Small mammal utilization by Middle Stone Age Humans at Die Kelders Cave 1 and Pinnacle Point Site 5-6, Western Cape Province, South Africa

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Abstract

Reported here are the results of a taphonomic analysis of the small mammals (between 0.75 kg and 4.5 kg adult body weight) and size 1 bovids (≤ 20 kg adult body weight) from the Middle Stone Age (MSA) sites of Die Kelders Cave 1 (DK1) and Pinnacle Point Site 5-6 (PP5-6), Western Cape Province, South Africa. This study provides a comprehensive taphonomic analysis of MSA small mammals with a focus on discerning the role of humans in their accumulation and the implications for human behavioral adaptations. Based on comparisons with control assemblages of known accumulation, it is evident that humans accumulated many of the Cape dune mole-rats, hares, and size 1 bovids at DK1. The patterning of cut-marked and burned mole-rat remains at DK1 provides evidence in the MSA for the systematic utilization of small mammals for their skins and as a protein source. Unlike DK1, small mammals and size 1 bovids constitute only a small portion of the PP5-6 mammals and they exhibit little evidence of human accumulation; nocturnal and diurnal raptors accumulated most of the small fauna at PP5-6. The nominal presence of small mammals in the PP5-6 fauna is atypical of MSA sites in the Cape Floristic Region, where they are abundant and often constitute large portions of MSA archaeofaunas. DK1 humans maximized the environmental yield by exploiting low-quality resources, a strategy employed possibly in response to localized environmental conditions and to greater human population densities. In comparison, the MIS5-4 humans at PP5-6 did not exploit small mammals and instead focused on higher-quality resources like shellfish and large ungulates. Humans and predators accumulated few small mammals at PP5-6, suggesting that these taxa may have been less abundant near the site and/or that humans could afford to concentrate on high-quality resources, perhaps because of a higher-yield local environment. This study suggests that an adaptive response to the environmental conditions of MIS4 was to maximize the resource yield of local habitats to include lower-quality resources when necessary. The incorporation of these resources in the face of changing environmental and perhaps population pressures is a subsistence adaptation that played a crucial role in the population stability and expansion evidenced by the number of sites in the Cape dating to MIS4.

Keywords: Die Kelders Cave 1; Pinnacle Point site 5-6; Middle Stone Age; Modern Human Behaviour;
Small Mammal Utilization; Taphonomy

Introduction

There is general agreement that the African Middle Stone Age (MSA) began by ca. 285,000 years ago (Tryon and McBrearty, 2002; 2006) and persisted until ca. 30,000 years ago (Deacon and Deacon, 1999; McBrearty and Tryon, 2005; Tryon and McBrearty, 2006). Paleoanthropological and archaeological investigations of this time period are frequently rooted in questions concerning the origins of modern human behavior. Throughout Africa, archaeological sequences dating to the last half of the MSA have produced evidence for behavioral characteristics thought to be central to the expansion of modern humans out of Africa. There is consensus that these behaviors include the creation and use of symbols (Henshilwood et al., 2002; 2009; 2011; d’Errico et al., 2005; 2012; Texier et al., 2010), technological and social complexity (Yellen and Brooks, 1995; Wurz, 1999; 2012; 2013; Brown et al., 2009; 2012; Wilkins et al., 2012), and adaptable foraging strategies and use of landscapes (Marean et al., 2007; McCall and Thomas, 2012; Nash et al., 2013; Marean, 2014; Thompson and Henshilwood, 2014a).

Recently, foraging strategies and landscape use in relation to modern human origins in southern Africa have received attention (Steele and Klein, 2009; Dusseldorp, 2010, 2012; Thompson, 2010a; Clark, 2011; Clark and Kendel, 2013; Henshilwood et al., 2014; Marean, 2014; Marean et al., 2014). The emphasis of this research has been the assessment (temporally and geographically) of purported changes in foraging strategies and landscape use as well as the analysis of subsistence adaptations that may have been driven by – or exhibited in – human behavioral changes during the MSA. While some research has considered time-saving technologies such as snares and traps in relation to small ungulates (Wadley, 2010) and flying birds (Avery, 1990), much of the research has focused on the ability (Milo, 1998; Marean et al., 2000a; Faith, 2008, 2011; Thompson, 2010b; Thompson and Henshilwood, 2011) or inability (Binford, 1984; Klein, 1994, 1995, 1998, 2000; Klein and Cruz-Urbe, 1996; Weaver et al., 2011) of MSA humans to effectively and efficiently exploit large and sometimes dangerous ungulates.

In addition to the focus on large ungulate research, sessile and slow moving organisms have received increased attention. Along the western and southern coasts of South Africa, shellfish (Parkington, 2003; Klein et al., 2004; Steele and Klein, 2005/6, 2008; Marean et al., 2007; Avery et al., 2008; Jerardino and Marean, 2010; Langejans et al., 2012; Klein and Steele, 2013; Wurz, 2013; Jerardino et al., 2014; Marean, 2014; Kyriacou and Parkington, 2015) and tortoises (Klein and Cruz-Urbe, 1983,

2000; al., Henshilwood et al., 2001a; Klein et al., 2004; Steele and Klein, 2005/6; Avery et al., 2008; Thompson, 2010b; Thompson and Henshilwood, 2014a, 2014b) are often abundant at MSA sites and, along with Klein's (1979) original observations on shellfish and tortoise size in relation to human paleodemography, the study of these remains have addressed questions concerning human mobility patterns, prey choice, subsistence adaptations and foraging strategies.

With the increased scrutiny of MSA hunting and foraging adaptations demonstrated by these and other studies, faunal analysts have redoubled their attention towards comprehensive taphonomic assessments of faunal remains, testing assumptions regarding the agents of faunal accumulation at southern African MSA archaeological sites and allowing for more comprehensive assessment of human foraging behaviors (Marean et al., 2000; Thompson, 2010; Thompson and Henshilwood, 2011; Faith, 2013). By building on the extensive body of zooarchaeological studies from the MSA of southern Africa -- where the focus has largely been on taxonomic counts and individual body size comparisons -- this line of investigation has proven fruitful regarding the attribution of agency and modes of human processing of large mammals, tortoises, and shellfish. However, with little exception (Badenhorst et al., 2014), small mammals from MSA archaeofaunas have not received the same level of attention as other faunas in spite of the fact that the Cape Floristic Region (CFR) has currently and historically supported a range of small-bodied mammals (mole-rats, leporids, porcupine, rock hyrax, small carnivores, and others) and small-bodied ungulates (klipspringer, steenbok, and grysbok). Many of these mammals regularly occur in MSA assemblages, some in large numbers (Blombos Cave [Henshilwood et al., 2001a], Die Kelders Cave 1 [Klein and Cruz-Urbe, 2000], Diepkloof Rock Shelter [Steele and Klein, 2013], Ysterfontein 1 [Avery et al., 2008], among others) in the Cape.

This paper considers the small mammal (>0.75 kg and <4.5 kg adult body weight, e.g., hares, rock hyrax, and Cape dune mole-rat) and size class 1 bovid (≤ 20 kg adult body weight [Brain, 1974], e.g., klipspringer, steenbok, and grysbok) archaeofaunas from Die Kelders Cave 1 (DK1) and Pinnacle Point site 5-6 (PP5-6) and provides taphonomic analyses of their remains in order to evaluate the degree to which humans, raptors, and mammalian carnivores were involved in the accumulation of small mammals and size 1 bovids at these sites. Included is a detailed evaluation of bone surface modification frequencies, bone breakage patterns, and comparisons of the DK1 and PP5-6 small mammal archaeofaunas with control assemblages of known human, raptor (diurnal and nocturnal), and mammalian carnivore accumulation. Based on the taphonomic assessment, the role of small mammals in the resource base of humans at these sites will be evaluated and combined with the observations on

large mammals, tortoises, and shellfish with a view to establishing a more complete understanding of the range of human subsistence strategies and foraging adaptations employed during the MSA.

Site description – Die Kelders Cave 1 (aka Klipgat)

The Die Kelders Cave complex (34°32'S, 19°02'E) is located in the Walker Bay Nature Reserve ~120 km southeast of Cape Town and ~250 km west of Pinnacle Point site 5-6 (Fig. 1). DK1 and the adjacent unexcavated site of DK2 form a complex situated >10 m above mean sea level at the eroded contact between the Paleozoic quartzites of the Table Mountain Sandstone Group and the Cenozoic Bredasdorp Limestone Group (Tankard and Schweitzer, 1974; Roberts et al., 2006). The site was originally excavated between 1969 and 1973 by Schweitzer and colleagues (Schweitzer, 1970, 1974, 1979; Schweitzer and Scott, 1973; Tankard and Schweitzer, 1974, 1976; Butzer, 1979), where the published focus was on the Later Stone Age (LSA) component. The excavation was extended between 1992 and 1995 by Avery, Grine, Klein, and Marean (Avery et al., 1997; Goldberg, 2000; Marean et al., 2000b) with emphasis on the expansion of the Middle Stone Age deposit. A descriptive and comparative summary table for DK1 and PP5-6 can be found in Table 1.

DK1 is divided into 14 distinct stratigraphic layers; layers 1-3 were deposited during the LSA and layers 4/5-15 are recognized as MSA in origin (Schweitzer, 1979; Marean et al., 2000b), though layer 15 contained few MSA stone artifacts in comparison to the younger layers (Thackeray, 2000). The sequence tends to alternate between layers of intense (even layers) and weak (odd layers) anthropogenic input (Goldberg, 2000; Marean et al., 2000b). For a complete description of the stratigraphy see Marean et al. (2000b). The LSA occupation has been radiocarbon dated to between 2000-1500 years BP (Schweitzer, 1974, 1979). The MSA sequence was dated with electron spin resonance and optically stimulated luminescence when these techniques were in the early stages of their application to cave sediments and therefore the dates may not be as precise as those estimated using more recent versions of these techniques (Roberts et al., 2015). Based on both original dating studies, age estimates for the MSA layers all fall within the error range of each other, making distinction of individual stratum ages unreliable. The consensus age estimate of the entire MSA sequence is $\sim 70 \pm 10$ ka BP (Feathers and Bush, 2000; Schwarcz and Rink, 2000). Further, luminescence dates obtained from throughout the MSA sequence suggest that the deposits accumulated fairly rapidly (Feathers and Bush, 2000) and the large faunal and sedimentological evidence further suggests that the entire MSA sequence was accumulated during a cool phase in Earth's climate, likely during marine isotope stage (MIS) 4 (71- 57 ka BP) (Grine et al., 1991; Avery et al., 1997; Goldberg, 2000; Klein and Cruz-Urbe, 2000). Given the cave's low elevation,

deposits accumulated prior to MIS5e would surely have been washed away by the sea level high stand of the period. Based on consensus of dating techniques, large fauna, sedimentology, and sea level, it seems that the MSA occupation of DK1 occurred during MIS4. However, it is necessary to note that the micromammal species diversity from throughout the MSA sequence does not entirely agree with these other lines of evidence (Avery, 1982). The micromammal composition from the earlier MSA sequence suggests wetter and warmer conditions, whereas the middle and later MSA sequence indicates a general trend towards cooler and drier climate conditions (Avery, 1982). Inclusion of the micromammal data indicates that the DK1 MSA sequence represents an occupation that may well include the end of MIS5a as well as MIS4.

During the human occupation at DK1, global sea level was between approximately -15 m and -80 m lower than present (Chappell and Shackleton, 1986; Shackleton, 1987; Lambeck and Chappell, 2001; Lambeck, 2004). Current estimates of coastline position during MIS5a and MIS4 indicate that it was ~4 km away at the beginning of MIS5a, fell to nearly 17 km during MIS4 and rose to within ~6 km by the end of the MSA occupation (Hendey and Volman, 1986; Van Andel, 1989; Fisher et al., 2010). This indicates that from the start to the end of the MSA occupation, the coastal geography of DK1 oscillated between a fully terrestrial to a near-coastal cave (see Fig. 1 for location of DK1 relative to sea level). The landscape near DK1 likely transitioned from a wetter environment featuring natural springs and streams and dominated by vegetated dune fields at the beginning of the MSA occupation to a drier environment with extensive grasses during the middle and end of the occupation (Tankard and Schweitzer, 1974, 1976; Avery, 1982; Goldberg, 2000; Klein and Cruz-Urbe, 2000; Marean et al., 2000b).

Marine mammals are modestly present throughout much of the site but complete marine shells are absent from the MSA layers. However, Goldberg (2000) notes that shell fragments are present in micromorphology thin sections from MSA layers 6 and 8 and that the absence of well-preserved shell is due to decalcification as opposed to strictly the lack of exploitation by humans. Marine mammals occur throughout the MSA sequence in proportions of between 1-13% by number of identified specimens (NISP) – except for layers 7 and 8 where there are none (Klein and Cruz-Urbe, 2000) – as do seabirds (G. Avery, pers. comm.). There is consistent ethnographic (Bird and Bliege Bird, 1997; Bird et al., 2002; Thomas, 2002) and archaeological (Parkington et al., 1988; Erlandson, 2001; Jerardino, 2003; Langejans et al., 2012; Marean, 2014) evidence to suggest that humans transport shellfish back to residential sites when the distance from the shore does not exceed 10 km. The presence of some marine resources at DK1 and current estimates of coastline position during MIS5a and MIS4 suggests that it was likely not

much more than 10 km from the cave for much of the MSA occupation. However, given the degraded state and/or modest presence of sea shells, marine mammals, and seabirds, it seems that the reliance on marine resources by MSA humans at DK1 was not extensive.

The lithic component of DK1 is composed mostly of course grained quartzite and some fine grained silcrete (Thackeray, 2000). Though the segments and backed-blades diagnostic of the Howiesons Poort (HP) are absent from the site, there is a shift from course to fine grained raw material in MSA layer 12, a pattern typical of southern African MSA sites that feature HP levels (Brown, 1999; Thackeray, 2000). However, definite assignment of the DK1 lithic material to a recognized MSA typology is precluded given the absence of characteristic elements of the HP (and Still Bay), and the tendency of southern African MSA artefact assemblages to lack distinct patterning outside of these industries (Thackeray, 2000).

The DK1 fossil component features a diverse and large assemblage (>220,000 NISP; Klein and Cruz-Urbe, 2000) that includes mammals, reptiles, birds, and hominins (Avery et al., 1997; Klein and Cruz-Urbe, 2000; Grine, 2000). The micromammals (<750 g adult body weight; Avery, 1982), macromammals (>750g adult body weight; Klein and Cruz-Urbe, 2000), and tortoises (Klein and Cruz-Urbe, 2000) have been analyzed for taxonomic abundance and paleoenvironmental interpretation. On the whole, the faunal assemblage is dominated by small mammals (those between 0.75 kg and 4.5 kg body weight) that account for the overwhelming majority of the assemblage (>85%; Klein and Cruz-Urbe, 2000), most of which are Cape dune mole-rats (*Bathyergus suillus*; Table 2). The ungulates predominantly consist of smaller-bodied (e.g., *Raphicerus* sp.) and larger-bodied bovids (e.g., *Taurotragus oryx*). The taxonomic composition of the LSA fauna suggests that environmental conditions during the LSA occupation were similar to those of today (Klein and Cruz-Urbe, 2000). The MSA faunal composition features species historically associated with the CFR as well as extralimital (i.e., quagga, black wildebeest, springbok, and southern reedbuck) taxa (Klein and Cruz-Urbe, 2000) often associated with lower regional sea levels. The presence of both extant and extralimital species as well as arid-adapted (e.g., black wildebeest and springbok), water-dependent (e.g., hippopotamus, grey rhebok, and southern reedbuck), and taxa associated with open grassy habitats (e.g., blue antelope and hare) signifies that environs in close proximity to DK1 were different than today, and appear to have included a mixture of more-closed and more-grassy habitats (Avery, 1982; Klein and Cruz-Urbe, 2000; Marean et al., 2000a). The MSA faunal composition of DK1 indicates that the cave was situated near a relative diversity of habitat types (Marean et al., 2000a).

