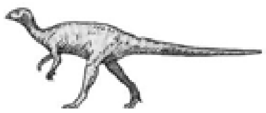
DINOSAUR DREAMING
2018 FIELD REPORT



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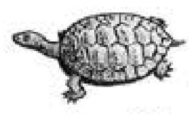

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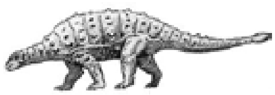
Bunurong Environment Centre
Bunurong Land Council, Frankston, especially Dan Turnbull



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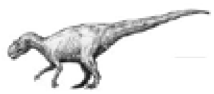
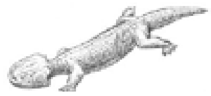


National Geographic Society
National Wool Museum
Parks Victoria, especially ranger Brian Martin
Peter Trusler



PrimeSCI! at Swinburne University of Technology
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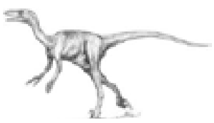
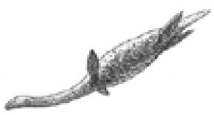


Swinburne University of Technology, Faculty of Science (Dept of Chemistry and Biotechnology)
VicRoads / Major Projects Victoria, especially Deborah McLees



Dinosaur Dreaming acknowledges the Eastern Maar and Bunurong peoples, the Traditional Owners of our Victorian Cretaceous dig sites, and pays respect to their Elders past and present.

Collection of Victorian Cretaceous material was completed under the Department of Environment, Land, Water & Planning, National Parks Act 1975 Research Permit No. 10008781, File No. FF383578.

FRONT COVER: Reconstruction of *Diluvicursor pickeringi* in its habitat by Peter Trusler (Herne *et al.* 2018, figure 36)

BACK COVER: The dinosaur trackway outside Winton, Queensland.

The Dinosaur Dreaming 2018 Field Report was compiled and edited by Wendy White. The editor would like to thank her proofreaders Alanna Maguire, Mary Walters, Lesley Kool and Stephen Poropat. Uncredited images by the editor.

Contents:

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Image courtesy of Museums Victoria

Tooth or teeth?

By Tom Rich

A discovery on the morning of 20 February 2015 by Tim Ziegler provided fossil evidence to significantly add to ideas about the mammals from Eric the Red West. However, it has taken three years for these insights to begin to emerge. It is only because of the scanning of the specimen by Alistair Evans and the subsequent production of 3D rapid prototype models enlarged x10 by Matt White, that detailed ideas concerning what the fossil is have begun to take shape.

A fundamental question raised by Tim's fossil (P252052) is whether it consists of one tooth in two pieces or four teeth. You can hardly imagine a more fundamental question about a mammalian dentition than that. As might be expected in such circumstances, the two interpretations of the fossil offered thus far are quite different.

The image of Tim's fossil in Figure 1 shows the two parts of it in their relative positions as best as can be restored on the basis of an image made by David Pickering prior to his preparation of the fossil. With a needle, David Pickering then carefully removed the upper three cusps from the rock in which they were embedded. Fortunately the lower part of the specimen in the image came out of the rock with no needle

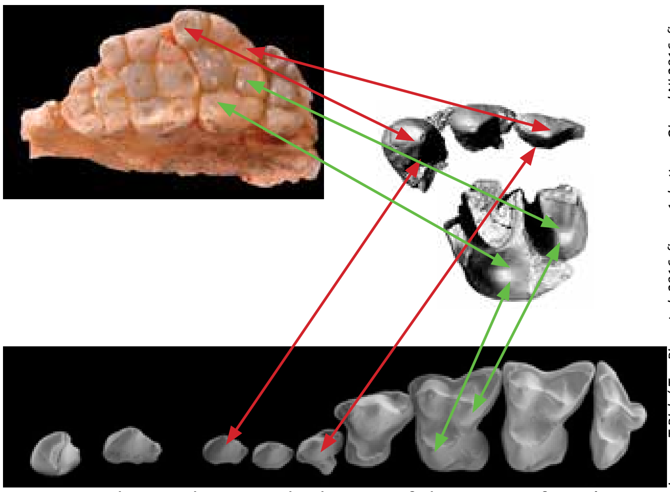

Image: T Rich (Top Pian et al. 2016, figure 1; bottom: Qi and Ni 2016, figure 1)

Figure 1. The similarity in the layout of the cusps of Tim's specimen to the monotreme Kollikodon *(top left) or tree shrew* Ptilocercusa *(bottom)*

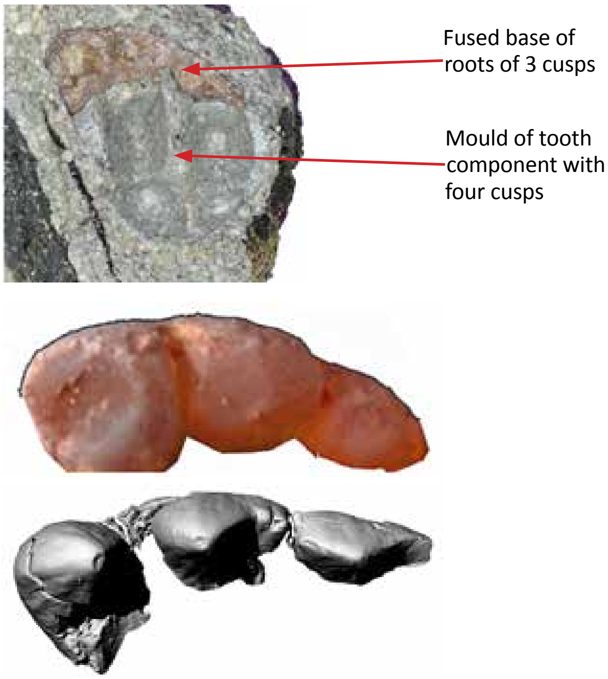

Image: T Rich (Top image: D Pickering; Middle Pian et al. 2016, figure 1; Bottom: M White)

Figure 2. Top: P252052 prior to preparation. Middle: Three outer cusps of the upper molar of Kollikodon galmani. *Bottom: Three cusps of P252052 (3D scan image)*

work needed. This left a mould of the crown in the surrounding rock which has been used to restore parts of that specimen that were otherwise not preserved.

If the specimen is a single tooth in two pieces, it has been suggested that it resembles part of an upper molar of the Cretaceous monotreme *Kollikodon* from Lightning Ridge. This is based on the similarity of the layout of the cusps. In Figure 1, a selection of some of the comparable cusps in the three dentitions are indicated with double headed arrows. The cusps in Tim's fossil and *Kollikodon* are quite different in shape and internal structure and there is no obvious fit between the two pieces that would be expected if Tim's fossil consists of a single tooth that had been broken apart. Also, there is no cingulum (shelf) on the margin of the upper molar of *Kollikodon*.

The four-tooth interpretation is based on the similarity of the upper three cusps in Tim's fossil to premolars of insectivorous marsupials and placentals. In Figure 2, Tim's fossil bears a resemblance to an upper molar of an insectivorous marsupial or placental. Two objections to this interpretation are that the roots of the premolars of Tim's fossil are fused to one another and, if they were in fact from the same individual, that the molar has shifted forward relative to the premolars. Fusion of premolars of insectivorous mammals, while rare, is not unknown. Post-mortem distortion of fossils is quite common.

From the dozen excavations at Eric the Red West since 2006, only three other mammalian specimens have been found that are sufficiently well preserved to be analysed with greater refinement in their identification beyond merely being mammals.

One (P228848), found by Mary Walters in 2006, is a lower jaw allocated to *Bishops* (Rich *et al*. 2009). Another (P252207) found by Olivia Campbell in 2015, is also likely *Bishops*. The last (P231328) consists of two heavily worn and broken upper molars found by Alanna Maguire in 2009.

The question raised by Alanna's specimen soon after its discovery is whether it is the otherwise unknown upper dentition of an ausktribosphenid, either *Bishops* or *Ausktribosphenos*. Conjecture on that question remains unresolved owing to the poor preservation of Alanna's specimen. No attempt has yet been made to address the comparable possibility that Tim's fossil represents an example of the upper dentition of an ausktribosphenid.

When viewed as they are in Figure 3, a significant difference in the outline of the teeth between these molars can be observed. Alanna's teeth have a triangular outline. By contrast, Tim's has a more rectangular outline. This aspect of Tim's upper molar is not seen elsewhere in marsupials and placental mammals until long after the Early Cretaceous, the age of the fossils from the Eric the Red West site. What caused this feature to occur in Australia earlier than elsewhere is quite a thought provoking question.

References

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Pian, R., Archer, M., Hand, S.J., Beck, R.M.D. and Cody, A. 2016. The upper dentition and relationships of the enigmatic Australian Cretaceous mammal Kollikodon ritchiei. *Memoirs of Museum Victoria* 74: 97-105.

Rich, T., Vickers Rich, P., Flannery, T., Pickering, D., Kool, L., Tait, A. and Fitzgerald, E. 2009. A fourth Australian Mesozoic mammal locality. *Museum of Northern Arizona Bulletin*. 65. 677–681.

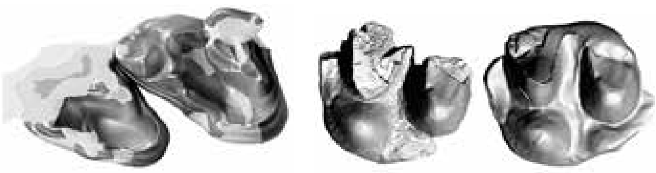


Image: P Trusler

Figure 3 Left: Alanna's two upper molars. Right: Two images of Tim Ziegler's upper molar: the fossil alone and with missing parts restored from the impression of the fossil preserved in the rock that surrounded it

Image courtesy of Museums Victoria

Gifts from the South Gippsland Highway

By Tom Rich

Major Projects Victoria is undertaking the realignment of the South Gippsland Highway in the vicinity of the Koonwarra Fossil Fish Beds Locality. Well aware of the possibility of this project encountering another fossil site of equal or even greater significance during the construction process, the Chief Engineer of the project, Deborah McLees, has been in touch with Museums Victoria in order to discuss the implications of such an outcome.

Efforts are continuing to identify, along the proposed realignment, where such an important site is most likely to be encountered. If one is identified either (preferably) prior to construction or during that process, Major Projects Victoria desires that the fossils be preserved. How this would be done will depend on the circumstances of any such occurrence. In advance of recognition of a significant site, that cannot be known.

In order to aid in the recognition of potential fossil sites, Deborah McLees authorised the drilling of a core through the fossiliferous rock at the Koonwarra Fossil Fish Beds locality. Having done this, there is now a comparative example of what to look for in the identification of other potential fossil sites drilled in nearby cores. This core has made it possible to study the history of the polar lake that formed the Koonwarra Fossil Fish Beds locality over the duration of the 5,000 to 10,000 years that the lake existed. Detailed studies of this core are being undertaken by researchers measuring the abundance of carbon and nitrogen isotopes, organic compounds, and spores and pollen at close intervals through the core to determine both the general nature of the lake and what changes may have taken place during its existence.

Image: D Pickering

Koonwarra fossil site overlooking the South Gippsland Highway

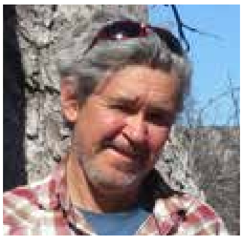


Image: J Nair

Dave's Flood-Runner: A New Dinosaur

By Matt Herne

In 2005, on a pretty stretch of beach near Cape Otway, George Caspar, hunting for bones with Mike Cleeland, noticed a fossil eroding from the rocky shore platform. After this fossil was excavated and prepared, the partial skeleton of a new turkey-sized ornithopod dinosaur was revealed. Although only the tail, which is almost complete, along with the right ankle and most of the right foot, was preserved in this skeleton, it clearly differed from all ornithopod skeletons previously known. It was provided with the new scientific name *Diluvicursor pickeringi* meaning Pickering's Flood-Running dinosaur.

Forming the genus name, *Diluvi-* is derived from the Latin for deluge, or flood, and *-cursor* is Latin for runner. *Diluvicursor*, therefore encapsulates the little dinosaur's likely physical capabilities as an agile runner and the environmental conditions under which this individual is thought to have died and been buried.

The species name is especially important. It honours David Pickering, Dinosaur Dreaming leader and Museums Victoria's Vertebrate Palaeontology Collections

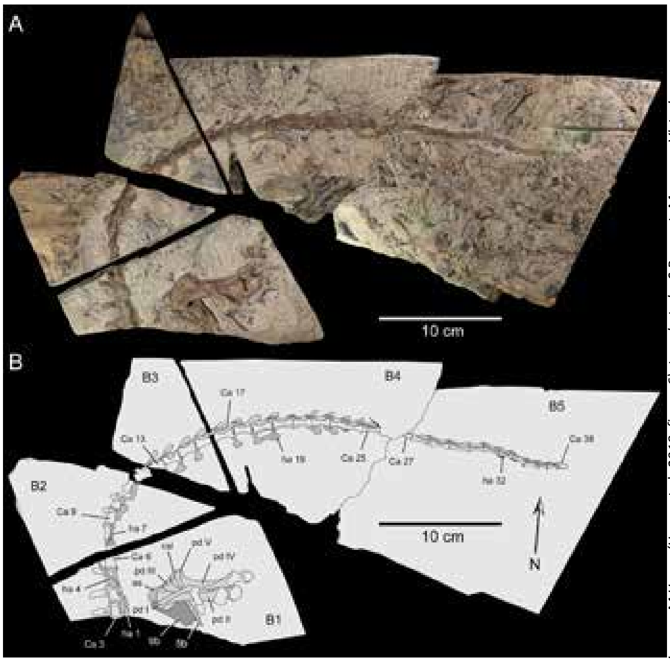


Image: M Herne (Herne et al. 2018, figure 6), top photo by S Poropat, Museums Victoria

The holotype of Diluvicursor pickeringi *NMV P221080*

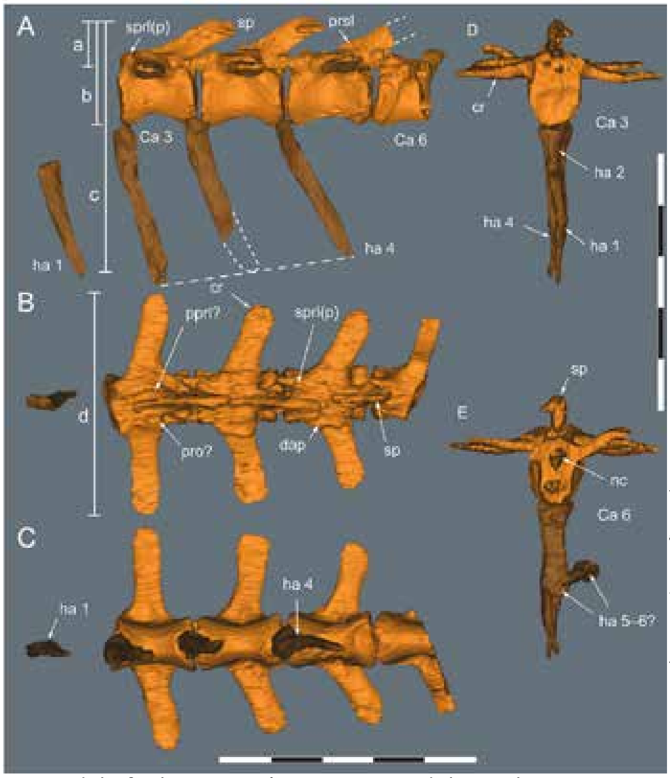


Image: M Herne (Herne et al. 2018, figure 9)

CT model of Diluvicursor*'s anterior caudal vertebrae Scale in cm*

Manager. Sadly, David passed away on Christmas Eve 2016. He tirelessly contributed to Australian palaeontology in both the lab and the field, and assisted countless students of palaeontology and researchers to achieve their goals.

The site where *Diluvicursor* was discovered, now called Eric the Red West, helps build a picture of the ancient rift valley ecosystem. Fossil vertebrate remains at this site were buried in deep scours at the base of a powerful river, along with flood-transported tree stumps, logs and branches. The carcass of the *Diluvicursor* holotype appears to have become entangled in a mass of woody plant debris. The sizes of some of the logs in the deposit and the abundance of wood suggest the river traversed a well-forested floodplain. The logs preserved at the site are likely to represent conifer forests of trees within families still seen in Australia today.

Diluvicursor is more solidly built than any of the previously described Victorian ornithopods, and had a far shorter tail. Our reconstruction of the tail musculature suggests that *Diluvicursor* had powerful leg retracting muscles attached to the femur and the caudal vertebrae (bones of the tail).

Our paper naming *Diluvicursor* was published in January 2018 in the open access journal *PeerJ*. Using digital 3D models from CT scans (courtesy of St Vincent's Hospital, Melbourne) we provided detailed descriptions of the caudal vertebrae, ankle and foot. The level of detail of the caudal vertebrae in this investigation was greater than previous studies of other ornithopods. This work showed that the fine features of the caudal vertebrae of ornithopods can help define different taxa.

The caudal vertebrae at the base of the tail in the *Diluvicursor* holotype are unfused, suggesting that this individual was not fully-grown when it died. The holotype would have been about 1.2 metres long from its nose to the tip of its tail. However, a larger caudal vertebra also found at Eric the Red West suggests that adults would have been at least 2.3 metres in length.

One of the interesting things about the *Diluvicursor* holotype is the pathological condition of its right foot. This foot has some osteophytosis (bone fusion) that occurred after some of the toe bones were injured and had become misaligned (in medical terms called subluxation). However, it is unlikely that this pathological condition was the cause of this dinosaur's death. Interestingly, another partial ornithopod skeleton found in Victoria (affectionately known as "Junior") also had a pathology of its hind leg, although a more severe condition than that of the *Diluvicursor* holotype. It seems that our little dinosaurs were a limpy lot!

