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Ludwig Leichhardt and the significance of the extinct Australian megafauna

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The first fossils of giant Australian mammals were of great interest to both colonial and British scientists in the mid-nineteenth century. Richard Owen, the foremost anatomist of the era, initially interpreted the *Diprotodon* as a relative of the elephant. Ludwig Leichhardt was the first scientist to unambiguously appreciate that the *Diprotodon* was a marsupial, along with the vast majority of Australia's other Pleistocene megafauna, although he was never acknowledged for these insights. Recognition of the marsupial affinities of several species of Australian megafauna was significant because it affirmed the continuity of lineages not only geographically but also through time. This was a fundamental cornerstone for the theory of natural selection introduced to the world more than a decade after Leichhardt's death.

❑ *Leichhardt, Australian megafauna, Richard Owen, Diprotodon.*

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FIRST IMPRESSIONS OF THE GIANT AUSTRALIAN MAMMALS

The mid-nineteenth century was a time of extraordinary biological discovery that had its climax when Charles Darwin presented to the world a mechanism for the evolution of species. The Linnaean system of classification was already well established to name and group the many new plants and animals that were then being collected by travelling scientists. The geographic distribution of the living mammalian archetypes was never more obvious than in Australia where kangaroos, possums and koalas exhibited the diversity of marsupial forms that were essentially absent from the northern hemisphere. What was not yet certain in the 1840s was whether the discrete spatial distributions extended back in time through ancient lineages. The extinct Australian mammal *Diprotodon* became the central character in a debate that would eventually clarify this uncertainty.

Were these giant animals relatives of elephants and mammoths known from Europe, Asia and Africa, or were they oversized marsupials and therefore relatives of the modern fauna that now dominates Australia? The resolution of this question was a critical development for science because the orderly extension of current lineages into the past would demand a novel explanation. Charles Darwin was one of a new breed of scientist who kept a watchful eye on the evidence emerging from across the world.[1] In Australia, a less prestigious scientist by the name of Ludwig Leichhardt had no clear understanding of the revolution that was unfolding in Darwin's mind but he would make his own modest, yet incisive contribution to the ferment.

Major Thomas Mitchell's claim that 'the animal remains found by me' in the Wellington Caves in 1831 marked the discovery of the first fossilized large mammal bones was not quite correct. He was escorted to the cave by George Ranken who had previously explored the limestone caverns. Ranken, in fact, had been about to lower himself over a precipice into one of the caves when his rope broke free from its anchor, revealing its attachment to a large fossilised bone. Mitchell made a collection of bones from the site and took them to England where they were given to the vertebrate anatomist, Richard Owen, for study.[2,3] Owen, a young professor at the Hunterian Museum, Royal College of Surgeons, was building a reputation as the most distinguished anatomist of the era.

Owen concluded that the bones belonged to several extinct species. In a letter to Mitchell he provided illustrations and descriptions of over-sized kangaroos and another even larger animal that was obviously not related to any animal still in existence in Australia. This letter reproduced in Mitchell's journal provides the name *Diprotodon* for the mysterious giant (Fig. 1) (Mitchell, 1838: 359).

The next substantial discoveries of Australian megafauna occurred soon after

FIG. 1. The type specimen of the *Diprotodon* jaw-bone from Wellington Valley held in the Natural History Museum, London. The lower incisor was understandably recognised as a 'tusk' by Richard Owen. The scale bar is 10 cm.

the settlement of the Darling Downs in south-eastern Queensland in the early 1840s. According to a note in Leichhardt's diary, made when he was heading north towards Moreton Bay in June 1843, fossil bones had been found 'in the creek on Mr Skogel's station' (Darragh and Fensham, 2013: 237). Leichhardt was referring to Jimbour station leased by Richard Scougall, and the location was probably Jimbour Creek.[4] Again, it was Mitchell to whom the bones were sent and he forwarded 'a portion of a molar tooth and of the shaft of a femur with part of a spine of a scapula, and some smaller fragments of a long bone' to Owen. Owen's prompt determination was that the fossils 'incontestably establish the former existence of a huge proboscidian Pachyderm in the Australian continent, referable to either the genus *Mastodon* or *Dinotherium*' (Fig. 2) (Owen, 1843a). Georges Cuvier, the founder of palaeontology and Owen's professional idol, had also examined the bones from Wellington Caves and perhaps it was his opinion that they belonged to an elephant which had influenced Owen's judgement (Mitchell, 1838: 359).