Taphonomic analyses of ungulates and marine mammals from MSA layers 9-15 have been conducted (Marean et al., 2000a; Thompson, 2008) and results from layers 10-11 have been published (Marean et al., 2000a). Overall, the bone surface preservation of mammals can be characterized as good, though there is some diagenetic decalcification (Marean et al., 2000a and pers. observation). The analyses by Marean and colleagues (2000a) and Thompson (2008) indicate that the larger mammals (particularly size 2-5 ungulates) were principally accumulated by MSA humans. Numerous percussion, filleting, and disarticulation marks on ungulate bones are the primary evidence for human agency. Some of the size 1 bovid remains displayed evidence of human accumulation in the forms of cut and percussion marks. However, many size 1 bovid bones exhibited gastric etching which Marean et al. (2000a) attributed to raptors, an observation supported by Klein and Cruz-Urbe (2000). Furthermore, Klein and Cruz-Urbe (2000) observed that many of small bovid individuals are juveniles, a prey demographic pattern associated with raptor predation (Avery, 1990). Overall, the occurrence of carnivore tooth-marked bone is moderate to low, indicating minimal levels of carnivore involvement in ungulate bone accumulation. Marean et al. (2000a) ascribed the carnivore tooth marks to scavengers which occupied the site occasionally when humans were not present.

DK1 small mammal investigation

The small mammal component of DK1 has not previously been taphonomically studied. However, Klein and Cruz-Urbe (2000) hypothesized that the MSA small mammal accumulation (particularly the Cape dune mole-rats) was likely the result of predators but did not rule out the possibility of some human agency. They reasoned that Cape eagle-owls (*Bubo capensis*) probably accumulated the MSA mole-rats (and implicitly other small mammals) based on three factors: (1) mole-rat remains were unusually abundant (accounting for 90% of the fauna by minimum number of individuals, MNI) in some areas of the site and reaching a density of 100 individuals per square meter in the middle of MSA layer 8), (2) mole-rat skeletal-part profiles resembled general eagle-owl prey patterning, and (3) some mole-rat remains appeared digested. In addition, the predatory behavior of the Cape eagle-owl -- namely the owl's tendency to prey on mammals up to 4.5 kg in size (Hockey et al., 2005) such as juvenile klipspringers and steenbok/grysbok as well as hares, rock hyraxes, and colonial species like mole-rats -- and the tendency to roost in caves and rockshelters (often on the floor) implicate the Cape eagle-owl as the principal candidate for small mammal accumulation. However, Klein and Cruz-Urbe's (2000) observations were macroscopic, largely impressionistic, and the mole-rat skeletal part frequencies, digested bone frequencies, and affected anatomical-part distributions were

not quantified and reported. Another line of evidence to suggest that raptors may have been involved in the accumulation of bone at DK1 is Marean et al.'s (2000a) observations that (1) some of the size 1 bovid remains display digestion damage indicative of raptors (though gastric etching of other predators could replicate this pattern) and (2) that these bones were recovered in spatial clusters.

Additionally, Klein and Cruz-Urbe (2000) note that it is conceivable that mammalian carnivores and/or humans could have been involved in the accumulation of small mammals but that the assemblage was not studied taphonomically and that their overall assessment of small mammal accumulation is provisional. They go on to suggest that “a damage analysis would be particularly telling if it revealed etching by eagle owl gastric acids . . . most etching might be visible only under very high magnification . . . a thorough microscope study would probably require many months” (Klein and Cruz-Urbe, 2000: p.188). Conversely, Klein and Cruz-Urbe (2000: p.188) concluded that humans played a role in the accumulation of LSA small mammals (including mole-rats) as “obviously burnt or cutmarked specimens occur only in the LSA assemblage.” Unfortunately, these macroscopic observations were not quantified and the surface modification patterns were not reported. They provide further evidence to support a LSA and MSA contrast in small mammal accumulation in noting that the mole-rat-rich LSA microstratigraphic layers tend to contain bones of many other taxa while mole-rat-rich MSA layers often contain bones of little else, which suggest a single (non-human) predator specializing on a lone prey species. Avery (1990: p. 121) articulated an alternative view in which he noted little difference between the LSA and MSA small mammal assemblages and states “in view of the fact that cultural remains (including bones of large mammals) of undeniably human origin make up a large proportion of the accumulation, and the argument regarding small mammals in LSA accumulations, it seems reasonable to accept that agents other than people did not add substantially to the samples of small mammals.”

Site description – PP5-6

Pinnacle Point site 5-6 (34.2°S, 22.1°E) is a rockshelter situated in wave-cut Paleozoic quartzitic cliffs of the Table Mountain Sandstone Group and is located ~6 km west of Mossel Bay on a southward oriented promontory facing the Indian Ocean (Fig.1). The site is divided into three areas: Northwest Remnant, Long Section, and South Remnant (Karkanas et al., 2015). The main archaeological sequence is the Long Section which is exposed by a continuous >14 m vertically excavated profile of MSA deposit (Brown et al., 2012; Karkanas et al., 2015). The northern and southern ends of the Long Section are ~25 m and ~16 m above mean sea level respectively (Brown et al., 2012). The archaeological sequence consists of 11 horizontally continuous stratigraphic aggregates each representing major changes in

anthropogenic and geogenic sedimentary inputs (Karkanas et al., 2015). The MSA basal deposit likely began accumulating prior to MIS5b (Brown, 2011); OSL samples at the top and near the bottom of the excavated profile have yielded dates of 51 ± 2 ka BP and 96 ± 6 ka BP respectively (Karkanas et al., 2015). There is no LSA in the main PP5-6 deposit. For a detailed discussion of the stratigraphy and ages see Karkanas et al. (2015).

The paleoenvironmental and paleoclimate context for the PP5-6 archaeological sequence is inferred from speleothem-based carbon and oxygen isotope records (Bar-Matthews et al., 2010) from speleothem samples dating from 53 to 90 ka BP (uranium-thorium) that were retrieved from a cave neighboring PP5-6. These high-resolution records, contemporaneous with the MSA occupation of PP5-6, show that Pinnacle Point and the surrounding environ changed rapidly during the period of human occupation. The late MIS5 period is typified by shrubby CFR (fynbos) vegetation and C3 grasses as well as increased winter rainfall. The cooler conditions of MIS4 are characterized by an increase in C4 grasses and more summer rainfall in the region (Bar-Matthews et al., 2010).

In conjunction with the terrestrial-based carbon and oxygen isotope records, Fisher et al. (2010) developed a three dimensional GIS-based coastline model for the southern African coastline that integrates the topography of the submerged Agulhas Bank and the sea cliffs at Pinnacle Point and provides estimates of coastline position at 1500-year intervals. During warmer periods in global climate, such as the late MIS5 occupation, PP5-6 was a coastal cave similar to today where inhabitants relied on CFR and marine resources, indicated by the shell deposits dated to this period (Karkanas et al., 2015). During the cooler phase of MIS4, PP5-6 was an inland cave located between ~10-20 km from the coastline on average (Fisher et al., 2010). The site would have overlooked mixed grass- and fynbos-covered plains that supported large herbivores but still offered access to the coastline and its resources. At this time there is a shift to microlith technology at PP5-6, which may have been used as armaments for large mammal hunting (Brown et al., 2012), suggesting the increased importance of large game during this period (Karkanas et al., 2015).

The MSA deposit at PP5-6 features abundant fauna, lithics, ochre, ostrich eggshell, and combustion features (Karkanas et al., 2015). To date, only the lithics (Brown et al., 2009, 2012; Brown, 2011), site formation processes, and occupation intensity (Karkanas et al., 2015) have been extensively reported. Similar to other South African coastal MSA sites, PP5-6 demonstrates a transition from coarse-grained quartzite to finer grained silcrete. The HP is present at PP5-6 (Brown et al., 2012) at an age consistent with other HP occurrences in southern Africa, ~65-60 ka BP (Jacobs et al., 2008a). In addition,

Brown and colleagues (2012) have reported a previously unidentified microlithic backed 'bladelet' technology that differs in form from microlithic HP segments. This distinctive PP5-6 'bladelet' technology appears ~6000 years prior to the HP, thereby representing an early origin for microlithic technology in southern Africa. In addition, Brown et al. (2009, 2012) demonstrate that heat treatment of lithic raw materials was integral to the microlith production sequence and that this technological innovation persisted for nearly 100 ky. Brown et al.'s research suggests that complex lithic technologies in southern Africa occurred both earlier and lasted longer than previously thought.

The geoarchaeological analysis reported by Karkanas and colleagues (2015) details the patterns of anthropogenic and geogenic input throughout the MSA occupation of PP5-6. Coarse and fine grained analyses of the sediments have revealed differences between the MIS5 and MIS4 human occupation patterns of the site. During MIS5, the coastline was close to the site and it appears that small groups of people were exploiting coastal resources and visiting the locale for short periods of time as parts of the sequence are characterized by numerous single hearth structures (Karkanas et al., 2015). With the beginning of MIS4, occupations became much more intense as evidenced by thick palimpsests of burned anthropogenic materials and the presence of aggregated combustion features. During this time, the inhabitants shifted to silcrete as a preferred raw material and began to make microlithic tools (Brown et al., 2012; Karkanas et al., 2015). Based on their study of PP5-6 and the abundance of sites dating to MIS4 in the region, Karkanas and colleagues suggest that human populations in the Cape adapted to the cooler climate through technological change and population growth or stability and that the response of MIS4 humans was different to that of those in the previous glacial phase.

Materials and methods

Though typically >4.5 kg, size 1 bovids have been included in the study samples as the suite of predators (raptors, carnivores, and humans) that commonly prey on small mammals also frequently target and accumulate size 1 bovids (Avery et al., 1987; Yellen, 1991a; Armstrong and Avery, 2014). In addition, digested size 1 bovid remains (particularly *Raphicercus* sp.) attributed to raptor accumulation were identified in the MSA fauna at DK1 (Marean et al., 2000a) and their relative frequencies in relation to other small fauna may provide evidence of the extent of raptor contribution in specific stratigraphic layers and the site as a whole. For the purpose of simplicity and succinctness within the context of this paper, the term small mammal will include specimens between 0.75 kg – 4.5 kg as well as size 1 bovids unless otherwise stated.

The portion of preserved bone, orientation of paired elements, and taxon were identified and recorded for each specimen. An attempt was made to identify each specimen regardless of size. Most specimens could be identified to a specific skeletal element, however some fragmentary specimens lacked diagnostic features and were identified as vertebra fragment, long bone shaft fragment, tooth fragment, or unidentifiable fragment >2 mm. Bone fragments that were unidentifiable and <2 mm in maximum dimension were excluded from the analysis. The maximum length and width of each specimen was measured using digital calipers. Comparative osteology collections from the Iziko Museum in Cape Town and the Diaz Museum in Mossel Bay were used in the specimen identification process.

All specimens were inspected with a 10-40x binocular zoom microscope under high incident light to examine for and document bone modifications using previously established criteria (Blumenschine et al., 1996). Digestive alteration to teeth and bones was observed and recorded after Andrews (1990) and summarized according to Lloveras et al. (2008a). A description of the tooth and bone digestion identification criteria and images can be found in the Supplementary Online Material (SOM Table S1 and Fig. S5). The presence or absence of burning was observed and characterized based on color variation ranging from absent to complete calcination (Stiner et al., 1995). Taphonomic attributes such as rodent gnawing, weathering (for small mammal remains [Andrews, 1990]), and post-depositional surface destruction (Thompson, 2005) were observed and their anatomical location was recorded. The characterization, frequency, and location of mammalian carnivore, raptor, and human induced punctures (Tappen and Wrangham, 2000; Elkin and Mondini, 2001; McGraw et al., 2006; Pobiner et al., 2007; Thompson and Henshilwood, 2014a; and references therein), pits (Pickering and Wallis, 1997; Domínguez-Rodrigo and Piqueras, 2003; Sanders et al., 2003; Landt, 2007; Domínguez-Rodrigo et al., 2013; and references therein), scores (Haynes, 1980; 1982; 1983b; Blumenschine et al., 1996; Trapani et al., 2006; and references therein), notches (Brain, 1981; Blumenschine and Selvaggio, 1991; Capaldo and Blumenschine, 1994; Fisher, 1995; Domínguez-Rodrigo et al., 2013; and references therein), and cut marks (Egeland, 2003; Domínguez-Rodrigo and Barba, 2005; Domínguez-Rodrigo and Yravedra, 2009; Domínguez-Rodrigo et al., 2009; Cochard et al., 2012; and references therein) were recorded using criteria adopted from established sources in the taphonomic literature. Examples of the bone surface modification documented in this study can be found in Fig. 2 and identification criteria for these bone surface modifications can be found in SOM Tables S1 and S2.

Experimental, actualistic, and ethnoarchaeological studies have demonstrated that humans (Hockett, 1991; Yellen, 1991a,b; Henshilwood, 1997; Lupo and Schmitt, 2005), mammalian carnivores (Schmitt and Juell, 1994; Cochard, 2004; Lloveras et al. 2008a, 2012; Álvarez et al., 2012; Rodríguez-Hidalgo et al., 2013; Armstrong, 2016), diurnal (Hockett, 1991; Schmitt, 1995; Cruz-Uribe and Klein, 1998; Lloveras et al., 2008b; 2014; Armstrong and Avery, 2014; Armstrong, 2016), and nocturnal (Sanchis Serra, 2000; Lloveras et al., 2009a; Armstrong, 2016) raptors accumulate and modify small mammal remains, and that different bone surface modification types and their relative frequencies can be used to differentiate between accumulators. For example, mammalian carnivores and raptors can digest the bones of small prey. However, based on raptor and canid feeding studies (Armstrong, 2016) bald eagles tended to consume fewer bones than great horned owls and coyotes – bald eagles swallowed ~25% of the bones of rabbit- and guinea pig-sized prey while great horned owls and coyotes swallowed ~65% and ~90%, respectively. Bones consumed by bald eagles tended to be axial skeletal elements, were often totally obliterated and deleted from an assemblage – bald eagles deleted ~16% of rabbit- and guinea pig-sized prey skeletal elements while great horned owls deleted only ~8% of prey bones – and those that survived digestion exhibited ‘extensive’ digestion damage (Armstrong, 2016; see SOM Tables S1-S2 for a description of grades of digestion). Small mammal bones consumed by great horned owls can be categorized as exhibiting ‘moderate’ digestion damage, included more appendicular elements, and were better preserved than those accumulated by bald eagles or coyotes (Armstrong, 2016). Coyotes thoroughly masticated small mammal prey and produced highly fragmented assemblages where prey remains displayed ‘extensive’ digestion damage – the fragmentation ratio (NISP/MNE) of coyote consumed long-bones was 2.35 for rabbit- and guinea pig-sized prey, while the ratio for bald eagle and great horned owls was only 1.44 and 1.70, respectively (Armstrong, 2016). Although more observations concerning raptor and mammalian carnivore prey accumulation and patterning are needed, it seems reasonable at this stage to use these results as a comparative model for the current study.

