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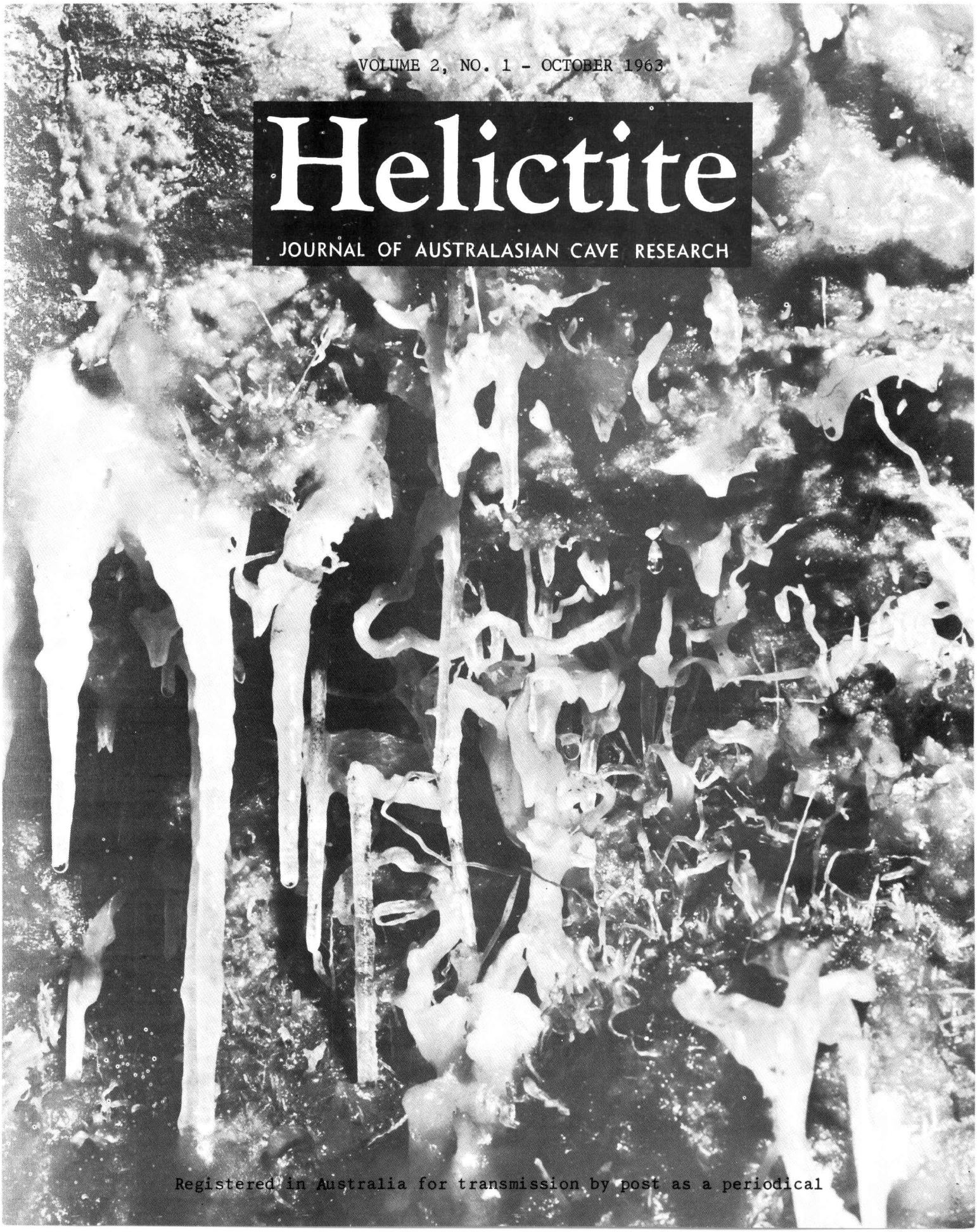

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E.A. Lane and A.M. Richards

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THE DISCOVERY, EXPLORATION AND SCIENTIFIC INVESTIGATION OF THE WELLINGTON CAVES, NEW SOUTH WALES

By

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INTRODUCTION

Although research has been unable to establish a definite date of discovery for the limestone caves at Wellington, New South Wales, documentary evidence has placed it as 1828. The actual discovery could have been made earlier by soldiers or convicts from the Wellington Settlement, which dated from 1823. Whether the aborigines knew of the caves' existance before 1828 is uncertain, but likely, as in 1830 they referred to them as "Mulwang."

A number of very small limestone caves were also discovered about the same time in the nearby Molong area. The Bungonia Caves, in the Marulan district near Goulburn, were first written about a short time later. On all the evidence available at present, the Wellington Caves can be considered to be the first of any size discovered on the mainland of Australia.

The Wellington Caves are situated in a low, limestone outcrop about six miles south by road from the present town of Wellington, and approximately 190 miles westnorthwest of Sydney. They are at an altitude of 1000 feet, about half a mile from the present bed of the Bell River, a tributory of the Macquarie River. One large cave and several small caves exist in the outcrop, and range in size from simple shafts to passages 200 to 300 feet long. Mining for phosphate has been carried out, resulting in extensive galleries, often unstable, at several levels. Two caves have been lit by electricity for the tourist trade: the Cathedral Cave, 400 feet long, maximum width 100 feet, and up to 50 feet high; and the smaller Gaden Cave. The Cathedral Cave contains what is believed to be the largest stalagmite in the world, "The Altar", which stands on a flat floor, is 100 feet round the base and almost touches the roof about 40 feet above. It appears that the name Cathedral was not applied to the cave until this century. The original names were "The Great Cave", "The Large Cave" or "The Main Cave." The Altar was named by Thomas Mitchell in 1830. See map of cave and Plate.

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Extensive Pleistocene bone deposits - a veritable mine of bone fragments - were found in 1830, and have been studied by palaeontologists almost continuously ever since. These bone deposits introduced to the world the extinct marsupials of Australia, and have a special importance in view of the peculiar features of the living fauna of the continent. The names of many famous explorers and scientists are associated with this history, among the most prominent being Sir Thomas Mitchell and Sir Richard Owen.

Anderson (1933) gives a brief outline of why the Wellington Caves fossil bone beds so rapidly attracted world-wide interest. During the 18th. and early 19th. Century, the great palaeontologist, Baron Georges Cuvier, and others, supposed that the earth had suffered a series of catastrophic changes in prehistoric times. As a result of each of these, the animals living in a certain area were destroyed, the area being repopulated from isolated portions of the earth that had escaped the catastrophe. The Biblical Deluge was believed to have been the most recent.

Darwin, during the voyage of the Beagle around the world (1832 - 37), was struck by the abundance of Pleistocene mammalian fossils in South America, and also by the fact that, while these differed from living forms, and were in part of gigantic dimensions, they were closely related to present-day forms in that continent. Darwin's theory of descent with modification did not reconcile with the ideas of Cuvier and others. As the living mammalian fauna of Australia was even more distinctive than that of South America, it was a matter of importance and excitement to discover the nature of the mammals which had lived in Australia in the late Tertiary and Pleistocene.

EARLY HISTORY OF THE DISTRICT

In 1813, the crossing of the Blue Mountains from east to west by Blaxland, Wentworth and Lawson, opened up the rich country in the vacinity of the present cities of Bathurst and Orange. In August, 1817, the Wellington Valley was discovered and named by Lieutenant John Oxley, the Surveyor-General of New South Wales, in company with the Deputy Surveyor-General, G.W. Evans, the botanist, Allan Cunningham, Colonial Botanist, Charles Frazer, and the mineralogist, William Parr. Oxley recorded the naming and discovery in his field book for August 18, 1817. Later, in his Journal, Oxley (1820) wrote that he had called the stream in the valley the Bell River, "in compliment to Brevet Major Bell of the 48th. Regt." The valley was named after the Duke of Wellington.

Oxley noted the occurrence of limestone in the hills bounding the east side of Wellington Vale during an expedition in 1818. He wrote (Oxley, 1820) that after crossing Bell's River, limestone was seen. This limestone was considered a valuable discovery, as only one earlier report of this rock had been made - "lime rocks" and "lime cliffs" seen and recorded by

Surveyor Evans in May-June, 1815, near the Belubula River and Mount Lewin. A perpendicular limestone rock overhanging the river terminated Oxley's "excursion." The party called it "Hove's Rock" because it was covered with a beautiful new species of Hovea.

On a second expedition in 1818, Oxley (1820) again referred to the limestone outcrops in the Wellington Valley. On his chart of the interior of New South Wales, Oxley noted limestone a short distance west of the junction of the Macquarie and Bell Rivers. He did not mark the limestone in the cave area which lies approximately southeast and only a short distance away, but his Journal references possibly included it.

Governor Lachlan Macquarie wrote in his Journal for October-November, 1820, that he had ridden out to examine the plains and had given them the name of "that distinguished military hero the Duke of Wellington, by calling them the Wellington Plains." Macquarie also noted that he had fixed the site of the future township of Wellington - this was only a matter of four or five miles from the cave limestone. Macquarie must have known of Oxley's naming of the Valley three years earlier, but chose to ignore it.

In March, 1823, the first settlement was set up in the valley under the command of Lieutenant Percy Simpson. The population consisted of a number of convicts and their soldier guards.

In 1823, Frazer, the Colonial Botanist, gave a description of the valley, including the geology, and made the following reference to limestone: "The hills bounding the valley on the east are composed of mountain limestone of the best quality."

GEOLOGY OF THE CAVE LIMESTONE

The caves occur in the low ground of the valley, in limestone which strikes in a southerly direction, and may be traced up the Bell River for several miles. The limestone is hard, finely crystalline, pale blue in colour, and mostly massive. In places it presents thin and well-defined stratifications, generally with a high dip, which is often in all directions, the beds having been folded into anticlines and synclines. Where the limestone crops out at the surface it runs for a long distance in parallel lines, like the furrows of a plough. On the whole, the Wellington limestone has a general dip to the west, on which side it is overlain by quartzite, passing upwards into a vast deposit of hard, red conglomerate. This conglomerate forms a range which marks the western boundary of the valley of the Bell. Fossil corals are abundant. Some of the caves (e.g. Cathedral, Breccia) have pools of water in them, which could form part of a slow-moving underground stream connecting with the Bell River.

The first geological report of the Wellington District was made by

Major Thomas Mitchell (1838) and included a map of the Bell River Valley from the caves to the junction of the Bell and Macquarie Rivers. The map indicated red sandstone, limestone, trap rock (andesite), alluvium and diluvial gravel.

Carne and Jones (1919), after studying the area, gave the age of the limestone as Silurian. Hill (1942), from the examination of fossils from two localities in the vacinity of the caves, suggested a Lower Devonian age for the limestone. In 1945, Basnett and Colditz gave a description of the general geology of the Wellington District. They considered the limestones of the district could be placed in Upper Silurian, Lower Devonian or Middle Devonian periods, and that the limestone of the Wellington Caves was included in the Lower Devonian beds. The area is one of minor folding and faulting and they suggested further collecting to the south of the caves could result in the discovery of Middle Devonian or Silurian beds. Joplin (1952) questioned Basnett and Colditz's statement and considered that a fault, visible in the Cathedral Cave, which brings rhythmically banded limestones against massive limestone, was possibly a fault bringing the Devonian against the Silurian. She believed the limestone on the Caves Reserve was Silurian (Nanima Formation). Further study of the area may help to elucidate the problem.

DISCOVERY OF THE CAVES

The earliest suggested date of discovery for the Wellington Caves is in a book "Eumalga, or the White Chief." The author, Robert Porter, founded the first newspaper in Mudgee in 1857, and the first newspaper in Wellington in 1874.

The book tells of events allegedly occurring in the Wellington Stockade and neighbouring country between 1822-1835. The story particularly concerns the "sensational career of John Saville" and "was told to the author by Richard Taylor, who was a prisoner at the Wellington Stockade, and other old hands with whom the writer has come in contact during a long period of years."

Only part of the book is relevant to this history. Briefly, Saville, a convict, arrived at the Stockade in 1823, and after being ill-treated, escaped and joined a group of blacks he had previously befriended. Later, while Taylor was looking for lost horses, Saville "revealed" himself because he thought he could trust Taylor. He agreed to give Saville some articles from the settlement (clothing and so forth) and, in return, Saville and the blacks brought the horses to Taylor. Taylor at this time was "acquainted with the secret of the now far-famed Wellington Caves, which he communicated to the officer in charge of the settlement. The information was deemed of such importance that Taylor was rewarded with a ticket of leave." He subsequently settled permanently in the district.

There does not seem to be any way of testing the authenticity of this narrative which the author himself calls "a historical romance." The story bears the earmarks of a romance, yet in spite of all, could have some truth. No cross-references are given, and so "Eumalga" must remain open to doubt.

The earliest authenticated references to the caves are found in a letter written by the explorer Hamilton Hume (1828), and in the published exploration Journal of Captain Charles Sturt (1833).

Hume, who was accompanying Sturt as second-in-command on his expedition down the unexplored Macquarie River, had joined the party at Bathurst on November 27, 1828. The expedition reached Wellington Valley at the end of November, during a severe drought, and departed westward on December 7. Temperatures during their time at Wellington reached 115°F. The settlement here was the most distant inland in New South Wales.

While at Wellington, Hume wrote a letter dated December 4, 1828, in which he said "there is near this place a very large and beautiful cave. I have been into it. It is formed on the side of a hill, among limestone. It extends about one quarter of a mile into the earth, in an angle of 45 deg., it then terminates in a deep pond of water. The inside of the cave is beautifully formed, some parts of it being full 50 ft. in height, supported by pillars beautifully carved by nature. I have got some specimens from the inside of it. We were obliged to have lights and torches made of tar and hemp." The original letter is now in the Mitchell Library, Sydney.

Sturt, in a preliminary chapter to volume one of his Journal, discusses the "Moulong Plains, a military station intermediate between Bathurst and Wellington Valley." He found that limestone occurred in the bed of a small creek and continued, with little interruption, to Wellington Valley and beyond. "The accidental discovery of some caves at Moulong Plains led to the more critical examination of the whole formation, and cavities of considerable size were subsequently found in various parts of it, but more particularly in the neighbourhood of Wellington Valley." The authors have been unable to find any additional reference in early literature to the Molong Caves.

Sturt continues: "The caves into which I penetrated (in 1828) did not present anything particular to my observation; they differed little from caves of a similar description into which I had penetrated in Europe.... They comprised various chambers or compartments, the most remote of which terminated at a deep chasm which was full of water."

Neither Sturt nor Hume claim discovery of the caves, nor, unfortunately, do they make reference as to how they learned of the caves' existance or how they were discovered. The reference to torches in Hume's account

Possibly explains black stains on the walls of the Cathedral Cave near the far end, which could be carbon from these or similar fiery brands. In a more frivolous vein, Hume's account possibly marks him as Australia's first cave vandal.

In the same chapter of his Journal, Sturt also wrote that local interest of that period was taken "in the prosecution of geological observations." This had "led many gentlemen to examine the contents of these caverns; and among the most forward, Major Mitchell, the Surveyor General, must justly be considered, to whose indefatigable perserverance the scientific world is already so much indebted."

Sturt added, somewhat prematurely: "A close examination of these caves has led to the discovery of some organic remains, bones of various animals imbedded in a light, red soil; but I am not aware that the remains of any extinct species have been found, or that any fossils have been met with in the limestone itself. There can, however, be little doubt but that the same causes operated in depositing these mouldering remains in the caves of Kirkdale (England) and those of Wellington Valley."

It is perhaps pertinent to mention here another publication by Robert Porter (Porter, 1906) on the history of Wellington. He says that "according to the best authority" in 1830, a man named Ranken (here called a Government surveyor) and some of his men, while riding over a limestone hill, came upon a hole in the ground which was too small to admit a man. Porter claimed this to be the first discovery of the caves.

The next day, five convicts from the nearby settlement were sent to open up the entrance. Many strange bones were found and taken to the stockade where they were packed and sent to Sydney. Later an order from Governor Darling offered a free pardon to any convicts who thoroughly explored the caves. Two volunteered and worked for three weeks breaking through various obstacles until they came to a large room containing the Altar formation. A few more days of hard labour by the light of a slush lamp brought them to the Well.

The above account seems to bear all the signs of a word-of-mouth story which has become cloudy and confused over a succession of tellings. The story of George Ranken which follows shortly is well documented.

DISCOVERY OF FOSSIL BONES

First Discovery of Fossil Bones in N.S.W.

The story of Wellington Caves now moves into the second phase - the finding of the fossil bone deposits, the first collections, and the intense interest of the great palaeontologists. Only two fossil vertebrate bones

had been recorded in Australia prior to the discovery of the Wellington bone caves.