Owen based his identification of the Darling Downs bones upon a perceived similarity to the antero-posterior compression of the femur in elephants, rhinoceros and mastodon. He also noted that the grinding surface of the molar, with its raised ridges, also suggested affinities to elephantoid relatives. Finally the presence of 'tusks' in the *Diprotodon* was, for Owen, further evidence of an alliance with either *Mastodon* or *Dinotherium*. Owen refined the identification in a subsequent paper, again referring the fossils definitively to *Dinotherium*, based on the shape and proportion of the teeth, in particular that the number of ridges decreases from the front to the back molars, a character that distinguishes *Dinotherium* from *Mastodon* (Owen, 1843b).

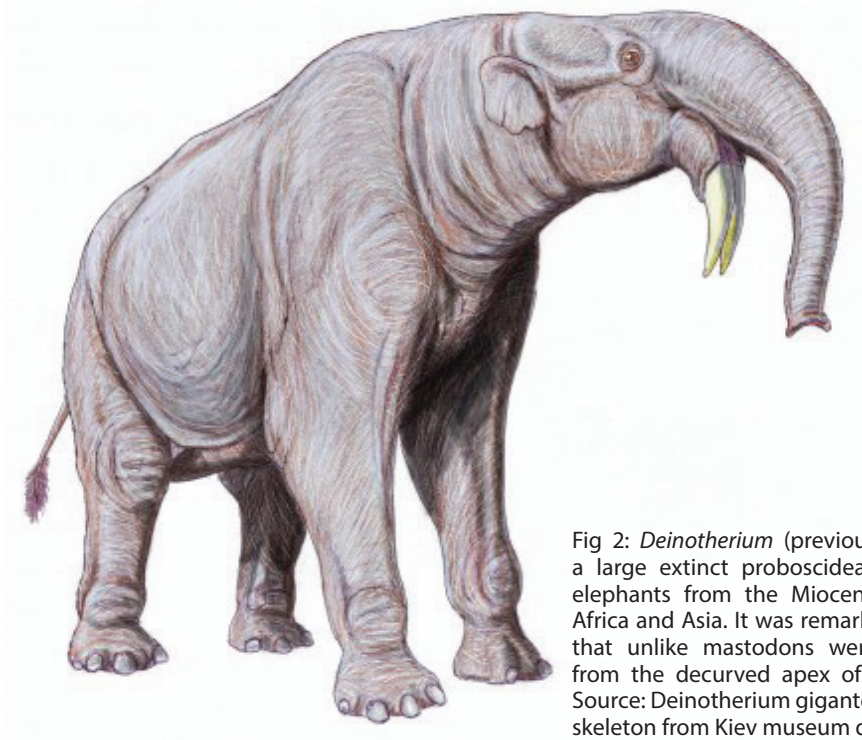
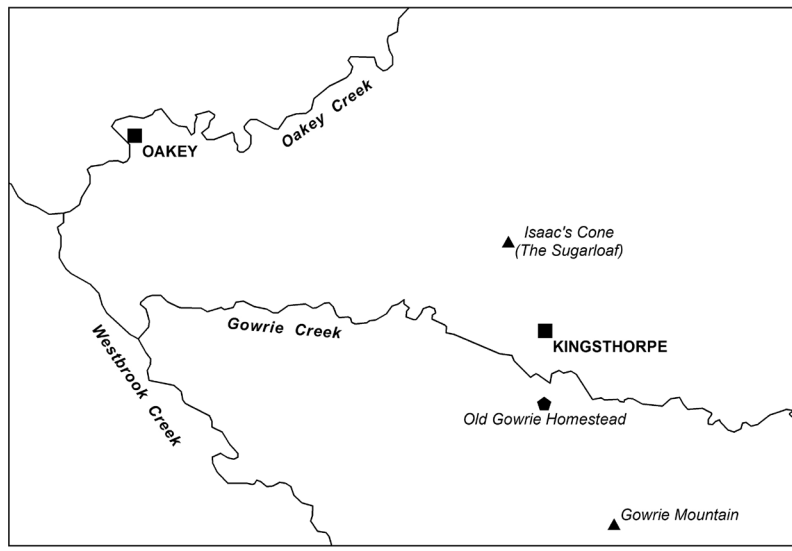


