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In Situ Taphonomic Investigation of Pleistocene Large Mammal Bone Deposits from The Ossuaries, Victoria Fossil Cave, Naracoorte, South Australia

E. H. Reed

School of Biological Sciences,
The Flinders University of South Australia,
GPO Box 2100 Adelaide SA 5001.
E-mail: liz.reed@flinders.edu.au

Abstract

The Ossuaries within the Victoria Fossil Cave (5U-1) contain a large, virtually untouched deposit of Pleistocene vertebrates. Discovered in the early 1970s, the chamber has been left unexcavated as a 'reference' section of the cave and contains taphonomic features analogous to the formation of other large deposits such as the Fossil Chamber. This paper presents the results of an *in situ* taphonomic investigation of large mammal fossils from The Ossuaries. The results suggest The Ossuaries acted as a pitfall trap for a range of large Pleistocene mammals, in particular kangaroos. Once accumulated, the skeletons of these animals were subject to burial and dispersal by water and modification by trampling and termite gnawing. The presence of articulated material suggests many animals survived their initial fall, only to wander further into the cave and perish at some distance from the entrance.

Keywords: karst, cave, taphonomy, palaeontology, mammal, Pleistocene.

Introduction

The caves within the Naracoorte Caves World Heritage Area are renowned for their large deposits of Pleistocene vertebrates (Reed & Bourne, 2000). Among these, the Victoria Fossil Cave (5U-1) stands out for the number and size of Pleistocene deposits it contains. Discovered in 1969, the Fossil Chamber within this cave has been the focus of research for more than thirty years (Wells *et al.*, 1984; Reed & Bourne, 2000; Reed, 2003). In the years following its discovery other large deposits were found within the cave, including the chamber known as The Ossuaries which was discovered in the early 1970s (Reed & Bourne, 2000).

The Upper and Lower Ossuaries consist of scatters of large Pleistocene vertebrate bones lying on the clayey-sand sediment floors of the chamber. The important nature of these deposits was recognised early and only a small number of specimens were collected for taxonomic identification, with the deposit left un-excavated for future reference (Reed & Bourne, 2000). The chamber is classified in the Park's management plan as a 'Reference' section of Victoria Fossil Cave (Department for Environment and Heritage, 2001). The management plan states that "Reference Caves will be protected against further disturbance as far as is practicable, and access will be only with written approval for research specifically related to the baseline functions of the cave, and where such research cannot reasonably be carried out elsewhere in the State" (Department for Environment and Heritage, 2001).

Taphonomic investigation of deeply stratified deposits such as those in the Fossil Chamber of Victoria Fossil Cave is complex and requires the identification of the full range of processes that have operated to produce the deposit. The Ossuaries deposits provide an important opportunity to study large surface scatters of Pleistocene bones in a relatively undisturbed (by humans) fossil deposit, one that is analogous in many ways to the larger Fossil Chamber and many other Pleistocene pitfall deposits at Naracoorte and the South East of South Australia in general. Several features evident on the surface of The Ossuaries deposit provide useful analogues for the depositional stages of the Fossil Chamber including evidence of hydraulic action.

This paper reports the results of a taphonomic investigation of The Ossuaries deposit. As there are no other 'un-disturbed' deposits of this size and age known at Naracoorte, permission was granted to conduct research in The Ossuaries with the condition that all data collection was made on bones remaining *in situ* with no excavation or disturbance to the sediment floors.

Materials and methods

Mapping The Ossuaries

Prior to this project there had been no detailed maps produced of The Ossuaries chambers, due largely to access restrictions and the logistical problems of mapping a chamber when most of the floor cannot be crossed. As part of this project, plan maps of the chambers were produced using laser surveying equipment which