There are also differences in the frequencies of punctures and pits created by carnivore teeth and raptor beaks and/or talons. Bald and Verreaux’s eagles swallow fewer bones than do other predators (Armstrong and Avery, 2014); consequently predation and feeding damage in the forms of punctures and pits are more often preserved in comparison to great horned owls and coyotes where the same marks were obscured by digestion damage and fragmentation (Armstrong and Avery, 2014; Armstrong, 2016). Signatures of human involvement in the accumulation of small mammals include cut-marked bone, percussion notches for marrow extraction (especially size 1 bovid long-bones and leporid

hind limb bones), and burned bones (Hockett, 1991; Yellen, 1991a,b; Henshilwood, 1997; Tagliacozzo and Fiore, 1998; Fernández-Jalvo et al., 1999; Hockett and Bicho, 2000; Hockett and Haws, 2002; Tortosa et al., 2002; Parkington and Fischer, 2006). Therefore the relative frequencies of digested, fragmented, pitted, punctured, cut marked, percussion notched, and burned bone are the suite of diagnostic bone surface modifications that are used in this study to differentiate between human, carnivore, and raptor accumulation of small mammals.

Long bone breakage concerning the morphology of fracture angle and fracture outline was recorded following Villa and Mahieu (1991). To evaluate whether the DK1 and PP5-6 bones were predominantly broken while 'green' or 'dry,' exact tests for goodness-of-fit were conducted comparing the observed distributions of fracture angle morphology frequencies for each small mammal taxonomic aggregate per layer in comparison to expected frequencies of oblique, right, and right/oblique fracture angles. Breakage samples of <10 specimens per analytical unit were not included in breakage analyses. Fragmentation indices and whole bone percentages were calculated for each skeletal element by dividing NISP by the minimum number of skeletal elements (MNE) and whole bones by NISP, respectively.

The DK1 small mammal faunal sample included in this study consists of specimens excavated by Schweitzer and by Avery, Grine, Klein, and Marean. Given the enormous quantity of faunal remains from DK1, it was necessary to sample the largest excavation layers; these include the LSA and MSA layers 6-8; the samples from layers 9-15 are smaller, making it possible to study each specimen, including the wet-sieved materials. MSA layer 4/5 was excluded from study as the two layers were difficult to distinguish and because of the overall time constraints of the project.

The fauna from DK1 were not piece-plotted. Excavation was conducted along natural micro-stratigraphic units for each 50 cm quadrates within 1 m excavation squares and faunal specimens were associated with individual micro-stratigraphic units (Marean et al., 2000b). Typically, there were multiple micro-stratigraphic units per 1 m excavation square and stratigraphic layer. To allow for robust samples, relative skeletal-part analysis, and examination of horizontal spatial patterning within and between the sampled layers (LSA and MSA 6-8), a minimum of 200 specimens were studied from each of the 1 m excavation squares (unless the square yielded a total of <200 small mammal specimens) per layer. Between both phases of the excavation, there were 72 excavation squares in MSA layer 6, 52 in MSA layer 7, and 53 in MSA layer 8. The faunal sample from each 1 m square was randomly selected and all small mammal specimens (including wet-sieved materials) from selected micro-stratigraphic units were

studied regardless of count total. In many cases, the count far exceeded the 200 specimen minimum per excavation square per layer. Where there were fewer than 200 specimens in a micro-stratigraphic unit, an additional micro-stratigraphic unit from the same square and layer was selected for study in order to achieve ≥ 200 specimens per excavation square. In total, 3912 LSA, 8496 MSA layer 6, 5890 MSA layer 7, and 9075 MSA layer 8 small mammal specimens were studied.

The PP5-6 small mammal faunal assemblage consists of specimens excavated during the 2006-2010 excavation seasons. All specimens in this study were piece-plotted or recovered from the wet-screened materials associated with specific stratigraphic units and proveniences. The site's stratigraphic aggregates consist of numerous horizontally bedded sub-aggregates in which there are multiple micro-stratigraphic units (called StratUnits) associated with each 1 m excavation square. In order to achieve a faunal sample that was temporally and spatially representative, unbiased, and robust, the fauna from several StratUnits from each sub-aggregate were randomly selected for study. A minimum of one StratUnit for every 10 was selected for study; the only condition for selection was that the unit contained fauna. In all, 115 StratUnits were sampled. As the fauna from PP5-6 had not been previously studied, the proportion of small to large mammalian fauna and the stratigraphic location of small mammal specimens were not known. Therefore, it was necessary to identify all randomly selected faunal materials. Of the 5724 faunal specimens sampled only 208 were small mammals. Figure 3 illustrates the spatial distribution of all sampled faunal specimens (Fig. 3A) and the location of the identified small mammals (Fig. 3B) in relation to the stratigraphic aggregates.

Analyses of the taphonomic patterning and temporal variation for DK1 and PP5-6 are presented in principal components analyses (PCA) of bone modification proportions for all identifiable bone fragments. The bone surface modifications considered in the PCAs are those listed previously in this section. Evidence of rodent gnawing was extremely rare at DK1 and PP5-6 and therefore excluded from the PCAs as an accumulator diagnostic. Between 50-100% of bones recovered from modern porcupine dens exhibit gnawing (Maguire et al., 1980; Brain, 1981; Lyman, 1994; O'Regan et al., 2011); the lack of rodent-gnawed bone suggests that porcupines played little – if any – role in the accumulation of bone at DK1 and PP5-6. In addition to the DK1 and PP5-6 assemblages, a series of small mammal control assemblages that were accumulated by a known agent and feature comparable taphonomic analyses have been included in the PCAs in order to assess similarities and differences between the archaeological assemblages and small mammal accumulations of known origin. These control assemblages include small mammals accumulated by (1) !Kung San foragers (Yellen, 1991a,b;

Armstrong, paper in preparation), (2) medium-sized carnivores (Schmitt and Juell, 1994; Lloveras et al., 2009a; Armstrong, 2016), (3) diurnal raptors (Armstrong and Avery, 2014; Armstrong, 2016), and (4) nocturnal raptors (Lloveras et al., 2009a; Armstrong, 2016). The PCAs were conducted with the PRINCOMP function of the R (version 2.15.3) statistical package.

In order to assess which predator(s) contributed most heavily to the DK1 and PP5-6 assemblages, Euclidean hierarchical cluster analyses were conducted using PCA axes 1 and 2 scores for both assemblages, a method similar to one employed by Faith (2013). The cluster analyses include the DK1 and PP5-6 assemblages as well as the human, mammalian carnivore, diurnal and nocturnal raptor control assemblages. The expectation is that the archaeological assemblages will cluster with the control assemblage(s) with which it is taphonomically most similar. The cluster analyses were conducted with the CRAN-VEGAN algorithm for community paleoecology data (Oksanen et al., 2015) utilizing the R (version 2.15.3) statistical package.

Results and discussion

DK1 – Taxonomic composition

Table 2 represents the DK1 faunal sample described in this paper and is in agreement with the identified small mammal taxa and counts reported by Klein and Cruz-Urbe (2000). For analytical purposes, the DK1 sample has been aggregated into five analytical units based on the taxonomic composition, morphological similarities, and relative abundance. The small mammal analytical aggregates (SMA) are: (1) mole-rats (consisting of only *B. suillus*), (2) size 1 bovids (all specimens identified as *Raphicerus* spp., *R. melanotis*, *R. campestris*, *O. oreotragus*, or size 1 bovid), (3) hares (all specimens identified as *Lepus* spp., *L. capensis*, and *L. saxatilis*), (4) rock hyraxes (consisting of only *P. capensis*), and (5) small carnivores (consisting of all herpestids, felids, mustelids, erinaceids, and viverrids). The relative proportions of the SMAs by level are reported in Table 2. Mole-rats are the dominant taxon by NISP in all but one level (MSA14) at DK1. Size 1 bovids, followed by hares, are the next two most numerous taxonomic aggregates, followed by rock hyraxes and small carnivores, each of which are noticeably less abundant than the other SMAs.

Mole-rats are numerous in relation to all mammals throughout the site representing a total of 75.3% by NISP of all specimens in this study, and account for >90% of all specimens in MSA layers 7-9 at DK1. For comparison, mole-rats account for 93.2%, 31.3%, 31.9%, and 0.0% by NISP of all small mammals at Ysterfontein 1 (YFT1; Avery et al., 2008), Blombos Cave (BBC; Henshilwood et al., 2001a),

Diepkloof Rockshelter (DRS; Steele and Klein, 2013), and Pinnacle Point 13B (PP13B; Thompson, 2010b), respectively. However, at DK1 the proportion by NISP of Cape dune mole-rats to other small mammals varies per stratum (LSA = 71.8%, MSA6 = 47.8%, MSA7 = 95.4%, MSA8 = 98.6%, MSA9 = 90.8%, MSA10 = 74.6%, MSA11 = 59.8%, MSA12 = 57.1%, MSA13 = 58.1%, MSA14 = 22.1%, MSA15 = 48.2%), and though the frequency of mole-rats as a percentage of all small fauna decreases from more recent to older layers, the correlation is not significant ($r_s = -0.509$, $p = 0.114$). It is clear, however, that mole-rats are abundant in all MSA layers and super abundant in layers MSA7-9, but that their relative frequency varies over time.

Of the MSA sites in the CFR for which taxonomic abundances of small and large mammals are reported, YFT1 (Halkett et al., 2003; Klein et al., 2004; Avery et al., 2008), BBC (Henshilwood et al., 2001a; Thompson and Henshilwood, 2011), and DRS (Steele and Klein, 2013) are more similar to DK1 in terms of small and large mammal relative abundances. Conversely, PP13B differs from DK1 as there are few small mammals in relation to large (Rector and Reed, 2010; Thompson, 2010b). Taxa such as Cape dune mole-rats, rock hyrax, hares, and small carnivores are far more common at DK1, YFT1, BBC, and DRS in comparison to PP13B. In addition, Thompson and Henshilwood (2014) observed that tortoise representation similarly varies in frequency between these sites. They also note that in the CFR, the “typical” pattern among MSA sites is to feature as many or more small mammals and tortoises by MNI in relation to larger fauna (Thompson and Henshilwood, 2011).

Where Cape dune mole-rats are somewhat less-abundant at DK1 (MSA layers 6, 11-15), hare and size 1 bovid counts increase. Composite chi-squared values comparing the distribution of SMAs for each level are provided in Table 3; all but two comparisons are shown to be statistically different when each is examined head-to-head with another level, revealing a general pattern of variation in SMA composition between layers. In addition, Table 4 shows the chi-squared values for each individual SMA in comparison to the previous level (Bonferroni correction has been applied). The scores are to be read in comparison to the level to the right of the test statistic column. For example, the change in mole-rat abundance between layers MSA11 and MSA12 ($\chi^2 = 0.9$, $p = 0.331$) is not significant at the 0.05 level. The statistical results provided in Tables 2 and 3 and the %NISP of each taxon in Table 2 reveals that the SMAs differ significantly across nearly every level and that this relationship is driven mostly by fluctuating abundances of mole-rats, hares, and size 1 bovids across the MSA layers (Table 4). The differences between levels are far less affected by the changes in abundance of rock hyraxes and small carnivores over time.

DK1- Taphonomic assessment of the small mammals

The DK1 specimens are very well preserved. In total, >70% of bone cortical surfaces are visible for analysis across all stratigraphic layers. Limiting factors such as bioerosion, bone surface exfoliation, matrix obfuscation, diagenetic decalcification, weathering, and rodent gnawing are present in the assemblage but not extensively, and complete specimens are relatively common (LSA = 18.7%, MSA6 = 13.9%, MSA7 = 13.0%, MSA8 = 13.1%, MSA9 = 12.9%, MSA10 = 13.4%, MSA11 = 16.2%, MSA12 = 14.1%, MSA13 = 13.7%, MSA14 = 11.4%, MSA15 = 10.2%) especially among Cape dune mole-rats, rock hyraxes, and small carnivores.

The correlation between stratigraphic level and ratio of complete to broken specimens ($r_s = -0.455$, $p = 0.164$) is not significant. There is a slight decrease in specimen length among the levels, however, the relationship between specimen length and stratum age is not significant ($r_s = 0.158$, $p = 0.642$). A Kruskal-Willis test for equality of medians demonstrates that there are significant differences in maximum fragment length of all specimens between stratigraphic layers ($H = 171.391$, $p < 0.001$) possibly as a result of differences in the number of complete specimens among the levels and/or the relative abundances of smaller to larger taxa (i.e., mole-rats versus size 1 bovids and hares). The median lengths in mm for each level are: LSA=19, MSA6=15, MSA7=17, MSA8=16, MSA9=16, MSA10=15, MSA11=15, MSA12=17, MSA13=16, MSA14=18, MSA15=18.

The analysis of long bone fracture morphology has been employed as a gauge of pre- and post-depositional fragmentation (Villa and Mahieu, 1991). Typically, this type of analysis has been applied to large mammals, but Armstrong (2016) and Armstrong and Avery (2014) have demonstrated that it can also be used to assess small mammal fragmentation patterns. Like large mammals, small mammal long bone shafts that were broken while 'green' tend to preserve more oblique fracture angles and V-shaped/curved fracture outlines whereas long bone shafts broken when 'dry' more often feature right fracture angles and transverse fracture outlines (Armstrong and Avery, 2014; Armstrong, 2016). After eliminating fractures that were the result of excavation damage, a total of 15,631 long bone fractures were analyzed. Table 5 reports fracture morphology frequencies and counts per taxonomic aggregate and stratum. There is no correlation between the frequency of right fracture angles and superposition of stratigraphic layers for any of the small mammal taxonomic aggregates (mole-rat: $r_s = -0.124$, $p = 0.717$; size 1 bovid: $r_s = 0.124$, $p = 0.716$; hare: $r_s = -0.228$, $p = 0.501$; rock hyrax: $r_s = -0.218$, $p = 0.638$; carnivore: $r_s = 0.800$, $p = 0.333$). In other words, dry breaks do not significantly increase or decrease in abundance from the most recent to the oldest layers. The goodness-of-fit tests show that all bone fracture angle

distributions for each SMA per layer are statistically different ($p < 0.05$) in comparison to the Sarrians assemblage; none of the SMAs resembles dry bone breakage (Sarrians and Fontbrégoua are archaeological control assemblages of bone that were broken when dry and fresh, respectively [Villa and Mahieu, 1991]). A different pattern is apparent when comparing the Fontbrégoua assemblage where most of SMAs per layer reveal statistically indistinguishable distributions of fracture angles (32 of 38 comparisons of SMA with the Fontbrégoua assemblage); therefore, it is reasonable to conclude that most SMA long bones at DK1 were broken while fresh. However, there are six instances (mole-rats in MSA layers 7, 8, 12; hares in MSA14; hyraxes in MSA12, and size 1 bovids MSA6) where the fracture angle distributions are statistically different ($p < 0.05$) compared to the Fontbrégoua assemblage. This indicates that some post-depositional breakage occurred. Further, experimental studies have demonstrated that roughly 4.5% of long-bone breaks (among bovids) will be right fracture angles even when bone is broken while fresh (Marean et al., 2000a). All right fracture angle frequencies per taxonomic aggregate per layer at DK1 exceed 4.5%, so some of the bones were indeed broken when dry.

