OF MICE and MEGAFAUNA:
NEW INSIGHTS into NARACOORTE'S FOSSIL DEPOSITS

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"The important thing in science is not so much to obtain new facts as to discover new ways of thinking about them."
Sir William Bragg, British physicist (1862 - 1942).

BEGINNINGS

Father Julian Tenison Woods first visited the Mosquito Plains Caves (Naracoorte Caves) in 1857. Although he found the landscape singularly unremarkable, he was enthralled by what lay beneath the surface. He wrote in 1862 :

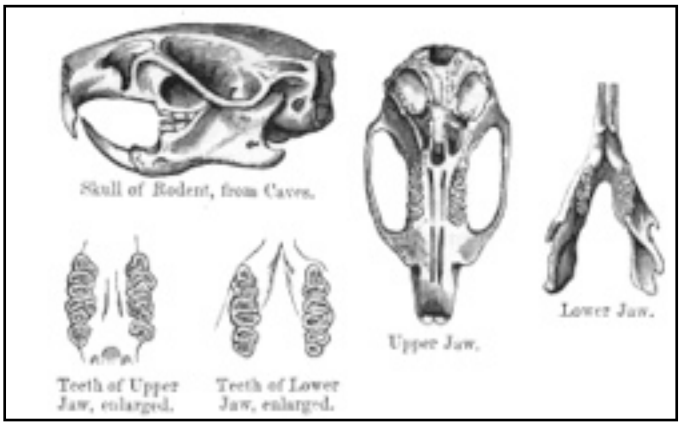
"....... in the midst of a swampy sandy country, plentifully covered with stringy bark, a series of caves are found, whose internal beauty is at strange variance with the wildness of the scenery around." (Woods, 1862).

In Blanche Cave, at the base of calcite columns, he found countless bones of small mammals. These he recognised as being of 'recent' origin; in contrast to the giant marsupial fossils previously discovered at Wellington Caves, New South Wales. He reported his discovery the following year and in doing so provided the first published record of vertebrate fossils from Naracoorte Caves (Woods, 1858).

Woods at Blanche Cave. From Woods (1862).

Megafauna bones were eventually discovered at Naracoorte in the late 19th and early 20th Century and reported by Edward Stirling, director of the South Australian Museum (Reed & Bourne, 2000). Fifty years later, cave explorers started finding fossil material during mapping and exploration trips to the caves. The crowning achievement came in 1969 when a party of cavers led by Grant Gartrell and Rod Wells discovered an enormous fossil deposit in Victoria Cave (Reed & Bourne, 2000). This discovery put Naracoorte on the map as a fossil site and ultimately paved the way for the park's World Heritage listing in 1994. Now considered one of the world's most significant Quaternary fossil localities, the caves within the Naracoorte Caves National Park contain literally dozens of fossil sites. Each one of these sites provides a window into the biodiversity and landscape history of the area during the past 500,000 years. While no one would claim the Naracoorte landscape is a scenic wonder, looks can be deceiving. The fossil record preserved in the caves reveals this unremarkable landscape has been a biodiversity 'hot spot' for hundreds of thousand of years.

Little did Woods know that what he had discovered in Blanche Cave was the remains of thousands of animals that had been brought into the cave by owls. The deposits were indeed 'recent' (geologically), but undoubtedly older than Woods suspected at the time. One can almost picture his disappointment at uncovering mice instead of megafauna. But if you were a betting person gambling on which of these would reveal more about climate and biodiversity change over time, you should probably put your money on the mice.



Rodent fossils discovered by Woods.

From Woods (1862).

