

https://dspace.org/

Complete volume 51

2017-05-02
Evolutionary Studies Institute
http://hdl.handle.net/10539/22444

Downloaded from a DSpace repository. https://dspace.org/

PALAEONTOLOGIA AFRICANA

Volume 51
April 2017

Annals of the
Evolutionary Studies Institute
University of the Witwatersrand



Supported by
PALAEONTOLOGICAL SCIENTIFIC TRUST



ISSN 2410-4418 [Online]

EVOLUTIONARY STUDIES INSTITUTE

Director, Evolutionary Studies Institute

M.K. Bamford BSc (Hons), MSc, PhD (Witwatersrand)

Academic Staff

F. Abdala BSc, PhD (UNT, Argentina)
L.R. Backwell BA (Hons), MSc, PhD (Witwatersrand)
L.R. Berger BA (Hons) (GA Southern), PhD (Witwatersrand)
J.N. Choiniere BSc (Massachusetts), PhD (GWU)
R. Clarke, PhD (Witwatersrand)
C. Henshilwood BA (Hons) (UCT), PhD (Cambridge)
J.F. Thackeray BSc (Hons), MSc (UCT), MPhil, PhD (Yale)
L. Wadley MSc (UCT), PhD (Wits) (Indiana, Bloomington)

University Curator of Collections

B. Zipfel NHD Pod., NHD PS Ed. (TWR), BSc (Hons) (Brighton), PhD (Witwatersrand)

Collections Manager

Mr Sifelani Jirah

Post Doctoral Fellows

Dr Natasha Barbolini
Dr Julien Benoit
Dr Silje Bentsen
Dr Joseph Chikumbirike
Dr Michael Day
Dr Paloma de la Peña
Dr Katja Douze
Dr Marina Elliott
Dr Jennifer Fitchett
Dr Christophe Hendrickx
Dr Sandra Jasinoski
Dr Caroline Phillips
Dr Tammy Reynard
Dr Riaan Rikfin
Dr Mirriam Tawane
Dr Aurore Val
Dr Christopher Woolley

Editorial Panel

J.N. Choiniere, Editor
L.R. Backwell, Associate Editor
M.K. Bamford, Associate Editor
B.S. Rubidge, Associate Editor

Consulting Editors

Dr Roger B.J. Benson, University of Oxford, UK, Dinosauria
Dr Juan Cisneros, Universidade Federal do Piauí Centro de Ciências da Natureza Teresina, PI, Brasil, Parareptiles
Dr Thomas Lehmann, Senckenberg Museum, Germany, Tertiary Mammals
Dr Kieran McNulty, University of Minnesota, USA, Hominid Palaeobiology
Prof. Kevin Padian, University of California, Berkeley, USA, Vertebrate Evolution
Prof. Louis Scott, University of the Free State, Palynology
Dr Chris Sidor, University of Washington, USA, Karoo Therapsids
Dr Roger H. Smith, Iziko South African Museum, Karoo Stratigraphy

Technical and Support Staff

Principal Technician

W.P. Germishuizen

Administrative Secretary

B. Quinn

Senior Administrative Officer

T. Scott-Turner

Technical coordinator

C.B. Dube

Technicians

Mrs Prosper Bande
Mr Wilfred Bilankulu
Mr Roseberry Languza
Mr Justin Makanku
Mr Magezi Maluleke
Mr Gilbert Mokgethoa
Mrs Gladys Mokoma
Mr Pepson Mukanela
Mr Thilivhali Nemavhundi

PALAEONTOLOGIA AFRICANA

ANNALS OF THE EVOLUTIONARY STUDIES INSTITUTE
UNIVERSITY OF THE WITWATERSRAND

ISSN 2410-4418 [Online]

Volume 51, April 2017

CONTENTS

Articles

Thackeray, J.F. & Fitchett, J.M. — Rainfall seasonality captured in micromammalian fauna in Late Quaternary contexts, South Africa **1**

Kuhn, B.F., Herries, A.I.R., Price, G.J., Baker, S.E., Hopley, P., Menter, C. & Caruana, M.V. — Renewed investigations at Taung; 90 years after the discovery of *Australopithecus africanus* **10**

Conference proceedings

Proceedings of the 19th Biennial Conference of the Palaeontological Society of Southern Africa, Stellenbosch, 5–9 July 2016 **27**

© 2017
EVOLUTIONARY STUDIES INSTITUTE
University of the Witwatersrand
Johannesburg

Articles contained in this volume (except where noted otherwise) are published under the Creative Commons Attribution 4.0 Unported License (CC BY 4.0).
This license permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

ACKNOWLEDGEMENTS

The Evolutionary Studies Institute gratefully acknowledges financial support for its programmes by

THE COUNCIL'S RESEARCH COMMITTEE, UNIVERSITY OF THE WITWATERSRAND

DST/NRF CENTRE OF EXCELLENCE IN PALAEONTOLOGICAL SCIENCES

and the

PALAEONTOLOGICAL SCIENTIFIC TRUST (PAST) and its
SCATTERLINGS OF AFRICA PROGRAMMES

for publication of this journal

Cover image: Logo of the 19th Biennial Conference of the Palaeontological Society of Southern Africa, by palaeoartist Dr Owen Li of Petrified Pencils, NSW, Australia

Production by Isteg Scientific Publications, Irene

Rainfall seasonality captured in micromammalian fauna in Late Quaternary contexts, South Africa

J. Francis Thackeray* & Jennifer M. Fitchett

Evolutionary Studies Institute, University of the Witwatersrand, Private Bag X3, WITS 2050, Johannesburg, South Africa

Received 11 April 2016. Accepted 14 July 2016

There exists ongoing debate regarding shifts in the latitudinal extent of the southern African winter-rainfall zone throughout the late Quaternary. Fossil proxies which can be related directly to rainfall seasonality have the potential to assist in quantifying these shifts. Relationships between mean monthly temperature and mean monthly rainfall in modern environments are quantified to generate a seasonality index associated with summer or winter rainfall. These seasonality indices can in turn be related to percentage occurrences reflecting relative abundances of rodent taxa represented in areas within southern Africa. Such data are used together to obtain an equation from which an index of seasonality in rainfall can be calculated, based on relative abundances of rodents in the modern landscape. The equation is applied to rodents represented in a Late Quaternary faunal sequence at Boomplaas Cave in the southeastern part of the Western Cape Province. Results confirm that this region experienced a predominantly winter-rainfall regime during the Last Glacial Maximum (LGM), though the amount of rain may have been relatively low for the coldest episodes *circa* 20 000 cal. yrs BP in the Boomplaas palaeo-environments.

Keywords: rainfall seasonality, Westerlies, microfauna, southern Africa, late Quaternary, Last Glacial Maximum.

Palaeontologia africana 2016. ©2016 J. Francis Thackeray & Jennifer M. Fitchett. This is an open-access article published under the Creative Commons Attribution 4.0 Unported License (CC BY4.0). To view a copy of the license, please visit http://creativecommons.org/licenses/by/4.0/. This license permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited. The article is permanently archived at: http://hdl.handle.net/10539/20851

INTRODUCTION

Situated at the intersection of the subtropical easterly and mid-latitude Westerly belts, southern African climate has a relatively unique boundary between clearly demarcated summer- and winter-rainfall zones (Chase & Meadows 2007; Chevalier & Chase 2015). The winter-rainfall zone, restricted at present to the southwestern Cape of South Africa, is controlled by the Westerlies, and notably the passage of frequent mid-latitude cyclones during winter months when the Inter-Tropical Convergence Zone shifts north (Barrable *et al.* 1998; Chevalier & Chase 2015). The summer-rainfall zone is influenced by a dominant high pressure cell throughout the winter months, and the intrusion of moist air from the Indian Ocean in summer (Carr *et al.* 2006; Mills *et al.* 2012). The resultant environment, and in particular the fauna, of the winter rainfall zone is thus markedly different from that of the interior, characterized by the rich fynbos centre of endemism (Mucina & Rutherford 2007). The most predominant synoptic scale changes that are likely to have occurred during the late Quaternary in South Africa are shifts in the position and strength of the Westerly belt, directly influencing the position of the winter-rainfall zone and associated flora, and indirectly influencing the degree of rainfall seasonality and rainfall patterns in the summer-rainfall zone (Chase & Meadows 2007; Norström *et al.* 2009; Stager *et al.* 2012).

