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Historical Records of Australian Science

Supplementary material

Kenton Stewart Wall Campbell 1927-2017

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S1. KSW Campbell — Honours and Awards (incl. scholarships, travelling fellowships etc.)

1948-50 CSIRO Research Studentship at the University of Queensland

1957 Nuffield Dominion Travelling Fellowship to Cambridge

1965 Australian-American Education Foundation Award

1965 US National Science Foundation Award (Silurian trilobites; Harvard University)

1973 NATO Award (primitive arthropods; Advanced Study Institute, Oslo)

1975 W.B. Clarke Memorial Lecture (Royal Society of NSW)

1981 Visiting Scientist, Field Museum, Chicago

1982 Academia Sinica exchange visit to China

1983 Fellow, Australian Academy of Science

1985 Visiting Professor, Anatomy Dept., Guys Hospital Medical School, London

1986 Mawson Medal and Lecture, Australian Academy of Science

1992 Honorary Member, Geological Society of Australia

2001 Centenary Medal (for service to Australian society and science in vertebrate palaeontology)

2006 W.R. Browne Medal of the Geological Society of Australia

2010 W.B. Clarke Medal of the Geological Society of Australia (NSW Division)

2012 Raymond C. Moore Medal of the US Society for Sedimentary Geology

S2. Fossil taxa named for KSW Campbell

CORAL

***Lithostrotion campbelli* Pickett, 1967**

Reference: Pickett J.W. (1967). Lower Carboniferous coral faunas from the New England District of New South Wales. *Geological Survey of N.S.W., Memoir Palaeontology* **15**, 1-38, pl. 1-20.

BRACHIOPODS

***Neospirifer campbelli* Maxwell, 1964**

Reference: Maxwell W.G.H. (1964). The geology of the Yarrol region. Part 1. Biostratigraphy. *Pap. Dept. Geol. Univ. Qld* **5**(9), 1-79.

***Fluctuaria campbelli* Roberts, 1964**

Reference: Roberts J. (1964). Lower Carboniferous brachiopods from Greenhills, New South Wales. *Journal of the Geological Society of Australia* **11**(2), 173-194.

***Kitakamithyris campbelli* (Cvancara, 1958)**

References: Cvancara, A.M. (1958). Invertebrate fossils from the Lower Carboniferous of New South Wales. *Journal of Paleontology* **32**, 846-888, Pls. 109-113.

Roberts J. (1964). Lower Carboniferous faunas from Wiragulla and Dungog, NSW. *Journal and Proceedings of the Royal Society of NSW* **97**, 193-215.

***Subansiria campbelli* Armstrong, 1970**

Reference: Armstrong J.D. (1970). Syringothyrid brachiopods from the Permian of eastern Australia. *Neues Jahrbuch fur Geologie et Paläontologie, Abhandlungen* **136**, 135-165.

***Spinulicosta campbelli* Chatterton, 1973**

Reference: Chatterton B.D.E. (1973). Brachiopods of the Murrumbidgee Group, Taemas, New South Wales. *BMR Bulletin* **137**, 146 pp, 35 pls.

***Imperiospira campbelli* Archbold & Thomas, 1993**

Reference: Archbold N.W. & Thomas G.A. (1993). *Imperiospira*, a new Western Australian Permian Spiriferidae (Brachiopoda). *Memoir of the Association of Australasian Palaeontologists* **15**, 313-328.

***Angustispatula campbelli* Qian & Roberts, 1995**

Reference Qian W.L. & Roberts J. (1995). Brachiopods of the Early Carboniferous *Schellwienella burlingtonensis* Zone in eastern Australia. *Alcheringa* **19**, 255-289.

***Ananais campbelli* Waterhouse, 2008**

Reference**:** Waterhouse J.B. (2008). Golden spikes and black flags — macro-invertebrate faunal zones for the Permian of east Australia. *Proceedings of the Royal Society of Victoria***120**, 345-72.

BIVALVE MOLLUSCS

***Inaequidens campbelli* Pojeta & Gilbert-Tomlinson, 1977**

Reference: Pojeta J. & Gilbert-Tomlinson J. (1977). Australian Ordovician pelecypod molluscs. *Bureau of Mineral Resources, Geology and Geophysics, Bulletin* **174**, 64 pp., 29 pl.

***Cornellites campbelli* Johnston, 1993**

Reference: Johnston P.A. (1993). Lower Devonian Pelecypoda from southeastern Australia. *Memoir of the Association of Australasian Palaeontologists* **14**, 134 pp.

TRILOBITES

***Primaspis (Taemasaspis) campbelli* Chatterton, 1971**

Reference: Chatterton B.D.E. (1971). Taxonomy and ontogeny of Siluro-Devonian trilobites from near Yass, New South Wales. *Palaeontographica* A, **137**, 1-108, 24 pls.

***Acanthopyge (Lobopyge) campbelli* Chatterton & Wright, 1986**

Reference: Chatterton B.D.E. & Wright A.J. (1986). Silicified Early Devonian trilobites from Mudgee, New South Wales. *Alcheringa* **10**, 279-296.

***Paciphacops campbelli* Ramsköld & Werdelin, 1991**

Reference: Ramsköld L. & Werdelin L. (1991). The phylogeny and evolution of some phacopid trilobites. *Cladistics* **7**, 29-74.

***Australosutura campbelli* Engel & Morris, 1992**

Reference Engel B.A. & Morris L.N. (1992). Aulacopleuridae and Brachymetopidae (Trilobita) from the Lower Carboniferous of eastern Australia (II) *Brachymetopus* (*Brachymetopus*) and *Australosutura*. *Geologica et Palaeontologica* **26**, 73-97.

***Perizostra campbelli* Holloway & Lane, 2016**

Reference: Holloway D.J. & Lane P.D. (2016). Trilobites of the suborder Illaenina from the Silurian of north Queensland, Australia. *Journal of Paleontology* **90**, 433–471.

CRINOID

***Campbellicrinus compactus* Jell & Willink, 1993**

Reference: Jell P.A. & Willink R.J. (1993). Early Permian cladid crinoids from the Gharif Formation of Oman. *Memoir of the Association of Australasian Palaeontologists* **15**, 305-312.

STARFISH (ASTEROIDA)

***Kswaster campbelli* Jell, 2026**

Reference: Jell P.A. (2026). Early Devonian stelleroid echinoderms from Central Victoria. *Alcheringa: An Australasian Journal of Palaeontology* 1-106. DOI: 10.1080/03115518.2025.2601987

FISHES

***Campbellodus decipiens* Miles & Young, 1977**

Reference: Miles R.S. & Young G.C. (1977). Placoderm interrelationships reconsidered in the light of new ptyctodontids from Gogo, Western Australia. In: S.M. Andrews, R.S. Miles & A.D. Walker (eds), *Problems in Vertebrate Evolution*, Linnean Society Symposium Series **4**, 123-198, 35 figs., 5 pls.

***Howittacanthus kentoni* Long, 1986**

Reference: Long J.A. (1986). A new Late Devonian acanthodian fish from Mt. Howitt, Victoria, Australia, with remarks on acanthodian biogeography. *Proceedings of the Royal Society of Victoria* **98**, 1-17.

***Kenichthys campbelli* Chang & Zhu, 1993**

Reference: Chang M.-M. & Zhu M. (1993). A new Middle Devonian osteolepidid from Qujing, Yunnan. *Memoir of the Association of Australasian Palaeontologists* **15**, 183-198.

***Amadeodipterus kencampbelli* Young & Schultze, 2005**

Reference: Young G.C. & Schultze H.-P. (2005). New osteichthyans (bony fishes) from the Devonian of central Australia. *Mitteilungen aus dem Museum für Naturkunde in Berlin, Geowissenschaftliche Reihe* **8**, 13-35.

S3. KSW Campbell — Full Bibliography (chronological order)

1. Campbell K.S.W. 1952. The geology of the Cressbrook-Buaraba area. *Pap. Dept. Geol. Univ. Qld* **3**(15), 1-44.
2. Campbell, K.S.W. 1953. The Fauna of the Permo-Carboniferous Ingelara Beds of Queensland. *Pap. Dept. Geol. Univ. Qld* **4**(1), 1-30.
3. Hill D., Tweedale D.W., Hawthorne W. & Campbell K.S.W. 1953. Geological Map of Queensland, 40 miles to 1 inch. *Geological Survey* of *Queensland.*
4. Campbell K.S.W. 1955. *Phricodothyris* in New South Wales. *Geol. Mag.* **92**, 374-384.
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6. Campbell K.S.W. 1957. A Lower Carboniferous brachiopod-coral fauna from New South Wales. *Journal of Paleontology* **31**, 34-98.
7. Campbell K.S.W. 1958. *Upper Palaeozoic Studies*. Unpublished PhD Thesis. University of Queensland.
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10. Amos A.J., Campbell K.S.W. & Goldring R. 1960. *Australosutura* gen. nov. (Trilobita) from the Carboniferous of Australia and Argentina. *Palaeontology* **3**, 227-236.
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14. Campbell K.S.W. 1961a. New species of the Permian spiriferoids *Ingelarella* and *Notospirifer* from Queensland and their stratigraphic implications. *Palaeontographica* **A117**, 159-192.
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26. Campbell K.S.W. & Talent J.A. 1967. *Malurostrophia,* a new genus of stropheodontid brachiopod from the Devonian of Australia. *Proc. R. Soc. Vict.* **80**, 309-330.
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29. Campbell K.S.W. (Ed) 1969a. *Stratigraphy and Palaeontology. Essays in honour of Dorothy Hill*. Australian National University Press, Canberra. 390 pp.
30. Campbell K.S.W. & McKellar R.G. 1969. Eastern Australian Carboniferous invertebrates: sequence and affinities. In *Stratigraphy and palaeontology. Essays in honour of Dorothy Hill*. Canberra. Australian National University Press. 77-117.
31. Campbell K.S.W. 1969b. Carboniferous System. *Journal of the Geological Society of Australia* **16**, 244-245.
32. Engel B.A., Roberts J. & Campbell K.S.W. 1969. Lower and middle Hunter Valley. *Journal of the Geological Society of Australia* **16**, 249-253.
33. Engel B.A., McKelvey B.C. & Campbell K.S.W. 1969. Stroud-Gloucester and Myall Synclines. *Journal of the Geological Society of Australia* **16**, 253-255.
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55. Campbell K.S.W. 1975c. The functional anatomy of phacopid trilobites: musculature and eyes. *J. Proc. R. Soc. N.S.W.* **108**, 168-188.
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60. Campbell K.S.W. 1977. Trilobites of the Haragan, Bois d'Arc, and Frisco Formations (Early Devonian) Arbuckle Mountains region, Oklahoma. *Bull Oklahoma Geol. Surv.* **123**, 1-227.
61. Campbell K.S.W., Rodgers, P.A. & Benbow, M. 1977. Fossiliferous Lower Devonian boulders from the Cretaceous of South Australia. *Quart. Geol. Notes, Geol. Surv. S. Aust.* **62**, 9-13.
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Bulletin **66**(3), 4-14.
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S4. KSW Campbell — Research contribution and impact

Introduction

As noted in the main text, the largest component of Ken Campbell's research was vertebrate palaeontology, with over 50 published papers and monographs, approaching 40% of his total published output. But number of publications is a very crude measure, and some of the lesser number of papers, categorised for example under 'Evolutionary theory', deal with big ideas, for example patterns presented by the fossil record that challenge accepted neo-Darwinian theory.

The following provides more detail of Ken Campbell's research contribution and impact for the various subject areas covered by his six decades of research. All cited publications are listed either in his full bibliography, or in the Supplementary References.

For the different sections below, contributing authors who provided information and contributed text are indicated by their initials in square brackets for their relevant areas of expertise, as follows: vertebrate palaeontology [JAL], theoretical palaeontology and evolutionary theory [CRM, PAJ], echinoderms [CRM, PAJ], cephalopods, corals and biostratigraphy [JWP], trilobites [DJH, PAJ], brachiopods and Permian biostratigraphy [GS, PAJ], and general geology and palaeontology [PAJ, JWP].

Geology, general palaeontology, biostratigraphy etc. [PAJ, JWP]

Ken's first publication (1952) was by any measure exemplary for a geology honours student. In 44 pages he covered the physiography, stratigraphy, petrology, palaeontology and structural geology of Cressbrook-Buaraba in the Brisbane Valley, a geologically complex, strongly fault-dissected area about 80 km west of the city. He traced a thin, fossiliferous unit and described its fauna as key to the stratigraphy. His contribution to the 1953 'Geological Map of Queensland' was sufficient for co-authorship. During his two years postgraduate study at UQ with his supervisor Dorothy Hill, Ken joined other students GW Tweedale and WL Hawthorne, compiling a geological map of Queensland, published by the Geological Survey of Queensland Survey in 1953. In 1960, it became part of Volume 7 of the *Journal of the Geological Society of Australia*, the updated volume on Geology of Queensland, to which he contributed geological papers on the Homevale area and Brisbane Valley.