Fig 2: *Deinotherium* (previously spelt *Dinotherium*), a large extinct proboscidean mammal related to elephants from the Miocene deposits of Europe, Africa and Asia. It was remarkable for a pair of tusks that unlike mastodons were directed downward from the decurved apex of the lower jaw. Image Source: Deinotherium giganteum, based on photo of skeleton from Kiev museum dmitrchel@mail.ru

FIG 3.

Top: Gowrie Creek near the town of Kingsthorpe where Leichhardt examined the fossil remains of marsupials with Isaac's Cone (The Sugarloaf) in the background.

Below: Site of old Gowrie Homestead and current localities.



LEICHHARDT'S ADJUDICATION

It was not until Leichhardt's return from Moreton Bay to Sydney that he visited Frederick Isaac's Gowrie station to examine the fossils and stratigraphy of the alluvial deposits (Fig. 3). His diary entry from 9 April 1844 provides precise details on the locations of the various fossil beds in this area:

> The stream [Gowrie Creek] that flows past Isaac's Station and joins five miles further with Campbells Creek [Westbrook Creek] and which two miles further falls into Oakey Creek on Hugh Ross's Station contains the most fossil bones. They are, however, also found in Oakey Creek, Campbells Creek and Hodgsons Creek. (Darragh and Fensham, 2013: 437)

Frederick Isaac was not in residence at the time of Leichhardt's visit, but an assemblage of bones was available for his inspection.[5] Leichhardt noted in his diary that:

> Although the teeth differ from the true kangaroo teeth, you do see that they are formed on the same plan and that even these huge incisors correspond to both the incisors of the kangaroo … The rest of the lower jaws belong unquestionably to true kangaroos and perhaps to species still living' (Darragh and Fensham, 2013: 437-438).

He also commented on the nature of the environment, pointing out that:

> the presence of these and all the still living freshwater molluscs clearly indicates that a gigantic herbivore, formed according to the plan of the Australian animals, lived under conditions very little different from the present day. Mr Dennis[6] told me that the Blacks chatter about inland lakes and large animals and that these are said to be only two days' journey away from his station. (Darragh and Fensham, 2013: 438).

Whether they still existed or not, their perfect state of preservation and the nature of the alluvial deposits suggested to Leichhardt that the animals belonged to a recent era (Leichhardt to Richard Owen, 10 July 1844, Aurousseau, 1968: 770-773; Leichhardt, 1867-1868: 62-63).

After arriving back in Sydney and learning of Owen's *Dinotherium* identification, Leichhardt responded by letter including a package of his specimens (Leichhardt to Richard Owen, 10 July 1844, Aurousseau, 1968: 770-773).[7] In his letter he stridently asserts that the fossils of the giant Australian mammals must be more properly assigned as relatives of the kangaroo. The critical evidence for Leichhardt was the resemblance of the 'lower jaw, and particularly, its two horizontal incisors' to current Australian animals, which despite different body forms, share this common jaw structure. According to Leichhardt this was the

> Australian type, and … that the large fossil jaw was formed on the same plan as the Kangaroo, of the Opossum, of the Flying squirrel of the Colonists, and of the Koala, is formed without pretending that the animal to which it belonged was either a gigantic kangaroo or the gigantic Opossum. (Leichhardt to Richard Owen, 10 July 1844, Aurousseau, 1968: 770-773).