The influence of the Westerlies in southern Africa during the late Quaternary has been of palaeoenvironmental interest for many decades, initiated by the work of Van Zinderen Bakker (1976) and Cockroft *et al.* (1987), who both argued for a considerable northward displacement of both the Westerly zone and of the influence of mid-latitude cyclones. More recent studies within the southern Cape of South Africa have led to some consensus that the strength of the Westerlies and the resultant winter-rainfall zone expanded in both northerly (Barrable *et al.* 1998; Chase & Meadows 2007; Stager *et al.* 2012) and easterly (Carr *et al.* 2006; Chase & Meadows 2007) directions, although the geographic limits of these shifts have yet to be quantified. This is due to difficulties in obtaining direct information pertaining to rainfall seasonality for a particular region from palaeoclimate proxies, which instead reflect broader fluctuations in total precipitation (Chase *et al.* 2015). Recent work presents quantified relative amounts of winter and summer rainfall for specific sites (Chase *et al.* 2015). Changes in the extent of the Westerly belt are not only of importance to the winter-rainfall zone, but also influence the frequency and intensity of mid-latitude cyclones in the interior regions of South Africa.

Existing attempts to reconstruct latitudinal shifts in the position of the Westerlies, and resultant changes in the region of influence of mid-latitude cyclones have predominantly relied on pollen assemblages (*cf.* Coetzee 1967; Norström *et al.* 2009) and climate modelling (Barrable *et al.* 1998; Mills *et al.* 2012). Pollen-based analyses rely on an assumption that the ratio of Poaceae to Asteraceae grains in a representative pollen count reflects the degree of seasonality of rainfall, with a greater Poaceae proportion

*Author for correspondence. E-mail: francis.thackeray@wits.ac.za

ZooBank: urn:lsid:zoobank.org:pub:55F96E3C-2346-4993-8E9D-E9E110326B0 (http://www.zoobank.org)
Permanently archived on the 11th of August 2016 at the University of the Witwatersrand, Johannesburg, South Africa.
The article is permanently archived at: http://hdl.handle.net/10539/20851

indicative of more pronounced summer-rainfall conditions (Coetzee 1967; Norström *et al.* 2009). Diatom and geochemical analyses have been used to explore changes in the amount of precipitation in the summer- (Stager *et al.* 2013) and winter-rainfall (Stager *et al.* 2012) zones, with implications for changes in rainfall seasonality discussed.

This paper proposes a method for identifying changes in rainfall seasonality during the Late Quaternary using fossil rodent abundances from late Quaternary sequences. A case study using fossil rodents from Boomplaas Cave, an archaeological site in the Western Cape of South Africa is used to assess the validity of the method. These results present the first rodent-based quantitative seasonality reconstruction for South Africa. A seasonality index is developed on the basis of the relationship between mean monthly temperature and mean monthly precipitation for South Africa, statistically segregating the contemporary winter rainfall areas which are characterized by an inverse relationship, and summer rainfall areas with positive relationships. These index values are then compared to the contemporary distribution of 12 rodent species common to the fossil record. This relationship, defined by a multiple regression model, is applied to fossil rodent distributions for a Late Quaternary sequence at Boomplaas cave in the southeastern region of the Western Cape published by Avery (1982), Deacon *et al.* (1984) and Thackeray (1987). From this, the rainfall seasonality at Boomplaas throughout the late Quaternary is quantified and temporal trends and cycles investigated.

METHODS

To determine the seasonal gradients across South Africa, a seasonality index was developed on the basis of the relationship between mean monthly temperature and mean monthly rainfall for a set of point locations across South Africa. Records of mean monthly temperature (MMT) and rainfall (MMR) records were obtained from the South African Weather Bureau for periods spanning 48–100 years, for 24 meteorological stations distributed across South Africa (Fig. 1), facilitating the exploration of rainfall to temperature ratios along north–south transects spanning the winter- to summer-rainfall zones. We quantify the seasonal relationship between MMR and MMT by the *m*-coefficient derived from the standard least squares linear regression equation $y = mx + c$, where y refers to the square-root transformed mean monthly rainfall values and x refers to the square-root transformed mean monthly temperature values.

The contemporary spatial distribution of 12 rodent species that are common to the Boomplaas fossil record and the contemporary microfauna of South Africa is determined using the De Graaff (1981) distribution maps, with relative percentage distributions determined for 31 grids at 2° latitude and longitude divisions locations across South Africa, all of which include meteorological stations from which temperature and rainfall measurements can be derived. These relative percentage distributions of each rodent species are then related statistically to the seasonality index score for each point location, defined by the position of the weather station. From this data, a multiple regression equation is developed of the form $m = b_0 + b_1x_1 + b_{2\times2}....b_nx_n$, where x_1, x_2....x_n reflect the relative abundance of each rodent taxon, expressed as percentage occurrences for each study area.

To quantify changes in late Quaternary moisture seasonality, the relative abundance of fossils from the same

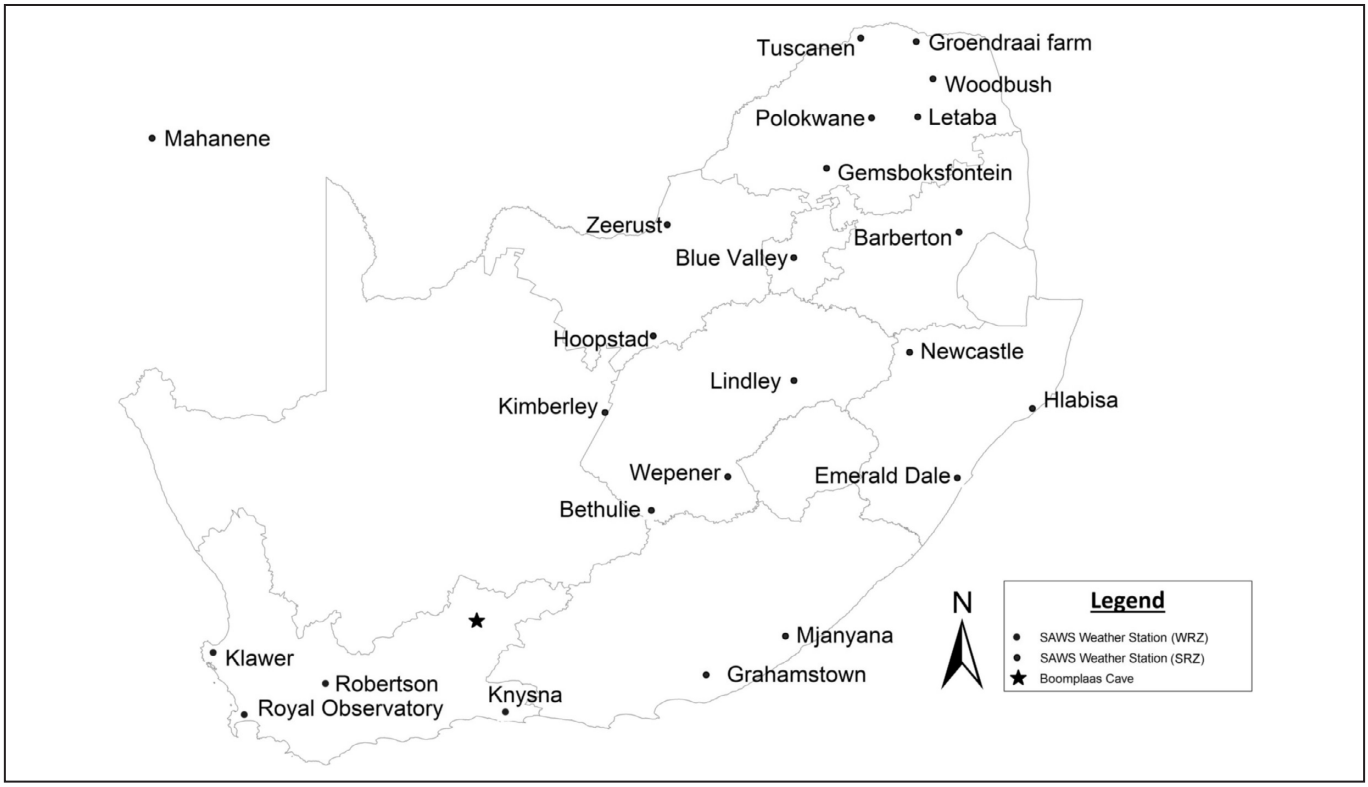

Figure 1. Map indicating the position of the South African Weather Service (SAWS) stations from which contemporary rainfall data were acquired. WRZ = winter rainfall zone; SRZ = summer rainfall zone.

group of 12 rodent fossils from the Boomplaas sequence is entered into the multiple regression model, providing a seasonality index output for each archaeological sample. A total of 12 samples have previously been dated on the basis of radiocarbon isotope analysis of charcoal, and are calibrated in this study using the ShCal13 calibration for the southern hemisphere. Dates for the remaining samples are interpolated using the BACON model, which employs millions of Markov Chain Monte Carlo simulations to provide estimates on the basis of depth, thickness and error margins (Blaauw & Christen 2011). These seasonality index scores calculated from the relative species distribution of rodent fossils from Boomplaas are plotted against age, using the C2 imaging software (Juggins 2007).