P. Cunningham, a Royal Naval surgeon who spent about two years in the Colony of New South Wales wrote in the Sydney Gazette of May 14, 1829: "I have heard of no fossil remains, with the exception of shells, having been discovered until the petrified sacrum of a large animal was found, a short time ago, upon the surface of the soil on Holdsworthy Downs....About a month since when visiting a sheep station about ten miles west from this, on a rivulet falling into the Goulburn from the north, the petrified second cervical vertebra of a large animal was picked up from the surface soil.... by Master Edward Ogilvie." Dimensions of the vertebra are given. Some of these, in inches, are: "Circumference of body, 11; circumference of the base of the dentoid process, 4½; circumference where the ligamentous noose encircles it, 3 3/4; length of body, 4; length of dentoid process, 1½; breadth of body superiority, 5; breadth of body inferiority, 3."

Though much larger, Cunningham said, the vertebra agreed closely in many points with that of man. The area where these fossils were discovered is about 120 miles eastnortheast of Wellington, close to Mt. Wingen - Australia's famous "Burning Mountain." In 1831, further reference was made to these fossils by the Rev. Charles Pleydell Neale Wilton in the Australian Almanack.

Ranken's Discovery of Fossil Bones at Wellington Caves

The Sydney Gazette of May 25, 1830, published a letter dated May 21 and signed "L". The letter referred to George Ranken as having "in a late excursion to Wellington Valley....visited and explored a remarkable cave about two miles from the settlement, the existance of which had been known for a considerable time and the entrance of which is in the face of the limestone range."

The settlement of 1830 is still marked by a few scattered remnants about half way between the present town of Wellington and the caves to the south. The limestone range mentioned in the text is an exaggerated description for the limestone outcrop which is no more than 100 feet higher than the surrounding flats.

Ranken is usually referred to as "Rankin" in the early literature, a mistake made by "L" and apparently perpetuated. George Ranken, of Kelloshiel, Bathurst, was a "very respectable colonist and magistrate" (Lang, 1831), and has often been given by historians as the discoverer of the Wellington Caves. While this is obviously not so, Ranken must be considered the first person to report the discovery of fossil bones in the caves and he was the first collector.

Speaking apparently of the Breccia Cave (also known as Mitchell's Cave, and Bone Cave No. 3), the Sydney Gazette account said that "at the further extremity of the first chamber, Mr. Rankin (sic) discovered a downward passage which he determined to explore and which he found terminated in another cave or chamber, the entrance of which was by a precipitous descent. On lowering himself down this third chamber, into which no mortal man had ever entered before (because the aborigines have a superstitious repugnance to entering any cavern, saying 'Koppa', the Spirit of the Caves in aborigine mythology, 'Koppa sit down there!'), Mr. Rankin observed, to his great surprise, a piece of bone lying on the floor of the cavern. He discovered a vast quantity of bones of various sizes and generally broken, some strewn on the floor of the cave, but the greater number embedded in a sort of reddish, indurated clay along its side.

"Mr. Rankin collected a small quantity of bones, or rather fragments of bones, and has brought them to Sydney with a view to their being forwarded to Professor Jamieson (sic) of the University of Edinburgh." Professor Robert Jameson enjoyed a high reputation as a zoologist and geologist.

Soon after Ranken's discovery of the fossil bones at Wellington, the Rev. Dr. John Dunmore Lang, a leading Presbyterian clergyman in Sydney and almost certainly the "L" of the Sydney Gazette report, sailed to England. In 1831, he wrote to Jameson, Regius Professor of Natural History at the Edinburgh University and editor of the Edinburgh New Philosophical Journal, to give him the exciting news. Jameson reprinted in the Journal, Part XXII, 1831, the Sydney Gazette letter of "L", together with a letter giving additional information on the Wellington bone caves. Both these were "communicated" by Lang.

At no time is it stated that "L" and "Lang" are synonymous, although this can be assumed. As a prominent churchman, Lang probably preferred to remain anonymous and not be involved in discussions on Divine Creation and evolution, which could have been occasioned by the fossil bone discoveries. However, "L" did support the idea of a Universal Deluge, a theory which at that time was being queried.

"L" said in his report that by early 1830 many stalactites in the cave had already been broken off "by the scientific barbarians of the neighbouring settlement." This cave was probably the Breccia Cave, and evidently it was known before entry by Ranken. Ranken, however, extended the cave considerably.

He said that on entering the cavern, Ranken found a piece of bone lying on the floor. "It struck him at first that it might have belonged to some bushranger who had attempted to hide in the cave, and had subsequently died; but on a more minute examination, he discovered a vast number of other bones of various sizes."

"L" added that the rope by which Ranken had lowered himself into the last cavern "had been fixed to what appeared a projecting point of the solid rock, but on its breaking off in consequence of the weight attached to it, it was ascertained to be a large fossil bone - the thigh bone, I conceive, of some quadruped much larger than the ox, or buffalo, and probably of the Irish elk, the rhinoceros, or elephant." Several of the bones were shown to aborigines, in the absence of persons trained in comparative anatomy, and the aborigines asked if the bones belonged to any animals then inhabiting the country. They had all answered such things as "Bail that belongit to Kangaroo," and "Bail that belongit to emu."

In the same issue of the Edinburgh New Philosophical Journal, Part XXII, 1831, but on an earlier page, Colonel C.B. Lindsay (or Lindesay) of the 39th. Regiment, had reported the discovery "of great quantities of fossil bones of animals, imbedded in marl and other substances, in caves in New Holland." This was undoubtedly an independent report of Ranken's discovery.

MAJOR THOMAS MITCHELL - EXPLORATION, COLLECTION AND REPORTS

The next, and most important, visitor to the Wellington Caves was the famous explorer and Surveyor General of the Colony of New South Wales, Major Thomas L. Mitchell, F.G.S. (afterwards Colonel Sir Thomas Mitchell). In June, 1830, Mitchell joined Ranken in Bathurst and they travelled together to Wellington to explore the caves visited by Ranken a short time earlier. On June 26, the two men, with a small number of un-named assistants, began investigations of the Breccia (believed named by Mitchell) and the Cathedral Caves.

In his book, "Three Expeditions into the Interior of Eastern Australia," published in 1838, Mitchell gives a fairly long account of the exploration of the caves and the search for bone fragments. The men apparently did considerable digging in the red earth fill in many of the fissures and caverns; on at least one occasion digging several feet down into the earth floor - without finding fossils. Among other things, he tells of a member of the party sinking up to his waist in a dry heap of white dust at the bottom of a vertical fissure near the entrance to the Cathedral Cave. Later, Mitchell (1834) learned that the dust, when analysed by a Dr. Turner, was principally calcium carbonate, with some phosphate of lime and animal matter.

Mitchell described the Breccia Cave and its masses of osseous breccia which lined walls, filled fissures and adhered to the roof. The red earth floors were also rich in bone fragments. As bone breccia occurrences extended to the surface, Mitchell had a pit dug at the surface about 20 feet from the mouth of the Breccia Cave. As a result, the hill in this area was found to be formed entirely of breccia. The matrix was harder and more compact than that inside the cave and was filled with organic remains. He also

examined the exposed rocks on top of the hill and found many weathered blocks of breccia from which bones protruded. Referring to the large bone broken off in the Breccia Cave by Ranken's rope from the upper part of the breccia, Mitchell said that no other bone of such great dimensions had been discovered since.

He thought that nothing could be discovered "in the present state of these caverns, at all likely to throw any light on the history or age of the breccia, but the phenomena they present seem to indicate more than one change in the physical outline of the adjacent regions, and probably of more distant portions of Australia, at a period antecedent to the existing state of the country." No entire skeleton had been discovered at Wellington Caves, and very rarely were any two bones of the same animal found together. In fact, even the corresponding fragments of a bone were frequently found some yards apart. On the other hand, certain bones appeared to have been deposited in the breccia while still bound together by ligaments, or while teeth were still embedded in jaw bones.

"It may, however, be observed, that the breccia is never found below ground without unequivocal proof in the rocks accompanying it of disruption and subsistance, and that the best specimens of single bones have been found wedged between huge rocks where the breccia is found like mortar between them, in situations eight to ten fathoms under ground" (1838).

Because of the hard nature of the breccia and the fragmentation of the bones, Mitchell had difficulty obtaining any perfect specimens. However, he collected more than 1,000 specimens of bones, teeth, and bone fragments from the Wellington Caves, packed them in wool, and later in 1830, sent them to the Geological Society of London for deposit in the Society's museum.

During their few days in the valley, Mitchell and Ranken visited the caves several times. They also explored a cave lower down the limestone (probably the one known as the Water Cave) but no bones were discovered. Mitchell wrote that the water level in this cave had been much lower when first visited "during a dry season." Discovery of the Water Cave was probably about 1828 also, as we know from Hume and Sturt that this was a period of drought. In addition to exploring and collecting bones, Mitchell surveyed the Cathedral and Breccia Caves and made many sketches. Some of these were used later to illustrate a letter to the Edinburgh New Philosophical Journal (1831) and his book (1838). To draw the Altar in the Cathedral, Mitchell sketched until midnight on July 1, 1830, and then finished the drawing the following day. On other days he drew scenes in the Breccia Cave and on the surface.

In December, 1830, Mitchell wrote to Ranken saying: "I have sent home by the Gilmore, Capt. Gearey, three large boxes of bones and a report (of

36 pages) with ten plans and drawings to the Geological Society. From these and your communications to Jamison (sic), we may hope, in time, to find out what 'Father Time has been about'" (Ranken, 1916).

Subsequently, other caverns containing osseous breccia were found eight miles east of the Wellington Caves, on the north bank of the Macquarie River, and at Buree (Boree), about 50 miles south of Wellington. One underground river passage had red breccia as richly filled with bone fragments as those in the Wellington Valley. Small areas of bone breccia were discovered in the Molong district, 36 miles east of Wellington, at the surface (Mitchell, 1838).

The report by Mitchell was read to the Geological Society on April 13, 1831. The paper dated October 14, 1830, at Sydney, was entitled "An Account of the limestone caves at Wellington Valley, and of the situation, near one of them, where fossil bones have been found." It was abstracted later in the Proceedings of the Society (Mitchell, 1834).

Mitchell described the limestones in the area saying they resembled in external characters the carboniferous series of Europe. He described the Cathedral and Breccia Caves, adding that the caves agreed in structure with many of those well-known from the writings of Dr. Buckland and others. Mitchell considered that there was a great resemblance between the breccias of N.S.W. and those of the shores of the Mediterranean described by Major Imrie in the Transactions of the Royal Society of Edinburgh.

A second paper, erroneously attributed to Dr. Lang, but actually written by Mitchell (Lang = Mitchell, 1831), was printed in the same volume of the Edinburgh New Philosophical Journal as the "L" report of Ranken's find. Mitchell's paper had been taken to England by Lang and forwarded to the editor of the Journal. The correction of authorship was made by Mitchell (1831) in the next issue of the Journal.

Mitchell (Lang = Mitchell, 1831) said the "most remarkable things connected with the bones" were that the occurrances were only in the vicinity of caves; that although the breccia always reached to the surface, it was distributed deeply and extensively downward into crevices in the limestone; that this cement-like substance only occurred in combination with bone fragments; that the bone fragments were mixed indiscriminately; and that the bone fragments showed no sign of being water-worn, but rather to the contrary.

In September, 1830, shortly after the departure of Major Mitchell, Surveyor Rogers, then working in the Wellington District, sent two men to dig for bones in the caves (Rogers, 1830). Rogers called the caves "Mulwang Caves," which appears to have been the name given to them by the aborigines.

On August 21, 1831, Mitchell wrote to Ranken that he might call on him

soon with a view to revisiting the caves and exploring new ones. "My motive for doing so now in particular is the circumstance of Captain La Place, of the French discovery ship, being a friend of Cuvier's and desirous to take a good collection of these fossil bones to Paris, and as I know that everything depends on accurate descriptions of the caves, and the particular position in which specimens are found, I am much inclined to go myself" (Ranken, 1916).

STUDY OF EARLY BONE COLLECTIONS

Jameson, Clift, Cuvier, Pentland

The actual sequence of movements of the Ranken bone collection and Mitchell's two collections is difficult to follow through the literature. Ranken's collection went to Jameson, then to W. Clift, of the Royal College of Surgeons, London, and later to Cuvier and Pentland in Paris. Mitchell's first collection went to the Geological Society, London, where part or all of it was examined by Clift. This collection was also sent to Cuvier and Pentland, and still later was examined by Richard Owen. Mitchell's second collection went direct to Cuvier, who probably died without examining it. Subsequently, it was examined by Pentland. Apparently another collection of bones from Wellington was made by Colonel Lindsay and forwarded to Jameson about the end of 1830 or early 1831. No details are available except in Pentland (1831).

Reports on Ranken's bone collection by Jameson and Clift were published as an addendum to Lang's letter in the Edinburgh New Philosophical Journal (Jameson, 1831; Clift, 1831).

Jameson said that from the bones and cave descriptions it appeared the caves agreed in character with those in Europe, as did the breccia. He thought the evidence showed that Australia, in former times, was distinguished from the rest of the world by the same pecularities in the organisation of its animals which still characterised it; that Australia formerly possessed animals much larger than its present-day fauna; that the bone caves and breccia contained a mixture of bones of extinct and present-day animals; that the accumulation and deposition of the bones seemed to be by the same agency, and during a similar series of geological changes, as had occurred in Europe.

At this time Australia was almost a terra incognita. Today, we can only imagine the eager curiosity with which these fossil bones were received and examined by the zoologists and palaeontologists of 130 years ago.

One particularly large bone created great interest. Jameson said it belonged "to an animal larger than any of the living species in the Australian world. It appeared, on comparing it with the splendid skeleton of the Hippopotamus in the Museum, to resemble the radial bone of that animal."

Clift considered the bone approached very nearly in form to the metacarpal bone of an ox, but was bigger. It also bore a great resemblance to the radius of the hippopotamus. He said the bone did not belong to the elephant, being too large for its length. He identified most of the other bone specimens as kangaroo, wombat and Dasyurus. In a footnote he added: "The Dasyurus (the animal called Devil by the early settlers) is said to be at present a native of Van Diemen's Land only" (Tasmania).

A bone from Mitchell's first collection was examined by Clift. He said it was "obscure and imperfect, but seems to be part of one of the superior maxillary bones of an animal resembling the Dugong; it also contains a portion of straight tusk pointing directly forward" (Mitchell, 1834). In 1838, Owen, referring to the same bone, called it "the anterior extremity of the right ramus, lower jaw." This bone was later to become the type specimen for the giant, extinct Diprotodon, the largest known marsupial. The leg bone, variously believed to be that of a hippopotamus or an elephant, was also from a Diprotodon.

In a letter published in the Edinburgh New Philosophical Journal, Pentland (1831) also gave a report dated April 22, 1831, on Ranken's bone collection. This collection was examined by both Cuvier and Pentland.

Pentland said they had identified eight species belonging to the following genera:- Dasyurus Geoffroy, 1796 (eastern native cat), one species; Hypsiprymnus Illiger, 1811 (rat-kangaroo), one species; Phascolomys (sic) Geoffroy, 1803 (= Vombatus Geoffroy, 1803) (wombat), one species; Kangaroo, two or three species; Halmaturus Illiger, 1811 (wallabies), two species; and Elephant, one species. Of these species, he thought four were probably extinct forms, namely, Hypsiprymnus, Phascolomys, Halmaturus and the Elephant.

In a note dated June 6, 1831, in the same report, Pentland said he was unable to identify a Dugong bone in the collection. Among the bones from Colonel Lindsay's collection he had identified an additional species of kangaroo one third larger than the largest species known previously.

On October 30, 1831, Mitchell wrote to Ranken saying: "You will, I have no doubt have heard from Dr. Lang that I have now the Edinburgh Philosophical Journal, where I see honourable mention made of you, and a good deal about the bones. They find most of them to be wombats and Kangaroos, but Cuvier calls your large bone an elephant's. The London surgeons, however, seemed puzzled about it, and I have doubts, although the little tusk I got, apparently belonging to the same individual, would go far to support its being a young elephant" (Ranken, 1916).

In the next issue of the Edinburgh New Philosophical Journal, Jameson (1832) referred to the bones he had received from the Wellington Valley.

He said the result of Baron Cuvier's examination of these bones was published in the same issue of the Journal. The actual description, however, was again written by Pentland, who gave a fuller description of the species mentioned in his 1831 paper. He did not mention Cuvier. In fact, no published report written by Cuvier on the Wellington Caves bones has been found in the literature. In Pentland's report the various bones identified are given reference numbers as the bones had been deposited in the Edinburgh College Museum.