The colonials were generally perceived as collectors, who should diligently supply all the necessary details relating to their discoveries, without adjudicating over the identity or meaning of their specimens (Moyal, 1993). Owen may have well been affronted by this challenge to his authority from a subordinate who had previously asked him for a reference.[8]

Perhaps Owen immediately recognised the accuracy of Leichhardt's opinion. The order Diprotodontia now includes most of the modern Australian marsupials, including

kangaroos, gliders, possums and koalas, and is characterised by the first two lower incisors being particularly large and forward pointing, and the large gap (diastema) between the incisors and the premolars (Aplin and Archer, 1987). Leichhardt's insight was remarkably prescient of modern marsupial taxonomy.

A paper of Owen's published in 1845 continued to propound the existence of elephant relatives (Owen, 1845a). In this update he concedes that the *Dinotherium* identification was 'premature and erroneous' given that the *Diprotodon* 'tusks' inclined upwards instead of bending downwards. He does not make any advance on the true identity of *Diprotodon* but he described some new additional molar teeth that were found in a second Wellington Valley cave. His account highlights a remarkable similarity to *Mastodon angustidens* known from 'European Tertiary strata'. Owen allows the possibility that the form of molar teeth may have converged between large mammals as divergent as the tapir, Dinotherium, manatee and kangaroo, but he settles on the conclusion that it is 'much more probable' that the teeth verify the existence of an Australian mastodon, provisionally named *Mastodon australis*.

Owen addressed the 14th meeting of the British Association for the Advancement of Science at York in September 1844 on the Australian fossil fauna. Owen received Leichhardt's package of fossils after the York meeting but well before the written report was published in 1845.[9] He may have had time to consider Leichhardt's opinion on the true affinities of the Australian mammals before finalising the manuscript, but if this were the case there is no acknowledgment. The 'Report on the extinct mammals of Australia' (Owen, 1845b) was certainly the most comprehensive discussion of the subject to date. For the first time Owen recognises an affinity of *Diprotodon* with kangaroos, although he continues to recognise that some characteristics are associated with other animals, including wombats, the placental tapir and extinct *Mastodon*. At one point he refers to *Diprotodon* as a 'pachydermoid marsupial' and that could be considered an unequivocal conclusion. However, he does not refer explicitly to an error in his former determination, and also reiterates that the molar teeth from the second Wellington Valley cave can be referred 'with certainty to an extra-Australian genus'.

The comparative anatomy in the paper left the central politician of Australian science, Reverend William Branwhite Clarke, confused. He noted that 'Professor Owen has indicated certain affinities between these great Australian beasts and the Kangaroo, Tapir, and Wombat, leaving it uncertain to which the *Diprotodon* is nearest' (Clarke, 1847a; Clarke, 1847b).

Many years later, in 1877, when Owen's reputation was firmly established, he recognised the value of Leichhardt's account of the geological setting of the fossil deposits and acclaims him as an 'accomplished and determined but unfortunate explorer' (Owen, 1877: 250, 266). His commendation falls short of recognising the significance of Leichhardt's recognition of the marsupial identity of the megafauna in 1844. Perhaps by way of mistake, or even possibly as a clumsy attempt to adjust the historical record, he made a point of specifying that Leichhardt's only communication arrived in 1847 (Owen, 1877: 266), despite the entry in his own diary that acknowledges that it was actually received in November 1844 (Owen, 1894: 245).

After reading Owen's 1845 article, Leichhardt sent a copy of his original letter to Clarke on 4 December 1847 and pointed out that Owen mentioned 'part of this letter in a meeting of the British Association but not that part which was most interesting to me [the anatomy of the jaw and teeth]' (Aurousseau, 1968: 977-978). Leichhardt goes on to assert

the originality of his own insight by pointing out that Owen 'was at the time under the impression, that those bones belonged to the *Dinotherium*, and the change of his opinions must have been in some connection, with that bone, and the loose incisors of the large animal sent to him at the same time'. Leichhardt's unambiguous recognition of a marsupial origin may well have pushed Owen's own assessments in that direction.

