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A Tribute to Professor Bruce Sidney Rubidge

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A Tribute to Professor Bruce Sidney Rubidge

Professor Bruce Sidney Rubidge has published hundreds of articles and papers covering various aspects of the geology of the Cape and Karoo supergroups and their palaeontological signatures. His work has significantly advanced our understanding of numerous taxonomic groups, as well as the litho- and biostratigraphy of the Karoo Supergroup. He has also driven the robust radiometric dating of the lower half of the Karoo Supergroup, and via supervision and collaboration with postgraduate students, our understanding of the basin fill and the end-Guadalupian extinction in South Africa. Bruce has also supervised numerous honours, masters and doctoral students (Fig. 1) and provided strong research leadership to many South African and international collaborators. Bruce's vision and dedication to first the Bernard Price Institute for Palaeontological Research (BPI) and now the Evolutionary Studies Institute (ESI) have guided it to become the connected 21st century establishment that it is today.

Keywords: Karoo Supergroup, sedimentology, palaeontology, biostratigraphy, basin analysis.

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INTRODUCTION

This paper forms the introduction to the Festschrift volume of papers in honour of Professor Bruce Sidney Rubidge (Bruce). As this introduction was completed before all the papers were received and refereed, it does not take the form of a traditional Festschrift volume introduction, but is rather the thoughts and recollections of two of his Ph.D. students, one from the early part of his career at the BPI at the University of the Witwatersrand (1990–2006), and the other from 2010 to the present.

THE PRE-WITS YEARS

Bruce Rubidge was born into being a palaeontologist, being influenced from a young age by the fossil collection on the farm Wellwood where he grew up, and the mentoring and influence of his grandfather, Sidney Rubidge. Unlike many children who are besotted with fossils, Bruce's childhood passions did not fade or transform into other pursuits as he grew older, and it was no real surprise then that when Bruce went off to Stellenbosch University, he studied Zoology and Geology, and landed his first job as a palaeontologist at the National Museum in Bloemfontein. Wasting as little time as possible, Bruce quickly embraced leadership, and in 1981, at the age of only 24, he became Head of the Department of Karoo Palaeontology at the National Museum. The same year also witnessed his first publication on the reptilian fauna from 'Ecca' rocks near Prince Albert (Rubidge & Oelofsen 1981).

Once at the National Museum, through his alma mater,



Figure 1. Bruce Rubidge (centre) and a sample of his assembled students from across his career. Photograph taken during the PSSA 2022 meeting, Golden Gate Highlands National Park, Free State Province, South Africa, September 12–15th. From left: Julien Benoit, Johann Neveling, Emese Bordy, John Hancox, Robert Gess, Bruce Rubidge, Sifelani Jirah, Pia Viglietti, Michael Day, Cameron Penn-Clarke, Marc van den Brandt, Luke Norton.

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he began an M.Sc. describing the cranial morphology of the early dicynodont *Eodicynodon*, and studying its presence in what was then thought to be the upper Ecca Group, a study that sparked a career-long interest in one of the most challenging collecting areas in the Karoo Supergroup for a vertebrate palaeontologist, as we are sure many a student and colleague can attest.

Bruce obtained his M.Sc. in 1983 and continued his studies on *Eodicynodon* (Rubidge 1984, 1987) and the Ecca-Beaufort contact, enrolling for a Ph.D. at the University of Port Elizabeth, which he completed in 1988 under the supervision of the legendary sedimentologist Izak Rust (Rubidge 1988). This work was seminal in proving that the fauna he had described was not from the Ecca Group as previously thought, but rather formed a new basal assemblage zone of the Beaufort Group, which he named the *Eodicynodon* Assemblage Zone (AZ; Rubidge 1990). It was on the fieldtrips for his M.Sc. and Ph.D. degrees to the southwestern Cape that Bruce developed a life-long friendship with John Nyaphuli, whose patience and tolerance for long and unsuccessful days in the veld Bruce would often tell to frustrated students. John was responsible for many of the early finds of fossils from the *Eodicynodon* AZ (Rubidge 1986), including six holotypes, a collecting skill and keen eye that earned him the Society of Vertebrate Paleontology's Morris F. Skinner Award in 2011. Bruce coached John to becoming a skilled preparator who was responsible for several technical advances in fossil preparation. Bruce also appointed Patrick Bender as a preparator at the National Museum, a move which led to Patrick being included in Bruce's Ecca-Beaufort boundary collecting trips, leading to the discovery of scales of *Namaichthys digitata* and a revision of the stratigraphic range of this palaeoniscid fish (Bender & Rubidge 1991). Patrick continued studying Permian fish, completing his Ph.D. under Bruce's co-supervision (Bender 2000), a piece of work that showed the potential of fossil fish in Karoo Basin research.

When not in the field, working on his thesis, or heading the Karoo Palaeontology Department, Bruce also oversaw the development of a new fossil gallery at the National Museum. He also had to contend with military service, for which he managed to convince the South African National Defence Force to post him to the Military Museum in Bloemfontein.

PHILIP JOHN HANCOX (1990–2006)

Bruce arrived at the BPI in April 1990, to discover to his horror, I can only assume, that he was to inherit four unruly Honours students. I must admit that the first few months of the year, when we had been under Professor James Kitching's supervision, had been something of a holiday camp, but Bruce soon put paid to that, changing the curriculum and our projects. As Bruce's focus at the time was still very much on the *Eodicynodon* AZ, my Honours Project rapidly changed to a description of the postcranium of *Eodicynodon*, which we published together in 1994 (Rubidge *et al*. 1994). Although Bruce's main research interest was in the middle Permian part of the Karoo succession, he actively encouraged research on the rest of the Karoo and aimed, through collaboration and student involvement, to develop expertise on all the different vertebrate taxonomic groups that were represented in fauna of the Karoo. It is worth noting that two of the unruly Honours students went on to gain Ph.D.s (Aitken 1998; Hancox 1998).