Genus Dasyurus - Pentland said he had compared the fossils with living material from the College of Surgeons, London. He concluded they were not identical, but were "at least very nearly allied to Dasyurus Ursinus of Harris." D. ursinus was the only living species of the genus approaching the fossil in size. Some years later, in 1841, D. ursinus was placed in the genus Sarcophilus Geoffroy and Cuvier, 1837, as S. harrisii Boitard, 1841 (the Tasmanian Devil). This genus was extinct on the Australian mainland, but still present in Tasmania. Clift in his report of 1831 had already noted the similarity of a mandible of Dasyurus to the Tasmanian Devil.

Genus Hypsiprymnus - Comparison of these fossils with the skulls of several living species of rat-kangaroo, led Pentland to believe that the fossil form belonged to an undescribed species.

Genus Macropus Shaw, 1790 (also referred to by Pentland in the heading as Kangaroo Proper) - One group of bones differed "by its gigantic stature alone from all the known living species of the genus Macropus" but resembled in every detail Macropus major Shaw, 1800 (grey kangaroo). A second group corresponded to "Macropus rufo-griseus of Peron and Lesueur." A third group closely resembled "Macropus ruficollis of Peron and Lesueur." (M. rufo-griseus and M. ruficollis have since been synonymised with Wallabia rufogrisea Desmarest, 1817 - the red-necked wallaby). Pentland considered the Wellington Caves fossils belonged to three or four species of kangaroo, two of which appeared to be new species. He had compared them with the skeletons of all known species, with the exception of "M. rufus of Desmarest, probably the M. Lanigerus of Hamilton Smith" (= Megaleia rufa Desmarest, 1822) (red kangaroo) "a species inhabiting the same district in which the fossils have been discovered." No specimens of this species were available in Europe and without examining it, Pentland was not prepared to state definitely whether the fossils belonged to an unknown species.

Genus Halmaturus - One group of specimens belonged to a species new to science and probably extinct. A second group belonged to a smaller species which differed also from known living species.

Genus Phascolomys (sic) - This fossil agreed in detail with living wombats, but was about one third as large again. "May not this arise from a specific difference between the fossil and the living ? which the few fragments of the former we possess does not permit of our establishing on more

certain characters, - I mean anatomical, - than those deduced from the mere difference of size."

Elephant - Pentland said no doubt existed that the bone attributed by Clift and Jameson to the hippopotamus belonged to a "small variety, or to a young individual, of the genus Elephant." With a single exception, the elephant, all these genera still had extant species in Australia.

Pentland also examined Mitchell's first collection sent to the Geological Society of London. It contained the same species as before with the exception of a cervical vertebra of an animal "little inferior in size to a large deer, the extraordinary form of which has not enabled me to refer it to any known genus."

In a later paper, Pentland (1833) said that after examining Mitchell's second collection, sent to Cuvier shortly before Cuvier's death on May 13, 1832, he was able to add five new species to the previous list of Wellington Caves fossils. These were: two species of Dasyurus; a small species of Perameles Geoffroy, 1804 (bandicoot); one species of Halmaturus; a small rodent belonging to a new genus; and a reptile related to the Gecko.

Mitchell again wrote to Ranken on July 24, 1833, saying: "I understand Buckland's nose is put completely out of joint by the bones from Australia, their not being those of lions and hyenas is, I find, a fact which is considered in England to entirely upset his theory. And I have now heard from the best authority that the fact of their fossil bones not belonging to animals similar to those now existing has worked a great change in all their learned speculating on such subjects at home. The big bone is neither a part of an elephant or dugong, but a nondescript animal, perhaps extinct, though peculiar to New South Wales" (Ranken, 1916).

Buckland (1824) was a strong advocate of the theory that bones in caves were relics of the Biblical Deluge. This view was strongly opposed by Lyell and others who believed in the theory of evolution. Lyell wrote his Principles of Geology (1830 - 1833) to refute the catastrophic theory. The discovery of fossil bones at Wellington Caves supported Lyell's theory.

Lyell (1833) summarised the discoveries of mammalian fossils in Australia. "The remains found most abundantly are those of the Kangaroo. Amongst others, those of the Wombat, Dasyurus, Koala, Phalangista have been recognised. The greater part of them belong to existing, but several to extinct, species."

He said: "These facts are full of interest; for they prove that the peculiar type of organisation that now characterises the marsupial tribes has prevailed from a remote period in Australia, and that....many species of mammalia have become extinct. It also appears, although the evidence is

less complete than we could have wished, that land quadrupeds far exceeding in magnitude the wild species now inhabiting New Holland (Australia), have at some former period existed in that country."

Richard Owen

In March, 1837, Mitchell went to England to have his book "Three Expeditions into the Interior of Eastern Australia" published. He wanted to include an account of the bones from Wellington Caves, and approached Professor Richard Owen, of the Hunterian Museum, Royal College of Surgeons, London, to examine them. Owen was a young palaeontologist, with a rapidly growing reputation. He studied Mitchell's 1830 bone collection and wrote a letter to Mitchell dated May 8, 1838, which was included in the book (Mitchell, 1838). The letter listed the genera of fossils collected by Mitchell at Wellington as Macropus; Hypsiprymnus; Phalangista Cuvier and Geoffroy, 1795 (possums); Phascolomys (sic); Diprotodon Owen, 1838; and Dasyurus. This first report of Owen's is accompanied by the first published illustrations of the Wellington Caves fossils. The drawings are by Mitchell.

Under Dasyurus, Owen named D. laniarius Owen, 1838, after examination of portions of upper and lower jaws. He said the species closely resembled D. ursinus, but was one third larger. D. laniarius was later placed in the genus Sarcophilus. Owen was uncertain whether one lower jaw fragment belonged to D. laniarius. This specimen was later placed in the genus Thylacinus Temminck, 1824, as Thylacinus major Owen, 1877. Several years later, on the basis of portions of jaw collected at Wellington Caves by Mitchell, Owen described a new species, Thylacinus spelaeus Owen, 1845. Further bones collected from the same locality by Count Paul de Strzelecki in 1842 confirmed this determination (Etheridge, 1891). T. cynocephalus Harris, 1808, bones were also described by Owen (1877) from the Wellington Caves. He commented that they were similar in size and structure to those of the existing species, the Tasmanian wolf, still living in the wilds of Tasmania. It follows, therefore, that none of the early bone collections from Wellington Caves contained any specimens belonging to the genus Dasyurus.

No recent revisions have been published of the genera Sarcophilus and Thylacinus and therefore Owen's fossil species still remain valid. The presence of these genera on the Australian mainland is further evidence that a landbridge formerly connected Australia and Tasmania. The recent discoveries of bones of S. harrisii in Victoria, and a tooth of Thylacoleo (see later in this paper) in Tasmania, strengthens this assumption.

Many of Owen's 1838 findings and conclusions echoed Pentland's remarks made in 1832. As regards the genus Macropus, Owen went a step further and named two new giant species - M. atlas Owen and M. titan Owen. In 1873, he

made M. atlas the type species for a new genus Sthenurus Owen as S. atlas (Owen). The same year, 1873, he erected the genus Protemnodon Owen, without designating a type species. In 1845, he had called a young maxilla collected at Wellington Caves by Strzelecki, M. atlas. In 1877, however, Owen decided to call this bone Protemnodon anak Owen. This was later corrected to Sthenurus atlas. The species M. titan still stands.

Owen also added two additional genera - Phalangista and Diprotodon. This was the first published mention of the name Diprotodon. Here, too, are the earliest illustrations of the characteristic tooth of Thylacoleo carnifex Owen, 1859 (the marsupial lion). No reference to this tooth appeared in the text. Owen was unable to describe and name this animal until years later when additional specimens were discovered. The common wombat, Vombatus hirsutus Perry, 1810, was described in this letter as Phascolomys mitchelli Owen, Owen believed it to be an extinct species.

Diprotodon

Owen wrote that he had given the name Diprotodon (meaning two protruding front teeth) to the genus of Mammalia distinguished by the anterior extremity of the right ramus of the mandible bearing a single large procumbent incisor. "This is the specimen conjectured to have belonged to the Dugong, but the incisor resembles the corresponding tooth of the wombat in its enamelled structure and position....but it differs in the quadrilateral figure of its transverse section, in which it corresponds with the inferior incisors of the hippopotamus." Mitchell commented later that "to this it may be added, that the wombat's skull is fully as large as the skull of an elephant" (Woods, 1862). It was to take Owen another 39 years before sufficient data was available to enable him to reconstruct the animal, and even then it was incomplete, the foot structure still being unknown. He published a reconstruction in 1877 with the feet conveniently concealed by grass and Australian plants (see plates). Professor Stirling, in 1893 (the year after Owen's death), reported that "hundreds of skeletons" of Diprotodon had been found at Lake Mulligan, South Australia. "It appears that the animal had five well-developed toes, the five terminal phalanges of which are almost equal in size. The carpal and metacarpal bones have also been found, though I am not specially informed whether the digits of the manus are also five in number....There is a tail of nine vertebrae, which in one instance was one foot 2½ inches long...."

Diprotodon was as large as, or even larger, than a full-grown rhinoceros and weighed about 4000 lb. An adult stood about six feet high, was about ten feet long, walked on all fours, rather like a wombat, had a huge head and thick neck, was a herbivore, had enormous chisel-like incisors, and had a short tail. It was a plantigrade animal, walking on palms and soles. The bone structure of the feet showed that this bulky animal was a descendent of tree-climbing ancestors. Perhaps the cervical vertebra discovered near

Mt. Wingen and described by Cunningham (1828) was the first diprotodon bone to be reported.

Summarising, Owen (1838) said that the Wellington Caves fossils were not referable to any known extra-Australian genus of mammals, nor were they referable to any existing species of Australian mammal. The greater number of specimens belonged to species either extinct or not yet discovered living in Australia. The extinct species of Macropus, Dasyurus, and Phascolomis were larger than the largest known existing species. The remains of the saltatory animals, such as Macropus, Halmaturus and Hypsiprymnus, were all of young animals; while those of the burrowing wombat, the climbing phalanger, and the ambulatory dasyure were of adults.

Owen described the species Diprotodon australis Owen, 1843, from an immature fragment of lower jaw from Mitchell's first collection (the "Dugong bone"). He erroneously referred the remains of larger and older individuals to Dinotherium (1843), an extinct type of elephant. However, the next year (Owen, 1844) he showed that the supposed Dinotherium remains were actually Diprotodon australis.

Of Diprotodon, Owen (1877) wrote: "Of no extinct animal of which a passing glimpse, as it were, had thus been caught, did I ever feel more eager to acquire fuller knowledge than of this huge marsupial. No chase can equal the excitement of that in which, bit by bit, and year after year, one captures the elements for reconstructing the entire creature of which a single tooth or fragment of bone may have initiated the quest; in the course of which one finally realises, with more or less exactitude, the picture which the laws of correlation had led one to frame of an animal which may have passed out of existance long ages ago."

Owen asked what had caused the extinction in Australia of the genera Diprotodon Owen, Nototherium Owen, 1845 (a type of diprotodon), Thylacoleo Owen, 1859 (the marsupial lion), Phascolonus Owen, 1872 (a fossil wombat), Thylacinus, Sarcophilus, Palorchestes Owen, 1873 (another type of diprotodon), Procoptodon Owen, 1873 (the largest of the extinct kangaroos), Pachysiagon Owen, 1874 (a type of kangaroo), Sthenurus (a type of kangaroo), together with the larger species of existing genera of kangaroos and wombats. No other adequate cause suggested itself save the hostile agency of man (Owen, 1877). The common characteristic of all the species of the extinct genera was superiority of size; this might also be said of several of the extinct species of existing genera.

He suggested that the extinct animals were destroyed by the combined assaults of "Australioid wielders of clubs and throwing-sticks. True it is that, as yet, no evidence of ancestry of the existing aborigines has been detected in the caves and breccias yielding fossil remains of their hypothetic prey, unless we assume the Dingo to have followed the Papuans in

their immigration. But the exploration of ossiferous caves has hitherto been limited to those originally discovered by Sir Thomas Mitchell. And whilst I write, an announcement has reached me of the discovery of others, 60 miles from Bathurst, in the limestone district midway between Cowra and Canowindra, also in limestone ranges near the stanniferous granites of Northern Queensland, which caves, if explored with due care, patience, and skill, may bring to light some indications of the prehistoric men of Australia, as well as largely supplement the partial restoration of extinct Marsupials...." (Owen, 1877). He adds, however, that Darwin's principle of the "contest for existance" was also possible and that the smaller animals could have survived unfavourable conditions which destroyed the larger species.

The bones showed that the fossil mammals of Australia told the same story as those from the Pleistocene of South America, and were allied to forms which are still extant. Darwin was in Australia in 1836 and was in personal communication with Mitchell, so must have been aware of these discoveries when formulating his theories. However, he gave no indication in his writings of knowledge of the Australian fossils until 50 years later (Darwin, 1884, 1886).

FURTHER COLLECTION AND STUDY OF FOSSIL BONES

Gerard Krefft

In 1867, a display of the "Natural and Industrial Products of New South Wales" was sent to the Paris Universal Exhibition. A collection of 1,393 fossil bones was included, most of which had been collected by Gerard Krefft at Wellington Caves (Krefft, 1867a). This introduces a new figure into the history of the caves - a German, Johann Louis Gerhard Krefft (Gerard Krefft) who had become Curator of the Australian Museum in 1861.

Writing of the Paris collection, Krefft said the Wellington bones exhibited were collected in "the same caves which the late Sir Thomas Mitchell discovered more than 30 years ago."

Describing the Breccia Cave, he said that the sides consisted of a kind of tufaceous limestone, full of animal remains. "To obtain good pieces out of this crust is very difficult," he wrote, echoing Mitchell, "as the bones are much more brittle than the crust and crumble to pieces before they can be loosened."

Krefft examined many old and new sections of the "cavery", finding the remains of bones and teeth plentiful. The tedious task of examining great heaps of red dust was difficult to conceive, he said, as the fine particles rose in clouds at every movement, often extinguishing the party's candles and making breathing difficult. He ran the earth through a rough sieve

obtaining a rich harvest of fossil bones, among them a lower left incisor of Thylacoleo carnifex. This tooth was discovered only a few feet from where Mitchell had discovered an incisor and a premolar in 1830, teeth which had been such a puzzle to Owen.

The new collection, with few exceptions, was referable to extinct genera and species and belonged to three distinct classes - mammals, birds and reptiles. Some of the bones belonged to recent animals which may have inhabited the caves or been carried in by predators. The marsupials were largely represented by Thylacinus, Sarcophilus, Phalangista, Perameles, Dasyurus, Macropus, Bettongia Gray, 1837 (rat-kangaroo), Hypsiprymnus, Halmaturus, Diprotodon, Thylacoleo, and Phascolomis. "In one of the caverns human remains were obtained, but though very old they were not fossil."

Owen Seeks More Specimens

On February 23, 1867, Owen, who in 1856 had become Superintendent of the Departments of Natural History at the British Museum, wrote to the Colonial Secretary, John Robertson, suggesting that "he encourage a careful and systematic exploration of the limestone caves of Wellington Valley." This letter was published in 1870 in Correspondence Relative to Exploration of Wellington Caves, Presented to Both Houses of Parliament, N.S.W. All the correspondence in this volume was included in Votes and Proceedings, N.S.W. Parliament, 1882.

Owen said in his letter that the fossil remains discovered at Wellington had revealed the important and suggestive fact that the marsupial type of structure prevailed in the ancient and extinct, as in the existing quadrupeds of Australia. "Besides the great accession of such evidences as would accrue to the museum at Sydney (The Australian Museum) from such exploration, most instructive evidence may be expected, bearing upon the antiquity and origin of the aboriginal races of Australia." He offered to determine and describe specimens from Wellington and wrote that the late Sir Thomas Mitchell had told him a grant by the N.S.W. Government of £200 or £300 for exploration would be amply repaid.

Owen was preparing an illustrated book on the fossil mammals of Australia, for which he had been receiving material from many parts of the continent since his original description of Wellington Caves fossils. He was anxious to obtain additional material. The absence of fossil human remains and signs of human artifacts in the caves had proved a disappointment to him, but he considered this an instructive negative fact which accorded with former experience of research at Wellington.

In 1869, the N.S.W. Parliament voted £200 to carry out Owen's suggestion and directed the Curator of the Australian Museum (Krefft) to undertake the necessary exploration. Later the same year, £15 was added for photographing

and lithographing the most interesting of the specimens recovered. Krefft had already visited the Wellington breccia caves in November, 1866, and was delighted to make another expedition.