RESULTS

Positive values of the *m*-coefficient, or ratio, for MMT and MMR are associated with summer-rainfall regimes, whereas negative values are associated winter-rainfall regions such as Cape Town (Table 1). A value of 0 would indicate the hypothetical situation of equivalent year-round rainfall. The true 'year-round rainfall zone', encompassing much of the southern Cape of South Africa, has some seasonal variation in precipitation, with greater precipitation usually occurring in winter months than in summer. Selecting sites located in the winter rainfall zone (Cape Town), the classified year-round rainfall zone (Knysna), and two locations in the summer rainfall zone at progressively more northeasterly locations (Kimberly and Polokwane), the accuracy of this temperature: rainfall index in reflecting seasonality is confirmed (Fig. 2). The strongest negative *m*-value is obtained for Cape Town ($m = –0.93$), located close to the southernmost tip of Africa, in an undisputed winter-rainfall zone (Table 1, Fig. 2). The strongest positive score is calculated for Polokwane ($m = 1.79$), located in the northern interior of southern Africa (Fig. 2, Table 1). This particularly high *m*-score is driven in part by numerous summer months with zero rainfall; for regions in the northeastern interior, the greater moisture influx from the Indian Ocean moderates these scores somewhat. The variation in the strength and sign of the *m*-coefficient along a north–south gradient, and the dichotomy in sign between undisputed summer- and winter-rainfall zones of South Africa, confirms the application of this *m*-coefficient as a contemporary seasonality index.

It is then necessary to determine the spatial distribution of rodents, as these will be influenced, at least in part, by the temperature and precipitation patterns of a given location (Thackeray 1987; Root *et al.* 2003). The relative percentage distribution of the 12 rodents was determined from the De Graaff (1981) rodent distribution maps for southern Africa, for 2° latitude and longitude grids across South Africa and Namibia (Table 2). Examples of distribution maps for each of the rodents have been previously published (Thackeray 1987).

The contemporary spatial distribution of 12 species of rodents common to the Boomplaas sequence can be related to the *m*-coefficient using multiple regression analysis.

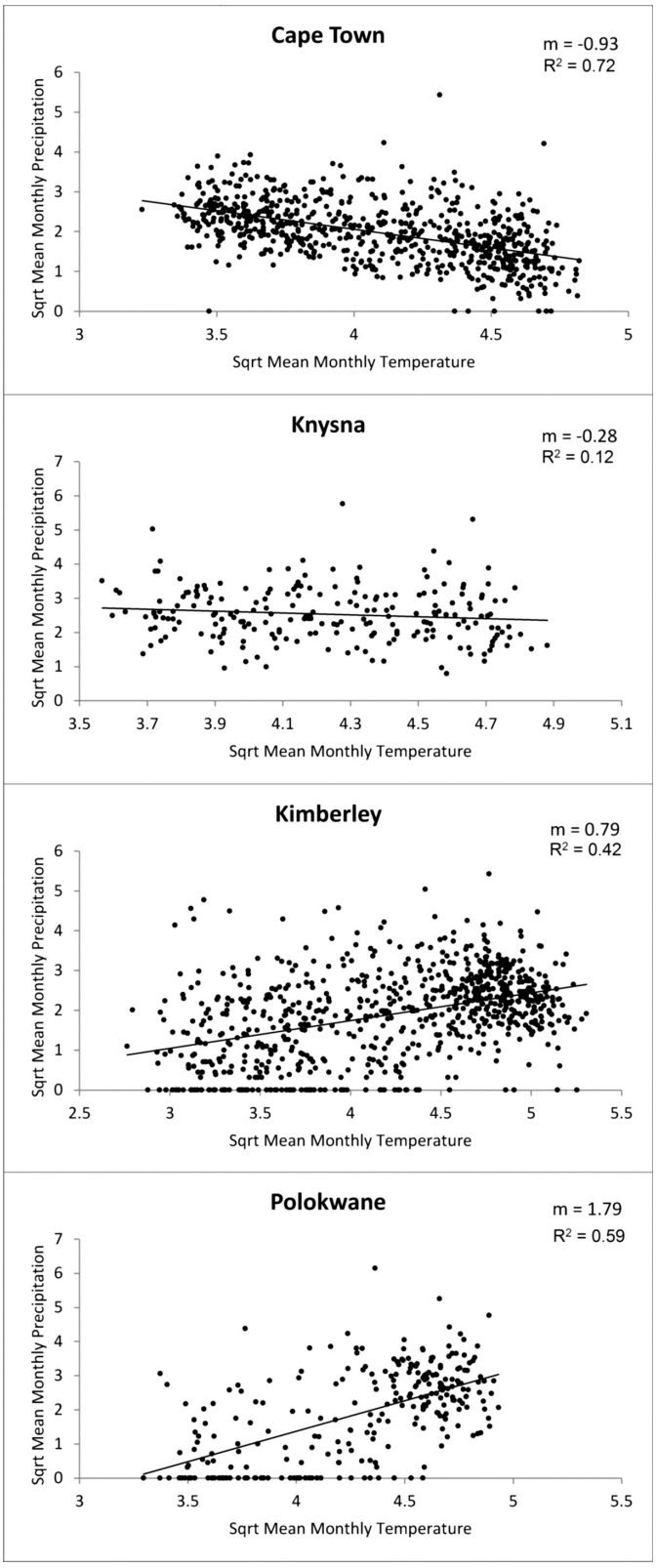

Figure 2. Relationships between square root transformed mean monthly rainfall (MMR) and mean monthly temperature (MMT) for four South Africa locations.

Input values for the calculation of this multiple regression model included the relative percentage distribution of each rodent type, and the rainfall:temperature ratio reflected by the regression term '*m*', for point locations designated at each of the 24 weather stations. The relationship between the *m*-coefficient and proxy measures of

Table 1. Seasonality index values for 20 stations in southern Africa (raw data from the South African Weather Services).

Weather station name and locality	Nearest town	Latitude (°S)	Longitude (°E)	Seasonality index value (*m*-coefficient)	Statistical strength (R^2)	Rainfall zone classification
Polokwane (South Africa)	Polokwane	23.9045	29.4689	1.79	0.59	Summer rainfall
Kimberley (South Africa)	Kimberley	28.7323	24.7623	0.79	0.42	Summer rainfall
Gemsboksfontein (South Africa)	Modimolle	28.4329	27.6740	0.706	0.96	Summer rainfall
Grahamstown (South Africa)	Grahamstown	33.3042	26.5328	0.513	0.82	Summer rainfall
Wepener (South Africa)	Wepener	29.7287	27.0381	0.456	0.96	Summer rainfall
Bethulie (South Africa)	Bethulie	30.4986	25.9746	0.455	0.95	Summer rainfall
Lindley (South Africa)	Bethlehem	27.8833	27.9167	0.380	0.98	Summer rainfall
Hoopstad (South Africa)	Bloemhof	27.8327	25.9083	0.270	0.88	Summer rainfall
Newcastle (South Africa)	Newcastle	27.7393	29.8762	0.260	0.98	Summer rainfall
Zeerust (South Africa)	Groot Marico	25.5370	26.0751	0.250	0.95	Summer rainfall
Emerald Dale (South Africa)	Port Shepstone	29.6833	29.4000	0.241	0.99	Summer rainfall
Barberton (South Africa)	Barberton	25.7884	31.0532	0.199	0.98	Summer rainfall
Mjanyana (South Africa)	Bisho	31.8378	28.1006	0.192	0.96	Summer rainfall
Letaba (South Africa)	Tzaneen	23.9000	30.0667	0.179	0.94	Summer rainfall
Groendraai Farm (South Africa)	Musina	24.1993	27.9848	0.167	0.89	Summer rainfall
Woodbush Forest (South Africa)	Louis Trichardt	23.7212	30.0572	0.167	0.95	Summer rainfall
Blue Valley (South Africa)	Johannesburg	25.9372	28.1152	0.157	0.78	Summer rainfall
Tuscanen (South Africa)	Mapungubwe	22.2075	29.2038	0.137	0.95	Summer rainfall
Hlabisa (South Africa)	Richards Bay	28.1452	31.8772	0.131	0.93	Summer rainfall
Mahanene (Namibia)	Ruacana	14.7830	17.4435	0.037	0.73	Summer rainfall
Klawer (South Africa)	Saldanha	31.7759	18.6250	–0.182	0.88	Winter rainfall
Knysna (South Africa)	Knysna	34.0366	23.0497	–0.28	0.12	Year round rainfall
Robertson (South Africa)	Robertson	33.8034	19.8854	–0.516	0.83	Winter rainfall
Royal Observatory (South Africa)	Cape Town	33.9258	18.4232	–0.93	0.72	Winter Rainfall

