micromammalian taxa from barn owl pellets were analysed with climatic variables in order to investigate the relationship between the two. Diversity indices were not found to be closely related to any climatic factors. It is thus uncertain how to interpret changes in diversity between the various facies. Diversity in the surface sediments is higher than in any of the fossil assemblages, with the exception of Lower Roof Spall. Both Lower Roof Spall and LB Sand 1 show a relatively high diversity relative to the other PP13B facies, and also to Nelson Bay Cave and Border Cave. The relatively high diversity appears to be a real feature of these assemblages rather than an artefact of sample size as these facies represent comparatively small samples. Upper Roof Spall also shows a high diversity given the small sample size.

In terms of comparison with the younger sites such as Byneskranskop I and Die Kelders 1 general diversity is relatively low in the PP13B facies, with the exception of Lower Roof Spall, LB Sand 1 and LC-MSA Lower. Avery (1987) noted that an index *H* of 2.2 appears to be a fairly consistent cut-off point between Holocene interglacial scores and Late Pleistocene glacial scores in South Africa, with the latter generally falling below 2.2. The PP13B facies show a similar pattern to the Late Pleistocene glacial sites, with the exception of the eastern area which contains a relatively high general diversity and which indicates that diversity has fluctuated quite considerably over time.

In Avery et al.'s (2005) comparative study of 27 Barn owl roost sites (multiple collections were made at some of these sites) from the Western Cape, *H* ranged from 1.39 to 2.58. In terms of this, and also, in comparison with modern owl pellet data from the south coast (Matthews unpubl. report), the range of variability of general diversity seen in the PP13B micromammals falls within that of modern barn and spotted eagle owl pellet assemblages. Differences between the PP13B facies could be related to differences in the season, or in the area in which the owl was hunting, as well as climatic change.

In terms of density, the micromammal assemblages enjoyed an inverse relationship with shellfish (Antonieta Jerardino, pers. comm.), and were scarce when shellfish were abundant. This suggests that owls were occupying the cave when people were absent. A low general diversity was observed in large mammal assemblages from the site (Amy Rector, pers. comm.).

The density of micromammal remains in PP13B suggests that the owls responsible for micromammal accumulations did not roost in the cave for long periods so it is likely that the micromammals offer a glimpse of the micromammal population in the area over a brief period of time. The reasons for the lack of long-term visits are uncertain, but it is unlikely that lack of prey was the reason as there were clearly a variety of prey species available as indicated by the diversity index in several facies. The short occupation periods are also puzzling given that Taylor (2002) found that once barn owls selected a nest site, they keep it for life (strong site fidelity is a characteristic of holenesting species). In a study of occupancy in relation to site quality in barn owls (Tyto alba) in south Scotland, Taylor (2002) found that sites with the lowest amount of preferred foraging habitat and lowest long-term breeding success were occupied just as often as sites with opposite characteristics.

Conclusions

It is impossible to extrapolate any definite picture of the paleoenvironment reflected by micromammals from the LC-MSA Facies as species present are all catholic in their habitat requirements. Whether there was selection for species which are adaptable and opportunistic must be substantiated by further research into micromammal assemblages from other Pinnacle Point cave sites bracketing the LC-MSA Lower in age, and from similarly aged deposits. There are some faunal differences between micromammal assemblages from the LC-MSA and the eastern and western areas and it appears that vegetation was less dense during MIS 6 compared to MIS 5. Further research into micromammal assemblages dating to both MIS 5 and MIS 6 should aid in establishing if this impression is correct.

Not only is there no indication for marked environmental change over the long time period represented by the western area facies, but there is surprising consistency in the pattern of species abundance over time. The degree of consistency is quite remarkable, even considering that the same predator, a barn owl, was responsible for the accumulation of almost all the assemblages.

In the eastern area the pattern of species representation of Roof Spall Lower was unusual, and general diversity is high for a relatively small sample. Some evidence suggests that the environment was less open and moister during deposition of eastern area sediments, but differences in micromammal populations between eastern and western facies of similar age could conceivably be linked to different hunting strategies of owls, sampling different micro environments near the cave.