An attempt had been made about this time to photograph the interior of the Cathedral Cave "by means of the magnesium light," but had proved a failure. The "artist" had been forced to content himself with views of the valley and limestone outcrop. Many of these pictures were spoiled by myriads of flies which penetrated everywhere, including the camera (Krefft, 1867a).

On August 18, 1869, Owen repeated his offer to the Colonial Secretary "to give immediate attention to the study and description of whatever specimens are transmitted to me, either temporarily, or with a view to being returned, namely to the Australian Museum, or as duplicates to be deposited in the British Museum."

Australian Museum Expedition to Caves

An expedition consisting of Krefft, Dr. A.M. Thomson (Professor of Geology, University of Sydney) and Henry Barnes (a museum assistant) visited Wellington in October, 1869. In a letter to Owen on the 30th. of the same month (Owen, 1877), Krefft said he had been to Wellington and, although very successful, he had not made any great discovery.

Krefft told Owen he had discovered a "Thylacoleo-set of teeth (which) will give you a good idea of the animal's dentition; they were all discovered together and by my own hands. It was probably a complete skull; but the soil was soapy, stiff, and the ground had been given up as no good; when I went into it again, and after taking a foot of clay off and finding nothing but limestone nodules which assumed, pardon the expression, the shape of bones, I drove my pick slap into it with a will, and broke probably the skull into a hundred fragments." Poor Krefft! One can visualise his horror at demolishing what was probably the first complete skull discovered of Thylacoleo.

In his full report of the expedition written in November, 1869, Krefft (Votes, 1882) said four caves were explored but only one contained loose bone breccia. "Since my last visit," he wrote, "....the ground has been much disturbed by stalactite hunters and amateur geologists, but some good ground was at last discovered and a considerable quantity of fossil remains secured. A shaft was sunk in one of the inner chambers of this cave to a depth of 16 feet without reaching the bottom, and fossil teeth and bones were observed to that depth in small quantities."

Digging continued for 15 days, with disposal of the dug earth presenting the main difficulty. However, they obtained "many valuable and rare specimens, some quite new to science, consisting of the remains of

mammals, birds and reptiles." Krefft added that the "largest bones and teeth are of a size equal to those of a full-grown elephant, others do not exceed that of a mouse."

At the same time, Thomson (Votes, 1882) wrote that several "cart-loads" of dirt were hauled from the Breccia Cave and sieved or washed to obtain bones. In one section of the same cave a single spadeful of earth contained several hundred rib, thigh and jaw bones of small rodents and rat-kangaroos. "On breaking open a small stalactite, it was found to be a mass of red breccia encrusted with calcium carbonate."

Krefft's report was sent to Owen in March, 1870, together with a series of 44 photographs of specimens. A set of the photographs, pasted in a large volume, is still at the Australian Museum. Krefft and Thomson prepared a series of fossil duplicates for the British Museum to enable Owen "to form some idea of the animals which inhabited the Wellington District during the post-Pliocene period." The collection included about 1,000 partly determined specimens, and Krefft hoped these would enable Owen to "produce new facts and help Australia maintain its reputation as the 'Land of Wonders.'" The set of duplicates was completed and ready for despatch to the British Museum in May, 1870. A full list of the fossils was published later (Votes, 1882).

After the departure of Krefft and party from Wellington, George Porter, a miner, was left in charge to obtain additional fossil specimens. These were sent to Sydney, and in May, 1870, a further series of 62 photographic plates was despatched to Owen. In October that year, the British Museum acknowledged the receipt of 2,100 specimens of fossils from Wellington Caves, being duplicates of those in the Australian Museum. Many of these "duplicates" were to become the types for Owen's species. In 1871, a series of casts of fossil remains was prepared at the Australian Museum and packed for despatch to Owen. The casts were coloured carefully in imitation of the original specimens, from which they could not be distinguished except by weight (Votes, 1882).

Thylacoleo carnifex

When finally published in 1877, Owen's book, Researches on the Fossil Remains of the Extinct Mammals of Australia, made multitudinous references to the Wellington Caves fossils, which had helped to start him on this project and which had proved such valuable research material. Most of the contents of the book was published first as a series of papers in the Philosophical Transactions of the Royal Society of London, and elsewhere.

His notes on Thylacoleo carnifex (the marsupial lion) are of interest. The first indications of this species were a "large unidentifiable, two-fanged sectorial tooth" (Owen, 1877) and a large pointed incisor collected by Mitchell from the Breccia Cave and figured in his book (Mitchell, 1838).

As mentioned earlier in this paper, no reference is made to these teeth in the text because Owen had been unable to determine their affinities at the time. Many years later, Owen referred to the premolar as belonging to T. carnifex, but did not mention the incisor.

In the 1840s, Owen proposed the generic name Thylacoleo for the fossil, but the first published mention of the name appeared in Gervais' Zoologie et Paléontologie françaises, first edition, 1848-1852, p. 192, in a table of Fossil Mammalia. Owen finally published a description of the species in 1859. The type material is in the collections of the Museum of the Royal College of Surgeons, London. The skull is rounded and about the size of a lion. The pointed incisors, large sectorial premolars, reduced molars and general structure of the skull and mandible led Owen to believe T. carnifex was "one of the fellest and most destructive of predatory beasts." He said one could assume "from the fact of the remains of young and inexperienced Diprotodons occurring in Australian caverns with those of Thylacoleo that the large marsupial herbivore had its enemies in, and occasionally fell victim to, the large marsupial carnivore, as at the present day the kangaroo is laid in wait for by the Thylacine or native wolf, and by the Dasyure or native cat." Owen did not take into account the reduced size of the canines, which are useless for grasping and tearing.

Few animals have created so much controversy as Thylacoleo carnifex. While Owen regarded it as a destructive carnivore, others such as Flower (1868) and Krefft (1866) believed it was a harmless vegetarian. Krefft illustrated his paper with "a conjectural restoration of the then unknown anterior part of the skull and incisor teeth." He believed that T. carnifex was a "gigantic Kangaroo-Rat." In a later paper (Krefft, 1873) he spoke of the "herbivorous habits of this 'lion in phalanger hide.'" Anderson (1926) said that the echoes of battle had not yet died down, but the general opinion was that the animal was a carnivore, and in 1933 he wrote "I myself seem to be the only one who still has doubts." Gill (1954) discussed "the menu of Thylacoleo" at length, but came to no satisfactory conclusions. The latest comments have been made by Woods (1956) who said it was still unproved whether the animal was carnivorous, but on an analysis of the morphology, he considered that this conjecture was well founded.

Ramsay - Further Australian Museum Collections

In 1879, Professor W. Boyd Dawkins, of Owen's College, Manchester, a geologist and author of Cave Hunting, Researches on the Evidence of Caves Respecting the Early Inhabitants of Europe, expressed an interest in Australian cave bone deposits. Dawkins asked "would the Government of N.S.W. undertake the systematic exploration of the wonderful caves which are in the Colony, and which certainly ought to be explored. Not only is there a certainty of adding to the great marsupials which have been obtained, but there is a great chance of finding proof that man was living at the same

time as the extinct animals, as has already been found in Europe and Asia. I should expect to find a very low form of the aborigine" (Votes, 1882).

The N.S.W. Government decided to appoint a Committee to manage the exploration of caves and rivers. In June, 1881, a list of cave areas was drawn up for exploration, Wellington heading the list as first preference. In July, the Curator of the Australian Museum, Dr. E.P. Ramsay, sent Henry Barnes, now articulator, photographer and modeler at the Museum, to Wellington. During the next few months, aided by various local labourers, a number of collections were made and sent back to the Museum. Ramsay supervised this work until it was discontinued in November, 1881. In a report dated December 31, 1881, Ramsay said that the caves had been numbered as follows:-

Cave No. 1 - The Water or Anticline Cave, nearest to the Bell River and containing several feet of water over the floor.
Cave No. 2 - Limekiln Cave, containing no bones.
Cave No. 3 - The Breccia Cave, also known as Mitchell's Cave and the Bone Cave.
Cave No. 4 - Cathedral Cave, also known as Large Cave, Great Cave and Main Cave; containing Bone Shaft No. 4.
(See map at end of this paper for position of caves)

A shaft sunk in the northwest chamber of the Breccia Cave had revealed bones from a depth of four feet below the surface of the earth fill to a total depth of 35 feet. Another shaft sunk to a depth of 25 feet had also yielded many bones. Many different floors had been penetrated showing that the bones had been washed in at different periods.

A number of shafts, ranging in depth from 10 to 35 feet, were also sunk in the floor of the main chamber of the Cathedral Cave, near the Altar formation, and all bottomed on solid limestone. Bones were found in all shafts, although they were not plentiful. These bones were generally in better condition than those found in the Breccia Cave and, on the whole, larger.

Many thousands of bones were collected during the period, the Breccia Cave alone yielding more than 1,000 specimens. Among the most important finds in the Breccia Cave was an almost perfect ramus of Thylacoleo "with the articulating condyle so anxiously looked for by Professor Owen", and the phalanges of a large species of Echidna. Owen (1884) referred to the Echidna bones, saying that evidence of a large extinct monotreme, Echidna ramsayi Owen, had been discovered in the caves. He considered it was probably identical with Krefft's species described from Queensland in 1868. It was considerably larger than any living relatives, but had few structural differences. Other bones, including portions of the pelvis of an immense kangaroo and jaws of large marsupials, especially five nearly perfect rami of Thylacoleo, were found in the Cathedral Cave (Ramsay, 1881).

A number of the photographs taken of the caves and bone specimens were lithographed and bound for the N.S.W. Parliament (Votes, 1882). Unfortunately, copies sighted are too faded for reproduction in this paper.

Some excitement was caused by the discovery in one of the hitherto unknown caves of two human skeletons. However, these were the remains of whites, not aborigines, and "evidently the sole remaining record of some tragedy in the early days of the Colony. A few remains of aborigines have been met with there - mostly teeth, and toe and finger bones - but these are believed to be of recent origin," Ramsay said.

In 1882, on one of his visits to Wellington, Ramsay found the water hole at the far end of the Cathedral Cave dry. This hole, known as the Well, was descended. "At a depth of 27 ft, I met with a ledge or shelf which extends in one direction about 14 ft by about 6 or 8 ft wide; this shelf runs under an archway for about 4 or 5 ft, then another well-like hole is met with, containing water over 10 ft deep. I believe there are extensive caves leading from the well, but these could not be reached without pumping" (Ramsay, 1882). In 1958, aqualung divers from the Sydney Speleological Society tried to force the Well, but found it sealed off with silt.

THE KREFFT TOOTH

One of the most controversial fossils ever found at Wellington came to be known as the "Krefft tooth." Arguments as to its authenticity, or otherwise, as a fossil human tooth have continued over the past 90 years.

Krefft, who found the tooth, thought that it was probably a human molar. "This being the only specimen obtained, it cannot well be sacrificed for the microscope; whatever this fragment may eventually prove to be, it resembles nothing so much as a human molar" (Krefft, 1870). Later, he wrote: "I have found the fractured crown of a human molar in the same matrix as Diprotodon and Thylacoleo, at Wellington" (Krefft, 1874). Sir T.W. Edgeworth David (1924) has dated this period from 7,000 to 12,000 years ago.

Krefft does not indicate the date of discovery, but it was probably 1869. Strangely enough, Krefft does not appear to have mentioned the tooth to Owen. In 1877, Owen wrote that no reliable evidence had reached him of the contemporaneity of man with Diprotodon in Australia. No human tooth, bone or weapon had been detected in the breccia caves.

Referring to the Krefft tooth, R. Etheridge, Jun., Director of the Australian Museum and Honorary Palaeontologist of the N.S.W. Department of Mines, said in 1890 that at first sight this appeared to be the most reliable evidence of the geological antiquity of Australian man, but, "after a careful weighing of the facts, I do not feel justified in attaching to it that amount of importance which the discovery would seem to justify."

When he examined the tooth, minute portions of red cave earth were still adhering to it, but if it ever existed in a block of breccia, with the bones mentioned by Krefft, it had long since been removed from it. If the bone was a floor specimen, it could have entered the cave in a fortuitous manner and would therefore be poor evidence. Furthermore, the value of the tooth was not increased by the fact that no other human remains had been found in the caves under similar circumstances.

Etheridge said that Henry Barnes had testified that the tooth had been found in the Breccia Cave by Krefft, in person, and that he, Barnes, had been present at the time. However, after the lapse of time, Barnes was uncertain whether the tooth was found in a block of breccia with the other bone fragments or was simply lying loose on the floor. Barnes had found portions of a human skeleton, believed to be a gin, in Number 2 Cave, but these bones were not fossil (Krefft, 1867a). In a paper on Australian Vertebrata, Krefft (1867b) referred in a foot note to "Bimana, genus Homo, Malaian variety," saying: "Bones of the extremities found in a cave at Wellington Valley, being left and right femur, left and right tibia, left and right humerus, and portions of fibula." Dr. C. Anderson (1933), Director of the Australian Museum, said that Dr. J. Mildred Creed had informed him that he was present when Krefft discovered the tooth in the breccia.

Etheridge apparently did not doubt that the fragment of tooth was of human origin, but he did doubt that it came from bona-fide bone breccia, saying it was "not proven." Mr. P.R. Pedley, a leading Sydney dentist of the time, who took a keen interest in natural history, agreed that the fragment was part of a human molar.

Etheridge's description of the controversial bone is as follows:- "The molar consists of about two-thirds of the crown broken off from the remainder of the tooth, the under surface exposing the fractured dentine. The entire crown is so much worn down as almost to reach the alveolar border. Regarding the tooth as an upper right molar, the two inner cusps are almost worn away, leaving the sulcus dividing them now, as a ridge. The inner anterior cusp is the portion broken away, the inner posterior being ground quite flat. The outer cusps are worn almost into concavities exposing the dentine, the enamel forming a ring or wall around the inner margin. The tooth appears to be fully fossilised...." (Etheridge, 1890).

Later, Etheridge (1916-17) acknowledged other evidence regarding the Krefft tooth. First, he had discovered that Krefft had figured a molar tooth in the Parliamentary Paper, "Exploration of the Caves and Rivers of N.S.W." (Votes, 1882. Plate 12, figs. 3,4). Secondly, Krefft at the time of his severance from the Australian Museum had a work in preparation to be called "Australian Fossil Remains" which referred to the tooth. Explanations of the plates in the Parliamentary Proceedings are among Krefft's papers, now in the Mitchell Library, N.S.W. In the note to Plate 12, in

Krefft's handwriting is the statement: "Figs. 3 and 4. Side view, natural size, and view from above enlarged of a human molar tooth, taken from the solid breccia of Wellington by the writer."

Also among Krefft's papers is a series of cave survey pencil drawings. A note dated February 4, 1870, is attached to one and reads: "In well-hole where Krefft found human skeleton, red breccia." The note was probably added to the work plan by a workman under Krefft's supervision (Krefft, undated). Krefft's papers have been examined by the authors, and these statements verified.

Etheridge said that as a result of this new evidence, "it would appear that Mr. Krefft did find at some time during the exploration of the Wellington Caves, the work being then under his control, not only the teeth, but a human skeleton therein also." Etheridge added that the occurrence of the molar tooth in the breccia might render necessary a modification in the former verdict of "not proven," but little deduction could be derived from the skeleton occurrence until further evidence was forthcoming of its precise position in the cave deposit.

No mention of this human skeleton appears to have been made in any previous publication. About 1940, the Director of the Australian Museum, Dr. A.B. Walkom, informed D.J. Mahony, Director of the National Museum of Victoria, that no record of such a skeleton could be found at the Australian Museum (Mahony, 1943).

Dr. T.D. Campbell, an Adelaide dentist, briefly examined the tooth in 1935, and noted that the attrition of the tooth fragment did not appear to accord with that usually found on aboriginal molars. This appearance, together with other features, left in his mind a definite doubt that the tooth fragment was human (Mahony, 1943). Mahony added to Campbell's comments that both the geological evidence of antiquity and the specific determination of the tooth were unsatisfactory. These comments of Campbell and Mahony appear to be the first outspoken doubts that the tooth was actually human.

Recent Study of Tooth

Several years later, Campbell (1949) said he had now made a close study of the specimen. He noted that it never seemed to have had the critical attention of anyone specially interested in human dental anatomy. In fact, very little attempt had been made in the past to describe the fragment in detail. In addition, the published records of Wellington Caves fossils showed the doubtful occurrence of man as a fossil in the caves.