September of 1990 was the 6th National Congress of the Palaeontological Society of Southern Africa (PSSA), held at the Golden Gate Highlands National Park, and Bruce made sure all four of his newly acquired students gave poster presentations. This was also the first real time I spent in the field with Bruce, and it rapidly became obvious that it was in the field that he was most at home; and not in the metropolis of Johannesburg.

I spent 1991 in the U.K. working in the family business, but returned to South Africa in 1992 to investigate the possibility of doing an M.Sc. in Palaeontology and Geology under Bruce and Professor Ian Stanistreet. Mike Raath had at the time received some fossils from a farm near Sterkstroom in the Eastern Cape and Bruce, James Kitching and I duly climbed into the old single cab BPI bakkie and headed south. So began my first Triassic tour with Bruce, a trip which led not only to my M.Sc. and Ph.D. study sites, but fortuitously also the discovery of the highly fossiliferous Heelbo (Spion Kop 932) dinosaur site (Yates *et al*. 2004, 2010; McPhee *et al*. 2015; McPhee & Choiniere 2018) and my introduction to the farm Driefontein 11, an exceptional Early Triassic site that I am still collecting to this day, some 30 years later, and which is now the type locality of the *Langbergia-Garjainia* subzone of the *Cynognathus* AZ (Hancox *et al*. 2020). I would like to believe that this trip led to Bruce taking an interest in fossil amphibians, a line of investigation that led to significant new work on these taxa being undertaken in both the Permian and Triassic of southern Africa (e.g. Warren *et al*. 2001; Hancox *et al*. 2000; Schoch & Rubidge 2005).

In 1992 Heidi Fourie registered for a Ph.D. on the postcrania of selected therocephalians, having then recently completed her M.Sc. on the internal cranial structure of *Pristerodon* at the BPI under Chris Gow (Fourie 1991, 1993). Hard to believe with today's technology that serial grinding was a valid technique in the 1990s. Bruce and Gillian King co-supervised her Ph.D., which she completed in 2001 (Fourie 2001), and published on in 2007 and 2009 (Fourie & Rubidge 2007, 2009).

During an extended research trip to Russia in 1992, Bruce met up with Dr Mikhail Shishkin (Palaeontological Institute, Moscow). Realizing his potential to instigate research on the Karoo temnospondyls, Bruce successfully applied for a W. D. Wilson Travel Fellowship for Shishkin to visit South Africa. In 1994 Mikhail and his wife Zhenia (also a palaeontologist) spent five months at the BPI researching fossil amphibians from the *Lystrosaurus* and *Cynognathus* assemblage zones of the Beaufort Group. Mikhail was particularly interested in the holotype sites of *Trematosuchus* and *Parotosuchus haughtoni* and as part of a road trip with Bruce and James Kitching we revisited most of the productive sites in the Aliwal North area, as well as the localities yielding the holotype of *Uranocentrodon* (near Senekal) and a referred skull of *Trematosuchus* (the farm

Verdun near Driefontein). This work ultimately also led to a re-description of *Kestrosaurus*, based mainly on material from Driefontein (Shishkin *et al*. 2004).

Discussions with Mikhail during this trip led to the initial two papers suggesting that a threefold sub-division of the *Cynognathus* AZ, then based largely on the range of various temnospondyls, may be possible (Hancox *et al*. 1995; Shishkin *et al*. 1995). The same year also saw Elizabeth Latimer first register for her M.Sc. on the revision of the Karoo amphibians of the family Rhinesuchidae. Although Elizabeth never completed her Ph.D., she did publish on the stratigraphic position of *Uranocentrodon* (Latimer *et al*. 2002), and her work later formed the basis for a revision of the Permian Rhinesuchidae (Marsicano *et al*. 2017). Bruce's amphibian interest also led to the Australian Ross Damiani undertaking an extended postdoc at the BPI (1999–2004) which resulted in numerous publications on temnospondyl taxonomy (e.g. Damiani & Rubidge [2003] and references therein).

Under Bruce's watch, in 1993 and 1994, Dr David Dilkes, who had recently graduated from the University of Toronto, spent 18 months at the BPI as a postdoctoral fellow researching fossil rhynchosaurs from the Beaufort Group, with publications on *Howesia* (Dilkes 1995) and *Mesosuchus* (Dilkes 1998), at the time the only two rhynchosaurs known from the *Cynognathus* AZ.

The year 1995 saw some major breakthroughs in Karoo palaeontology, biostratigraphy and basin analysis. By far the most important of these was the publication of the revised 'Biostratigraphy of the Beaufort Group' (more affectionately known as the Purple Book), which was edited by Bruce, and to which he contributed the chapter on the *Eodicynodon* AZ. This would stand as the biostratigraphy of the Karoo Supergroup for some 25 years, until the 2020 revision. 1995 also saw the registration of three more of Bruce's Ph.D. students, Patrick Bender, Alain Renaut and Johann Neveling.

Patrick focussed on Permian actinopterygians (Bender 2000, 2001), a move into fish studies for Bruce, guided by his relationship with John Long of Gogo fishes fame, who co-supervised the work. Alain Renaut worked on the re-evaluation of the cranial morphology and taxonomy of the Triassic dicynodont *Kannemeyeria*; and Johann Neveling focussed on a palaeontological, stratigraphic and palaeoenvironmental synthesis of the contact between the Triassic *Lystrosaurus* and *Cynognathus* assemblage zones (Neveling 2003, 2004; Neveling *et al*. 2005).

