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The taphonomy of the Lancefield swamp megafaunal accumulation, Lancefield, Victoria

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Abstract – The late Quaternary megafaunal assemblage at Lancefield, Victoria, was deposited by fluvial transportation processes. Evidence for predepositional weathering of the bones indicates a prolonged period of exposure prior to transportation and burial.

The sediments associated with the bone bed indicate a high energy flow regime, which would have contributed to the abrasion found on the majority of the bones, and to the destruction and/or removal of larger fragile elements and those from small animals; neither of which are found within the deposit.

New dates on bones and teeth of about 40,000 BP differ significantly from the maximum date of 26,000 BP for the bone bed, and tend to confirm that the bones at Lancefield constitute a secondary or reworked deposit.

INTRODUCTION

The Lancefield megafaunal accumulation is located on the outskirts of the township of Lancefield, 70 km north-northeast of Melbourne, at 37°16'S., 144°44'E., in swamp deposits fed by flow from the water-table underlying the Pliocene-aged basalts that blanket the surrounding area.

Palaeontological investigations at Lancefield swamp began after large fossil bones were recovered by J.P. Mayne during excavations for a well in 1843, at what is now known as the Mayne Site. Subsequent excavations by William Blandowski in 1850 and Sir Frederick McCoy in 1858 were abandoned due to the over-abundant flow of ground water (Orchiston *et al.* 1977). The first accounts of the deposit were published by E.C. Hobson, Curator of the National Museum of Victoria (now Museum Victoria) (Hobson 1845), and N. Taylor, Government Surveyor (Taylor 1863).

In 1973 the Classic Site at Lancefield swamp was discovered through the efforts of geologist Robin Glenie, and was extensively excavated by a team comprising archaeologists from Sydney University and the Institute of Aboriginal Studies, Canberra, and palaeontologists from the National Museum of Victoria and Monash University. In 1974 further field work was undertaken in an attempt to provide a "sharper focus on the time of the [megafaunal] extinctions" (Gillespie *et al.* 1978). Two subsequent excavations were undertaken in 1975 and 1976 (T.H. Rich pers. comm. 1993). This work resulted in publications by Horton (1976), Ladd (1976), Orchiston *et al.* (1977), Gillespie *et al.* (1978), Horton and Samuel (1978), and Horton and Wright (1981).

The findings of Gillespie *et al.* (1978) included two dates of 26,000 years BP from the channel fill at the base of the bone-bearing sequence. This was considered contemporaneous with occupation of the area by humans, on the basis of the discovery of a large quartzite blade *in situ* within the bone bed. Other findings included some evidence for water controlling the distribution and local orientation of bones, and that bones showed little evidence for exposure prior to deposition and burial. Gillespie *et al.* (1978) also noted that there was little evidence for small-sized species. They argued that this was not "... the biased result of some post-mortem sorting process" but rather "This remarkably restricted species list, of large species only, shows that some special selective event was causing death".

In 1984, the South Site was discovered and excavated by a team from the Museum of Victoria and Brigham Young University, Utah, U.S.A. Their findings were recorded in an unpublished Monash University project report by Munro (1984).

A new excavation was undertaken in 1991 by the author to assess the influence of water sorting in more detail, to try to identify the "special selective event" that occurred at Lancefield swamp and to attempt to discover an age for the bones, rather than the sediments, within the bone bed (Van Huet 1993). Only the South and Mayne Sites were sampled during this field season, due to problems obtaining access to the Classic Site. This paper is based upon the results of that investigation (Van Huet 1994a, 1994b), and a new dating study undertaken by Van Huet *et al.* (1998).