Table 2. Percentage distribution of the 12 rodent species for 31 locations across southern Africa interpolated from De Graaff's (1981) rodent distribution maps. *Aethomys namaquensis* **(ANAM),** *Cryptomys hottentotus* **(CHOT),** *Dendromus melanotis* **(DMEL),** *Mus minutoides* **(MMIN),** *Mystromys albicaudatus* **(MALB),** *Otomys irroratus* **(OIRR),** *Otomys laminatus* **(OLAM),** *Otomys saundersae* **(OSAU),** *Otomys unisulcatus* **(OUNI),** *Praomys natalensis* **(PNAT),** *Saccostomus campestris* **(SCAM) and** *Steatomys krebsi* **(SKRE).**

Latitude	Longitude	Province & country	CHOT	ANAM	MMIN	PNAT	MALB	DMEL	SKE	SCAM	OLAM	OSAU	OIRR	OUNI
18	14	Oshakati, Namibia	2.6	25.6	20.5	38.5	0.0	2.6	0.0	10.3	0.0	0.0	0.0	0.0
18	16	Oshana, Namibia	15.4	11.5	15.4	42.3	0.0	0.0	0.0	15.4	0.0	0.0	0.0	0.0
18	20	Runtu, Namibia	14.8	3.7	14.8	33.3	0.0	14.8	0.0	18.5	0.0	0.0	0.0	0.0
20	18	Otjozondjupa, Namibia	8.7	39.1	4.3	30.4	0.0	0.0	0.0	17.4	0.0	0.0	0.0	0.0
22	16	Erongo, Namibia	8.0	52.0	12.0	12.0	0.0	0.0	0.0	16.0	0.0	0.0	0.0	0.0
22	18	Windhoek, Namibia	10.3	34.5	0.0	24.1	0.0	0.0	0.0	31.0	0.0	0.0	0.0	0.0
22	20	Omaheke, Namibia	15.0	20.0	20.0	25.0	0.0	0.0	0.0	20.0	0.0	0.0	0.0	0.0
22	28	Limpopo, South Africa	10.6	42.6	6.4	19.1	0.0	0.0	0.0	21.3	0.0	0.0	0.0	0.0
24	28	Limpopo, South Africa	21.9	17.8	16.4	21.9	0.0	1.4	0.0	19.2	0.0	0.0	1.4	0.0
24	30	Limpopo, South Africa	12.2	14.6	13.4	36.6	0.0	4.9	0.0	11.0	1.2	0.0	6.1	0.0
24	32	Limpopo, South Africa	27.7	15.4	4.6	38.5	0.0	0.0	0.0	13.8	0.0	0.0	0.0	0.0
26	20	Kgalagadi, Namibia	44.0	16.0	20.0	0.0	0.0	12.0	0.0	8.0	0.0	0.0	0.0	0.0
26	26	North West, South Africa	14.8	21.3	4.9	23.0	6.6	9.8	1.6	9.8	0.0	0.0	8.2	0.0
26	28	Gauteng, South Africa	18.0	16.4	10.7	20.5	12.3	4.9	3.3	6.6	0.0	0.0	7.4	0.0
26	30	Limpopo, South Africa	10.9	15.6	10.9	39.1	1.6	6.3	0.0	1.6	1.6	0.0	12.5	0.0
26	32	Mpumalanga, South Africa	11.5	12.8	14.1	38.5	1.3	2.6	0.0	14.1	1.3	0.0	3.8	0.0
28	24	Northern Cape, South Africa	20.8	33.3	0.0	8.3	4.2	0.0	0.0	20.8	0.0	0.0	12.5	0.0
28	26	Bloemfontein, South Africa	20.7	13.8	15.5	29.3	12.1	3.4	1.7	3.4	0.0	0.0	0.0	0.0
28	28	Bloemfontein, South Africa	6.5	11.3	11.3	40.3	19.4	1.6	0.0	0.0	0.0	1.6	8.1	0.0
28	30	KwaZulu-Natal, South Africa	3.0	21.2	7.6	37.9	6.1	3.0	0.0	4.5	0.0	0.0	16.7	0.0
28	32	KwaZulu-Natal, South Africa	9.9	14.1	8.5	35.2	2.8	5.6	0.0	14.1	4.2	0.0	5.6	0.0
30	26	Free State, South Africa	18.0	20.0	10.0	22.0	8.0	2.0	0.0	8.0	0.0	2.0	8.0	2.0
30	28	Free State, South Africa	1.9	25.0	7.7	19.2	9.6	7.7	0.0	0.0	0.0	0.0	28.8	0.0
30	30	KwaZulu-Natal, South Africa	17.7	3.2	12.9	24.2	8.1	8.1	0.0	0.0	4.8	0.0	21.0	0.0
32	18	KwaZulu-Natal, South Africa	11.1	13.9	13.9	0.0	5.6	11.1	1.1	0.0	0.0	8.3	11.1	13.9
32	20	Northern Cape, South Africa	20.7	10.3	10.3	0.0	0.0	3.4	3.4	0.0	0.0	6.9	6.9	37.9
32	28	Eastern Cape, South Africa	12.3	8.8	12.3	26.3	12.3	0.0	0.0	5.3	0.0	10.5	12.3	0.0
33.5	22	Western Cape, South Africa	18.0	13.1	8.2	0.0	4.9	9.8	3.3	1.6	1.6	4.9	14.8	19.7
33.5	24	Eastern Cape, South Africa	20.0	16.7	10.0	3.3	3.3	3.3	3.3	6.7	0.0	0.0	10.0	23.3
33.5	26	Eastern Cape, South Africa	4.5	4.5	9.1	18.2	0.0	0.0	0.0	0.0	0.0	0.0	18.2	45.5
34	24	Western Cape, South Africa	9.4	9.4	6.3	20.3	3.1	3.1	0.0	9.4	0.0	7.8	14.1	17.2

relative abundances of modern rodent taxa, obtained from multiple linear regression analysis is given by:

m = 0.468ANAM + 0.474CHOT + 0.470DMEL + 0.468MMIN + 0.484MALB + 0.490OIRR + 0.419OLAM + 0.464OSAU + 0.467OUNI + 0.478PNAT + 0.487SCAM + 0.465SKRE – 47.353 (r = 0.758)

where the proxies for relative abundances of rodent taxa are percentage occurrences of the following taxa: *Aethomys namaquensis* (ANAM), *Cryptomys hottentotus* (CHOT), *Dendromus melanotis* (DMEL), *Mus minutoides* (MMIN), *Mystromys albicaudatus* (MALB), *Otomys irroratus* (OIRR), *Otomys laminatus* (OLAM), *Otomys saundersae* (OSAU), *Otomys unisulcatus* (OUNI), *Praomys natalensis* (PNAT), *Saccostomus campestris* (SCAM) and *Steatomys krebsi* (SKRE).

For validation purposes, this equation has been tested against climate datasets for a further 20 years for four locations, with a correlation in output described by Pearson's correlation coefficient at r = 0.89 (P > 0.001).

To explore the fluctuations in late Quaternary rainfall seasonality, this equation can be applied to the relative percentage distributions of fossil rodent assemblages throughout a quantified period of time. The fossil rodent assemblages from Boomplaas Cave (Avery 1982; Deacon *et al.* 1984; Thackeray 1987) were selected due to the high quality of preservation, and the position of the cave at the southwestern-most border of the summer rainfall zone. The proportional distribution of the rodent species was determined from 38 archaeological samples from the Boomplaas excavation, as detailed by Thackeray (1987). Radiocarbon dates were available for 12 samples, as outlined in Table 3. Dates were calibrated using ShCal13, and for the remaining samples, age–depth interpolations were made using the BACON model (Fig. 3). The sequence is confirmed to span the late Quaternary from ~80 000 cal. yrs BP to present, with high sample resolution spanning the LGM, terminal Pleistocene and Holocene (Fig. 3).