In 1996 we met Octavian Catuneanu, a fortuitous introduction that set in motion the reciprocal basin stratigraphy work that culminated in the 1998 Basin Analysis paper (Catuneanu *et al*. 1998) and a number of Ecca-Beaufort contact papers up until 2002 (Catuneanu *et al*. 2002), as well as the highly cited paper on Karoo basins of south-central Africa (Catuneanu *et al*. 2005).

In August 1996 I travelled with Bruce to Beijing, China, to participate in the 'International Geological Conference'. Following on this conference we spent considerable time in the Institute of Vertebrate Paleontology and Paleoanthropology (IVPP) and on a field visit to the Permian and Triassic of northwestern China with Spencer Lucas, Heinz Kozur and Prof. Chen Zhenwu. This and Bruce's previous visit to China set in motion a longstanding collaboration with numerous Chinese workers, which is ongoing to this day (Li et al. 1996; Liu et al. 2009, 2010; Duhamel *et al*. 2021).

In acknowledgement to his forerunners at the BPI who had all worked on Plio-Pleistocene mammals, Bruce also kept up his earlier connection with the late James Brink at Bloemfontein (Rubidge & Brink 1985), co-supervising Lloyd Rossouw's M.Sc. on the taxonomic status of *Antidorcas australis* (Rossouw 2000).

Ken Angielczyk entered the picture in 1997, corresponding with Bruce about undertaking a research project looking into stable isotope ratios in *Lystrosaurus* specimens. Whilst the project did not develop, it did awake a love for dicynodonts in Ken, and the beginning of a long association with Bruce and the BPI/ESI.

I ground out my Ph.D. by 1998 (Hancox 1998) and with it grew an enhanced understanding of the upper Burgersdorp Formation and its contained *Cynognathus* AZ fauna; as well as the critical role fossils were playing in our understanding of Karoo Basin development (Hancox & Rubidge 1997, 2001). The same year saw Sean Modesto arrive at the BPI to undertake postdoctoral studies on basal tetrapods from the Karoo, which included various parareptiles, dinocephalians and anomodonts (Rubidge & Modesto 1998; Modesto *et al*. 1999, 2002, 2003). Well I remember the first field trip with Bruce and Sean to the Prince Albert area in February 1998, with Sean having come from –30°C into +35°C.

1998 also saw Cape Town host the 10th International Gondwana Symposium, a meeting which gave birth to the Gondwana Alive project, which Bruce was initially involved with. Once again our focus was on basinal studies, the abstracts of which were published in a special issue of the *Journal of African Earth Sciences*, of which Bruce was a guest editor. If that was not enough, under the leadership of Roger Smith, and joined by Octavian Catuneanu, we also led the first of a several trans-Karoo excursions (Smith *et al*. 1998). Bruce got involved with radiometric dating around this time and took Maarten de Wit, Doug Erwin and Sam Bowring on a tour of the southern Karoo to collect ash tuffs for CA-ID-TIMS dating. Although there would be a long wait (Rubidge *et al*. 2013), this would provide a breakthrough in Late Permian tetrapod biochronology, and relieve the Karoo Supergroup of its dependence on correlation with the Russian Permian. Chris Sidor first visited the BPI in 1999, spending some five weeks collecting data for his Ph.D. Bruce and Chris discovered a shared love of burnetiamorphs, and the rest is history (Rubidge & Sidor 2002; Rubidge *et al*. 2006; Sidor & Rubidge 2006).

From 1998–2002 Bruce's interest in tapinocephalid dinocephalians continued, co-supervising two M.Sc. theses; Darlington Munyikwa's work on tapinocephalids from the Permian aged Madumabisa Mudstone Formation of Zimbabwe (Munyikwa 2001); and Romala Govender's work on the postcranial anatomy of the most basal tapinocephalid dinocephalian *Tapinocaninus pamelae*

(Govender 2002; Govender *et al*. 2002). Romala would go on to complete her Ph.D. on postcrania, although this time on the dicynodont *Kannemeyeria* (Govender 2004).

July and October of 2000 saw Bruce and I attending first the 18th Colloquium of African Geology in Graz, Austria, Bruce as a Keynote Speaker. This was followed by the Society of Vertebrate Paleontology's 60th Annual Meeting in Mexico City. Bruce, Sean Modesto, Alain Renaut and I presented on the systematics of the Triassic dicynodonts; and with Johann Neveling and Ross Damiani on the Early Triassic faunas from the *Lystrosaurus* and *Cynognathus* assemblage zones. The Triassic work was scaling up. Our joint focus at this time was then still on biostratigraphy and the role of fossils in basin analysis, leading to the 2001 paper, 'Breakthroughs in the biodiversity, biogeography, biostratigraphy and basin analysis of the Beaufort Group' (Hancox & Rubidge 2001).

The focus on dicynodonts continued with Alain Renaut's work on *Kannemeyeria* and the completion of his Ph.D. thesis (Renaut 2000a,b), which Bruce and I co-supervised. We then concentrated our co-supervisory roles on Johann Neveling, until he too achieved his Ph.D. in 2003 (Neveling 2003, 2004). Unfortunately, Alain left the sciences after publishing a few articles on dicynodonts (Renaut & Hancox 2001; Renaut *et al*. 2003; Damiani *et al*. 2009) but Johann is still very active, with a research focus on the sedimentology of the Permo-Triassic Boundary (PTB; Neveling *et al*. 2016; Gastaldo *et al*. 2021). At the same time Bruce was co-supervising Ashleigh Pitcher's M.Sc. with Ross Damiani, and another Triassic amphibian (*Lydekkerina*) was decrypted (Jeannot *et al*. 2004).