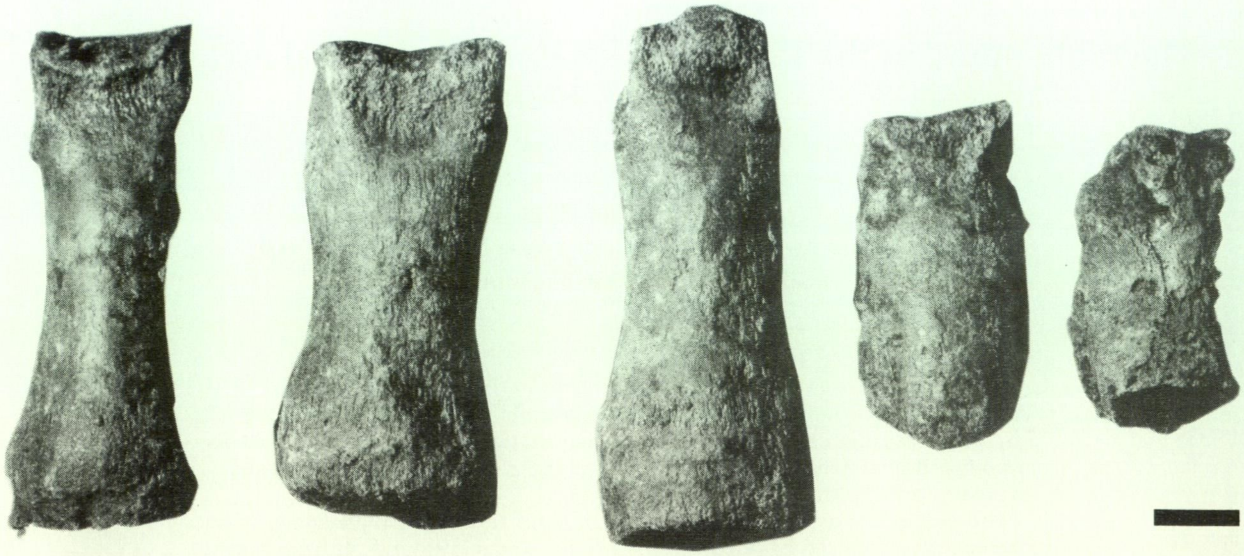

Figure 1 Fossil phalanges from Lancefield swamp showing variation in the extent of transportational abrasion (from left to right): no abrasion (0%); little abrasion (1–4%); some abrasion (4–8%); well abraded (8–12%); very abraded (>12%); cf. Table 1. Scale bar = 1 cm.

MATERIALS AND METHODS

The South and Mayne Sites were relocated by hand augering in a grid sequence to the level of the channel fill / bone bed recorded by previous workers (between 1.5 and 2 m below the surface). Where bone was recovered in the auger, pits were dug to the upper stratigraphic boundary of the bone bed. Lateral excavation followed the observed direction of each bone deposit.

In situ bone material was exposed with hand trowels, small scrapers and fingers. The orientation of each bone was recorded prior to removal from the matrix and its relative position in the stratigraphy was noted. All bones were washed in water, soaked in a dilute emulsion of polyvinyl chloride in water, to assist with preservation, and air dried prior to packing for transport. Very fragile specimens were brushed with a concentrated emulsion of polyvinyl chloride. All matrix from the bone layer was collected, soaked in a water/detergent mix overnight and the resulting slurry was washed, passed through 1 mm and 3 mm sieves and the screen residues air dried prior to sorting in the laboratory.

Fragments of *Diprotodon* incisors from the South Site were collected for radiocarbon, amino acid racemization (AAR) and electron spin resonance (ESR) analysis. A sample of *in situ* charcoal from the South Site was also collected for radiocarbon dating.

To date, approximately half of the faunal material from the 1991 excavation has been catalogued into the vertebrate palaeontological collections of the Museum Victoria (MV). Other material is on display in the Department of Earth Sciences, Monash University.

The fossil bones were identified to family, and species where possible. Each element was assessed for transportational wear (percentage abrasion), the presence of cracking and flaking caused by predepositional weathering processes and obvious signs of carnivory such as puncture and gnaw marks (e.g. Marshall 1989).

Abrasion was assessed using a descriptive scale that estimated the percentage of the element removed through abrasive damage, and assessment was made for each bone, relative to all other bones in the sample (Table 1 and Figures 1 and 2).

Figure 2 Fossil phalanx from Lancefield swamp which has been abraded to a bone pebble (>12% abrasion). Scale bar = 1 cm.

Table 1 Descriptive terminology, percentage wear and diagnostic features used in the appraisal of abrasion of bone elements from the South and Mayne Sites, Lancefield.

Term	Estimated % Wear	Diagnostic Features
None	0% of bone lost to abrasion	No abrasion is evident. Recognition of diagnostic features — excellent.
Little	1–4% of bone lost to abrasion	Articular facets, processes and other articular surfaces display a small degree of smoothing. Recognition of diagnostic features — very good.
Some	4–8% of bone lost to abrasion	Processes displaying the inner bone fibre. The shafts of longer bones display areas of abrasion. Recognition of diagnostic features — satisfactory.
Well	8–12% of bone lost to abrasion	Outer layer of bone completely removed from processes, long bones displaying abrasion to this degree are probably incomplete. Recognition of diagnostic features — poor.
Very	>12% of bone lost to abrasion	Bone pebble formed, almost all diagnostic features have been removed through abrasion. All surfaces of the bone will display some degree of abrasion.

The presence of cracking and flaking on the fossil bones (Figure 3), symptomatic of predepositional weathering, was assessed using criteria from Behrensmeyer (1978). Behrensmeyer observed that bones "... freed of covering tissue and exposed on the ground surface usually undergo rather rapid changes in appearance ..." (bone decomposition). These changes include flaking (where the outer layers of the bone peel away in an 'onion skin' fashion) and cracking (where, initially, surface, then deepening cracks occur in the bones parallel to the bone fibre). This decomposition, especially in advanced stages, renders the bones highly susceptible to fragmentation.

Behrensmeyer (1978) identified six progressive stages of predepositional bone weathering, which can be summarized as: Stage 0 — no sign of cracking or flaking; Stage 1 — cracking; Stage 2 — flaking; Stage 3 — entire bone surface roughened (shallow); Stage 4 — entire bone surface roughened (penetrates inner cavities); Stage 5 — bones falling apart *in situ*.