He said it was obvious that the Krefft tooth was a remnant of crown enamel and underlying dentine, the latter changed by fossilisation. The

broken condition of the specimen and its state of wear undoubtedly had provided a problem concerning its origin, human or otherwise, and the kind of tooth it represented. Comparing the Krefft tooth with aboriginal molars in similar condition, Campbell said consideration of many points showed that the Krefft specimen was so much at variance with the typical conditions of upper aboriginal molars - or any other human tooth - he was convinced that the previously suggested designations of the fragment were incorrect. The criteria of wear, contour, transverse enamel ridge persistance, all went to make it unacceptable as a fragment of any human tooth.

In the same year, 1949, H.H. Finlayson, Honorary Curator in Mammalogy at the South Australian Museum, said Campbell had found that the evidence was strongly against the tooth being human, and at Campbell's suggestion he had considered the tooth's possible relationship to the lower mammals. The fragment had been compared minutely with all indigenous Australian mammals, with all introduced and domestic mammals, and with many exotic species.

"As a result there would now appear no reasonable doubt that the fossil is derived from the Pleistocene macropod Macropus (Protemnodon) anak Owen, a giant 'Wallaby,' remains of which are already known from the Wellington Caves, and which also occur in profusion in beds of similar and earlier age over a large part of eastern and southeastern Australia."

Finlayson then provided several pages of discussion and comparisons, writing at the conclusion of his paper: "The identification of Krefft's find which is here advanced is necessarily inferential rather than absolute, but the inference is of the strongest and most acceptable kind."

Fossil Dingo Teeth

David (1924) said that Man was almost certainly living in Australia at the same time as extinct marsupials such as Diprotodon and Thylacoleo carnifex. He noted that Krefft had recorded the occurrence of the first two molars of the lower jaw of a dog in the Wellington Caves breccia, associated with bones of Thylacoleo, Sarcophilus and Diprotodon. The discovery of dingo teeth was important confirmatory evidence that the Krefft tooth had been found in situ in the breccia.

Etheridge (1916) verified the occurrence of teeth of the dingo or Warrigal, Canis antarticus Kerr, 1792, among the Wellington Caves breccia specimens in the Australian Museum collections. If one assumes, with David, that the dingo accompanied the ancestoral aborigines to Australia, then to whatever age the dingo fossils belong the aborigine was contemporaneous. As the fossil marsupials are considered to have become extinct in the Pleistocene, this supports the idea of a considerable geological antiquity for the aborigine.

THEORIES ON SPELEOGENESIS AND BONE DEPOSITS AT WELLINGTON

Introduction

Many theories have been put forward, over the years, to account for the accumulation of bones and for the formation of the bone breccia at Wellington. All these theories are unsatisfactory, and none of them is supported by actual research work. In many instances the theories pose more questions than they answer.

The nature of the occurrence of fossils at Wellington complicates attempts to determine the contemporaneity or otherwise of the bones. Lack of stratification has made it difficult, if not impossible, to give accurate carbon 14 dating.

1. Rev. Dr. J.D. Lang - 1831

Lang (1831), while disclaiming any authority as a comparative anatomist, considered that most of the Wellington Caves bones belonged to species no longer living in Australia. He believed that the cave deposits were another convincing proof of the universality of the Deluge, and was grateful to Divine Providence "for that long-forgotten visitation for destroying the beasts of prey" that he believed had been responsible for the accumulation of shattered bones in the caves.

"If the territory were overrun with such beasts of prey as the antediluvian inhabitants of the cave at Wellington Valley, it would not have been so eligible a place for the residence of man as it actually is. The tiger or hyaena would have been a much more formidable enemy to the Bathurst settler than the despicable native dog, though indeed they would certainly have afforded a much nobler game to the gentlemen of the Bathurst Hunt."

2. W. Pentland - 1832

After examining Ranken's collection and Mitchell's first collection, Pentland (1832) was unable to discover any trace of gnawing by carnivorous animals, or of water erosion, as were frequently found in European caves. Mitchell's second collection, however, contained bones most of which he believed had been gnawed by small carnivorous animals. These animals formerly inhabited the caves and had carried the bones underground.

3. Major T.L. Mitchell - 1838

Mitchell (1838) listed four possible periods of cave fill at Wellington. First, an aqueous deposit of red earth; second, a long dry period, evidenced by a thick crust of stalagmite covering the lowest deposit in the largest cavern, and during which some cavities were filled with breccia;

third, a subsistance in the breccia and associated rocks; and, lastly, a deposit of red earth similar to the first.

The floor of the main caves bore all the evidence of deposition from water which probably filled the caverns to an unknown height. As the water subsided, the sediment was deposited in the state of fine mud, which, on drying, became a more or less friable earth. Water containing calcium carbonate would deposit calcite to form stalagmites, stalactites, and other formations. However, the general scarcity of these was probably due to the dryness of the caves. The sedimentary floor contained few or no bones, except such as had previously belonged to the breccia.

It was evident from the sediments of mud forming the extensive margins of the Darling River, that at one period the waters of that basin were of much greater volume than at present and it was more than probable that the Wellington Caves were twice immersed under temporary inundations. He suggested, from evidence of changes of level in the coastline, that the plains of the interior were formerly arms of the sea, and that inundations of greater height had twice penetrated into or filled the underground cavities with water.

The accumulation of bones "very much broken and filling up hollow parts of the surface," showed that it had been modified since first inhabited. This seemed to have taken place after the extinction, in that part of Australia, of the species whose remains were found in the breccia. The breccia was never found below ground without definite proof of disruption and subsistance in the surrounding rocks.

4. S. Stutchbury - 1852

In 1852, the Government Geologist, S. Stutchbury, examined the Cathedral Cave. He considered the limestone corresponded to an ancient coral reef in which the cave was a space left naturally vacant. Thomson (Votes, 1882) pointed out that this view could not be supported. The sculptured walls and roof, as well as the arches, pillars and buttresses of rock which remained, agreed with the commonly held opinion that such structures were caused by "the dissolving action of carbonic acid water, which has the power of gradually wasting away limestone rocks."

5. Dr. A.M. Thomson - 1870

A report by Thomson was sent to Owen in 1870. He said that bones were plentiful in the upper portions of the Breccia Cave and became scarcer as the depth increased. This led to the supposition that they were originally deposited near the surface. What was now the surface was formerly the floor of an earlier cave, the upper part of which had been swept away entirely. The organic remains probably had accumulated here. As the old cave was

undermined by the present Breccia Cave, the osseous floor had fallen in or been washed down to lower levels and mingled with red earth. This would account for the present position of the breccia, for the scattered and fractured condition of the bones and their freedom from all water-worn appearance, and for the lack of stratification (Votes, 1882). Thomson failed to answer the question: how did the bones accumulate in the earlier, high-level caves?

He suggests that at the time the bones were accumulating, the Bell River probably ran much closer to the caves and the valley was a different shape. The caves may have served as drainage channels after rain. A cave near the bank of a river liable to sudden floods, would be a likely spot to receive such bone accumulations. Animals which had taken refuge in the cave may have been hemmed in by the waters and drowned.

The Wellington Caves could have been dens of carnivorous animals. Several bones had been discovered which showed distinct marks of having been gnawed by a carnivorous animal. Holes would have served as pitfalls for larger animals. There was also the possibility of animals having been poisoned or suffocated by gas in, or emanating from, the caves. This might have happened to a small extent deep in the caves as, even today, certain caves at Wellington are noted for their accumulations of noxious air.

Pentland and Thomson's idea that the caves could have been the den of carnivorous animals is repeated by Trickett (1906).

6. Dr. C. Anderson - 1926

Anderson (1926) pointed out the well-known fact that the red earth fill is the insoluble residue of limestone breakdown, the red colour being due to iron oxide. He supports the ideas of floods washing in bones, animals accidentally falling down shafts, and a few having been carried in by carnivorous animals. He believes it improbable that animals were poisoned by emanations of carbonic acid gas, or that animals took refuge in the caves during volcanic eruptions in the area. Earth fill had been known to build up rapidly in caves of the Wellington type burying objects on the floor in relatively short periods. Anderson suggests that, as cave floors and caves were undermined, collapse would jumble up animal skeletons and would also cause many individual bones to be fractured and scattered.

During a visit to the caves by Anderson in 1926, the greater part of the skeleton of a possum was discovered deep down in the Cathedral Cave at the bottom of a chute entered through an opening in the wall. The animal had not been dead long. "Imagine a fall of the roof to occur here carrying with it some 'prehistoric' red earth, and this specimen might then become enveloped in the same matrix as much older bones. Under favourable circumstances the drip of carbonated water might in a comparatively short period

seal up these recent bones in such a manner that it would be hard to recognise their relative youth" (Anderson, 1926).

A story by H.O. Fletcher, Curator of Fossils at the Australian Museum, supports the opinion expressed by Anderson. He visited Wellington Caves about 1948 following a request to inspect a skeleton in the Water Cave. The skeleton was believed to be a complete Diprotodon. A plan had been proposed to open up the cave for tourists, the prime attraction being two leg bones thrust straight up from the red cave earth. Fletcher found the legs ended in hoofs and the mummified body of a horse was uncovered. The horse, obviously, had fallen down the cave shaft fairly recently, rolled to the bottom of the slope and died. The cave contains a pool of water and is subject to flooding. The rise and fall of the water had caused the horse's body to become covered and encrusted with red earth (Personal communication, Fletcher, 1963). It is understood that the Water Cave is no longer accessible.

7. Dr. Campbell Brown - 1926

Dr. Brown (1926) suggests a similar theory to that advanced by the Rev. J.E. Woods in 1862 for South Australian caves. The surrounding valley flooded, probably many times, forcing animals to higher ground and into the caves, finally drowning them. This was followed by cave breakdown, earth fill, and further floods.

8. E.M. Basnett and M.J. Colditz - 1945

Basnett and Colditz (1945) suggest that after the caves filled with red earth and bone deposits, surface water cemented the top-most material. The earth beneath this hard surface remained friable, and the bones were easily separated from the matrix.

PHOSPHATE MINING

Phosphate has long been a primary need in Australia. One of the earliest reports on this mineral was made by Stutchbury in 1851 to the N.S.W. Legislative Council. Referring to the limestone deposits of the Wellington Parish, Stutchbury said that beds of breccia occupied old lines of fissures, that this was characteristic of the deposit, and bends, veins, and irregular replacements by phosphatic rock occurred. He added that prospecting operations for phosphatic deposits were proceeding in the area. Carne and Jones (1919) made a similar statement in their paper on the limestones of N.S.W.

Between 1913 and 1917, the New South Wales Phosphate Company put in a number of drives and shafts in search of phosphate rock and bones for use in the manufacture of fertiliser. A honeycomb of natural and artificial passages still remains, some in a state of near collapse, and today, extreme care must be exercised in the area (Anderson, 1926; Jervis, 1958; Personal communication, Barrett, 1963).

Very large numbers of valuable fossil bones were found during these mining operations, but, unfortunately, most were crushed for fertiliser. The closing down of the company considerably reduced the chances of extensive finds of animal remains again taking place, but, on the other hand, has preserved the remaining bones. All discoveries of the past few years have been the outcome of individual effort, mainly in the bone beds of the old mine area.

NOXIOUS AIR

Various caves at Wellington have long had a reputation for noxious air. Certain caves always have areas of noxious air containing an abnormally high percentage of carbon dioxide. This gas is odourless, and as a result a person can enter such an area without realising it.

Pure dry air at sea level contains 20.94 percent oxygen and 0.03 percent carbon dioxide. Though not toxic in itself, carbon dioxide on occasion in caves and mines can occur in concentrations sufficient to cause distress in man, and at high concentrations even unconsciousness and death. At 5 percent carbon dioxide the ventilation of the lungs increases about 300 percent. Normally, a man cannot endure 10 p.c. for more than one minute or so. The effects are severe headache, sweating, dimness of vision, tremor, increase in depth and rate of respiration.

Frequently in caves, carbon dioxide concentration is accompanied by a deficiency of oxygen in the atmosphere. Man can exist at much lower oxygen levels than the normal 21 p.c. At 17 p.c. a man will breathe slightly faster and deeper; at 15 p.c. he will become dizzy, have rapid heart action, notice a buzzing in the ears, and frequently experience headache; at 10 p.c. almost all men will show symptoms. Consciousness may be lost around the 9 p.c. level, and below about 7 p.c. death will occur from want of oxygen.

A flame is extremely sensitive to any variation in the oxygen percentage of air. For example, the flame of a candle is extinguished at 16.5 p.c., or less, and the flame of a carbide light at about 13 p.c., or less. No one should attempt to enter a cave or mine in which the atmosphere will not support an acetylene flame. Methane, and increased concentrations of nitrogen and hydrogen can also be met underground. Whilst they have no toxic effect upon the body, they may act as diluents of oxygen and thus indirectly cause the effects of oxygen deficiency (Sayers, 1923). Aqueous vapour can also diminish the percentage of oxygen and cause the extinction of a flame. For further discussion on symptoms and effects, see Balcombe (1953).

Gaden Cave

In the lower, non-tourist level of the Gaden Cave at Wellington, reached

via a passage dug out some years ago, is a small cavern approximately 9 by 15 feet and 9 feet high, with a depth below the surface of about 75 feet. A shallow pit in the earth floor has a hole in it about two feet diameter. Below this hole, a shaft goes down an estimated 30 feet. When a lighted carbide lamp is held a few feet above the hole and slowly lowered, the flame reduces slowly as the lamp nears floor level, and when lowered an inch or two more, goes out abruptly, showing the presence of a gas that will not support combustion.

In December, 1954, members of the Sydney Speleological Society collected a bottle of gas from the hole. This was later analysed by the N.S.W. Department of Mines, and gave a reading of 12.4 percent carbon dioxide and 9.2 percent oxygen (Nurse, 1954). This sample, on the concentration of carbon dioxide and the deficiency of oxygen, would certainly have caused loss of consciousness extremely rapidly.

In 1958, members of the Sydney University Speleological Society made three trips to Wellington to assess the concentration of carbon dioxide and oxygen in the Gas Pipe and Gaden Caves. The instrument used was a Fyrite Carbon Dioxide Indicator. The Gaden Cave gas hole provided maximum readings of 12, 12.5 and 13.5 percent carbon dioxide in January, April and May, 1958. Corresponding oxygen registrations were unusually high at approximately 22, 20.5 and 20 percent (Fraser, 1958).

Discussing the readings taken in 1958, Fraser said that at 48 feet below the surface the air was "cool and pleasant"; at 60 feet the concentration of carbon dioxide was 7 to 8 p.c. - lamps remained alight, but breathing rate increased considerably, some members complained of headache, and pulse rate increased. Lower down, carbide lights were found to go out at about 10 p.c. At this concentration breathing was extremely difficult and other recognised symptoms appeared. No member of the party was able to spend more than 30 seconds collecting air samples, and even after this brief exposure experienced severe symptoms.

The shaft down from the lower level of the Gaden may or may not lead into a new series of caves. In 1958, a member of the Sydney Speleological Society, wearing an aqualung, attempted to descend the shaft but gave up because of the extreme difficulty of manoeuvering his air bottles in the confined space.

Gas Pipe Cave

The Gas Pipe Cave is lower down the hill and was formerly a tourist cave. During January, 1958, noxious air was encountered at a level 21 feet below the surface. In this cave, the concentration of carbon dioxide remained fairly constant throughout the whole length of the cave (between the 21 and 48 ft levels) at 2 to 3 p.c. The S.U.S.S. party spent half an hour

at this concentration without any effects except deeper breathing. In March, noxious air was not found until the 42 ft level, near the bottom of the cave. The percentage of carbon dioxide was from 4 to 5 p.c., and oxygen approximately 18 p.c. In May, carbon dioxide concentrations up to 6 p.c. were found in the cave, but a high oxygen percentage - about 22 p.c. - resulted in comparatively minor discomfort.

Fraser concluded that the cave atmosphere at Wellington was far from homogeneous and that concentrations of carbon dioxide also appeared to occur in pockets. Tests indicated that the percentage of inert gases present (mainly nitrogen) were reasonably constant. The rise in carbon dioxide level was usually accompanied by a proportional fall in the oxygen level. This appeared to indicate that the carbon dioxide was generated in or near the caves and so merely replaced oxygen which had been used in its production. The process was probably one of organic decomposition.

The level of the noxious air (also known as foul air) seems to vary slightly over a long period of time. To the best of the present authors' knowledge, no work has been done on fluctuations of this level as related, say, to rise and fall of the water table or changes in barometric pressure; no attempts have been made to correlate the noxious air levels in various caves and shafts; nor have any detailed gas-pocket and cave-atmosphere analyses been prepared.