Emese Bordy joined the team as a post-doctoral researcher in 2002, having just graduated with a Ph.D. on the sedimentology of the Karoo Supergroup in the Tuli Basin, under the supervision of Octavian Catuneanu at Rhodes University and Bruce acted as an advisor. Her work and endless drive led to a resurgence in interest in the uppermost Molteno, Elliot and Clarens formations from a basin and sedimentological perspective (Bordy *et al*. 2004a–d, Bordy *et al*. 2005a,b). 2002 also saw Fernando Abdala begin a two decade long association with Bruce and the BPI/ESI – and the focus moved onto therocephalians (Abdala *et al*. 2008) and cynodonts, work which is continuing to the present (Abdala *et al*. 2020). 2002 was also a busy conference year, with both the 16th International Sedimentological Conference and the 8th International Symposium on Mesozoic Terrestrial Ecosystems being held in South Africa, and the 11th International Gondwana Conference in Christchurch, New Zealand. Bruce was involved with numerous presentations covering various aspects of the Ecca-Beaufort contact, phylogenetic analysis of the Triassic dicynodonts, the vertebrate fauna, palaeoecology and palaeoenvironments of the Early Triassic Burgersdorp Formation, and Karoo basin analysis. Bruce, Roger Smith, Johann Neveling, Octavian Catuneanu and I also led two successful trans-Karoo field excursions (Hancox *et al*. 2002; Smith *et al*. 2002), bringing the world of the Karoo Supergroup to numerous overseas researchers.

The early 2000s also saw Bruce driving a resurgence in parareptile studies with Sean Modesto and Ross Damiani, with Juan Cisneros registering for his Ph.D. in 2003; a work on the cranial anatomy of the South African genus *Procolophon* (Cisneros 2006), which was co-supervised by Bruce and Ross Damiani. Following the successful completion of his Ph.D. Juan continued his work on parareptiles with an analysis of millerettid parareptile relationships (Cisneros *et al*. 2008).

In 2003 the collection management side of Bruce resurfaced, with Merrill Nicolas registering for a Ph.D. on the tetrapod biodiversity through the Beaufort Group (Nicolas 2007). This pioneering research work focussed on creating a single standardized database for the fossils collected from the Beaufort Group (Nicolas & Rubidge 2009) as well as a GIS system incorporating all the South African databases of fossil records, and eventually to a new GIS based biozone map for the Beaufort Group (van der Walt *et al*. 2010). September 2003 saw Bruce participating in the Goldschmidt Conference, with Michiel de Kock presenting new findings on the magnetostratigraphy of the PTB.

2004 brought with it the resignation of Alain Renaut, to be replaced by Adam Yates as senior lecturer at the BPI. Adam had previously held a post-doctoral position at the BPI working on dinosaurs from the Elliot Formation under Bruce's supervision. This appointment invigorated renewed interest in the dinosaurs of the Karoo, and led to the discovery of the first sauropod from the Upper Elliot Formation (Yates *et al*. 2004).

In August 2004 Bruce and I again jetted off overseas for participation in the 32nd International Geological Conference, Florence, Italy. Papers presented by Bruce and his students, included work on middle-late Permian biostratigraphy of the Karoo Basin and the vertebrate fauna, palaeoecology and palaeoenvironment of the Burgersdorp Formation. 2005 saw Bruce being invited to present the prestigious 27th Alex du Toit Memorial Lecture of the Geological Society of South Africa (Rubidge 2005), and providing an opportunity to tour South Africa and instil his love of fossils and the Karoo into both scientists and the general public. By the end of 2005 I relinquished the position of sedimentologist in the School of Geosciences at the University of the Witwatersrand, and was out of mainstream science, but still kept the work going (or rather Bruce did) and we co-supervised the M.Sc. studies of both Richard Mason on the Ecca Beaufort Boundary in the Albany District (Mason 2007) and Anthony Rutherford on the sedimentology and stratigraphy of the Beaufort Group in the Vicinity of Thaba Nchu (Rutherford 2009; Rutherford *et al*. 2015). During this time Bruce continued his outreach work, setting up the Kitching Fossil Exploration Centre in Nieu Bethesda in 2005 as an experiment to establish whether palaeotourism in rural parts of the Karoo is viable. This successful venture, which has entailed the training and accreditation of guides from the local township, has since expanded and is still operational after 17 years. I re-joined the BPI for a year as a post-doctoral researcher during 2005–2006, presenting with Richard Mason and Bruce at the 14th biannual conference of the PSSA in Grahamstown. In the

same year Zubair Jinnah (who now holds the position of sedimentologist in the School of Geoscience at the University of the Witwatersrand) was an Honours student working on a double-tusked specimen of *Eodicynodon* (Jinnah & Rubidge 2007).

A short gap separates my leaving the BPI to follow a career in geological consultancy and Mike Day taking up the story, but Bruce was not idle, and was a pioneer in using the European Synchrotron Radiation Facility at Grenoble, France, for scanning Karoo fossils and encouraging others to follow. He continued to foster both scientific research and encouraged palaeontological conservation and tourism, whilst all the time giving various presentations on the role of fossils in understanding Gondwanan development. He and Terence McCarthy, who previously headed the Geology Department at Wits, organized a day-long series of short public lectures on the development of Earth and Life using the diverse expertise of Wits academics. These day-long lecture series were so popular that they were repeated over successive years to packed audiences in the Wits Great Hall, and led to the publication of the book 'The Story of Earth and Life'. This was first published in 2005, but has since undergone several reprints and has become the standard text for geology students studying at South African universities, also being used extensively by the lay public as a guide to the geology of South Africa.

To conclude, and before I hand over to Mike – the 20 years from 1990 to 2010 saw numerous work streams driven by Bruce, with expertise and scientific capacity built around numerous vertebrate taxonomic groups, in sedimentology, and litho- and biostratigraphy, as well as integrated basinal analysis studies based on robust absolute dates.