The weathering stages have been outlined here because their features occur on many of the bones from Lancefield swamp. However, only the presence or absence of weathering features has been noted, as the Lancefield bones do not progressively follow Behrensmeyer's scale of weathering. (For example, flaking occurs independently of cracking in over 80% of the bones from Lancefield.) Behrensmeyer's 'Stage' sequence was studied under savanna conditions in the Amboseli Basin in Kenya and is not wholly transferable to temperate Australian conditions.

Minimum numbers of individuals (MNI) for the Classic and South Sites have been taken from the literature: Gillespie *et al.* (1978) and Munro (1984)

Figure 3 Fossil phalanges from Lancefield swamp showing evidence of predepositional weathering. Note longitudinal flaking and cracking parallel to the bone fibre. Scale bar = 1 cm.

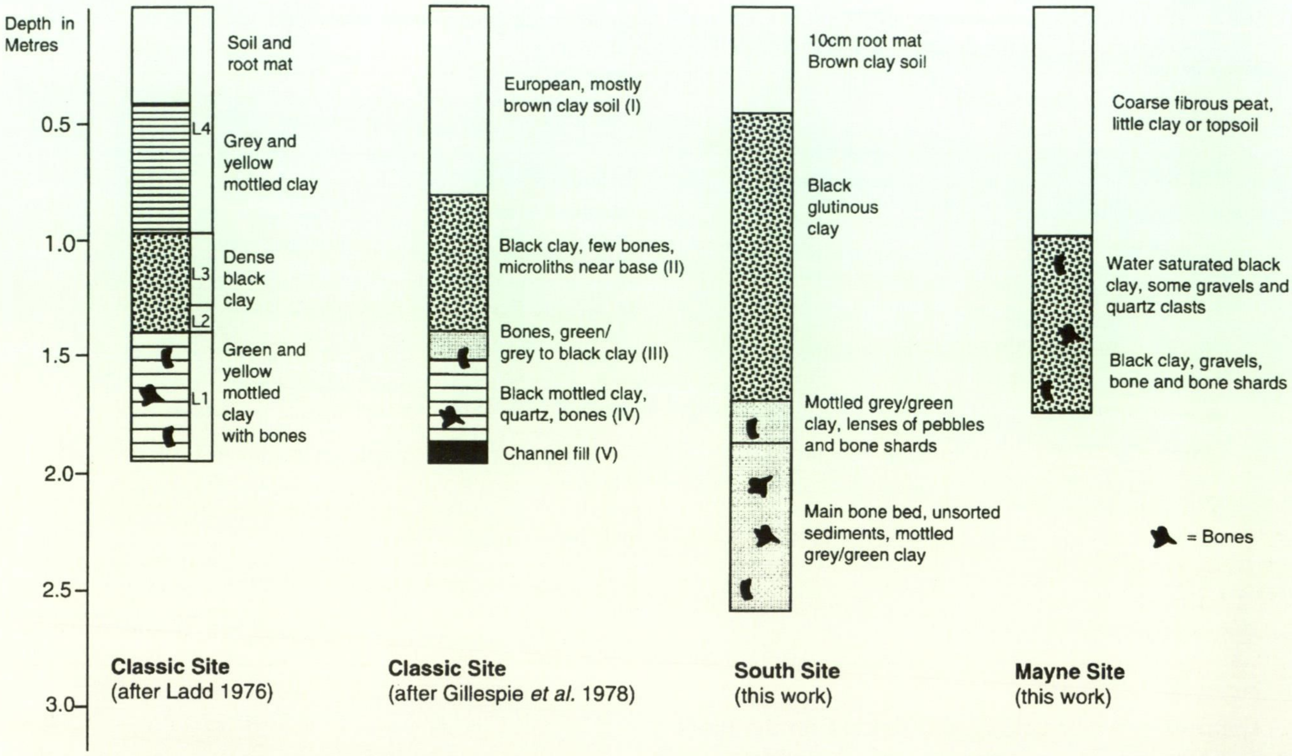

Figure 4 Stratigraphic profiles for the three Sites at Lancefield swamp. L1 to L4 indicate pollen zones defined by Ladd (1976). Roman numerals in brackets indicate the horizons defined by Gillespie *et al.* (1978).

for the Classic Site; Munro (1984) for the South Site. MNI for the Mayne Site were based on cranial and dentary elements identified to species level, because these provide highly recognizable characteristics for identification, and dentary elements are the most robust, most abundant and best preserved in the Site.