The multiple regression equation relating the contemporary rodent distribution to the contemporary rainfall seasonality is then applied to these microfaunal data. The m-coefficient for each sample, derived from the multiple regression equation, is plotted against age (Fig. 4), to deter-

Table 3. Radiocarbon dates for the samples used in the palaeoenvironmental reconstruction presented in this study. Conventional dates calibrated using ShCal13.

Sample number	Sample name	Top depth (m)	Bottom depth (m)	Laboratory code	Radiocarbon date (yr BP)	Uncertainty (yr)
50	DGLL1	0.28	0.42	UW-337	1 630	50
52	BLD2	0.82	0.83	UW-338	1 700	50
57	BLA	0.88	0.97	UW-306	6 400	75
59	BRL2	1.10	1.21	UW-410	9 100	135
63	BRL6	1.26	1.30	UW-411	10 425	125
65	CL1	1.30	1.40	Pta-1828	12 060	105
67	CL3	1.50	1.60	UW-301	14 200	240
68	GWA	1.60	1.67	Pta-3283	17 830	180
73	LPC2CB	2.03	2.23	UW-300	21 110	420
76	YOL	2.23	2.63	UW-304	32 400	700
80	OLP1	3.10	3.17	Pta-1811	37 390	1370
81	OLP2	3.18	3.30	UW-305	40 000	Radiocarbon limit

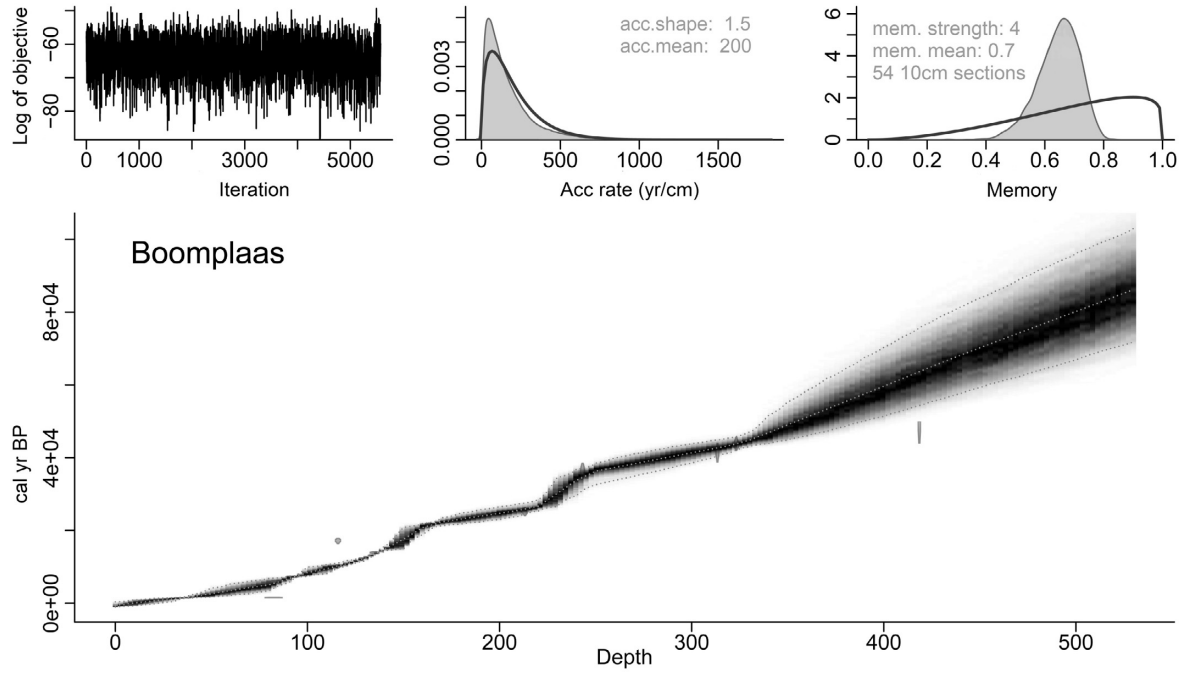

Figure 3. Age–depth output from the BACON model.

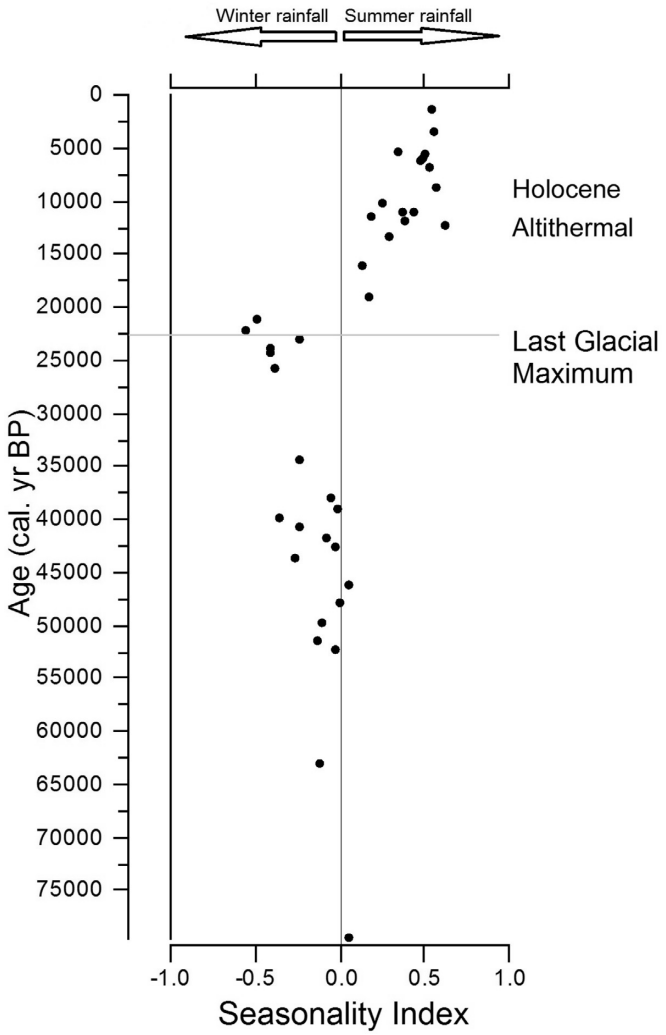

Figure 4. Temporal variability in rainfall seasonality calculated from the relative abundances of rodents at Boomplaas Cave, based multiple regression analysis of rodent data and *m*-coefficient based on modern climatic statistics.

mine fluctuations in rainfall seasonality at Boomplaas Cave throughout the late Quaternary. A notable shift from negative to positive *m*-coefficient scores is notable at ~19 200 cal. yrs BP; coinciding with the termination of the LGM. The strongest negative scores (m = –0.403 – m = –0.546) are calculated from ~23 940–21 270 cal. yrs BP (Fig. 4); coinciding with the coldest period of the LGM (Scott 1999). The *m*-coefficient scores increase throughout the terminal Pleistocene and early Holocene to a sustained peak (m = 0.542 – m = 0.573) from ~8840–7030 cal. yrs BP (Fig. 4), potentially indicating the Holocene Altithermal (Neumann *et al.* 2014). Following fluctuations in the mid- to late-Holocene, sustained strong positive scores mark the period 3360 cal. yrs BP to present (Fig. 4). It should also be noted that for much of the late Pleistocene period from ~80 000 cal. yrs BP – 39 050 cal. yrs BP, the seasonality index scores were very close to zero (Fig. 4), indicating that the site would have been characterized by year-round rainfall with no distinct seasonality.

DISCUSSION AND CONCLUSIONS

Following Van Zinderen Bakker (1974) and Tyson's (1986) models of southern African climatic change, periods of increased winter rainfall are associated with a northward displacement of the Westerlies. Microfauna results from Boomplaas indicate a striking difference in rainfall seasonality before and after the LGM. The strongest negative seasonality index values coincide with the LGM (Fig. 3), indicating that during this period, the climate at Boomplaas was characterized by winter-rainfall conditions when temperatures may have been at least 5°C lower than modern conditions. (Partridge 1999; Holmgren *et al.* 2003). This is supported by findings from glacial moraines in eastern Lesotho (Mills *et al.* 2012), and pollen and diatom results for Braamhoek Wetland in the Free State (Norström *et al.* 2009; 2014).