From 1952 Ken conducted geological field-work with students in new areas of Carboniferous rocks to the west of Tamworth, and in the Gloucester area (1954-57). He was assisted in the study of the faunas by American Fullbright Scholar Alan Cvancara. Ken's work on the Carboniferous brachiopods of New England was probably initially stimulated by Alan Voisey's abiding interest in the geological evolution of New England. Ken's efforts to develop a Carboniferous biostratigraphy started the careers of some of his early post-graduate students: Brian Engel (bryozoa, trilobites), John Roberts (brachiopods, biostratigraphy) and John Pickett (rugose and tabulate corals).

Already noted is the significant contribution by Ken Campbell (all the Palaeozoic chapters, and the marine portion for the Tertiary) to '*The geological evolution of Australia and New Zealand*' (Brown, Campbell & Crook 1968). The previous monograph on Australian geology (David & Browne 1950) had preceded major post-war advances in geological knowledge. Reconnaissance geological mapping of Australia and New Zealand had expanded apace after World War II, along with increased oil and mining company activity. Other available publications were too specialised for geology students. Brown, Campbell & Crook was intended as a text-book and teaching aid, and became a standard reference in university geology departments throughout Australasia. In those years, ideas of continental drift and plate tectonics were still contentious, and Ken helped champion these with David Brown.

Ken recognised his mentor and honours supervisor, Prof. Dorothy Hill FAA FRS, by editing the 390-page volume '*Stratigraphy and palaeontology. Essays in honour of Dorothy Hill*'

(1969), to which he contributed two papers on Carboniferous biostratigraphy and correlation. He also co-authored correlation charts for the Carboniferous (with P.J. Jones and J. Roberts) and for the Permian, Triassic, and Jurassic (with M.R. Banks, J.M. Dickins and others). Geological mapping in New England, and stratigraphy and correlation of the Shoalhaven Group, came out in six contributions to '*The Geology of New South Wales*' (ed. G. Packham, 1969). Wide-ranging reviews of Australian late Palaeozoic faunas and biostratigraphy were published by Campbell & McKellar (1969) and Runnegar & Campbell (1976).

Ken's geological work in New England (e.g. with Barrie McKelvey on the Barrington area; Carboniferous faunas and correlation with John Roberts) was later formally recognised by other geologists. Korsch & Harrington (1981) named the 'Campbell High' east of the Peel Fault in honour of Ken Campbell, 'to remind readers of your work in New England' (annotation on Ken's personal reprint by Dr Larry Harrington). Ken also convened, edited and contributed to the published proceedings of an ANZAAS Symposium on 'The Devonian System in Australia' (1972). With A.R. Crawford was a paper on large-scale Ordovician displacement between Australia and Antarctica published in *Nature* (1973), proposing earth movement across a major lineament through southern South Australia and northern Tasmania. This idea was challenged, but it promoted more careful study of the geology of those areas and a far better understanding of what is now called the Delamerian Orogeny. He helped identifying and dating brachiopods in a limestone unit in Papua New Guinea in 1976, confirming the late Triassic age although he had never previously studied Triassic faunas. For the South Australian Geological Survey Ken identified Devonian age fossils in morainic boulders of the Cretaceous Caddnaowie Formation, evidently transported during the Permian glaciation, and reworked into the Cretaceous succession by the marine inundation of the Eromanga Basin.

A very significant contribution to the geology and palaeontology of Australia, the Southern Hemisphere continents, and India, was Ken Campbell's editing of the 705-page proceedings (1975) of the Third Gondwana Symposium, held in Canberra in 1973 (Supplementary Fig. S7).

Brachiopods [GS, PAJ]

Ken's brachiopod research had its origins in his B.Sc Honours work, the palaeontology section of his first paper (1952) describing remains of five Permian brachiopod genera. In his mapping he had also found brachiopods at Kipper Creek, for which there seemed no comparable Australian descriptions. Thanks to Dorothy Hill negotiating with the Geological Survey, Ken sampled Permian brachiopods in the Serocold Anticline to assist with correlation for a Shell oil company drilling program. He collected and described the Cattle Creek and Ingelara faunas for his M.Sc (published in 1953). His careful identification and description of distinctive features of the numerous species of the spiriferoid brachiopods *Ingellarella*/*Martiniopsis* and *Notospirifer* became the basis for later brachiopod-based Permian biostratigraphic zones (e.g. Runnegar & McClung 1975). Briggs' (1998) historical account of Permian biostratigraphy in eastern Australia noted it was 'long hindered by inadequate taxonomic study ... before the systematic studies of Hill … Maxwell … and Campbell (1952, 1953, 1959, 1960, 1961)'.

In Armidale, Ken's interest expanded into Carboniferous brachiopods, with papers on *Phricodothyris* and Carboniferous productids (1955-56), his first publications in overseas journals. His 1958 research in Cambridge under a Nuffield Scholarship focused on Permian tetrebratuloids, a consideration of the functional significance of different shaped lophophores stimulated by Martin Rudwick's functional analysis experiments. He met British Palaeontological Association colleagues starting up a new journal (*Palaeontology*), and his two spiriferid papers (1959a-b) were published in the first volume. Martin Rudwick's experimental methods with the aberrant Permian brachiopod *Prorichthofenia* inspired Ken towards a deeper consideration of functional morphology – a focus he retained throughout his

palaeontological research, to interpret fossils as living animals of the past. Analysis of the morphology and environment of now extinct animals, to interpret essential functions like feeding, respiration etc., were concepts that produced positive feedback from students when Ken elaborated these ideas in his lectures to undergraduates.

Guang Shi, commencing as a student of Permian brachiopods in the late 1980s, was much impressed by Professor Campbell's studies of Permian brachiopods of eastern Australia, in particular the elegant research on the Permian *Ingelarella*-group spiriferids. Campbell (1959) erected a new subfamily Ingelarellinae, now elevated to the family Ingelarellidae (Williams *et al*. 2006). This clade is among the most distinctive, widespread and also highly endemic of the Permian marine invertebrate faunas of eastern Australia, and several of Ken's new species later became biostratigraphic index species. Summarising Campbell's published Permian brachiopod studies, he established at least one new family (Gillediidae), two new subfamilies (Ingelarellinae and Gillediinae), 14 new genera, and 76 new species/subspecies, all achieved within the space of ~13 years (1953 – 1965 inclusive). Except for one genus (?*Booralia* Campbell 1961; listed with a question mark in the revised brachiopod treatise; Williams *et al*. 2006, p. 2024), all other Permian brachiopod genera erected by Campbell are recognised in latest revisions of the Palaeontology Treatise on Brachiopoda (Williams *et al*. 2000a, b, 2002, 2006, 2007).

A strong features of Campbell's taxonomic studies of Permian brachiopods was the abundance of detailed photographic illustrations of specimens, often accompanied by meticulously reconstructed sketches emphasising certain morphological characteristics, reflecting his attention to detail in all his palaeontological descriptions.

Trilobites [PAJ, DJH]

Ken Campbell's first paper entirely devoted to a non-brachiopod topic was as co-author (Amos *et al.* 1960) erecting a new Carboniferous trilobite genus *Australosutura*, of interest for its 'Gondwanan' distribution pattern (Australia-Argentina). His interest in trilobites developed after moving to the ANU, the surrounding early Palaeozoic rocks having quite different fossil faunas to the Carboniferous-Permian he was familiar with. He approached Prof. Harry Whittington at Harvard, who supported funding for his nine months at Harvard in 1965, giving him a 'vastly superior knowledge of trilobites', and resulting in the two major monographs on Silurian trilobites from Oklahoma and Maine (1967). Another (1977) described Early Devonian trilobites from Oklahoma, based on overseas collections that were brought back to Canberra for preparation and study. After return from Harvard he published on local Ordovician (1970), Silurian (1974) and Devonian (1972) trilobites with student co-authors. Campbell & Durham (1970) documented the new trinucleid genus *Parkesolithus* from the Ordovician of central-western New South Wales, and Holloway & Campbell (1974) revised the previously poorly-known genus *Onycopyge* based on new material collected during student field mapping in the Silurian of southern New South Wales, confirming its affinities with the family Cheiruridae which had been questioned a few years earlier. Former PhD student, Brian Chatterton (University of Alberta), returned to ANU on sabbatical to collaborate with Ken on Early Devonian trilobites from central-western New South Wales (Chatterton, Johnson & Campbell 1979) and on Silurian faunas from Canberra and Yass (Chatterton & Campbell 1980).

Ken's ideas on trilobite functional morphology and behaviour (Campbell 1975b, c) had been presented at the Oslo, 1973 first International Conference on Trilobites, on reconstructed musculature and other soft tissue morphology of the trinucleid *Cryptolithus*, its feeding behaviour inferred from trace fossils created by the animal. His presentation for the Royal Society of New South Wales W.B. Clarke Lecture dealt with reconstructed musculature, lens structure and possible sublensar soft morphology of the eye in phacopid trilobites, building on previous work by E.N.K. Clarkson (Edinburgh). Aspects of functional morphology

in both phacopid and dalmanitid trilobites were also dealt with in his Oklahoma monograph (Campbell 1977), where he expanded on his earlier work on evolutionary relationships within the Phacopidae, and clarified relationships between certain members of the Dalmanitidae whose affinities had been previously misinterpreted.

Other invertebrate groups [JWP, PAJ, CRM]

The 'Palaeontology' section in Ken's first publication (1952) described and illustrated Permian bryozoans, rugose and tabulate corals, and bivalve and gastropod molluscs. His initial approach to palaeontology involved describing the complete assemblage from the locality involved, a style passed on to student John Roberts which greatly helped their later joint biostratigraphic work (e.g. Jones *et al*. 1973). Although generally dominated by brachiopods, the Permian and, particularly the Carboniferous assemblages he described included a variery of corals, bryozoans and molluscs. His familiarity with a broad range of invertebrate groups meant he was able to stimulate students to pursue studies of them. Thus, on **Bryozoa** he worked with Brian Engel (Campbell & Engel 1963). For **Coelenterata** he had published on an Early Carboniferous brachiopod-coral fauna in 1957. Reinforcing the heritage of his mentor Dorothy Hill, he encouraged John Pickett to study the Carboniferous **corals** (e.g. Pickett 1967).

For **Cephalopoda**, an essay of the student's choice had been part of Ken's third year geology course in 1947, his chosen subject being 'The evolution of nautiloids'. He later published two ammonoid papers (1965, 1983; both with DA Brown as co-author). The 1983 paper, with Al Coleman as third author, brought to light numerous Carboniferous goniatites, a relatively rare element of the Australian fauna, accumulated over the years since the earlier publication on the group (Brown *et al.* 1965). Ken undertook this goniatite research to put into international context the Australian brachiopod zonation for the Carboniferous that had been largely developed by his former student John Roberts. These zones were easily recognisable by the common brachiopod content, but their international correlation was difficult because of the generally more restricted distribution of brachiopod species. Although rare, Ken assessed that the more widely geographically distributed goniatite species would give better correlation of the Australian succession with the rest of the world. He was proved correct by concurrent studies of co-occurring conodont faunas, and later by absolute dating of interbedded volcanic units. This proved to be Ken's last paper involving description of new invertebrate fauna.

Late Palaeozoic palaeontology of Australia remained an abiding interest for Ken for most of his career, and he made occasional contributions of new data when possible, as well as several important reviews. For the **Echinodermata**, he had recognised that so little was known of Australian Carboniferous crinoids that the material encountered during geological mapping in New England was significant, and he assigned it for study by ANU postgraduate student J. Bein (Campbell & Bein 1971). This was Ken's only systematic echinoderm paper, with eight new species described from Lower Carboniferous localities near Tamworth, NSW. However, a theoretically oriented paper on echinoderms (Campbell & Marshall, 1987; see next section) also involved a taxonomic component, given the need to analyze commensurate monophyletic groups. Thus, for example, Campbell & Marshall argued that the classes Parablastoidea and Edrioblastoidea be demoted to unassigned orders, part of the data for their comprehensive analysis of the rates of taxonomic versus morphological evolution for Cambrian-Ordovician Echinodermata.

Another enigmatic fossil group, the **receptaculitids**, was dealt with by Campbell, Holloway & Smith (1974), who described the new genus *Hexabactron* from the Silurian of the Orange district, NSW. The affinities and life orientation of receptaculitids had been problematic, alternatively interpreted to be some sort of calcareous sponges (Porifera), or considered to be dasycladacean-like calcareous algae. Functional analysis of the *Hexabactron*

specimens indicated orientation in life with the apertural end lowermost, rather that uppermost as previously believed, consistent with the latter interpretation.

During his 1965 visit to Harvard, Ken Campbell had experienced Harry Whittington's acid laboratory, used to extract silicified trilobite exoskeletons (e.g. Whittington & Campbell 1967). The acid-etching technique, initially developed to liberate siliceous microfossils from limestones, could be applied to calcareous macrofossils when the skeleton had been silicified during post-mortem diagenesis. Ken's experience at Harvard allowed him to set up a modest laboratory for this technique at ANU, essentially the first use in Australia for etching invertebrate macrofossils. In the nearby Devonian limestones at Burrinjuck Dam silicified layers were evident from geological mapping, and Ken's PhD and MSc students Brian Chatterton, Paul Johnston and Linda Reynolds put this to good use in their studies on trilobites and brachiopods, bivalves, and ostracods (e.g. Chatterton 1973, Chatterton *et al*. 1979; Johnston 1993; and Reynolds 1978 respectively). Ken was equally delighted when acid-etching in his laboratory contributed significantly to revelation of Cambrian molluscan evolution through work by Runnegar & Jell (1976).