RESULTS

Stratigraphy

Lancefield swamp contains a sequence of distinctive sedimentary horizons, whose total thickness exceeds 3.5 m (Figure 4). The stratigraphy found in the South Site was comparable to that described for the Classic

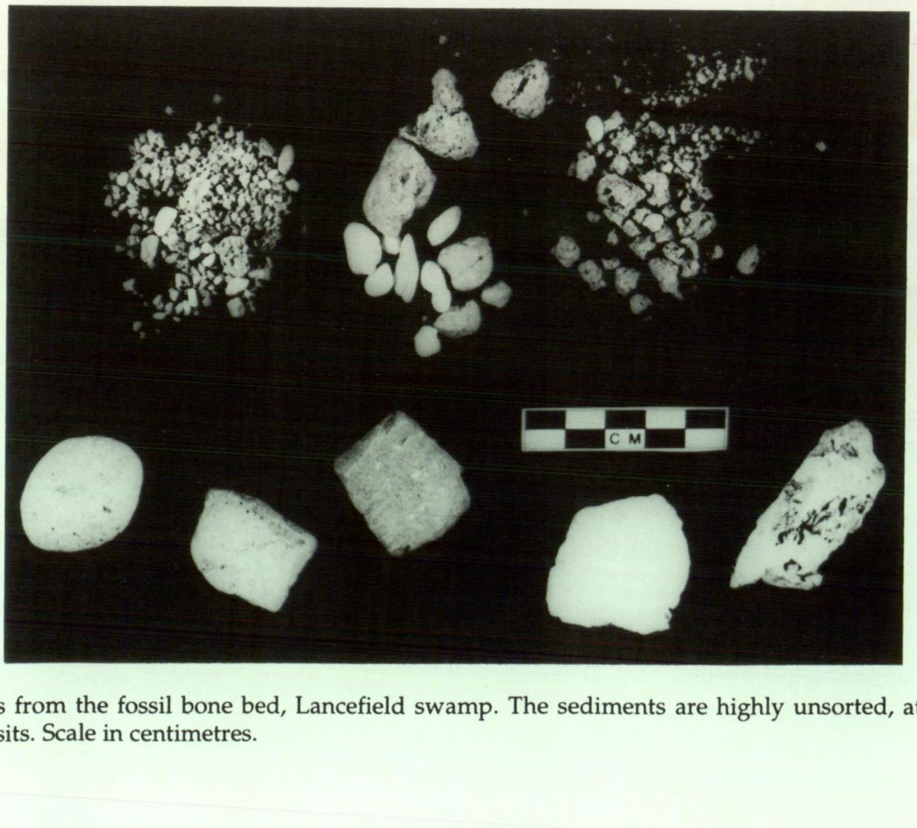

Figure 5 Clasts from the fossil bone bed, Lancefield swamp. The sediments are highly unsorted, atypical of swamp deposits. Scale in centimetres.

Site by Ladd (1976) and Gillespie *et al.* (1978), but that of the Mayne Site was not.

South Site

The top horizon consists of soil and plant root mats, consistent with typical results of European agriculture (Ladd 1976). This is underlain across the Site by an amorphous, glutinous black clay with 5–10% by volume organic content, typical of a paludal deposit (Allen and Collinson 1986).

The layer directly below this is a mottled grey/green, dense, inorganic, anoxic clay which gradually grades into the main bone bed. Both deposits contain 'floating' isolated pockets or lenses of fossil bones, quartz gravels and other lithic clasts. The total thickness of these two horizons is more than 2.4 m at their northern end. The boundary between the black and grey/green clay horizons is undulating but clearly defined. The channel fill, which is of limited horizontal extent (Gillespie *et al.* 1978), was not observed in the South Site.

Mayne Site

The upper 1 m is composed of a coarse, fibrous, peat-like mat with little inorganic sediment. This is directly underlain by a water-saturated, ungleyed, black clay within which fossil bones are randomly scattered. The lack of differentiated grey/green clay layers and the presence of bones throughout the depth of the black clay are consistent with a stratigraphy resulting from disturbance and backfilling at the time of the Mayne excavation in 1843. This is confirmed by the finding, during the 1991 excavation, of a 2 m square area delineated by axe-hewn posts within the bone bed, and, next to various diprotodontid fossils, some old strips of leather, a glass "H.P. Sauce" bottle and broken crockery. Elsewhere in the swamp such European artefacts are restricted to the upper brown clay (Gillespie *et al.* 1978).

Sedimentology

South Site

Evidence for fluvial transport is seen within the grey/green clay horizon associated with the bone deposit. The clay contains lenses of texturally and compositionally immature sediments, which can be likened to an unconsolidated litharenite (Pettijohn *et al.* 1972: 158). The clasts (Figure 5) range from silt to pebble size, are highly unsorted, and generally unrounded. They appear to be of mixed provenance with granite, quartz, feldspar and pisolitic laterite nodules all present within the clay matrix. These clasts are only associated with fossil bone, and do not occur elsewhere. They are not characteristic of paludal deposits, but instead indicate fluvial transport processes.

A rose diagram plot of the orientation of long bones in this Site (Figure 6), shows a strong south-southwest to north-northeast trend, concurring with general drainage in the area.

Mayne Site

This Site displays a similar range of clasts to that of the South Site, but they are distributed chaotically throughout the black clay horizon.