Seasonality index scores close to zero, indicating low seasonality of rainfall similar to that of the contemporary year-round rainfall zone are noted prior to the LGM, with stronger negative seasonality index scores from ~63 100–49 900 cal. yrs BP (Fig. 4). There is an abrupt shift to positive seasonality index scores at ~19 210 cal. yrs BP (Fig. 4), indicating a rapid shift from winter-rainfall to summer-rainfall conditions at Boomplaas. Summer-rainfall to year-round-rainfall conditions characterize the climate of the site today. The rainfall seasonality index correlates closely with inferred changes in temperature for Boomplaas (Thackeray 1987). The seasonality chronology presented here is notably also similar to climatic reconstructions for Seweweekspoort (Chase *et al.* 2013) and Cango Caves (Talma & Vogel 1992), both located in close proximity to Boomplaas. This association would suggest that changes in the seasonality index for the Pleistocene/Holocene transition may be attributable to displacements in the Westerlies (Chase *et al.* 2013; Chevalier & Chase 2015). However, low moisture index values for Boomplaas samples inferred from rodent fossils from units dated from ~23 940–21 270 cal. yrs BP, provide good evidence for relatively dry conditions in comparison with Holocene climates in the same region. If equator-ward displacement of the Westerlies brought more winter rainfall to the southern Cape during the LGM, it is probable that moisture availability for plant and animal growth may have been limited during this period (Mills *et al.* 2012).

Notably, Chase *et al.* (2013) highlight a pronounced dry period from 7–5 cal. yrs BP, which they associate with a southward retreat of the Westerlies. The seasonality index for Boomplaas indicates a period of strongest positive scores from ~8840–5720 cal. yrs BP (Fig. 4), which reflecting more pronounced summer-rainfall conditions, would similarly require a southward displacement of the Westerlies. This is followed by significantly reduced seasonality index values at Boomplaas, which are largely consistent with the reduced temperatures at Cango Cave (Talma & Vogel 1992; Stute & Talma 1998), as a reduction strong summer-rainfall seasonality would be associated with a northward return of the Westerlies, and an increased incidence of mid-latitude cyclones and associated cold front conditions. The seasonality chronology for Boomplaas is also largely consistent with climate reconstructions for what Chevalier & Chase (2015) define as the region influenced predominantly by shifts in the Westerlies. The timing of the shift in seasonality marking the termination of the LGM is consistent with that for the South Atlantic,

occurring earlier than for the regions dominated by the warmer Indian Ocean (Sonzogni *et al.* 1998).

Proxy-based climate reconstructions are inherently limited in their accuracy due to the complexity of environmental factors which control the proportional abundances of sub-groups of the proxy (Jackson 2012; Juggins 2013). It is therefore difficult to assign a trend specifically to a unique climate driver, rather than to the more complex interrelationship of climatic and non-climatic forces (Juggins 2013). It is for this reason that this study begins with modelling patterns in rainfall seasonality across South Africa from contemporary multi-decadal meteorological records. These records are then related to the contemporary spatial distribution of a group of rodents consistent with those in the fossil record. In so doing, a transfer function is developed, improving the accuracy from more qualitative interpretations from the fossil assemblages alone (Fritz *et al.* 1991; Stevenson & Pan 2004; Juggins 2013)

This study makes two significant contributions to improved understanding of late Quaternary variations in South African rainfall seasonality, and causal shifts in the Westerlies. At a broad scale, this study responds to the continued call for, and attempts in finding, proxies of palaeoclimatic rainfall seasonality in southern Africa (*cf.* Van Zinderen Bakker 1976; Barrable *et al.* 1998; Chase & Meadows 2007; Stager *et al.* 2012), by presenting the application of fossil microfauna. More specifically, through the application of this approach, this study confirms winter-rainfall conditions at Boomplaas during the LGM, associated with lowered mean annual precipitation, and a transition to summer-rainfall conditions at the termination of the LGM, which persist throughout the Holocene This contributes to improving the understanding of regional rainfall variability during the LGM and particularly under periods of shifts in the extent of the Westerlies. While it is a challenge to try to integrate data from micromammals (in this case rodents and insectivores) with climatic data, we believe that this approach provides a valuable contribution to the reconstruction of rainfall seasonality throughout the late Quaternary. Moreover, in this particular instance, the data reveal that winter rainfall during the time of the Last Glacial Maximum in the southern Cape coincided with limited precipitation, such that cold, dry conditions prevailed.

This work was supported by the National Research Foundation and the Andrew Mellon Foundation through grants awarded to J.F.T., and the DST/NRF Centre of Excellence for Palaeosciences through grants awarded to J.M.F.

REFERENCES

AVERY, D.M. 1982. Micromammals as palaeoenvironmental indicators and an interpretation of the late Quaternary in the southern cape province, South Africa. *Annals of the South African Museum* **8**, 183–374.

BARRABLE, A., MEADOWS, M.E. & HEWITSON, B.C. 1998. Environmental reconstruction and climate modelling of the Late Quaternary in the winter rainfall region of the Western Cape, South Africa. *South African Journal of Science* **98**, 611–616.

BLAAUW, M. & CHRISTEN, J.A. 2011. Flexible paleoclimate age–depth models using an autoregressive gamma process. *Bayesian Analysis* **6**(3), 457–474.

CARR, A.S., THOMAS, D.S.G., BATEMAN, M.D., MEADOWS, M.E. & CHASE, B. 2006. Late Quaternary palaeoenvironments of the winter-rainfall zone of southern Africa: Palynological and sedimentological evidence from the Agulhas Plain. *Palaeogeography, Palaeoecology, Palaeoclimatology* **239**, 147–165.

CHASE, B.M. & MEADOWS, M.E. 2007. Late Quaternary dynamics of southern Africa's winter rainfall zone. *Earth Science Reviews* **84**, 103–138.

CHASE, B.M., BOOM, A., CARR, A.S., MEADOWS, M.E. & REIMER, P.J. 2013. Holocene climate change in southernmost South Africa: rock hyrax middens record shifts in southern westerlies. *Quaternary Science Reviews* **82**, 199–205.

CHASE, B.M., LIM, S., CHEVALIER, M., BOOM, A., CARR, A.S., MEADOWS, M.E. & REIMER, P.J. 2015. Influence of tropical easterlies in southern Africa's winter rainfall zone during the Holocene. *Quaternary Science Reviews* **107**, 138–148.

CHEVALIER, M. & CHASE, B.M. 2015. Southeast African records reveal a coherent shift from high- to low-latitude forcing mechanisms along the east African margin across last glacial–interglacial transition. *Quaternary Science Reviews* **125**, 117–130.

COCKROFT, M.J., WILKINSON, M.J. & TYSON, P.D. 1987. The application of a present-day climatic mode to the Late Quaternary in southern Africa. *Climatic Change* **10**, 161–181.

COETZEE, J.A. 1967. Pollen analytical studies in East and southern Africa. *Palaeoecology of Africa* **3**, 1–146.

DEACON, H.J., DEACON, J., SCHOLTZ, A., THACKERAY, J.F., BRINK, J.S. & VOGEL, J.C. 1984. Correlation of palaeoenvironmental data from the late Pleistocene and Holocene deposits at Boomplaas cave, Southern Cape. **In**: J.C. Vogel (ed.), Late Cainozoic Palaeoclimates of the Southern Hemisphere, 339–352. Rotterdam, Balkema.

DE GRAAFF, G. 1981. *The Rodents of Southern Africa.* Durban, Butterworths.

FRITZ, S.C., JUGGINS, S., BATTARBEE, R.W. & ENGSTRUM, D.R. 1991. Reconstruction of past changes in salinity and climate using a diatom-based transfer function. *Nature* **352**, 706–708.

HOLMGREN, K., LEE-THORP, J.A., COOPER, G.R.J., LUNDBLAD, K., PARTRIDGE, T.C., SCOTT, L., SITHALDEEN, R., TALMA, A.S. & TYSON, P.D. 2003. Persistent millennial-scale climatic variability over the past 25 000 years in southern Africa. *Quaternary Science Reviews* **22**, 2311–2326.

JACKSON, S. 2012. Representation of flora and vegetation in Quaternary fossil assemblages: known and unknown knowns and unknowns. *Quaternary Science Reviews* **49**, 1–15.

JUGGINS, S. 2007. C2, Software for ecological and palaeoecological data analysis and visualisation, User guide Version 1.5. Retrieved on 11 July 2014 from www.staff.ncl.ac.uk/stephen.juggins/software/code/C2.pdf

JUGGINS, S. 2013. Quantitative reconstructions in palaeolimnology: new paradigm or sick science? *Quaternary Science Reviews* **64**, 20–32.

MILLS, S., GRAB, S., REA, B., CARR, S. & FARROW, A. 2012. Shifting westerlies and precipitation patterns during the Late Pleistocene in southern Africa determined using glacier reconstruction and mass balance modelling. *Quaternary Science Reviews* **55**, 145–159.