Contributions to evolutionary theory [CRM, PAJ]

From his first encounters with university science, Ken Campbell was disenchanted with rote learning. Undergraduate geology teaching as he experienced it seemed to involve too much memory work and no introduction to developing new concepts. In his own words (Ian Campbell, email 1 Dec 2017): 'the foundations of geology were taught as accepted fact. Deference was paid to certain titans of geology who were apparently to have their theories accepted without question. This seemed to run entirely contrary to the very purposes of scientific endeavour'. Ken's assessment of some overseas palaeontologists was in similar vein during his 1958 visit to Europe; he bemoaned the 'absence of new thinking' of some 'conventional' researchers who were 'stuck in century-old ideas'.

Ken vigorously debated new concepts that significantly affected his science. He grappled with the 'punctuated equilibria' model for speciation advocated by American palaeontologists Niles Eldredge and Stephen Jay Gould. He did not accept cladistic analysis as a dominant tool to reveal evolutionary lineages, presenting very different conclusions from his Oklahoma study of phacopid trilobites compared to the relationships of certain species advocated by Niles Eldredge using cladistic methods (Campbell 1975). He never agreed with the 'principle of parsimony' as espoused by cladists (e.g. Campbell & Barwick 1990; 'evolution without parsimony'). As applied to his key vertebrate research group, the lungfishes, this principle led to radically different conclusions (see more discussion under 'Vertebrate palaeontology' below).

An early focused effort to quantify his theoretical ideas began in 1984 with Charles Marshall (1983 Honours zoology with R.E. Barwick, 1983 Tillyard Prize and ANU Medal), at the time preparing Gogo lungfish before departing to the University of Chicago for his PhD. Their analysis (Campbell & Marshall 1987) concluded that for Cambrian-Ordovician echinoderms the rate of cladogenesis (rates of diversification of lower-level taxa) was decoupled from the rate of major morphological innovation (the rates of diversification of higher taxa, the classes and orders). The result that major innovation need not lead to lower-level diversification was supported by description of major morphological innovations within the phylum Echinodermata (e.g. evolution of the test, elaboration of the ambulacra, the evolution of coelomic respiratory structures, etc.). This morphological analysis was aimed to counteract the argument that the earlier origin of higher taxa reflects nothing more than the simple fact that in a phylogeny the origin of higher taxa must precede the origin of their constituent lower taxa.

Campbell & Marshall (1987) dovetailed with Ken's major interest towards understanding the genomic and developmental underpinnings of major morphological change

(e.g. Miklos 1993; Miklos & Campbell 1994), interests he pursued in active conversation with George Miklos (ANU Research School of Biological Sciences; Supplementary Fig. S18), sabbatical visitor John Campbell from UCLA, and Academy colleague Max Day (see Robin & Day 2020), with whom he co-convened the 1985 'Rates of Evolution' symposium at ANU. Based on insights that might be gained from the fossil record, and in light of their echinoderm analysis, Campbell & Marshall (1987) hypothesised that the early genome may have offered the opportunity for rapid innovation that was subsequently lost, consistent with Wimsatt's notion of generative entrenchment (e.g. Schank & Wimsatt 1986), and presaging more substantial works on the genomic and developmental basis of innovation (Raff & Kaufman 1991, Raff 1996), and the future discipline of evo-devo (Raff 2000).

Ken Campbell's keynote address for the 1986 25th anniversary of the New England branch of the Royal Society of New South Wales, had the topic 'Evolution Evolving'. As published, Campbell (1987) supported ideas of influential American palaeontologist GG Simpson, that 'macroevolution' (the sudden appearance of major groups in the fossil record) was inconsistent with gradual evolution by an accumulation of small modifications, as widely accepted by neontologists under 'neo-Darwinist' theory. He maintained that discrepancies could not be explained by gaps in the geological record, as had been posited by Charles Darwin in 1859, and he promoted the evidence from the fossil record for periodic extinction events (Raup & Sepkoski 1984), which 'reset the evolutionary clock through geological time'. The contribution by palaeontology to modern evolutionary theory was expanded with publication of his 1986 Mawson lecture (Campbell 1990). Elaborating on his work with Charles Marshall (Campbell & Marshall 1987), he compared the echinoderm fossil record with the origin of jawed vertebrates, arguing that the major gnathostome groups were 'absolutely distinct at first appearance, and most heavily ossified at the outset, rendering an incomplete fossil record explanation as untenable'. Nevertheless, subsequent discovery of Siluro-Devonian basal gnathostomes in China (e.g. Zhu *et al*. 2013, 2016) have undermined the latter argument.

Vertebrate Palaeontology [JAL, GCY]

Ken Campbell's significant contribution to Australian Palaeozoic fish studies resulted from a serendipitous find in 1964 during a field trip to the Early Devonian limestones around Burrinjuck Dam. This highly fossiliferous sequence had been observed by Europeans as early as 1824, when Hume and Hovell noted limestones with embedded shells in the region of the 'Yass Plains' and 'Limestone Valley' (Andrews 1981). Nearly a century later, extensive new exposures of clean fossiliferous limestone resulted from construction of the dam wall across the Murrumbidgee River (1912-17), with dramatic changes in the water level of Lake Burrinjuck (e.g. Supplementary Fig. S23). The area had been visited regularly for research and student geology excursions by the University of Sydney (the definitive geological map was published by Ida Browne, 1959), and from 1960 the newly established ANU Geology Department did the same, it being only ~50 km from Canberra.

A few fossil fish remains had been found in these limestones, but their significance only became apparent in the 1940s by applying a method to extract fossil bone from limestone using acetic acid. This preparation technique was developed at the British Natural History Museum (BMNH), actually using some Burrinjuck Devonian fish samples that had been sent to London in 1939 (for more detail see Young 2011, 2015a). The description of these, by White (1952), noted they were 'even more interesting and important than first supposed', because preserved braincase structures could be acid-extracted for the first time. The preparator who developed the acetic acid technique (Harry Toombs) was sent out to Australia to search for more specimens, on two visits (1955, 1963) spending over five months collecting at Burrinjuck, and removing some 560 fossil fish specimens back to London.

At ANU Geology in 1963 there was consternation when it was learnt that the British

Natural History Museum had been collecting fossil fish specimens from nearby without their knowledge. Ken Campbell recalled the 1963 courtesy visit to ANU by Harry Toombs, who by the time he visited ANU Geology had already packed most of his samples to be shipped to London. ANU Foundation Professor of Geology DA Brown, supported by Prof. ES Hills (University of Melbourne), sent protest letters about this to the BMNH. However, within six months a local discovery had changed the situation dramatically.

The following year British palaeontologist Prof. FHT Rhodes was a Visiting Fellow at ANU Geology. Ken Campbell accompanied Prof. Brown (and ANU Vice-Chancellor Prof. L. Huxley) on a day trip to Burrinjuck, to show Frank Rhodes the excellent fossil exposure at 'Shearby's Wallpaper' near Taemas, a heritage fossil site (Percival 1985). Here, Ken found a beautiful skull of a Devonian lungfish, a spectacular discovery that would have major impact on his subsequent research. From this discovery grew his significant contribution to understanding the evolutionary history of an iconic group of living freshwater fishes, the Dipnoi (lungfishes). He recalled that the excitement on that day caused him to punch the air, and exclaim 'I am the greatest!', in the style of then boxing champion Cassius Clay! The following weekend members of ANU Geology helped Ken look for associated remains, and PhD student Robert (Bob) Day found the broken posterior skull portion.

This was the second known example of a lungfish skull of these Early Devonian limestones (dating from about 400 million years ago). The first specimen, the holotype of *Dipnorhynchus sussmilchi* (Etheridge), had been found at the nearby Taemas locality over 60 years previously (Etheridge 1906). Only 26 years earlier, Gerard Krefft (Australian Museum, Sydney) had documented one of the most amazing natural science discoveries of the 19th century — the Queensland lungfish *Neoceratodus*. This 'living fossil' is one of only three surviving genera of this ancient group, and one of the most primitive of living jawed fishes. Recognizing the significance of the Burrinjuck skull, as the oldest lungfish then known from the fossil record, German Professor Otto Jaekel assigned it the new generic name *Dipnorhynchus* Jaekel (1927).

Against this background, Ken Campbell immediately began study of his new specimen, evidently another *Dipnorhynchus*. Even without preparation, the sutures between dermal bones of the skull were much clearer than in the holotype. Ken submitted his first vertebrate palaeontology paper in November 1964, a preliminary account of the skull roof bone pattern (Campbell 1965b). He noted also that the rich associated invertebrate fauna undoubtedly indicated a marine environment for this earliest representative of the Dipnoi. The distinguished American vertebrate palaeontologist Professor A.S. Romer (e.g. Romer 1966, 1970) had dismissed such claims. Romer (1966, pp. 46, 75) had asserted that as a whole the class Osteichthyes (bony fishes) originated 'in Devonian freshwaters … and [only] by the end of the Paleozoic had invaded the seas'. The lungfishes were 'first found in the early Devonian', became 'moderately abundant and varied in the freshwater environment in which they arose and to which they were adapted'. Ken enlisted the collaboration of an ANU geochemist for independent data supporting his view that his early lungfishes lived in the sea (published in *Nature*; Dasch & Campbell 1970). The following year Professor Romer visited Australia, and Ken took him to Wee Jasper to demonstrate the marine limestones (Supplementary Fig. S5). This dispelled any idea in Romer's mind that such lungfish remains could have been washed in from freshwater.

In response to Prof. Brown's complaints to the BMNH about unauthorized removal of Australian fossil specimens, Dr Errol White FRS, Keeper of Palaeontology, provided ANU Geology with casts of the Burrinjuck fish type specimens, and details about the acetic acid preparation technique developed at the BMNH. Errol White was already studying the Burrinjuck fossil fish, and had referred to two lungfish lower jaws that had been collected in 1963 (White 1965, 1966).

With details of the acid technique to extract bone from limestone, Ken Campbell

arranged to process his Devonian lungfish skull in an acid-etching facility set up outside the back of the ANU Geology building. Initially crystalline monochloracetic acid was used, delivered in 44-gallon drums. The type specimen of *Dipnorhynchus* was later borrowed from the Australian Museum and also acid etched. This revealed another exceptionally preserved complete braincase and palate (Supplementary Fig. S54). Ken arranged a collaboration with Dr Keith Thomson, a vertebrate palaeontologist from Yale University who had published on both fossil and living lungfishes (Thomson 1965a-b). Keith Thomson had a key interest in functional aspects of these remarkable fishes (for example lung ventilation; Thomson 1968). Thomson was a Visiting Fellow at ANU Geology in 1967, and their co-authored monograph on *Dipnorhynchus* was published four years later (Thomson & Campbell 1971).

Shortly after, Ken was upset by a review published in *Nature* by a 'Correspondent' (Anon, 1972), who he strongly suspected to be Dr Errol White. The review queried Thomson & Campbell's interpretation of a 'posterior sulcus' as the lateral occipital fissure, and suggested instead that the described braincase was incomplete, lacking the occipital region. The implication was that their vagus nerve foramen was mis-interpreted, and more likely for the glossopharyngeal nerve.

A decade later, Ken had the benefit of comparing with exceptional acid-etched braincases of the Devonian lungfishes *Griphognathus* (e.g. Supplementary Fig. S35) and *Chirodipterus* from Gogo WA (see below). Campbell & Barwick (1982b, p. 294) noted that the *Dipnorhynchus* holotype was eroded through at about the level of the occipital fissure, and they reversed the identification of foramina for the 9th and 10th cranial nerves compared to Thompson & Campbell (1971). The 'Correspondent' in 1972 also queried the assumption that a mosaic of small bones on the dipnoan skull was the primitive condition, given that Thompson & Campbell (1971) had recognised direct homologues with the dermal bones of the lower jaw in other lobe-finned fishes. (However, Ken later cast doubt on the presence of a 'dentary' in Early Devonian lungfishes; see below.)

A separate limestone tract, in the Goodradigbee valley near Wee Jasper, and visited only once by the BMNH, proved to be a rich new source for fossil fish specimens. A major collection was made by ANU Geology and the Bureau of Mineral Resources during a severe drought in 1968 that exposed large areas of clean limestone, previously under water (e.g. Supplementary Figs. S11, S23). This area increased lungfish diversity in the Burrinjuck limestones, with a new genus *Speonesydrion* (Supplementary Fig. S36; Campbell & Barwick 1983, 1984), and a new species of *Dipnorhynchus* (*D. kurikae* Campbell & Barwick 1985). Gavin Young's 1969 Honours project, on these Goodradigbee valley limestones and their Devonian fish fossils was the beginning of his long research collaboration with Ken Campbell. During Ken Campbell's 1973 NATO overseas trip to Oslo he also visited London, taking Gavin Young's photographs and illustrations of very strange new placoderm fish skulls to show Errol White at the BMNH. This connection paved the way for Young's PhD research in London (1974-76).

An incident at the BMNH during that time demonstrates the international reach of Ken Campbell's reputation, which helped in raising the profile of Australasian palaeontology. One day in 1975, Colin Patterson, the most distinguished palaeontologist at the museum (he wrote the 1978 '*Evolution*' handbook for the museum), rushed into PhD student Gavin Young's office exclaiming: "Ken Campbell has written a paper called 'A spectre is haunting palaeontology', in some new Australian palaeontology journal! Do you have a copy?"