Bone surface modification frequencies for each SMA by layer are reported in Table 6 and depicted in Fig. 2. Additional supporting image documentation has been added to the SOM; Fig. S1-S4 are SEM images of cut marks to Cape dune mole-rat bones, Fig. S5 depicts the range of observed predator digestion, and Tables S1 and S2 provide diagnostic descriptions of digestion categories and bone surface modifications. Analysis of the taphonomic patterning and temporal variation for the SMAs at DK1 is presented in Figure 4. Axis 1 of the DK1 PCA accounts for 37.7% of the variance while axis 2 accounts for 23.7% (Fig. 4). Axis 1 discriminates between aggregates with human bone surface modifications (cut marks, burning, and percussion notches) versus modifications indicative of mammalian carnivore and raptor accumulation (digestion, fragmentation, tooth/beak/talon pits and punctures). Axis 2 discriminates between assemblages with differing frequencies of mammalian carnivore (fragmentation), nocturnal raptor (digestion), and diurnal raptor (pits and puncture) bone surface modifications. The SMAs with strong positive axis 1 scores exhibit greater frequencies of human-induced bone surface modifications while strong and moderate negative scores are indicative of predator-induced bone surface modifications. For axis 2, strong positive scores represent aggregates with greater frequencies of carnivore modifications while intermediate scores are associated with nocturnal raptors and strong negative scores associate with diurnal raptors.

Figure 5 depicts the axis 1 scores which illustrate the statistical variability between human and predator accumulated SMAs per stratum (positive scores denote human and negative scores denote

predator accumulation). For Cape dune mole-rats, size 1 bovids, and hares, the taphonomic pattern of accumulation tends to alternate between strata where even numbered layers feature stronger anthropogenic input while odd layers favor greater predator contribution. This alternating pattern between layers with strong (even) and weak (odd) anthropogenic input was observed in the large mammal (Marean et al., 2000ab), micromorphology (Goldberg, 2000), and stone tool (Thackeray, 2000) accumulation analyses as well as Schweitzer's (Tankard and Schweitzer, 1976; Schweitzer, 1979) initial observations concerning site formation processes at DK1. Based on the DK1 bone surface modification PCA, it is clear that both humans and predators played roles in the accumulation of fauna and that their relative contributions varied by small mammal taxonomic aggregate and by stratum. The DK1 cluster analysis identifies five distinct taphonomic clusters (Fig. 6 and Table 6): mixed human and raptor (cluster 1), diurnal raptor-only (cluster 2), human-only (cluster 3), carnivore-only (cluster 4), and nocturnal raptor-only (cluster 5).

The mixed human and raptor taphonomic cluster (1) contains the most SMAs and includes at least one aggregate from each stratigraphic level with the exceptions of layers MSA 13 and MSA 15 (each of which show heavy raptor input). The cluster can be characterized by moderate levels of fragmentation (1.56 NISP/MNE), burning (2.3%), cut marks (1.0%), percussion notches (0.2%), and beak/talon pits (2.3%), and low levels of beak/talon punctures (0.6%) and digestion (10.1%). There are only four SMAs associated with the diurnal raptor-only taphonomic cluster (2) all of which are small carnivores. These are characterized by high frequencies of punctures (4.6%) and pits (3.6%), low rates of fragmentation (1.18) and digestion (12.8%), and the absence of burned and cut marked bone, and percussion notches. There are 10 SMAs associated with the human-only cluster (3), nearly all of which are Cape dune mole-rat and size 1 bovid aggregates. This cluster is characterized by high degrees of burning (7.0%), cut marks (2.7%), and percussion notches (1.4%), moderate levels of fragmentation (1.77) and pits (1.5%), and low levels of punctures (0.3%) and digestions (3.7%). None of the DK1 SMAs groups with the carnivore only cluster (4). This group is defined by high levels of fragmentation (2.14) and digestion (90.0%), low levels of punctures (0.03%) and pits (0.02%), and the absence of burned and cut marked bone, and percussion notches. Fourteen SMAs – mostly from odd-numbered layers – make up the majority of the nocturnal raptor-only cluster (5). This cluster is characterized by moderate levels of fragmentation (1.58) and punctures (1.0%), high levels digestion (61.6%), low levels of pitting (0.7%), and the absence of burned and cut marked bone, and percussion notches.

Based on the taphonomic analysis of bone surface modifications, the accumulation of small mammals at DK1 can be chiefly attributed to nocturnal raptors and humans. Mammalian carnivores appear to have had virtually no role in small mammal accumulation. The few SMAs that associate with diurnal raptors (Fig. 6) – all of which are small carnivores – feature small sample sizes, warranting some caution in regards to the attribution of their role in accumulations at DK1.

The roosting and feeding perch preferences of diurnal raptors provide another reason to be skeptical of their involvement at DK1. Diurnal raptors (such as eagles, hawks, and harriers) prefer nests and feeding perches in relatively open, elevated, and secure settings such as tree tops and steep cliffs (Steyn, 1982; Hockey et al., 2005). It would be highly unusual for a diurnal raptor to roost or perch within a cave, either inside on the cave wall or ground surface (Steyn, 1982; Hockey et al., 2005). They very well may have roosted or perched on the cliff face above DK1 and their prey remains may have accumulated below, near the cave opening. However, the archaeological deposits were excavated from within and extend towards the back of the cave, upslope from the cave mouth where their prey remains would likely not have accumulated. It is unlikely that massive quantities of discarded prey remains fell from above the cave and were moved upslope into the cave. There is no taphonomic evidence to suggest that terrestrial carnivores or rodents transported bones to the back of the cave after discard by diurnal raptors. Further, there is no evidence that humans accumulated the small carnivores at DK1, it is most likely that these prey were accumulated by nocturnal raptors or small carnivores that periodically scavenged as the remains exhibit digestion, punctures, and pits but the relatively small sample of complete bones distorts the identification of their accumulator.

The present taphonomic analysis confirms Klein and Cruz-Urbe's (2000) hypothesis that nocturnal raptors played a role in small mammal accumulation at DK1. In some instances they appear to be the main accumulator (Fig. 6 and Table 6), while in others, their accumulations are mixed with human-accumulated small mammal remains (Fig. 6). However, in relation to some SMAs they seem to play almost no role at all. Though it is impossible to unambiguously identify a specific nocturnal raptor taxon as the accumulator, Klein and Cruz-Urbe's (2000) identification of the Cape eagle-owl is consistent with the prey taxa recovered at the site, the roosting and feeding preferences of the bird, and the general taphonomic pattern of the bones accumulated by raptors.

PP5-6 – Taxonomic composition

The PP5-6 specimen counts by stratum can be found in Table 7, which includes small mammals as well as all other identified fauna. As a species list and abundances of small and large fauna have not been previously published for PP5-6, specimen counts and basic taxonomic identification by stratum of small and larger mammals, avifauna, tortoises, etc., have been included in order to illustrate the relative abundances of different types of fauna at PP5-6. Large mammals dominate the assemblage, only 4% of all mammals by NISP are small mammals. Size 1 bovids (53%) are the most abundant small mammal followed by small mammal bones (non-bovid) for which the species is indeterminate (38%); these specimens consist mostly of rib and long bone shaft fragments. Other typical CFR small mammals (Cape dune mole-rat, hare, rock hyrax, and small carnivore) are represented in very low frequencies when calculated as either percentages of all mammals or as a fraction of only the small mammals.

In terms of small mammal relative abundance, PP5-6 differs from YST1, BBC, DKR, and DK1 in that they are not well represented. The ratio of small to large mammals is far more similar to PP13B in this regard; small mammals and size 1 bovids are 5% of all mammals at PP13B and 4% of mammals at PP5-6. A clear deviation from YFT1, BBC, DRS, and DK1 is the lack of Cape dune mole-rats at PP5-6. On average, mole-rats account for 55.3% of the fauna at these sites but constitute <2% of small mammals at PP5-6; there are no mole-rats reported from PP13B. The present range of the Cape dune mole-rat extends from Knysna (east) to Lambert's Bay (west). PP5-6 is towards the eastern extent of their current range but clearly within it (Skinner and Chimimba, 2005) and mole-rats are abundant in contemporary levels at nearby BBC, therefore their virtual absence from PP5-6 is likely not solely attributable to change in geographic range. Hares, rock hyraxes, and small carnivores comprise only 3.8%, 1.9%, and 1.0% of small mammals at PP5-6 respectively. Like PP13B, PP5-6 does not follow the "typical" pattern of MSA sites in the CFR in which many or more small mammals are present in relation to larger fauna.

In addition, there is a significant positive relationship between the small mammal NISP totals and the total number of mammal bones by stratigraphic layer at PP5-6 ($\chi^2 = 110.26$, $p = <0.001$). In other words, small mammal specimens do not cluster in any particular stratum, their abundance – or lack thereof – is simply associated with the total number of mammal bones recovered from each layer. Strata which yield relatively large numbers of mammal bone, such as layers DBCS and SADBS, are also the levels which feature the greatest numbers of small mammal remains. Conversely, strata that yield relatively few bones, such as layers OBS1 and OBS2, feature among the fewest small mammal remains.

PP5-6 – Taphonomic assessment of the small mammals

The PP5-6 specimens are not well preserved. In total, ~50% of bone cortical surfaces are preserved and visible for analysis across all layers, versus, >70% for DK1. The PP5-6 specimens have been considerably affected by bone surface exfoliation and fragmentation. Bioerosion, matrix obfuscation, weathering, and rodent gnawing are each minimally present in the small mammal sample but none of these conditions (aside from matrix obfuscation) contributes towards the lack of bone surface visibility as prominently as exfoliation and fragmentation. Complete specimens are not common among the PP5-6 sample as they account for only 6% of the assemblage by NISP compared to 14% at DK1. All of the complete specimens at PP5-6 are small compact bones (such as sesamoids, carpals, and tarsals), phalanges, or metapodials.

The average specimen length at PP5-6 is 12 mm whereas at DK1 the length is 17 mm. This difference is amplified by the fact that most of the DK1 specimens belong to the relatively small bodied Cape dune mole-rat whereas at PP5-6 most identified specimens are the comparatively larger size 1 bovids. The lack of original bone surfaces, dearth of complete specimens, and relatively small bone fragment size all demonstrate that the PP5-6 small mammal remains are not particularly well preserved. A consequence of this preservation state is that few bone features have been preserved. Twenty-six percent of mammal specimens are small and fragmented cortical or trabecular bone fragments that lack diagnostic features and cannot be assigned to a specific skeletal element or taxon beyond bone fragment and mammal. The preservation state of PP5-6 renders both species and skeletal element attribution difficult and the tallying of MNIs and MNEs largely impracticable.

The assessment of long bone fracture morphology can only be conducted for size 1 bovids and indeterminate small mammal specimens as there are too few mole-rat, hare, rock hyrax, and carnivore long bone fragments available to conduct meaningful analyses. In all, there are 145 size 1 bovid and indeterminate small mammal long bone fracture surfaces visible for analysis. The vast majority of these specimens can be identified only as long bone shaft fragments. Fracture morphology frequencies and counts per taxonomic aggregate and stratum can be found in Table 8. There is no correlation between the frequency of right fracture angles and age of stratigraphic level for the size 1 bovids ($r_s=0.360$, $p=0.427$) or indeterminate small mammal ($r_s=-0.900$, $p=0.083$) long bone fragments. In other words, dry breaks do not significantly increase or decrease in abundance from the most recent to the oldest layers.

Fractured bone from only one-third of the sample aggregates by stratum have sufficient sample sizes ($n \geq 10$) to compare to the Fontbrégoua and Sarriens assemblages in goodness-of-fit tests. Of these, none of the size 1 bovid or indeterminate small mammal fracture angle frequency distributions are

statistically different from the Fontbrégoua or Sarrians assemblages. These intermediate results indicate that numerous specimens were broken while fresh and that sufficient numbers of fragments retain indication of 'green' breakage, enough so that the frequencies of bone fractures are statistically indistinguishable from the Fontbrégoua assemblage. However, consequent portions of long bone fragments also exhibit 'dry' breakage, indicative of considerable post-depositional fragmentation. The result is that the samples are also statistically indistinguishable from the Sarrians assemblage where the vast majority of bones were broken when 'dry.' In sum, it appears that many size 1 bovid and indeterminate small mammal bones were broken while fresh, possibly by mammalian carnivores, humans, or predatory birds. The specimens were further fractured during the non-nutritive phase of the bones, perhaps as a result of trampling since a number of strata exhibit evidence of intense human occupation (Karkanas et al., 2015).

Bone surface modification frequencies for each of the PP5-6 SMAs by stratum are reported in Table 9. An analysis of the taphonomic patterning and temporal variation of the SMAs at PP5-6 is provided in a PCA of the bone modification proportions for all identifiable bone fragments (Fig. 7). The bone surface modifications considered in the PCA are those presented in Table 9. Also included in the PCA are the small mammal assemblages of known accumulation discussed previously: (1) !Kung San foragers, (2) medium-sized carnivores, (3) diurnal raptors, and (4) nocturnal raptors. The PP5-6 PCA axis 1 accounts for 32.9% of the variance while axis 2 accounts for 25.4%. The axis 1 vector discriminates between aggregates with human bone surface modifications (cut marks, burning, and percussion damage) and modifications indicative of mammalian carnivore and raptor accumulation (digestion, tooth/beak/talon pits, and punctures, but excluding fragmentation as the vector is moderately positive along axis 1 in this PCA). Axis 2 discriminates between assemblages with differing frequencies of carnivore (fragmentation), nocturnal raptor (digestion), and diurnal raptor (pits and puncture) bone surface modifications. The SMAs with strongly positive axis 1 scores exhibit greater frequencies of human-induced bone surface modifications, while moderately positive and negative scores are indicative of predator-induced bone surface modifications. Strongly positive scores along axis 2 represent aggregates with greater frequencies of carnivore modifications, whereas moderately positive scores reveal association with nocturnal raptors. Negative scores along axis 2 are associated with diurnal raptors.

Figure 8 depicts the axis 1 scores which illustrate the irregularity of human-accumulated SMAs over time compared to predator-accumulated bone (strong positive scores denote human, while

moderate and negative scores denote predator accumulations). Only the NWR size 1 bovids and LBSR small mammal group have strongly positive scores, signifying human accumulation of these aggregates. These two human-accumulated aggregates are temporally separate, dating to 61(±4) ky and 81(±4) ky, respectively. All other size 1 bovid and small mammal groups have strong negative or moderate axis 1 scores suggesting non-human accumulation for the bulk of the small mammal faunas at PP5-6.