A COLONIAL CONSENSUS

The years 1844 to 1847 were a busy time for Leichhardt with a successful expedition to Port Essington and an aborted attempt to cross the continent from east to west. Leichhardt was in Sydney towards the end of 1847 considering another attempt to reach the west coast of the continent when Mr R.B. Turner brought another large collection of bones from the Darling Downs to Sydney. They were collected from Kings Creek on Innes's Haldon station. The fossils included a nearly complete head of *Diprotodon*, as well as both femora, both scapulae, one humerus, several of the ribs and several vertebrae from the neck, back and tail (Clarke, 1847a).

Leichhardt immediately saw their value although his attempt to purchase them for the newly established Australian Museum could not extend to an existing offer of £50 from the entrepreneur Benjamin Boyd (Leichhardt to Clarke, 4 December 1847, Aurousseau, 1968: 977-978). Boyd sent the fossil bones to England but the ship was wrecked off the Sussex coastline. Parts of the cargo were rescued including the *Diprotodon* skull which was acquired by Richard Owen (Clarke footnote in Leichhardt, 1867-1868: 63).

Before the bones left Australia on their troubled passage, Leichhardt, Clarke and William Sheridan Wall, the first curator of the Australian Museum, examined the specimens during their preparation. Clarke described the bones as belonging to 'very near a Kangaroo', an opinion to which William Macleay also concurred, describing it as some kind of 'marsupial Pachyderm' (Clarke, 1847a; Macleay, 1847). Thus, three years after Leichhardt had expressed his clear opinion, a consensus had emerged among the other colonial scientists.

In his last public document written on the eve of his final journey in 1847, Leichhardt paid particular attention to *Diprotodon* (Leichhardt, 1855: 15-16).[10] Drawing on the anatomical training he had gained in Europe he noted a sinus on the interior surface of the posterior angle of the jaw corresponding to a hollow which was peculiar to the kangaroo. He recognised that the general shape of the skull had similarities to the koala, but differed from other modern terrestrial mammals in that the occipital foramen and condyles form the posterior extremity of the skull, suggesting that these dense bone structures were used to support the heavy head. The flat ribs, short sinuous processes of the vertebrae, long shoulders with a very thick posterior extremity, compressed humerus and a femur lacking prominent processes at the lower condyles suggested to Leichhardt that the animal had relatively free movement. In conclusion, he suggested that the animal shared most affinities with marsupials, particularly the formula of the teeth (with kangaroos), the posterior angle of the lower jaw and crest and general form of the head (like the koala) and the shape of the ankle (with the wombat). It is now recognized in modern taxonomy that the inflected jaw angle and the tooth formula (e.g. four molars in marsupials, compared to three or less in placentals) are among the least ambiguous characters separating the skeletons of the major mammalian groups (Dawson et al., 1989: 17). Like Leichhardt's earlier observations, his new refinements mirrored modern taxonomy.

HABITAT, ANTIQUITY AND EXTINCTION

Leichhardt made other observations in relation to the habit of *Diprotodon*. He noted that the outwards and forwards orientation of the lower incisors was unusual and the arched form of the upper median incisors would have served to plough the ground while the next pair of teeth could hold edible roots.[11] These traits suggested to Leichhardt that *Diprotodon* occupied an aquatic habitat, and that if this were the case then it could not carry its young in a pouch or else they would surely drown. Leichhardt's idea is not substantiated by current understanding because the distribution of *Diprotodon* fossils includes many locations that would not have included permanent water. Furthermore, adult skeletons have been found associated with juvenile skeletons in the area where the pouch would have been (Price, 2008).