Dr Patterson was informed that *Alcheringa*, an Aboriginal term meaning 'in the beginning', was the name of a new journal published by the Association of Australasian Palaeontologists (Supplementary Fig. S8). Ken's paper, in the first issue of Volume 1, was entitled 'Cladism and phacopid trilobites' (Campbell 1975), even if there was an allusion to the opening words of the Marx-Engels 'Communist Manifesto' in Ken's first sentence. This provocative paper certainly helped put the new Australian journal *Alcheringa* into the minds

of many overseas palaeontologists.

A second paper in part 4 of Volume 1 of *Alcheringa* (published 1977) was the third vertebrate palaeontology publication by Ken Campbell, co-authored with his 1972 Honours student Maurice Bell (Supplementary Fig. S6). This was significant for two reasons. It describes the first, and only confirmed Devonian tetrapod body fossil from the entire Gondwana supercontinent. *Metaxygnathus denticulus* was erected for a lower jaw from the Jemalong Range near Forbes, NSW, and interpreted as belonging to an early tetrapod (land animal). For over a decade this interpretation was dismissed by Northern Hemisphere researchers as merely the jaw of a fish, until new specimens from Europe (Ahlberg *et al*. 1994) confirmed that *Metaxygnathus* was a tetrapod (Ahlberg & Clack 1998). Ken Campbell said in 1998: 'we always knew we were right – it just took them two decades to agree with us!' Recent work, indicating the age of the Jemalong assemblage is possibly Middle Devonian (Young 2024), increases its significance, making *Metaxygnathus* one of the oldest tetrapods known from the fossil record.

Campbell & Bell (1977) is significant for a second reason, because the illustration of the *Metaxygnathus* jaw was the work of Dr RE (Dick) Barwick (e.g. Supplementary Figs. S18, S23, S34) from the ANU Zoology Department. This is the first published collaboration between Dick Barwick and Ken Campbell. Some 40 co-authored publications by them over the next three decades (1982-2012; see S3 KSW Campbell Bibliography), represents a significant body of research on Devonian-Carboniferous vertebrates. The first two (Campbell & Barwick 1982a-b) include 35 illustrations drawn and/or labelled by Dick Barwick, the second paper providing the first comprehensive description of the neurocranium of any primitive dipnoan. In addition, this description relied on comparisons with exceptional lungfish remains from another, now-famous Australian Devonian fossil locality, Gogo, in the Kimberley region of WA. This material had been first described a few years earlier in a monograph by Roger Miles (1977; see Supplementary Fig. S46).

Remarkably well preserved Devonian fish specimens from Gogo had been noted in the WA Museum in 1963, when fossil collector Harry Toombs (BMNH) passed through Perth on his way to collecting fossil fish at Burrinjuck (see above). A joint collecting expedition between the BMNH and the WA Museum was organised for 1967, when some 2.5 tonnes of fossil nodules were sent back to London (for more detail, see Long 2006; Young 2015b). Two participants, the British palaeontologists Dr Howard Brunton (BMNH brachiopod specialist), and Dr Ian Rolfe (Hunterian Museum, fossil arthropod specialist) visited ANU Geology in 1967, reporting on the numerous three-dimensional Devonian fish skeletons. Preserved in calcareous nodules, these were amenable to the acid extraction technique. At that time, the only acid-etching of vertebrate fossils in Australia was Ken Campbell's ANU research on the Burrinjuck lungfish. If excellent lungfish skulls had been found at another Australian fossil locality, it seemed obvious that an all-Australian expedition to Gogo should be organised. This was realised in May, 1970.

Participants of the first Australian Gogo expedition were Prof. David Brown, Dr Ken Campbell and Mr George Halford (ANU Geology), and Dr Alex Ritchie (recently appointed as the new Curator of Fossils at the Australian Museum). The ANU team spent 3 weeks collecting mainly in 'Paddys Valley' between the Laidlaw and Emmanuel Ranges. Here were rich fossil sites that had been discovered by the 1967 British expedition only in their last few days. Vehicle difficulties detracted from valuable collecting time (see Supplementary Fig. S4), but a substantial quantity of fossiliferous Gogo nodules was brought back to ANU. Detailed acid extraction commenced without delay, confirming the exceptional preservation, never before seen in any Devonian fish fossils, and 'comparable in quality with present-day skeletons' (Ahlberg 1989). Almost all the lungfish papers published by Ken Campbell from 1981 onwards featured illustrations of Gogo lungfish, mainly *Griphognathus* (Supplementary Fig. S35) and *Chirodipterus.*

John Long arrived at ANU Geology in 1984, on a two-year Rothmans Postdoctoral Fellowship. This began his life-long collaboration with Ken Campbell and Dick Barwick, mostly involving Palaeozoic lungfishes, but also other sarcopterygians (lobe-finned fishes). His first collaboration (Long & Campbell 1985) described a new Carboniferous lungfish *Delatitia* from Long's 1983 PhD research on Middle Palaeozoic fossil fishes from Victoria. But also awaiting study at ANU was a wealth of newly prepared Gogo lungfish specimens. Within the Gogo collection he also found a single example of an osteolepidid tetrapodomorph lobe-fin (also called 'stem tetrapods').

The stem-tetrapod lobe-finned fishes of the Devonian are of key importance. This group gave rise to the first tetrapods (four-legged vertebrates), ancestral to all subsequent land animals, including humans. John Long noticed a tiny shining snout held at ANU, and Ken assigned this specimen for him to work on. In 1985 *Gogonasus* (literally 'the snout from Gogo') was the first Gogo genus and species to be named from Australian research (Long 1985). A second *Gogonasus* specimen was found by John Long the following year (his first Gogo expedition as a QEII Fellow at University of WA). John Long had gone to Perth from ANU, and then in 1989 was appointed Vertebrate Palaeontology Curator at the Western Australian Museum (WAM). He continued his ANU collaboration, offering any Gogo lungfish material he found to Campbell and Barwick to research without requiring co-authorship. Several new genera and species resulted from this partnership, with some species names honouring the finder (e.g. *Pillararhynchus longi, Holodipterus longi*). In 1990 Dr Peter Pridmore found a third *Gogonasus* specimen (a superb skull and jaws, later CT scanned at ANU), on a joint ANU Gogo Expedition with John Long.

The 1990 ANU-WAM Gogo expedition involved John Long, Ken Campbell, Dick Barwick, Peter Pridmore and Val Elder (Supplementary Figs. S19, S20). The field trip involved 10 days collecting many fossil nodules, including significant specimens such as new lungfish like *Adololopas*. Ken's creativity in teaching geology came out on this trip, by organising a 3-hour plane flight from Fitzroy Crossing for a cameraman to film over the spectacular Devonian reef complexes. John Long was on the flight, taking colour slide photos of the geology from the air. A film crew then joined the team for a few days, obtaining good coverage of the fossil sites. All this footage was compiled and edited to make an educational 20-minute documentary for use in teaching geology and palaeontology at the ANU. The field camp was run on a strict no-alcohol basis, with evenings spent sipping tea around the camp fire. However, returning to 'civilisation' at the end of the trip, when participants hit the Fitzroy Lodge bar with a big thirst, it was appreciated that Ken joined in with a celebratory glass of white wine, no doubt justified by the excellent fossil collecting, and proving he wasn't always a teetotaller.

In 1994 Australia's oldest known lungfish *Ichnomylax*, a jaw from the Pragian of Victoria was described (Long, Campbell & Barwick 1994; featured on the cover of *Journal of Vertebrate Paleontology*, vol. 14, part 1). Concurrently, detailed descriptions were prepared of the three *Gogonasus* specimens, which formed the basis for a 90 pp. monograph (Long, Barwick & Campbell 1997). This was a highly significant contribution, documenting the world's best-preserved examples of the Devonian fish group that bridged the gap between fishes and tetrapods.

To summarise Ken Campbell's Gogo lungfish research at ANU, this involved many years of detailed acid extraction to produce some 150 superb acid-prepared specimens, with numerous publications over three decades co-authored by Campbell and Barwick (with occasional additional authors). These include type specimens of *Pillararhynchus* and *Adololopas*, and many examples of previously named species (e.g. *Griphognathus*, *Chirodipterus*), on which much new anatomical information could be added to the previous descriptions by Miles (1997) on the Gogo collection in London. This included significant taxonomic revisions (e.g. Long 1992; Pridmore *et al*. 1994). Campbell and Barwick are

authors on about half of all Australian publications on Gogo fossil fishes (as listed by Long & Trinajstic 2010).

John Long's collaboration continued when he moved to Museum Victoria in late 2004. The most significant papers arising from this period include documenting the exceptional new *Gogonasus* collected in 2005 (Long *et al.* 2006), and a monograph on the best-preserved material known for another Devonian lobe-finned fish group, the Onychodontida (Andrews, Long, Ahlberg, Barwick & Campbell 2006). The authorship of that paper, a description of *Onychodus jandemarrai* from Gogo (Supplementary Fig. S30), says a lot about Ken Campbell's character and integrity.

John Long at the ANU in 1985-86 had prepared some superb *Onychodus* specimens, and later collected more for the WAM. However, Dr Mahala Andrews (e.g. Supplementary Figs. S9, S14) of the Royal Scottish Museum, Edinburgh, had priority for the formal description, having spent years studying specimens acquired during the initial 1967 expedition and taken to London. Mahala Andrews visited the ANU twice (1983, 1989). On the second visit Ken Campbell invited her to work with him at ANU to finalise her years of research, but she died in 1997 before this could be realised.

The 100-page monograph published in 2006 was co-ordinated and achieved largely by Campbell and Barwick at the ANU. Ken Campbell visited Scotland the year after she died (Supplementary Figs. S26-S29), examined her Gogo specimens in Edinburgh, and borrowed all her documentation, including many photographs, line drawings and preliminary sketches. However, no text could be found. The entire description of hundreds of bones in the skeleton was written at ANU, for which 75 superb new illustrations were prepared by Richard Barwick. Ken Campbell had invited John Long to collaborate as co-author, and also Per Ahlberg, representing the BMNH in London. However, Ken ensured that Mahala Andrews was named as first author. It is noted that both Long and Ahlberg proposed including a phylogenetic analysis in the paper using cladistic methodology, but out of respect to Ken's dislike of such approaches, the paper was settled upon to be only a descriptive work.

A publication by Rosen, Forey, Gardiner & Patterson (1981) caused a strong reaction when it appeared, including by Ken Campbell. Heretic ideas about the Dipnoi (lungfishes) by what Ken called the 'Gang of Four' (see Supplementary Fig. S46) were the topic of tea-time discussion for months. A cladistic approach to tetrapod origins (the 'salmon, lungfish, cow' question; Halstead 1978) stimulated numerous exchanges published in *Nature* 1978-81 (see full discussion in Chapter 5 of Gee 2000). Ken had already challenged the cladistic approach to determining phylogenetic relationships in his paper on phacopid trilobites (Campbell 1975), and the issue continued to be hotly debated in Australia (e.g. JH Campbell 1993). Campbell & Barwick (1988, p. 208) had criticised the results of cladistics as 'internally consistent fables'. Campbell & Barwick (1990) argued that relationships between major groups should be analysed in terms of functional systems, not isolated characters as in cladistics.

Rosen *et al.* (1981) had proposed lungfishes as the closest fish relatives to tetrapods, and argued this could be demonstrated from the anatomy of modern groups, without recourse to fossils. They maintained that inferences about soft tissue structures based on fossil skulls and braincases were unreliable, and traditionally had been misinterpreted by relying on similarities (e.g. the skull roof pattern) that were invalid symplesiomorphies (shared primitive characters). According to the 'Gang of Four', modern lungfish had the tetrapod internal nostril (choana), and the gap in bones interpreted as the choana in the iconic Devonian fish *Eusthenopteron* (traditionally interpreted as the closest fish relative to tetrapods; Jarvik 1980) more likely was to receive a fang of the lower jaw.

These ideas were complete anathema to Ken Campbell, with his strong belief in the significance of the fossil record as evidence for evolution. Again, the exceptionally preserved Gogo fossil fish provided crucial data, with the tetrapodomorph *Gogonasus* refuting Rosen *et*

al.'s choana interpretation (Long 1988; Ahlberg 1989), reinforced later with more complete specimens of *Gogonasus* (Long *et al*. 1997, 2006).

Ironically, it was the Early Devonian tetrapodomorph fish named in Ken's honour, *Kenichthys campbelli* from China (Chang & Zhu 1993), which eventually demonstrated the evolutionary transition between an external posterior nostril and the choana (Zhu & Ahlberg 2004). Close relatives of the Chinese *Kenichthys* had been documented in the Hatchery Creek Group near Wee Jasper (Chang & Yu 1997; Hunt & Young 2012), and fieldwork by ANU students (e.g. Supplementary Fig. S33) produced new specimens, including exceptional CT-scanned skulls and braincases (analysed in Beijing by Dr Jing Lu; Supplementary Fig. S53). Regrettably, description of this significant material remains unpublished.