The paper included a painting by palaeoartist Peter Trusler reconstructing *Diluvicursor* within its habitat on the bank of a large river (see front cover of this Field Report). Including a reconstruction in a scientific article is not without its challenges. The vegetation in the painting is based upon the types of plant fossils evident from the Victorian Cretaceous. The logs being washed down the river depicted in the scene

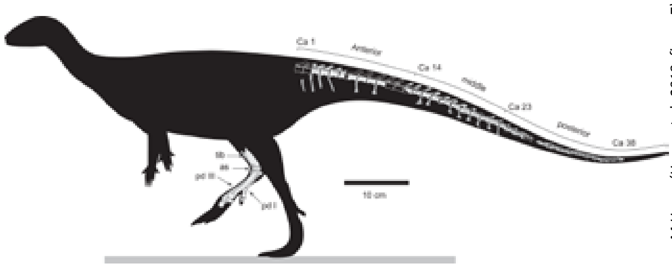


Image: M Herne (Herne et al. 2018, figure 7)

Schematic restoration of the Diluvicursor pickeringi *holotype showing preserved and incomplete bones*

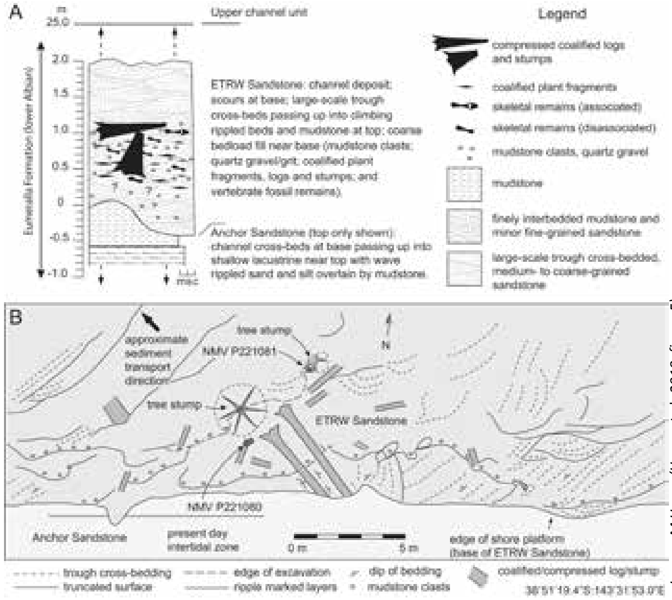


Image: M Herne (Herne et al. 2018, figure 5)

Schematic illustrating the deposition of the Dilivicursor *holotype*

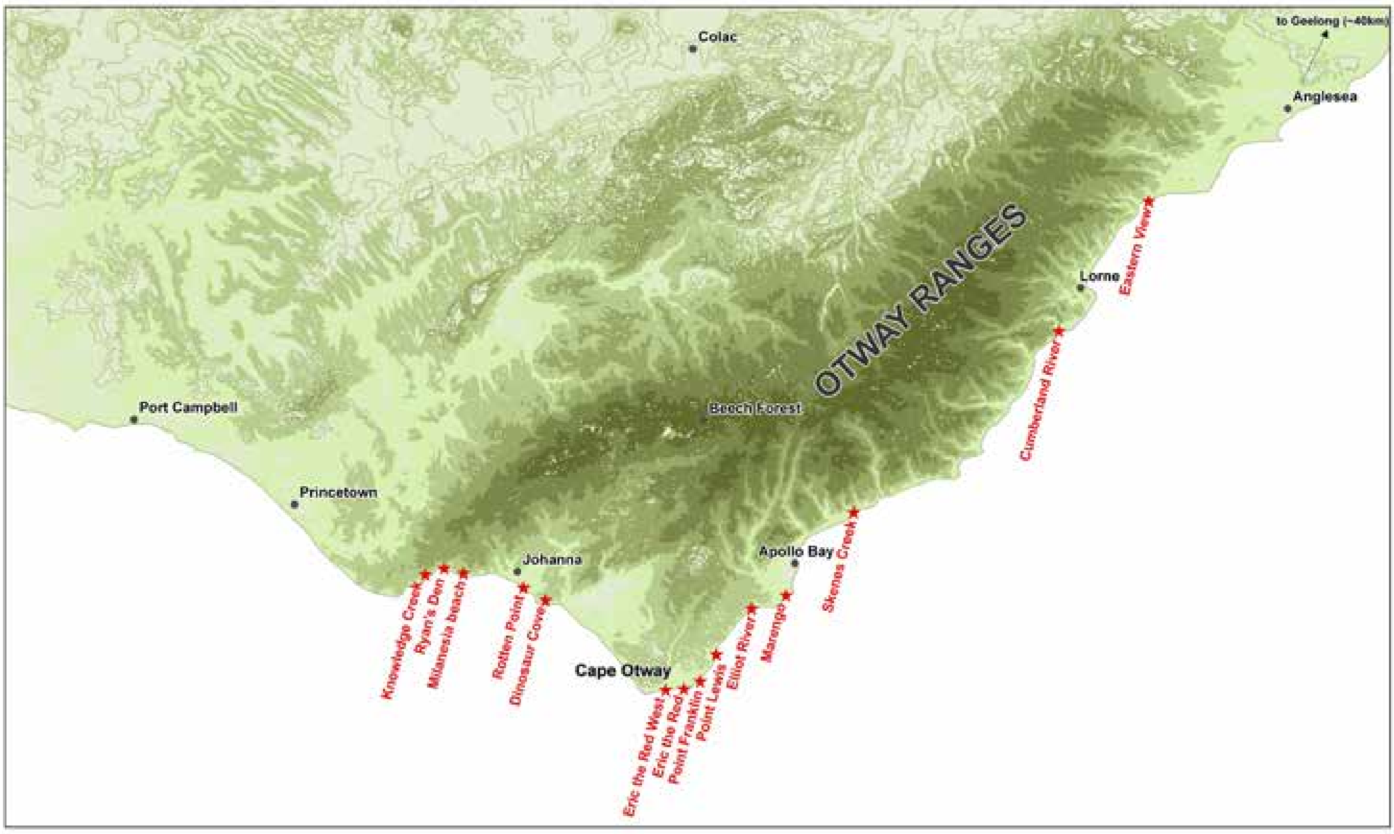
are similar to those preserved at Eric the Red West. The two fleshed-out *Diluvicursor* individuals in the painting incorporate information and insight from work on other ornithopods. Peter and I decided to depict the *Diluvicursor* in the foreground as viewed from behind to focus attention on the part of the holotype that was preserved. The skin of *Diluvicursor* is depicted with scales. Although many non-avian theropod dinosaurs had feathers, as do birds (avian theropods), there is no evidence to suggest that small-bodied ornithopods did. Hadrosaurs (duck-billed dinosaurs) are the closest relatives to *Diluvicursor* that have well-preserved skin impressions—in fact the best skin impressions of any dinosaur group known. The integuments of those hadrosaurs only had scales. This information was used to reconstruct the skin of *Diluvicursor*. It is of note that no ornithischian has feathers, but filamentous (bristle-like) structures are known in some non-ornithopod ornithischians and these have been referred to by some authors as 'feathers.'

George Caspar's find sparked the beginning of the Eric the Red West excavations, which, over subsequent years, have contributed hundreds of fossils to the Museums Victoria collection.

Reference

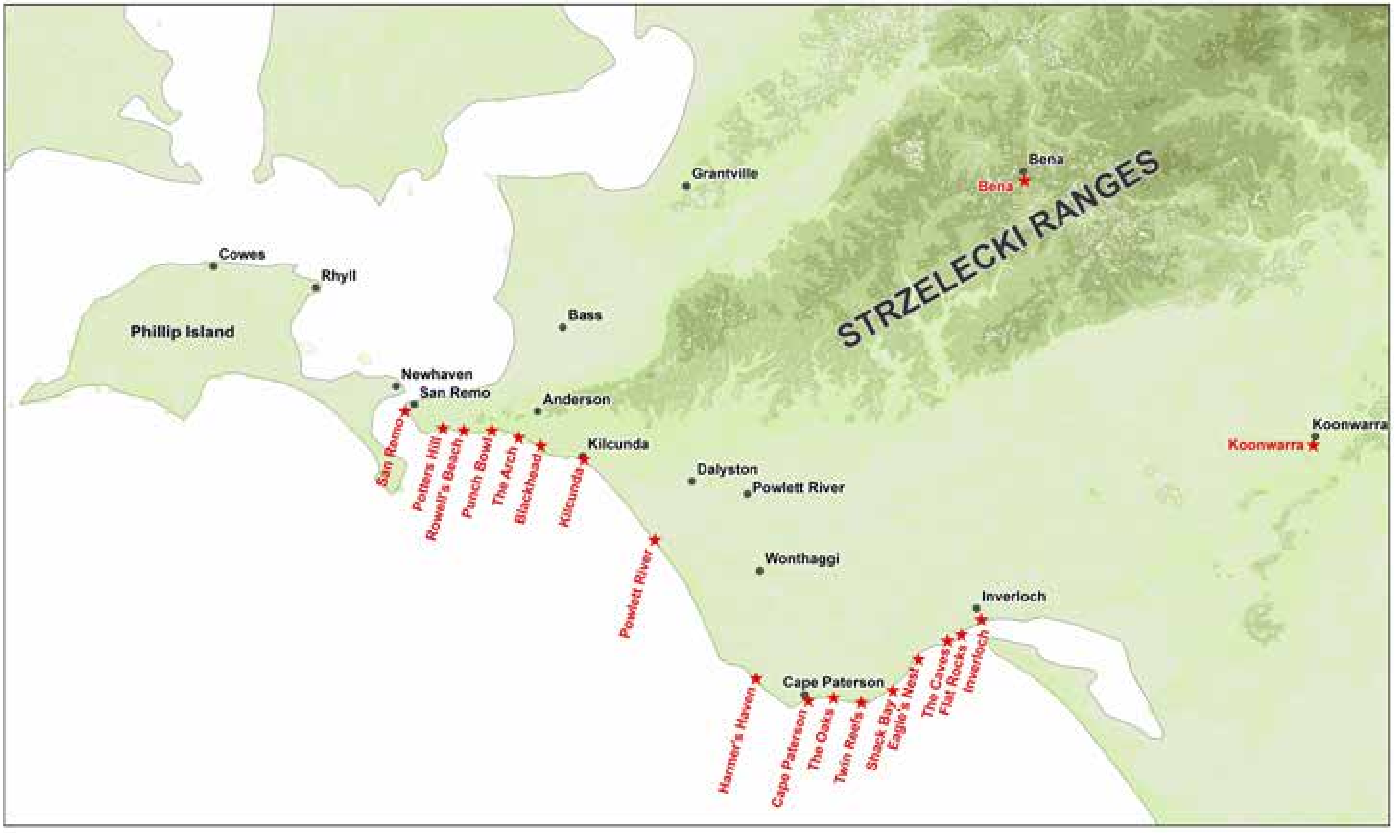
Herne M.C., Tait A.M., Weisbecker V., Hall M., Nair J.P., Cleeland M. and Salisbury S.W. 2018 A new small-bodied ornithopod (Dinosauria, Ornithischia) from a deep, high-energy Early Cretaceous river of the Australian–Antarctic rift system. *PeerJ* 5:e4113 https://doi.org/10.7717/peerj.4113

Cretaceous Vertebrate Localities in the Otways



TAXA	Knowledge Creek	Ryan's Den	Milanesia Beach	Rotten Point	Dinosaur Cove	Eric the Red West	Eric the Red	Point Franklin	Point Lewis	Elliott River	Marengo	Skenes Creek	Cumberland River	Eastern View
Mammalia:														
Tribosphenic (Unidentified)						X								
Bishops sp.						X								
Monotremata (Unidentified)						X								
Kryoryctes cadburyi					X									
Dinosauria:														
Dinosaur (Unidentified)		X		X	X	X	X	X	X	X	X			X
Ornithopoda (Unidentified)		X		X	X	X		X	X	X	X			
Atlascopcosaurus loadsi					X				X					
Diluvicursor pickeringi						X								
Fulgurotherium australe					X									
Leaellynasaura amicagraphica					X									
Ankylosaurs/nodosaurs					X									
Neoceratopsian					X									
Theropoda (Unidentified)					X	X		X						
Spinosaurid						X								
Oviraptorosaur					X									
Ornithomimid					X									
Tyrannosauroid					X									
Neovenatorid					X	X								
Other Vertebrates:														
Plesiosauria (aquatic reptiles)					X	X							X	
Crocodylia (crocodiles)					X									
Pterosauria (flying reptiles)					X	X								
Testudines (turtles)		X			X	X	X	X	X					
Otwayemys cunicularius					X									
Dipnoi (lungfish)					X	X			X					
Neoceratodus nargun					X				X					
Actinopterygii (ray finned fish)					X	X								
Trace Fossils:														
Dinosaur footprints	X		X		X							X		
Bird footprints					X							X		
Dinosaur Burrows	X													

Cretaceous Vertebrate Localities in South Gippsland



TAXA	San Remo	Potters Hill	Rowell's Beach	Punch Bowl	The Arch	Blackhead	Kilcunda	Powlett River	Harmer's Haven	Cape Paterson	The Oaks	Twin Reefs	Shack Bay	Eagle's Nest	The Caves	Flat Rocks	Inverloch	Bena	Koonwarra
Mammalia:																			
Tribosphenic (Unidentified)																X			
Ausktribosphenos nyktos																X			
Ausktribosphenos sp.																X			
Bishops whitmorei																X			
Monotremata (Unidentified)																X			
Teinolophos trusleri																X			
Multituberculata (Unidentified)																X			
Corriebaatar marywaltersae																X			
Dinosauria:																			
Dinosaur (Unidentified)	X	X	X	X	X	X	X	X	X		X			X	X	X	X	X	
Ornithopoda (Unidentified)	X	X		X	X	X	X	X						X	X	X			
Fulgurotherium australe					X									X					
Qantassaurus intrepidus																X			
Ankylosaurs/nodosaurs					X				X							X	X		
Neoceratopsidae (Unidentified)																			
Serendipaceratops arthurcclarkei					X														
Theropoda (Unidentified)	X			X	X	X	X	X					X	X		X			
Ornithomimid	X					X										X			
Megaraptoran					X									X					
Ceratosaur	X																		
Other Vertebrates:																			
Plesiosauria (aquatic reptiles)	X		X					X						X		X	X		
Pterosauria (flying reptiles)														X		X			
Testudines (turtles)						X		X		X				X	X	X	X	X	
Aves (birds)																X			X
Temnospondyli (amphibians)				X													X		
Koolasuchus cleelandi	X	X	X	X															
Dipnoi (lungfish)	X			X			X	X					X	X		X	X		X
Neoceratodus nargun				X										X		X			
Archaeoceratodus avus														X					
Actinopterygii (ray finned fish)					X	X		X						X		X		X	X
Waldmanichthys koonwarri																			X
Koonwarria manifrons																			X
Wadeichthys oxyops																			X
Coccolepis woodwardi																			X
Psilichthys sp.																			X
Trace Fossils:																			
Dinosaur footprints																X			

Initial Thoughts on the New Multi

By Tom Rich

In the northern hemisphere, multituberculates are the most commonly found Mesozoic mammals. In a single afternoon, when Pat and I were honeymooning, we collected several hundred isolated multituberculate teeth.

Here in Australia, things are just a bit different. To date, only two multituberculate specimens from this continent have been found.

The first of these, the holotype of *Corriebaatar marywaltersae*, established the presence of this major mammalian group in Australia. Furthermore, that single tooth implied that rather advanced members of these rodent-like mammals occurred on this continent.

At a gathering of determined weekend rock breakers at Lesley's home in 2017, Wendy White found her second Mesozoic mammal, a more complete specimen of *Corriebaatar*.

The additional features available on Wendy's jaw add further support to the idea that this multituberculate was an advanced member of the group.

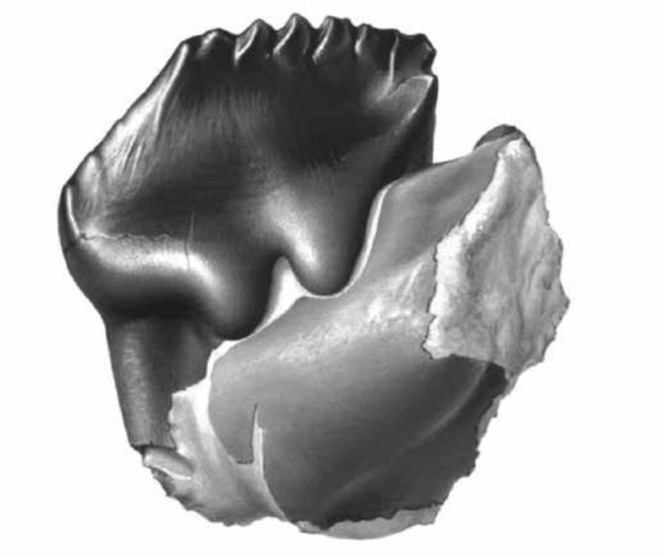


Image: P Trusler

Corriebaatar marywaltersae *holotype found by Mary Walters in 2004*

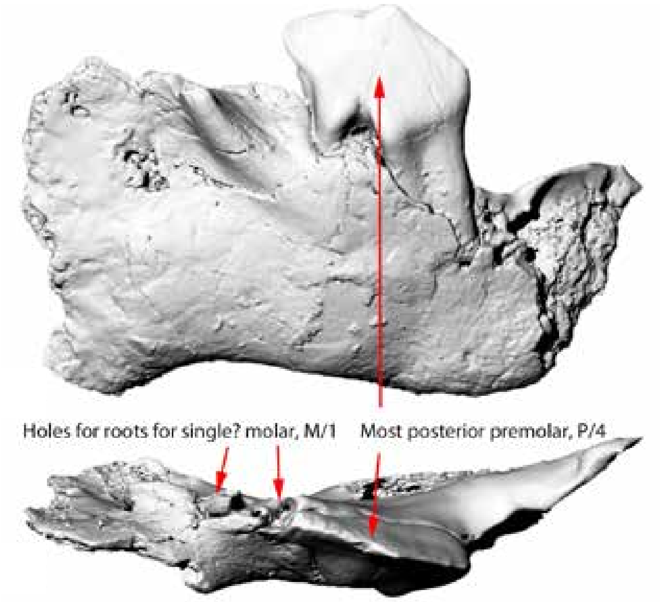


Image: M White

Scanned image of Wendy's Corriebaatar *jaw*

Multituberculates typically have two lower molars in each jaw. Based on what can be seen of this specimen, there are two holes behind the premolar for the two roots of one molar. There does not appear to be such a hole or holes for the root of a second molar. If this difference is real and not an artefact of preservation, it would set *Corriebaatar* apart from all other multituberculates. Given the fact that none of the few Australian Cretaceous mammals known are found on other continents, it should not seem implausible that the one multituberculate from this continent should be fundamentally different in this way. An X-ray of Wendy's jaw could possibly pick up additional holes for the roots of a second molar if one or more exist — something that should be done.