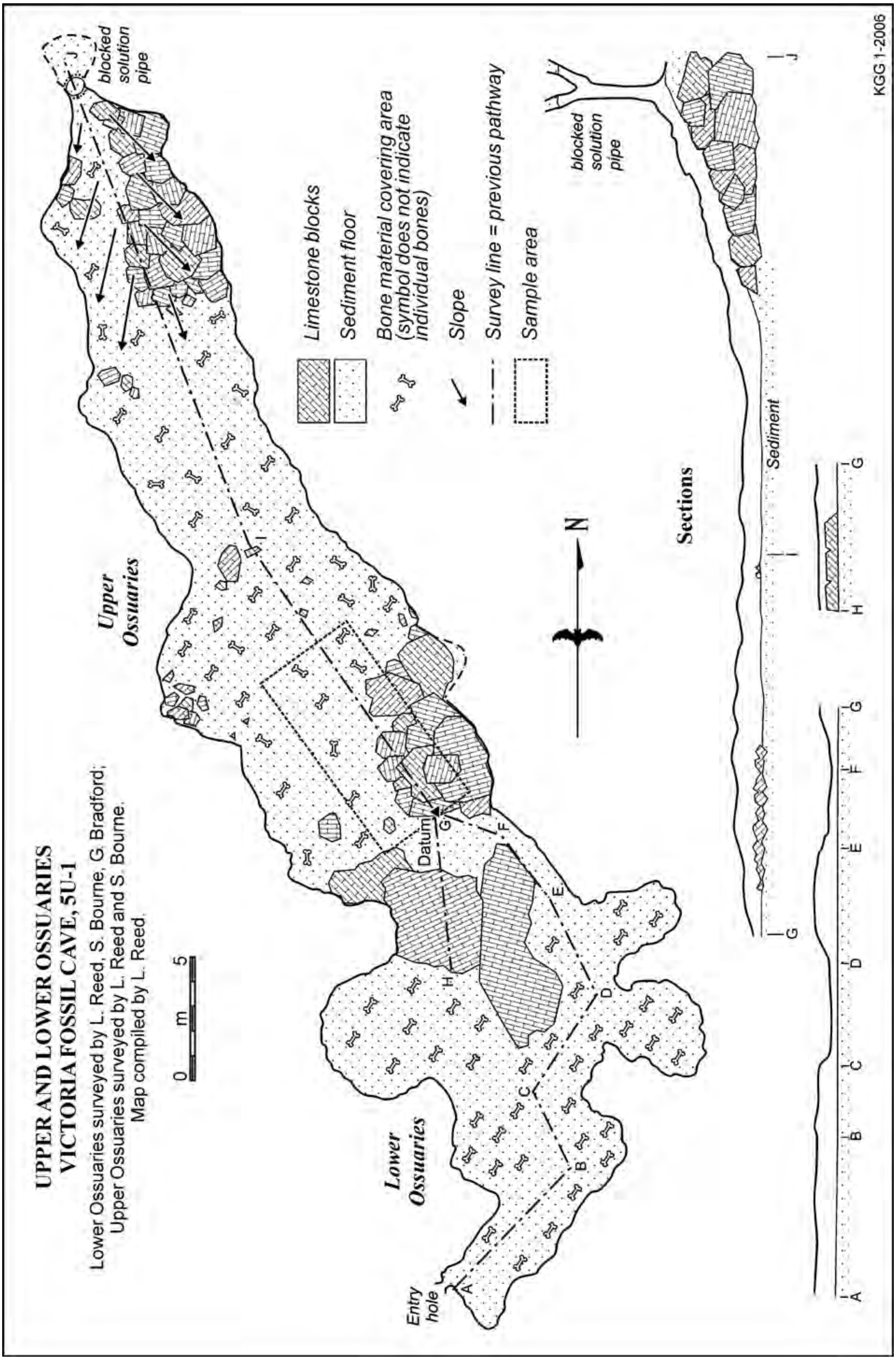

Figure 1. Map and sections of The Ossuaries, Victoria Fossil Cave (5U-1), Naracoorte.

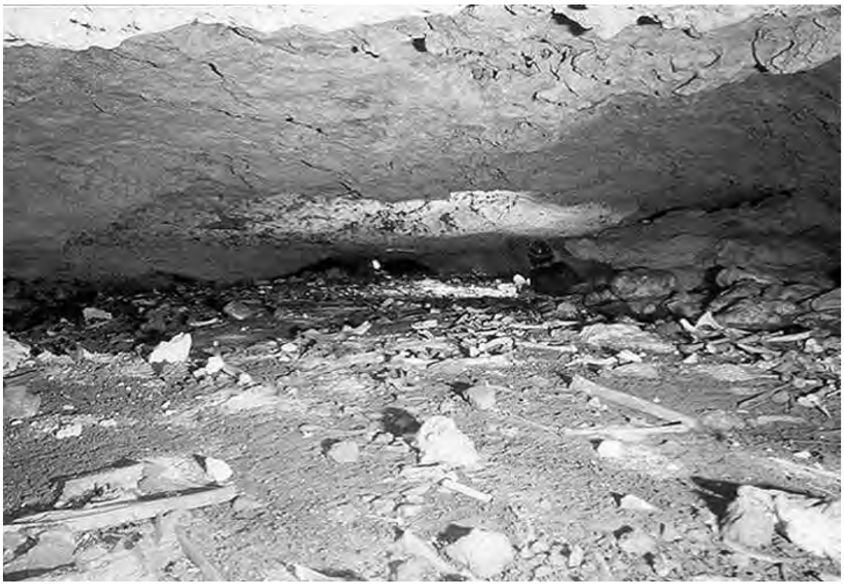

Figure 2. View of The Upper Ossuaries chamber looking Northwest.
Note caver's light in distance.

obviated any need to cross the undisturbed floor. The chambers were surveyed by running a tape along the centre-line (following the established narrow pathway) and measuring the distance to the walls and the roof height with a laser rangefinder at every 0.50 m along bearings defined by a digital compass. The mapping data were used to draw maps by hand. The topography of the floor was not surveyed, as access to most of the floor was restricted.

Four data collection trips were made, each lasting up to eight hours. The first trip was to photograph and map the entire chamber and to plan a strategy for the project. The survey of bone material was restricted largely to The Upper Ossuaries, as the roof height in The Lower Ossuaries was extremely low making work in that area practically impossible; nevertheless, the area was mapped and photographed. A datum point (small steel peg) was surveyed in and used on subsequent trips. Following the initial trip a map of The Upper Ossuaries chamber was completed and a grid overlain onto it to be used as a guideline for documenting bone material within the chamber for future trips. The grids used were 2 m square (with some variation resulting from difficulties accessing some areas of extremely low roof height) and were given X and Y co-ordinates for reference (eg. A2, B4).

Documenting bone material

Large, visible bones in The Upper Ossuaries were plotted onto the grid map, with cranial and post cranial material distinguished on the map. A few bones near the far walls of the chamber were omitted from the map as they were too far away to be easily identified, although some identifications were made after photographing using a zoom lens on a camera. No physical markers were used to define the limits of each grid and all data recording was done from the existing pathway. Grid boundaries were established by sight using the laser rangefinder, a tape measure (for distance along centre line), and compass (for bearings). A portable halogen light was used to provide strong light. Two people were involved in collecting data. One person plotted the position of bones onto the grid map as communicated by the other person who made element identifications and recorded positional data (measured at centre-point of bone). Due to the difficulties of recording bones in this manner, there is likely to be some degree of error in the accuracy of plotted locations of bones (particularly smaller elements), despite the care taken during the data gathering.

Other features such as rock piles, visible water-cut channels, associated and articulated sub-assemblies, modified bones and any other features of interest were noted on the map. These features were also extensively photographed using an SLR camera and a range of lenses. In addition, the entire Ossuaries were photo-documented for management reference. The Lower Ossuaries was also mapped and the survey tied in to that for The Upper Ossuaries. The maps produced from the study will be integrated with the entire cave survey currently being completed by CEGSA (Cave Exploration Group, South Australia).