Among the bones from Kings Creek, Leichhardt recognised the vertebrae of a crocodile. The identification was disputed by Clarke and must have seemed extremely unlikely given the remoteness of the Darling Downs from the geographic range and types of habitats these giant reptiles prefer (see Clarke to Richard Owen, 30 November 1847, in Moyal, 2003: 217). Leichhardt's identification is entirely plausible given that crocodiles, closely allied to the modern saltwater crocodile of northern Australia (*Crocodylus porosus*), are relatively common amongst Australian Pleistocene fossil assemblages. *Diprotodon* thrived during times that were wetter than today, when the Darling Downs included large streams and permanent swamps (Price and Webb, 2006).

After three years of exploration spanning a quarter of the continent, the previous existence of the giant marsupials was no longer a question in Leichhardt's mind. Confirmation that the megafauna were definitely extinct prompted speculation as to the cause of their demise. Clarke interpreted the affinities of the ancient fossils with their modern relatives to indicate the great antiquity of the Australian continent, although not necessarily over a period that was entirely stable (Clarke, 1847b). With accurate insight into the evolution of the Australian landscape during the Tertiary period, he recognised the legacy of marine transgressions, deposition and uplift. Clarke goes on to determine that the damaged condition of the ancient marsupial fossils suggests extinction by 'violent catastrophe' rather than by gradual 'quiet death'. The catastrophe he asserts could have been a flooding deluge given the 25 feet of ironstone rubble and clay under which the fossils were buried. Leichhardt had a converse view believing that the draining of swamps associated with uplift was the most likely cause of their demise (Leichhardt, 1847).

Owen had a different explanation for the demise of the giant Australian mammals.

> No other adequate cause suggests itself save the hostile agency of man …. As the elephant succumbs to the spears and pitfall of the negro hunters, the minor bulk of *Diprotodon* is not likely to have availed it against the combined assaults of the tribes of Australoid wielders of club and throwing-sticks (Owen, 1877).

Owen's opinion and Clarke's insight foreshadow the contemporary debate embroiling the fate of *Diprotodon* and the other megafauna. Some researchers argue that their sudden demise, coincident with the arrival of humans, indicates they were exterminated by a *blitzkrieg* of hunting (Roberts *et al*., 2001; Roberts and Brook, 2010). Other schools of thought provide evidence of coexistence between megafauna and humans (Trueman *et al*., 2005) or gradual decline, suggesting extinction was ultimately related to a drying climate (Price *et al*., 2011).

AUSTRALIAN MAMMALS AND THE THEORY OF EVOLUTION

In 1838 Owen had examined fossils of extinct species collected by Charles Darwin from South America and correctly identified them as giant ancestors of the rodents and sloths that were still present on the continent, rather than relatives of the large animals in Africa (Rachootin, 1985). This realisation from the southern hemisphere was an important contribution to Darwin's thinking. Unfortunately Owen had neglected to further develop his own awakening when confronted by large bones from Australia. It was not until his presentation to the meeting of the British Association for the Advancement of Science at York in 1844 that Owen described the continuity of lineages as a general law:

> with extinct as with existing Mammalia, particular forms were assigned to particular provinces, and, what is still more interesting and suggestive, that *the same forms were restricted to the same provinces at a former geological period as they are at the present day* (italics in original Owen, 1845b: 242).

Owen's diary affirms that his great awakening owed nothing to Leichhardt.[12] Remember, however, that in the same forum that Owen proclaimed his general law, he still proposed that elephant relatives had existed in Australia. Leichhardt knew better and if Owen had appreciated his unambiguous position on the Australian fossils he would have been able to proclaim his law with far greater confidence and precision.

Richard Owen's contribution made during one of science's greatest eras clearly demonstrates that he had advanced far beyond a biblical interpretation of the origin of species. In fact his co-ordinated insights into the fundamental archetypes of the animal groups underpinned the essence of evolution and without these foundations palaeontology would have been unable to proceed. His disagreements with the Darwinists were not the result of any fundamental disagreement with the evolutionary process. While Owen did have trouble accepting that humans were as much a product of evolutionary process as other animals, the subsequent acrimony between Owen and the Darwinians seems to have mostly resulted from personal animosities driven by Owen's arrogance and envy (Cosans, 2009). On matters of science, his infamy as Darwin's antagonist was mostly unwarranted.