MUCINA, L. & RUTHERFORD, M.C. 2006. *The Vegetation of South Africa, Lesotho and Swaziland*. Cape Town, South African National Biodiversity Institute.

NEUMANN, F.H., BOTHA, G.A. & SCOTT, L. 2014. 18,000 years of grassland evolution in the summer rainfall region of South Africa: evidence from Mahwaqa Mountain, KwaZulu-Natal. *Vegetation History and Archaeobotany* **23**(6), 665–681.

NORSTRÖM, E., SCOTT, L., PARTRIDGE, T., RISBERG, J. & HOLMGREN, K. 2009. Reconstruction of environmental and climate changes at Braamhoek wetland, eastern escarpment South Africa, during the last 16 000 years with emphasis on the Pleistocene–Holocene transition. *Palaeogeography, Palaeoecology, Palaeoclimatology* **271**(3), 240–258.

NORSTRÖM, E., NEUMANN, F.H., SCOTT, L., SMITTENBERG, R.H., HOLMSTRAND, H., LUNDQVIST, S., SNOWBALL, I., SUNDQVIST, H.S., RISBERG, J. & BAMFORD, M. 2014. Late Quaternary vegetation dynamics and hydro-climate in the Drakensberg, South Africa. *Quaternary Science Reviews* **105**, 48–65.

PARTRIDGE, T.C., SCOTT, L. & HAMILTON, J.E. 1999. Synthetic reconstructions of southern African environments during the Last Glacial Maximum (21–18 kyr) and the Holocene altithermal (8–6 kyr). *Quaternary International* **57/58**, 207–214.

ROOT, T., PRICE, J., HALL, K., SCHNEIDER, S., ROSENZWEIG, C. & POUNDS, J. 2003. Fingerprints of global warming on wild animals and plants. *Nature* **421**, 57–60.

SCOTT, L. 1999. Vegetation history and climate in the Savanna biome South Africa since 190,000 ka: a comparison of pollen data from the Tswaing Crater (the Pretoria Saltpan) and Wonderkrater. *Quaternary International* **57/58**, 215–223.

SONZOGNI, C., BARD, E. & ROSTEK, F. 1998. Tropical sea-surface temperatures during the last glacial period: a view based on alkenones in Indian Ocean sediments. *Quaternary Science Reviews* **17**, 1185–1201.

STAGER, J.C., MAYEWSKI, P.A., WHITE, J., CHASE, B.M., NEUMANN, F.H., MEADOWS, M.E., KING, C.D. & DIXON, D.A. 2012. Precipitation variability in the winter rainfall zone of South Africa during the last 1400 yr linked to the austral westerlies. *Climate of the Past* **8**, 877–887.

STAGER, J.C., RYVES, D.B., KING, C., MADSON, J., HAZZARD, M., NEUMANN, F.H. & MAUD, R. 2013. Late Holocene precipitation variability in the summer rainfall region of South Africa. *Quaternary Science Reviews* **67**, 105–120.

STEVENSON, R.J. & PAN, Y. 2004. Assessing environmental conditions in rivers and streams with diatoms. **In**: E.F Stoermer & J.P. Smol (eds), *The Diatoms: Applications for the Environmental and Earth Science*, 11–40. Cambridge, Cambridge University Press.

STUTE, M. & TALMA, A.S. 1998. Glacial temperatures and moisture transport regimes reconstructed from noble gas and d18O, Stampriet aquifer, Namibia. **In**: *Isotope Techniques in the Study of Past and Current Environmental Changes in the Hydrosphere and the Atmosphere*, 307–328 IAEA Vienna Symposium 1997, Vienna.

TALMA, A.S. & VOGEL, J.C. 1992. Late Quaternary paleotemperatures derived from a speleothem Cango Caves, Cape Province, South Africa. *Quaternary Research* **213**, 203–213.

THACKERAY, J.F. 1987. Late Quaternary environmental changes inferred from small mammalian fauna, southern Africa. *Climatic Change* **10**, 285–305.

TYSON, P.D. 1986. *Climatic Change and Variability in Southern Africa*. Cape Town, Oxford University Press.

VAN ZINDEREN BAKKER, E.M. 1976. The evolution of late Quaternary paleoclimates of southern Africa. *Palaeoecology of Africa* **9**, 160–202.

Renewed investigations at Taung; 90 years after the discovery of *Australopithecus africanus*

Brian F. Kuhn[1*], Andy I.R. Herries[2,1], Gilbert J. Price[3], Stephanie E. Baker[1], Philip Hopley[4,5], Colin Menter[1] & Matthew V. Caruana[1]

[1]*Centre for Anthropological Research (CfAR), House 10, Humanities Research Village, University of Johannesburg, Bunting Road Campus, Auckland Park, 2092, South Africa*

[2]*The Australian Archaeomagnetism Laboratory, Department of Archaeology and History, La Trobe University, Melbourne Campus, Bundoora, 3086, VIC, Australia*

[3]*School of Earth Sciences, University of Queensland, St Lucia, QLD, Australia*

[4]*Department of Earth and Planetary Sciences, Birkbeck, University of London, London, WC1E 7HX, U.K.*

[5]*Department of Earth Sciences, University College London, London, WC1E 6BT, U.K.*

Received 10 July 2015. Accepted 15 July 2016

2015 marked the 90th anniversary of the description of the first fossil of *Australopithecus africanus,* commonly known as the Taung Child, which was unearthed during blasting at the Buxton-Norlim Limeworks (referred to as the BNL) 15 km SE of the town of Taung, South Africa. Subsequently, this site has been recognized as a UNESCO World Heritage site on the basis of its importance to southern African palaeoanthropology. Some other sites such as Equus Cave and Black Earth Cave have also been investigated; but the latter not since the 1940s. These sites indicate that the complex of palaeontological and archaeological localities at the BNL preserve a time sequence spanning the Pliocene to the Holocene. The relationship of these various sites and how they fit into the sequence of formation of tufa, landscapes and caves at the limeworks have also not been investigated or discussed in detail since Peabody's efforts in the 1940s. In this contribution we mark the 90th anniversary of the discovery and description of the Taung Child by providing a critical review of previous work at Taung based on our recent preliminary work at the site. This includes a reassessment of the Taung Child Type Site, as well as renewed excavations at Equus Cave and the lesser-known locality and little-investigated Black Earth Cave. Preliminary results suggest that much of our previous understandings of the BNL's formational history and site formation processes need to be reassessed. Only through detailed analysis on the BNL as a whole can we understand this complex depositional environment.

Keywords: Taung Child, Geochronology, *Australopithecus africanus*, Plio-Pleistocene, Equus Cave, Black Earth Cave, Later Stone Age.

Palaeontologia africana 2016. ©2016 Brian F. Kuhn, Andy I.R. Herries, Gilbert J. Price, Stephanie E. Baker, Philip Hopley, Colin Menter & Matthew V. Caruana. This is an open-access article published under the Creative Commons Attribution 4.0 Unported License (CC BY4.0). To view a copy of the license, please visit http://creativecommons.org/licenses/by/4.0/. This license permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited. The article is permanently archived at: http://wiredspace.wits.ac.za/handle/10539/21251

INTRODUCTION AND BRIEF HISTORICAL BACKGROUND

In November of 1924, geologists R.B. Young delivered a 'cercopithecid' skull from the Buxton-Norlim Limeworks (BNL), near Taung (now the North West Province), South Africa, for description to Raymond Dart at the University of the Witwatersrand Medical School (Tobias 1985). This 'monkey' turned out to be something rather different, representing the first early hominin fossil ever recovered from Africa and the type specimen for *Australopithecus africanus* (Dart 1925). Numerous adult versions have since been found at the sites of Sterkfontein, the Makapansgat Limeworks and possibly Gladysvale (Berger *et al.* 1992; Broom 1938; Dart 1948). The identification of the 'Taung Child' as an early human ancestor changed contemporary perspectives on human evolution and generated interest in the site of Taung(s) as an important palaeoanthropological locality.

Immediately following Dart's 1925 *Nature* paper, a number of researchers made exploratory trips to the BNL and produced publications. These included Hrdlička (1925), Young (1925), Cipriani (1928), Dart (1926, 1929) and Broom (1925a,b, 1929, 1930, 1934, 1938, 1939, 1943, 1945, 1946, 1948a,b). Most collected fossils in no strategic or documented fashion. While Hrdlička (1925) attempted to recover *in situ* fossils at the proposed site of the Taung Child discovery, it seems this consisted of only a few fragments of primate skull due to the heavily calcified nature of the 'pinkish' deposits.