Bone material within a 40 m^2 area adjacent to the pathway (representing 13.5% of the total floor area, see Figure 4), was sampled for taphonomic data. A total of 269 bones was examined and where practical, details such as element type, taxon (at least to family), bone orientation, modifications, associations and articulations recorded. The orientations of 182 bones (accessible from the pathway) with a long axis were measured using a digital compass mounted with a spirit level.

Analysis of bone material

Taphonomic data was catalogued using a spreadsheet. Statistical analyses were completed using SPSS™ version 11. Rose diagrams were created using the program Stereographic Projections version 1.00. The number of identifiable specimens (NISP) within the

Taphonomy

sampled area was calculated by counting all specimens identifiable to anatomical element and taxon. The minimum number of individuals (MNI) from this sample was determined by counting the relative proportions of left and right specimens of the most abundant element type, in this case the tibia.

Following counting and grouping of specimens the relative abundances (Ri) of elements was determined using the equation of Andrews (1990):

$$Ri\ \% = \frac{Ni \times 100}{(MNI)(Ei)}$$

where Ni indicates the number of specimens per element type counted, MNI being the minimum number of individuals determined for the relevant taxon or stratigraphic unit and Ei the expected number of each element type in a complete skeleton.

The index of skeletal representation (Ir) was calculated using the equation:

$$Ir = \frac{(NISP \times 100)}{(NE \times MNI)}$$

where NISP is the number of identified specimens recovered, NE is the number of elements in a single skeleton and MNI is the minimum number of individuals in the assemblage (method follows Arribas & Palmqvist, 1998). This figure gives an indication of the degree of element 'loss' (i.e. transport, dispersal) from that expected should the bones of all skeletons initially deposited in the assemblage still be present. It was used as it may offer some insight into the degree of dispersal and preferential burial within the sample.

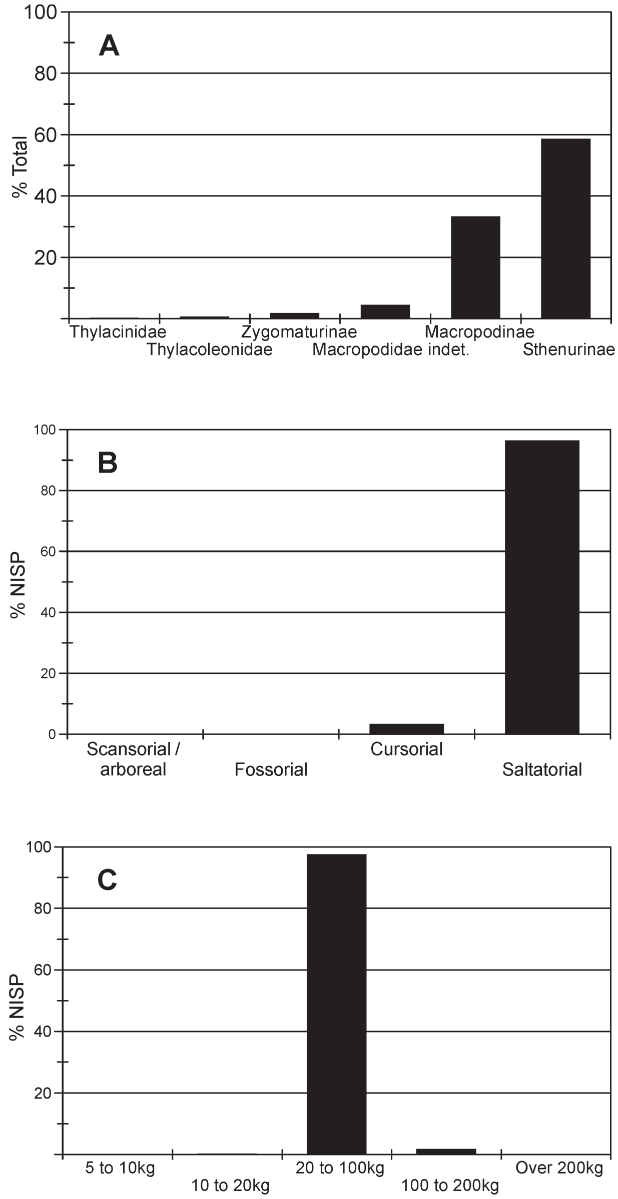

Figure 3. **A:** Relative abundances of the large mammalian families (or sub-families) based on NISP values for bones *in situ* in The Upper Ossuaries. N = 269; **B:** Locomotory mode class representations for the Ossuaries sample based on NISP (N = 269); **C:** Body size class representations for the Ossuaries sample based on NISP (N = 269).

Results

Chamber morphology and geological features

Description of the chamber

Although designated The Lower and Upper Ossuaries, The Ossuaries forms a single, large chamber with areas of rock collapse separating the two areas (Figure 1). The combined Upper and Lower Ossuaries chamber is approximately 63 metres long and 18 metres at its widest point. The floor surface area is around 475 m^2 and roof height is generally less than one metre (Figure 1). The chamber extends from the area of the Victoria Fossil Cave known as the Main Leg and is entered via a small dug hole. The Lower Ossuaries area is low and flat with a floor of clayey sediment littered with bone material. The Upper Ossuaries is much larger, although the chamber is still low with an average roof height of around one metre. The sediment floor is littered with bone material (Figure 2) with some roof fall limestone boulders and smaller pebbles in several areas. Limestone dust and evidence of minor roof fretting is obvious across the sediment floor. The depth of sediment is unknown as probing or coring has not been undertaken due to sensitivity of the floor. Both chambers of The Ossuaries are devoid of calcite speleothems.