Reference

Rich, T.H., Vickers-Rich, P., Flannery, T.F., Kear, B.P., Cantrill, D.J., Komarower, P., Kool, L., Pickering, D., Trusler, P., Morton, S., van Klaveren, N., and Fitzgerald, E.M.G. 2009. An Australian multituberculate and its palaeobiogeographic implications. *Acta Palaeontologica Polonica* 54(1):1-6

Image: L Kool

Wendy's Corriebaatar *jaw the day after it was discovered. Scale in cm.*

THE MAMMALS OF VICTORIA'S CRETACEOUS

As long-time Dinosaur Dreaming diggers can attest, the tiny fragments of Cretaceous mammals that we find are celebrated and prized. But mammal jaw (and other element) finders don't always get to find out what became of their precious scrap. Here is a list of all confirmed mammal fossils from the Victorian Cretaceous, with their Museums Victoria catalogue numbers, notes and taxa.

Reg #	Taxonomy	Collector	Field Number	Year	Preparator	Notes
P208090	*Auskribosphenos nyktos*	N. Barton	#1111	1997	L. Kool	HOLOTYPE. Right. P6, M1-3
P208094	*Kryoryctes cadburyi*		Dinosaur Cove	1993	L. Kool	HOLOTYPE. Right humerus. Slippery Rock Pillar, Dinosaur Cove
P208228	*Bishops* sp.		#329	1995	L. Kool	600my Exhibition display. Right. P4-M2
P208230	*Ausktribosphenos* ?			1995	L. Kool	Edentulous jaw fragment
P208231	*Teinolophos trusleri*		Mentors trip	Nov. 1993	L. Kool	HOLOTYPE. M3 or M4
P208383	Monotremata		Dinosaur Cove	1993	L. Kool	Premolar. Slippery Rock Pillar, Dinosaur Cove
P208482	*Ausktribosphenos nyktos*	N. Gardiner	#150	1999	L. Kool	Right. M2-3, badly crushed. Found in rock from DD1998
P208483	Ausktribosphenidae ?	N. van Klaveren	#140	1999	L. Kool	Probably Left. x1 premolar & partial tooth
P208484	*Bishops whitmorei*	K. Bacheller	#450	1999	L. Kool	Right. M2
P208526	*Teinolophos trusleri*		#560	1994	L. Kool	Right. Edentulous
P208580	Mammalia	A. Maguire	#200	2000	L. Kool	Jaw fragment. (unprepared)
P208582	Ausktribosphenidae	L. Irvine	#500	2000	L. Kool	Right. M3
P209975	*Bishops whitmorei*	R. Close ?	#387	2000	L. Kool	Right. Roots M1, worn M2. OK M3
P210030	*Teinolophos trusleri*			2000	L. Kool	Right. Edentulous
P210070	*Bishops whitmorei*		Rookies day	03.12.2000	L. Kool	Right. Badly broken M1, M2 and x6 Premolars
P210075	*Bishops whitmorei*		Rookies day	03.12.2000	L. Kool	HOLOTYPE. 600my Exhibition display. Left. P2-6, M1-3. (P1 lost since initial preparation)
P210086	Ausktribosphenidae ?	J. Wilkins	#250	2001	L. Kool	Right. Root fragment
P210087	"Gerry's jaw"	G. Kool	#620	2001	L. Kool	Right. Rear half M1, M2-3
P212785	Mammalia	M. Anderson	Rookies day	03.12.2000	L. Kool	Fragment only
P212810	*Bishops whitmorei*		#300	2002	L. Kool	Left. M2-3
P212811	*Teinolophos trusleri*	D. Sanderson	#187	2002	L. Kool	Right. Edentulous
P212925	Mammalia ?		#222	1996	D. Pickering	Edentulous
P212933	*Teinolophos trusleri*		#179	2001	L. Kool	Left. Edentulous. (Plus associated molar)
P212940	"Gerry's jaw"	W. White	#171	2003	D. Pickering	Left. M1, M2-3
P212950	*Bishops whitmorei*	C. Ennis	#292	2003	L. Kool	Left. P6, M1-3
P216575	*Teinolophos trusleri*	N. Gardiner	#180	2004	D. Pickering	Left. x2 molars. Probably M2-3
P216576	Mammalia	A. Musser	#500	2004	L. Kool	Isolated tooth
P216578	*Bishops whitmorei*	A. Leorke	#600	2004	D. Pickering	Left. M1-3
P216579	*Teinolophos trusleri*	N.van Klaveren	#635	2004	L. Kool	Edentulous jaw
P216580	*Bishops whitmorei*	G. Kool	#800	2004	D. Pickering	Right. P6, M1-3
P216590	*Teinolophos trusleri*	J. Wilkins	#447	2004	D. Pickering	Posterior part of right edentulous jaw
P216610	*Teinolophos trusleri*		#557	2004	L. Kool	Left. Edentulous
P216655	*Corriebaatar marywaltersae*	M. Walters	#142	2004	L. Kool	HOLOTYPE. Multituberculata. Left. P4
P216670	*Ausktribosphenos nyktos*		#184	1999	L. Kool	Left. M2-3
P216680	*Teinolophos trusleri*	R. Long	#132	2004	L. Kool	Right. Fragment
P216720	*Teinolophos trusleri*		#648	2002	L. Kool	Right. Edentulous
P216750	*Teinolophos trusleri*	R. Long	#162	2005	D. Pickering	Right. Edentulous
P221043	*Bishops whitmorei*	A. Leorke	#100	2005	D. Pickering	Right. M1-2?
P221044	Ausktribosphenidae	C. Ennis	#300	2005	D. Pickering	Left. M2
P221045	*Teinolophos trusleri*	J. Wilkins	#395	2005	D. Pickering	Right. Edentulous
P221046	Mammalia	H. Wilson	#480	2005	L. Kool	Isolated tooth
P221150	*Teinolophos trusleri*	J. Swinkels	#340	2006	D. Pickering	600my Exhibition display. Right. x2 molars. Probably M2-3
P221156	Ausktribosphenidae	N. van Klaveren	#360	2006	D. Pickering	Right. M2 (requires preparation to confirm)
P221157	*Bishops whitmorei*	M. Walters	#585	2006	D. Pickering	Right. Edentulous with alveolae for P6, M1-3
P221158	*Bishops whitmorei*	R. Close	#200	2006	D. Pickering	Right. P5-6, half M plus M2-3
P228432	Ausktribosphenidae		scrap rock	2009	L. Kool	Right. Molar talonid
P228848	*Bishops* sp.	M. Walters	ETRW, Otways	10.12.2006	D. Pickering	Left. P6, M1, partial M2
P229037	*Teinolophos trusleri*	M. Cleeland	#91	2008	D. Pickering	Right. Edentulous with alveolae for x4 molars and ultimate premolar
P229194	Mammalia	N. Barton	#770	07.03.2007	D. Pickering	Isolated upper Premolar
P229408	*Teinolophos trusleri*	M. Walters	#300	14.02.2008	D. Pickering	Left. Ultimate premolar, M1-4
P229409	Ausktribosphenidae	N. Evered	#180	07.02.2007	D. Pickering	Possibly *Bishops whitmorei* . Left. P5-6, M1-3
P229410	*Teinolophos trusleri*	C. Ennis	#90	2008	D. Pickering	Right. ?M1 plus M3
P229649	*Bishops whitmorei*	J. Tumney	#330	2009	D. Pickering	Right. P2-3,5-6, M1-3
P231328	Mammalia	A. Maguire	ETRW, Otways	29.11.2009	D. Pickering	Maxilla fragment with x2 molars
P232567	*Ausktribosphenos* sp.	M. Walters & J. Wilkins	#270	26.02.2012	D. Pickering	Right. Broken premolars. M1-3
P232892	*Bishops* sp.	A. Werner		16.02.2013	D. Pickering	Left. ?M2
P252052	Mammalia	T. Ziegler	ETRW #626	20.02.2015	D. Pickering	Upper premolar
P252207	*Bishops* sp.	O. Campbell	ETRW #200	07.02.2015	D. Pickering	Posterior part of right mandible w x1 molar
P252730	*Corriebaatar*	W. White	Tragics day	11.11.2017	L. Kool	Multituberculata. Left. P4

Image supplied by P Gill

Did our mammals hibernate?

By Pam Gill

Last year I told you about a new project involving the Flat Rocks mammals, using high resolution synchrotron CT scanning to look at the detailed internal structure of their jaws for clues about their life history. I reported on the initial scans of two specimens that I had on loan, and noted that we were getting a further seven specimens that we were planning to scan at the synchrotron.

In collaboration with my colleagues Ian Corfe and Elis Newham, I have been investigating all three mammals found at Flat Rocks: *Teinolophos trusleri* within the Monotremata and *Ausktribosphenos nyktos* and *Bishops whitmorei* in Ausktribosphenidae. As I discussed last year, although the jaws have suffered some cracking, the internal preservation was very detailed. All nine specimens (four *Teinolophos*, two *Ausktribosphenos* and three *Bishops*) provided by Museums Victoria have been imaged at sub-micron resolution at the European Synchrotron Radiation Facility (ESRF) and Swiss Light Source (SLS).

Using a similar method to that we had used on older (Jurassic) Mesozoic mammals from outside Australia, we were initially looking at the tooth roots to count the encasing cementum rings. These give an estimate of individual lifespan count and although this Flat Rocks sample is limited in comparison, we hope to shed some light on two questions:

A. Are there differences in estimated lifespan between the Flat Rocks mammals and living mammals of similar size?
B. In the Aptian, south-eastern Australia lay within the Antarctic Circle, at about 70 degrees of latitude, so are there life history clues as to how the small Flat Rocks mammals were adapted to living through the polar winter, with months of twilight and relatively low mean annual temperatures?

To investigate this, we are looking at two histological features: the tooth root cementum, and the development of secondary osteons in the bone.
Tooth root cementum is a continuously growing dental tissue, wrapping around the tooth roots and which has incremental annuli (growth rings), from which an individual's age at death can be assessed. Osteons are cylindrical structural units of bone, with a diameter of about 200 microns. Secondary osteons are sometimes later produced by remodelling of bone, due to micro damage, and are rare in small animals (such as small rodents) which are unlikely to experience high loading demands. However, they are more prevalent in mammals with longer lifespans allowing time to create significant damage.

So far, analysis of cementum annuli has produced two clear examples: an *Ausktribosphenos* with three annuli and a *Bishops* (NMV P208484) with 2.5 annuli (Figure 1). Even two and a half years is a longer lifespan than would be expected for a mammal of such small size (about 8 g for *Bishops*). These two specimens have developed hardly any secondary osteons, but another *Bishops* specimen (P209975) has notably more remodelling and development of secondary osteons (Figure 2), suggesting a longer lifespan for this individual. It also has far more advanced tooth wear (Figure 2 inset). While relative degree of tooth wear cannot be an absolute indicator of age at death due to individual dietary variation, it is suggestive of a lifespan beyond two and a half years.

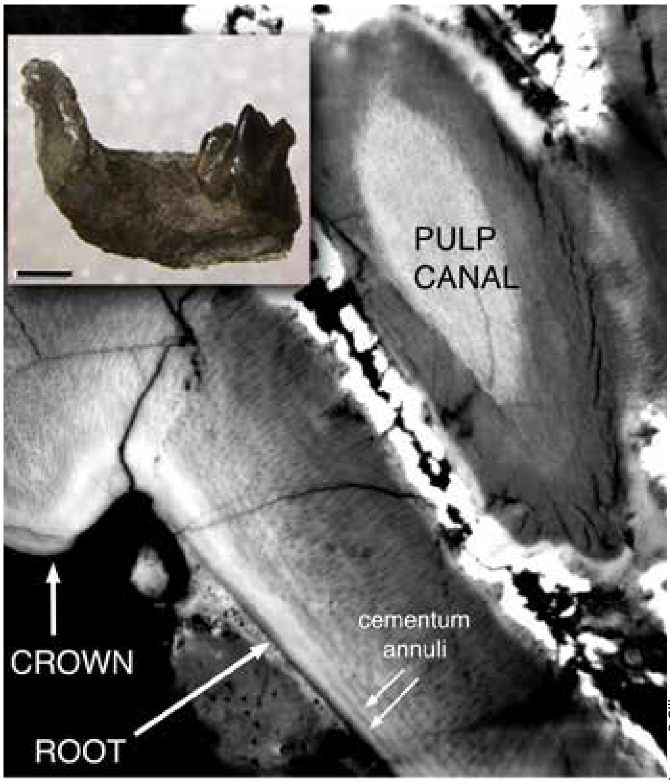


Image: P Gill

Figure 1. P208484. Bishops whitmorei*, showing the cementum annuli. This specimen gives a count of 2.5 years. Scanning at TOMCAT beamline, SLS.*
Inset shows the specimen in buccal view. Scale 1 mm.

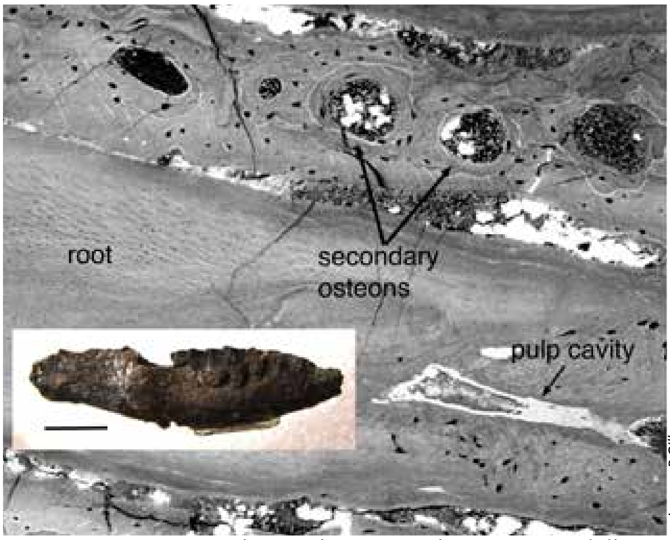


Figure 2. P209975. Bishops whitmorei*, showing remodelling and development of secondary osteons.*
Inset shows the specimen in buccal view. Scale 2 mm.

So far then, we have evidence for a relatively long lifespan in at least one taxon (*Bishops*) of these Flat Rocks Cretaceous mammals. A strong correlation between body mass, lifespan, and basal metabolic rate (BMR) has been reported (De Magalhães *et al*. 2007), so, by estimating lifespan and body mass, we are also able to provide an estimation of metabolic rate for our Early Cretaceous mammal fossils. The longest living extant mammals of similar small body size are all heterotherms, with the ability to enter short periods of torpor or longer periods of hibernation in which body temperature and metabolic rate are both considerably decreased. We suggest that, as our data provisionally shows at least one ausktribosphenidan to have had an extended lifespan, they likely had low metabolic rates and/or entered a state of torpor or hibernation as a strategy to survive the polar winter. Turbill *et al*. (2011) conclude that hibernation is a physiological mechanism permitting small mammals to remain dormant and increase survival when conditions are not optimal for reproduction, which appears to have co-evolved with a relatively slow life history.

Regarding larger members of the fauna, analysis of bone microstructure in Cretaceous dinosaurs from Victoria provides no evidence to support seasonal hibernation (Woodward *et al*. 2018). Although encouraging caution with small sample sizes, as is also the case here for the mammals, they suggest that important life history insights at the individual level are still obtainable and critical for foundational knowledge. So this recent work suggests that the *Bishops* in Figure 3 should perhaps have been asleep!

We suggest that the use of nondestructive Synchrotron Radiation Computed Tomography (SRCT) gives access to the life histories of the small mammals inhabiting the Cretaceous southern polar ecosystem that would otherwise be unavailable. For future work, we plan to revisit the scans for all those individuals with preserved cementum, and see if the rings can be made clearer. This sounds like a quick task, but the scans contain huge amounts of data and it needs quite some time! Museums Victoria has also kindly loaned a further eleven specimens, and we hope to scan those at a future synchrotron visit. We plan to also investigate whether we can see growth rate lines in the tooth enamel, and compare them to those for living mammals. This really is pushing the preservation and scanning possibilities to their limits, but fingers crossed!

I presented our findings on these investigations into the possible life history of the Flat Rocks mammals at an international palaeontological conference in Germany, and it generated a lot of interest — including an interview on German radio! So, I want to thank you all for making this possible, from the dedicated hard work by all the people involved in the dig, to the preparation and care of the specimens in the museum, and those who carried the specimens with such care for us. And, of course, to Tom and Pat for their continuing interest and help with our work.

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Turbill, C., Bieber C., and Ruf T. 2011. Hibernation is associated with increased survival and the evolution of slow life histories among mammals. *Proceedings. Biological Sciences* 278: 3355–3363.

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Figure 3. Detail from a reconstruction by Peter Trusler illustrating Bishops whitmori *active in the Cretaceous winter*

Prospecting Report

By Mike Cleeland

Relatively little prospecting was done in the Victorian Cretaceous in 2018 as the National Parks Research Permit expired, limiting the amount of time that could be spent at the known sites.

A highlight was the discovery of a possible Ankylosaurid vertebral element from the "Honey Locality" between The Caves and Eagles Nest. This bone has now been collected and is scheduled to be scanned before preparation. If its identification can be confirmed, it would add valuable information to our knowledge of Australian ankylosaurs — *Minmi* and *Kunbarrasaurus* (both from Queensland) are the only named ankylosaurs from a relatively meagre collection of specimens. It remains now to determine whether our new fossil belongs to either of these taxa or to something new.

Three smaller bones including one found by Asti Fletcher at Ferguson's layer and two others on the shore platform near Eagles Nest have also been collected, showing that this traditionally significant site continues to produce a modest number of fossils.

Outside the Cretaceous, several small trackways and footprints were found in Pleistocene sediments between Darby River and Wilson's Promontory. Sand movement in this area may continue to expose more of these ichnofossils.

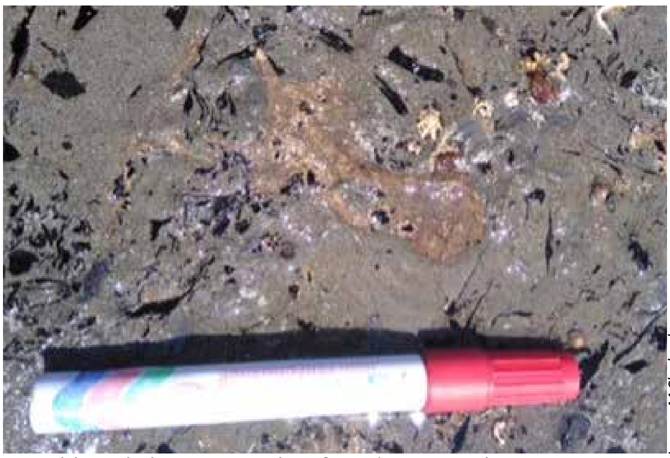


Image: M Cleeland

Possible ankylosaur vertebra found near Eagles Nest

The Next Generation of Diggers

By Amber Craig

As an alternative to this year's dig, Dinosaur Dreamers Tim Hain, Asti Fletcher and I were fortunate enough to be chosen to work with Mike Cleeland at Bunurong Coast Education in Inverloch, introducing school groups and families to the exciting world of Victorian dinosaurs.