MICHAEL O. DAY (2010–2022)

I first met Bruce in late January 2010, in the arrivals hall of OR Tambo International Airport. I was supposed to have met him at the 2009 SVP in Bristol, U.K., but though I attended his talk, he vanished like a wraith in the crowd that rose to flee to lunch at the end of the session, and so it never transpired; he tells a different story. Nevertheless, seeking adventure beyond the seas, I had successfully applied to study for a Ph.D. on the biostratigraphy of the Ecca-Beaufort contact on the promise of several months fieldwork and the chance to find real vertebrate fossils. It was the year of South Africa hosting the football World Cup, but the Gautrain was not yet operational, so Bruce came to fetch me at the airport. He was late, which I was soon to discover was quite atypical for him. When we got to the University of the Witwatersrand, he dutifully accompanied me through the registration process and just like that I became one of the BPI family.

Only a couple of weeks after arriving, we were off on Bruce's big annual February fieldtrip which had become an institution at the BPI, this year to the *Tapinocephalus* AZ near Merweville, where the team were to collect fossils to contribute to Sifelani Jirah's M.Sc. on the stratigraphy of the Abrahamskraal Formation. Apart from a BPI crew, we were accompanied by international visitors Tom Kemp (Oxford) and Ken Angielczyk (Chicago) and, once in the field, were joined by parties from Grahamstown (Billy de Klerk) and Cape Town (Sandra Jasinoski). This coming-together characterized Bruce's February fieldtrips for the rest of the decade and contributed to making them excellent fun. These trips were run according to a well-established timetable, and punitive measures could be administered for infringements: How many palaeontologists have awoken 6.05 am in the cool breeze of a Karoo morning to be met by Bruce presenting them with a cup of tea and the baffling claim that the sun was setting? Too many, and many more than once. But Bruce always ensures that beer is plentiful after a hard day's work, which was much appreciated, though may have occasionally contributed to further punitive measures.

The fieldwork itself was an expansion of work the previous year for Sifelani's Honours, when I believe there had been first mention of the now infamous graveyard for unusable and fragmentary field fossils: *the wall*. The story goes that this original wall was pressed into service to accommodate the vast bags of dinocephalian rubble brought to Bruce by Raoul Mutter and by 2010 it had already become tradition, a warning to deter exuberant students from denuding the veld of fossil scrap.

Now, following on from where John left off, in the late 2000s Bruce's research team had grown to include Fernando Abdala, who had joined the BPI initially as a postdoc working under Bruce, and later as a researcher working mainly on cynodonts, and Sifelani, who had joined the BPI as a preparator and began to study part time. Both of these men are truly 'lekker ous' and made for a very welcoming team. So too for Luke Norton and Saniye Güven, who had arrived as students, with Luke working towards an M.Sc. on the gorgonopsian *Aelurognathus* (followed by a Ph.D. on therapsid tooth replacement) and Saniye towards a Ph.D. on reviewing the taxonomy of tapinocephalid dinocephalians.

Since his Ph.D., Bruce's passion for the Karoo had primarily focussed on the older part of the sequence, and by 2010, having initiated others to undertake research on higher stratigraphic levels in the Karoo, he was directing more energy towards this area. Saniye's project formed part of a drive by Bruce to review the taxonomy of all the vertebrate groups of the middle Permian and the same goal led to Ph.D. projects by Sifelani Jirah (titanosuchid dinocephalians; registered 2014) and Marc van den Brandt (basal pareiasaurs; registered 2017). This was complemented by Bruce's own previous work with people like Sean Modesto, and then at that time with Ken Angielczyk to both review and describe dicynodonts (Angielczyk & Rubidge 2009, 2010, 2013). Fernando Abdala was pulled into the middle Permian and along with Christian Kammerer reviewed the lycosuchid therocephalians (Abdala *et al*. 2014), and shortly after Christian led a review of the gorgonopsians and found they all belonged to one species (Kammerer *et al*. 2015). As mentioned above, a review of rhinesuchid temnospondyls, building on the work begun by Elizabeth Latimer in 1994, was finally completed by Claudia Marsicano and colleagues in 2017 (Marsicano *et al*. 2017). All these

were informed by fossils Bruce's team had found over the previous years.

These projects laid the foundation for an area Bruce was very keen to pursue, and an area that was his main area of expertise: stratigraphy. The Ph.D. that I was undertaking was designed by him to bring together the tetrapod story for the middle Permian, and do for lowest assemblage zones of the Beaufort Group what John Hancox had done for the *Cynognathus* AZ. They were of course mighty boots to fill. It was based heavily on the georeferenced database that Merrill van der Walt had produced for her thesis in 2007 (another foundation), from which Merrill and Bruce were still producing a string of papers (Nicolas & Rubidge 2010; van der Walt *et al*. 2015).

Naturally, I worked very closely with Bruce on this and by 2013 I was able to submit my Ph.D. having constructed fairly high-resolution stratigraphic ranges for then-valid vertebrate taxa in the middle Permian part of the Beaufort Group. How did we know it was middle Permian? Well, in the year I submitted Bruce finally published the U-Pb TIMS dates from Karoo tuffs that he had collected 15 years earlier with Sam Bowring and Doug Erwin (Rubidge *et al*. 2013), which was a huge contribution as it meant the Karoo no longer relied on relative-dating by correlation to other sequences. Furthermore, we began collecting more tuffs, and from one at the top of the *Tapinocephalus* AZ, which we collected in 2012, Jahan Ramezani at the Massachusetts Institute of Technology was able to extract an age of 260 million years, which nicely linked the loss of diversity we observed at this point to the Capitanian (or the end-Guadalupian) mass extinction. We condensed the best bits of this into a paper a couple of years later (Day *et al*. 2015).