The taphonomy of PP5-6 indicates that predators were largely responsible for the accumulation of small fauna. The Euclidean hierarchical cluster analysis which utilizes the axis 1 and 2 scores of the PP5-6 PCA, and includes the SMAs as well as human, mammalian carnivore, and nocturnal and diurnal raptor control assemblages, indicates that five taphonomic clusters are apparent (Fig. 9 and Table 9): diurnal raptor-only (cluster 1), nocturnal raptor-only (cluster 2), mixed diurnal and nocturnal raptor (cluster 3), carnivore-only (cluster 4), and human-only (cluster 5).

The human-only taphonomic cluster (5) includes NWR size 1 bovids, LBSR small mammal group, and the human-accumulated control samples. The factors driving the association of the two archaeological samples with the human-accumulated control assemblages are similar levels of fragmentation (1.7 NISP/MNE), the presence of burned (9.3%) and cut-marked bone (3.9%), and minimal frequencies of digested bone (0.01%), punctures (0.01%), and pits (0.01%). There are no PP5-6 SMAs associated with the diurnal raptor-only (1) taphonomic cluster; it consists of four of the five prey aggregates accumulated by Verreaux's eagle. There are four PP5-6 SMAs associated with the nocturnal raptor-only cluster (2), which can be attributed to the small mammal group aggregate. This cluster is characterized by elevated levels of fragmentation (1.80), the presence of digested bone (37.6%), punctured (1.0%) or pitted bone (1.5%), the lack of cut marks and percussion notches, and low frequencies of burned bone (0.9%). None of the PP5-6 SMA groups with the carnivore-only cluster (4). This group is defined by high levels of fragmentation (2.14) and digestion (90.0%), low levels of punctures (0.03%) and pits (0.02%), and the absence of burned, cut-marked, and percussion-notched bone.

The mixed raptor cluster (3) is comprised of 11 PP5-6 SMAs as well as one Verreaux's eagle and two bald eagle control sample assemblages. In addition to clustering with these three diurnal raptor prey aggregates, this cluster shares some taphonomic affinities with nocturnal raptors in the form of digested bone and fragmentation, and to a lesser extent, the human-accumulated assemblages in relation to the presence of burned bone. This is apparent in Fig. 7 where the mixed raptor cluster is situated near the diurnal and nocturnal raptor-only clusters, supporting the hypothesis that both diurnal

and nocturnal raptors contributed to the accumulations. A few of the mixed cluster aggregates fall near the human-only cluster due to the shared presence of burned bone. In spite of this, the relative frequencies of other taphonomic indicators suggest greater affinities with the raptor assemblages as opposed to human accumulation. The mixed cluster (3) is characterized by moderate levels of fragmentation (1.47) and punctures (1.3%), some digestion (3.7%) and burning (4.1%), and the absence of cut marks and percussion notches.

Based on the similarities of bone surface modifications, the accumulation of small mammals at PP5-6 can largely be attributed to nocturnal and diurnal raptors. Humans played a minimal role in the accumulation of the fauna but were likely the primary agent responsible for the accumulation of two SMAs in two separate strata. Yet the presence of burned bone in layers SADBS and OBS1 suggests that humans may also have played a limited role in the accumulation of specimens in these strata. It is also possible that bones were first deposited by raptors and incorporated into sediments that were subsequently burned, as is also attested to by the apparent burning on the artifacts and sediments associated with the SADBS. Mammalian carnivores seem to have had no role in small mammal accumulation at PP5-6.

The role of diurnal and nocturnal raptors in the accumulation of the PP5-6 sample is supported by the types and frequencies of observed bone surface modifications. In addition, the topographical features in the immediate vicinity of the PP5-6 rockshelter are agreeable to raptor roost preferences. The steep and inaccessible quartzitic cliffs above the site provide ideal nest localities for diurnal raptors while the rockshelter below provides a catchment for prey remains dropped from nests and feeding perches above. Today, jackal buzzards (*Buteo rufofuscus*) roost on the cliffs near the rockshelter and Verreaux's eagles (*Aquila verreauxii*) have been seen perched on cliffs near the site, once with a kill (author personal observation). In contrast to DK1, it is reasonable to suppose that small prey remains collected by diurnal raptors made their way into the PP5-6 faunal assemblage. As for nocturnal raptors, there are active nests inside some of the caves and rockshelters in the immediate vicinity of PP5-6. Barn owls (*Tyto alba*) and spotted eagle-owls (*Bubo africanus*) have been observed in the area by the author and collections of owl pellets have been noticed in the caves and rockshelters adjacent to PP5-6 (E. Fisher, pers. comm.). As with the diurnal raptor prey remains, it is reasonable to imagine that owl pellets and prey bones were discarded on the rockshelter floor or expelled from nests and found their way into the PP5-6 faunal sample.

Human accumulation of Cape dune mole-rats at DK1

Cape dune mole-rat accumulations are common at Later and MSA sites in the CFR and the question of their accumulation origins has been a persistent issue. Researchers have argued that some LSA accumulations of mole-rats were human derived (particularly those that are <5,000 year old) while MSA accumulations were most likely collected by non-human predators. For instance, researchers contend that the mole-rats from LSA sites or strata at Pancho's Kitchen Midden (Jerardino, 1998), Eland's Bay Cave (Klein and Cruz-Urbe, 1987), DK1 (Schweitzer, 1979; Avery et al., 1997; Klein and Cruz-Urbe, 2000;), BBC (Henshilwood, 1997), Byneskranskop 1 (Schweitzer and Wilson, 1982), and Tortoise Cave (Klein and Cruz-Urbe, 1987; Robey, 1987) are probably human accumulated. In some cases, the evidence for human agency centers on the presence of cut and burned bone (LSA portions of DK1 and BBC). In other instances, more tentative forms of evidence, such as the co-occurrence of mole-rat bones in strata which also contain anthropogenic materials (Byneskranskop 1, Eland's Bay Cave, and Tortoise Cave), or the lack of suitable raptor roosting space near the mole-rat accumulations, or both factors (Pancho's Kitchen Midden and Eland's Bay Open), have been evoked as evidence for human agency.

These latter arguments are challengeable as they suppose that only raptors or humans could be responsible for mole-rat accumulation and discount carnivores and other means of bone accumulation; taphonomic analyses which could clarify this have not been reported for these LSA sites. With the exception of Henshilwood's (1997) ethnoarchaeological documentation and comparison of mole-rat bones burned by contemporary people and LSA humans at BBC, none of the studies explicitly reports and describes the counts and anatomical patterning of bone surface modifications, factors that could be used to illuminate the origin of mole-rat bone accumulation. Nevertheless, it has been largely accepted that humans were frequently responsible for mole-rat accumulations during the LSA.

Conversely, MSA accumulations of Cape dune mole-rats at DK1 (Avery et al., 1997; Klein and Cruz-Urbe, 2000; Marean et al., 2000b; however, see Avery, 1990 for alternative interpretation), BBC (Henshilwood, 1997; Badenhorst et al., 2014), and YFT1 (Halkett et al., 2003; Klein et al., 2004; Avery et al., 2008) as well as LSA layers >5,000 years old at Elands Bay Cave (Klein and Cruz-Urbe, 1987), Tortoise Cave (Klein and Cruz-Urbe, 1987; Robey, 1987), and Byneskranskop 1 (Schweitzer and Wilson, 1982) have been thought to be non-human accumulated. The reported presence of digested bone similar in appearance to bone generated by owl gastric etching (MSA portion of DK1 and layers >5,000 years old at Elands Bay Cave and Byneskranskop 1) and the reported lack of cut-marked and burned bone (MSA portion of BBC) have led researchers to suggest that MSA accumulations of mole-rats are likely not the result of human activities. Ancillary evidence in support of this interpretation, such as the presence of

bone accumulators like porcupine and small carnivores in layers that also contain mole-rats as well as possible mole-rat burrows (YFT1), the disproportionately high frequencies of juvenile size 1 bovids (particularly *Raphicerus* spp.) and the suitability of these locales as raptor roosts (MSA portion of DK1 and layers >5,000 years old at Tortoise Cave), have also been cited as evidence for non-human accumulation of mole-rats. While various taphonomic factors have been evoked as evidence for raptor and/or carnivore accumulation of mole-rats at MSA sites and LSA sites >5,000 years old, analyses that plainly describe bone surface modifications, anatomical patterning, and the overall frequency of modifications (or the lack thereof) in these assemblages have not been reported.

The bone surface modification patterns found on mole-rats at DK1 are unique and the LSA and MSA assemblages exhibit clear evidence of human agency. The primary forms of evidence are cut-marked and burned bone (much of which is calcined), frequencies of which are reported in Table 6. In the LSA and MSA portions of the DK1 assemblage, 81% of cut marks occur in these anatomical locations (Fig. 10): the underside of the premaxilla (14%), the anterior portion (16%) and coronoid process of the mandible (13%), the distal ulna (4%), distal radius (10%), and the distal tibia (23%). The remaining cut marks fall among the other skeletal elements (such as the innominate, humerus, femur, calcaneus, incisors, and vertebrae) in less frequent and more random patterns (19%). Included in Fig. 10 are summaries of cut mark frequencies on mole-rat bones by skeletal element for each stratum at DK1; SOM Fig. S1-S4 are SEM images of cut marks to mole-rat bones.

The anatomical location of cut marks on Cape dune mole-rat bones are analogous to patterns of damage frequently associated with the skinning of small, fur-bearing mammals (Rowley-Conwy, 1994; Charles, 1997; Strid, 2000; Vigne and Guilaine, 2004; Fairnell, 2008; Lloveras et al., 2009b; Mallye, 2011). Cut marks are the most recognizable indication of skinning left on the bones of a carcass and the documentation of cut marks to the bones of small, fur-bearing mammals such as canids (Compagnoni et al., 1997; Strid, 2000; Vigne and Guilaine, 2004; Fairnell and Barrett, 2007; Yeshurun et al., 2009; Martín et al., 2014;), erinaceids (Fernández-Jalvo et al., 1999), felids (Yravedra, 2005; Crezzini et al., 2014), herpestids (van Rijssen and Avery, 1992; Parkington and Fisher, 2006;), lagomorphs (Charles et al., 1994; Lloveras et al., 2009b), mustelids (Wigh, 1997; Parks, 2003; Richter, 2005; Fairnell and Barrett, 2007; Mallye, 2011), and rodents (Tamplin et al., 1983; Trolle-Lassen, 1987; Zeiler, 1987;) present a consistent and robust anatomical pattern of cut marks for the indication of skinning. The pattern of cut marks left on specific mole-rat skeletal elements at DK1 are interpreted as such evidence. This pattern consists of the clustering of cut marks at (1) the maxilla and premaxilla as well as the eye orbits of the cranium, (2)

the corpus and ascending ramus of the mandible, (3) the lower limbs (particularly the distal radius, ulna, and tibia), and occasionally (4) podial elements (such as the calcaneus, metapodials, and phalanges) which varies by species and seems to depend on whether fur is present on the feet, if that fur is desirable, and if attached claws are preferred. Mole-rat feet are hairless (and small) which may account for there being fewer identified cut marks on podial elements.

In some instances, patterns of discarded skeletal elements – particularly the relative overabundances of podial bones and mandibles in relation to limb and axial elements – associated with small mammal field processing has been identified as evidence for skinning and fur utilization, especially of canids and felids (Klein, 1973; Tamplin et al., 1983; Charles, 1997; Compagnoni et al., 1997; Schmidt, 1999; Baxter and Hamilton-Dyer, 2003). However, this skeletal-part pattern is not always associated with the processing of fur-bearing mammals for their skins (Charles et al., 1994; Wigh, 1997; Yravedra, 2005; Parkington and Fisher, 2006; Fairnell and Barrett, 2007; Yeshurun et al., 2009; Crezzini et al., 2014; Martín et al., 2014) as consistently as are cut marks. Though mandibles are abundant at DK1, podial elements are not particularly well represented. Furthermore, mole-rat upper limb skeletal elements and innominates are fairly well represented, a skeletal-part pattern that differs from the part representation pattern reported in studies regarding the processing of fur-bearing mammals.

The other small mammal prey species at DK1 do not exhibit a pattern of cut marks similar to that of the mole-rats, nor do they exhibit skeletal-part patterns indicative of skinning. For example, cut marks on hares, hyraxes, carnivores, and size 1 bovids mostly cluster around scapula and humerus, the innominates and femurs, and vertebrae and ribs, locations indicative of disarticulation and filleting (Binford, 1981; Hill and Behrensmeyer, 1984; O'Connell and Hawkes, 1988; O'Connell et al., 1990; Nilssen, 2000; Domínguez-Rodrigo, 2002; Domínguez-Rodrigo and Pickering, 2003;) as opposed to skinning.

Taphonomic evidence for the skinning of Cape dune mole-rats is evident in multiple strata at DK1. It is markedly apparent in LSA and MSA layers 6, 7, 10, 12, and 14 where in each case >80% of cut marks are found in anatomical locations suggestive of skinning. This pattern implies that MSA humans habitually utilized mole-rats -- possibly for their fur -- over a prolonged period of time, spanning the MSA and LSA occupations. This pattern represents the first evidence for the habitual skinning of fur-bearing mammals by MSA humans.

In addition to their fur, MSA humans may also have used mole-rats as a food resource. Mole-rats are consumed by people today and are an important protein source for some rural populations in parts of the Western Cape Province (Schweitzer, 1979; Henshilwood, 1997). Henshilwood (1997) documented mole-rat capture and preparation and studied the discarded remains of mole-rats consumed by modern people, observing that mole-rats were not usually skinned before being roasted over hot coals. However, this does not rule out such behavior in the past. He noted that, when prepared in this way, there was a distinctive burning pattern in which the premaxillae, incisors, and podial bones were disproportionally burned in relation to other skeletal elements. This exact anatomical pattern of burned skeletal elements was not observed in the DK1 LSA or MSA mole-rat remains. However, burned and calcined mole-rat bones are present in varying frequencies throughout the assemblage (Table 6) and a variety of skeletal elements exhibit burning, including premaxillae, incisors, and podial bones as well as other skeletal elements. There are, however, no particular elements that are more burned than others. Further, there are some bones which are both cut-marked and burned. Many elements are completely or partially calcined, a process which requires exposure to a high degree of heat for a prolonged period of time in a reducing environment (Stiner et al., 1995).

Implications for MSA human populations

The estimation of MSA population densities from archaeological evidence is challenging. Hunter-gatherer societies leave behind ephemeral traces of their existence and only a small portion of the material they produced is likely to be preserved. In southern Africa, researchers have relied on proxy indicators of MSA human population densities such as the number of archaeological sites dated to a particular time period (Klein, 2001, 2008; Mellars, 2006; Jacobs et al., 2008a,b), the intensity of site occupations (Wadley and Jacobs, 2006; Avery et al., 2008; Thompson, 2010b; Thompson and Henshilwood, 2011, 2014a; Faith, 2013; Parkington, 2013; Steele and Klein, 2013; Henshilwood et al., 2014; Karkanas et al., 2015;), the impact of humans on specific types of resources (Klein, 1998, 2008; Klein and Cruz-Urbe, 2000; Henshilwood et al., 2001a; Halkett et al., 2003; Parkington, 2003, 2008; Klein et al., 2004; Steele and Klein, 2005/6; Clark, 2011; Klein and Steele, 2013;), and evidence for (and against) the transmission of adaptive cultural innovations (Shennan, 2001; Klein, 2008; Powell et al., 2009; Lombard and Parsons, 2011; Brown et al., 2012; Porraz et al., 2013a; Dusseldorp, 2014; Mackay et al., 2014; Conard and Will, 2015).