Our training day early in the year was definitely a dive into the deep end as Mike lost his voice and his teaching instructions were delivered through a whisper.

We took two groups through a short introduction inside the Inverloch Education Centre, in which we:

- shared what the day would hold;
- learnt what a fossil looks like outside of the movies;
- explained the Australian environment at that time.

We then spent time on the beach where we showed our new friends the classic dinosaur footprint and hunted for dinosaur bones in the shore platform… SUCCESS! Dinosaur bones were found and met with beaming smiles from kids and parents!

After that we went to Wallace Avenue Community Park, which houses the sculpture of *Koolasuchus cleelandi,* to break rock with mashies in search of more fossils — one lucky youngster walked away with an almost complete fish skeleton!

Each of the two groups were different but had the same boundless excitement and enthusiasm for dinosaurs. Sometimes it was hard to tell who was more excited – the kids or their parents. It was incredible to see everyone so engaged and enjoying discovering what is right in our backyard! Who knows, some of those who joined us may be Dinosaur Dreamers in a decade's time? If so, I think we have some good rookies on the horizon.

Image: A Craig

Fossil dinosaur bones found on Amber Craig's training day

On the Beach

By Sharyn Madder

Image supplied by L Porro

Finding Noddy

By Laura Porro

Ask someone to picture a palaeontologist and most people envision a rock hammer-wielding field worker roaming badlands in search of new fossils or perhaps a white-coated lab technician using dental tools to carefully prepare specimens. Alternatively, some might think of scientists with privileged access to the vaults of the world's great museums, poring over the remains of thousands of extinct animals.

While all of these portrayals are true to some extent, palaeontology, like many scientific disciplines, has experienced a digital revolution. Over the past two decades, huge leaps in imaging and computer technology has resulted in new methods to discover, prepare, and study long dead organisms. One fossil critter now benefitting from this cutting-edge technology is "Noddy".

Noddy was discovered in 2010 by prospector Mike Cleeland at the Flat Rocks site along the Bass Coast of Victoria in sediments dating from the Cretaceous, about 120 million years ago. The fossil's nickname derives from the fact that the specimen was encased in a peanut-shaped sandstone concretion, or nodule. The nodule was found in the intertidal zone and was covered with marine growth. As the algae and seaweed were cleaned off, tantalizing hints emerged suggesting a special fossil might lie within. The Dinosaur Dreaming team carried out a CT scan of the nodule at St Vincent's Hospital in Melbourne. CT (also known as computed tomography or CAT) scanning uses X-rays taken from

Mike Cleeland holds Noddy in 2010

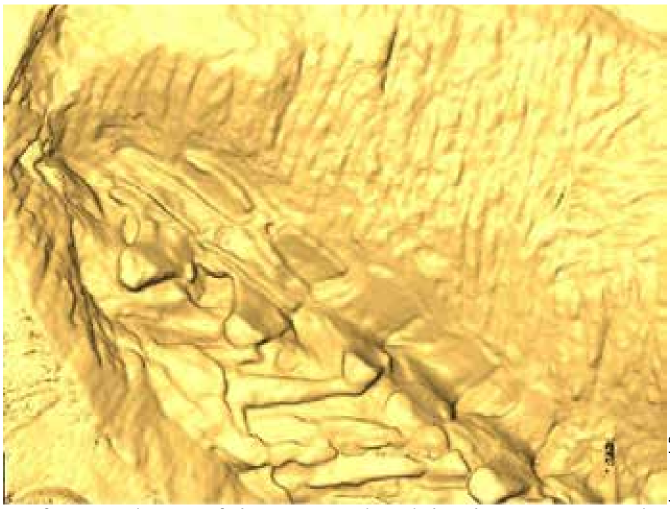


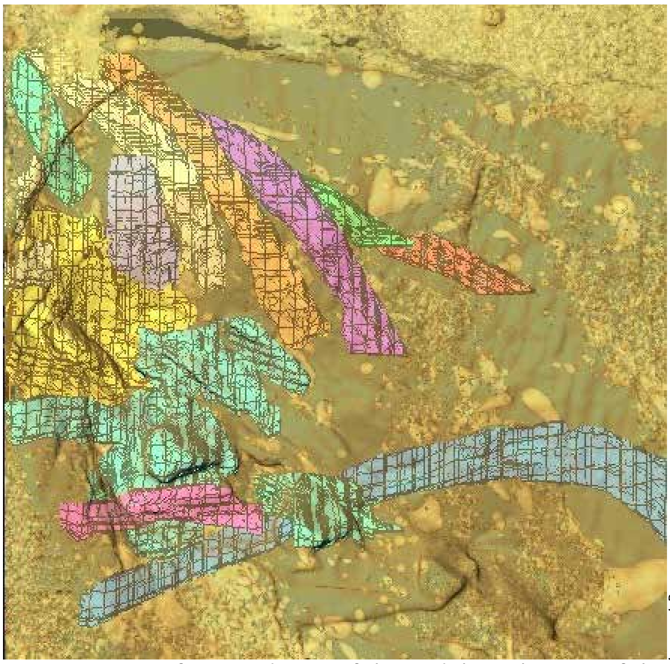
Image: L Porro

Surface rendering of the prepared nodule, showing exposed processes of the vertebrae of the lower back

different angles to produce virtual slices of an object and is commonly used in medicine. To minimize radiation dosages for human patients, medical CT scanners are low energy and have trouble penetrating dense materials, including the Flat Rocks nodule. Although these first CT scans were very grainy, they confirmed the team's hunch – the nodule contained a nearly complete dinosaur skeleton!

The team decided to prepare the nodule. Physically preparing fossils is risky. In the case of Noddy, scientists realized that removing rock could result in damage to the specimen. To reduce the chance that the fossil would fall apart, the original exposed side of Noddy was stabilized using a steel mesh and silicon. Then, the nodule was turned over and the second side prepared. Scientists could now see that the nodule preserved part of the skull and vertebrae (back bones). They knew from the CT scan that more of the dinosaur's skeleton was preserved within the nodule; however, stripping away additional rock would be very risky. Furthermore, the nodule was now encased in a metal mesh that a medical CT scanner could never see through.

In order to see more of Noddy the specimen was taken to the Australian Synchrotron in Clayton Victoria. A synchrotron is a type of particle accelerator that can produce large X-ray beams at very high energies — high enough to penetrate rock and even metal. The synchrotron was powerful enough to see through the supporting metal mesh and distinguish between fossil bone and rock deep inside the nodule without physically endangering the specimen. The resulting data set was enormous – the synchrotron produced over 6,700 digital slices through the specimen, over 140 GB of imaging data.



Transparent surface rendering of the nodule with some of the segmented vertebrae and ribs shown in colour, demonstrating bones preserved deep within the nodule and visible only in scan data

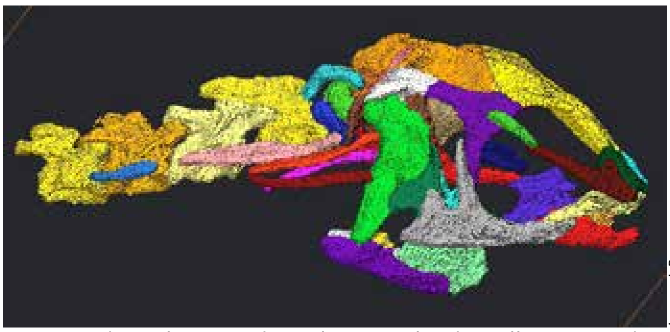
The next part of the project involves visualising the specimen using state-of-the-art software and computers powerful enough to handle the massive data set. The most time-consuming step is segmentation, which requires digitally separating out different materials. Sometimes this process can be automated; unfortunately, in the case of Noddy, the fossil bone and surrounding rock have similar densities and must be distinguished by a trained eye and a steady hand working slice-by-slice through the entire data set. Just as with physical preparation, the process is both long and arduous but also exciting — slowly but surely, the entire fossil is digitally extracted from the surrounding rock and individual bones begin to emerge. There is a thrilling moment as a bone buried deep within the rock or exposed as only a sliver on the surface can be clearly identified as a bit of skull, a limb or part of the spine.

So what do we know about Noddy so far? Noddy was small – smaller than a modern squirrel. It belonged to a highly successful group of dinosaurs called ornithopods, which ranged from tiny animals such as Noddy to huge Hadrosaurs (duckbills) weighing close to 20 tonnes. Noddy was bipedal (it walked on two legs) and probably a fast runner. We also know that Noddy was a plant-eater and, in fact, the fossil preserves what appear to be carbonized seeds in the region of the gut, possible evidence of a last meal. In addition to the bones of the skull roof and vertebrae exposed in the prepared nodule, scans reveal bones of the snout, palate, braincase and lower jaw, as well as a large number of ribs and some limb bones. Oddly, there appears to be only a single tooth preserved in the specimen — however, this may be pivotal in determining whether Noddy belongs to one of the known species of small ornithopods from Victoria or represents an entirely new species. Finally, Noddy features enormous orbits (eye sockets), a short snout and loosely joined bones, all evidence that it was probably a very young animal.

The process of digitally preparing Noddy is ongoing but, when complete, will allow a detailed description of this intriguing specimen, possibly representing a new species of Australian dinosaur. Perhaps most exhilarating is the prospect of digitally reconstructing Noddy in 3D. Fossils are usually incomplete and suffer millions of years of damage and deformation. The segmented scan data can be used to generate 3D models. Disarticulated bones can be realigned, small breaks or missing regions repaired, and bones preserved on only one side of the body mirrored and restored on the other side. And of course, the digital bones can be manipulated in 3D space to reassemble the skull or even the entire skeleton with zero risk to the original, fragile fossil. An ultimate aim of this project is to produce a 3D digital reconstruction of the preserved Noddy skeleton to get an accurate picture of what this tiny dinosaur looked like in life. Finally, digital models can be converted to accessible formats (such as 3D PDFs) and 3D printed, a wonderful future resource for museum exhibits, education and outreach.

So stay tuned for further updates and future publications on Noddy, the little polar dinosaur that is slowly (and digitally) coming into the light!

Laura Porro is from the Department of Cell and Developmental Biology, University College London.



Processed synchrotron data showing the digitally prepared bones of the skull and neck of Noddy

Image supplied by H Woodward

Dinosaur Growth Rings

By Holly Woodward

In 2010, I received an East Asia and Pacific Summer Institutes (EAPSI) grant from the National Science Foundation to study the bone tissue microstructure of fossils from wallaby-sized hypsilophodontid (ornithopod) dinosaurs that lived in Victoria 112 million years ago. The dinosaurs of Victoria were living in very unique conditions compared to dinosaurs elsewhere: a cool, semi-annually dark environment within the Antarctic Circle. I wanted to know if their physiology or growth rates were different than those of their lower latitude relatives. Looking at the microscopic tissue of fossil bone reveals this about a vertebrate, as well as how old it was when it died and whether or not it was fully grown. For this project, I teamed up with Tom Rich and Pat Vickers-Rich, who have spent years collecting and studying these interesting dinosaurs. The results of our collaboration were published in *PLoS ONE* in 2012. We found that the little hypsilophodontids had annually forming growth rings, just like their relatives living elsewhere, and that their bone tissue organization also very closely resembled them. Essentially, the patterns in bone tissue showed us that the hypsilophodontids living in Victoria were physiologically similar to those living in milder climates. This was actually an amazing discovery, because it showed that the ancestors of the dinosaurs in Victoria already possessed the physiology necessary to survive in such a unique and stressful environment — their metabolism, growth rate, and growth trajectory were ideal for moving into the Antarctic Circle and surviving the pressures of living there.

I have continued collaborating with my colleagues from Australia, as there is more to learn about hypsilophodontids from Victoria. For our next project, we took a detailed look at the bone tissue thin section slides produced by our original project, to get a better idea of the ontogeny (life history) of these dinosaurs. The results of our study were published in *Scientific Reports* in January 2018. By studying the bone tissue of seventeen hypsilophodontids, we produced the first life history reconstructions for these small Australian polar dinosaurs. Growth rings (like tree rings) helped determine individual age. Bone fibre orientation, blood vessel density and the amount of bone between growth rings quantified annual growth rates. Bone histology revealed that, in general, growth was most rapid during the first three years of life, and the dinosaurs were fully grown — as big as a medium-sized wallaby or normal-sized turkey — in five to seven years.

The hypsilophodontid samples were recovered from two localities along the southern Victorian coast, that are geologically separated by about 12 million years. Despite this, the trend of rapid growth for three years followed by adult body size between five and seven years was conserved across both samples. Given the geologic time involved, there may be several polar dinosaur species in this sample, but their growth trajectories are so similar that we cannot differentiate them based on their growth patterns and rates alone. Instead, our life history assessment demonstrates that this generalized growth trajectory was a successful lifestyle for surviving in a region experiencing unique conditions.

The tibia (shin-bone) of one hypsilophodontid individual in the sample had clearly suffered from a pathologic condition known as osteomyelitis. Histologic examination revealed the cause of this pathology was most likely a broken bone, which then became infected. Counting the growth rings preserved in this tibia prior to the formation of the pathologic bone, the team was able to place the injury as having occurred when this individual was approximately four years old. Histologic examination of the unaffected femur (thigh bone) of this individual demonstrates that it survived with the injury and pathology for three more years.

We are now studying the bone tissue of this injured individual in detail, and hope to present the results of this work in the near future.

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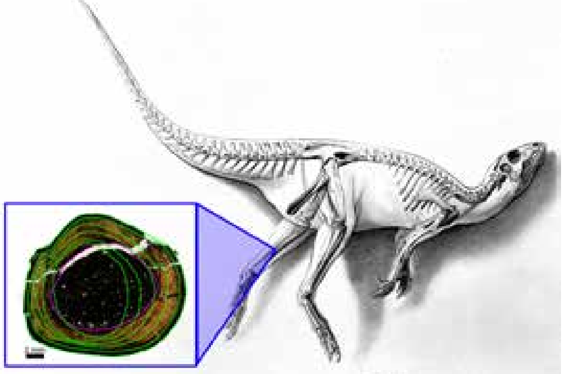

Image: H Woodward, reconstruction by P Trusler

Growth rings (outlined in green)

Recently Prepared Fossils

By Darren Bellingham

P253862 Ornithopod jaw found in 2016

P254120 Ornithopod vertebra found by James Rule in 2015

P254137 Theropod caudal (tail) vertebra found in 2014

Image: L Kool

Gingko found in 2018

P254150 Possible dinosaur braincase found by Darren Bellingham in 2016

P254153, P252697 Ornithopod teeth found in 2017

P254004 Araucaria cone found by Mary Walters in 2017

P254113 Ornithopod vertebra found by Mary Walters in 2014

P253799 Ornithopod humerus found in 2017

Image: L Kool

Ornithopod femur found at ETRW in 2017 being prepared by Alison Dorman

P254134 Possible ornithopod ilium (pelvic bone) found by David Pickering and Alan Tait in 2016

Image D Hocking

Giant Shark a Matter of Taste

By Tim Ziegler

An assemblage of over 30 fossil teeth from an eight-metre Oligocene shark, *Carcharocles angustidens*, was unveiled at Melbourne Museum on 9 August, 2018. The Jan Juc area find was not only a national first, but also included unique evidence that ancient sixgill sharks (*Hexanchus* sp.) scavenged the predatory giant's corpse on the seabed. The first tooth was found in 2015 in a boulder from the Jan Juc cliffs by a local teacher, Phil Mullaly, who subsequently contacted Museums Victoria. Phil is a keen fossicker along the Surf Coast, and has donated many fossils (including elements from whales, sharks, fish, invertebrates and amber) to the State Collection. Teeth belonging to *C. angustidens* were first distinguished by geologist Louis Agassiz over 180 years ago — since then, fossils have shown that it lived throughout the world's temperate oceans for a period of at least 10 million years. But despite the species' cosmopolitan abundance, associated dentitions of *C. angustidens* are incredibly rare. Phil's find on the Surf Coast was only the third worldwide, and the first in Australia.

Reaching the boulder at Jan Juc required either wading around points or clambering over boulder debris for about a kilometre from the nearest access. As the silty marl gradually eroded with each high tide, Phil

Image supplied by T Ziegler

Food writer and MasterChef Australia judge Matt Preston (joined here by Erich Fitzgerald and Tim Ziegler) reckons sixgill sharks are good eating

Image: D Hocking

The largest tooth from the Carcharocles angustidens *dentition (P253864) is nearly three inches along its edge*

collected more than a dozen teeth, with complete roots and finely preserved serrations. We first visited the fossil site with Phil in December 2017. The ocean tides meant that we only had a few hours at a time before the site was swamped; nonetheless, more teeth were quickly spotted on the boulder surface. Hand tools were enough to clear away surrounding marl and isolate teeth for strengthening and collection. While investigating, two circumstances arose that surprised us. Firstly, there were many more fossil teeth preserved at this spot, beyond those already recovered by Phil. Most shark fossils are found as single teeth, with multiple teeth from the same animal found only rarely. Secondly, although the teeth we were finding belonged to *C. angustidens*, and were of comparable size to those already found, they were of very different condition.

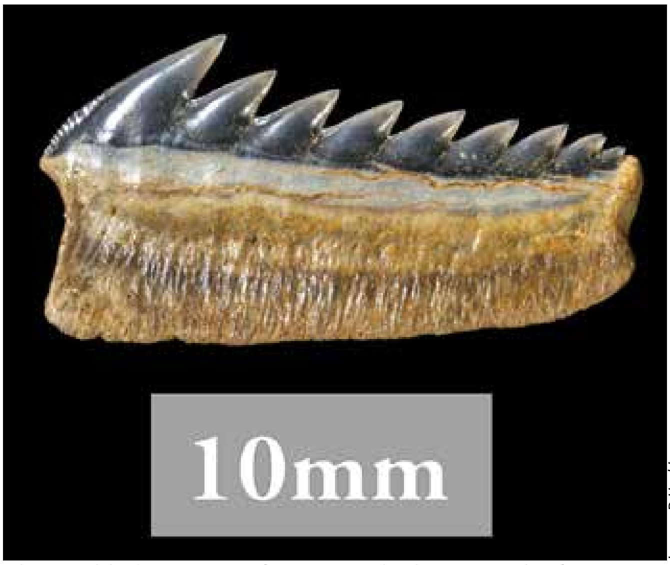

Image: D Hocking

The sawblade pattern of cusps on the lower teeth of Hexanchus sharks efficiently removes flesh from carcasses (P253894)

The teeth Phil had shown us earlier were complete, with bulbous roots and well-preserved enamel, and fairly impermeable to thin consolidant glues. Now, with the tide beginning to wash in and our time shortening, we found fragile, fragmentary teeth that comprised only a thin enamel shell. There was no root, and the blade of the tooth was hollow and infilled by marl. These teeth didn't match the aesthetic quality of Phil's early discoveries, but were scientifically exceptional. Importantly, the fragile replacement teeth could not have survived scattering, transport and accumulation at this point on the seabed. What we had were not the naturally shed teeth of an individual cruising the Bass Strait basin, but partially formed replacement teeth from further back in the jaw.