DIGGING AROUND IN THE TOPSOIL

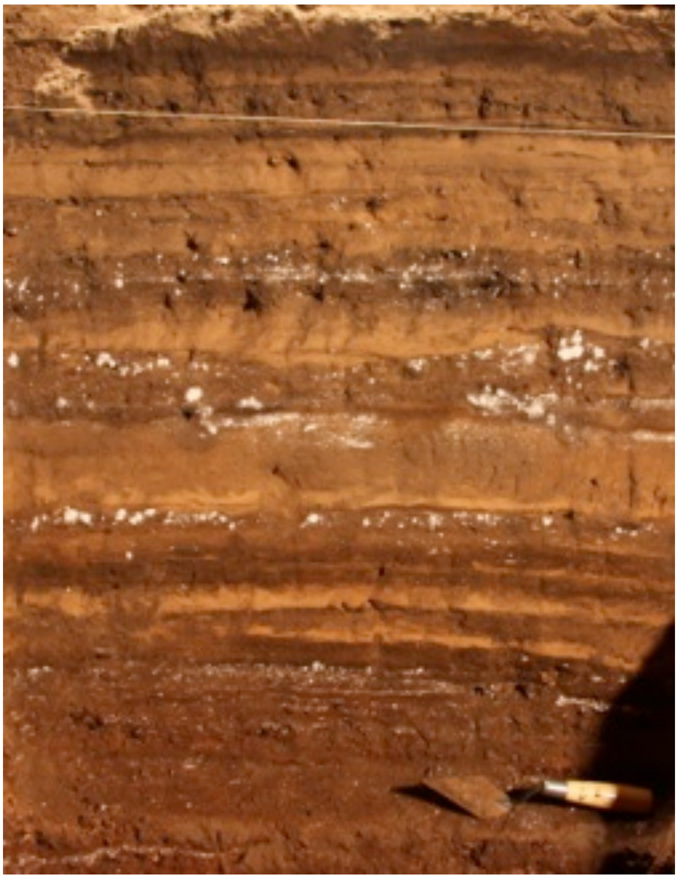
Announcing that one 'works' in the late Quaternary usually elicits a derisive snigger from those palaeontologists scaling the lofty heights of the Mesozoic and beyond. Despite still being 'warm' (geologically speaking), late Pleistocene and Holocene deposits provide an opportunity to elicit finely resolved and detailed records of climate and biodiversity change in a way that significantly older deposits cannot. As these deposits represent largely 'modern' species and ecosystems they can be used to address questions relevant to current and future conservation of the natural environment.

Leopold *et al.* (1963) wrote:

"The first step in park management is historical research, to ascertain as accurately as possible what plants and animals and biotic associations existed originally in each locality."

Traditionally, this has involved trawling through biological survey data, publications, unpublished records and anecdotal evidence. All of these sources have an important role to play; however, they are limited by a 'short' time frame and the fact that in most cases they describe an anthropogenically altered landscape. Information gleaned from within the temporal constraints of recorded history cannot shed light on 'big-picture' patterns of change over significant timescales, particularly pre-human settlement. Using a fixed point in time as a blueprint for conservation doesn't take into account the range of natural variation experienced by ecosystems over ecological and evolutionary time (Hadly & Barnosky, 2009). Future conservation managers will need to broaden their strategies beyond preserving species within their current range. It will become increasingly necessary to develop tools for predicting where species can exist in light of rapid climate change, human expansion and habitat fragmentation (Hadly & Barnosky, 2009). The fossil record provides the only means for assessing long-term patterns of faunal change against climate and supplying meaningful data for such predictive models.

The role of palaeobiology in conservation has been highlighted by numerous authors (eg. Lyman, 2006; Hadly & Barnosky, 2009; Dietl & Flessa, 2011). Despite its promise, palaeontological data has seen little 'on the ground' application by conservation managers. In some cases it has been used to great effect. In Yellowstone National Park, palaeoecological data from Holocene cave deposits were used to assess elk populations and restore wolves to the park (Hadly & Barnosky, 2009). Other studies have revealed striking results that highlight limitations to our current understanding of ecological niches. Bilney *et al.* (2010) found that Sooty Owl (*Tyto tenebricosa*) pellet remains from sub-fossil deposits dating to the time of European settlement contained 28 mammalian prey species compared with just ten in contemporary pellets. This indicates severe decline and niche contraction of small mammal species which had a greater distribution and habitat diversity prior to settlement.



Finely stratified sediment section in Blanche Cave.
Photo: Steve Bourne.

A CAVE IS A CAVE….OR IS IT?

So where does Naracoorte Caves fit into all of this? Naracoorte's deposits are well placed to contribute significant information to address 'big picture' ecological questions. Unlike most fossil localities, Naracoorte has multiple, contemporaneous deposits in a small geographic area (Reed & Bourne, 2000, 2009). This enables comparisons to be made between patterns observed in one assemblage and those in similar sites (eg. McDowell, 2001; Macken *et al.* 2012). Given the high resolution and faunal abundance of the 'young' sites, they have become the focus of current recent research at Naracoorte. Further, the South East region of South Australia is one of the most dramatically human-altered landscapes in Australia, subject to drastic biodiversity loss since European settlement (Croft *et al.*, 1999; O'Connor, 2001). Nearly 80% of major, pre-European plant communities are now considered rare or threatened in the region, with only 13% of native vegetation remaining (O'Connor, 2001). Of the surviving species, nearly 40% of vertebrates and almost 50% of plants now have a conservation status (Croft *et al.*, 1999). Clearing, grazing, drainage, introduction of pest species and habitat fragmentation have all played a role in this devastation. It should be clear from these figures that estimations of the 'original' ecological niches in the region would be severely limited if based on data from modern surveys. If there is one region in Australia that should be using the 'recent' fossil record to inform conservation management it is the South East; coincidentally, a region with a wealth of Quaternary fossil sites (Reed & Bourne, 2000).