On the southern and western coasts of South Africa, archaeological sites dating to late MIS5 and MIS4 are common (Jacobs et al., 2008a,b). Even though global climate conditions were cooler during

MIS4, there is strong evidence for periodically intensive human occupations at sites such as BBC (Jacobs et al., 2006; Tribolo et al., 2006), DRS (Miller et al., 2013; Parkington, 2013; Porraz et al., 2013b), Klipdrift Shelter (Henshilwood et al., 2014), PP5-6 (Brown et al., 2012; Karkanas et al., 2015), and Klasies River Mouth (Singer and Wymer, 1982; Deacon, 1995; Feathers, 2002) as well as others. Humans occupying these sites appear to have ameliorated changing climate conditions by exploiting a range of coastal and terrestrial resources (Klein, 1976; Klein and Cruz-Urbe, 1996; Thompson, 2010b; Thompson and Henshilwood, 2011; Clark and Kandel, 2013; Faith, 2013; Steele and Klein, 2013; Marean, 2014). In addition, evidence for adaptive cultural innovations in the forms of symbolism (Henshilwood et al., 2002, 2004; Texier et al., 2010) and technological innovations (Henshilwood et al., 2001b; d'Errico and Henshilwood, 2007; Brown et al., 2009; 2012; Villa et al., 2010; Porraz et al., 2013a) are evident.

Some researchers have argued that these factors may reflect a broader regional shift towards larger human populations in response to the glacial conditions of MIS4 (Mellars, 2006; Jacobs, 2008a; Wadley et al., 2011; Marean et al., 2014; Karkanas et al., 2015). This pattern contrasts with the archaeological record of the previous glacial phase of MIS6 as far fewer archaeological sites in the Cape date to this period, though it is likely that many near-coastal deposits were subsequently lost due to high sea levels. The population expansion during MIS4 is evidenced by (1) the marked increase in the number of archaeological sites, (2) comparatively intensive human occupations at archaeological sites, and (3) increased visibility of adaptive technological and cultural innovations, suggesting that the response(s) to cooling and environmental fluxes by MIS4 human populations diverged from those of MIS6 populations.

The supposed demographic shift towards greater population densities may have been driven by – and/or exhibited in – human behavioral changes during MIS4 that made it possible to not only survive changes to local environment and climate conditions but to thrive. These adaptive changes appear to have included a turn towards focused and intensive use of habitats as evidenced by the range of coastal and terrestrial resources exploited during this period. With the assumption that the MSA occupation at DK1 dates to the end of MIS5 and MIS4, the evidence for periodic but concentrated exploitation of Cape dune mole-rats (particularly in layers MSA6, 10, 12, and 14) reflects this adaptive response by humans towards the intensive utilization of habitats as demonstrated by the exploitation of this lower-ranked resource (rank based on optimal foraging theory [Stephens and Krebs, 1986]).

The anthropogenic accumulation of higher-ranked, higher-yield resources, such as large ungulates, has been documented in MSA layers at DK1 (Marean et al., 2000a; Thompson, 2008).

923 However, evidence for the exploitation of medium-sized ungulates is somewhat less common in these
924 same layers (Marean et al., 2000a; Thompson, 2008), possibly as a result of local decline in abundance of
925 these ungulates as the climate and local environments shifted during MIS4. Small mammals endemic to
926 the CFR appear to have been less affected by the changing climate and environmental conditions as they
927 are abundant at DK1 across all MSA layers and consistently represented at other sites dated to MIS4 in
928 the CFR. Micromorphology thin sections from layers MSA6 and 8 at DK1 reveal shellfish – a high-ranking
929 resource due to population densities and spatial predictability – in a state of dissolution suggesting that
930 shellfish were once present in these layers but since removed by decalcification (Goldberg, 2000).
931 Because traces of shell are visible in only two MSA layers, it is likely that shellfish were not regularly
932 exploited by MSA people at DK1. In addition to large ungulates, it seems that humans relied on small
933 mammals – particularly mole-rats but also size 1 bovids and hares – and tortoises to fill the void left
934 locally by the unavailability of higher-ranked resources, namely shellfish and medium-sized ungulates.

935 The emphasis on lower-ranked resources for sustenance and, perhaps, skins suggests that the
936 MSA inhabitants of DK1 expanded their resource base as an adaptive response to a changing landscape.
937 It can be surmised that high-yield habitats that featured ample hunting opportunities as well as access
938 to coastal resources were the preferred occupation zones of hunter-gatherers during MIS4 in the CFR.
939 However, it is likely that these high productivity habitats were infrequent on the landscape (as they are
940 today) and elevated population densities potentially led to increased competition for these habitats. The
941 utilization of small mammals at DK1 is evidence for the exploitation of lower-ranked resources and the
942 maximization of habitat yield as an adaptive response to a fluctuating environment and competition for
943 resources, a shift not previously discerned in MSA archaeofaunas.

944 At PP5-6, the MIS5 occupations have been described as repeated, short visits by small groups of
945 hunter-gatherers (Karkanas et al., 2015). Geoarchaeological analysis of PP5-6 shows that the MIS4
946 occupations were more intense than those of MIS5, probably a reflection of more frequent and longer
947 occupations, possibly by larger groups of people (Karkanas et al., 2015). Shellfish remains are abundant
948 in the MIS5 and MIS4 strata at PP5-6. A taphonomic analysis of the large mammals from PP5-6 has not
949 been reported, but there is reason to believe that large mammal hunting was an important aspect of the
950 PP5-6 inhabitants life-ways as large mammal bones are common (personal observation) and there is a
951 marked shift to microlithic technology just after the beginning of the climate deterioration of MIS4
952 (Brown et al., 2012). The microliths reported from PP5-6 resemble those typically utilized as armaments
953 on small, long throw projectile weapons used to hunt large mammals (Brown et al., 2012).

Unlike at DK1, small mammals do not seem to have been an important part of the resource base at PP5-6. In all layers, they make up only a tiny fraction of the sampled fauna and, with the exception of specimens from layers NWR and LBSR, the taphonomy indicates that humans played little to no role in the accumulation of small fauna. Predators contributed comparatively few Cape dune mole-rats, hares, and rock hyraxes to the deposit at PP5-6, however raptors are likely responsible for many of the size 1 bovid remains recovered at the site. It is also possible that density-mediated destruction and trampling played a role in the reduction of small mammal frequencies, given the fractured and diminished state of the specimens. Yet if small mammal remains were once present in greater numbers, one would expect to recover more than four mole-rat, nine hare, and four rock hyrax bones given their general abundance at other CFR MSA sites. The taxonomic pattern of small mammals predated on by non-human predators suggests that mole-rats, hares, and rock hyraxes may not have been particularly abundant in the immediate vicinity of PP5-6; neither predators nor humans accumulated them in any substantial way. During MIS4, humans probably focused their attention on the abundant high-quality coastal and terrestrial resources provided by access to the coastline and the large ungulates that inhabited the grassy plains adjacent to the rockshelter.

Die Kelders Cave 1 small mammal discussion

Of the specific small mammal taxonomic aggregates, Cape dune mole-rats, size 1 bovids, and hares exhibit the strongest indications of anthropogenic accumulation. This pattern is apparent across multiple strata, with particular emphasis on layers LSA, MSA 6, 10, 12, and 14 (Fig. 5). Rock hyraxes show some signs of human accumulation (especially layers MSA 6 and 12) but for the most part appear to have been accumulated by raptors. Carnivores are the least-numerous SMA by NISP, show no evidence of human accumulation, and exclusively exhibit taphonomic characteristics of non-human accumulation.

At DK1, Cape dune mole-rats are by far the most abundant mammalian taxon. What is unusual is the unmistakable taphonomic evidence (principally cut marks) that indicates humans played a substantial role in the accumulation of mole-rats at DK1. Clear evidence for mole-rats as part of the resource base of MSA humans has not been previously documented. However, anthropogenic accumulation of size 1 bovids is fairly typical at southern African MSA sites; examples include PP13B (Thompson, 2010b), BBC (Thompson and Henshilwood, 2011), Sibudu Cave (Clark and Plug, 2008; Wadley, 2010), DRS (Steele and Klein, 2013), and YFT1 (Avery et al., 2008) among others. Additionally, taphonomic support for human accumulation of rock hyraxes during the MSA has been recognized (Cruz-Urbe and Klein, 1998; Badenhorst et al., 2014), however, it is not particularly common. There is

little mention in the literature of anthropogenic accumulations of hares at MSA sites in the CFR – though this may simply reflect the lack of detailed taphonomic analyses of hare archaeofaunal remains (the same may apply to rock hyraxes as well). Nevertheless, many hare remains at DK1 exhibit evidence of anthropogenic accumulation.

Given the abundance of Cape dune mole-rats at DK1 and the evidence for anthropogenic accumulation, the question arises: Were humans responsible for few, some, or most of the MSA mole-rats? There is strong evidence for at least a degree of human agency in all but two of the sampled strata at DK1 (MSA layers 13 and 15). Layers LSA, MSA10, and MSA14 each feature substantial portions of cut-marked and burned bone (much of it calcined) and very few digested or beak/talon/tooth punctured and/or pitted specimens (Table 6). The mole-rats from these layers cluster very closely with the small mammal control assemblages that were accumulated by humans (Fig. 4). It seems reasonable, therefore, to conclude that the mole-rats from layers LSA, MSA10, and MSA14 were accumulated primarily by humans. The mole-rats from layers MSA6 and MSA12 exhibit large counts of cut-marked and burned (much of it calcined) specimens but also include some predator digested, punctured, and/or pitted bone. Specimens from layers MSA6 and MSA12 are of mixed agency but favor anthropogenic accumulation given the frequency of human-induced bone surface modifications in contrast to the predator modifications. In these layers, humans probably accumulated the majority of mole-rats with raptors playing a secondary role.

The remaining layers exhibit mixed human and raptor contribution but with greater proportions of raptor introduced bone surface modifications. In layers MSA7, MSA8, MSA9, and MSA11 raptors appear to have contributed the majority of the mole-rats (Fig. 5). Raptors (likely nocturnal) accumulated nearly all of the mole-rats in layers MSA13 and MSA15 given the abundance of raptor bone surface modifications and the relative lack of human induced modifications. Additionally, these layers (along with MSA8 and MSA9) are among those that show the fewest signs of human accumulation across all SMAs.

Pinnacle Point Site 5-6 small mammal discussion

Small mammals are a much smaller portion of the mammalian fauna at PP5-6, accounting for only 4% of all mammals as opposed to 85% at DK1. Of the identifiable small mammals at PP5-6, Cape dune-mole rats, hares, and rock hyraxes make up only a small fraction of the sampled specimens. These taxa are often a substantial portion of MSA archaeofaunas from sites in the CFR, and mole-rats in

particular are typically well represented (though there is frequency variation in relation to time and location). For instance, mole-rats at DK1 are 75% of the small mammal sample by NISP but make up <2% of the small mammals at PP5-6. The small mammal representation at PP5-6, in terms of overall proportion of the assemblage as well as representation of individual small mammal taxa, is dissimilar to many other MSA sites in the CFR such as BBC, YFT1, and DRS. PP5-6 is similar to PP13B in that there are few small mammal specimens in relation to other mammals and very few mole-rats, in particular, at both sites.

The taphonomy of the small mammals at PP5-6 differs from DK1 in relation to preservation history and accumulation as they are largely not well preserved. In comparison to DK1, they are more fragmented, smaller in maximum dimension, and there are fewer of the original bone surfaces visible for analysis (where bone surface modifications might be preserved). Because of these factors, comparatively fewer PP5-6 specimens are identifiable to taxon and skeletal element. Undoubtedly, preservation conditions have had an impact on the survivorship and visibility of some bone surface modifications.

However, several predator-induced bone surface modifications were preserved and these suggest that most of the PP5-6 small mammals were accumulated by raptors. Mammalian carnivores do not appear to have played a significant role in the accumulation of small mammals. Both nocturnal and diurnal raptors accumulated the bulk of the small mammals, with diurnal raptors likely responsible for accumulating the majority of small mammals (Fig. 9) as evidenced by high relative frequencies of punctured and pitted small mammal bones as well as moderate relative levels of digestion. Humans played a small, yet detectable, role in the accumulation of faunal remains as the size 1 bovids from stratum NWR and the small mammal group from stratum LBSR exhibit evidence of human accumulation in the form of cut marked and burned bones. In addition, these specific taxonomic aggregates exhibit minimal levels of predator accumulation. Though only these two aggregates cluster with the human-accumulated control samples (Fig. 9), a pocket of burned bone is apparent in stratum DBCS. However, specimens from this layer also exhibit elevated levels of beak/talon/tooth punctures and pits, suggesting a more complex accumulation history and one that favors raptor accumulation, with humans playing a secondary role.

In comparison to DK1, the small mammal taphonomy at PP5-6 exhibits nominal evidence for human accumulation. The diminished relative frequencies of human-induced bone surface modifications and the proportion of small to large mammalian fauna suggests that small mammals may not have been

an important part of the resource base for MSA humans at PP5-6 as they were at DK1. The abundance of mole-rats and lack of shellfish at DK1 implies that the inhabitants substituted one for the other, whereas at PP5-6, where shellfish appear to have been consistently available, a reliance on small mammals may not have been required.

Conclusion

This taphonomic analysis demonstrates that humans played a central role in the accumulation of small mammal archaeofaunas at DK1 in layers LSA, MSA6, MSA10, MSA12, and MSA14 and that nocturnal raptors were the leading contributor in the other layers. Humans were frequently the primary accumulators of Cape dune mole-rats as well as of hares and size 1 bovids. The majority of cut marks on mole-rat bones are found at anatomical locations indicative of skinning and are interpreted as such. Mole-rat remains also show evidence of intentional burning -- some specimens being both cut-marked and burned -- suggesting that carcasses were also utilized as a food source. This analysis provides the first formal/systematic evidence for the habitual capture and utilization of small, fur-bearing mammals for their skins and as food during the MSA of southern Africa. The MSA occupations at PP5-6 differ from those at DK1. They do not show the same concentrations of small mammal accumulations by humans; the taxonomic composition, relative abundancies, and taphonomic profiles differ from those of DK1, indicating that small mammals were not an important part of the resource base of humans at PP5-6 during late MIS5 and MIS4. Concentrations of shellfish and microlithic stone tools suggest that humans were focusing their subsistence efforts on high-quality resources, probably in response to the high-yield habitats in the vicinity of PP5-6. Additionally, most of the PP5-6 sample was accumulated by diurnal and nocturnal raptors but few of the prey species found in great numbers at DK1 (i.e., mole-rats, hares, and hyraxes) and other sites in the CFR were recovered in abundance at PP5-6, indicating that these species may have been less prevalent on the landscape near PP5-6 or represented a less-preferable option to humans and predators.