Anyway, Bruce was happy enough to keep me on as a postdoc and our work continued collecting data around the Capitanian mass extinction until 2016. The fossils we collected at this time provided sufficient data to look at rates of extinction and origination across this interval, thanks in large part to the statistical prowess of Roger Benson (Oxford University) and the taxonomic knowledge of Christian Kammerer (Day *et al*. 2018a). A call for Permian extinction papers by Spencer Lucas coincided with the beginning of the Covid lockdowns, and finally gave Bruce and I the opportunity to get the majority of what we had discovered about this event out into the world (Day & Rubidge 2021).

After 2016 our collecting moved down in the Abrahamskraal Formation, because another result of my thesis was that we knew very little about the transition between the *Eodicynodon* and *Tapinocephalus* assemblage zones. We published on the lithostratigraphy of the Abrahamskraal Formation (Day & Rubidge 2014) in the same issue of the *Journal of African Earth Sciences* where Sifelani Jirah published the results of his M.Sc. (Jirah & Rubidge 2014), based a lot on Bruce's earlier work with Johann Loock and James Kitching, and thus had set our nomenclature. Our first field trip to these low horizons was in the Moordenaars Karoo, north of Laingsburg, in heat that nearly led Vincent Fernandez (Centre national de la recherche scientifique, France) to perish on the banks of the Buffels River. I'm sure it was also a major contributing factor to a panic I found myself in at one point whilst trying to negotiate some folds when measuring my stratigraphic section; but Bruce saved the day by calming me down and directing me to take a nap under a bush, after which all was better.

Although our fossil pickings at these low stratigraphic levels of the Abrahamskraal Formation were meagre in 2016, we returned in 2018 and this time we did find fossils, very interesting ones, right where we expected the transition to be. This was a wonderful discovery, and the fieldtrip was made even more remarkable as it was the first time that I was able to bring Bruce a cup of tea in bed after a late start! (I'm sure he'd wish me to stress that this was the *only* time that this has happened). Anyway, the discovery of the first fossil was made by Frank Schie, a retired geologist with a passion for tuffaceous horizons, who had joined all our February fieldtrips since 2014 and did so until 2020, and the hill on which it was found subsequently became known as Frank's Hill. Sadly, Frank passed away in 2021 but his contribution will be remembered.

Other interesting fossils were found by Julien Benoit, who had joined the ESI in 2014 as a post-doctoral researcher under Bruce. They had worked together with Paul Manger on a suite of fascinating aspects of therapsid neurology and published *a lot* (e.g. Benoit *et al*. 2016a–c, 2017a–c). In 2018 Julien had taken the post of senior researcher at the Evolutionary Studies Institute (ESI) after Fernando's return to Argentina, and was getting more involved in our fieldwork. And one way he became more involved was that he began to find most of the fossils, and that is what you want in a collaborator.

Other student members of Bruce's team are David Groenewald, Marc van den Brandt, and Kévin Rey. David had arrived at the ESI in 2015 to study for an Honours under Bruce and I describing a Permian palaeosurface in KwaZulu-Natal, and then registered for an M.Sc. His project was to initially to elucidate the biostratigraphy of the lowest Beaufort Group in the southern Free State, where Bruce had long known some kind of middle Permian fauna to be present (Welman *et al*. 2001). We had been scouting this area since 2011 and David started there in 2016, but his project was then extended across to include KwaZulu-Natal when he upgraded to a Ph.D. He recently graduated and has a couple of papers out (Groenewald *et al*. 2019, 2022). Marc came to the ESI for an Honours in 2013, and joined Bruce's team in 2014 to work on the pareiasaur *Embrithosaurus*. He followed this with his Ph.D. on all the basal pareiasaurs, which has now been published (van den Brandt *et al*. 2020, 2021a–c). Last but not least, Kévin had worked with Bruce and other members of the ESI during his Ph.D. in Lyon, France, studying, among other things, broad changes in climate through the Beaufort Group (Rey *et al*. 2016). He joined Bruce as a postdoc in 2017 to try and determine if climatic signatures could be observed through the Capitanian mass extinction using stable isotopes in therapsid tooth enamel. Though the data were limited, his work suggested that aridification without warming may have contributed to this (Rey *et al*. 2018) and was also able to shed some light

on feeding habits of several species (Rey *et al*. 2020a–b). Yikes, so many papers with these guys!

Returning to the project, one of Bruce's great aims was to sort out the biostratigraphy of the middle Permian. With our collecting in the lower *Tapinocephalus* AZ we were able to demonstrate that in the lower part of the biozone the small dicynodont *Diictodon* was absent, whereas the previously enigmatic *Eosimops* was pretty common at this horizon. This helped us to recognize two subzones in the *Tapinocephalus* AZ, just in time for the grand review of Karoo tetrapod biostratigraphy in 2020 (Day & Rubidge 2020). Interestingly, the first specimens that were referred to *Eosimops* were initially considered by Bruce and Ken Angielczyk to be a new species of the dicynodont *Robertia*, and it was only after Ken came across the old Broom holotype in the Natural History Museum in London that he realized Bruce had in fact found more *Eosimops*. If things had been different, we may today be talking of the *Robertia-Glanosuchus* sub-assemblage. In the same volume we published on the *Eodicynodon* AZ (Rubidge & Day 2020) and Bruce worked with John Hancox and Johann Neveling to formalize the subdivisions of the *Cynognathus* AZ (Hancox *et al*. 2020).

Our most recent work finally published eight U-Pb dates from tuff horizons in the middle Permian, analysed by Jahan Ramezani and Ryan Frazer from MIT, that have pulled the chronological constraints on the Karoo biozones down to near the top of the *Eodicynodon* AZ (Day *et al*. 2022). Currently we are searching for more of the new animal species which occur in the interval between the *Eodicynodon* and *Tapinocephalus* assemblage zones and working towards a description of this fauna. One such animal, the weird dicynodont *Lanthanostegus mohoii*, was previously known from only two specimens from the Eastern Cape, but a skull found by Julien now shows it was present in the west as well (Rubidge *et al*. 2021). This story is still unfolding.