In order to investigate highly resolved patterns of landscape and faunal change over time and explore conservation applications, fossil deposits must meet a few important criteria. Caves are a good place to start as they typically contain deep, stratified sediment beds which are well preserved within the relatively sheltered confines of the cave (Reed & Gillieson, 2003). The site must have good stratigraphy with little evidence of re-working and post-depositional disturbance. It must also contain material that can be dated to provide a timeline for the deposit; and of course it must contain bones. However, not all caves are created (geologically as opposed to supernaturally) equal and there is no point comparing 'apples with oranges'. It is important to consider the taphonomic (site formation) history of the caves to ensure comparison between sites with a similar depositional history and accumulation mode.

At Naracoorte there are three broad types of cave deposit (Reed, 2003). The 'classic' pitfall trap cave has a deep, narrow solution pipe entrance which accumulates sediment cones via low energy water flow and slumping; leading to rather coarsely stratified deposits. Small and large animals fall into the cave via well concealed entrances. Large mammals are well represented and usually dominated by groups susceptible to entrapment such as kangaroos (Reed, 2003, 2008). These caves are warm and humid with stable within-cave conditions and virtually no light zone. Organic remains decompose rapidly, leaving deposits composed primarily of bones and sediment (Reed, 2009).

Other caves, such as Blanche Cave, have large roof-collapse window entrances with extensive light zones, vegetation growing on the cone, fluctuating temperature and humidity and generally drier within-cave conditions. Sediment accumulates as a cone beneath the entrance and is re-deposited further down slope by high energy water flow during storm events, resulting in finely laminated sediment beds (Reed, 2003). Decomposition is much slower, with animal remains and other organic material often becoming desiccated (Reed, 2009). While some animals do become trapped in these caves via pitfall, the major accumulation type is owl pellet deposition, with some contribution from regular cave inhabitants. These deposits are dominated by small vertebrates with smaller numbers of large individuals.

The third type of deposit is basically a variation on the roof window cave, where the entrance has further collapsed or been modified in some way to remove any vertical component to the entrance. Animals can literally just walk in and these caves serve as dens and shelter for predators and herbivores alike (Reed, 2003). In the past animals such as Tasmanian Devils would have used these caves as dens, bringing their prey back to the cave to consume and allowing bones to accumulate.

Solution pipe entrance and associated sediment cone, Sand Cave, Naracoorte. Photo: Steve Bourne

THERE'S NO CAVE LIKE HOME

Why is cave type important? The structure of the cave and its entrance/s has a profound effect on the nature of the accumulated fossil assemblage (Reed, 2008). It also influences the way in which bones, organics and geological materials are deposited and dispersed in the cave. The combination of physical characteristics of the cave dictate the 'recipe' for the deposits collected within. Environmental conditions in the cave, which in turn are influenced by the structure of the cave, have a direct influence on how and what materials will be preserved (Reed, 2009). Scientific research projects are based on a series of questions and hypotheses. The range of data and methods of collection must be appropriate to the questions being asked. In the case of fine-scaled palaeoecological questions at Naracoorte it is important to select the right cave for the job.

Due to their natural abundance, short generation time and undeniable popularity with bone-collecting predators, small mammals provide an excellent resource

Roof window entrance with large light zone, Robertson Cave, Naracoorte. Photo: Steve Bourne

for assessing faunal change over time (eg. McDowell, 2001; Macken *et al.*, 2012; Prideaux *et al.*, 2007). Some owl species roost in caves, leaving behind the remains of their prey in the form of regurgitated pellets (Andrews, 1990). In effect they act as biological surveyors, collecting a sample of the local fauna during each hunting trip. Over extended time periods, owls concentrate thousands of bones which become incorporated into cave sediments. Owl assemblages typically reflect the prey range and size of the predator and are biased towards small vertebrates. At Naracoorte, owls tend to use the more open, roof window type caves, producing deposits such as the ones discovered by Woods in 1857. These caves also collect larger animals via pitfall entrapment and are frequented by several species of mammals, birds, reptiles and amphibians (Reed, 2003). This enables a broad sample of the local faunal diversity to be accumulated. The sheer volume of material in owl deposits makes them highly suitable for the statistical analyses required to investigate fine scale faunal changes over time.

Rodent vertebra with digestive corrosion from owl consumption. Each species of owl leaves a different degree of modification. Scale bar = 2 mm.