Long bone orientation is also chaotic at this Site

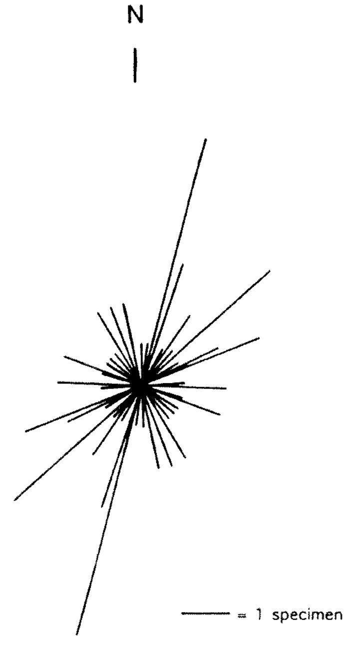

Figure 6 Rose diagram of orientations of long axes of elongate bones in the South Site, Lancefield swamp.

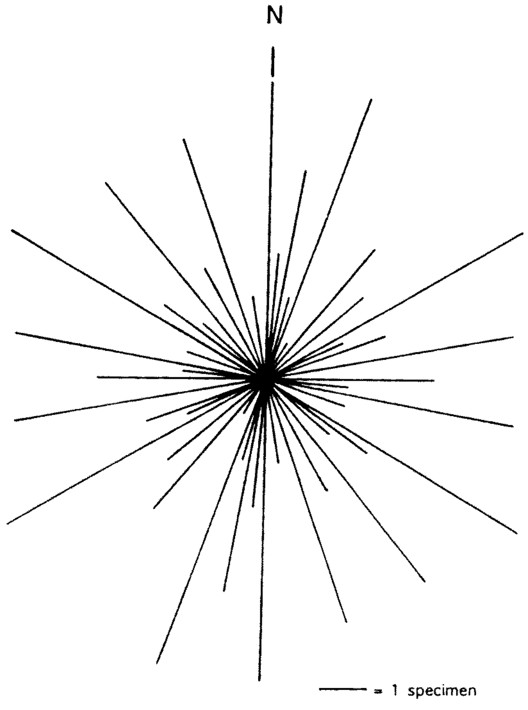

Figure 7 Rose diagram of orientations of long axes of elongate bones in the Mayne Site, Lancefield swamp.

Table 2 Results from dating samples collected during the 1991 excavations from the South Site, Lancefield swamp, (data from Van Huet *et al.* 1998).

Method	Sample no.	Material dated	Result (yr BP)
^{14}C	Wk-2565	Charcoal	14950 ± 1240
^{14}C	NZ-4191	Tooth apatite	27250 ± 300
^{14}C	NZ-4424	Tooth apatite	27210 ± 210
ESR	ANU-1052A	Diprotodon incisor	50100 ± 9700
ESR	ANU-1052B	Diprotodon incisor	46300 ± 8900
ESR	ANU-1052C	Diprotodon incisor	56000 ± 10800
AAR	UWGA	Diprotodon incisor	40500 ± 11000
AAR	UWGA	Diprotodon incisor	34000 ± 9500

(Figure 7), and is consistent with most of the site having been previously disturbed and backfilled during the Mayne excavation in 1843.

Dating

Dates obtained from samples collected from the South Site are given in Table 2. From these results Van Huet *et al.* (1998) concluded that the radiocarbon ages are a minimum for the apatite and hence the teeth are likely to prove older; 50,000 BP is a best average estimate of the age of the *Diprotodon* from the ESR results; and the AAR results indicate an age in the range 30–50,000 BP.

The radiocarbon date on charcoal of 14950 ± 1240 BP (Wk-2565) obtained from within the bone bed at the South Site, has a very large error, rendering it imprecise, but it may indicate the time of last deposition of the bone material in that part of Lancefield swamp (Van Huet *et al.* 1998).

Taphonomic results

Up to 96% of some skeletal elements from the South and Mayne Sites show some degree of abrasion and/or predepositional weathering. Elements vary in completeness from small match-sized splinters to complete bones 215 mm in length. The bulk of the collected material comprises splinters or shards of bone which are typically unidentifiable (e.g. Klein and Cruz-Uribe 1984: 17). Complete, or near complete, elements are the exception. Heavier, more robust bones from larger species tend to be less fragmented.

Abrasion is greater on vertebrae, metatarsals and maxillae and less on the robust and compactly-shaped phalanges and mandibles (Figure 8). The most common elements are phalanges, metatarsals, mandibles and single molars from *Macropus titan*. Elements such as crania and sterna are totally absent from the assemblage.

There is marked variation in the extent of weathering shown by bones, suggesting different periods of predepositional exposure (Figure 9). The bones that display the greatest evidence for weathering are also the most fragmented. Variation in the extent of abrasion indicates either different lengths of time in transportation (as evident when comparing abrasion on similar elements) or differences in robustness between elements.