The last Campbell & Barwick co-authored publication (2011), very elaborately illustrated by Dick Barwick with 28 figures, described a single incomplete Gogo fish skull as a new taxon *Cainocara enigma*. They interpreted this as 'so different from other known osteichthyans … that it represents a new kind of biological organisation in the Devonian'. The specimen is a highly eroded skull, and the manuscript had been rejected by at least one previous journal. Both John Long and Gavin Young thought it too incomplete to determine the correct orientation, and had urged delaying publication until a second specimen could support their interpretation. Recent work based on new CT scanning confirms incorrect orientation for the original description, the endocast resembling other Gogo lungfish (especially *Holodipterus*), but with a distinctive parasphenoid suggesting *Cainocara* is still a valid taxon (Thiele *et al.* 2025).

Ken's last scientific presentation (Supplementary Fig. S43) was to the AGM of the Geological Society of Australia, ACT Division (April 19, 2011). His topic 'Cautionary tales in research' used the Gogo lungfish *Gryphognathus* (Supplementary Fig. S35) to illustrate incorporation of vertebrae into the occipital part of the braincase (published by Campbell *et al.* 2012).

After the death of his long-term collaborator and co-author, zoologist Dr Richard Barwick, in November 2012 (Supplementary Fig. S50), Ken completed only one paper. Dick Barwick's zoological expertise and understanding of comparative anatomy had added great depth to their morphological interpretations of ancient skulls and braincases. Barwick had also facilitated comparative study of the living (and now endangered) Australian lungfish *Neoceratodus forsteri*, with live specimens obtained from Lake Wivenhoe (SE Queensland) by Dr Peter Pridmore and brought to Canberra for comparing the distribution of electroreceptors with those of fossil species from Gogo. (The *Neoceratodus* remain on public display in Canberra at the National Zoo and Aquarium.)

It was appropriate therefore that Ken's last paper (Campbell & Wragg 2014) was published in the *Australian Journal of Zoology* Special Issue '*Evolution and adaptation: a tribute to Richard Essex Barwick*'. For decades, as well as zoological expertise in the Campbell-Barwick collaboration, Dick Barwick had prepared the superb photographs and meticulous scientific illustrations adorning their numerous co-authored papers and monographs. Now Dick was gone, and Ken was living in St. Andrews retirement village, making access to fossil specimens much more difficult. GCY would drive him in to the ANU campus (his office in the DA Brown Building) where he examined specimens and would oversee whitening and photography of some of his prized acid-etched Burrinjuck lungfish skulls and braincases. The seven photographic images in Campbell & Wragg (2014) were selected from over 50 taken by GCY, who also labelled the figures. For scientific illustration Ken had contacted Sharyn Wragg, a former close friend of Dick Barwick and professional scientific illustrator in the ANU Research School of Biology. However, lacking the research involvement of Dick, and never previously working on incomplete fossils, she had difficulty comprehending Ken's requests on subtle illustrative points. She was also fully employed on other projects, and when these

difficulties were explained to Ken he immediately agreed to the suggestion of co-authorship with Sharyn.

Campbell & Wragg (2014) updated several previously described specimens in the light of more recent research literature, to comment on contentious scientific questions Ken had long disagreed with (e.g. Campbell and Barwick 2001); in particular the cladistic placement (e.g. Cloutier & Ahlberg 1996; Zhu & Schultze 2001) of the genera *Diabolepis*, *Youngolepis* and *Powichthys* as sister group to the Dipnoi. The Early Devonian Chinese taxon *Diabolepis* was first described as a 'dipnoan-like form' in the proceedings of the 1983 Early Vertebrates symposium in Canberra (Chang & Yu 1984). Ken Campbell had enormous respect for his friend and colleague Chang Mee-mann, former director of IVPP, Beijing (e.g. Supplementary Figs. S9, S10, S14), but he always maintained that *Diabolepis* was not a lungfish, as argued by Campbell & Barwick (2001). The dipnomorph position was later reinforced by Chang (1995, 2004), and more recently supported by Lu *et al.* (2012) and Qiao *et al*. (2025). Ken no longer agreed that the mandible of *Dipnorhynchus* included the dentary, nor with the histological arguments by Smith & Chang (1990) that the *Diabolepis* dentition was primitive for dipnoans. Campbell & Wragg (2014, p. 24) reiterated his previous view that 'cladistic methods are not appropriate in analysing these genera'. Rather than primitive dipnomorphs, these taxa should be considered as 'isolated entities' that had developed morphological innovations resulting from 'gene regulatory networks'.

Ken Campbell's last two scientific manuscripts remained unpublished. In 2015 'The braincase of the Early Devonian *Dipnorhynchus kurikae* …', was submitted on his behalf, evidently prematurely. It received an initial rejection, but was never revised and resubmitted. This was unfortunate, because it comprised Ken's critical assessment of three recently published papers on dipnoans (Clement 2012; Clement & Ahlberg 2014; Clement *et al*. 2016). This manuscript demonstrated that in his final years Ken Campbell was up-to-date with the latest publications in the field to which he had devoted five decades of research.

The themes of Campbell & Wragg (2014) were elaborated in Ken's final scientific manuscript. Entitled 'Diversity in Early Devonian dipnoans', it had copious illustrations of the genera *Dipnorhynchus*, *Speonesydrion*, *Uranolophus*, *Ichnomylax*, *Sorbitorhynchus*, *Tarachomylax* and *Diabolepis*. After a previous rejection, this had been revised by Ken and was corrected and submitted by GCY on his behalf to the *Records of the Australian Museum* in late 2016, but remained with the status of 'submitted MS' due to reviewer disagreement. It is unfortunate that Ken Campbell's final opinions were never published, given that they covered a range of still contentious theoretical aspects of palaeobiology.

In his last six months Ken had also indicated he was working on a book, but the progress on this (whatever the topic) is unknown.

S5. KSW Campbell — Supplementary references

(Other KSW Campbell publications are listed separately in his full Bibliography)

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Brisbane Grammar School
5th Oct. 1944.

The bearer K. S. W. Campbell has been a student of Chemistry in my Classes for four years. His Junior Public results were good and he has since proved a keen intelligent student. He should do well in the Senior Public Examination. He has a particular leaning towards and aptitude for the subject.

A. Allen
Senior Chemistry Master

BRISBANE GRAMMAR SCHOOL.

3/10/44.

Name. K. S. W. Campbell

Period of School Career. 4 years (1941-44)

Position in School. Form 6 (Senior Candidate)

Ability. Good. An able and studious boy.

Character. Good. Reliable, well behaved, earnest and of good moral character.

Remarks. Passed the 1942 Junior Public Examination with 4A's, 4 B's, 1C. He should obtain a creditsble pass at the Senior Public Examination this year. He shows a distinct aptitude for Science and Mathematics, and has well in these subjects.

Sports. Cricket, football. Was a Corporal in the School Cadet Corps; now a member of the school A.T.C.

(Signed) G. Carson-Cooling,
Head Master.

Fig. S1. Ken Campbell at Brisbane Grammar School. Above: in 1943 standing at left with fellow students. Below: his 1944 final reports from the Chemistry Master and Headmaster [Campbell family images].

Fig. S2. Ken Campbell on early student excursions. Above: UNE in 1956, Ken Campbell reclined (or asleep) at front L. Others present include, standing (3rd from L) Alan Voisey (Foundation Geology Professor, UNE and Macquarie), Edmund Gill (on his L), Keith Crook (on his R); seated/kneeling (5th from L) John Pickett (NSW Geol. Survey, *Alcheringa* editor), Bruce Chappell (ANU, on his R), Gordon Packham (Sydney Uni, 2nd from R) [J. Pickett image].
Below: ANU at Mandurama in 1968, L to R: Prof. David Brown, W. McKay, Keith Crook, I. Powell, G. Young, D. Christie, Ken Campbell [A. Felton image].

Fig. S3. Early overseas trips. Top: the 'Sedgwick Club' at Cambridge, 1958 [Ken Campbell 3rd from L, back row]. Below: 1968 trip to Russia, and aborted International Geological Congress in Prague. Middle L: Ken Campbell in lab coat looking somewhat apprehensive [July 10, 1968]. Middle R: On fieldwork in Siberia. Below: View from hotel window, showing Russian tanks in the streets of central Prague, morning of August 22, 1968 [Campbell family images].

Fig. S4. 1970 ANU Field trip to Gogo, WA. Above: David Brown [L] and Ken Campbell in the field camp [A. Ritchie image]. Middle: Ken Campbell evidently pleased with his camp cooking [Campbell family image]. Below: Alex Ritchie (L), David Brown (M) and Ken Campbell (R) contemplating the faulty engine of their Land Rover [A. Ritchie image].

Fig. S5. 'Picnic Point', N of Wee Jasper on Goodradigbee Inlet of Lake Burrinjuck. The marine limestones here produced many Devonian lungfish specimens studied by Ken Campbell. On this visit in 1971 Ken convinced Prof. A.S. Romer [Harvard] that early lungfish lived in the sea. L to R: Prof. Al Romer, Prof. David Brown, Mrs Romer, Mike Plane [BMR] and Ken Campbell [G. Young image].

Fig. S6. Ken Campbell [centre] with honours student Maurice Bell [L] in early 1972, at the entrance to Bundaburra quarry in the Jemalong Range, ~30 km SW of Forbes, NSW. The large slabs of red siltstone, covered in fossil bone, were loaded in the van and taken back to ANU, and studied for Bell's honours project. This material produced the lower jaw of *Metaxygnathus denticulus* Campbell & Bell, 1977, one of the oldest tetrapods [land animals] known from the fossil record [Campbell family image].

Fig. S7. International gathering of vertebrate palaeontologists during the 3rd Gondwana Symposium in Canberra [August, 1973]. L to R [standing behind]: Alan Thorne [ANU], ?G. Finch, Neville Pledge [SA], Jeannette Hope [ANU], Alan Charig [BM, London], Ken Campbell [ANU], Mike Plane [BMR], Al Romer [Harvard], Bruce Erikson [Minnesota]; [sitting]: Anne Warren [Latrobe], Gavin Young [BMR], Ruth Romer [USA], Geoff Hope [ANU], Bob Jones and Alex Ritchie [both Australian Museum]. [A. Ritchie image].

Fig. S8. Launch of the new AAP journal *Alcheringa* [Vol.1, No.1] at Sydney University, December 28, 1975. L to R: [standing] Robin Helby, Gordon Packham, Rod Gould, Barry Webby, Robin Wass, John Roberts, John Jell, and David Taylor; [sitting] Ken Campbell, Huw Jenkins, Bruce Runnegar, and Graeme Philip [Campbell family image].

Fig. S9. Group photo [behind the ANU Geology building] of participants for the Fourth International Symposium on Early/Lower vertebrates [ISELV] held in Sydney and Canberra, February 1983. L to R [back row, standing]: Alex Ritchie, Moya Smith, Peter Forey, Charles Marshall, John Long, Bob Jones, Emilia Vorobjeva, Anne Kemp, Jim Warren, Mahala Andrews, Ken Campbell, and Daniel Goujet; [front row]: Dick Lund, Pan Jiang, Elga Mark-Kurik, Hans-Peter Schultze, Chang Mee-mann, Richard Barwick, Wang Nian-zhong [G. Young image].

Fig. S10. Sightseeing in Canberra [Black Mountain tower] for Chinese participants of the 4th ISELV, February 1983. L to R: Gavin Young, Pan Jiang [Museum of Geology, Beijing], Ken Campbell, Chang Mee-mann [Institute of Vertebrate Palaeontology & Palaeoanthropology, Beijing] [G. Young image].

Fig. S11. Fossil collecting at 'Caravan Point' on the field trip to Wee Jasper for the 4th ISELV, February 1983. L to R: Alain Blieck [Paris], Ken Campbell, Dave Dineley [Bristol], Dick Barwick [D. Goujet image].

Fig. S12. Ken Campbell explaining geological context for the Canowindra and Jemalong Devonian fish sites on the central NSW field trip for the 4th ISELV, February 1983. Some visible participants are Moya Smith [behind Ken,] Chang Mee-mann, Peter Forey and Wang Nian-zhong [top R], David Dineley [bottom R] [G. Young image].

Fig. S13. Courtyard of Institute of Vertebrate Palaeontology & Palaeoanthropology, Beijing, for the 5th International Symposium on Early/Lower vertebrates, held at Fangshan/Beijing and Kunming, September 1987. L to R: Ken Campbell, Alain Blieck, Hervé Lelièvre, Richard Barwick, Cecile Poplin [H.-P. Schultze image].

Fig. S14. Participants on the field trip to Yunnan Province, China, for the 5th ISELV [Beijing and Kunming, September 1987]. L to R: Ken Campbell, Richard Cloutier, Mahala Andrews, Moya Smith, Hans-Peter Schultze, Chang Mee-mann, Richard Barwick, Marius Arsenault, Song Chang-qi [H.-P. Schultze image].