A cave deposit is much more than the sum of its parts. While each individual component has a story to tell, powerful and robust interpretations are made by drawing together multiple lines of evidence. Traditionally, palaeontologists have primarily been concerned with bones. If the aim of the research is to reconstruct whole of landscape palaeobiology, then the bones will only take the story so far. To complete the picture, data are needed to elucidate climate, vegetation, geology and site formation history. Recent research at Naracoorte has shown that another positive aspect of the roof window sites is that these drier caves tend to preserve more than just bones.

LESSONS FROM THE PAST

A frustrating aspect of working on the Naracoorte fossil deposits has been the lack of palaeovegetation record. Vegetation reconstructions have relied on inferences made from the dietary preferences of the excavated fauna and pollen cores obtained from other localities. Attempts had been made to extract fossil pollen from Victoria Fossil Cave in the early days of excavation; but these were all unsuccessful (Rod Wells pers. comm.). It was considered there was no pollen record at Naracoorte and no further attempts were made. While completing a study of the various processes of accumulation and preservation in the caves, the author noted how different cave types preserved material in different ways. The deeper, more humid caves did not have the leaf litter and organic material seen in the open caves. Perhaps the previous attempts to obtain pollen had been unsuccessful because the samples were from the wrong type of cave? The dry, dusty, open caves might contain the right stuff!

Eucalyptus leaf in situ in an excavated sediment section, Robertson Cave. The charcoal from this layer dated to approximately 16,000 years BP. Scale bar segments = 10 mm. Photo: Steve Bourne

During a palaeontological survey in 2004, the author identified a potentially interesting site in the third chamber of Blanche Cave. Tegan Laslett, a Flinders University Honours student, completed a pilot study of the site in 2006 (Laslett, 2006). The site proved to be rich in vertebrate fauna, was well stratified with preserved scats and some small remnants of plant material. The author has continued excavation of the site, expanding the dig laterally and obtaining a chronology and geochemical profile for the site with colleagues from the Australian National University and University of Queensland (Darrenogue *et al.*, 2009; St. Pierre *et al.*, 2009). Radiocarbon dating has revealed the age range of the one metre deep sequence to be 14,600 ± 432 BP to 47,086 ± 2892 BP (St. Pierre *et al.*, 2012). Importantly, the sequence spans the Last Glacial Maximum (LGM) and the periods leading into and out of this major climatic phase. The lowest layers contain megafaunal species. Sediment samples were analysed for fossil pollen and yielded good counts throughout the sequence, providing the first vegetation record from a Naracoorte deposit. On a broad scale the pollen shows an abundant woody vegetation prior to the LGM, with an increase in herbaceous taxa during the LGM and an increase in woody-herbaceous taxa following the LGM (Darrenogue *et al.*, 2009). A detailed paper on the pollen record from Blanche Cave is currently in preparation.

The author's current research (funded by the Federal Caring for Our Country initiative), expands on this work and involves excavation and analysis of three roof window cave assemblages. This includes increasing the depth of the Blanche Cave section which has now reached two metres. The three chosen sites share a similar stratigraphic sequence, are contemporaneous and have comparable site formation histories. The aim is to analyse patterns of biodiversity change against climate during the past 50,000 years, utilising multiple lines of evidence from cave sediments, pollen, macro plant material (wood, seeds, leaves), speleothems, chronology, charcoal, scats and vertebrate faunas (amphibians, reptiles, birds and mammals). As part of this project Flinders University PhD student Amy Macken is conducting finely resolved analyses of the small mammal faunas from Blanche Cave to assess the utility of these assemblages as baselines for modern conservation management. Colleagues from Australian and international universities are also contributing to various aspects of this multi-disciplinary project. The project is interesting as it not only assesses the patterns present in one assemblage, but also aims to determine if similar patterns are discernible in the 'replicate' sites. The results will provide a detailed picture of the Naracoorte region during the more 'recent' past. Another important aspect of the project is to incorporate the results into on-site interpretation at the park and to share the lessons learned from the past. It is also expected to contribute information that will assist in conservation of the fossil deposits themselves and highlight methodologies that maximise information gain while minimising impact on the deposits. These are important considerations if the deposits are to benefit future generations and be preserved for their own intrinsic value.

Recent excavation in Blanche Cave will extend the fossil record beyond 47,000 years. Photo: Steve Bourne

CONSERVING THE PAST AND FUTURE

Bilbo & Bilbo (2006) wrote:

"Cultural resources should be protected and preserved, not only because there are laws saying so, but also because they are the basis of history."