As we collected, excavated and prepared the *C. angustidens* fossils, we also periodically found smaller, low-slung sawblade-shaped shark teeth. These clearly belonged to a different species — specifically, the sixgill shark, *Hexanchus* — but were found amongst the teeth of the mega shark. Fossil remains at Jan Juc are not usually found grouped in one place. If the teeth had passed through the acidic gut of the *angustidens*, their blades would have been stripped of enamel. There are no signs of digestion, but several sixgill teeth are chipped and broken, and they all appear to be shed, adult teeth. Sixgill sharks still live in the ocean today, where they grow more than six metres in length. As adults, they spend more time in deep waters, where they have been observed scavenging the carcasses of whales. A carcass such as that of the *C. angustidens* would likely have attracted sixgills from kilometres away, with the normally solitary sharks tolerating large congregations as long as food was available.

The museum commissioned Peter Trusler to provide in-life depictions of the animals whose remnants we had found. This culminated in a minutely detailed reconstruction of *C. angustidens*, printed as an eight-metre (life-sized) wall panel in the Melbourne Museum foyer. The image of the shark in profile was so large it had to be displayed diagonally — even then, we couldn't find a space big enough to fit the whole body. Peter also conceived a reconstruction of the giant shark in death, as it was stripped of flesh by the scavenging sixgills. This scene includes such characteristically Truslerian details as the defleshed vertebra of a toothed mysticete whale, fish known from the Jan Juc Formation, and the characteristic silt, mud, and shell debris of the strata.

Image: P Trusler

Artists's reconstruction of the post-mortem scavenging of a giant shark. Scenes like this have occurred off Victorian shores for tens of millions of years.

Return to Koonwarra

By Stephen Poropat

The Koonwarra Fossil Bed has produced a plethora of fossils in the six decades since it was discovered in 1961 by road workers who were straightening and widening the South Gippsland Highway. The majority of these fossils were collected through systematic excavations in the 1960s by University of Melbourne, Geological Survey of Victoria and Monash University crews, a dedicated dig in 1981 coordinated by the University of Melbourne and the National Museum of Victoria (now Museums Victoria), and by curious amateurs who took an interest in the site.

Since the 1980s, only two major excavations have been held at the Koonwarra Fossil Bed. One of these was held in April 2013. The motivation for it was Tom Rich's hypothesis that the Koonwarra site had the potential to preserve fossil skeletons of Cretaceous tetrapods, rather than "just" the feathers, fish, invertebrates and plants for which it is rightfully renowned. This idea was based on similarities in the preserved biota in the Koonwarra Fossil Bed and the now-world famous Jehol Group of China, which has produced an abundance of feathered dinosaurs over the last few decades.

Between April 2013 and March 2018, no palaeontological excavations took place in the vicinity of Koonwarra. However, over the past twelve months Major Projects Victoria has embarked on a project that will see the South Gippsland Highway shifted some distance from its current position. This will result in it no longer running right past the site. From our perspective, this is great news, for two main reasons.

The first reason is that it will make conducting fieldwork at the Koonwarra site much safer. As it stands, it is not too hazardous: there is a reasonably large, albeit overgrown, flat area near the site where vehicles can be parked fairly safely, and the site itself is away from the road. Indeed, there are few reasons why any team members would need to cross the road, unless one wants to survey the original discovery site (north of the road) or follow the stratigraphic section along the nearby rail trail (as Tim Ziegler and I did). Nevertheless, we need to bear in mind that vehicles approaching the vicinity of the fossil site from the eastern end do so blindly because of a curve in the road. Consequently, it is necessary to set out witches hats and flashing yellow lights along the curve to alert motorists of the ongoing excavation. Once the South Gippsland Highway has been shifted, few (if any) vehicles will have reason to pass by the site, meaning that it will be far safer to dig there — not to mention less noisy.

The other reason that the shifting of the South Gippsland Highway is good news for fossil nuts like us is that roads that cross rivers or valleys or are otherwise elevated above the surrounding countryside need solid supports with deep foundations. This means that Major Projects Victoria workers will be digging through a substantial amount of rock in order to lay bases for these road supports. You can guess where this is going — the rocks that underlie all of the rolling hills in the hamlet of Koonwarra are part of the Upper Strzelecki Group, as are those at both the Koonwarra and Flat Rocks sites. Given that Major Projects Victoria will be freshly exposing Cretaceous rocks on an unprecedented scale, it is possible they might find another Koonwarra-like site — or perhaps a site of even higher quality!

In March 2018, Tom Rich and Pat Vickers-Rich asked a small team of Dinosaur Dreamers to participate in a week-long excavation at Koonwarra. The purpose of this particular expedition, perhaps surprisingly, was not really to find fossils, although we knew we would do so as a matter of course. The Koonwarra site is, after all, prolific. Instead, the purpose was to collect blocks of Koonwarra rock for the purposes of Computed Tomography (CT) and synchrotron scanning. The hope was that fossils preserved within the rock would be visible in the scan data. This would mean that we could remove large slabs of rock from the site, then scan them at a hospital or the Australian Synchrotron to determine how carefully they should be broken up, if at all.

Image: S Poropat

Tim Ziegler and John Wilkins excavating rock


Image: L Kool

Gary Wallis loading rock onto his trailer

When the crew arrived at site on the first day, we found it hideously overgrown. The prospect of spending the whole day pulling up plants by hand and shovelling dirt in order to get down to the deposit — especially for such a small team — was not exactly appealing. We were all relieved when Gary Wallis, a geologist who had prospected at Koonwarra back in the 1960s and 1970s, joined the team with his tractor. What would otherwise have taken the team a day was achieved in less than an hour.

I'd never seen the actual deposit layer at Koonwarra before, but I vaguely knew what to expect from photographs and published descriptions of the site. Sedimentary layers that were deposited horizontally are now tilted up at a steep angle, so digging laterally takes you through time rather than through a single layer. Digging downwards into the hill, on the other hand, enabled individual layers to be followed. We found that one layer was particularly well separated from those below, making it ideal for us to focus on. With Dean and John doing the bulk of the jackhammering, the aim was to remove sections around 10–15 cm thick, and about the size of an A4 page.

Unfortunately, no matter which system we implemented, getting blocks out proved to be extremely difficult. The only system that worked even remotely well was to slide a steel plate in the gap between two beds. Once the plate was in position, we attempted to break the rock closest to the unexcavated face; this was tricky, but achievable. Once detached, we then attempted to lift the plate with the rock in place above. Unfortunately, because of the way in which the rock has been affected by weathering, the block did not stay in one piece once it was free — instead, it broke into numerous pieces, sitting loosely on the board. To overcome this problem, the surface of the block was plaster jacketed, keeping all of the pieces in place.

We were originally intending to remove 30–50 blocks, but, by the end of day three we'd barely managed one. At that point, Tom actually seemed satisfied that one block would do — after all, scanning is a nondestructive process, so we could just subject that single block to scanning at the hospital and the Synchrotron.

In the meantime, the rest of the team broke rock. Unsurprisingly, given that this was the Koonwarra Fossil Bed, we found partial fish and plant specimens, including several beautiful ginkgo leaves. We even found a few invertebrates — a damselfly naiad ("nymph"), several mayfly larvae, and a single adult cicadelloid, which looked to the untrained eye like a tiny, squished cicada. Sadly, we did not find any feathers or any tetrapod remains. Maybe one day…

Once the digging was done, the single block exhumed from the Koonwarra site was ready for scanning. We took the freshly excavated block, as well as a few large Museums Victoria specimens with prominent fossils, to both St Vincent's Hospital and the Australian Synchrotron for scanning. Unfortunately, as far as we have been able to ascertain, neither scanning mode revealed anything within the rocks, nor at the surface, even when a fish, feather, plant or invertebrate was easily visible. Nevertheless, these data still need to be processed properly — maybe when that is complete, the story will be somewhat different.

At this point, with excavations ongoing in the area and Mike Hall enthusiastically mapping the local geology, we're hoping that a new Koonwarra-like site might be situated not too far from the one amazing site of which we are already aware. One potential fossil site that Mike has identified is located so close to the present South Gippsland Highway that it would not be safe to now work it. However, it is on a section of that road that will be bypassed by the realignment of the highway. When that occurs in a few years time then we should make a major effort to test that locality for its fossil potential.


Image: L Kool

Mayfly larva found by Mary Walters

Between a Rock and a Hard Place

By Lesley Kool

The initial purpose for the field trip to the Koonwarra site in March 2018 was to find a method whereby large blocks of fossiliferous rock could be cut from the fossil layer and then encased in plaster jackets. Unfortunately, once the blocks were cut and attempts were made to extract them, they tended to break into smaller pieces. The first block was plaster jacketed but it became obvious that the exercise would not work on a larger scale. It was then decided to remove the largest blocks we could without rock sawing. These blocks were placed in large bags and transported to Gary Wallis's property nearby, where they were stored until they could be processed in the future.

As mentioned in Poropat 2018, Peter Duncan had experimented in the 1960s with weathering some of the Koonwarra rock in an effort to make it easier to break apart and expose the fossils. We had always been told that they split "like the leaves of a book". Following the dig Tom Rich asked me if I could try to emulate Peter's experiments and find a way to cause the rock to break apart naturally.

Over the next few months I tried various methods with differing results.

My first effort was to try and duplicate Peter Duncan's experiments in exposing the individual blocks to natural weather conditions. I found that rocks that were exposed to more than 10 mm of rain quickly developed cracks, some parallel to the bedding planes but also as many perpendicular to the bedding planes. If the block was left outside for a week or more, exposed to a few showers of rain, it quickly disintegrated into small cuboid blocks and lost all integrity.

Images: L Kool

Block A before rain

Block A after 10 mm rain

Block A on day four

Block D in freezer

Block D on day two

Block C in water

Block C wicking water

I also experimented with blocks placed in plastic trays and kept out of the environment. Blocks sitting up off the floor of the tray were sprayed with water on all sides except the ventral surface. Cracks developed slowly and it took a number of spray applications to develop substantial cracking, resulting in cracking both parallel and perpendicular to the bedding planes.

The most dramatic result came from applying a small amount of water (less than 100 ml) to the bottom of the tray and allowing the water to wick up the block from below. Even with a small amount of water the blocks quickly disintegrated into small fragments.

Next I tried wetting individual blocks on all surfaces and then freezing them for 24 hours. I then allowed the blocks to thaw and examined them for evidence of cracking. This method seemed to have very little effect on the blocks.

I also tried wetting and heating the blocks to see if, as the water in the rock evaporated, it might force cracks to appear. This method also produced poor results, with very little cracking.

I am forced to conclude that I was unable to duplicate Peter Duncan's success. In fact we had more success recently when a group of Dinosaur Dreamers joined me for a weekend rock-breaking and we were able to split the blocks just as well with hammers as the various wetting methods.

I am open to suggestions on how to tackle this problem, so please let me know if you know the secret of the Koonwarra rocks.

Reference:

Poropat, S.F., 2018. The Koonwarra Fossil Bed. Ferns, flowers, fleas and fish... and feathers for good measure! *Australian Age of Dinosaurs Museum of Natural History Annual* 15, 64–82.

Of Dragons and Damsels

By Elaine Anderson

“Do honours”, they said. “It’ll be fun”, they said. Ok, so no one actually said it would be fun (apart from maybe Stephen Poropat). It was definitely the most challenging year of my life, but I can’t complain as I got to work on some incredible specimens from the famous Koonwarra fossil beds from the Victorian Cretaceous.

This year, I have been working on the Odonata specimens (dragonflies and damselflies), comprising four dragonfly naiads, nine damselfly naiads and a partial dragonfly wing. All specimens, apart from one of the damselfly naiads, were described by Jell and Duncan in their 1986 paper. The odd one out was found in March 2018 by a small team, led by Tom Rich.

So, what did I find? The main aim of my report was to redescribe the specimens. Since that original paper, a few researchers have pointed out discrepancies in the original descriptions and classifications. However, these remarks were only done in an informal manner and without supporting evidence. That is what I set out to correct.

Firstly, I removed all dragonfly naiads from the classification of *Peraphlebia tetrastichia* (the adult wing fragment). It is almost impossible to link a naiad with an adult, unless it is an extant species that you can raise in the laboratory. Very few, if any, features are seen in both naiad and adult odonatans.

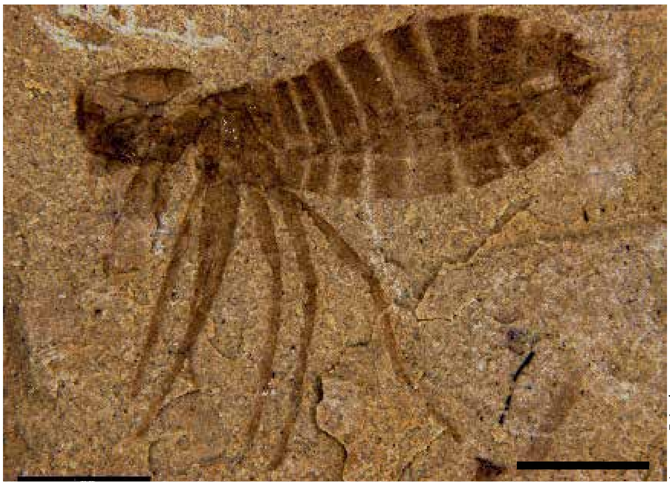

Image: E Anderson

Niwratia elongata*, dragonfly naiad. Scale 1 mm.*

Next, I removed *Niwratia elongata* from the classification of Siphonaptera (flea) and placed it within Odonata. It is clear that this specimen is a dragonfly naiad due to the presence of unique features:

- retractable, distinctive mouthparts; and
- an anal appendage (called an anal pyramid) consisting of two paraprocts and an epiproct.

This specimen looks very similar to another of the dragonfly naiads, which indicates that it is likely that these two specimens are in the same family. However, it can’t be said that they pertain to a different genera or species, because odonatan naiads can moult up to 15 times before becoming an adult, and after each moult they can look quite different. Therefore, they could be different stages of the same genus or species of naiad.

The rest of the odonatan naiads were described and compared to one another, and to other fossil naiads which have been found. All family titles were removed from the naiads, as none of them had enough details preserved for a concrete placement within a family. Families were suggested for a few. I followed the advice of my brilliant supervisors, Stephen Poropat and Sarah Martin, that it was more important to accurately describe the specimens than to try and lock them into a certain taxon.

Lastly, I tackled the *Peraphlebia tetrastichia* wing. Similarly to the naiads, I removed its family classification. This was because the wing is missing the basal portion (the area closest to the body), which contains the veins which are the most taxonomically diagnostic.

The environmental indication for these specimens will require a bit more study, potentially as part of my first scientific paper! However, they do add to the bigger picture of the Victorian Cretaceous.

Reference

Jell, P.A. and Duncan, P.M. 1986. Invertebrates, mainly insects, from the freshwater, Lower Cretaceous, Koonwarra Fossil Bed (Korumburra Group), south Gippsland, Victoria. *Memoir of the Association of Australasian Palaeontologists*, 3: 111–205. ISBN 0 949466 02 6

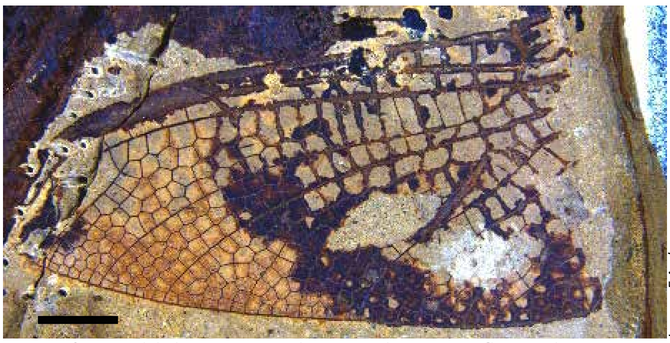

Image: E Anderson

Part of Peraphlebia tetrastichia*, adult dragonfly. Scale 1 mm.*

Image supplied by S Martin

The Koonwarra Factor

By Sarah Martin

The Lower Cretaceous rocks of Victoria are a palaeontological treasure trove, providing insights into the evolution of numerous groups of animals and plants in a high-latitude continental setting, at an important time in Earth history. The importance and breadth of this record was neatly highlighted by a summary recently published in *Alcheringa* (Poropat *et al*. 2018), to which I had the privilege of contributing summaries on the various invertebrate groups.

As a palaeoentomologist, I was already keenly aware of the importance of the Victorian Early Cretaceous record in understanding the evolution of the Australian insect fauna. Virtually everything we know about Australian insects in the Cretaceous comes from Victoria, specifically from a single site — the Koonwarra fossil bed. A *lagerstätten* in every sense of the word, Koonwarra has contributed thousands of well-preserved fossils, including plants, fish and invertebrates, to the fossil record. As our recent review illustrated, none of the other Early Cretaceous localities in Victoria approaches the Koonwarra assemblage in the sheer number or diversity of invertebrate fossils recovered. An additional bonus is the impressive preservation of the fossils, mostly whole-body compressions within the fine siltstone/mudstone layers, which provide additional insights into Cretaceous invertebrate ecology and life history. Together, these factors make Koonwarra one of Australia's great fossil sites.