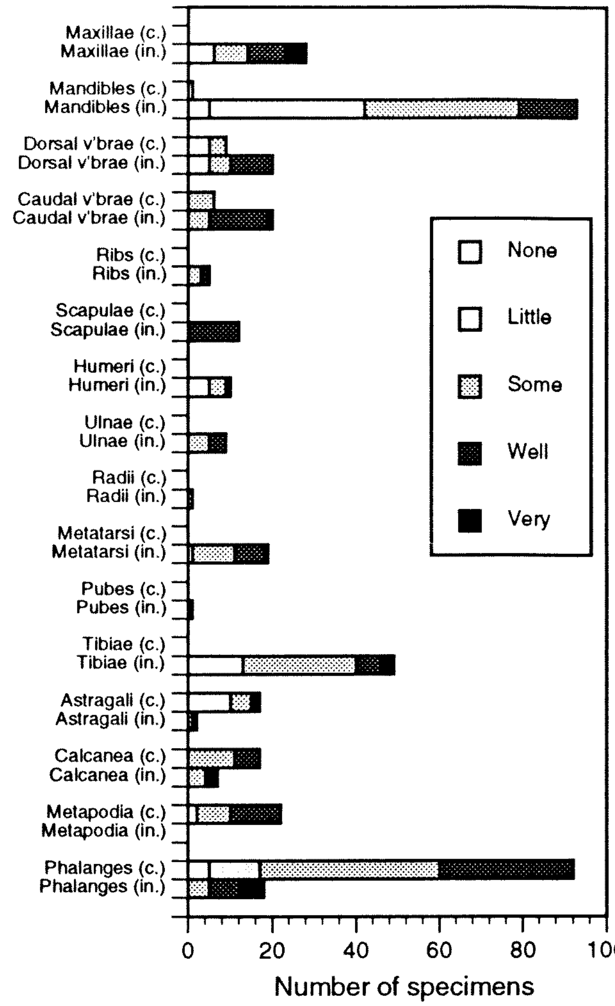

Figure 8 Levels of abrasion recorded on the combined samples of skeletal elements of all mammal species from the South and Mayne Sites, Lancefield swamp, collected during the 1991 field season, divided into complete (c.) and incomplete (in.) elements. "Dorsal v'brae" includes cervical, thoracic and lumbar vertebrae. Phalanges include those from both manus and pes, which were not differentiated.

No evidence of skeletal articulation or articulation by association was found. No bones of small-sized animals were recovered from either the South or Mayne Sites during the 1991 excavations.

It is acknowledged that the feeding habits of carnivores or scavengers such as *Sarcophilus* sp. and the accumulation of bone fragments in scats, can produce similar characteristics on bone (Douglas *et al.* 1966; Marshall and Cosgrove 1990) as those produced by predepositonal subaerial weathering. However, such activity is not considered to be the cause of the bone accumulation for three reasons.

Firstly, the distinctive sedimentary matrix

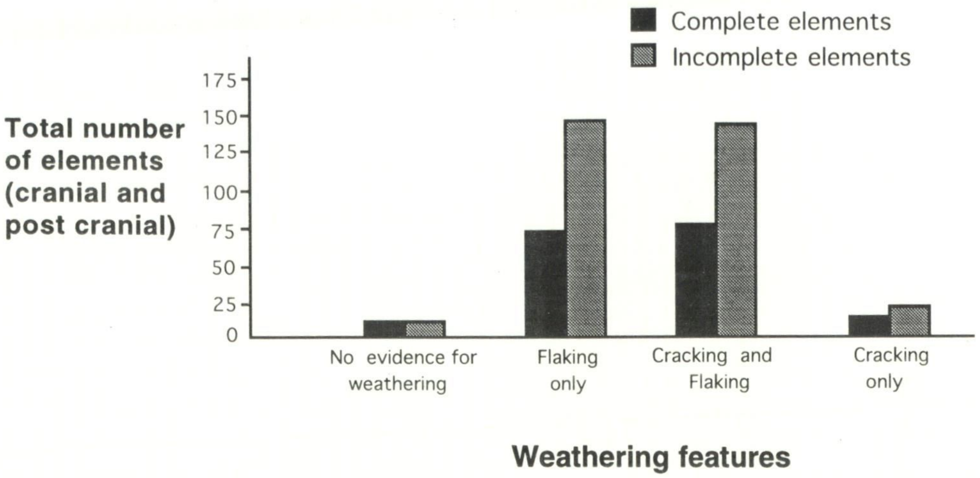

Figure 9 Proportions of different weathering features on bone elements from Lancefield swamp.

associated with the bone in the assemblage is indicative of high energy fluvial transportation. The tractional processes, such as saltation and rolling, required to transport larger and heavier clasts over distance, are also highly destructive to bone material. Destruction would have increased in proportion to the distance transported and would have contributed to the abrasion and fragmentation of bone material that had been subaerially exposed prior to transportation.