Zelotomys was the most surprising find in PP13B and serves as a reminder that using habitat requirements of extant species to extrapolate that of their fossil relatives may be problematic. The presence of *Zelotomys* in PP13B deposits suggests that this species enjoyed a far wider distribution in the past, and adaptation to arid environments occurred recently in its evolutionary history. Apparently, prior to 92 ka, *Zelotomys* had very different ecological requirements to that of today.

On-going research into the micromammalian assemblages from other Pinnacle Point archaeological sites aims to place the PP13B micromammalian assemblages within context, and to provide a well elucidated continuum of how micromammal populations on the south coast reacted to paleoenvironmental and paleoclimatic change over time.

We acknowledge the National Science Foundation (U.S.A.) (grant numbers BCS-9912465, BCS-0130713, and BCS-0524087 to C.W. Marean), the Hyde Family Trust, IHO, and ASU for funding the excavations, analysis, and write-up. Our thanks to the many people who have worked on PP13B and contributed to this research.

REFERENCES

- ANDREWS, P. 1990. *Owls, Caves and Fossils*. London, Natural History Museum Publications.
- AVERY, D.M. 1979. The micromammalian fauna from the Late Stone Age Levels at Die Kelders. *Annals of the South African Museum*. Appendix 2. 78(10), 229–232.
- AVERY, D.M. 1986. Preliminary interpretation of micromammalian remains from the 1984 excavations at Klasies River Mouth. 1A. Palaeoecology of Africa 17, 39–47.
- AVERY, D.M. 1987. Late Pleistocene coastal environment of the southern Cape Province of South Africa: micromammals from Klasies River Mouth. *Journal of Archaeological Science* 14, 405–421.
- AVERY, D.M. 1999a. Holocene coastal environments in the Western Cape Province, South Africa: micromammalian evidence from Steenbokfontein. *Archaeozoology* **10**, 163–180.
- AVERY, D.M. 1999b. A preliminary assessment of the relationship between trophic variability in southern African barn owls (*Tyto alba*) and climate. *Ostrich* **70**, 179–186.
- AVERY, D.M., AVERY, G. & PALMER, N.G. 2005. Micromammalian distribution and abundance in the Western Cape Province, South Africa, as evidenced by barn owls *Tyto alba* (Scopoli). *Journal of Natural History* 39(22), 2047–2071.

CRUZ-URIBE, K. 1988. The use and meaning of species diversity and richness in archaeological faunas. Journal of Archaeological Science 15, 179–196.

- DE GRAAFF, G. 1981. The Rodents of Southern Africa. Durban, Pretoria, Butterworths.
- DENYS, C. 1999. Of mice and men: evolution in East and South Africa during Plio-Pleistocene times. In: Bromage, T.G. & Schrenk, F. (eds), *African Biogeography, Climate Change and Human Evolution*, 216–226. New York, Oxford University Press.
- DEWAR, G. & JERARDINO, A. 2007. Micromammals: when humans are the hunters. *Journal of Taphonomy* 5(1), 1–14.
- FERNANDEZ-JALVO, Y. & ANDREWS, P. 1992. Small mammal taphonomy of Gran Dolina, Atapuerca (Burgos), Spain. *Journal of Archaeological Science* 19, 407–428.
- KARKANAŠ, P. & GOLDBERG, P. In press. Site formation processes in Site PP13B (Pinnacle Point, South Africa): resolving stratigraphic and depositional complexities with micromorphology. *Journal of Human Evolution.*
- LEVINSON, M.L. 1985. Are fossil rodents useful in palaeo-ecological interpretations? Annals of the Geological Survey of South Africa 19, 53–64.
- MANTHI, F.K. 2002. The taphonomy of a micromammalian faunal assemblage from the Saldanha Bay Yacht Club: a contribution to the study of the South African west coast palaeoenvironments. Unpublished M.A. thesis, University of Cape Town, Cape Town.
- MAREAN, C.W., NILSSEN, P.J., BROWN, K., JERARDINO, A. & STYNDER, D. 2004. Paleoanthropological investigations of Middle Stone Age sites at Pinnacle Point, Mossel Bay (South Africa): Archaeology and hominid remains from the 2000 Field Season. *Paleoanthropology* 2, 14–83.
- MAREAN, C.W., BAR-MATTHEWS, M., FISCHER, E., GOLDBERG, P., HERRIES, A., KARKANAS, P., NILSSEN, P., & THOMPSON, E. In press. The stratigraphy of the Middle Stone Age sediments at Pinnacle Point Cave 13B (Mossel Bay, Western Cape Province, South Africa). Journal of Human Evolution.