The analysis presented here also demonstrates that taphonomic studies can be used to address aspects of modern human behavior during this critical time period in human evolution. It is clear that humans utilized a range of resources and protein sources during the MSA and that small mammals were at times an important resource at DK1 and perhaps other MSA sites. Small mammals, however, were not a significant resource for the contemporaneous humans who occupied PP5-6. This difference in subsistence strategies suggests that the adaptive response of MIS4 humans to glacial conditions and resultant habitat fluctuations was to maximize their resource base and exploit lower-quality resources

when necessary. The increased visibility of MIS4 archaeological sites in the Cape suggests that human population densities were greater and that these humans responded differently than previous populations did to glacial conditions. The flexibility to incorporate new resources into their subsistence base may have been one of the behavioral differences that allowed MIS4 human populations to thrive.

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Figures

Figure 1: Locations of DK1, PP5-6, and other MSA sites discussed in the text.

Figure 2A-N: Examples of the bone surface modifications described in this study: A-B=punctured mole-rat ilium and tibia; C-D=pitted rock hyrax mandible and mole-rat ulna; E-F=scored hare tibia and mole-rat mandible; G-H=notched bovid tibia and long bone shaft fragment; I-J=digested mole-rat patella and bovid fibula; K-L=cut-marked mole-rat mandible and tibia; M-N=burned hare femur and mole-rat humerus.

Figure 3: (A) Depiction of the PP5-6 Long Section and the locations of all sampled faunal specimens in relation to the stratigraphic aggregates. (B) Locations of the identified small mammal specimens. Stratigraphic aggregate ages are thousand years BP

Figure 4: Principal components analysis of bone modification frequencies for the DK1 SMAs by stratum and control assemblages of known accumulation. Taphonomic aggregates are based on the cluster analysis (Fig. 6): green=human/raptor, red=diurnal raptor-only, blue=human-only, black=carnivore-only, and light blue=nocturnal raptor-only. Barycentre ellipses represent the weighted relative center of each cluster. The control assemblages (predator followed by prey) are: BE1=bald eagle rabbit, BE2=bald eagle guinea pig, C1=coyote rabbit, C2= coyote guinea pig, C3=coyote rabbit, DBC1=human porcupine, DBC2=human hare, DBC3=human springhare, DBC4=human size 1 bovid, EEO1=European eagle owl rabbit, EEO2=European eagle owl rabbit, GHO1=great horned owl rabbit, GHO2=great horned owl guinea pig, L1=lynx rabbit, VE1=Verreaux's eagle mole-rat, VE2=Verreaux's eagle size 1 bovid, VE3=Verreaux's eagle hare, VE4=Verreaux's eagle hyrax, VE5=Verreaux's eagle small carnivore.

Figure 5: Variance in the DK1 PCA axis 1 scores showing predator and anthropogenic accumulations of the SMAs by stratum. Strongly positive scores denote human accumulation, moderate scores denote mixed predator accumulation, and strong negative scores denote non-human accumulation.

Figure 6: Euclidean cluster analysis of the DK1 PCA axes 1 and 2 scores for the SMAs by stratum. The control assemblages of known accumulation are included (predator followed by prey): VE=Verreaux's eagle, BE=bald eagle, GHO= great horned owl, EEO=European eagle owl, C=coyote, L=lynx, and DBC=Dobe Base Camps.

Figure 7: Principal components analysis of bone modification frequencies for the PP5-6 SMAs by stratum and control assemblages of known accumulation. Taphonomic aggregates are based on the cluster analysis (Fig. 9): green = mixed diurnal and nocturnal raptor, red = diurnal raptor-only, blue = human-only, black = carnivore-only, and light blue = nocturnal raptor-only. Barycentre ellipses represent the weighted relative center of each cluster. The control assemblages (predator followed by prey) are: BE1=bald eagle rabbit, BE2=bald eagle guinea pig, C1=coyote rabbit, C2= coyote guinea pig, C3=coyote rabbit, DBC1=human porcupine, DBC2=human hare, DBC3=human springhare, DBC4=human size 1 bovid, EEO1=European eagle owl rabbit, EEO2=European eagle owl rabbit, GHO1=great horned owl rabbit, GHO2=great horned owl guinea pig, L1=lynx rabbit, VE1=Verreaux's eagle mole-rat,

1134 VE2=Verreaux's eagle size 1 bovid, VE3=Verreaux's eagle hare, VE4=Verreaux's eagle hyrax,
1135 VE5=Verreaux's eagle small carnivore.

1136 **Figure 8:** Variance in the PP5-6 PCA axis 1 scores showing predator and anthropogenic accumulations of
1137 the SMAs by stratum. Strongly positive scores denote human accumulation, moderate scores denote
1138 mixed predator accumulation, and strong negative scores denote non-human accumulation.

1139 **Figure 9:** Euclidean cluster analysis of the PP5-6 PCA axes 1 and 2 scores for the SMAs by stratum. The
1140 control assemblages of known accumulation are included (predator followed by prey): VE=Verreaux's
1141 eagle, BE=bald eagle, GHO= great horned owl, EEO=European eagle owl, C=coyote, L=lynx, and
1142 DBC=Dobe Base Camps.

1143 **Figure 10:** Photographs showing cut marks to the premaxilla and mandible (anterior portion and
1144 coronoid process) as well as the distal radius, ulna, and tibia of Cape dune mole-rats from MSA layers at
1145 DK1. Line drawings show the locations of recurrent cut marks indicative of skinning for these skeletal
1146 elements. The tables report the frequencies of cut marks at the specific skeletal elements by stratum.

1147 **Tables**

1148 **Table 2:** Taxonomic representation by NISP of each identified taxon and analytical aggregate by
1149 stratigraphic layer for the DK1 sample.

1150 **Table 3:** (HEADER) Composite chi-squared values comparing the distribution of SMAs for each of the
1151 DK1 stratigraphic levels. (FOOTER) Bold values are significant at 0.01 level, un-bolded values are not
1152 significant.

1153 **Table 4:** (HEADER) Chi-squared values for the comparison of each individual SMA in relation to the
1154 abundance of the previous level at DK1. The scores are to be read in comparison to the level to the right
1155 of the test statistic column. (FOOTER) Bonferroni correction: significant at 0.05 level <0.01; bold values
1156 are significant.

1157 **Table 5:** Fracture angle and fracture outline frequencies for the DK1 long bones by small mammal
1158 taxonomic aggregate and stratum. Expected frequencies are assemblages of known breakage origin:
1159 Fontbrégoua fresh bone breakage sample (fracture angle frequency of: oblique=65.5%, right=27.0%,
1160 oblique/right=7.5%) and the Sarrians dry bone breakage sample (fracture angle frequency of:
1161 oblique=8.2%, right=65.4%, oblique/right=26.4%) reported by Villa and Mahieu (1991).

Table 6: Bone modification frequencies for each DK1 small mammal taxonomic aggregate. Taphonomic cluster designation based on the Euclidian cluster analysis (Fig. 5).

Table 7: Taxonomic representation by NISP of each identified taxon and analytical aggregate by stratigraphic aggregate for the PP5-6 sample.

Table 8: Fracture angle and fracture outline frequencies for the PP5-6 long bones by small mammal taxonomic aggregate and stratum.

Table 9: Bone modification frequencies for the PP5-6 small mammal taxonomic aggregate. Taphonomic cluster designation based on the Euclidian cluster analysis (Fig. 9).

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Table

	Age	Environment	Lithic Industry	Fauna	Relation to sea level	References
DK1	LSA: 2-1.5 ka (¹⁴ C) MSA: 70 ±10 ka (ESR, OSL)	Beginning of MSA occupation typified by wetter conditions with C3 vegetated dune fields; transitioned to dryer environment with increase in C4 grasses by middle and end of MSA occupation	Dominated by course-grained raw materials with a notable shift to fine-grained raw material in MSA layer 12, pattern typical of MSA sites featuring Howiesons Poort levels; however, HP and Still Bay are absent	Micro-, small, large mammals, and tortoises abundant throughout sequence; marine mammals and seabirds modestly present throughout; shellfish minimally present in layers MSA6 and 8	>10 m above mean sea level	Schweitzer, 1974; 1979; Tankard and Schweitzer, 1974; 1976; Avery, 1982; Grine et al., 1991; Avery et al., 1997; Feathers and Bush, 2000; Goldberg, 2000; Klein and Cruz-Uribe, 2000; Marean et al., 2000a,b; Schwarcz and Rink, 2000; Thackeray, 2000
PP5-6	MSA: 96±6-51±2 ka (OSL)	Beginning of MSA occupation typified by shrubby vegetation, C3 grasses, and increased winter rainfall; by end of MSA occupation cooler conditions persisted characterized by increase in C4 grasses and more summer rainfall	Shift from coarse-grained quartzite in oldest layers to finer grained silcrete in younger layers; HP is present as is microlithic backed ‘bladelet’ technology differing from microlithic HP segments; Still Bay is absent	Micro-, small, large mammals, and tortoises variably present throughout the sequence; marine mammals modestly present in parts of sequence; seabird abundance unknown at present; shellfish variably present, abundant in layers OBS1, SADBS, ALBS, and LBSR	>16 m above mean sea level	Brown et al., 2009; Bar-Matthews et al., 2010; Fisher et al., 2010; Brown, 2011; 2012; Marean, 2014; Karkanas et al., 2015

Table

Taxa	Common name	LSA	%	MSA6	%	MSA7	%	MSA8	%	MSA9	%	MSA10	%	MSA11	%	MSA12	%
<i>Bathyergus suillus</i>	Cape dune mole-rat	2810	71.8	4058	47.8	5622	95.4	8952	98.6	4063	90.8	1520	74.6	368	59.8	457	57.1
<i>Lepus</i> spp.	Hares	23	0.6	1789	21.1	98	1.7	56	0.6	129	2.9	95	4.7	15	2.4	54	6.8
<i>Procavia capensis</i>	Rock hyrax	295	7.5	171	2.0	9	0.2	6	0.1	54	1.2	57	2.8	7	1.1	55	6.9
<i>Hystrix africaeaustralis</i>	Porcupine	7	0.2							2	0.0						
<i>Atelerix frontalis</i>	Hedgehog			5	0.1												
<i>Mellivora capensis</i>	Honey badger	3	0.1	1	0.0	2	0.0			1	0.0						
<i>Genetta</i> spp.	Genet	27	0.7	4	0.0	1	0.0										
<i>Galerella pulverulenta</i>	Cape grey mongoose	16	0.4	17	0.2							1	0.0			7	0.9
<i>Mongoose</i> indet.	Mongoose			12	0.1												
<i>Felis silvestris lybica</i>	Wildcat	11	0.3	9	0.1											1	0.1
<i>Caracal caracal</i>	Caracal	8	0.2							2	0.0						
<i>Canis mesomelas</i>	Black-backed jackal	1	0.0					1	0.0			3	0.1				
<i>Vulpes chama</i>	Cape fox	7	0.2														
<i>Ictonyx striatus</i>	Striped polecat	41	1.0									1	0.0				
<i>Oreotragus oreotragus</i>	Klipspringer			2	0.0	1	0.0			1	0.0			1	0.2		
<i>Raphicerus</i> spp.	Grysbok / steenbok	238	6.1	454	5.3	16	0.3	11	0.1	35	0.8	95	4.7	13	2.1	58	7.3
	Size 1 bovid	425	10.9	1974	23.2	141	2.4	49	0.5	186	4.2	266	13.1	211	34.3	168	21.0
	Total	3912		8496		5890		9075		4473		2038		615		800	
	Analytical Agg.																
	Mole-rats	2810	72.0	4058	47.8	5622	95.4	8952	98.6	4063	90.9	1520	74.6	368	59.8	457	57.1
	Hares	23	0.6	1789	21.1	98	1.7	56	0.6	129	2.9	95	4.7	15	2.4	54	6.8
	Hyraxes	295	7.6	171	2.0	9	0.2	6	0.1	54	1.2	57	2.8	7	1.1	55	6.9
	Carnivores	114	2.9	48	0.6	3	0.1	1	0.0	3	0.1	5	0.2	0	0.0	8	1.0
	Size 1 bovids	663	17.0	2430	28.6	158	2.7	60	0.7	222	5.0	361	17.7	225	36.6	226	28.3
	Total	3905		8496		5890		9075		4471		2038		615		800	

Table

MSA13	%	MSA14	%	MSA15	%	Total	%
284	58.1	460	22.1	109	48.2	28703	75.3
50	10.2	749	35.9	48	21.2	3106	8.2
19	3.9	119	5.7	10	4.4	802	2.1
						9	0.0
		2	0.1			7	0.0
2	0.4					9	0.0
2	0.4					34	0.1
		28	1.3			69	0.2
						12	0.0
1	0.2	1	0.0			23	0.1
		1	0.0			11	0.0
2	0.4					7	0.0
						7	0.0
		3	0.1			45	0.1
		3	0.1	2	0.9	10	0.0
23	4.7	214	10.3	2	0.9	1159	3.0
106	21.7	504	24.2	55	24.3	4085	10.7
489		2084		226		38098	
284	58.1	460	22.1	109	48.2	28703	75.4
50	10.2	749	35.9	48	21.2	3106	8.2
19	3.9	119	5.7	10	4.4	802	2.1
7	1.4	35	1.7	0	0.0	224	0.6
129	26.4	721	34.6	59	26.1	5254	13.8
489		2084		226		38089	

Table

[illegible]

Table

	LSA	MSA6	MSA7	MSA8	MSA9	MSA10	MSA11	MSA12	MSA13	MSA14	MSA15
Mole-rats	632.8	3591.4	142.0	478.1	303.2	49.3	0.9	0.1	248.0	73.7	-
Hares	896.7	1146.2	37.4	112.7	12.8	5.3	13.0	11.7	121.1	18.9	-
Hyraxes	225.7	95.9	1.9	86.0	20.2	4.8	26.0	4.5	2.3	0.4	-
Carnivores	113.2	24.6	0.9	1.6	2.3	0.5	4.5	0.2	0.0	2.8	-
Size 1 bovid	192.3	1582.2	100.3	270.1	277.4	96.7	10.7	0.4	11.7	6.2	-