Entry point for sediment and animals

The only discernible point in the chamber for entry of sediment and animals is a solution pipe in the northern end of The Upper Ossuaries (Figure 1). The pipe is 70 to 80 cm in diameter on average and extends upwards as a single pipe for four metres before branching into twin pipes that continue for approximately another two metres until constrictions are reached. The depth below the land surface at this point is not known, but it is likely

Table 1. Large mammal species recorded for The Ossuaries, Victoria Fossil Cave (5U-1). See also Reed & Bourne (2000). *† = extinct during Pleistocene, ** = extinct since European settlement

Class / sub-class & order	Family	Genus & species
MAMMALIA		
MONOTREMATA	Tachyglossidae	*† *Megalibgwilia ramsayi*
MARSUPIALIA		
DASYUROMORPHIA	Thylacinidae	***Thylacinus cynocephalus*
	Dasyuridae	*Sarcophilus* sp. cf. ***S. laniarius*
DIPROTODONTIA	Diprotodontidae	*† *Zygomaturus trilobus*
	Thylacoleonidae	*† *Thylacoleo carnifex*
	Macropodidae	*Macropus* sp. cf. *M. giganteus*
		M. rufogriseus
		*† *Simosthenurus browneorum*
		*† *Simosthenurus gilli*
		*† *Simosthenurus maddocki*
		*† *Simosthenurus occidentalis*
		*† *Sthenurus andersoni*

to be several metres. The sediment cone slopes steeply up to the base of the solution pipe suggesting this as the sediment source. Other evidence supporting this conclusion is the presence of sediment adhering to the inner portions of the pipe and bone material at its base.

Evidence of water action

Evidence of past water channelling is obvious across the sediment floor of the chamber, although the chamber is now dry. Water flow appears to have originated at the solution pipe, with evidence of flow over a large rock pile and branching micro-channel systems, generally less than 5 cm across and a few millimetres deep, extending 30 m beyond the pipe across the fan. At least one area within the chamber shows evidence of water ponding and there are desiccation cracks evident on the sediment surface in places. Deviations in channels occur where flows met rocks and large bone material. Within the micro-channels, pebbles (15-30mm; mostly carbonate) form obvious lag deposits with winnowing of finer grains having occurred suggesting a relatively low energy water flow. Some staining is present on bone specimens attesting to partial inundation of the bones and many bones are partially buried by sediment washed down the cone and fan. The chamber is now completely dry with evidence of recent water flows.

The bone assemblage

Species composition

Table 1 presents a list of large mammal species identified from The Upper and Lower Ossuaries chambers based mainly on identifications of specimens collected in the 1970s when the pathway was defined and material identified during this project. Species represented include: *Megalibgwilia ramsayi* (extinct, giant, long-beaked Echidna), *Thylacinus cynocephalus* (Tasmanian Tiger), *Sarcophilus laniarius* (extinct giant Devil), *Zygomaturus trilobus* (extinct, cow-sized marsupial), *Thylacoleo carnifex* ('Marsupial Lion'), *Macropus rufogriseus* (Red-necked Wallaby), *Macropus giganteus* (Eastern Grey Kangaroo) and the extinct browsing kangaroos *Simosthenurus browneorum*, *Simosthenurus gilli*, *Simosthenurus maddocki*, *Simosthenurus occidentalis* and *Sthenurus andersoni*. Of these species, 69% are megafaunal taxa that became extinct during the Pleistocene with the remaining species either extant in the region today or extinct since European settlement as shown in Table 1. As no excavation has been conducted in the chamber, this is undoubtedly an incomplete list particularly with regard to small vertebrates. However, it does give an indication of the large mammal diversity within the deposit. In addition to the large mammal remains, Emu (*Dromaius novaehollandiae*) bones from several individuals are visible on the sediment surface. There is a definite bias toward large species in the surface sample and this may be related to preferential burial of smaller bones, hiding them from view of the surface survey.

The sample of bones recorded *in situ* during this study is composed primarily of kangaroos (96.9%), with the sthenurines the most numerous (58.8%). Other species recorded include *Thylacinus cynocephalus* (0.4%), *Thylacoleo carnifex* (0.8%) and *Zygomaturus trilobus* (2.0%) (Figure 3a). Carnivores make up just 1.2% of the total with the remainder herbivorous species. Of the herbivores, 60.8% are browsing species.

Body size and locomotion

The largest animal recorded from the sampled area is *Zygomaturus trilobus* (300-500 kg – Murray,