PROTECTION OF THE CAVES AND TOURIST ACTIVITIES

The caves generally have very little formation and the tourist caves show few obvious signs of vandalism. The collection of bones by visitors over the years has been a major form of souvenir hunting and has probably accounted for the loss of thousands of specimens. The caves were given a measure of protection when the first keeper was appointed in 1886. Although two caves have locked gates today, the area is thoroughly policed and maintained as a tourist attraction. However, access is normally provided to people with genuine scientific interest.

In the early days, many suggestions were made for the protection of the caves. The Bathurst Free Press of April 17, 1858, reported that "Robinson of the Sportsman's Arms, Wellington" had discovered a new cave and suggested a new door be erected at the entrance and a caretaker appointed to protect the caves. This seems to have been the first attempt to protect the caves, but nothing eventuated.

On August 1, 1876, the Sydney Morning Herald published an article on Wellington concerning vandalism in the caves. As a sequel to this, the Curator of the Australian Museum, Dr. Ramsay, wrote to the Minister for Justice asking him to consider the necessity for taking immediate steps to prevent pillaging, disturbing, or removing bone deposits from the Wellington

Caves by unauthorised persons. He also suggested police action to protect the bone deposits (Jervis, 1958).

The Secretary of the N.S.W. Department of Mines, Harrie Wood, announced in 1884 that the Wellington Caves would be preserved for exploration because of their special scientific interest (Mines Reports, 1884). An area of 129 acres was dedicated for the Preservation of Caves.

The Town and Country Journal, on August 23, 1884, also advocated the adoption of protective measures as "visitors were loading themselves with specimens which they removed from the caves." This same year, James Sibbald was engaged locally as a labourer to collect fossils and was reported to have obtained some valuable specimens. He was appointed first keeper of the caves in 1885 by the Department of Mines, and when not engaged with visitors was employed in the collection of fossils for the "Geological and Australian Museums" (Mines Reports, 1884, 1888). The first caretaker's residence was erected about the end of 1888.

Although many caves have been discovered at Wellington since the Breccia and Cathedral Caves, the only new one of any size, and containing any decoration, is the Gaden Cave (now called the "Gaden Coral Cave"). It was found by Sibbald in 1902, and named after the first President of the Macquarie Shire Council. In 1909, Redman, who succeeded Sibbald as caretaker, opened the cave as a tourist attraction.

Trickett prepared a sketch-map of the area in 1897, which was printed in the Annual Report of the Department of Mines for 1897, and reprinted in his Notes on the Limestone Caves of N.S.W. (1898). In 1906, the Department of Mines published the first guide book on the Wellington Caves. This was written by Trickett and contains a brief description of the caves reserve, the caves and bone deposits, also some history (Trickett, 1906).

It might be added here that many unfounded and inaccurate accounts have been published in tourist literature and general articles on the Wellington Caves right up to the present time. Many of the references concern human remains in the caves. For example: "Here are the remains of men who used strange tools and weapons, who made grotesque drawings, and who left their footprints upon clay that had long since turned into stone" (Coghlan, 1903). The Railway Guide (Guide, 1886) gives a more complicated version.

J.H. Truman, the Shire Clerk of Wellington, visited the caves with Anderson and G. Clutton of the Australian Museum, in 1926. Truman found a large skull in the ceiling of one of the phosphate mine passages; it was believed to be that of a giant kangaroo. The discovery awakened general interest in the caves and they were taken over as a tourist attraction the same year by the Macquarie Shire Council. The Council still controls the

Caves, with S. Barrett in charge. Electric lighting was first installed in the Cathedral Cave in 1926 on a voluntary basis, with a power generator driven by an old car engine (Anderson, 1926; Brown, 1926). The steps and tracks in this cave were installed in 1930-31.

In 1938-39, two Germans are reported by residents of Wellington to have undertaken a collection of fossil bones, but were interrupted by the beginning of the 1939-45 War. Rumour says that the Germans, whose names are not known, were interned in a Prisoner of War Camp, and their bone collection stored at the Australian Museum, Sydney. The authors have been unable to confirm this report.

A cave is reported to lie beneath the Cathedral Cave, with possible entrances from the Cathedral and Breccia Caves. A trip by the Sydney University Speleological Society in 1954 (Burke, Dew, Havenstein, 1955) investigated the prospect of forcing a siphon in the Breccia Cave and stated that it might be possible. A narrow fissure below the Altar in the Cathedral appeared to enter another cavern below.

Another possibility of extension to the Cathedral Cave is by means of a scaling pole climb (about 30 ft vertical) near the Altar. This was attempted with inadequate equipment by E. Lane in 1958, and by S. Barrett in 1963.

CURRENT PALAEONTOLOGICAL RESEARCH

Over the past ten years there has been a renewed interest in the fossil marsupial fauna of Australia. In 1953, Professor R.A. Stirton, of the Department of Palaeontology at the University of California, came to Australia with a team of scientists to attempt to obtain further information on the origin of mammals. On the bone evidence known to date, the Australian fossil marsupials such as Diprotodon, Nototherium and Thylacoleo seem to have sprung into existance fully developed, and the evolutionary lines of development and inter-relationships have yet to be discovered.

Stirton's expedition was sponsored by the Geology Department of the University of Adelaide, and assisted by the South Australian Museum. Since then Stirton has made several more trips to Australia to continue his researches. Although he has not actually visited the Wellington Caves, much of the material he has discovered in South Australia and the western parts of Queensland and N.S.W. is identical, or closely related, to specimens occurring in the bone breccia at Wellington.

Stirton, Marcus and Miller, all members of this team, have recently published papers which have bearing on the Wellington Caves fossils. Miller's paper is concerned with the distribution of fossil and recent ratite birds in eastern Australia, while Marcus and Stirton's papers are on fossil kangaroos.

Woods and Bartholomai, of the Queensland Museum, Ride of the Western Australian Museum, and Stephenson of the Zoology Department, University of Sydney, are also studying fossil marsupials. Woods has recently published on Thylacoleo and Procoptodon, and Bartholomai on Sthenurus.

Birds

Very few bird bones have been discovered in the Wellington bone breccia. Krefft (1870; Votes, 1882) said he had examined a sacrum of the common emu, Dromiceius novae hollandiae (Lath.), in the possession of the Rev. W. B. Clarke, which "looked" as if it had come from Wellington. No further bones of large birds had come to Krefft's notice. In fact, remains of birds at Wellington were so scarce that the genera and species could not be determined.

In 1891, Lydekker recorded the tibiotarsus of a fossil cassowary from the Pleistocene of N.S.W. His report was based on a cast of a specimen collected from the Wellington Caves, and sent to the British Museum by the Trustees of the Australian Museum. The original specimen is still housed in the Australian Museum. In 1911, Rothschild named the species Casuarius lydekkeri Rothschild. In 1960, Miller (1962) compared the tibiotarsus of C. lydekkeri with specimens of the recent species C. bennetti Gould, and showed the two species are very closely related.

Miller says that the significance of the C. lydekkeri bone found at Wellington is that it shows the distinctive bennetti group of cassowaries, which occur today in New Guinea and New Britain, existed in Australia in the Pleistocene and extended far south of the present range of C. casuarius (L.) to the Wellington Valley in N.S.W. Cassowaries today are mainly confined to the New Guinea area, only one species, C. casuarius, being found in Australia, in Northern Queensland.

Marsupials

Family Macropodidae

Stirton (1963) has recently reviewed the genus Protemnodon Owen. He considers the genus to be distinct from Wallabia Trouessart, 1905, and Prionotemnus Stirton, 1955, but related to them probably through a common ancestry at some time in the late Tertiary. Owen described six species of Protemnodon, but Stirton considers it questionable that there are even as many as two species. Many of the illustrations in the paper are of bones collected from the Wellington Caves deposits. Protemnodon brehus (Owen) is the only species occurring in N.S.W. Specimens were collected from the Wellington Caves by Thomson and Krefft and became the type material for the species Sthenurus brehus Owen, 1874. Stirton (1963) has now placed brehus in the genus Protemnodon.

Marcus (1962) described a new species of Sthenurus from the Pleistocene of N.S.W. as Sthenurus andersoni Marcus, after Dr. C. Anderson, formerly of the Australian Museum. The type material came from Bingara; other specimens were obtained from the Wellington Caves. S. andersoni is closely related to S. atlas (Owen), but is smaller. The two species occur together in the Wellington Caves breccia.

He said that Diprotodon optatus, Thylacoleo carnifex, Macropus titan, Zygomaturus trilobus (a type of diprotodon) are associated with S. andersoni at Bingara and Wellington Caves in N.S.W. and at Darling Downs in Queensland. They formed part of a wide-spread middle to late Pleistocene fauna. Anderson (1933) pointed out that Zygomaturus trilobus McLeay is a synonym of Nototherium mitchelli Owen.

In September, 1963, Bartholomai published a revision of the genus Sthenurus Owen in Queensland. The genus is placed in the family Macropodidae, subfamily Macropodinae. Of the five species he discusses, only S. andersoni occurs at Wellington Caves. He considers the two genera Procoptodon and Sthenurus are related and that it is likely Procoptodon was derived from a primative Sthenurus stock. Procoptodon was probably a rapidly evolving genus derived late in the geological history of the group. Structural characters which indicate the aberrant nature of Sthenurus and Procoptodon as macropodine genera appear to be due to a secondary reversion to the browsing habit.

Family Diprotodontidae

Woods (1958) published a paper on the extinct marsupial genus Palorchestes Owen. The genus contains two species, Palorchestes azael Owen and P. parvus De Vis, both of which Woods redescribes. The genus is known only from the skull, no definite postcranial remains having been discovered. Owen placed Palorchestes in the family Macropodidae, and since then it has been placed variously in the subfamilies Macropodinae, Sthenurinae and Palorchestinae. It was considered to be the largest of the kangaroos.

Specimens of P. azael have been obtained from the Wellington Caves. In 1891, the palatal remains of P. azael were found by Sibbald in the bone bed of Number 4 Cave (Cathedral). Only one other specimen, the type, had been found previously - in Victoria (Dun, 1893).

A reconstruction of P. azael in the Australian Museum is based on this palate, and other bones identified by Anderson from widely separated localities. It shows that when standing erect in a defensive attitude, the animal reached a height of more than ten feet (Fletcher, 1945). Woods (1958) says that, in the absence of established field association, the identity of these postcranial bones is doubtful. The skull is about 16 inches in length and is comparable in size with that of an ox. Both P. azael and P. parvus are wide-

spread in Pleistocene deposits, and P. parvus possibly also occurs in Pliocene deposits.

Owen (1877) suggested that Palorchestes might occupy a transitional position between the small existing Macropodidae and Nototherium and Diprotodon. Woods (1958) considers Palorchestes had been placed in the wrong family and says that analysis of the structure of the skull and "dental evidence shows that Palorchestes must be regarded as an aberrant genus of the dominantly browsing Diprotodontidae....Individuals were relatively small, probably lightly built diprotodontids, specialised for grazing."

DISCUSSION

The Wellington Caves, New South Wales, were the first caves of any size to be discovered in Australia. In most publications to date, credit for the discovery of the caves and their fossil bone deposits has been given to either George Ranken or Sir Thomas Mitchell. The authors have been able to produce evidence to show that Charles Sturt and Hamilton Hume visited the caves in 1828, two years before Ranken and Mitchell, and their comments permit the assumption that the existance of the caves was known already to the inhabitants of the district. Credit for the discovery of fossil bones in the caves, however, belongs to Ranken. It was Ranken's discovery, made in 1830, which led Mitchell to visit the caves shortly afterwards. Only one earlier discovery of fossil mammalian bones has been recorded in Australia - by Cunningham in 1829.

All the pioneering work of examining the fossil bone collections from the Wellington Caves has been widely attributed to Sir Richard Owen. The authors show that Owen was not the first in this field.

The driving forces in the collection and study of the early Wellington Caves bone collections were Mitchell and Professor Robert Jameson. Then, some years later, Owen became the important figure in the study of Australian fossil bones. Mitchell's exploration, bone collections and reports are of major importance in the history of the caves. He prepared maps and illustrations of the caves, and drawings of the bone specimens. Jameson arranged for distribution and study of two of the four early collections, and, as editor of the Edinburgh New Philosophical Journal, published findings on all four collections. These were the first published scientific papers on the Wellington Caves fossils.

The early examinations were made by Jameson, W. Clift, Baron Georges Cuvier and W. Pentland; the first papers organising the bones into genera and species were by Clift and Pentland, the latter identifying 14 species belonging to seven genera. Part of the interest in the Australian cave fossils lay in whether they were similar to the extinct forms described by

Cuvier, Buckland and others, from European caves.

Although Pentland divided the bones into several species, it was left to Owen to describe and name many new genera and species. Pentland appears to have had no further interest in Australian fossil marsupials as his last paper on them is dated 1833. Whether this is referable to Cuvier's death in 1832 is not known.

Owen first reported on the bones in 1838, five years after Pentland, and maintained his interest in Australian fossil mammals for more than 50 years. To Owen we owe the stimulus for the many extensive collections made at Wellington by the Australian Museum.

Since the 1860's there has been a very strong tie between the Australian Museum and the Wellington Caves bone collections, and many former Curators and Directors - Krefft, Ramsay, Etheridge and Anderson - were active in research on the fossil bones. Very large collections have been made over the years and it is estimated that from 10,000 to 20,000 bone specimens were removed from Wellington Caves for official collections. This is quite apart from bones destroyed for phosphate, privately collected, or vandalised. Few, if any, complete skeletons have been obtained due to the nature of the breccia. Many of the official bone collections are still housed in the Australian Museum, but lack or loss of labels has made positive identification of many of Krefft's and Ramsay's specimens very difficult. Australian Museum collections made by Anderson in the middle 1920's are well documented.

A considerable collection is also held by the British Museum (Natural History) which includes most of the specimens sent to Owen, and much type material. Other collections, including some type material, are held by the Royal College of Surgeons, London, the University of Edinburgh, and the Museum of the Department of Mines, Sydney.

It should be stressed that the Wellington Caves deposits also contain the bones of many recent animals. Among these can be mentioned snakes, lizards, birds, bandicoots, red kangaroos, possums, and horse.

Many attempts have been made to prove Man was contemporaneous with the fossil marsupials. All human bones found to date in the Wellington Caves have been recent and are believed to include both aborigine and European. The most famous, the "Krefft tooth", was formerly believed to be a human fossil and proof of the antiquity of Man in Australia. The tooth is now believed to be that of a type of kangaroo.

No-one can even estimate the volume of bone and earth filling in the caverns and crevices, or the amount of breccia remaining. Bones are there in profusion, jumbled, broken, mixed up in a baffling manner in earth,

clay or breccia, awaiting future collection and study. Some dripstone formations, such as stalactites, have been found with bones inside them; again, many bones when split open have been filled with hardened mud and some contain crystals of calcite.

It is fairly common to find that Pleistocene mammals in all parts of the world were larger than their living representatives today. This phenomenon is found amongst the extinct Australian marsupials and was immediately recognised by Jameson, Pentland, Lyell, Owen and Darwin, after examination of bones of Diprotodon, Nototherium, Palorchestes, Thylacoleo, Procoptodon, etc.

The extinct marsupials support a theory that just before extinction of a species there is a trend towards increase in bulk. Large size is a type of specialisation which appears to handicap the race, especially if food supplies become limited due to some change in the environment. It is generally supposed that when Diprotodon and its contemporaries roamed Australia the climate was more humid and extensive freshwater lakes and abundant vegetation existed where today there is, in part, desert country.

With the passing of the ice age, the rainfall rapidly decreased, the rich vegetation dwindled and finally almost completely disappeared. The fresh waters of the central Australian lakes diminished in quantity and became saline. Lack of food and water caused the giant Pleistocene marsupials to die in thousands in and around dried-up lakes, waterholes and springs, and among the worst affected were the giant Diprotodon and Nototherium.

The smaller, faster-moving marsupials and some of the diprotodontids followed the food and water supply to the east. The reason why many marsupials became extinct in eastern Australia is unknown as plentiful food and water were available and conditions probably not greatly different from today. Owen (1877) suggested that the early aborigines may have hunted them for food, but there is no available evidence to confirm this. Fletcher (1945) considers that carnivores, such as Thylacinus and the dingo, could have hunted in large packs and overcome the defenceless herbivores. A material decrease in numbers of herbivorous animals would lead to an increased number of attacks on the survivors by carnivorous forms, eventually leading to extinction.

We can assume that the rich Wellington Valley formerly supported a considerable population of animals, but no satisfactory explanation has yet been put forward as to why a huge deposit of fossil bones should have accumulated in this limestone area.