Groundwater flow is not suggested as the dominant factor in the accumulation of bone and matrix at Lancefield swamp. Rather, overland or sheet flow, a result of heavy seasonal rainfall in the catchment surrounding the swamp would have been the main transportation mechanism. Weigelt (1989) observed that "Water tumbled pebbles, gravel and sand are characteristics of ... mountain streams that spread out over the plains. Not uncommonly in these sediments are fossils, transported by water." The occurrence of heavy seasonal rainfall during the late Pleistocene glacial period in southeastern Australia is supported by Ladd (1976) and Frakes *et al.* (1987: 16).

Secondly, the assemblage at Lancefield displays the characteristics of a lag deposit, which supports fluvial accumulation. A lag deposit is described by Behrensmeyer (1988), and summarized by Shipman (1993: 56), as "... coarse deposits of gravel, bone fragments, teeth and other dense particles that remain in suspension with high current velocities". Smaller elements are selectively winnowed out and transported away as the larger, heavier elements are deposited.

Thirdly, the contribution of carnivores and scavengers to the bone assemblage and depositional bias at Lancefield swamp was not considered in this study, because no signs of carnivore activity were observed on the bones collected during the 1991 excavations. Evidence for carnivory on bones collected from the Classic Site at Lancefield swamp was investigated by Horton and Wright (1981), who found that only 0.35% of the bones showed puncture marks or signs of gnawing.

Fauna

Evidence for 72 individuals (based on approximately 3,000 bones) was recovered from the Classic Site alone, and Gillespie *et al.* (1978) estimated that 10,000 individuals may be represented by remains in the entire swamp. For all three Sites, 26 taxa have so far been identified, including 10 megafauna. Site provenance and aggregate minimum numbers of individuals are given in Table 3. There has been discussion as to whether *Macropus titan* and *M. giganteus* are separate, or *M. titan* merely represents the gigantic Pleistocene form of the modern species (Flannery 1981; Van Huet 1994a: 82). For the purpose of this paper, the species name *M. titan* is retained to indicate that all remains are from the large form and to avoid confusion in reference to previous work on Lancefield.

Thylacoleo, then unrecorded from Lancefield swamp, was suggested by Horton and Wright (1981) as the cause of the cut marks on elements from the Classic Site. Specimens of *Thylacoleo* (MV P200742 and P200852) have since been found in the South Site at Lancefield.

DISCUSSION

Taphonomy

Evidence from the bones and sediments suggests that transportation played a major role in the deposition of the assemblage at the South Site, and probably the Mayne and Classic Sites, at Lancefield swamp. Skeletons from animals that died in the area around the swamp were subjected to disarticulation and weathering prior to fluvial transportation. Transported bone material was subsequently deposited, along with sediment, in the swamp.

Any elements from small animals originally present were probably either destroyed in transit or washed away by virtue of their size or density. Larger and heavier elements were deposited in a depression defining the area of the swamp, many indicating the direction of current flow. Fragile elements from larger species, made even more fragile through exposure, disintegrated and were deposited as bone fragments; while other elements were probably removed by saltation, flotation or tractional processes (similar to those observed in a vertebrate deposit in Verdigre Quarry, Nebraska by Voorhies 1969a). It was noted for Lancefield that the specimens displaying the most weathering were also those that were highly fragmented. The most robust elements in the deposit displayed a variation in abrasion attributable to their shape, compactness and reaction to abrasive processes.

Gillespie *et al.* (1978) suggested that deposition of the Lancefield swamp sediments, including the bone bed, began about 26,000 BP as a result of a major decrease in spring output leading to a change from an erosive to a depositional flow regime. They noted that this was consistent with a major hydrologic change recorded elsewhere in southeastern Australia at about that date, and confirmed by subsequent work (e.g., Chappell 1991, and references therein). However, the results of the present study indicate that the bone bed was deposited under high rather than low energy fluvial conditions. The radiocarbon date of 14,950 ± 1240 on charcoal from the bone bed in the South Site, although very imprecise and badly in need of replication, raises the possibility that deposition occurred after, rather than before, the last glacial maximum. The pollens recorded from the Classic Site (Ladd 1976; Gillespie *et al.* 1978), show that the swamp was surrounded by an almost treeless grassy plain at the time of deposition of the bone bed and overlying mottled clay, consistent with the dryer than present late glacial climate. Conditions under which sheet water flow could have caused erosion and transportation of sediments and redeposition of bone, appear more likely to have

Table 3 Fossil vertebrates recorded from Lancefield swamp. Minimum numbers of individuals (MNI) are aggregate figures of those reported in Gillespie *et al.* (1978), Munro (1984), and the results of the 1991 field work. X = present; .. = absent; * megafauna. *Protemnodon* species from the Mayne Site were not differentiated: MNI is for both species combined from all sites.