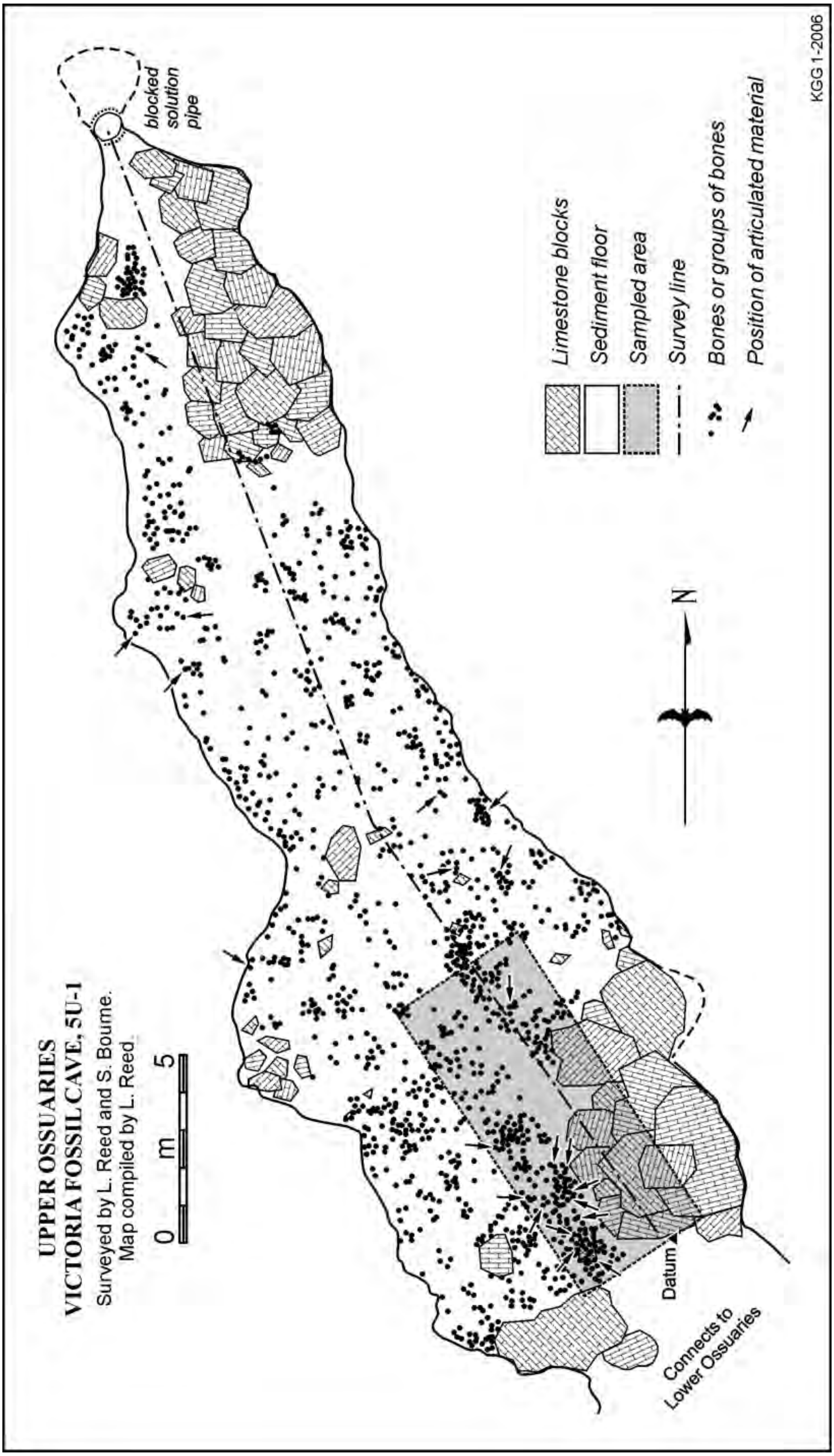

Figure 4. Map showing the distribution of bone material across the floor surface of The Upper Ossuaries.

Table 2. Total numbers (Ni), % total Ni and relative abundances (Ri%) for the bone sample from The Upper Ossuaries. N = 269, MNI = 34 (determined from the most abundant element type for each family or sub-family represented).

Element type	Ni	% Total	Ri%
Cranium	8	2.97	23.53
Dentary	12	4.46	17.65
Atlas	1	0.37	2.94
Axis	0	0.00	0.00
Cervical vertebrae	6	2.23	2.94
Thoracic vertebrae	13	4.83	2.94
Rib	10	3.72	2.26
Lumbar vertebrae	16	5.95	7.84
Sacrum	2	0.74	5.88
Caudal vertebrae	35	13.01	4.68
Chevron	1	0.37	0.13
Clavicle	0	0.00	0.00
Sternebrae	0	0.00	0.00
Scapula	2	0.74	2.94
Humerus	4	1.49	5.88
Radius	3	1.12	4.41
Ulna	1	0.37	1.47
Carpal	0	0.00	0.00
Metacarpal	1	0.37	0.29
Phalanges - manus	0	0.00	0.00
Pelvis	32	11.90	47.06
Epipubic	2	0.74	2.94
Femur	50	18.59	73.53
Tibia	60	22.30	88.24
Fibula	3	1.12	4.41
Tarsals	3	1.12	1.10
Metatarsals	4	1.49	1.47
Phalanges - pes	0	0.00	0.00
Total	269		

1991). Remains of this animal are not evident on the distal portions of the cone. A few isolated remains of a juvenile individual were observed at around 24 and 29 metres from the solution pipe and bones of an associated skeleton lie near the base of the pipe. The body size classes for all individuals (based on NISP) reflect the abundances of the macropodidae. Animals less than 20 kg and over 100 kg are poorly represented (Figure 3c). The sample is dominated by saltatory animals, but that is not surprising given kangaroos were a dominant feature of the palaeocommunity and the mode of locomotion increases susceptibility to trapping via pitfall (Figure 3b).

Skeletal element abundance and spatial patterning

Most element types were recorded from the surface sample, with the exception of the axis, clavicle, sternebrae, carpals and phalanges of the manus and pes. The dominant element types are the bones of the hindlimb and the larger vertebrae (caudal, lumbar). Most specimens visible on the surface are large, with a mean

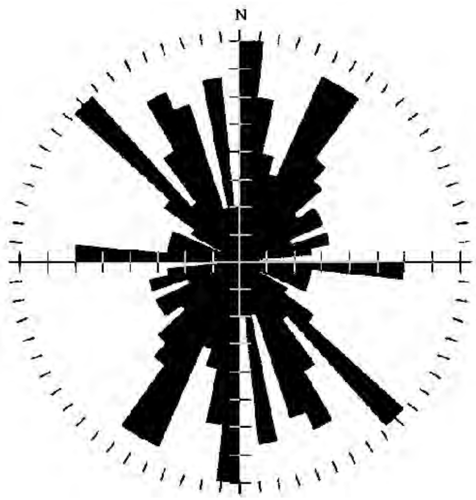

Figure 5. Orientations of bones for the area sampled from the floor surface of The Upper Ossuaries chamber. N = 182, Mean = 172.56°, standard deviation = 106.54.

length of 20.7 cm for the sample recorded. Analysis of the relative abundances (Ri%) of the various element types show that for the individuals represented in the sample (MNI = 34), the tibia, femur and pelvis are very well represented, with crania and dentaries (including mandibles) moderately well represented (Table 2). All other element types have relative abundance values of less than ten percent (the majority <5%), indicating substantial loss from the surface. The index of skeletal representation (Ir = 3.10) reflects this.