The type material of many of the species of fossil marsupials has been obtained from the Wellington Caves bone deposits, and fossils from the

caves have figured repeatedly in the general study of Australian marsupials. Several genera of fossil marsupials, recently revised, include many specimens from Wellington Caves, and many other genera closely associated with these caves, such as Sarcophilus and Thylacinus, still await revision. The caves at Wellington have been prominent in scientific writing over the past 130 years, and the possibilities for further collecting, study and discovery of new species still remain.

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CAPTIONS

MAP : Sketches and plans from O. Trickett (1898) and T.L. Mitchell (1838), with some modifications. The plan of the area is as drawn by Trickett in 1897, with the Gaden Cave approximate position shown.

PLATE 1 : An aquatint of the interior of the Breccia Cave, Wellington, by Thomas Mitchell, published in 1831 in Part XXIII of the Edinburgh New Philosophical Journal. This hand-tinted drawing is the first published illustration of the Wellington Caves. Mitchell published another version of the same scene in his book, Three Expeditions (1838).

PLATE 2 : Drawing by Thomas Mitchell of the Altar in the Cathedral Cave, Wellington. From his book, Three Expeditions into the Interior of Eastern Australia (1838).

PLATE 3 : Drawings on zinc by Thomas Mitchell of bone fragments from the Breccia Cave, Wellington. Published in Mitchell's book, Three Expeditions (1838). The figures are:- 1. The united radius and ulna of a kangaroo. 2. Foot of a dasyurus. 3. No reference in Mitchell. 4, 5. Right upper incisor of Thylacoleo carnifex Owen. No reference in Mitchell. 6 - 9. Lower incisor of T. carnifex. No reference in Mitchell. 12, 13. Leg bone of Diprotodon optatum Owen, broken by Ranken's rope in 1830. The figures 3 to 11 were unidentified at the time Mitchell's book was published in 1838. Krefft (1867) identified figures 6 to 11. Fletcher (Personal Communication, 1963) identified figures 4 and 5.

PLATE 4 : Drawing by Thomas Mitchell of the entrance to the Cathedral Cave, Wellington, in 1830. From Mitchell's book, Three Expeditions (1838).

PLATE 5 : Drawing on stone and lithographed. From Sir Richard Owen's book, Researches on the Fossil Remains of the Extinct Mammals of Australia (1877). Figures are:- 1. Side view of skull of Diprotodon optatum Owen, 1838 (usually referred to as D. australis Owen, 1844). Natural size, 3 ft. 1½ in. long. Fig. 2 Front view of skull. 3. Back view of skull. 4. Portion of molar. 5. Side view of skull of Macropus laniger (Ref. Owen, 1877). Nat. size 8 1/4 in. long; probably included for size comparison.

PLATE 6 : Restoration of the skeleton of Diprotodon optatum Owen. Nat. size, 9 ft. 9 in. long. Shown among indigenous Australian plants including the grass-tree Xanthorrhoea on the left and the cycad Macrozamia next to it. Note the absence of tail and feet, details of which were not known at the time of publication. Drawn on stone and lithographed. From Owen's Extinct Mammals of Australia (1877).

PLATE 7 : Section of skull of Thylacoleo carnifex Owen as known in 1877, showing the cerebral cavity and the entire dentition from nature. Natural size, 10 3/4 in. long. Drawn on stone and lithographed. From Sir Richard Owen's Extinct Mammals of Australia (1877).

PLATE 8 : Top. Part of the interior of the Bone Cave, Wellington. Fossil bones can be seen as white marks on walls and roof. Photo: D. Havenstein, Geology Dept., University of Sydney. Bottom left. Part of limestone outcrop at Wellington Caves showing about half the elevation above the surrounding flats. Photo: E.A. Lane. Bottom right. Entrance to the Breccia Cave, Wellington, with tourist track leading up to Cathedral Cave on right. Photo: E.A. Lane.

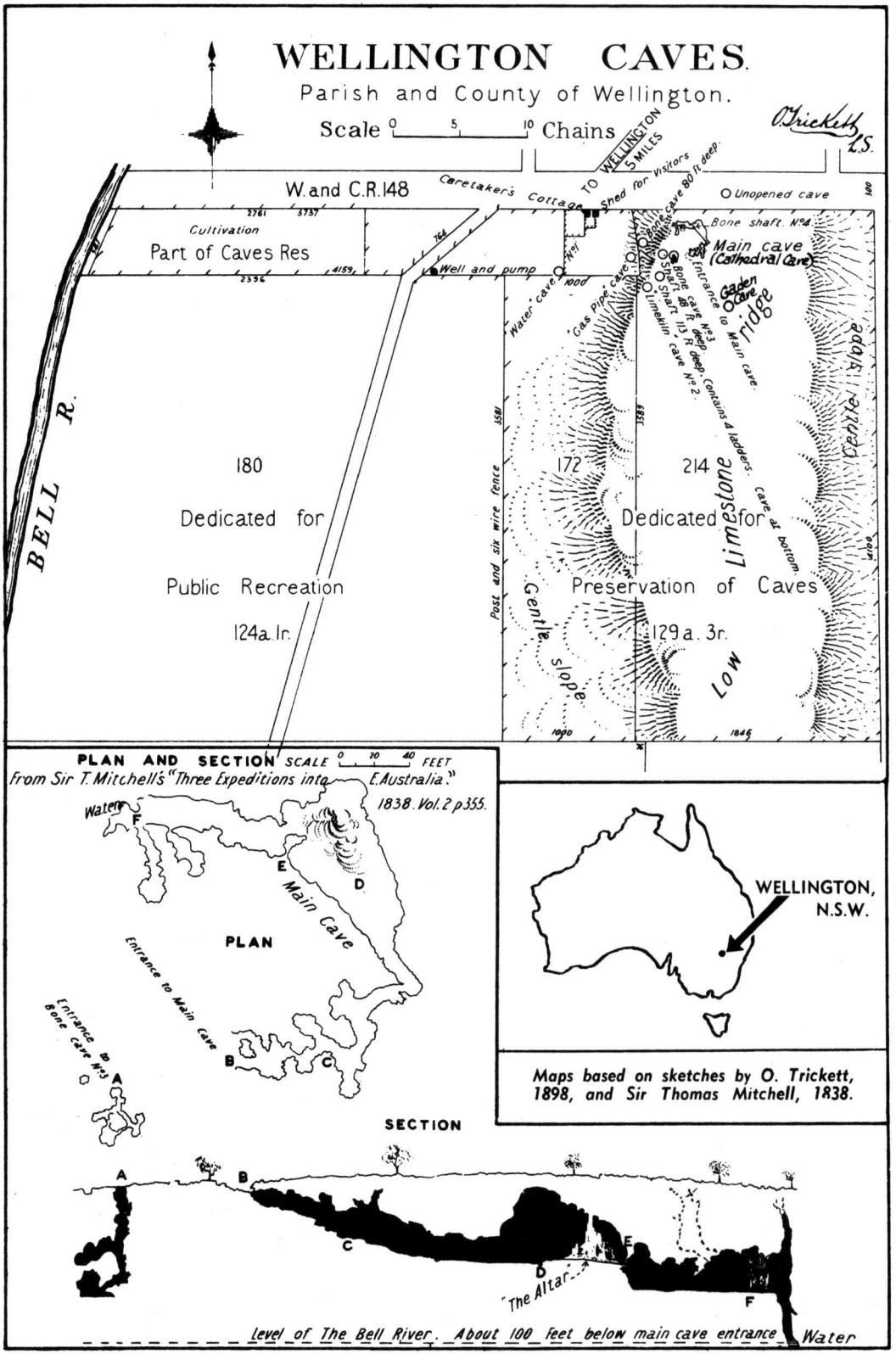
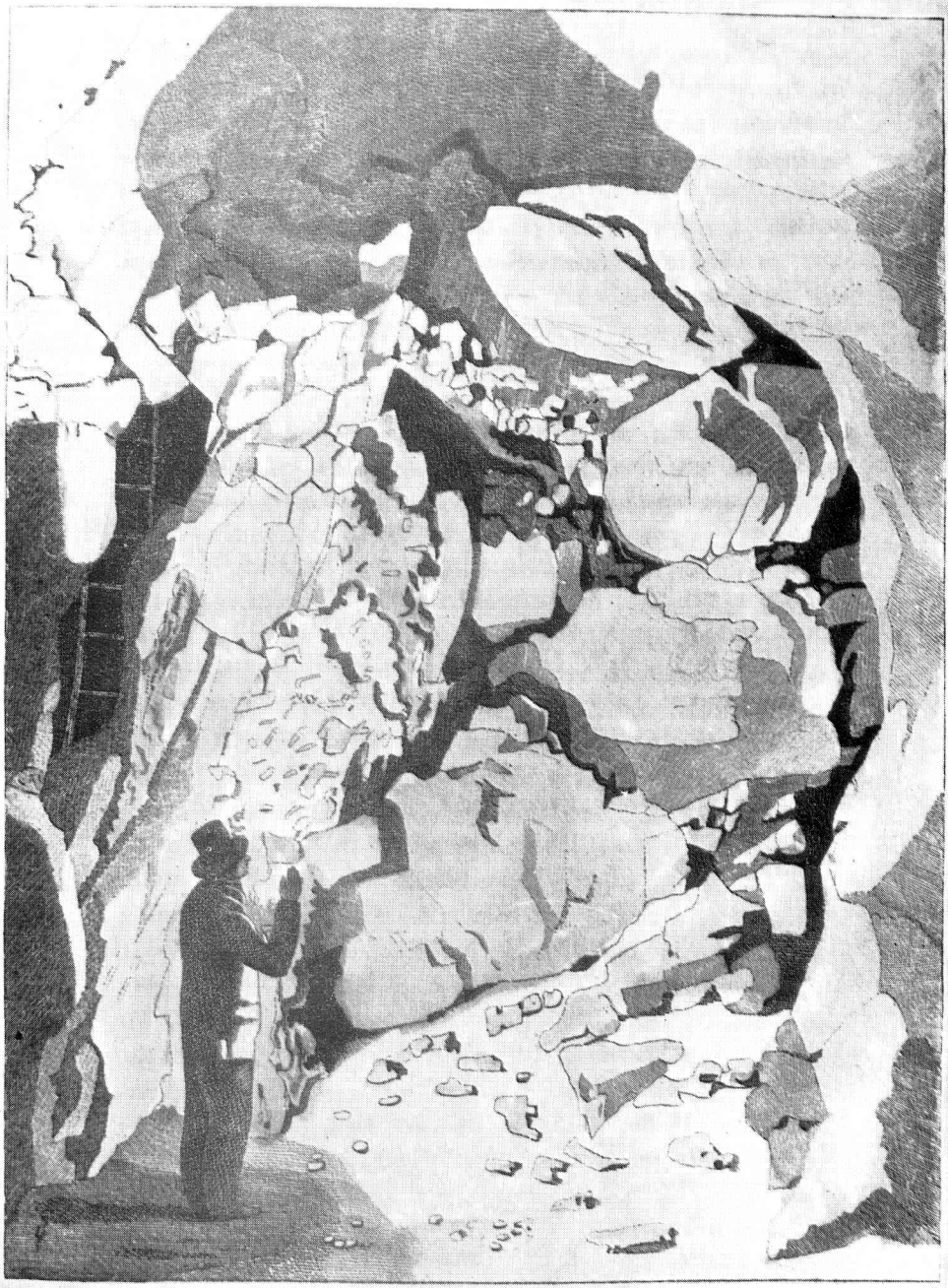

WELLINGTON CAVES.
Parish and County of Wellington.
Scale 0 5 10 Chains
O. Trickett, L.S.
WELLINGTON 5 MILES
TO
W. and C.R. 148
Caretaker's Cottage
Shed for Visitors
Unopened cave
Cultivation
Part of Caves Res
Well and pump
Bone shaft. No4
Main cave (Cathedral Cave)
Entrance to Main cave
Garden Cave
Ridge
Water cave
"Gas Pipe" Cave
Limekiln cave No 2.
Bone cave No3
Shaft 80 ft. deep
Shaft 113 ft. deep. Contains 4 ladders.
cave at bottom
Central slope
Limestone
BELL R.
180
Dedicated for
Public Recreation
124a. 1r.
172
214
Dedicated for
Preservation of Caves
129a. 3r.
Post and six wire fence
Gentle slope
Low
PLAN AND SECTION SCALE 0 20 40 FEET
from Sir T. Mitchell's "Three Expeditions into E. Australia."
1838. Vol. 2 p 355.
Water
Main Cave
Entrance to Main Cave
Entrance to Bone Cave No3
PLAN
SECTION
"The Altar"
Level of The Bell River. About 100 feet below main cave entrance
Water
WELLINGTON, N.S.W.
Maps based on sketches by O. Trickett, 1898, and Sir Thomas Mitchell, 1838.

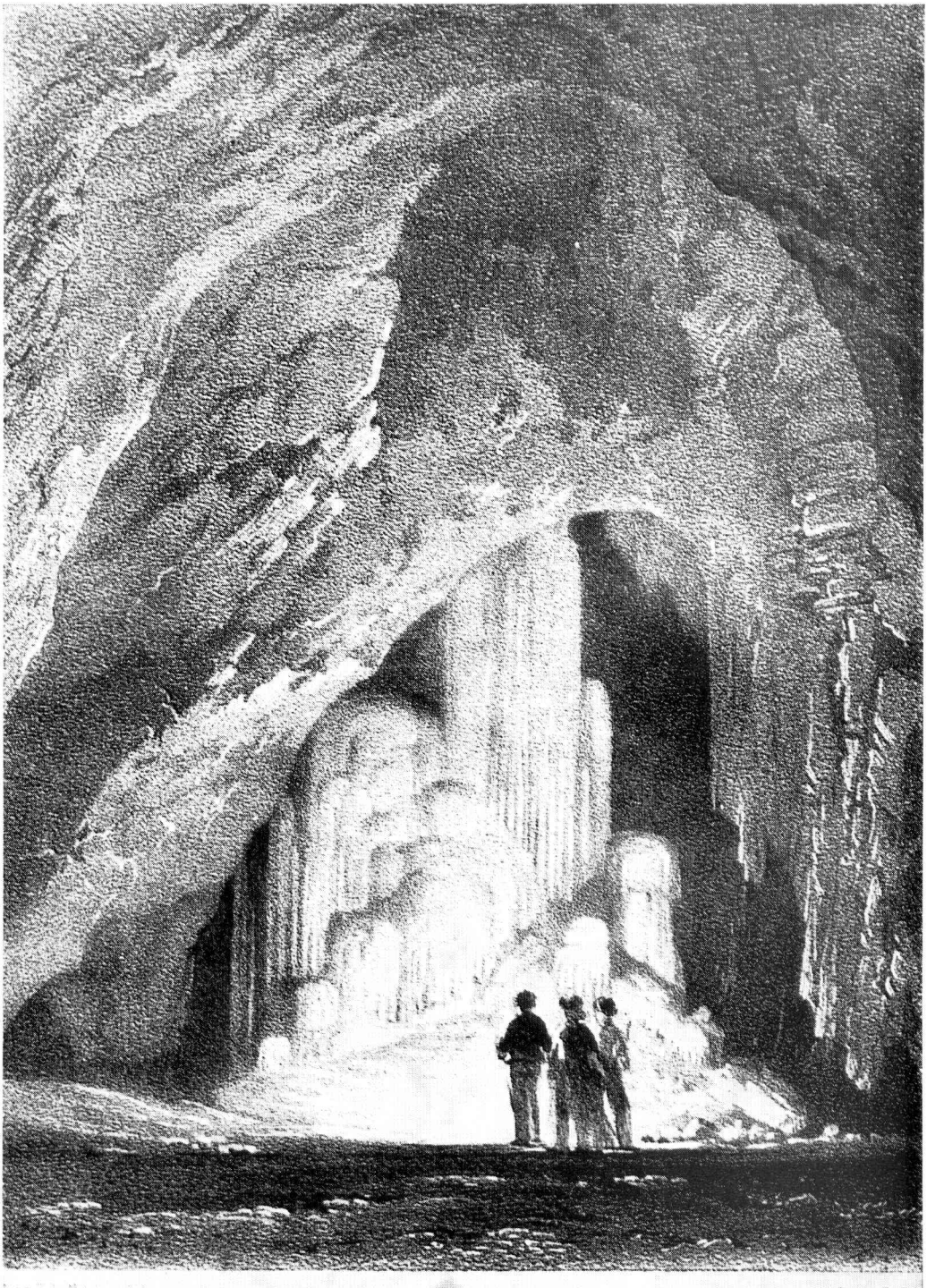
PLATE V.