The story of how the Koonwarra site was identified is well known — fossiliferous mudstones were uncovered by workers of the Country Roads Board in 1961, during works to straighten and widen a section of the South Gippsland Highway east of Koonwarra in the South Gippsland area. The first formal collection made from this site was by the University of Melbourne, with preliminary results initially reported the next year (Carroll 1962). The first invertebrate described from the site (Talent 1965) was a spinicaudatan (clam shrimp) *Cyzicus* (*Lioestheria*) *banchocarus*, with the first feather described soon after (Talent *et al*. 1966). In August 1970, a letter written by CSIRO entomologist Edgar Riek to the journal *Nature* brought the site's most intriguing find to international attention — the 'pre-flea' later named *Tarwinia australis*. The first extensive work on the fossils of the site was on fish collected during this initial trip (Waldman 1971), with the well-preserved xiphosuran *Victalimulus macqueeni* described the same year (Riek & Gill 1971). In 1981, a second collecting trip was made at the Koonwarra site, which resulted in a trio of key monographs on the macroplants (Drinnan & Chambers 1986), palynomorphs (Dettmann 1986) and invertebrates (Jell & Duncan 1986), although the invertebrate volume also benefitted greatly from a large collection of fossils made by local resident Peter M. Duncan and subsequently donated to the Melbourne Museum. The importance of Jell & Duncan's (1986) monograph to the Koonwarra story cannot be overstated. Although many of the invertebrate groups described therein now need revision (unsurprisingly, taxonomy in many of these groups has changed a lot in thirty years!), this well-illustrated catalogue of the Koonwarra invertebrates highlighted the breadth of the assemblage to researchers worldwide. Many of the groups have been, or are in the process of being, revised, with the increasing rate of review in recent years a result of improved imagery and electronic communication.

The Koonwarra deposit has been interpreted as the remnants of an oxbow or lake, reflected in the strongly aquatic and semi-aquatic nature of the invertebrate assemblage which includes insects, crustaceans (daphnids, ostracods, syncarids, anostracans,

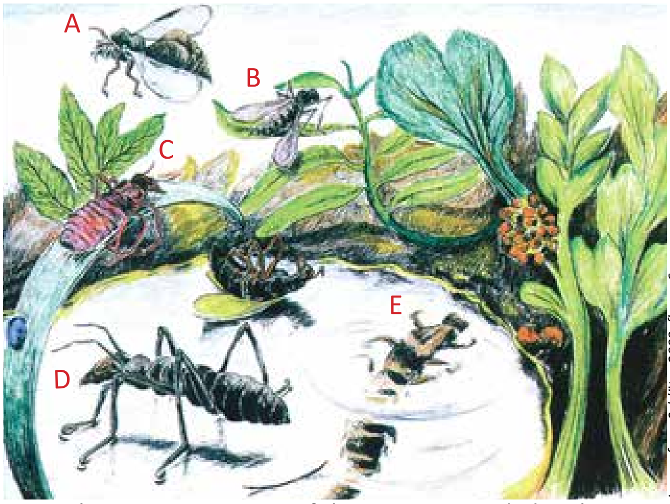

Image from Schlüter 2003, figure 6.

A simplistic reconstruction of the insects recorded in the Koonwarra fossil bed including terrestrial (A: hymenopteran Westratia nana *Jell & Duncan, 1986; B: a dipteran, possibly '*Pseudalysiinia*'* fragmenta *Jell & Duncan, 1986; and C: a hemipteran, possibly* Homopterulum jelli *Hamilton, 1992), semi-aquatic (D: hemipteran* Duncanovelia extensa *Jell & Duncan, 1986) and aquatic (E: an ephemeropteran, possibly* Australurus plexa *Jell & Duncan, 1986) taxa.*

spinicaudatans), a xiphosuran, freshwater bivalves and freshwater bryozoans. The site also records a variety of terrestrial insects and rarer arachnids; the oligochaete fossils previously described from Koonwarra are more likely to represent coprolites (fossilised faeces, probably produced by fish), although annelid mesofossils (egg cases and opercula) have been recorded from other Victorian Cretaceous sites. Overall, the insects are the most commonly recorded and most diverse invertebrates in the assemblage, represented by 13 insect orders and some 70 or so species. Although the diversity of the terrestrial insects is higher than that of aquatic taxa, each of the terrestrial species is generally represented by one or two fossils, compared to higher numbers of individuals in most aquatic species. The ephemeropteran (mayfly) naiads are by far the most numerous invertebrates in the assemblage, particularly *Australurus plexus*, of which more than 100 specimens have been collected. The large numbers of aquatic juveniles makes the Koonwarra insect assemblage very different from all other Australian insect-bearing sites, where terrestrial adults either dominate the assemblage or are the only groups recorded.

Intriguingly, the Koonwarra assemblage appears to preserve two separate aquatic communities, with Jell and Duncan (1986) identifying aresident lake (lentic) fauna and separate transported stream (lotic) fauna. Simuliid (black fly) larvae are one group known to occur today only in flowing water, with Koonwarra the only fossil record of these insects in lacustrine deposits (Sinitshenkova 2002). Conversely, the semi-aquatic bugs (*Duncanovelia extensa* Jell & Duncan, 1986) and Veliid indet.) almost certainly preferred still or stagnant waters, as most modern representatives rely on water surface tension to walk across the water body, and they feed on arthropods that have fallen onto the lake and are trapped by the same surface tension. Other aquatic groups are more difficult to assign as either stream or lake denizens, and some may have been found in both environments. The aquatic taxa also cover a broad range of diets and habitat preferences. Predatory taxa are very common, including the xiphosuran, semi-aquatic bugs, odonatan naiads, mecopteran larvae, and potentially some of the dipteran larvae, aquatic beetles and ephemeropteran naiads. *Australurus*, the stonefly naiads and chironomid larvae were likely herbivorous, feeding on algae, whereas scirtid beetles and syncarids seem to have been scavengers or detritivores; the chaoborid fly larvae, bryozoans, bivalves and branchiopod crustaceans (spinicaudatans, cladocerans, anostracans and ostracods) would likely be filter-feeders removing plankton or other organic particles from the water column. A number of the recorded taxa are oxyphilous (mayfly and plecopteran naiads, and mecopteran larvae), suggesting the water body was well-oxygenated. The large numbers and broad range of aquatic organisms (including fish) seen at Koonwarra suggests that the lake and surrounding area were highly productive, and the food webs were complex.

The terrestrial invertebrates also cover a range of ecologies, including predators, detritivores, scavengers and herbivores. Many of the insects show a preference for moist conditions, or belong to groups that prefer to live close to water bodies, which might explain how they became entombed in a lake deposit. Also common are flying taxa strongly associated with vegetation, such as the thrip, aphid and other bugs, and ground-dwelling leaf-litter taxa, including the roaches (mostly belonging to the extinct stem-group roachoids rather than true cockroaches), orthopterans (including tridactylids or mole crickets) and staphylinids (rove beetles). Aerial predators are incredibly rare in the assemblage, represented by single dragonfly and anthocorid (minute pirate bug) wings. Non-flying predators include the arachnids — two Araneae (true spiders) and one opilione (harvestmen) — and possibly some of the beetle larvae. Interestingly, the site includes no social insects, such as the ants, termites or bees — a fossil described by Carroll (1962) as a stingless bee was later redescribed as a bug, and the putative ant *Cretacoformica explicata* was reassigned to the Diapriidae, a family of non-social wasps still living today. To date, the world's oldest record of both bees and ants is in the Late Cretaceous, and although Early Cretaceous termites are known from other sites worldwide, they are only recorded at low palaeolatitudes. Also intriguing is lack of terrestrial vertebrate fossils known from the Koonwarra deposit apart from a small number of feathers, which is surprising considering the rich vertebrate record seen elsewhere in Victoria!

Image: S Poropat, Museums Victoria (Poropat et al. 2018, figure 13A)

Cyzicus (Lioestheria) banchocarus *Talent 1965 holotype P34293. Scale in mm.*

Image: S Poropat, Museums Victoria (Poropat et al. 2018, figure 11M)

Tarwinia australis *Jell & Duncan, 1986 holotype (P26202) in dorsolateral view*

One of the most controversial and intensely discussed fossils from Koonwarra is the famous 'flea' *Tarwinia australis*, which represents the only ectoparasite known from the site. Taxonomists agree that *Tarwinia* and other 'pre-fleas' found in the Late Jurassic and Early Cretaceous worldwide are ancestral to the modern order (Siphonaptera), and therefore represent a distinctive Mesozoic innovation in insect ecology. What vertebrates this flea (and other potential Koonwarra blood-suckers, namely the adult simuliid and ceratopogonid flies) was feeding on is somewhat of a mystery, although the long legs seen in *Tarwinia* and other pre-fleas are generally noted only in modern fleas living on birds, leading some workers to suggest these insects were originally adapted as pterosaur parasites (for example Ponomarenko 1976). It is also possible that the flea ancestors were not host-specific, unlike the fleas of today. Regardless, *Tarwinia*'s large body size (7 mm length) indicates it would have been a parasite to reckon with! Koonwarra's other invertebrate claims to fame include Australia's only fossil records of fresh-water bryozoans, harvestman, and anostracans (fairy shrimp); and the stratigraphically youngest fossil syncarid crustaceans and xiphosurans in Australia; in both cases, the continent's only other fossils of these extant groups are in Middle Triassic rocks of the Sydney Basin in New South Wales.

As a result of the combination of ecologies seen in the invertebrate fauna, Jell & Duncan (1986) followed Waldman (1971) in favouring a complex depositional model, with Koonwarra a shallow low-energy waterbody occasionally linked to a stream or larger water body. In this model, the stream residents were periodically washed into the lake, and the terrestrial invertebrates were introduced to the lake in two ways — by falling onto the water surface (more likely for flying taxa) or being washed in during flooding events (more likely for ground dwelling groups). Waldman (1971) had also argued that the lake was periodically affected by mass mortality events, which he ascribed to 'winterkills' caused by the seasonal freezing of the waterbody. Jell & Duncan (1986) noted some contradictions within the theory, including the presence of terrestrial invertebrates (plus some plants and the feathers), which could not have passed through a solid ice sheet, alongside other aquatic taxa. As a result, these authors commented that the influence of these events on the invertebrates seemed less than on the fish, and that additional work was needed to confirm the possibility of ice as the cause of these mortality events. However, both Drinnan & Chambers (1986) and Jell & Duncan (1986) noted that the insects and plants were mostly recovered from the lower part of the unit, whereas fish occur predominantly at the top, and it is possible that the winterkill events did occur, but only at certain times during the lake's history.

Koonwarra is also important in palaeobiogeographic studies, particularly in understanding the origins of the insect fauna in Australia, and in the southern hemisphere as a whole. The Koonwarra insects provide a fascinating comparison to contemporaneous Gondwanan assemblages, such as those from the Santana and Crato faunas of Brazil and the Lebanese amber, and numerous well-studied Early Cretaceous sites of the northern hemisphere. Interestingly, the Koonwarra insect assemblage has been noted to be more similar to the temperate lacustrine sites of Siberia and Transbaikalia (then at high northern latitudes) than the geographically closer tropical Gondwanan assemblages (Sinitshenkova 2002), suggesting that climate was the main control on insect distribution at the time. Despite this, there is more endemism in the

Image: S Poropat, Museums Victoria (Poropat et al. 2018, figure 12F)

Cretacoformica explicata *Jell & Duncan, 1986 holotype (P102501) in dorsal view. Scale in mm.*

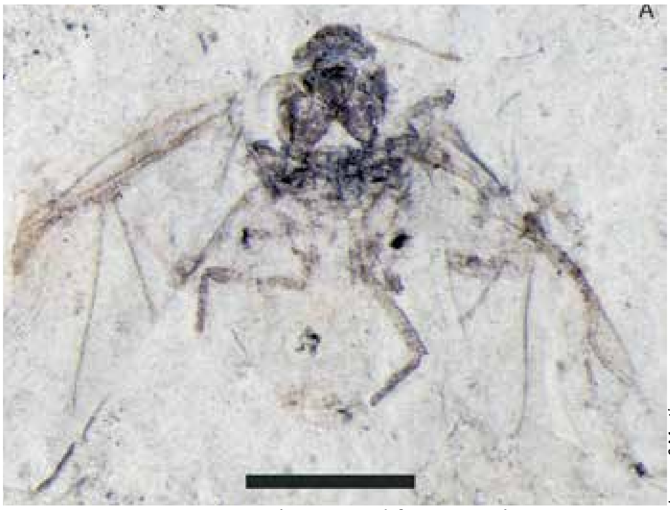

Image: S Martin

AM F072793 Koonwarraphis rotundifrons*. Scale 1 mm.*

Early Cretaceous insects than in Australian insect faunas of the Triassic and Jurassic, suggesting the beginnings of the unique insect fauna seen in Australia today.

Despite the good work conducted so far, there remain a number of uncertainties surrounding the Koonwarra fossil bed, including questions regarding the depositional environment and lake geometry. The site would benefit greatly from a detailed geological study, mapping changes in fauna, flora and lithology through the lake's lifespan, although difficulties with site access means a great deal of planning and additional funding may be needed before such a study can commence. Additional collecting work may also broaden the range of invertebrates known from the site and clarify the affinities of some presently ambiguous or poorly known taxa. The 2016 description of *Koonwarraphis rotundafrons*, a new aphid— the first Cretaceous aphid from Australia and the only aphid recorded from the eastern Gondwanan landmass (the only other Cretaceous Gondwanan aphids are from Africa) — found in collections of the Australian Museum, proves that there is still more for us to discover at this wonderful locality!

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Image: S Poropat, Museums Victoria (Poropat et al. 2018, figure 12L)

Araneae *indet. (P102516) in dorsal view. Scale in mm.*

Image supplied by A-M Tosolini

Cretaceous Gondwanan Forests of Victoria

By Anne-Marie Tosolini

In an ancient rift valley, at the bottom end of the world, within the Antarctic Circle and facing months of darkness - almost at the brink of existence - survived vast forests that covered Gondwana. The Gondwanan supercontinent was a patchwork of today's continents stitched together from modern-day Australia, Africa, India, South America and Antarctica. As Gondwana began to break up in the Late Jurassic, Australia and Antarctica began to pull apart, forming a rift valley across southeastern Australia. Had it continued, this initial rift, would have left Tasmania behind, joined to Antarctica and hugging the South Pole. However, this first rift failed and a new rift south of Tasmania resulted, before the modern continent of Australia, with Tasmania tagging along, began its long journey north to warmer climes in lower latitudes.

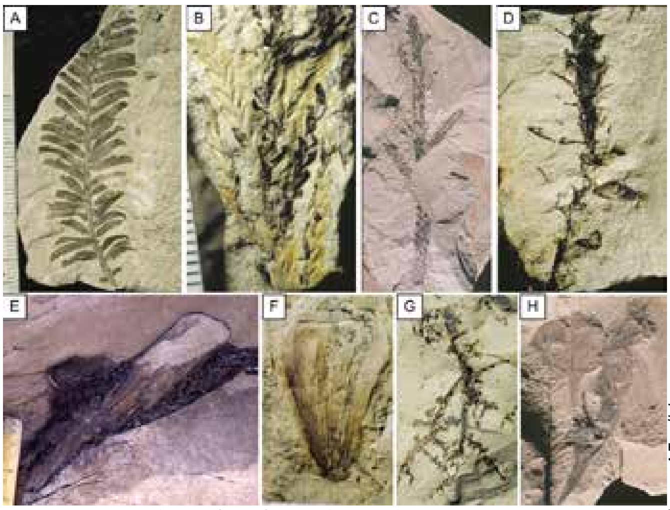

Image: A Tosolini

Figure 1. Fossil conifers from the Early Cretaceous in Victoria. A) Bellarinea richardsii*, B)* Otwayia tetragona*, C)* Brachyphyllum gippslandicum*, D)* Podozamites *sp., E) A large fossilized tree trunk from Eagles Nest, near Inverloch, Gippsland. F) Large conifer cone scale with seed scar belonging to* Araucaria *sp., from the Otways. G) Mycorrhizal root nodules on the cheirolepid* Otwayia tetragona *preserved in ancient soil horizons near Wreck Beach, Otways. H) Earliest fossil flower from the Southern Hemisphere, attached to a stem and leaf, from Koonwarra Fossil Beds, Gippsland, held in Museum Victoria.*

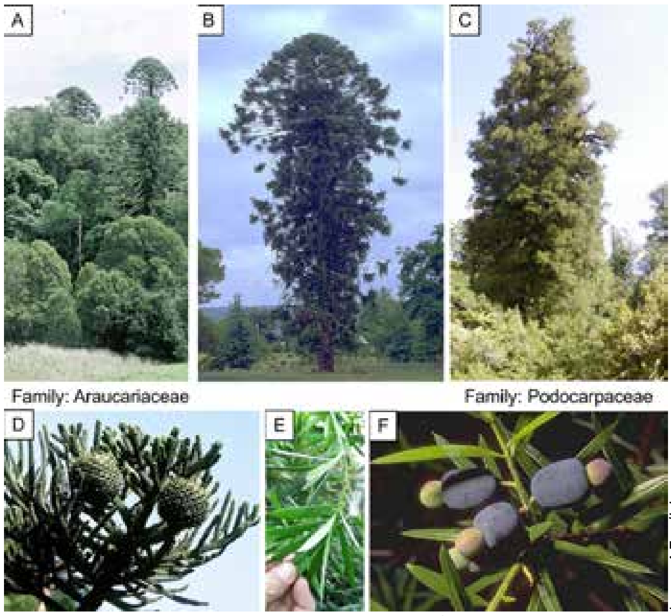

Image: A Tosolini

Figure 2. Modern equivalent extant conifers that dominated the canopy in Early Cretaceous forests. A) Araucaria bidwillii *and* Araucaria cunninghamii *in Queensland. B)* Araucaria bidwillii *form emergent trees in Queensland. C)* Podocarpus totara *in New Zealand. D) Pinnule foliage and cones of* Araucaria cunninghamii*, Hoop Pine. E) Pinnule foliage of* Podocarpus elatus*. F) Black fruits of* Podocarpus elatus*, the Illawarra plum in Queensland.*

During the Early Cretaceous, three stages of floral evolution can be determined that follow the geological time scale stages of Barremian, Aptian and Albian. The oldest Barremian floras are found in sediments near Tyers, confined to the northern part of Gippsland, north of Morwell. Floras of Aptian age come from sediments forming the Strzelecki Ranges, Gippsland coastal areas, including the Koonwarra fossil bed and Flat Rocks near Inverloch, and the Otway Ranges, such as at Binns Rd Quarry. The Albian floras come from the Otway Ranges, where sediments stretch along the coast from Eastern View, east of Lorne, to Wreck Beach and include the fossil sites Dinosaur Cove and Eric the Red West.