In the area sampled, 269 large bones representing 34 individuals (MNI calculated from the most numerous element type) were recorded, giving a density of 0.85 individuals /m^2. The mean spatial density of bone material for the area sampled is 6.75 bones /m^2, and spatial distribution is patchy. Across the floor of The Upper Ossuaries concentrations of bones are interspersed with areas of sparse bone material, with a greater concentration of bone material on the distal portions of the fan (Figure 4). The orientations of 182 bones from the sampling area were measured and the results show a non-random orientation (X^2 = 29.97, N = 182, d.f. = 18, p = 0.04), with some tendency for alignment of bones with the longitudinal axis of the chamber (Figure 5). Some bones are plunging almost vertically.

Articulation and association

Several articulated sub-assemblies (Table 3) are visible on the floor surface of The Upper Ossuaries mostly on the distal portions of the fan or adjacent to cave walls, but some are present on the proximal cone and others near large limestone rocks (Figure 4). The elements that remain articulated tend to be those that separate late in the disarticulation sequence of Reed (2001). In the sampled area several associations were recorded (N = 19 matched pairs of elements). The mean distance separating these elements was 32.4 cm.

Taphonomy

Table 3. Composition of the various articulated sub-assemblies visible on the floor surface of The Upper Ossuaries chamber. Sthe = sthenurine, Macn = macropodine.

Articulated sub-assembly	**Taxon**	Rank order of disarticulation (from Reed 2001)
Pelvis, Lumbar vertebrae x 2	Sthe	27
Femur & Tibia	Macn	26
Pelvis, Lumbar vertebrae x 2	Sthe	27
Lumbar vertebrae x 2	Macn	30
Pelvis, Lumbar vertebrae x 2	Sthe	27
Pelvis, Lumbar vertebrae x 2	Macn	27
Pelvis, Lumbar vertebrae x 2, Sacrum, Lumbar vertebrae x 6, Thoracic vertebrae x 1	Sthe	25 to 30
Tibia, Femur	Sthe	26
Lumbar vertebrae x 2	Sthe	30
Tibia, Femur	Sthe	26
Pelvis, Lumbar vertebrae x 2, Sacrum	Sthe	27
Lumbar vertebrae x 5	Sthe	30
Caudal vertebrae x 4	Sthe	22
Caudal vertebrae x 2	Sthe	22
Lumbar vertebrae x 3	Sthe	30
Thoracic vertebrae x 3	Sthe	25
Thoracic vertebrae x 2	Sthe	25

Bone modification

The bones from The Upper Ossuaries are generally in an excellent state of preservation; however, some examples of bone modifications are observable. Insect gnawing consistent with termite modification (Watson and Abbey, 1986; Reed, 2003) is evident on numerous bones as are dirt tunnels and minor sediment disturbances. Many bones display very fine longitudinal cracking and some specimens have more extensive cracking. Access limitations severely restricted assessment of the degree of surface modification to bones other than those adjacent to the path. However, scratch marks, similar to those produced by trampling (Oliver, 1989; Reed, 2003) are discernible on some specimens. Similarly, fracturing is evident on some specimens with impact, irregular perpendicular and spiral fractures represented. The highest degree of fracturing is present on a pile of bones (representing at least one complete *Macropus* kangaroo skeleton) near the base of the entrance pipe. Many of these bones display impact, spiral and irregular fractures as well as termite damage. Bones not covered by sediment display a 'chalky' texture.

Discussion

Chamber morphology and geological features

The Ossuaries is essentially a large collapse chamber separated by a large rubble pile and accessible via a low passage. The depth of the sediment infill is difficult to ascertain (no probing or coring was permitted); however, the chamber has almost been filled to the roof in places. The entry point for bones and sediments appears to have been the single solution pipe evident and dispersion was via a complex series of water-cut micro channels emanating from the cone adjacent to the pipe. The pattern of water channelling evident in The Upper Ossuaries is very similar to that observed for currently active caves at Naracoorte (Reed, 2003), and is suggestive of low energy water flow. Other features similar to those observed in the modern analogue caves (Reed, 2003) include the lag of coarser limestone pebbles, winnowing of finer-grained material in the channels and the apparent movement of saturated sediment and slow burial of bones. The staining of bone material suggests water flow over the bones. The surface layer of The Ossuaries provides a good example of the processes proposed by Wells *et al.* (1984) and Reed (2003) for the formation of some sedimentary units of the Fossil Chamber, which show sedimentary evidence of low energy water flow (Wells *et al.*, 1984; Reed, 2003).

Numerous white, chalky, angular, un-stained limestone flakes/rocks spread over the floor of The Upper Ossuaries probably result from roof fretting. Wells *et al.* (1984) suggest that the amount of fretting might give some indication of exposure time of the floor surface, and as accumulation of The Ossuaries deposit ceased thousands of years ago (evidenced by the presence of extinct megafauna), this appears to support such a conclusion.

The bone assemblage

The fauna

The faunal composition of the large mammal assemblage from The Ossuaries is a subset of that of the Fossil Chamber of Victoria Fossil Cave (Wells, *et al.* 1984; Reed & Bourne, 2000; Reed, 2003). The smaller number of species recorded from The Ossuaries is probably an artefact of the limited sample size. The fauna is dominated by the macropodidae, as in the Fossil Chamber assemblage and other major Pleistocene deposits in the region (Reed & Bourne, 2000). This is also the case for modern caves at Naracoorte with solution pipe entrances (Reed, 2003), and the entrance for The Ossuaries chamber was very likely a narrow solution pipe. Kangaroos appear to be particularly susceptible to pitfall entrapment, predominantly where the entrance is small or a solution pipe (Reed, 2003). As macropodids were a highly speciose group with a high local faunal diversity (at least 7 species of 12 in the sample) it is probable they were dominant in the palaeocommunity as well. One very interesting feature of The Ossuaries sample is that sthenurine remains are more prevalent than those of macropodines and this may reflect relative abundances in the community and habitat proximal to the cave. Alternatively, this feature may also be related to sample size or other palaeoecological factors. Overall, the composition of the large mammal fauna suggests a habitat composed mainly of open woodland to sclerophyll forest with areas of shrub land, heath land and grass land.