Similarly, palaeontological and geological resources are the basis of the evolutionary and ecological history of a cave and its surrounding landscape. From a conservation and management perspective fossil deposits should be treated as whole entities, composed of multiple and varied materials that only reach their full scientific potential when studied as a single unit. It is not just the fossils themselves that warrant protection and a cave floor shouldn't be taken at face value. What may look like just a pile of dirt covered in leaves and rocks could be thousands of years old and an important link to pre-European biodiversity and climate change. Management of fossil deposits in caves has been discussed in detail by various authors (eg. Ramsay, 2004). Most managers and custodians recognise the need to preserve them and take measures to do so. In other cases, cavers and other groups have been instrumental in protecting important deposits in caves (eg. Spate 2011).

Given the current rate of technological advance it is logical that future palaeontologists will be able to investigate the Naracoorte deposits in ways that can only be imagined today. Fortunately, past custodians of the park had the vision to segregate some sections of the caves, leaving them untouched for future generations. Currently, reference sections receiving the highest level of protection are largely restricted to extensive megafauna pitfall deposits deep within the cave system. Naturally they are worthy of such levels of protection and to put it plainly, 'they're' not making them any more. They are a finite resource and their conservation recognises the intrinsic value and significance of the deposits. However, consideration should also be given to some of the younger sites, which in many ways have more potential to answer many of the questions researchers have been trying to address at Naracoorte for decades. Nearly all of these sites, including the ones discussed in this paper, occur in what is listed as show, adventure or wild caves in the current management plan (Department for Environment and Heritage, 2001). Many of these have been walked on, tunneled into or dug up for lighting cables simply because they weren't recognised as being as important as their flasher cousins. Part of the same fossil bearing sediments in Blanche Cave that are now yielding late Pleistocene material were once used as simulated excavation sites for school children. Just 10 cm below the surface of a floor that has been walked on for more than a hundred years are 14,500 year old sediments, bones and fossil plants. Go down another 70 cm and there's megafauna!

This is not intended as a criticism of the way the park has been managed. On the contrary, conservation of the fossil sites has always been a high priority for managers and executed very effectively at Naracoorte. Indeed, the actual management of the park is considerably more advanced than the written plan and that is because managers work closely with researchers and others to develop management strategies in light of new information. What is being suggested here is a re-assessment of the sites of special value and what actually constitutes a 'fossil' deposit, so that some will be re-classified. As it stands, the official management framework for the park, i.e. the management plan, doesn't adequately reflect the World Heritage values as revealed by ongoing research.

In the management plan only five caves are listed as containing fossil deposits (Department for Environment and Heritage, 2001). Ironically, none of the sites that form the basis for the current research at Naracoorte are included; and many others are overlooked. This is no doubt due to the fact that when it was written there had been no research done on any of these younger deposits. It wasn't until the late 1990s that the first detailed work commenced on such sites (McDowell, 2001). Since then further research and palaeontological surveying has revealed the full scale of the resource at Naracoorte (Reed & Bourne, 2000, 2009). At the very least a representative selection of the various 'types' of deposit should be afforded the highest level of protection. In addition, those sites that are still collecting material today should get special consideration as they continue the strong tradition of accumulation that Naracoorte is famous for. Without these sites, the fossil record that has so much to tell about extinctions and faunal change is in danger of becoming extinct itself.

Science should always reveal more questions than it answers. Research over the past two decades at Naracoorte has paved the way for a paradigm shift in thinking about management of this important World Heritage site. New interpretations of Naracoorte's fossil record will be driven by technological advances, a greater awareness of the extent of the resource and the discovery of new facts. At a locality where science is such a core part of the park's function it is logical that the management framework should keep pace with the science and not be left behind. Regular reviews of the management plan should be an important part of future strategies for Naracoorte Caves National Park.

In the meantime, spare a thought for that dusty old cave floor when next caving. Those dry old gum leaves and bits of wood could be thousands of years old. Remember, in a cave, looks can be very deceiving.

Spot the difference. The samples on the left were sourced from the author's garden at the time of writing, those on the right were excavated from Robertson Cave and are nearly 20,000 years old. Photo: Steve Bourne

ACKNOWLEDGEMENTS

Thanks to Steve Bourne for ongoing assistance with fieldwork, excavation and intellectual input into the research. The author acknowledges students and colleagues who are currently contributing to various research aspects of this project including Amy Macken, Patricia Fuentes-Cross, Vicki Snelson, Sander van der Kaars, Stewart Fallon, Mark Hutchinson and Erick Bestland. Thanks to student and Friends of Naracoorte Caves volunteers who help with research. Thanks to staff at Naracoorte Caves for help and general support. This research is funded via the Federal Caring for our Country initiative (Grant OC11-00487).

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