As for Leichhardt, his foray into vertebrate anatomy is another testament to the depth of his intellect and the breadth of his scientific interests. Here he was, in Australia, a well-trained but unqualified scientist primarily concerned with botany and geology, but also consumed by the preparation, triumph and humiliating defeat of his major exploratory expeditions. Amidst all that turmoil Leichhardt managed to provide an extremely accurate opinion on the true relations of the Australian megafauna, founded on defining characteristics of marsupials that would only be formally recognised many decades later. His insight, recorded in his diary on 9 April 1844, that the extinct Australian giants were 'formed according to the plan of the [contemporary] Australian animals' (Darragh and Fensham, 2013: 438) came at the very moment when it could have had maximum influence. Instead, Leichhardt's insights were to be subsumed into the coordinated efforts of the great scientists of the time who were in much better positions to develop coherent theories, theories that would provide an enduring explanation for the diversity of life and its patterns across the globe.

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❑ ENDNOTES

1. In a letter to Edward Holland on 12 July 1843, Darwin revealed his knowledge of the fossil beds on the Darling Downs, and he also acknowledged Richard Owen's interest (Burkhardt and Smith, 1985: 373-4).
2. Ranken also took his fossil bones to England, prior to Mitchell, but they were not examined by Owen (Branagan, 1992).
3. Richard Owen (1804-1892) would become the most eminent anatomist of his era. His central interest was palaeontology and he is perhaps most famous for coining the term 'dinosaur'.
4. There are collections from Jimbour Creek in the Queensland Museum (Molnar and Kurz, 1997).
5. Leichhardt was so impressed by the collection that he wrote to Isaac offering to exchange a horse or his collection of 300 plants that he had painstakingly collected from around Moreton Bay (Leichhardt to Isaacs, 3 June 1844, Aurousseau, 1968: 768-769). It is unclear whether Isaac's collection made it to Britain, although there are numerous references to collections from both Isaacs and his partner Henry Hughes (Owen, 1877: 240, 250, 260, 266, 281).
6. Dennis was Scougall's manager on Jimbour station.
7. The bones inspected and sent by Leichhardt included a lower jaw with incisors and parts of femur, atlas, caudal vertebrae, scapula and humerus (Leichhardt, 1867-1868: 62-63; see also Owen, 1877: 240, 250, 266). In a later letter to Clarke on 4 December 1847 Leichhardt makes an obscure reference to one of these animals as a 'sucking diprotodon' (Moyal, 2003: 218-219). In his diary of 11 July 1844 Leichhardt confirms that he delivered the box on 9 July 1844 to the *Ocean Queen*, which departed on 14 July 1844, as reported in the *Sydney Morning Herald* on 15 July 1844.
8. As discussed in Leichhardt's letter of 10 July 1844, Owen had given him a reference just prior to his departure to Australia in 1841 and he used it to gain an invitation to a dinner where he met Surveyor General Thomas Mitchell (Aurousseau, 1968: 770).
9. Owen wrote in his diary, 14 November 1844: 'received two letters from Sydney. A man called Leichhardt sends the lower jaw of a giant kangaroo-like extinct animal'. And again on 3 December: 'This evening the box of diprotodon bones came from Herr Leichhardt. We opened it and found a vertebra, a beautiful half-jaw of a young animal, &c.' (Owen, 1894: 245).
10. The date of the correspondence is unclear in the published form, but it was written in late November 1847 (Leichhardt to Clarke, 4 December 1847, Moyal, 2003: 218-219).
11. This latter point was also subsequently made by William Macleay without acknowledgement to Leichhardt (Macleay to Clarke, 6 December 1847, Moyal, 2003: 219-220).
12. Owen's diary states, 4 October 1844: 'Sedgwick told me that the idea I had thrown out in my speech on a new geographical partition of the continents of the earth, in accordance with the extinct animals found in them, and other grounds, I have not room for, was good and new' (Owen, 1894: 242).