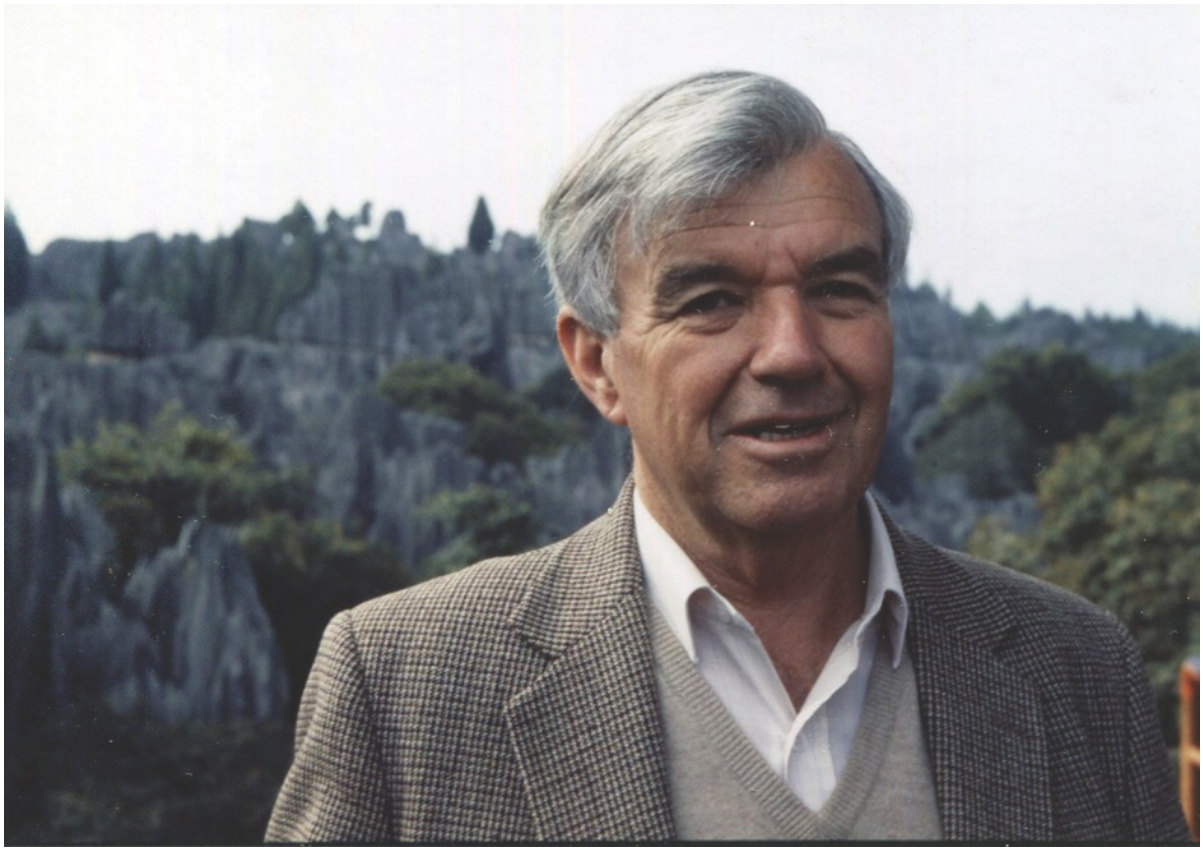


Fig. S15. Ken Campbell at the 'Stone Forest' tourist site, Yunnan field trip for 5th ISELV, September 1987 [Campbell family image].

Fig. S16. Ken Campbell, with Pan Jiang [on his L], Sue Turner and Gavin Young, with local Chinese school children, Yunnan field trip for 5th ISELV, September 1987 [S. Turner image].

Fig. S17. 1988 ANU vertebrate palaeontology student excursion to Wee Jasper led by Ken Campbell. Identified include L to R: Ben Young, Nick Drayson, Ken Campbell, and Radi Popovic. On the far R is Angela Davis, with Dick Barwick [in hat] to her L [G. Young image].

Fig. S18. 1988 ANU vertebrate palaeo student Wee Jasper excursion, at Cooradigbee Shearer's Quarters. In the foreground are L to R: George Miklos [seated], Dick Barwick [leather jacket] and Ken Campbell [G. Young image].

Fig. S19. Joint ANU/WA Museum expedition to Gogo WA, 1990. L to R: Peter Pridmore, Ken Campbell, Val Elder, Dick Barwick [J. Long image].

Fig. S20. Ken Campbell collecting fossils at the 'Long's Well' locality, joint ANU/WA Museum expedition to Gogo WA, 1990. Calcareous Gogo nodules are seen scattered across the ground [J. Long image].

Fig. S21. Ken Campbell [L] in discussion with Professor Erik Jarvik from Stockholm [R] at the 7th Internation al Symposium on Early/Lower vertebrates in Miguasha, Québec, Canada, 9-22 June 1991 [A. Ritchie image].

Fig. S22. Ken Campbell [L] in discussion with Professor Erik Jarvik from Stockholm [R] at the 7th International Symposium on Early/Lower vertebrates in Miguasha, Québec, Canada, 9-22 June 1991 [A. Ritchie image].

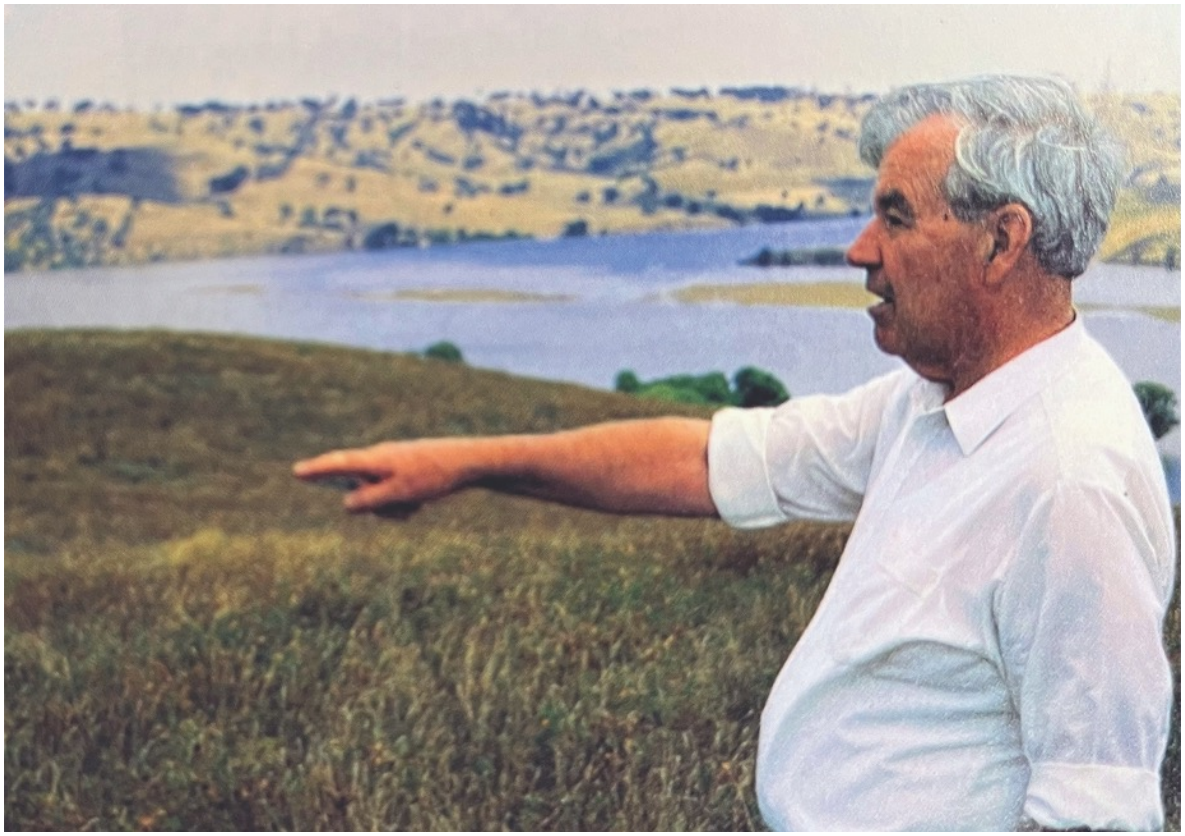


Fig. S23. Ken Campbell in the Devonian limestones at Lake Burrinjuck under very different climatic conditions. Above: leading a one-day excursion to Taemas for participants of the February 1993 'Ken Campbell Symposium' held on the occasion of his retirement [J. Long image]. Below: in the Wee Jasper Valley with Dick Barwick in the 2000s, when clean limestone, normally submerged, is exposed by very low lake levels during drought conditions. Note the bare ground, compared to the lush green grass cover in 1993 [Campbell family image].

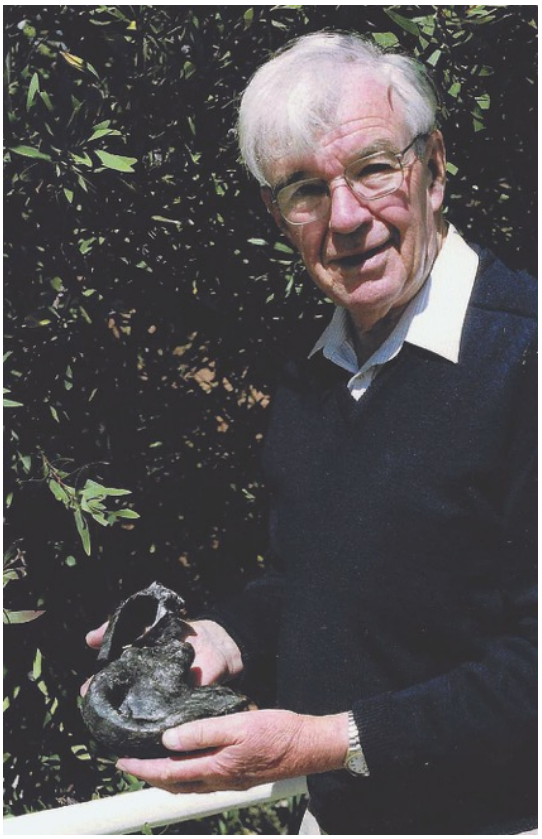


Fig. S24. The massive lower jaw of *Placorhynchus cathlesae*, at 22 cm across the largest lungfish known from the Early Devonian. Above: being collected by Ian Cathles of Wee Jasper, May 13 1997 [G. Young image]. Below: Jaw being held by Ken Campbell in 2000, after acid preparation to remove limestone matrix [Campbell family image].

Fig. S25. ANU Geology Dept. morning tea in the DA Brown Building celebrating Ken Campbell's 70th birthday, September 9, 1997. L to R: Dick Barwick, Tim Munson, Robin Westcott, Ken Campbell, John Vickers, Judith Caton, Judy Papps, Wolf Meyer, Mike Rickard [standing], Prame Chopra, [Judith Shelley and Dave Ellis obscured], Des Strusz, Tony Phimphisane [G. Young image].

Fig. S26. Trip to Scotland, August 1998. Ken Campbell [centre] with Laurie Westcott [L] and Jack Saxon [R, of Thurso, caretaker of Achanarras quarry] in Caithness, Scotland. Jack Saxon helped collect the fossil lungfish described by Campbell *et al*. (2006), and den Blaauwen *et al*. (2006) [R. Westcott image].

Fig. S27. Ken Campbell, with Laurie Westcott [L] in a bar at Loch Leven Scotland, August 27 1998 [R. Westcott image].

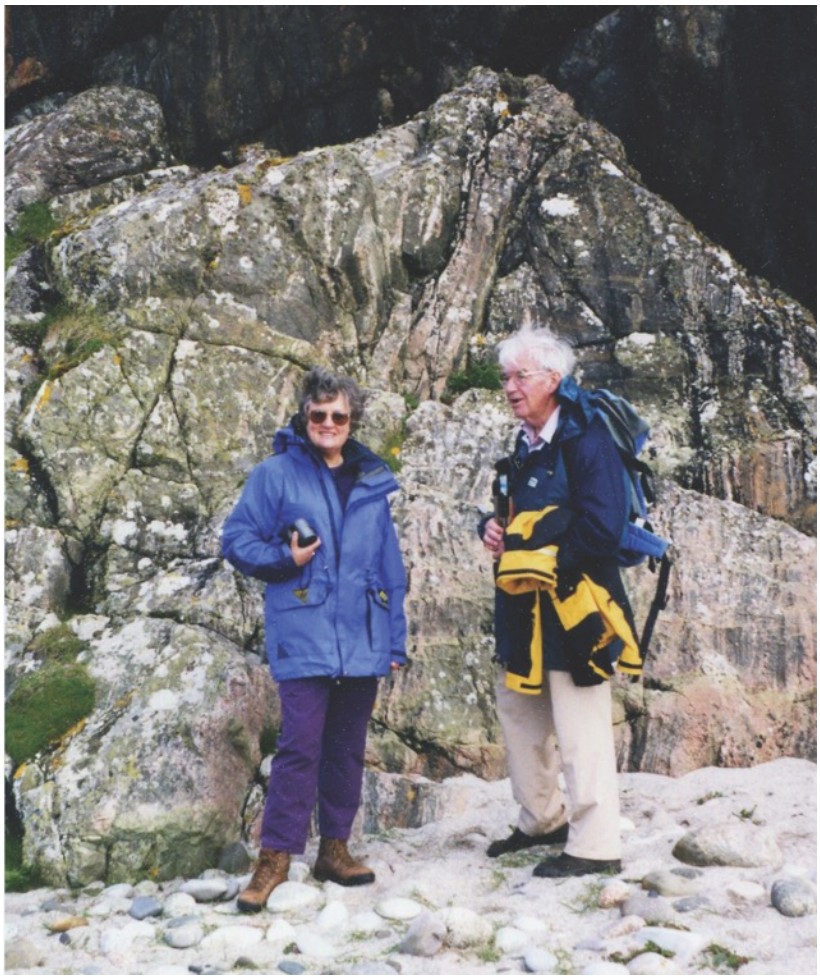


Fig. S28. Ken Campbell [R] with Robin Westcott at Columba's Bay, island of Iona, Inner Hebrides, August 1998 [R. Westcott image].