Table

Layer	Taxon agg.	n	Fracture angle (%)			Fracture outline			Transverse/curved
			Oblique (fresh)	Right (dry)	Oblique/ri ght	V-shaped (fresh)	Transverse (dry)	Intermediate	
LSA	Mole-rat	824	74	24	2	79	17	1	3
	Bovid	628	74	25	1	82	16	1	1
	Hare	3	67	33	0	67	33	0	0
	Hyrax	28	75	25	0	71	24	2	3
	Carnivore	10	70	30	0	70	20	0	10
MSA6	Mole-rat	1318	69	28	3	73	22	1	4
	Bovid	2574	70	29	1	70	21	2	7
	Hare	711	74	24	2	81	15	1	3
	Hyrax	25	65	30	5	76	23	0	1
	Carnivore	8	100	0	0	100	0	0	0
MSA7	Mole-rat	1534	68	30	2	74	19	1	6
	Bovid	158	67	30	3	69	27	1	3
	Hare	39	82	17	1	78	20	0	2
	Hyrax	3	100	0	0	75	25	0	0
	Carnivore	3	100	0	0	100	0	0	0
MSA8	Mole-rat	2856	76	23	1	69	27	1	3
	Bovid	69	74	25	1	71	27	1	1
	Hare	13	90	10	0	85	15	0	0
	Hyrax	1	100	0	0	100	0	0	0
	Carnivore	1	0	100	0	0	100	0	0
MSA9	Mole-rat	1243	69	28	3	77	20	1	2
	Bovid	257	72	26	2	71	25	1	3
	Hare	74	74	25	1	60	34	1	5
	Hyrax	11	80	20	0	75	25	0	0
	Carnivore	1	100	0	0	100	0	0	0
MSA10	Mole-rat	467	75	24	1	68	27	2	3
	Bovid	486	69	30	1	76	15	3	6
	Hare	35	81	18	1	83	15	0	2
	Hyrax	8	100	0	0	72	28	0	0
	Carnivore	3	100	0	0	75	25	0	0
MSA11	Mole-rat	117	76	22	2	74	24	0	2
	Bovid	100	76	23	1	84	9	3	4
	Hare	7	70	30	0	70	30	0	0
	Hyrax	1	50	50	0	50	50	0	0
	Carnivore	0	-	-	-	-	-	100	-
MSA12	Mole-rat	148	80	18	2	78	19	1	2
	Bovid	318	68	31	1	69	28	1	2
	Hare	17	75	21	4	84	14	0	2
	Hyrax	11	100	0	0	86	14	0	0
	Carnivore	4	67	33	0	67	33	0	0
MSA13	Mole-rat	71	74	23	3	72	25	0	3
	Bovid	147	66	33	1	65	33	1	1
	Hare	24	72	25	3	80	15	2	3
	Hyrax	8	80	10	10	91	9	0	0
	Carnivore	1	100	0	0	50	0	0	50
MSA14	Mole-rat	141	68	31	1	74	23	1	2
	Bovid	715	70	28	2	73	21	2	4
	Hare	239	79	20	1	80	18	0	2
	Hyrax	35	69	30	1	82	17	1	0
	Carnivore	20	60	40	0	76	20	2	2
MSA15	Mole-rat	35	71	27	2	71	28	0	1
	Bovid	61	73	25	2	73	26	0	1
	Hare	13	85	15	0	78	19	0	3
	Hyrax	4	80	20	0	80	0	0	20
	Carnivore	0	-	-	-	-	-	100	-

Table

Layer	Taxon Agg.	Frage ntation	%Punct ure	%Diges tion	%Burni ng	%Cutma rk	%Not ch	%Pittin g	Taphonomic Cluster
LSA	Mole-rats	1.35	0.2	3.4	11.2	1.8	0.0	1.1	Human
LSA	Size 1 bovids	1.69	0.5	1.1	8.1	5.1	2.9	0.8	Human
LSA	Hares	1.10	0.0	8.7	8.7	4.3	0.0	0.0	Human
LSA	Hyraxes	1.38	0.7	5.1	1.7	1.4	0.0	1.4	Human/Raptor
LSA	Carnivores	1.06	0.0	0.9	2.6	3.5	0.0	0.0	Human/Raptor
MSA6	Mole-rats	1.63	0.3	11.8	4.8	2.3	0.0	4.4	Human/Raptor
MSA6	Size 1 bovids	2.38	0.1	2.3	3.8	1.9	1.6	2.6	Human
MSA6	Hares	1.53	0.2	2.3	3.5	1.2	1.1	1.4	Human/Raptor
MSA6	Hyraxes	1.51	0.6	2.3	5.3	0.6	0.6	1.8	Human/Raptor
MSA6	Carnivores	1.40	0.0	18.8	0.0	0.0	0.0	0.0	Nocturnal raptor
MSA7	Mole-rats	1.63	0.8	12.3	2.1	0.8	0.0	2.9	Human/Raptor
MSA7	Size 1 bovids	2.42	2.0	20.7	3.0	3.4	1.5	4.9	Human
MSA7	Hares	1.60	1.9	10.3	5.6	0.9	0.0	3.7	Human/Raptor
MSA7	Hyraxes	1.37	0.0	28.6	0.0	0.0	0.0	0.0	Nocturnal raptor
MSA7	Carnivores	1.00	0.0	0.0	0.0	0.0	0.0	0.0	Diurnal raptor
MSA8	Mole-rats	1.83	0.5	7.2	1.4	0.3	0.0	1.4	Human/Raptor
MSA8	Size 1 bovids	1.50	0.0	6.7	0.0	0.0	3.3	5.0	Human/Raptor
MSA8	Hares	1.47	0.0	16.1	0.0	0.0	1.8	3.6	Human/Raptor
MSA8	Hyraxes	1.20	0.0	33.3	0.0	0.0	0.0	0.0	Nocturnal raptor
MSA8	Carnivores	1.00	0.0	100.0	0.0	0.0	0.0	0.0	Nocturnal raptor
MSA9	Mole-rats	1.81	0.6	16.7	1.3	0.2	0.0	2.2	Human/Raptor
MSA9	Size 1 bovids	1.76	1.4	20.7	2.3	0.9	2.7	4.5	Human/Raptor
MSA9	Hares	1.40	1.6	31.8	0.8	0.0	0.8	2.3	Nocturnal raptor
MSA9	Hyraxes	1.29	1.9	13.0	1.9	0.0	1.9	3.7	Human/Raptor
MSA9	Carnivores	1.00	33.3	0.0	0.0	0.0	0.0	0.0	Diurnal raptor
MSA10	Mole-rats	1.52	0.1	3.8	7.4	2.4	0.0	0.8	Human
MSA10	Size 1 bovids	1.50	1.1	6.6	5.1	6.0	3.9	1.9	Human
MSA10	Hares	1.56	0.0	3.2	2.1	1.1	2.1	0.0	Human/Raptor
MSA10	Hyraxes	1.39	0.0	5.3	1.8	0.0	1.8	0.0	Human/Raptor
MSA10	Carnivores	1.00	0.0	20.0	0.0	0.0	0.0	20.0	Diurnal raptor
MSA11	Mole-rats	1.74	0.8	17.4	0.8	1.1	0.0	2.2	Human/Raptor
MSA11	Size 1 bovids	2.17	4.3	22.3	0.0	3.3	1.9	5.2	Human/Raptor
MSA11	Hares	1.56	0.0	6.7	0.0	0.0	0.0	0.0	Nocturnal raptor
MSA11	Hyraxes	1.40	0.0	14.3	0.0	0.0	0.0	0.0	Nocturnal raptor
MSA12	Mole-rats	1.69	0.7	6.8	6.1	2.0	0.0	1.3	Human/Raptor
MSA12	Size 1 bovids	1.87	0.0	5.8	7.5	2.7	4.0	0.4	Human
MSA12	Hares	1.35	0.0	13.0	1.9	0.0	0.0	0.0	Human/Raptor
MSA12	Hyraxes	1.45	0.0	1.8	1.8	1.8	1.8	0.0	Human/Raptor
MSA12	Carnivores	1.44	0.0	37.5	0.0	0.0	0.0	0.0	Nocturnal raptor
MSA13	Mole-rats	1.80	1.4	18.3	0.7	0.0	0.0	1.1	Nocturnal raptor
MSA13	Size 1 bovids	2.58	1.6	9.3	0.0	0.8	0.0	2.3	Nocturnal raptor
MSA13	Hares	1.56	0.0	18.0	0.0	0.0	0.0	2.0	Nocturnal raptor
MSA13	Hyraxes	1.58	0.0	5.3	0.0	0.0	0.0	0.0	Nocturnal raptor
MSA13	Carnivores	1.37	0.0	28.6	0.0	0.0	0.0	14.3	Diurnal raptor
MSA14	Mole-rats	1.72	0.7	12.2	7.0	3.5	0.0	2.4	Human
MSA14	Size 1 bovids	2.16	0.3	2.9	0.8	2.4	6.2	0.7	Human
MSA14	Hares	1.65	0.3	1.3	3.2	0.9	1.2	0.3	Human/Raptor
MSA14	Hyraxes	1.65	0.8	14.3	0.8	0.8	0.0	1.7	Human/Raptor
MSA14	Carnivores	1.35	0.0	8.6	0.0	2.9	0.0	2.9	Human/Raptor
MSA15	Mole-rats	1.58	0.0	33.9	0.9	0.0	0.0	1.8	Nocturnal raptor
MSA15	Size 1 bovids	2.36	0.0	11.9	0.0	0.0	0.0	3.4	Nocturnal raptor
MSA15	Hares	1.92	2.1	25.0	0.0	0.0	0.0	2.1	Nocturnal raptor
MSA15	Hyraxes	1.31	0.0	50.0	0.0	0.0	0.0	0.0	Nocturnal raptor

Table

Taxon	Common name	RBSR	BCSR	NWR	DBCS	OBS2	SGS	OBS1	SADBS	ALBS	LBSR	YBSR	YBS	Total
Small mammals														
<i>Bathyerugs suillus</i>	Cape dune mole-rat	4	0	0	0	0	0	0	0	0	0	0	0	4
<i>Genetta spp.</i>	Genet	0	0	1	0	0	0	0	0	0	0	0	0	1
<i>Galerella pulverulenta</i>	Cape grey mongoose	0	0	0	0	0	0	0	0	1	0	0	0	1
<i>Lepus spp.</i>	Hare	1	0	0	1	0	0	0	4	2	0	0	0	8
<i>Procavia capensis</i>	Rock hyrax	0	0	0	0	1	0	0	1	1	1	0	0	4
	Indet small mammal	8	1	5	16	0	3	3	27	9	7	0	0	79
	Size 1 bovid	8	1	9	14	2	9	6	32	22	8	0	0	111
	Sum	21	2	15	31	3	12	9	64	35	16	0	0	208
Other ID fauna														
	Amphibian	0	0	0	0	0	0	0	1	0	0	0	0	1
	Avian	0	0	0	0	0	0	0	0	5	0	0	0	5
	Size 2-4 bovid	98	311	296	1026	209	409	154	483	303	339	1	0	3629
	Indet large mammal	156	130	16	419	103	92	37	241	68	77	0	0	1339
	Micro mammal	2	0	0	1	5	0	1	0	1	0	0	0	10
<i>Arctocephalus pusillus</i>	Seal	0	0	0	0	0	0	0	0	0	1	0	0	1
	Tortoise	47	24	95	161	47	44	13	33	6	55	0	0	525
	Ostrich Egg Shell	0	0	0	0	0	5	0	1	0	0	0	0	6
	Sum	303	465	407	1607	364	550	205	759	383	472	1	0	5516
	Total	324	467	422	1638	367	562	214	823	418	488	1	0	5724
Analytical Aggregates														
	Small mammal group	13	1	6	17	1	3	3	32	13	8	0	0	97
	Size 1 bovid	8	1	9	14	2	9	6	32	22	8	0	0	111

Table

Layer	Taxa	n	Fracture angle (%)			Fracture outline (%)			
			Oblique (fresh)	Right (dry)	Oblique/r igh	V-shaped (fresh)	Transverse (dry)	Intermediate	Transverse/c urved
RBSR	Bovid size 1	8	1	0	0	63	25	13	0
	Indet. small mam.	4	25	0	75	0	25	0	75
NWR	Bovid size 1	13	54	23	23	69	23	0	8
	Indet. small mam.	6	33	67	0	50	33	0	17
DBCS	Bovid size 1	12	33	33	33	58	25	0	17
	Indet. small mam.	14	36	57	7	50	36	0	14
OBS2	Bovid size 1	1	1	0	0	1	0	0	0
	Indet. small mam.	0	-	-	-	-	-	-	-
SGS	Bovid size 1	7	86	14	0	86	14	0	0
	Indet. small mam.	0	-	-	-	-	-	-	-
OBS1	Bovid size 1	7	14	57	29	57	29	0	14
	Indet. small mam.	0	-	-	-	-	-	-	-
SADBS	Bovid size 1	22	55	14	32	55	9	5	32
	Indet. small mam.	14	50	36	14	57	21	0	21
ALBS	Bovid size 1	23	48	26	26	70	13	0	17
	Indet. small mam.	6	17	50	33	67	17	0	17
LBSR	Bovid size 1	2	0	0	1	0	50	0	50
	Indet. small mam.	6	17	33	50	50	17	0	33
Total	Bovid size 1	95	53	22	25	63	18	2	17
	Indet. small mam.	50	34	44	22	50	26	0	24

Table

Layer	Taxon Agg.	Fragment ation	%Punct ure	%Digest ion	%Burni ng	%Cutm ark	%Notch	%Pitting	Taphonomic Cluster
RBSR	Small mam. group	1.44	4.6	15.4	0.0	0.0	0.0	3.7	Mixed raptor
	Size 1 bovid	1.33	0.0	0.0	0.0	0.0	0.0	0.0	Mixed raptor
NWR	Small mam. group	2.00	11.0	0.0	0.0	0.0	0.0	5.0	Mixed raptor
	Size 1 bovid	1.80	0.0	0.0	33.3	0.0	0.0	0.0	Human
DBCS	Small mam. group	2.40	5.9	0.0	2.9	0.0	0.0	0.0	Nocturnal raptor
	Size 1 bovid	1.56	0.0	0.0	0.0	0.0	0.0	1.0	Mixed raptor
OBS2	Size 1 bovid	1.00	0.0	0.0	5.0	0.0	0.0	0.0	Mixed raptor
SGS	Small mam. group	1.50	0.0	33.3	0.0	0.0	0.0	0.0	Nocturnal raptor
	Size 1 bovid	1.50	0.0	0.0	0.0	0.0	0.0	1.0	Mixed raptor
OBS1	Small mam. group	1.50	0.0	0.0	11.1	0.0	0.0	0.0	Mixed raptor
	Size 1 bovid	1.50	0.0	0.0	16.7	0.0	0.0	0.0	Mixed raptor
SADBS	Small mam. group	2.46	0.0	3.1	6.3	0.0	0.0	0.0	Nocturnal raptor
	Size 1 bovid	1.68	1.5	3.1	6.3	0.0	0.0	2.1	Mixed raptor
ALBS	Small mam. group	1.86	0.0	0.0	0.0	0.0	0.0	0.0	Nocturnal raptor
	Size 1 bovid	1.57	3.2	0.0	13.6	0.0	0.0	1.3	Mixed raptor
LBSR	Small mam. group	1.67	1.3	1.0	4.3	5.3	0.0	0.0	Human
	Size 1 bovid	1.14	0.0	0.0	0.0	0.0	0.0	0.0	Mixed raptor

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Figure

Figure

Figure

Premaxilla

Mandible

Radius

Radius

Layer	LSA	MSA6	MSA7	MSA8	MSA9	MSA10	MSA11	MSA12	MSA13	MSA14	MSA15
%Cutmark	9.8	10.9	9.1	6.5	0.0	10.8	0.0	11.1	0.0	12.5	0.0

Ulna

Ulna

Layer	LSA	MSA6	MSA7	MSA8	MSA9	MSA10	MSA11	MSA12	MSA13	MSA14	MSA15
%Cutmark	3.9	6.5	0.0	3.2	0.0	5.4	0.0	11.1	0.0	6.3	0.0

Tibia

Tibia

Layer	LSA	MSA6	MSA7	MSA8	MSA9	MSA10	MSA11	MSA12	MSA13	MSA14	MSA15
%Cutmark	15.7	25.0	27.3	16.1	42.9	21.6	0.0	33.3	0.0	31.3	0.0