Body size and locomotion

The largest animal recorded from the assemblage is the cow-sized *Zygomaturus trilobus*. This animal is also the largest recorded for other pitfall deposits at Naracoorte (Brown & Wells, 2000; Reed & Bourne, 2000). *Diprotodon optatum*, the biggest mid to late Pleistocene marsupial recorded from the Naracoorte region is absent. This may reflect actual abundances of diprotodontids in the habitat near the cave, or alternatively, it could reflect a body size filtering effect due to the entrance size and susceptibility of diprotodontids to entrapment. The solution pipe entrance to The Ossuaries is narrow and branches into two narrower pipes about half-way up its length. The majority of *Zygomaturus* material is found only on the more proximal portions of the cone, with bones found on the fan representing a younger individual. The largest concentration of *Zygomaturus* material is approximately five metres from the entrance and may represent the remains of an adult animal that was wedged in the pipe with its bones entering the chamber following decomposition. As with the Fossil Chamber, The Ossuaries assemblage is dominated by saltatorial kangaroos, with cursorial species poorly represented and fossorial and scansorial species absent. This may be related to sample size, but is more likely to reflect the nature of the entrance and the susceptibility of kangaroos to entrapment (Reed, 2003).

Skeletal element representation and spatial patterning

The majority of skeletal element types are present in the sampled assemblage, suggesting the animals entered the cave as whole entities. The higher relative abundances for the larger elements of the skeleton, notably the limb elements (particularly the hindlimbs) and cranial elements is probably related to differential transport and more rapid burial of the smaller, compact elements. This pattern has been observed for recent surface assemblages from water-washed sediment cones at Naracoorte (Reed, 2003). Smaller elements would no doubt be recovered with excavation.

The spatial distribution of bones across the floor surface of The Upper Ossuaries is patchy and uneven, a pattern also observed for the Fossil Chamber (Reed, 2003). The concentration of bones on the distal portions of the fan and against the walls of the chamber is probably related to the higher potential for disturbance nearer the entrance and the initial position of deposition of carcasses. In the areas of the chamber that are clearly micro-channelled by water, there are fewer bones apparent and this may be related to burial of smaller elements and transport due to sediment movement induced by water run-off from the cone. Within the sampled area, bones display a preferred orientation. However, this is an area with no surface evidence of water flow. Taphonomic study of modern caves at Naracoorte has shown that the overall pattern of orientation can be overprinted by subsequent disturbance and trampling by trapped animals (Reed, 2003). Oliver (1989) also noted a similar situation for a pitfall cave in North America. Therefore, it is difficult to ascertain whether this represents the 'real' pattern indicating water transport or not.

Articulation and association

The presence of articulated sub-assemblies on the floor surface of the fan suggests animals survived the fall into the cave and perished away from the entrance, further supporting a pitfall accumulation analogous to the Fossil Chamber and other large pitfall deposits at Naracoorte (Wells *et al.*, 1984; Brown and Wells, 2000; Reed, 2003). With only one exception, all articulated and associated remains are found on the distal portions of the cone or in some 'sheltered' location such as against the cave walls or behind large rocks (Figure 4). This pattern was observed for modern Naracoorte pitfall deposits and the Fossil Chamber (Reed, 2003); suggesting the position of skeletons within a cave has a strong influence on the range of taphonomic processes they will be exposed to, particularly dispersal by trampling and water action. All bones remaining articulated in The Ossuaries are those elements that separate late in the disarticulation sequence for kangaroos (Reed, 2001). During disarticulation, joints with the strongest soft tissue and muscle structure generally remain articulated longer (Reed, 2001). In the kangaroo this includes the joints of the hind limb, vertebrae and in particular the caudal vertebrae (Reed, 2001). Those elements that disarticulate earlier in the sequence (ie. the cranial bones, forelimb, hand and foot bones) would be susceptible to dispersal and transport earlier. The Ossuaries data suggest that disarticulation is primarily influenced by the anatomy of the animal regardless of depositional environment.

Bone modification

Despite methodological and sampling restrictions, some general patterns of modification were detectable. The presence of spiral fracturing which is indicative of 'green' or 'fresh' bone fracturing suggests some modification occurred at or shortly after death. A lack of fracturing, or fracturing resembling that seen for 'fresh' bones, has been suggested as a characteristic of pitfall deposits by some authors (Andrews, 1990; Baird, 1991). Spiral fracturing could be attributable to trampling or the fall into the cave. The 'pile' of fractured kangaroo bones (largely from one individual) found near the base of the solution pipe may represent the remains of an individual that was killed by the fall into the cave and was subsequently trampled by other trapped animals as they fell into the cave. Termite use of bone as a food source is evidenced as gnawed tunnels both in the bones themselves and across the floor. Termites are known to prefer 'fresh' bone so this indicates some modification took place relatively early in the taphonomic history as described in Watson and Abbey (1986) and Reed (2003).

Scratch marks indicative of trampling and also impact fractures suggest additional modification occurred to bones lying on the floor surface following deposition. Similar damages have been noted for other pitfall caves (Oliver, 1989; Andrews, 1990). Longitudinal cracking of the outer surface of bones is probably related to within-cave processes, with variations in moisture content over time weakening the bone structure. There is no exfoliation associated with the cracking as is the case in sub-aerial weathering on the land surface (Behrensmeyer, 1978), suggesting the bones were not washed into the cave from outside. Therefore, all modification occurred after the animals entered the cave.

Conclusions

The taphonomic data presented suggest a taphonomic history that followed four broad stages.

1. Accumulation of remains and resulting modification produced by the mode of accumulation ie. pitfall entrapment, the most prevalent accumulating mode for large mammal bone deposits at Naracoorte (Reed & Bourne, 2000).

2. Decomposition and disarticulation of carcasses leading to secondary modification eg. termite modification, trampling, fracturing.