In the Barremian, different forest ecosystems dwelled in the hills and down on the plains, along fast flowing, braided rivers that formed in the rift valley, similar to today's Canterbury Plains on the South Island of New Zealand. To the east, New Zealand was rifting away from Australia, which caused large volcanoes to erupt that fed the rivers with sediment formed from eroded lava. These huge braided rivers were high in energy, carrying large loads of volcanic-rich sediment within small, shallow channels that weaved and cut across each other, confined within a single, broad, main channel. They swept away branches and all in their path, even entire trees, depositing them into gravel and sand

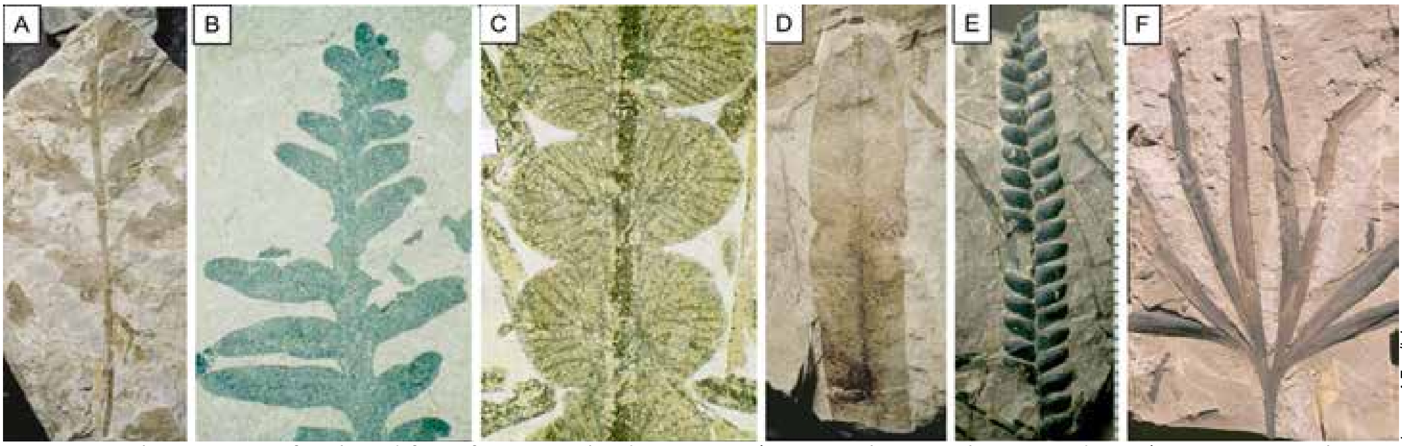

Figure 3. Early Cretaceous fossil seed-ferns from Gippsland, Victoria. A) Caytonialean Komlopteris indica*. B) Corystospermalean* Pachydermophyllum austropapillosum*. C) Possible peltaspermalean* Rintoulia variabilis*. D) Pentoxylalean* Taeniopteris daintreei*. E) Bennettitalean* Otozamites boolensis*. F)* Ginkgoites australis*.*

bars. Behind the main broad river channels, billabongs developed where leaves accumulated in quieter, still waters.

Upland and mountainous areas were covered with large conifer forests. Snow burdened the branches, however, no permanent icecaps covered the poles at this time. The forest canopy consisted of podocarps and araucarians (Figure 1), which often formed emergent trees (Figure 2B). Podocarps were dominated by longer leafed varieties called *Bellarinea richardsii* (Figure 1A), similar to the modern Plum Pine. Araucarians with short bracts, *Brachyphyllum tyersensis*, were similar to Hoop Pines in Tasmania or the Norfolk Island Pine. Late Jurassic forests were dominated by araucarians, and ginkgoes were essentially absent. However, by the Barremian, podocarps had risen to dominance at the expense of the araucarians, and ginkgoes gradually returned, although macrofossils do not reappear until the Aptian (Figure 3). Ginkgoes in the past were diverse and widespread across Gondwana. Often their leaves were much more dissected and palm-shaped, whereas today, the single last surviving species has a leaf with two lobes, *Ginkgo biloba*, the Chinese Maiden-hair tree (Figure 5A,C).

Down on the plains, the taller podocarp conifers were interspersed by smaller trees and bushes. Extinct conifers of the Cheirolepidiaceae family, *Otwayia hermata*, had small bracts, hugging close to the stem and stomates (pores on the leaf for gas exchange) that were sunken and covered with hairs to prevent water loss. They probably grew in impoverished soils away from the rivers and were rarer elements of the ecosystem. Deciduous elements were abundant in the mid-storey, including a range of now extinct seed-ferns, such as the pentoxylalean *Taeniopteris daintreei*, corystospermalean *Pachydermophyllum austropapillosum* and caytonialean *Komlopteris indica* and a possible peltaspermalean *Rintoulia variabilis* (Figure 3). Predecessors of the cycads, the bennettitaleans such as *Otozamites boolensis* and *O. douglasii*, were also abundant in the mid-storey.

Figure 4. Early Cretaceous fossil lower plants (A-C) and ferns (D-F) from Gippsland, Victoria. A) A small lycophyte grew in wet habitats, Isoetites*. B) A thalloid liverwort also from wet habitats. C) Equisetalean rhizome from a horsetail that grew in the marshes. D)* Medwellia lacerata*. E)* Cladophlebis australis*. F) Fern frond of* Sphenopteris warragulensis*.*

Closer to the water, the riparian vegetation was dominated by ferns and seed-ferns, with rarer liverworts, horsetails and lycopods (Figure 4). A plethora of abundant ferns, such as the osmundacean ferns *Phyllopteroides laevis* in the order Polypodiales (which comprises 80% of extant ferns) formed the undergrowth (Figure 4). *Cladophlebis australis* may be osmundacean, but has also been placed in the dicksoniacean tree fern family. Extinct groups of ferns included *Aculea bifida*, *Sphenopteris warragulensis*, *Coniopteris fruitiformis* and *Medwellia lacerata*. Small but abundant horsetails (equisetaleans) and lycophytes (such as *Isoetites* and lycopods) clung to the water's edge and in marshes (Figure 5).

As the rift valley widened in the Aptian, rivers slowed and became more sluggish, broad and deep, within single meandering channels. Glaciers developed in the mountains. Drop stones in Queensland are evidence of permanent ice in this polar climate. Drop stones can only form from glacial deposits because they are large, lone boulders rafted by the ice a long way from their origin and found out of place within fine-grained layers. Wood from northern Australia shows distinctive growth rings similar to Cretaceous wood in Antarctica that indicates cooler climates. Abundant *Ginkgoites australis* signified cooling, and together with *Taeniopteris daintreei*, its rare pollen-bearing organ *Sahnia laxiphora* and the fern *Phyllopteroides serrata*, were key elements of the flora.

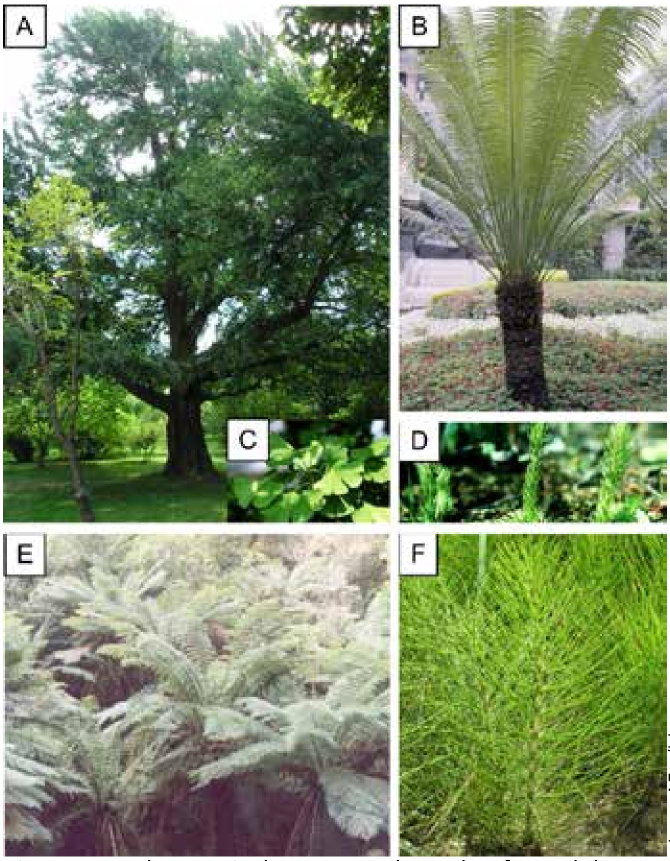

Image: A Tosolini

Figure 5. Modern equivalent extant plants that formed the undergrowth in Early Cretaceous forests. A) Ginkgo biloba *are a large tree that are bisexual. B)* Zamites*, a cycad from Queensland. C) Detail of the bi-lobed leaves of* Ginkgo biloba*. D)* Lycopod *species of club moss (lycophytes) in New Zealand. E) A tree fern stand of* Dicksonia australis*, in Gippsland cool-temperate rainforest. F) Horsetails (*Equisetum*) in a marsh environment.*

On the fringes of these thick forests, in the dark and disturbed environments of the floodplain, the first flowering plants evolved. These small, herbaceous shrubs, possibly existing in marshy environments, hid in the undergrowth and were opportunists that could take advantage of the low light levels. The Koonwarra Fossil Beds represent a rare lake deposit of very finely laminated siltstone that experienced episodic flooding in the wider rift valley, where exquisite leaf impressions, feathers and one of the earliest flowers in the world have been found fossilized. The flower has been assigned to the dicotyledon Magnoliids and thought to have had an herbaceous, prostrate habit. A weed-like plant that struggled to survive in amongst abundant ferns and seedferns, it was possibly aquatic, dwelling in low marshes which were flanked by mudflats colonised by equisetaleans, liverworts and lycophytes. *Taeniopteris*, cypress and cheirolepid conifers, osmundacean ferns and tree ferns thrived in the lowlands, whilst araucarians (*Araucaria* cf. *A. heterophylla* and *Brachyphyllum gippslandicum*), podocarps (*Bellarinea barklyi*) and *Ginkgoites australis* dominated the slopes and hills.

The Albian heralded in a major vegetation change associated with warming. Angiosperms diversified and became abundant, although macrofossils were still rare, with one leaf assigned to *Hydrocotylophyllum lusitanicum* (Douglas, 1994). Within just a very short space of Geological Time, angiosperms rapidly radiated and rose to dominate the flora — how this was achieved was what Charles Darwin termed an "abominable mystery". Evidence now points to angiosperms evolving specialised leaves, whose high densities of veins captured sun's energy and were better adapted to transport food and energy around the plant. They out-competed other plants in the forests, grew to become woody trees and pushed the seed ferns and ginkgoes to the brink of extinction. Only a few records of bennettitaleans, corystospermaleans and ginkgoes occur in younger Late Cretaceous sediments of eastern Australia, where they had been largely restricted to environmental refugia. In the past decade, extraordinary discoveries of these fossil leaves from Tasmania and New South Wales of Palaeogene age (< 66 million years

Figure 6. Detail from Peter Trusler's reconstruction of the Victorian Cretaceous containing a canopy of podocarpacean conifers and emergent araucarians, a mid-storey of diverse seed ferns (including bennettitaleans) and tree ferns, and a thick undergrowth of seed ferns, ferns and lycopods.

ago) provide evidence that these plants, unlike the dinosaurs, did indeed survive the end-Cretaceous mass extinction.

Forests became more diverse in conifer canopy trees; araucarians (*Araucaria lanceolatus*, *A. acutifoliatus* and *Podozamites* spp.) and podocarps were joined by cypresses and a greater abundance of cheirolepids (*Otwayia tetragona*). Long-leafed araucarian varieties, *Araucaria* and *Podozamites* spp., were akin to modern Bunya Bunya Pines that grow in Queensland, or to the South American equivalent Monkey Puzzle trees. Albian cheirolepid conifers preserved in an ancient soil horizon had mycorrhizal root nodules, which indicated a conifer-fungi association to harvest nutrients from deficient soils. Recent findings of marine algae indicate that the ocean had advanced from the west in the Great Australian Bight to inundate the Otway plains, so that the cheirolepids grew in coastal areas. In addition, ferns diversified, dominated by *Phyllopteroides dentata*, supported by *Amanda floribunda*, *Alamatus bifarius* and marseliacean water ferns *Marselliaceaphyllum*, also indicative of a warmer climate.

Today, a walk in the Otway Ranges near Apollo Bay, in places such as Maits Rest, or in the Strzelecki Ranges in Gippsland, in places such as Tarra Bulga National Park, will take you through cool temperate rainforests that are remnant Gondwanan forests — relicts from a time long ago (Figures 6, 7, front cover). Echoes of dinosaurs lurk in the thick, wet forests, way down south, with the now-living trees enriched by the carbon-rich fossil remains of their forebears.

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Figure 7. Detail from Peter Trusler's reconstruction of the Victorian Cretaceous containing a thick undergrowth formed by early flowering plants, ferns, horsetails and lycopods, scattered with leaf litter and cones from araucarian and podocarpacean canopy trees.

Where Dinosaurs Walked the Earth

By Wendy White

In the absence of a permit to work Eric the Red West or Flat Rocks this year, a small but intrepid band of Dinosaur Dreamers joined forces with the Australian Age of Dinosaurs Museum of Natural History (AAOD) to protect and relocate a 95-million-year-old dinosaur trackway outside Winton in outback Queensland.

This Field Report does not discuss the science behind or significance of these trackways – I will leave this for the AAOD Journal. (Don't receive a copy? Become an AAOD member right away – they do great stuff up there!)

I am privileged to be amongst the Dreamers that have spent decades looking for tiny little Mesozoic mammals for Tom Rich, so the first thing that struck me when we arrived at site on Sunday 9 September was the sheer overwhelming magnificent size of the fossil. I stood for a moment in awesome wonder.

Over a span of some 40 metres, a trail of more than 30 sauropod footprints was exposed in a dry creek bed. We ventured timidly down to the trackway edge, and started taking it all in. Near the giant sauropod trackway, were tiny little footprints, with tiny little claw imprints. The sauropod footprints are new to Queensland (no others have been documented), but the tiny ones might be *Skartopus* (which means nimble foot), a theropod footprint known from the Dinosaur Stampede National Monument about 100 km distant. My mind was full of striding four-legged giants ignoring the tiny two-legged scamperers that darted across the same plain.

Image: D Elliot, AAOD

The crew wrapping footprints in plaster

John Wilkins and Mary Walters wrapping footprints in aluminium foil

The footprints are a kilometre or two inside one of the large cattle stations owned by the friendly Mikey Elliott, who visited us on his quad bike or tractor each day to check out our progress and to lend a hand. For some reason, his visits nearly always coincided with Smoko (what people in big cities would call morning or afternoon tea). Although our site manager, Trish Sloan, had a nice clear voice calling the break, Mikey's hearing must be awfully good to have heard it from his homestead or wherever he happened to be working at the time.

David Elliott explained to us that the sauropod footprints have no base (only the sides of the footprints are preserved). These amazing fossils were exposed when a gully changed course in the 2000 floods (some of our trackway was freshly uncovered in April 2018 and was still pristine) and get damaged in the creek bed each time it rains, or when a cow decides to break through the temporary barbed wire fence erected to protect them (as an aside, several of our crew, unused to being on a working property, have clothing slightly worse for wear after close encounters with that fence).

Since David wants to preserve the trackway and show it to the world, it needed to be moved up to the AAOD museum (some 100 km away at The Jump-Up). Our main task was to dig out the most vulnerable footprints, those not preserved as solid rock, as they would go underwater and be lost if it rained enough to fill the creek. We needed to plaster jacket them, measure exactly where they were positioned in three dimensions relative to each other, cut them into sections, transport them to The Jump-Up, and lay them out there on a site that had been prepared earlier. This was a completely different sort of challenge to that which usually encounter in the Victorian Cretaceous — closest, I guess, to removing the footprint block from Milanesia Beach (that Tom Rich described in last year's Field Report), but multiplied up to an industrial scale.

Wendy White and Steve Poropat (with barbed wire tears in their shirts) puzzlin'

Once we stopped standing and staring, we set to work. The landscape outside Winton is beautiful, but can be unyielding, so the first order of business was to set up some shade tents (complete with tables and chairs!) and other things to make us comfortable. AAOD operates their digs from a large trailer — a storeroom on wheels containing everything we might possibly need.

Some of the crew grabbed tape measures and started collecting data to validate that what we saw was indeed a trackway, and to work out how big the various footprint makers were.

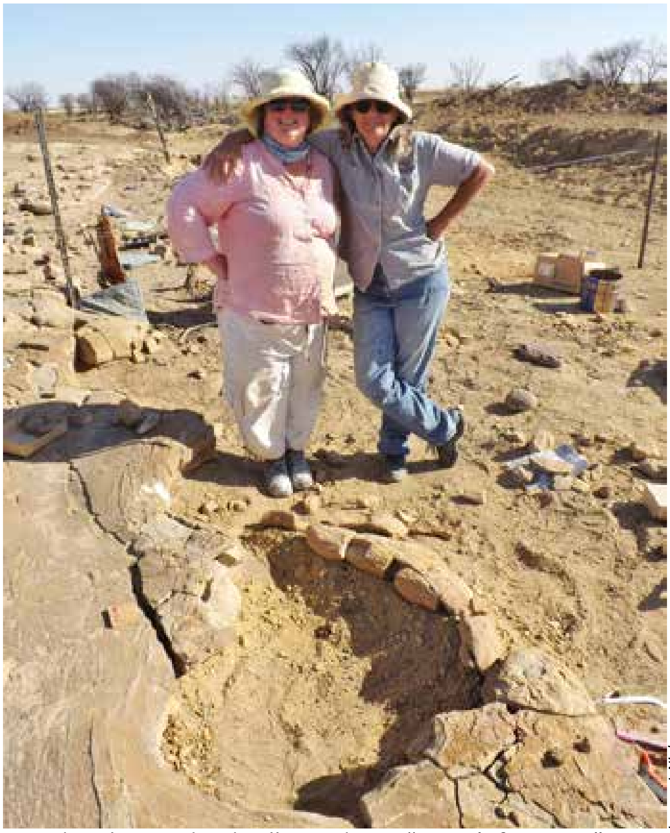
After lending a hand wetting newspaper for later work, I joined the Puzzlin' Team led by the entertaining and warm Judy Elliott. Our puzzlin' aimed to repair the damage done by previous floods where pieces of the trackway were washed away from their positions. It involved strolling downstream along the gully, grabbing a likely looking rock, brushing the caked mud off, and trying to fit it back into the edge of the trackway. Once a match was made, we used a paint pen to mark the inside matching faces with a unique colour or symbol. It surprised me how quickly I drew a mental blank after A, B, C, X and smiley face. Once we had collected enough matches, we mixed some Araldite and joined as many loose rocks together as we could before the glue set — which was not very long in the hot Queensland sun. Puzzlin' is compelling, addictive work and whilst the rest of the crew moved onto other things, I volunteered again and again for the Puzzlin' Team. It was always a thrill identifying a home for a piece that other crew members had walked past, but my happiest moment was reconstructing the footprint that Harry Elliott noticed was significantly less complete than a couple of years ago, and that many of the crew helped to rebuild.