Taxon	Classic Site Channel fill	Classic Site Bone bed	South Site Bone bed	Mayne Site Bone bed	MNI
Reptilia					
Scincidae	..	..	X	..	1
Aves					
Dromaius sp.	..	X	X	..	11
**Genyornis* sp.	X	X	..	..	4
Gallinula mortierii	..	..	X	..	1
Mammalia					
Thylacinus cynocephalus	X	..	X	X	3
Sarcophilus sp.	X	..	..	..	1
**Diprotodon optatum/australis*	X	X	X	X	11
**Zygomaturus trilobus*	..	..	X	X	7
Vombatus sp. cf. *V. ursinus*	X	..	X	X	3
**Thylacoleo carnifex*	..	..	X	..	1
Aepyprymnus rufescens	X	..	..	..	1
Potorous sp.	..	..	X	..	1
**Propleopus* sp.	X	..	..	..	4
Macropus dorsalis	X	..	..	..	1
Macropus rufogriseus	..	X	..	..	1
**Macropus titan*	X	X	X	X	263
Cf. *Onychogalea*	..	..	X	..	1
Cf. *Petrogale*	..	..	X	..	1
Prionotemnus sp.	..	..	X	..	1
**Protemnodon anak*	X	X	X	..	
**Protemnodon brehus*	X	X	X	..	
**Protemnodon*	..	..	..	X	22
Cf. *Thylogale*	X	..	X	..	2
**Procoptodon rapha*	..	..	X	..	7
**Sthenurus occidentalis*	X	X	X	..	7
Mastacomys fuscus	X	..	X	..	2
Rattus sp.	..	..	X	..	1

arisen under a regime of increasing precipitation on lightly vegetated soils at the end of the glacial than under decreasing rainfall on probably more stable soils before the last glacial maximum. Post glacial maximum deposition of the bones implies a substantial unconformity between the channel fill deposit and the overlying bone bed, which was not observed by Gillespie *et al.* (1978). The presence of at least one major unconformity in the deposit is indicated by the microliths near the base of the black clay (Gillespie *et al.* 1978). It is possible that another exists lower in the section, where the waterlogged working conditions of the site make it difficult to detect.

The collection displays a strong bias in favour of the representation of larger animals. Because the life span of a smaller mammal is significantly shorter than that of a larger animal, the attrition rate of small animals is naturally much greater, and it can be expected that a greater number of bones and teeth representing small animals will be found within fossil assemblages. This is not the case at Lancefield where evidence for large mammals greatly outweighs that for small. As Voorhies (1969b) noted "... since there are few modern communities in which small mammals, especially rodents, do not outnumber large ones, their absence or rarity in any fossil deposit should be viewed with extreme suspicion". Low representation of small animal species provides a strong indication of selective bias in an accumulation. Lancefield is not an anomalous case. Under-representation of smaller animals in fossil assemblages is quite common, particularly in collections accumulated under fluviatile conditions (Wolff 1973; Behrensmeyer *et al.* 1979): in the Amboseli Basin the representation of smaller animals was inversely related to size. A lack of small animal remains suggests a bias towards the selection of bone from larger animals, for whatever reason, and thus is not a full representation of the contemporary fauna.

Dating

Emplacement of the bone bed at Lancefield could not have occurred before 26,000 BP, the date of the underlying channel fill (Gillespie *et al.* 1978), and, as discussed above, could have happened considerably later. The taphonomic evidence for reworking presented in this paper implies that the bones within the bed are older than the bed itself. This has been confirmed by new dates obtained from megafaunal material by Van Huet *et al.* (1998), which indicate that the age of diprotodontid remains from the South Site falls within the range 60,000 to 30,000, with a best average age of about 40,000 BP. The primary deposition of bone material occurred many thousands of years prior to reworking and redeposition.

Van Huet *et al.* (1998) discussed the implications of the new dates from Lancefield for the overlap of humans and megafauna in Australia. They concluded that while the dates may indicate that Lancefield is a pre-human site, the lengthening chronology of human occupation of Australia suggests that some overlap did still occur, although further sites are needed to support this chronology. Victoria is very poorly endowed with early dates associated with humans, compared to more arid parts of Australia. By far the oldest is a date from Keilor of 31600 +1100 -1300 BP (ANU-65; Allen and Holdaway 1995), but it is probably a minimum date for the arrival of humans in Victoria. That probably occurred at a time beyond the practical limits of radiocarbon dating (Roberts *et al.* 1994; Chappell *et al.* 1996) and, like the extinction of the megafauna, will require the application of multiple dating techniques to elucidate.

CONCLUSION

On the basis of the very limited fauna, including only large species, recorded from the bone bed at Lancefield, Gillespie *et al.* (1978) argued that a 'special selective' agent was responsible for the deaths of the animals, and that the low faunal diversity was not the biased result of a post mortem sorting process. While the present study does not rule out the possibility of a selective agent at the time of death, the evidence for fluvial transportation of skeletal remains that yield substantially older dates than those of the underlying deposit, shows that post mortem sorting is an equally plausible cause of the biased faunal composition of the assemblage. Both factors may have been in operation at different times.

At Lancefield, carcasses and skeletons were subjected to subaerial weathering. Bones that were highly weathered were more prone to breakage during transportation than those less weathered. This resulted in variation in the condition and completeness of elements within the assemblage. Fluvial conditions were also responsible for reworking of the deposit, and are the probable cause of the age difference between the faunal material and charcoal from below the bone bed.

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