Fig. S29. Ken Campbell visiting Mahala Andrews' former cottage on Iona, August 1998 [R. Westcott image].

Fig. S30. The holotype skull of *Onychodus jandemarrai* Andrews *et al*. 2006, from Gogo WA. Mahala Andrews worked on the British material of this species for over 25 years, but died in 1997 with her research unfinished. The published monograph, finalised by Ken Campbell, appeared posthumously nine years later [J. Long image].

Fig. S31. Three ANU Geology professors in 2001. L to R: then current Professor Richard Arkulus; Foundation Professor David Brown; Emeritus Professor Ken Campbell [Campbell family image].

Fig. S32. Ken Campbell's presentation on being awarded the WR Browne Medal of the Geological Society of Australia, Melbourne, 2006 [Campbell family image].

Fig. S33. Ken Campbell in the field at Wee Jasper with honours student Jen Francis, October 20, 2003 [G. Young image].

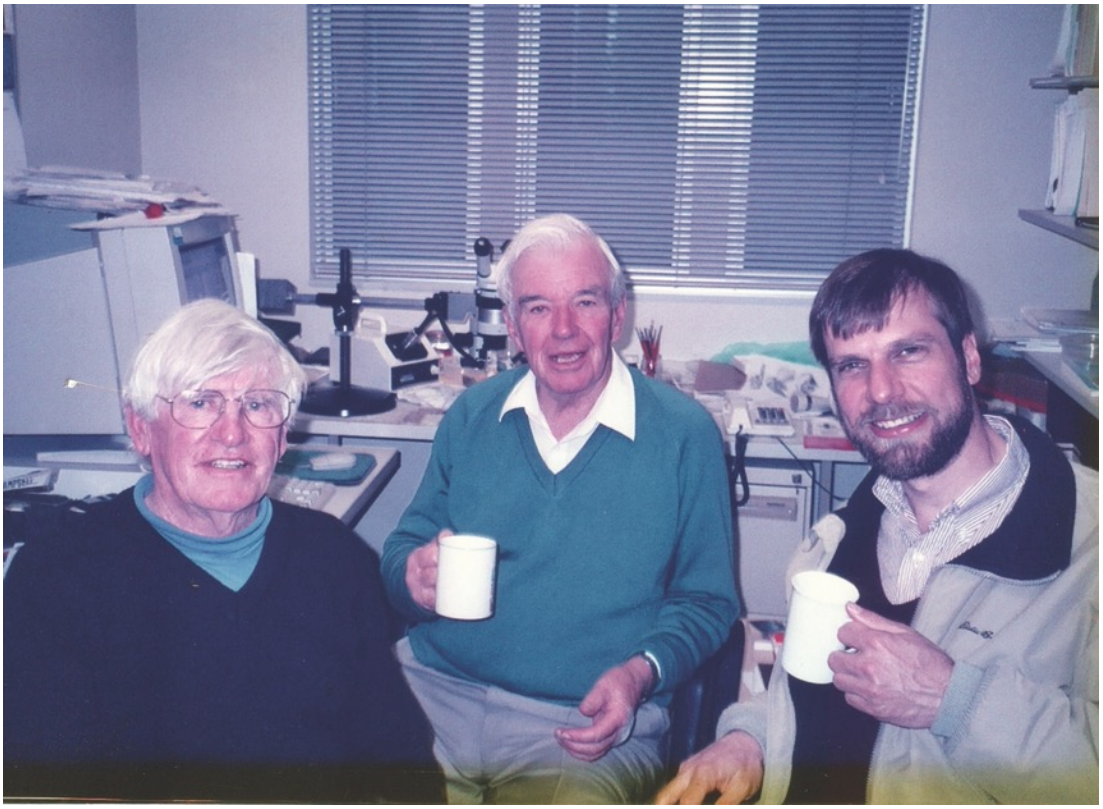


Fig. S34. Ken Campbell in his office with Dick Barwick [L] and their former student Charles Marshall [R], during a visit by Professor Marshall to ANU, June 30, 2004 [C. Marshall image].

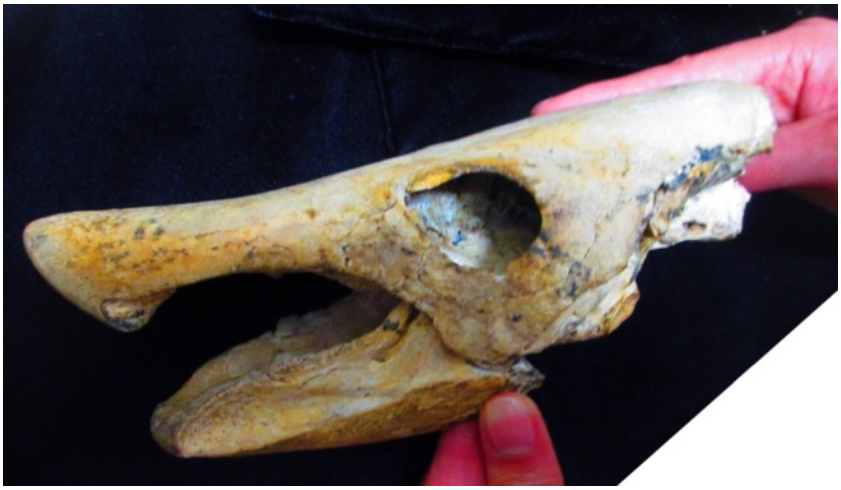


Fig. S35. Above: superb articulated skull of the Devonian lungfish *Griphognathus* from Gogo W.A. Below: Gavin Young and Ken Campbell in May 2006 carefully handling the same specimen in the Fireproof Store of the DA Brown Building. From 1965 until 2014 all such irreplaceable fossils were housed securely in a locked fireproof storeroom [G. Young images].

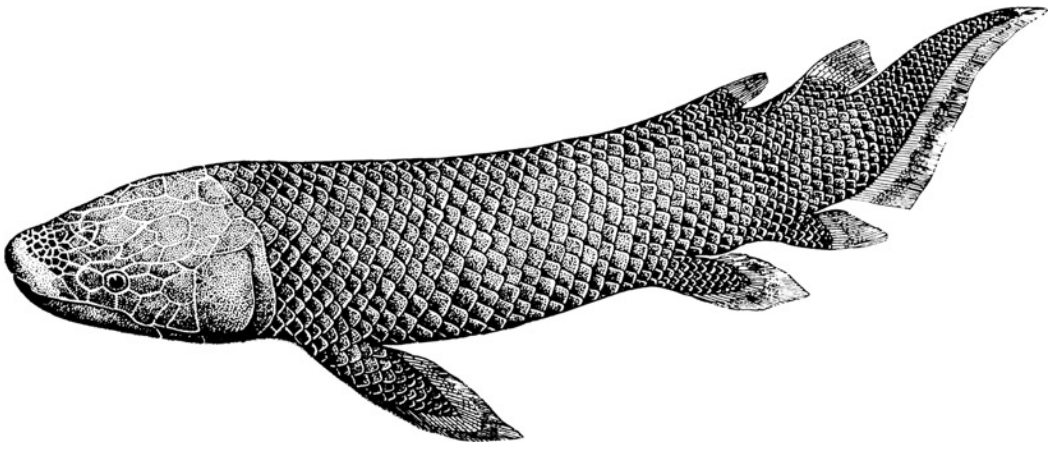


Fig. S36. Dick Barwick's whole-body reconstruction of the Early Devonian Burrinjuck lungfish *Speonesydrion iani* described by Campbell & Barwick (1984) [R. Barwick image].

Fig. S37. Ken Campbell takes student Faye Lux to fossil sites in the Jemalong Range, August 28, 2006. Above: morning coffee in Forbes; Below: lunch at Jemalong Weir [G. Young images].

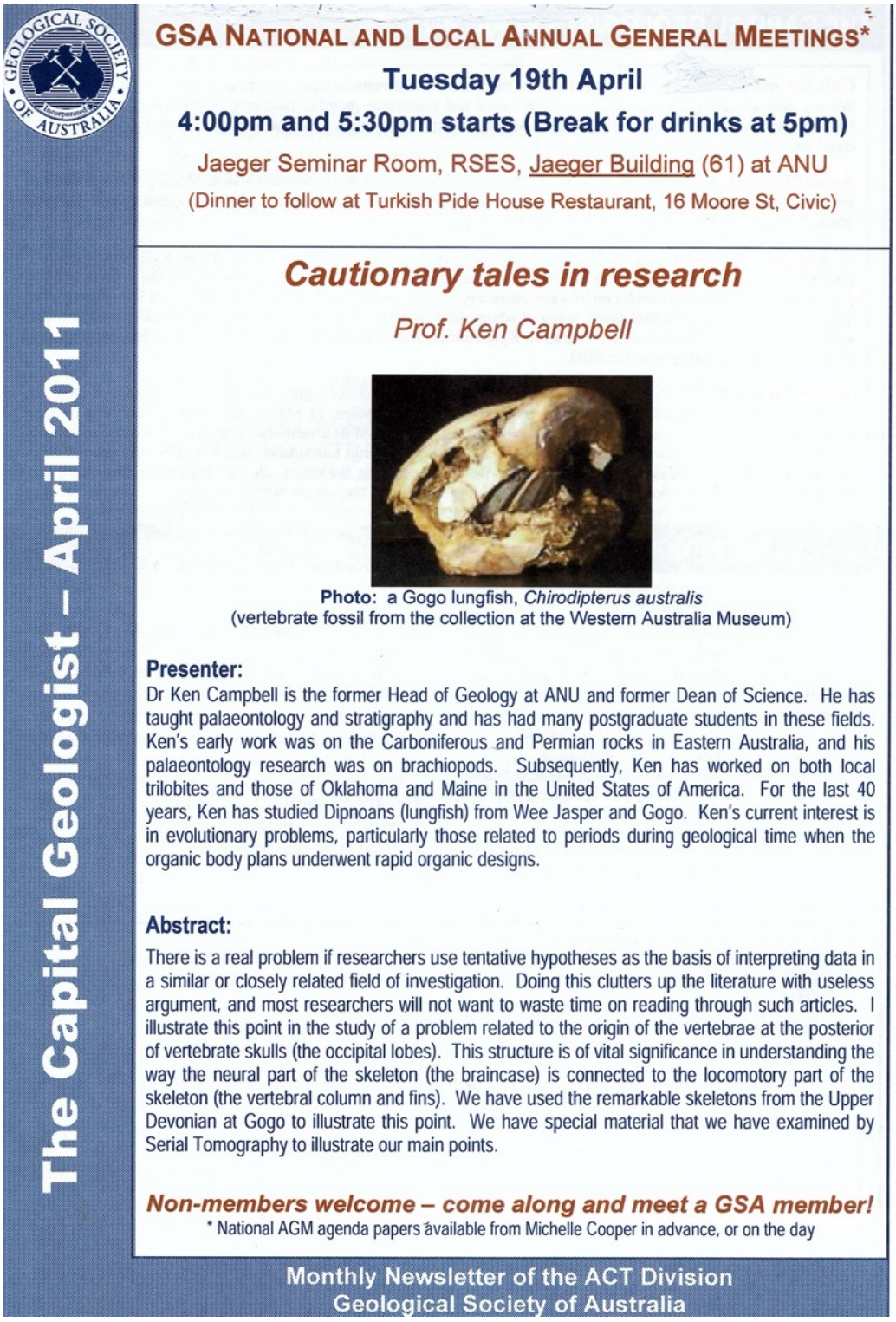
Fig. S38. University House, March 7 2009, Ken and Daphne Campbell attending the reunion dinner marking the 50th anniversary of the founding of ANU Geology. Pat Brown, wife of Foundation Professor DA Brown, is on the left [J. Gorter image].

Fig. S39. Evening meal at Vivaldi's Restaurant, ANU campus, August 27, 2009. L to R: Bob Dunstone, Peter Jones, Judith Caton, Dick Barwick, Tim Senden, Ben Young, Patrick De Deckker, and Ken Campbell [G. Young image].

Fig. S40. Dr Bob Day [at L] speaking at a University House dinner in his honour on October 9, 2009, hosted by ANU Pro Vice-Chancellor Professor Mandy Thomas [on his left]. Bob Day was one of Ken Campbell's earliest PhD students, and had made a significant $50K donation towards the ANU Palaeontology Endowment Fund [David Brown and Ken Campbell had also each donated $10K to the fund]. His proposal to fund a long-term endowment for a PhD scholarship and curation of the ANU fossil collection never eventuated. Other participants shown are [R to L] Dick Barwick, Faye Lux, and Daphne Campbell [G. Young image].

Fig. S41. Ken Campbell's speech in reply at the Bob Day University House dinner, October 9, 2009 [G. Young image].