- MAREAN, C.W, BAR-MATTHEWS, BERNATCHEZ, J., FISHER, E., GOLDBERG, P., HERRIES, A. I. R., JACOBS, Z., JERARDINO, A., KARKANAS, P., MINICHILLO, T., NILSSEN, P. J., THOMPSON, E., WATTS, I., AND WILLIAMS, H. 2007. Early human use of marine resources and pigment in South Africa during the Middle Pleistocene. *Nature*, **449**, 905–909.
- MATTHEWS, T. 1999. Taphonomy and the micromammals from Elands Bay Cave. South African Archaeological Bulletin **170**, 133–140.
- MATTHEWS, T. 2002. South African micromammals and predators: some comparative results. *Archaeometry* **44**, 363–370.
- MATTHEWS, T., 2004. The taxonomy and taphonomy of Mio-Pliocene and Middle Pleistocene micromammals, west coast, South Africa. Unpublished Ph.D. thesis, University of Cape Town, Cape Town.
- MATTHEWS, T. 2006. Taphonomic characteristics of micromammals predated by small mammalian carnivores in South Africa: Application to fossil accumulations. *Journal of Taphonomy* 4(3), 143–160.
- MATTHEWS, T. Results of a taxonomic and taphonomic analysis of micromammal assemblages from owl pellet and small carnivore scat assemblages on the south coast, Cape Province. Unpublished report, Iziko South African Museum
- MATTHEWS, T, DENYS C. & PARKINGTON, J.E. 2005. The palaeoecology of the micromammals from the late middle Pleistocene site of Hoedjiespunt 1 (Cape Province, South Africa). *Journal of Human of Evolution* **49**, 432–451.
- MATTHEWS, T., PARKINGTON, J.E. & DENYS C. 2006. The taphonomy of the micromammals from the late Middle Pleistocene site of Hoedjiespunt 1 (Cape Province, South Africa). *Journal of Taphonomy* 4(1), 11–26.
- STUART C. & STUART, T. 2001. Field Guide to the Mammals of Southern Africa. Cape Town, Struik Publishers.
- TAYLOR, I. R. 2002. Occupancy in relation to site quality in barn owls (*Tyto alba*) in south Scotland. In: Newton, I., Kavanagh, R., Olsen, J. & TAYLOR, I. (eds), *Ecology and Conservation of Owls*, 30–41. Cambridge, Cambridge University Press.

APPENDIX A

The micromammal fauna from the eastern area of PP13B Surface Re-deposited Truncation Fill Shelly Brown Upper Roof Lower Roof Section sediments Disturbance Śand Spall Cleanings Spall Thamnomys dolichurus 1 Gerbilliscus afra 2 1 1 2 Mystromys albicaudatus Dendromus mysticalis 2 Suncus varilla 2 2 cf. 2 cf. Myosorex varius 2 Myosorex sp. 2 Rhabdomys pumilio 1 1 Otomys irroratus 1 3 3 1 1 1 1 3 Otomys saundersiae 4 6 Myomyscus verreauxi 2 1 2 Mus minutoides Crocidura flavescens 1 Aethomy namaquensis 1 2 O. saundersiae/O. irroratus Cryptomys hottentotus 1 1 Indet. chrysochlorid 2 1 Indet. Chiroptera 1 1

* = represented by teeth other than the M¹ or M₁, or by maxillary fragments.

The micromammal fauna from the northeastern area of PP13B

The interomaninal fauna from	in the northeastern area of 11150	
	LC-MSA Middle	LC-MSA Lower
<i>Suncus</i> sp.	1	2
Myosorex varius	2	1
Crocidura flavescens	0	3
Gerbilliscus afra	0	7
Mystromys albicaudatus	0	1
Rhabdomys pumilio	0	1
Otomys irroratus	4	13
Otomys saundersiae	3	24
Otomys unisulcatus	0	2
O. saundersiae/O. irroratus	0	7
Cryptomys hottentotus	0	1
Indet. bathyergid	0	1
Indet. chrysochlorid	0	1