Edin. New Phil. Jour. Vol. XVI.

Sketch shewing the manner in which the Osseous Breccia occurs in the Cave at Wellington, in New South Wales

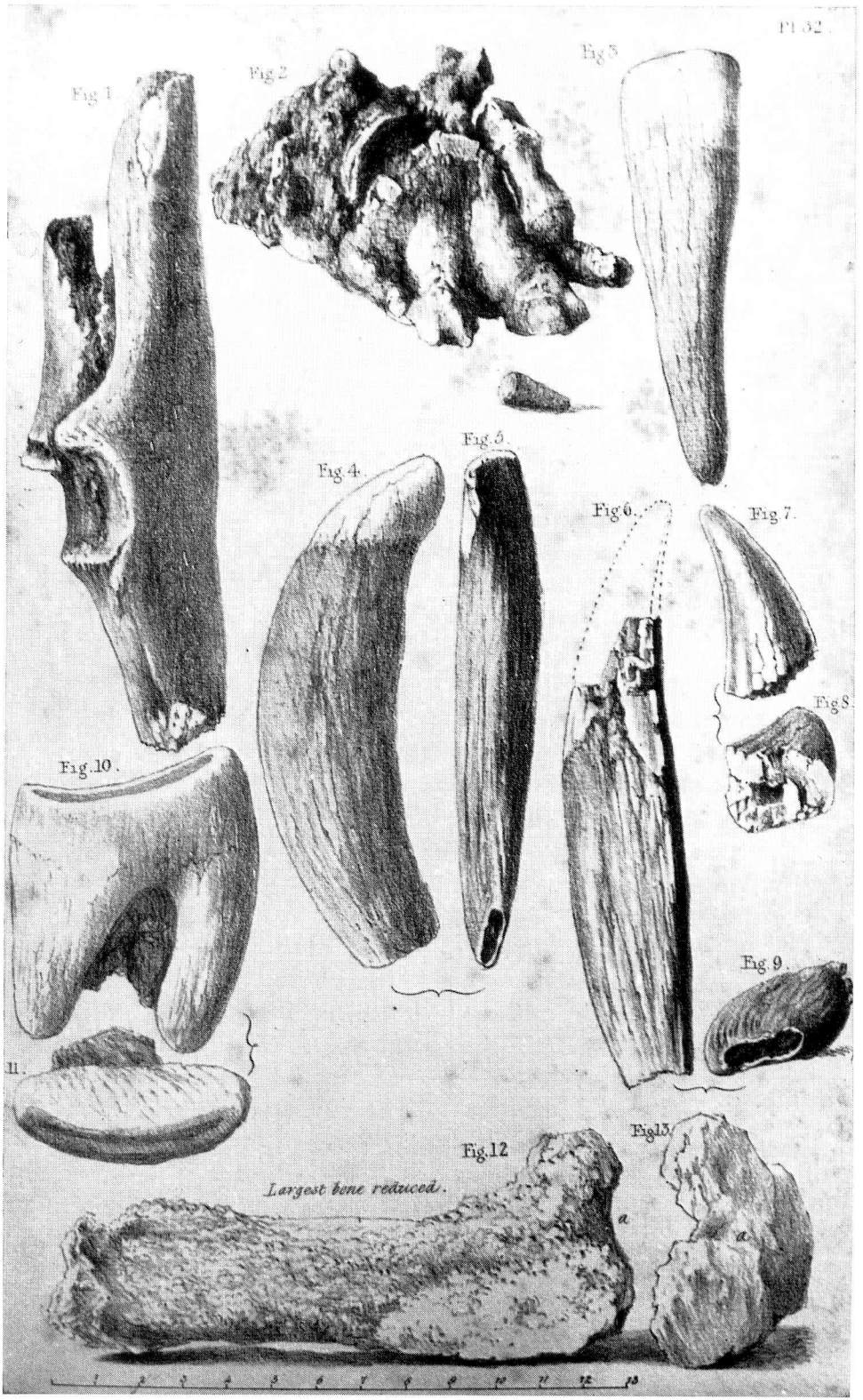


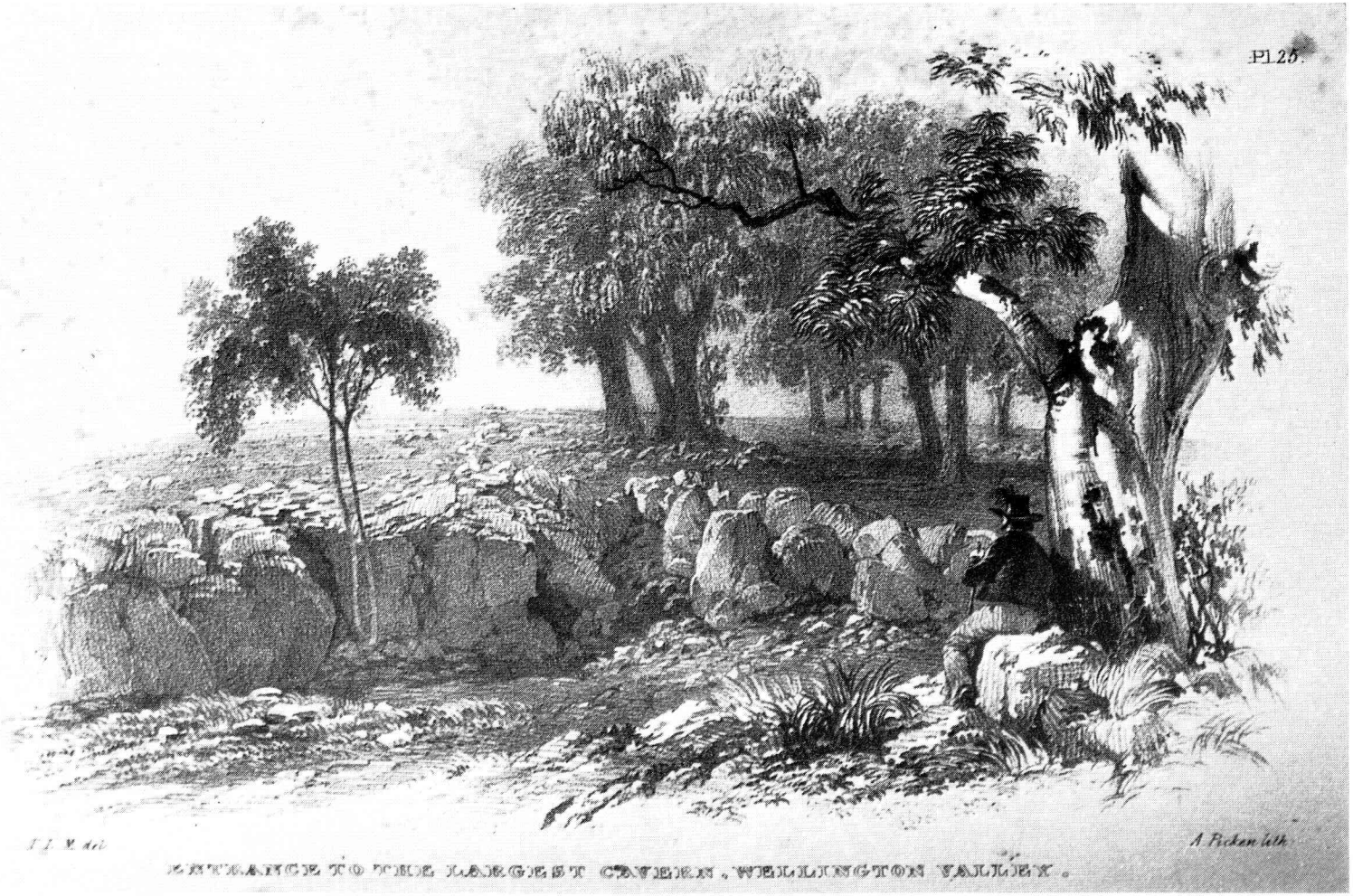
The Cave in which the fossil bones are found at Wellington Valley is in Compact secondary Limestone, as discribed more fully in a memorandum which accompanied a very large bone sent by Mr Rankin to Prof.r Jameson. It is near a larger Cave where no breccia has been found, and which is very different in character from that of which this drawing is intended to convey an idea, the appearance of disruption with unshapely masses of rock overhanging being very characteristic of all the situations where the fossil bones have hitherto been discovered in N.S.Wales. The bone above mentioned is that of an Elephant.



A Picken lith.

LARGE CAVERN AT WELLINGTON VALLEY.


Pl 32.
Fig 1.
Fig 2.
Fig 3.
Fig 4.
Fig 5.
Fig 6.
Fig 7.
Fig 8.
Fig 9.
Fig 10.
11.
Fig 12
Largest bone reduced.
Fig 13
a
a


Pl. 25.
J. J. W. del.
A. Picken lith.
ENTRANCE TO THE LARGEST CAVERN, WELLINGTON VALLEY.

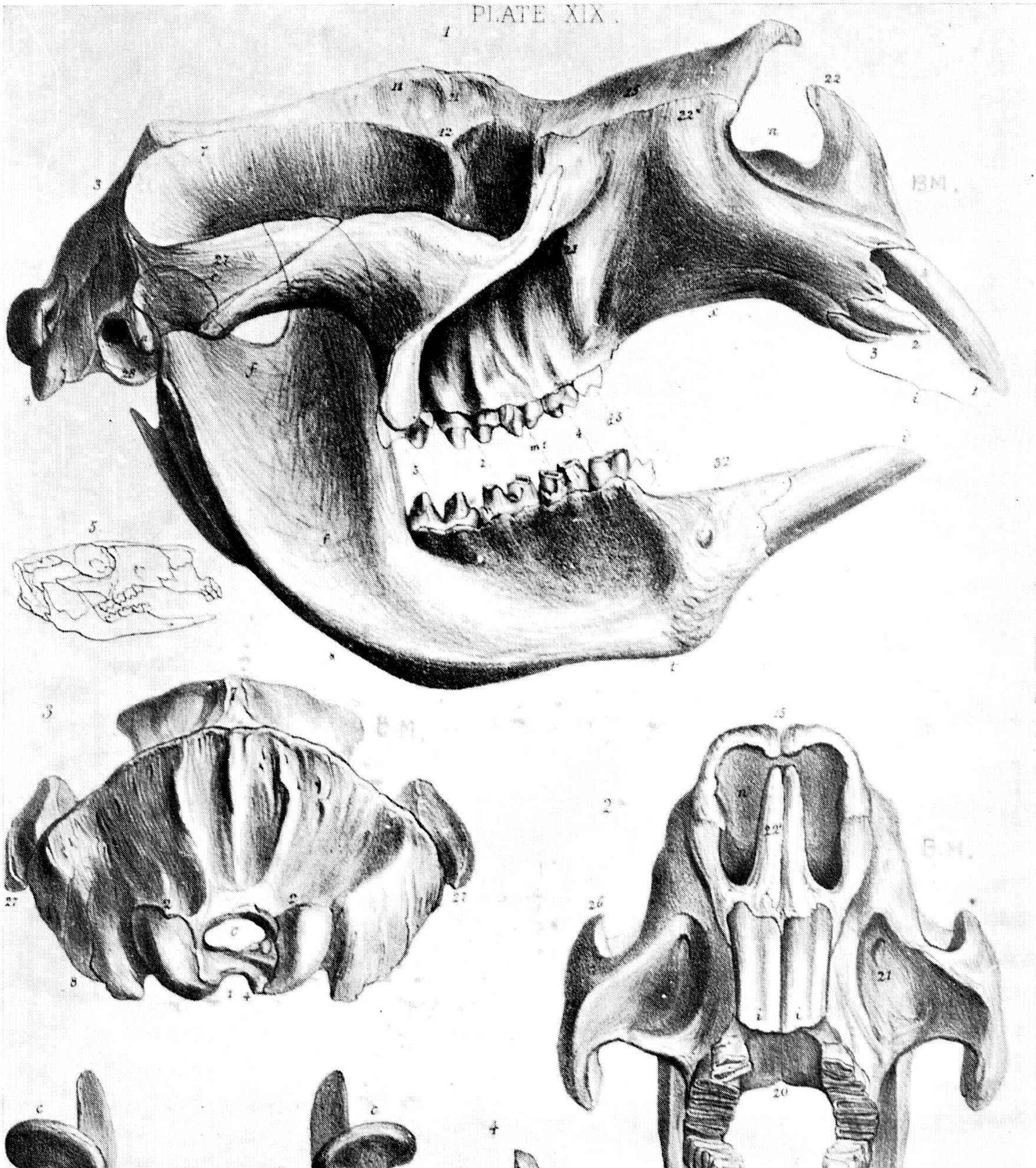


PLATE XIX.
1
2
3
4
5
B.M.

Plate 6

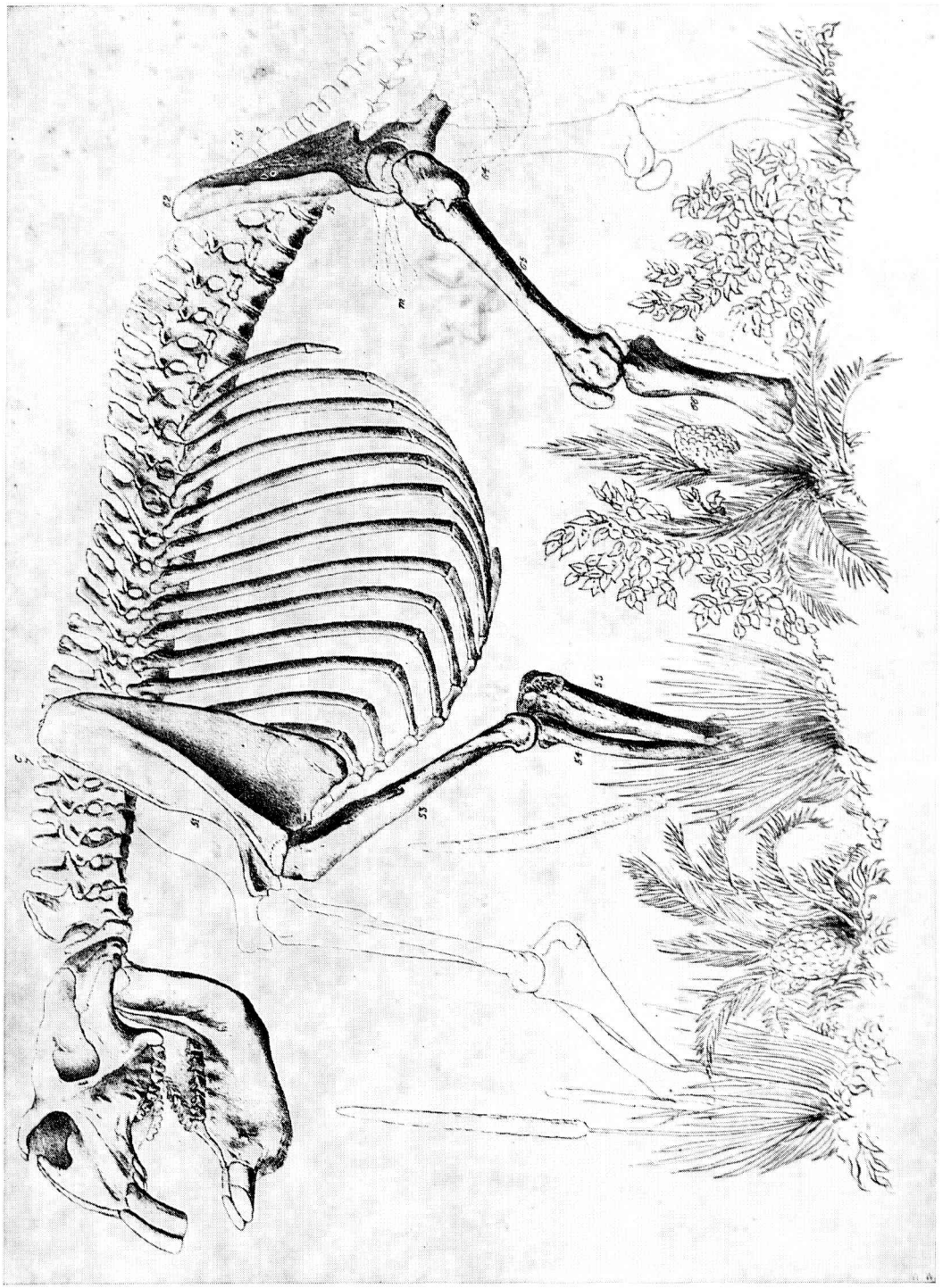


Plate 7

Plate 8