Fig. S42. Above: Ken Campbell's opening speech, March 4, 2011, for a commemoration stone honouring Foundation Professor of Geology DA Brown, installed in the foyer of the original ANU Geology building. Below: Ken Campbell with former students Pat Davoren [L] and Neil Williams [R] at a gathering in the courtyard of the DA Brown building after the ceremony [G. Young images].



The Capital Geologist – April 2011

GSA National and Local Annual General Meetings*

Tuesday 19th April

4:00pm and 5:30pm starts (Break for drinks at 5pm)

Jaeger Seminar Room, RSES, Jaeger Building (61) at ANU

(Dinner to follow at Turkish Pide House Restaurant, 16 Moore St, Civic)

Cautionary tales in research

Prof. Ken Campbell

Photo: a Gogo lungfish, *Chirodipterus australis*
(vertebrate fossil from the collection at the Western Australia Museum)

Presenter:

Dr Ken Campbell is the former Head of Geology at ANU and former Dean of Science. He has taught palaeontology and stratigraphy and has had many postgraduate students in these fields. Ken's early work was on the Carboniferous and Permian rocks in Eastern Australia, and his palaeontology research was on brachiopods. Subsequently, Ken has worked on both local trilobites and those of Oklahoma and Maine in the United States of America. For the last 40 years, Ken has studied Dipnoans (lungfish) from Wee Jasper and Gogo. Ken's current interest is in evolutionary problems, particularly those related to periods during geological time when the organic body plans underwent rapid organic designs.

Abstract:

There is a real problem if researchers use tentative hypotheses as the basis of interpreting data in a similar or closely related field of investigation. Doing this clutters up the literature with useless argument, and most researchers will not want to waste time on reading through such articles. I illustrate this point in the study of a problem related to the origin of the vertebrae at the posterior of vertebrate skulls (the occipital lobes). This structure is of vital significance in understanding the way the neural part of the skeleton (the braincase) is connected to the locomotory part of the skeleton (the vertebral column and fins). We have used the remarkable skeletons from the Upper Devonian at Gogo to illustrate this point. We have special material that we have examined by Serial Tomography to illustrate our main points.

Non-members welcome – come along and meet a GSA member!

* National AGM agenda papers available from Michelle Cooper in advance, or on the day

Monthly Newsletter of the ACT Division
Geological Society of Australia

Fig. S43. Notice for Ken Campbell's last presentation, at the AGM of the ACT division of the Geological Society of Australia, April 19, 2011 [G. Young image].

Fig. S44. Family gathering in Canberra [2011] to celebrate Ken and Daphne Campbell's 60th Wedding Anniversary [Campbell family image].

Fig. S45. Vertebrate palaeontologists in discussion in Canberra, at the Tudo restaurant July 23, 2011. L to R: Alex Ritchie, Ken Campbell, Dick Barwick, John Long [G. Young image].

Fig. S46. Vertebrate palaeontologists in London [1976]. The three British members of Ken Campbell's 'Gang of Four', Colin Patterson FRS [on L], Peter Forey [3rd from L], and Brian Gardiner [2nd from R]. Others present are Prof. Stanley Westoll FRS [2nd from L], Dr Roger Miles [3rd from R], and Dr Gordon Reid [R]. Dr Miles wrote the 1977 monograph describing Gogo lungfishes in the British Museum collection [G. Young image].

Fig. S47. Opening night for the '*Old Bones — New Insights*' public exhibition of ANU vertebrate fossils in the Canberra Museum & Gallery, December 9, 2011. Ken Campbell [L] in discussion with Gavin Young and Bob Dunstone [R] regarding the life-size model in the adjacent display cabinet of the giant lobe-finned fish *Edenopteron keithcrooki* [G. Young images].

THE AUSTRALIAN NATIONAL UNIVERSITY

ANU PALAEONTOLOGICAL COLLECTION

Palaeontological collections at ANU include many pivotal fossil specimens for the global understanding of evolution and development. These specimens, many that cannot be replaced by further collecting, are now available for study by new means such as tomography and geochemistry.

In order to maintain the collection, support the work of a curator and provide funds for PhD studies, we are seeking support from a range of interested individuals, companies and the community.

Exoskeleton around eyeball of a placoderm (380 million years old).

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I wish to make a donation of $A to The Australian National University to support the Palaeontological collection.

ANU COLLEGE OF PHYSICAL SCIENCES

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Public appeal to raise funds for fossils research unit

The University is mounting a public appeal to finance a research unit to preserve in Australia historically valuable fossils at present being lost overseas. Mineral companies, other firms and persons are being asked to subscribe enough money to keep the research unit viable for at least three years when government aid will be sought. The research unit would be responsible for collecting and describing Australian vertebrate fossils, which would eventually be housed in one centrally available collection.

Scientific investigations in recent years have revealed that Australian rock formations contain a superb collection of rare and ancient animals, including the ancestors of our present marsupials. Palaeontologists have found fossils of reptiles, amphibians, fishes, and an early wombat as big as a rhinoceros. Some of the fossils date back more than 350 million years to the Devonian Period.

A Vertebrate Palaeontology Research Unit to coordinate Australian efforts to collect and describe fossils was suggested by Professor D.A. Brown, Professor of Geology, and Dr K.S.W. Campbell, Reader in Geology. The project has the personal support of the Vice-Chancellor, Professor Sir John Crawford.

Professor Brown told the *Reporter* last week that the magnificence of the Australian marsupial fossil collections had only recently been appreciated as a result mainly of American investigations in the Lake Eyre Basin.

'Scientists have known for the last century that Australia, in common with many other parts of the world, contains fossils much more primitive than the early marsupials,' Professor Brown said. 'But it is only in the last ten years or so that we have become aware of the abundance, exquisite preservation and diversity of these animals.'

Specimens of Devonian fish had been found in a number of places throughout the world but Australian environmental conditions had resulted in an almost perfect preservation of some of these primitive vertebrates.

The value of these finds has been recognised by overseas scientists. In addition to the American investigations in the Lake Eyre Basin, much work has been done by the staff of the British Museum (Natural History), who, in expeditions to Australia, have made extensive collections. Their research has yielded a great deal of information about the anatomy of primitive fish, including very detailed information about their nervous and circulatory systems.

Palaeontology is benefiting from these scientific advances but the price Australia has to pay is the loss and scattering overseas of its fossilised animals. Overseas expeditions are now arriving at the rate of two or three a year, and although they are usually run in co-operation with Australian museums and they do return some fossils to Australia later, much of the best material leaves the country never to return.

Professor Brown said 'a sort of lip-service' was paid to restricting the export of Australian fossil material but it did not work in practice. 'Translate the situation into living fauna,' he said. 'How would Australians feel if all their living native animals were somehow transported to the other side of the world?'

South America, another rich source of fossil remains, has a similar problem. There, because of the comparatively small scale of local activity, United States palaeontologists were doing the work and the fossils were finding their way into North American museums.

Australian fossil material is also being lost in other ways, such as natural erosion. The clearing of the land since the arrival of the white man has probably meant the loss through soil erosion of many valuable deposits of fossils.

The unavailability of expert collectors to go quickly to the sport when mining and quarrying companies during their operations turn up valuable specimens has meant their loss. 'Mining and quarrying companies are frequently willing to hold up work till someone competent has looked at what they have turned up provided that only a short time is involved,' Professor Brown said. 'Often there is nobody available and so the specimens are lost.'

Another problem is the amateur fossil hunter. 'If an amateur finds a fossil vertebrate and excavates it inexpertly, all manner of information is lost,' said Professor Brown. 'Once the preserved material is gone, nothing can be done to replace it.'

It seemed reasonable that the study of ancient Australian vertebrates should be undertaken seriously in Australia and not left almost entirely in the hands of outsiders.

Professor Brown (left) and Dr Campbell examine a piece of fossil material in a Department of Geology laboratory.

Compared with other parts of the world there was very little work on vertebrate palaeontology being done in Australia and what little was being done was in isolation.

Most State museums have a member of staff with an interest in palaeontology, although this interest is sometimes marginal and results from the fact that there is no person specifically responsible for vertebrate fossils. Many museum workers are fully occupied with their museum work and have little time for research and field work. The Bureau of Mineral Resources in Canberra has two active researchers, one in marsupials and the other in Devonian fish. The Professor of Zoology at Monash University, Professor J. Warren, is a vertebrate palaeontologist but his time is largely occupied with administration and teaching.

'What is needed is a small group of research palaeontologists without other commitments, who are able to devote all their time to collecting and interpreting Australian vertebrate fossils,' Professor Brown said. 'We need a centre for research to break down the present isolation of interests in Australia, to produce work of internationally accepted standard and make it available in published form.

'Such a group, because of its research interests, should be associated with a university and should be national in character. We suggest that Canberra is an appropriate location, and that the Australian National University is the appropriate institution. ANU is strong in many fields of Australian and Pacific research. It is close to the Bureau of Mineral Resources, it has good local library facilities, and there is accommodation available in the existing Department of Geology.'

Such a research unit would initially need a staff of three research workers, probably at the level of Research Fellow, and three technicians. There would be no difficulty in finding staff as there are some palaeontologists in Australia employed in other fields, as well as researchers studying Australian material overseas who could be attracted to work closer to the source.

Professor Brown said it would cost about $50,000 a year to finance a Vertebrate Palaeontology Research Unit for three years. Personal approaches were being made to mining and oil companies, and other firms and persons to raise this money. 'When an enormous amount is being made out of the earth it is not unreasonable to expect a little to be set aside to preserve its historical record.'

Professor Brown said that when the fossils had been collected it was not intended to house them in the University. They would probably be displayed somewhere else in Canberra for inspection by the public and would be centrally available for other research workers.

Fig. S48. Above: ANU Palaeontology Endowment Fund appeal brochure prepared for the '*Old Bones — New Insights*' Exhibition in the Canberra Museum & Gallery, December 2011 — March 2012, the only time spectacular vertebrate fossils in the ANU Collection were on public display [G. Young image]. Below: article in the July 23 1971 *ANU Reporter* showing that attempts to raise funds had persisted for over four decades [Campbell family image].

Fig. S49. Professor Per Ahlberg [Uppsala] visits Ken Campbell in his room at St. Andrew's retirement village, Woden ACT, July 2, 2012 [G. Young image].

Fig. S50. Ken Campbell at Dick Barwick's funeral, November 20, 2012 [Tim Senden to his L; Brad Pillans in R background] [G. Young image].

Fig. S51. Ken and Daphne Campbell attending a luncheon at RSES for the two sons of Foundation Professor DA Brown [standing behind] September 26, 2013 [G. Young image].

Fig. S52. Visiting Ken Campbell in 2013 in his room at St. Andrew's retirement village, Woden ACT. Above: John Long, April 10; Below: Tim Senden, December 24 [G. Young images].

Fig. S53. Dr Jing Lu [ANU post-doc] visiting Ken Campbell at St. Andrew's retirement village, August 20 2016. One of the top younger researchers on Devonian bony fishes, her RSPhys project was XCT analysis of Australian material close to the Chinese tetrapodomorph *Kenichthys campbelli*. She was a potential replacement for Ken Campbell's position at ANU. Her application for an ARC Early Career Researcher Award was supported by the Research School of Physics, but not by RSES, and was unsuccessful. She is now a Research Professor at IVPP, Beijing [G. Young image].

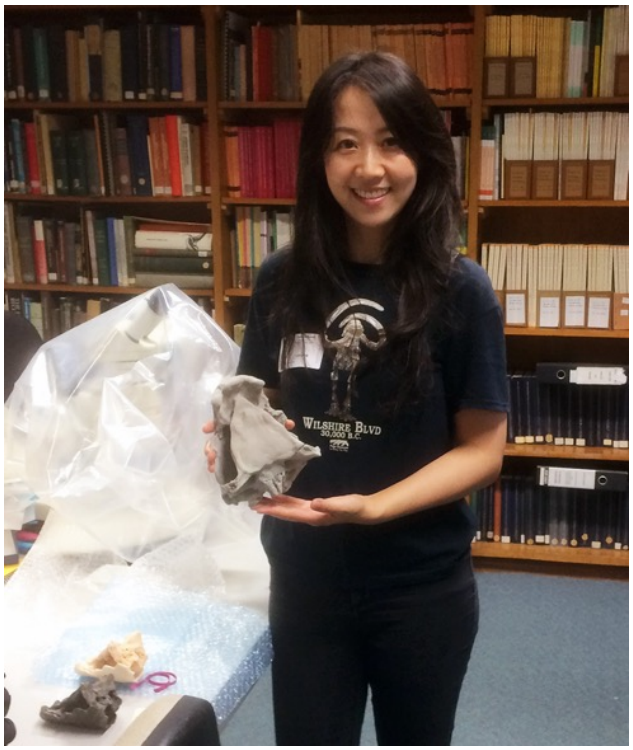

Fig. S54. Dr Jing Lu [ANU post-doc] returning the holotype of *Dipnorhynchus sussmilchi* to the Australian Museum, January 31, 2018. Ken Campbell had borrowed this specimen in 1967, and with permission had used acid etching to reveal a complete palate, well displayed on this enlarged 3-D printout, based on XCT scanning at the ANU CT Lab by Dr Lu [G. Young image].