After puzzlin', the job I loved most was the plastering. After the footprints were dug out, including angling in at the bottom to create a lip, they were wrapped with aluminium foil, wet newspaper and hessian dipped in Plaster of Paris. Each layer is massaged onto the fossil to remove any air pockets. That massaging, especially of the hessian/plaster layer is very tactile and very rewarding. It felt like we were soothing and caring for the rock before sending it on its way.

After the first week, it was time to start removing the footprint blocks. Using crowbars, Mikey's tractor, a number of trailers and utes and a lot of hard work, crew members flipped the pieces and transported them to The Jump-Up.

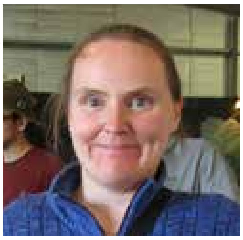
We split the crew, and whilst a few stayed on Mikey's property puzzlin', most went to The Jump-Up to make concrete bases for the footprint pieces, and to start laying them out.

We didn't quite finish repositioning all of the footprints that we had intended (the AAOD staff did this in the weeks after we left), but we left Winton tired but triumphant with memories of amazing fossils, sunsets and sunrises, brolgas and bustards and budgies, Berry-Ice Powerade, friendly dogs and old-fashioned country hospitality.



Wendy White and Judy Elliott admire "Harry's footprint"

In the Footprints of Giants



By Lisa Nink

What does a crew do when confronted with moving a sauropod trackway? Take some photos sitting in the footprints, of course! Photos by Lisa Nink.

Pip Cleeland

Lisa Nink and Mary Walters

Mike Cleeland

John Swinkels

Pat Vickers-Rich and Tom Rich

Trish Sloan

Dean Wright

Stephen Poropat

David Elliott

Ruairidh Duncan

Harry Elliott

Tim Ziegler

Wendy White and Mary Walters

Australia's Oldest Crocs

By Cassia Paragnani

Never smile at a crocodile. Timeless wisdom shared between generations, but with my Honours project last year I couldn't help giving a smile that would shame the Cheshire Cat, looking at all the fossils that represented Australia's oldest member of the clade Crocodylomorpha.

Only two species of crocodile live in Australia today: the relatively inoffensive freshwater croc (*Crocodylus johnstoni*) and the massive, panic-inducing saltwater or estuarine croc (*Crocodylus porosus*). Worldwide, croc diversity is relatively low, with only around 25 species alive today. All of these are semi-aquatic predators that don't stray far from the equator — except in the form of handbags. However, in the past, crocodylomorphs (the group which includes all modern crocs and their extinct relatives) had a much larger range, due to the warmer climate. They also displayed a variety of body shapes: some were bipedal, some were mostly terrestrial, and others were fully marine. Some fed on fish, others on flesh, some filter-fed and still others, oddly enough, fed on plants!

The Australian Mesozoic croc fossil record is, surprisingly, quite poor. It is relatively restricted to the Cretaceous and comprises only a few skeletons from central Queensland (dubbed *Isisfordia*) and isolated fragments from Lightning Ridge in New South Wales. Victoria boasts the oldest crocodile fossils from Australia, found in familiar ol' Dinosaur Cove — famous for its dinosaur discoveries. Strangely, these fossils, which were collected between 1986 and 1993, have never been described. Until now…

Image: C Paragnani

Victorian Cretaceous Crocodile teeth. Scale 1 cm.

This is where I come into play — that is, myself and my supervisor Stephen Poropat, with an Honours project to figure out what kind of crocodylomorph could tolerate the high latitude of Victoria during the Cretaceous, and what that might in turn tell us about the climate and environment. You might find yourself asking, "Gosh! How does one do that?". Well, as I found, you can learn a lot about a creature by just describing each individual element that you have and, oftentimes, you'll find they complement each other and support a certain assessment.

The 28 crocodile teeth from the Victorian Cretaceous are conical, with smooth ridges on both sides nearest to the neighbouring teeth. All these teeth were found isolated and could not be associated with other specimens. Although the teeth span a range of sizes, their shape is relatively consistent and similar to that of fish-eating crocodylomorphs. This might indicate that they all belonged to the same species. One of the few skull bones preserved, a quadratojugal, indicates that at least one croc in Victoria had a skull that was flattened top to bottom, as evident in crocodiles today. In modern crocs, the spinal column comprises vertebrae that connect with each other via a ball and socket arrangement — the front of the vertebra is concave, and the back is convex. The only Victorian croc vertebra preserved does not show this structure: instead, both the front and back surfaces are concave. The curvature of the humerus is subtle, a feature generally found in creatures that frequent water and do not need supporting structures to deal with gravity. Finally, the osteoderms (bony scutes) show little attachment to one another except in the neck region. This feature in modern crocs allows for ease of movement while swimming.

The rocks at Dinosaur Cove are slightly younger than those exposed along the Bass Coast and they appear to document a significant faunal change. Temnospondyls, preserved in sites like San Remo and the Punchbowl, are unrepresented at Dinosaur Cove. In the past it has been suggested that natural climatic warming enabled crocodylomorphs to live at high latitudes and to displace the temnospondyls. The Dinosaur Cove crocodylomorphs were found in rocks deposited by a shallow river, shooting off from a major river flowing in the rift valley between modern day Victoria and Tasmania. These crocs were not marine — they were semi-aquatic freshwater hunters preying mainly on fish.

It has been my greatest pleasure trying to piece the ancient clues of this puzzle back together. From now on, I shall always smile at those crocodiles.

What I did in February instead of digging

By Peggy Cole

After lamenting that February 2018 had been for me quite unmemorable, I asked for your contributions to your, hopefully more exciting, alternatives to the February Fossil Fix. Here they are — so different, so creative and in some cases extremely exciting.

THE DINOSAUR DREAMING ALTERNATIVE

From: Amber Craig
Subject: Missing a limb
I love that you are putting this piece together! I am afraid though that I have nothing exciting to contribute. I was in fact working Fridays to Sundays at my retail job and genuinely missing the dig. I remember making comments to staff at work that "this time last year I was on the dig and I found etc etc..." It was like missing a limb. I hope you have more interesting things from other crew members!

From: Dean Wright
Subject: Hobart hooch
In February, 2018 I went to Hobart Tasmania and visited my favourite friend. She picked me up from the airport and we went straight to Salamanca Market for a late breakfast. After browsing the local fair and tasting some gin and vodka from the local distilleries we settled in a nearby park with some Valhalla ice cream. Valhalla ice cream is like regular ice cream only better in every conceivable way. We caught two movies (as our friendship had blossomed as movie buddies), ate all kinds of amazing food — from hamburgers to Japanese take-away. Southern style broccoli with Ranch dressing was the unexpected highlight. My friend is vegetarian, and in regard to food, Tasmania is amazingly progressive with vegetarian, vegan and gluten free options available at most eateries. I stayed overnight at the second oldest pub in Australia. I did not see MONA, as I had spent a day there last visit. I found some treasures at a pop-culture store that in Melbourne would have been snatched up as soon as they were placed on the shelf. High-priced whiskey from local distilleries was tasted at Lark - it has since changed hands to a large Chinese consortium. The trip was nothing special, but an amazing weekend away.

From: John Wilkins
Subject: Delayed family celebrations
My son is now 23 — I missed his first day of school by being on the dig. This is also around the time of my wedding anniversary — last February was the first time in ages that we actually planned (or tried to plan) to do something. I had, on the odd important anniversary, sprinted home to surprise and celebrate. On this occasion, we tried to plan many things but it seemed like everything was on in Geelong and Melbourne where we were looking at going, accommodation costs were through the roof, so we ended up having lunch at a fancy restaurant (Petit Tractor) and cruising The Peninsula, ending by having desert and coffee at the Strawberry farm. Note: I detest Strawberries!

From: James Rule
Subject: A Perfect palaeontological substitute
During February 2018, I was on a bit of a PhD adventure!

I found myself visiting the Muséum national d'Histoire naturelle in Paris, to see the holotypes of three Peruvian fossil seals (*Piscophoca pacifica*, *Acrophoca longirostris* and *Hadrokirus martini*). These seals are important for helping me understand how true seals evolved in the Southern Ocean. I spent two weeks scanning and studying their bones, struggling to speak French, and checking out the sights and the food with the limited free time I could afford myself.

After that, I ran off to London to fulfil a childhood dream of researching at the Natural History Museum in London. Whilst over there, I stayed with fellow Dinosaur Dreamer Travis Park (now doing a postdoc there) and caught up with Melbourne's Alana Sharp (now at University College London). Both are very busy doing some really cool palaeo-research. As for myself, I got to run around in one of the largest seal collections in the world. So my February was filled with lots of palaeontology goodness!

Image: J Rule

James Rule's fossil substitute

Wendy White visits the dig (virtually)

From: Wendy White
Subject: Almost like being there!
I had a Virtual Reality dig experience in February. On the 16th, I went to the opening of The Little L Project at the Geelong Wool Museum. Wearing VR goggles, I was standing half a metre above "the hole", listening to Mike Cleeland talk about something, seeing the quiz in action at the other end of the beach and watching a second me high-five Nova Taylor (presumably congratulating her on a fabulous fossil find). It was just like being there for a few minutes — all it missed to complete the illusion was a cup of lukewarm tea sprinkled with coal dust.

Image: M Mackenzie

Melanie Mackenzie enjoyed the British Antarctic Survey fossil collection

Image: M Mackenzie

Melanie Mackenzie's view from the deck

From: Melanie Mackenzie
Subject: Heading south
What? I can't spend my summer breaking rocks and being blasted by sand?

Guess I'd better head South….

I spent my usual Feb/March dino-digging slot on a research ship in the chilly wilds of Antarctica. Having joined the scientific crew for a rapid-response survey, we went in search of a giant iceberg that had calved from the Larsen C ice-shelf and, more importantly, the marine animals that had been concealed below since the last inter-glacial period. Alas, it was not to be. As we tried to crunch our way south along the Antarctic Peninsula we were thwarted by the moving multilayered ice, and had to turn back to Prince Gustav Channel, or risk an accidental over-wintering. Luckily the channel, formerly covered by ice sheets, was now surrounded by glaciers, stunning scenery and ice floes carrying moulting penguins and lazy seals. We managed some good scientific trawls and sleds, with a nice selection of weird worms, squishy sea cucumbers and alien-like amphipods to add to the Antarctic story. I joined my crew-mates in the UK before heading south, so managed to see the British Antarctic Survey fossil collection (and prep for the Lyme Regis fossil fair) in Cambridge, shared the ship with a palaeontologist who has just published a paper on fossil crinoids, and even read the novel 'Strange Creatures' about Mary Anning while on board… so I still got my palaeo fix!

For more information about Mel's trip, go to https://www.bas.ac.uk/project/larsen-c-benthos/

Images supplied by the authors

The Little L Project

By Kaja Antlej, Ben Horan and Marie Allaman

The Little L Project is a Mixed Reality (MR) pilot research exhibition that took place at the City of Greater Geelong's National Wool Museum from the 16th of February to the 15th of April 2018. The project was initiated by the researchers from the School of Engineering at Deakin University and developed in collaboration with the palaeontologists from Swinburne University's PrimeSCI! and Museums Victoria and the National Wool Museum — City of Greater Geelong.

After recent closure of a heavy manufacturing sector, post-industrial Geelong is embarking on a major reinvention as 'clever and creative' and a 'digital-driven' city-region. Not only is it essential to explore uncovered heritage content but also engineering areas that haven't yet been well utilised in the region of innovators and manufacturers. Helped by a strong creative tradition, in late 2017 Geelong was named the

Image: J Carnegie

Some of the talent behind the Little L Project at the launch

UNESCO City of Design. Our project was a case study in the application submitted to UNESCO.

At the exhibition, a wallaby-sized, plant-eating, locally-found polar dinosaur, *Leaellynasaura amicagraphica* (affectionately nicknamed Little L), was used as a case study to investigate how creative and meaningful content can be deployed using Virtual Reality (VR), Augmented Reality (AR) and 3D printing. Little L was first discovered in 1987 in the Otway Ranges and named after Leaellyn, the daughter of Pat Vickers-Rich and Tom Rich.

Despite their relatively small size, due to extreme climate and restricted location, Victoria's polar dinosaurs are unique — they were far more diverse than those found elsewhere in the world. It is still unknown why polar dinosaurs' adaptation to a tough climate did not allow them to survive the catastrophic

Image: Chax Rivera

A still from the Eric the Red West Virtual Reality experience

Image: K Antlej

A visitor enjoys the Virtual Reality

Image: K Antlej

Multi-material 3D printed reconstructed dinosaur skin

events around 66 million years ago. Exploring dinosaurs' appearance and their environment may help us understand and plan our future in the face of escalating climate change.

Over two months, the temporary exhibition brought together 10,000 museum visitors who were able to learn about the local dinosaurs through two major engaging experiences:

1. a 360-degree video of an excavation occurring at a dinosaur dig site at Cape Otway (Eric the Red West, recorded on the 17th of February 2017) contextualising present time; and
2. a co-creative tactile-immersive virtual colouring serious game, presenting past Victoria.

Through these experiences, Virtual Reality (VR) was used to provide access to places and events that are hard to access (present) or no longer exist (past).

The two major experiences provided different levels of interaction to fulfil expectations of museum visitors with different levels of tech-savviness. The 360-degree dig video was a linear pre-recorded documentation of a real-world event while virtual colouring was a representation of a previous time and demanded much more active participation. In addition to the virtual colouring, a hands-on table with multi-material 3D printed reconstructed dinosaur skin enabled visitors to feel dinosaur scales. A 3D printed dinosaur skin relief stamp was also developed and used as part of the Easter School holiday activities. The virtual colouring of the 3D printed reconstructed body of Little L was conducted in an immersed virtual environment by using a virtual airbrush. Visitors were also able to pet the physical dinosaur while in VR or in a real world. This experience communicated to museum visitors how dinosaurs looked and felt, as well as how palaeontologists determine the colour and texture of dinosaur skin. By colouring, visitors learnt not only about dinosaurs but also about the role of scientists and their methods, as well as how crucial it is to observe nature and environment around us.

The Little L Project has been well accepted, resulting in the interest by local schools and heritage institutions. The project has also been highly commended at the 2018 Victorian Museum Awards in the category of Medium Museums (8-50 Paid Staff).

Image: K Antlej

The virtual dinosaur painted in bright colours

Image: D Squire

Visitors enjoy painting (and petting) the virtual dinosaur

DinoQuest — The Little L Story

Image courtesy of P Vickers-Rich

By Jade Koekoe and Pat Vickers-Rich

By the time we are adults, we have at least a rudimentary knowledge of dinosaurs. But how many of us know enough to learn from these fantastic beasts and to look at the past in order to plan for the future? Well, that is the focus of *DinoQuest — The Little L Story*, a new exhibition featuring our polar dinosaurs. You might be wondering, “why The Little L Story?”. Well, it stands for little *Leaellynasaura*, one of our famous and well-loved Victorian polar dinosaurs. However, *DinoQuest — The Little L Story* is only a working title — if anyone wants to make suggestions, get in touch with Pat.

The exhibition is currently under construction, and plans to open in Singapore in May 2019. Our Victorian polar dinosaurs are to be the centrepiece of the exhibition!

The exhibition contains Victorian dinosaurs like *Timimus*, “Megalosaurus” and *Leaellynasaura* which are also featured in the educational material that accompanies it. Students will learn how to tell the difference between lizards and dinosaurs. They learn that it is the hip bones that allow some dinosaurs to walk upright. A very efficient posture, it turns out, as it meant dinosaurs could stand and walk for a much

Image supplied by P Vickers-Rich

A deconstructed dinosaur

Image supplied by P Vickers-Rich

Some of the contents of the DinoQuest schools’ kit

longer period of time (than lizards) without running out of energy. It’s always exciting to see a child’s eye light up when they learn something that Mum and Dad may not know! Students will also learn about the climate of Australia during the Cretaceous era — imagining a home much closer to Antarctica than it is today and looking at the various characteristics polar dinosaurs developed that helped them survive in much cooler climates.

As our polar dinosaurs continue to inspire and teach future generations about the history of our world, they also give us opportunities to collaborate with global experts. The DinoQuest exhibition is being put together with a vibrant team including staff of the Singapore Science Centre, Deakin University, Digimagic, DezignFormat and PrimeSCI! at Swinburne University. Continued collaboration within the palaeontology community is vital to expanding and re-evaluating our knowledge of dinosaurs and their world, so we are very pleased to have such a diversity of colleagues working with us to produce this exhibition.

Once the exhibition leaves Singapore it will travel internationally, which is great news for us Dinosaur Dreamers as DinoQuest will provide another source of income for Victorian palaeontology research at Swinburne, Monash and Deakin universities. These funds will help to keep alive our yearly tradition of spending weeks on the Victorian coast hunting for those ever-elusive fossils.

Image supplied by P Vickers-Rich

Diane Chatwin documenting the exhibition

FIELD CREWS

KOONWARRA FIELD CREW

17 - 23 MARCH 2018

Mike Hall
Gerry Kool
Lesley Kool
Stephen Poropat
Tom Rich
Pat Vickers-Rich
Gary Wallis
Mary Walters
John Wilkins
Dean Wright
Tim Ziegler

WINTON FOOTPRINTS FIELD CREW

8 - 23 SEPTEMBER 2018

Tom Beeston
Steve Bishop
Mike Cleeland
Pip Cleeland
Ruairidh Duncan
Bob Elliott
David Elliott
Grace Elliott
Harry Elliott
Judy Elliott
Mikey Elliott
Steven Lippis
Lisa Nink
Adele Pentland
Stephen Poropat
Tom Rich
Samantha Rigby
Steve Rumbold
Trish Sloan
George Sinapius
John Swinkels
Pat Vickers-Rich
Mary Walters
Matt White
Wendy White
John Wilkins
Dean Wright
Tim Ziegler

WINTON FOOTPRINTS CREW

Image: T Sloan, AAOD

L-R:
Mike Cleeland
John Swinkels
Pip Cleeland
Judy Elliott
David Elliott
George Sinapius
John Wilkins
Ruairidh Duncan
Tim Ziegler
Stephen Poropat
Steve Lippis
Bob Elliott
Trish Sloan
Lisa Nink
Wendy White
Pat Vickers-Rich
Mary Walters
Tom Rich