Of course, Bruce's research encompassed much more than just our *Tapinocephalus* AZ project. When I appeared in 2010, Natasha Barbolini was also embarking on a Ph.D. with Bruce and Marion Bamford to study the palynostratigraphy of the Karoo Supergroup. Her work helped reveal differences in the timing of palynomorphs across the Permian of Gondwana and establish palynozones within the Karoo Basin (Barbolini *et al*. 2016, 2018). Pia Viglietti arrived in 2013 from Cape Town to begin a Ph.D. with Bruce and Roger Smith on the sedimentology and palaeontology of the Late Permian Barberskrans Member. This was inspired by a prominent white sandstone that Bruce had for some time unfailingly pointed out to any students who travelled with him along the N1 between Springfontein and Gariep Dam. Apart from solving this sandstone occurrence and designating it as the new Ripplemead Member of the Balfour Formation, Pia also reviewed the biostratigraphy of the old '*Dicynodon*' AZ and resurrected the name *Daptocephalus* AZ, as well as using her data to discuss ecological and environmental change across the PTB (Viglietti *et al*. 2016, 2017a–b, 2018).

Of the strange creatures that populate his field of research, Bruce is a leading authority on one of the strangest, the burnetiamorphs (and biarmosuchians more broadly). He had been working with these knobbly oddities since the early 2000s, frequently with Chris Sidor, helping review the then-known burnetiamorphs *Burnetia* and *Proburnetia* (Rubidge & Sidor 2002; Rubidge *et al*. 2006) and subsequently with the description of a handful of new genera prior to 2010 (Rubidge & Kitching 2003; Sidor & Rubidge 2006; Smith *et al*. 2006). One day in the early 2010s, a fossil skull landed on his desk having been purchased by someone who knew of his interest in fossils by the side of the road in Malawi. It turned out this was a fossil burnetiamorph that is now registered in the collections of the Malawi Department of Antiquities that was briefly described in 2005! Bruce took the opportunity to inform the host collection and then offer to prepare the specimen further, which Ashley Kruger then went on to fully describe for an Honours project (Kruger *et al*. 2015). They named the specimen *Lende*, after a Malawian spirit known to disappear from view.

In 2011 I found a rather mutilated skull that Bruce immediately recognized as a burnetiamorph. We described this as the first burnetiamorph from the *Pristerognathus* AZ (Day *et al*. 2016) along with a different take on the relationships between these animals; an approach that did not catch on, as some papers in this volume will attest. Bruce and I then described an excellent skull found by Roger Smith from the *Endothiodon* AZ, along with Julien Benoit and Vincent Fernandez (Day *et al*. 2018b) and, most recently, a paper by Alienor Duhamel (Duhamel *et al*. 2021b) has discussed the development of cranial ornamentation as an ontogenetic character. Altogether, Bruce is an author on the description of all but two South African biarmosuchians from the last 20 years.

One line of enquiry that Bruce has long advocated from his stratigraphic work is the evolution of the Karoo Basin itself, and in particular has become a fervent proponent of the reciprocal stratigraphy model for the Karoo foreland basin (Rubidge *et al*. 2016). This follows on from his work with John Hancox and Octavian Catuneanu way back in the previous century (Catuneanu *et al*. 1998). His stratigraphic Ph.D. students have thus addressed this (e.g. Rutherford 2009; Rutherford *et al*. 2015; Viglietti *et al*. 2017; Groenewald *et al*. 2022).

In 2012 Bruce took some responsibility for research efforts into the Devonian, when Cameron Penn-Clarke registered for an M.Sc. (later upgraded to a Ph.D.) on the stratigraphy and sedimentology of the Bokkeveld Group, and Rob Gess joined as a postdoc to continue his studies on the ecosystem of the Witpoort Formation (Gess *et al*. 2006), having graduated with his Ph.D. under Bruce the previous year (Gess 2011). Cameron published his Ph.D. (Penn-Clarke *et al*. 2018a–b, 2019) and was so taken by the Bokkeveld he went on to the Council for Geoscience to map it all out in the Cederberg.

Two other postdocs in the last few years have helped satisfy some of Bruce's curiosity: Vincent Fernandez and Marco Romano. Vincent arrived in 2011 from the European Synchrotron Radiation Facility to assist Kris Carlson in setting up CT scanning facilities. His research focus was to use CT scanning to explore the fossil contents in

vertebrate burrow infills from the Karoo and he spent a couple of years studying the contents of a burrow (Fernandez *et al*. 2013), which proved to contain not only a complete skeleton of the cynodont *Thrinaxodon* but also the temnospondyl *Broomistega*! This tragic couple went on to inspire at least two graphic novels, which is more than most of us can claim. From 2018–2019 Marco joined Bruce at the ESI and in this short time gave Bruce the support he needed to finally publish a postcranial description of *Tapinocaninus pamelae*, as well as reconstruct its body mass (Rubidge *et al*. 2019; Romano & Rubidge 2021). Marco's exceptional power of publication led to several other papers with Bruce (Romano & Rubidge 2019; Romano *et al*. 2020, 2021a), even one on Milankovich cycles (Romano *et al*. 2021b).

Outside of South Africa Bruce was called on to help describe some middle Permian therapsids from Brazil along with former Ph.D. student Juan Cisneros (Cisneros *et al*. 2011, 2012), including a strange tusked anomodont, *Tiarajudens eccentricus*. This showed similarities to *Anomocephalus*, an animal that had been found by John Nyaphuli on fieldwork with Bruce in 1994 (Modesto & Rubidge 2000). Bruce also collaborated with Tyler Lyson, Gabe Bever and others on the respiratory apparatus of the peculiar reptile *Eunotosaurus* (Lyson *et al*. 2014) and proposed a fossorial origin for the tortoise shell (Lyson *et al*. 2016).