3. Dispersal, transport and incorporation of bones into the cave sediments eg. burial and/or dispersal of bones by hydraulic re-working of proximal cone sediments.

4. Modification occurring after burial in sediment eg. re-working and diagenesis. Stage 4 was largely unobserved during this study as no excavation of buried material was conducted; however, some evidence of re-exposure of bones following water flow was observed.

The composition of the large mammal fauna shares similarities with other deposits at Naracoorte including the Fossil Chamber, and is indicative of open woodland to sclerophyll forest with areas of shrub land, heathland and grassland. The age of the deposit is Pleistocene as indicated by the presence of extinct megafauna, but the precise age is unknown. The pattern of skeletal element representation and spatial patterning of bones suggests differential burial and/or hydraulic transport of small element types. The presence of articulated remains on the distal fan indicates some animals survived the fall into the cave, their remains accumulating away from the entrance where disturbance was limited. Due to the constraints of the project, sample size is limited. Further taphonomic investigation of The Ossuaries would increase sample size and allow more in-depth interpretation.

The Ossuaries deposits provided an important opportunity for investigation of a relatively undisturbed Pleistocene fossil site that is analogous taphonomically to other large pitfall deposits at Naracoorte and the wider South East region of South Australia. There are also taphonomic similarities with results published for other pitfall caves (see Oliver, 1989). The spatial distribution of the bones and the taphonomic features of the surface of this deposit could be studied virtually as they were found. Such an investigation was not possible for most of the Fossil Chamber deposit, as it had been the subject of decades of excavation prior to the commencement of this project. An *in situ* investigation of bones lying on the floor of The Ossuaries allowed analysis of a surface unit, providing further insight into interpreting the processes influential in the formation of deep, multi-layered deposits such as the Fossil Chamber.

The results of this study are not only interesting from a scientific perspective, but also for fossil site management. Useful information was collected with little impact to the fossil site and in the case of a deposit such as The Ossuaries this should be a priority. The scientific importance of The Ossuaries has been noted in the management plan for the Naracoorte Caves National Park in which it is categorised as a 'Reference' area of Victoria Fossil Cave (Department for Environment and Heritage, 2001). Reference areas are set aside in order to protect them from disturbance, with access only given for "research specifically related to the baseline functions of the cave" (Department for Environment and Heritage, 2001). Effective management of a site such as The Ossuaries requires more than simply categorising it and denying access. Park managers should have a thorough knowledge of the resources they are protecting. Prior to this project there was little or no information available to assist managers with decision-making regarding access to the site. This project has provided critical baseline data for management and will also aid in planning future research strategies for the park. Fossil deposits in caves are finite resources and the benefits of research and other activities should be carefully weighed against impact to the resource. Excavation of The Ossuaries deposits would undoubtedly reveal a greater body of data than this study has and it could certainly be done in such a way as to limit impacts to the site. Relatively undisturbed Pleistocene large mammal sites such as The Ossuaries are rare. In this particular case one could argue that the intrinsic values outweigh the scientific benefits that would be provided by excavation using current methods.

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References

ANDREWS, P. 1990: *Owls, Caves and Fossils*. University of Chicago Press, Chicago.

ARRIBAS, A. and PALMQVIST, P. 1998: Taphonomy and palaeoecology of an assemblage of large mammals: hyaenid activity in the lower Pleistocene site at Venta Micena (Orce, Guadix-Baza basin, Granada, Spain). *Geobios* **31**: 3-47.

BAIRD, R.F. 1991: The taphonomy of late Quaternary cave localities yielding vertebrate remains in Australia pp. 267-309 *in* Vickers-Rich, P., Monaghan, J. M., Baird, R. F. & Rich, T. H. (Eds) *Vertebrate palaeontology of Australasia.* Pioneer Design Studio, Lilydale.

BEHRENSMEYER, A.K. 1978: Taphonomic and ecologic information from bone weathering. *Paleobiology* **4**: 150-162.

BROWN, S.P. and WELLS, R.T. 2000: A middle Pleistocene vertebrate fossil assemblage from Cathedral Cave, Naracoorte, South Australia. *Trans. Roy. Soc. Sth. Aust.* **124**: 91-104.

DEPARTMENT FOR ENVIRONMENT AND HERITAGE 2001: *Naracoorte Caves National Park Management Plan.* Department for Environment & Heritage, Adelaide.

MURRAY, P.F. 1991: The Pleistocene megafauna of Australia. pp. 1071-1164 *in* P.V. RICH, J.M. MONAGHAN, R.F. BAIRD and T.H. RICH (eds), *Vertebrate Palaeontology of Australasia*. Pioneer Design Studio, Lilydale.

OLIVER, J.S. 1989: Analogues and site context: Bone damages from Shield Trap Cave (24CB91), Carbon County, Montana, U.S.A. pp. 73-98 *in* Bonnichsen, R. & Sorg, M.H. (Eds.) *Bone modification*. University of Maine Center for the study of the first Americans, Orono.

REED, E.H. 2001: Disarticulation of kangaroo skeletons in semi-arid Australia. *Aust. J. Zool.* **49**: 615-632.

REED, E.H. 2003: *Vertebrate taphonomy of large mammal bone deposits, Naracoorte Caves World Heritage Area*. Unpublished PhD thesis, the Flinders University of South Australia.

REED, E.H. and BOURNE, S.J. 2000: Pleistocene fossil vertebrate sites of the South East region of South Australia. *Trans. Roy. Soc. Sth. Aust.* **124**: 61-90.

WATSON, J.A.L. and ABBEY, H.M. 1986: The effects of termites (Isoptera) on bone: some archeological implications. *Sociobiology* **11**: 245-254.

WELLS, R.T., MORIARTY, K.C. and WILLIAMS, D.L.G. 1984: The fossil vertebrate deposits of Victoria Fossil Cave Naracoorte: an introduction to the geology and fauna. *Aust. Zool.* **21:** 305-333.