Apart from his academic endeavours, Bruce has spent his career expanding the palaeontological community in South Africa and modernizing research infrastructure at the institutions at which he has worked. When I arrived at the BPI in 2010 the institute was undergoing a collections-move and considerable building works that strained even Bruce's formidable organizational skills for much of the year. I spent several of my first few months at the BPI trying to type with gloves on in a freezing office in the 'Wedge' but in September 2010 the newly-renovated building was officially opened. This was shortly complemented by the arrival and installation in early 2012 of an X-ray micro-computed tomography (μCT) facility, where the former Kitching Museum had been, an acquisition driven in large part by Kris Carlson. This really changed the game at the BPI and now plays a key role in the research undertaken there.

This early work was part of a greater plan, and a big year for Bruce and for many of us came in 2013 when two great projects led by him came to fruition: the coming together of the BPI and the Institute for Human Evolution (IHE) to form the new Evolutionary Studies Institute (ESI), and the inauguration of the NRF/DST Centre of Excellence in Palaeoscience (CoE-Pal). The latter in particular has provided funding for many staff and students in South Africa and continues to support research and outreach at its constituent institutions. Bruce headed both the ESI and the CoE simultaneously until 2017 when he stood down from the headship of the ESI, and has continued to direct the CoE (now rebranded to GENUS). In all he was Director of the BPI Palaeontology (later the ESI) for a total of 27 years.

Bruce has always been a massive contributor to local conferences such as the PSSA; at least during my time, this has been most clearly demonstrated by his funding and organizing for all the ESI students to attend. PSSA conferences really felt like a coming-together of the palaeontological community, and the presence of so many students is a big part of this. Internationally, Bruce was mostly satisfied to send students to speak about their research. He made a few exceptions, such as in 2011 when we travelled to Las Vegas for the Society of Vertebrate Palaeontology (SVP) meeting, where he was very pleased to see John Nyaphuli recognized with the Skinner Award for his huge contribution to the collecting and preparation of fossils from the Karoo Supergroup.

He has run numerous field trips, often attached to conferences, notably for the International Geological Congress in Cape Town in 2016 alongside Roger Smith, and in 2015 to show off the Karoo to Andrey Sennikov, Valeriy Golubev, and Elena Boyarinova. He has a passion to inform the public, and particularly school learners, about the fossil wealth of South Africa and throughout his career has supported palaeontological outreach activities. From 1980 to 1983 he designed and coordinated the production of large displays on the origin and development of life at the National Museum; 1990–1994 he set up the fossil display in the James Kitching Gallery at the University of the Witwatersrand; in 1996 he designed a fossil display in the Blelloch Museum in the Geology Department at the University of the Witwatersrand; and in 2005 he, together with Billy de Klerk and Ian McKay, established the Kitching Fossil Exploration Centre in Nieu Bethesda as a novel venture in palaeotourism. He and Mike Raath were intitiators in enthusing SANParks to set up a palaeontological display centre on the *Massospondylus* nesting site at Golden Gate. Through his vision, with the dedicated services of Ian McKay, an ambitious outreach programme was established at Wits which, until the Covid-19 pandemic hit the world, received in excess of 400 000 learners annually. Despite his very busy schedule in directing palaeosciences at Wits and in South Africa, Bruce has never shied away from serving on relevant University and national scientific bodies, and has led by example in teaching several different undergraduate courses at Wits on an annual basis.

CONCLUSION

Bruce Rubidge is passionate about understanding the story of the development of Earth and Life, particularly that of the Karoo which he loves dearly, and gets pleasure from involving others in this pursuit. His motto is to enjoy what you are doing, and output and productivity will follow naturally. Throughout his career he has had the loving support of his wife Marina and their sons Sidney and Mark. His outputs and achievements would not have been possible without their backing and encouragement.

Bruce and Marina moved to Graaff-Reinet in the heart of the Karoo during the southern winter of 2020 in the midst of the Covid-19 pandemic. Of course, this is far from the end of Bruce's academic life, and he continues to supervise his research laboratory and is working on plans for the sustainable future of his grandfather's fossil collec-

tion; no doubt the people of Graaff-Reinet will soon be far more educated in the fossil heritage of the Karoo than ever before. Being much closer to the fertile collecting grounds, who can tell what discoveries will be attributed to him in the coming years? One thing is for certain though: Bruce will not readily accept isolation, and we expect the inevitable stream of visitors and Bruce and Marina's famous hospitality will be sufficient to keep the local tequila distillery in business.

It has been a difficult task to summarize Bruce's career. So many people have been a part of his career that we have been unable to mention them all; to those people we offer our apologies, yet we trust we have conveyed the huge impact Bruce has made to South African palaeontology, especially the students who owe him their degrees. His passionate drive to better understand the Permian and Triassic rocks of the Karoo Supergroup has lifted many of us up with him, including the authors, and for that we are grateful. Thanks to him, the distant ecosystems of the ancient Karoo are rather less mysterious than they otherwise would be.

To conclude, it is doubtful that anyone has influenced South African vertebrate palaeontology to the degree that Bruce Rubidge has, other than perhaps Robert Broom or James Kitching. Broom's 1945 lecture at Wits led to the creation of the BPI, but it was Bruce's vision and dedication that have guided it to become the connected 21st century institute that it is today. His academic record is impressive (and he still carries his NRF A-rating), yet his greatest legacy is to be found in the vibrant palaeontological community that he has so conscientiously nurtured. The papers in this special issue are dedicated to him.

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