Despite these early investigations into the type locality of *Australopithecus africanus,* a proper exploratory foray into the region only occurred in 1947–48 when Frank Peabody and Charles Camp conducted work at the BNL as part of the University of California Africa Expedition (Camp 1948; Peabody 1954). This work identified several important fossil and archaeological sites at the BNL and in the surrounding area. This involved excavations at the proposed location of the recovery of the Taung Child and excavations at another site termed Black Earth Cave, although the descriptions of any actual excavations were minimal. This was followed by isolated

*Author for correspondence. E-mail: kuhnbf@gmail.com

ZooBank: urn:lsid:zoobank.org:pub:55F96E3C-2346-4993-8E9D-E9E110326B0 (http://www.zoobank.org)
Permanently archived on the 20th of October 2016 at the University of the Witwatersrand, Johannesburg, South Africa.
Both the supplement and the article are permanently archived at: http://wiredspace.wits.ac.za/handle/10539/21251

geological work by Butzer (1974) and Partridge (1985) and excavations at Equus Cave in 1978 by Myra Shackley (1981) and by Peter Beaumont in 1982 (Klein *et al.* 1991). Until recently, the last expedition into the region was under the direction of Phillip Tobias, of the University of the Witwatersrand Medical School and run by Toussaint & McKee in 1988 and by McKee from 1989 to 1994 (McKee 1993a,b, 1994; McKee & Tobias 1990, 1994).

In 1994, McKee published a catalogue of fossil sites that still exist in the demarcated world heritage site. Some of these were previously identified by Peabody (Cooke 1990; Peabody 1954), while teams led by McKee discovered others. While Peabody's (1954) geological description of the BNL remains the most definitive to date, it was conducted at a time of active mining and as such much more of the deposit had been removed by the time the Tobias expedition took place. The 17 fossil deposits documented by McKee (1994) are the: Hrdlička deposits, Dart deposits, Tobias Pinnacle deposit, Berger Cave complex, Lucky Moon Cave complex, LSN Cave, Innominate Cave, Cut-through Alley, Quinney Cave, Black Earth Cave, Equus Cave, Peabody's Equus Site, Blom Cave, Acacia Cave, Satan Cave, Oxland Large Mammal Site and Alcove Cave (McKee 1994; Fig. 1). Sites documented earlier such as Spiers' Cave, Tobias Cave and Peabody Cave have yet to be relocated and may have been eroded away as mining at the site continued until the 1970s. Tobias and McKee's efforts mark the last period of scientific research at the site, now some 20 years ago, albeit most of these localities remain unexplored as they concentrated their efforts at the Taung Child Type Site; represented by the Dart and Hrdlička deposits.

A RENEWED MULTIDISCIPLINARY RESEARCH AGENDA AT TAUNG

Despite its pivotal role in redirecting human evolutionary studies towards Africa, the fact that: 1) only one hominin has ever been recovered from the Taung Type Site; 2) its distance (360 km) from the major research universities; and 3) the discovery of richer hominin sites in what is known locally as the Cradle of Humankind, just outside of Johannesburg, has meant that Taung has not undergone the extensive scientific work compared to other sites such as Sterkfontein and Swartkrans. Thus, despite 90 years since the discovery of the Taung Child there are many things that we do not know about the fossil, including its age and the local environments in which it lived. Yet these are extremely important questions given how little we know about early hominin evolution in southern Africa outside the 300 km^2 dolomite area of the Cradle of Humankind, or outside the time range between 2.6 and 1.4 Ma (Herries *et al.* 2009, 2013). Moreover, virtually nothing is known about the other sites at the Taung World Heritage Site, other than Equus Cave, whose exact age is still a matter of debate (Johnson *et al.* 1997). These other sites potentially preserve a rich record of the Middle Pleistocene to Holocene period. Investigations into the fossil and archaeological remains of this time period are sparse for the interior regions of South Africa. Black Earth Cave remains essentially unstudied beyond Peabody's (1954) very limited description of work at the site. While the Type Site may always remain the primary focal point of scientific interest at Taung, these lesser-known sites are potentially critical for illuminating the true expanse of time preserved at the heritage site.

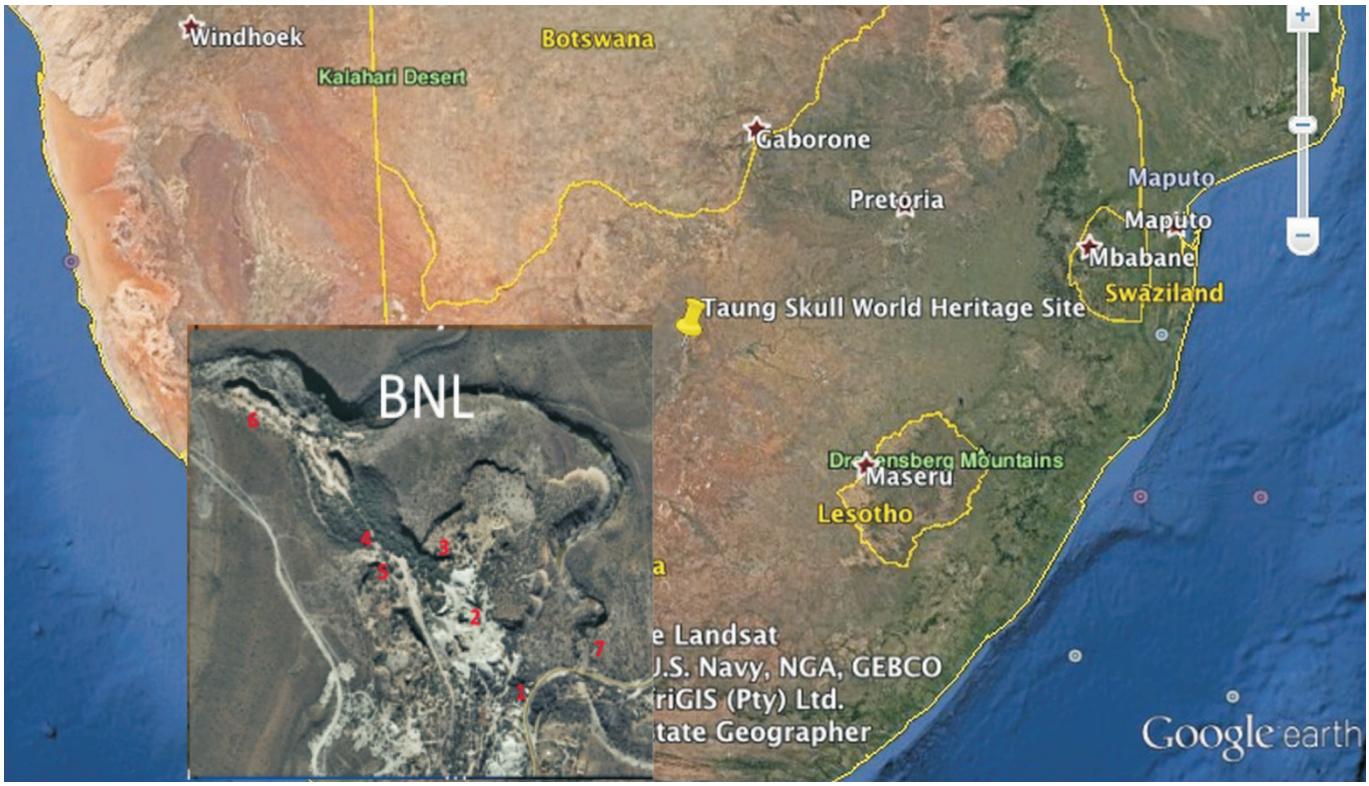

Figure 1. Map showing Taung in South Africa. The Buxton-Norlim Limeworks is 16 km south west of Taung. 1 is the location of the dump prior to recovery. 2 is the location of the Type Site. 3 is the location of Black Earth cave. 4 is the location of Quinney Cave. 5 is the location of Equus Cave. 6 is the Oxland large mammal site and 7 is the location of Power House Cave.

In an effort to address these issues, a multidisciplinary team of international scientists (from South Africa, Australia and the U.K.) returned to the BNL in 2010 to gain a better understanding of the geology, palaeontology and archaeology of the site and to review previous interpretations. Current results of this renewed research are presented below according to site and interpretive focus, which includes the Type Site (geology, site formation and geochronology), Black Earth Cave (BEC; palaeontology) and Equus Cave (EQC; archaeology); as well as work on the overall sequencing of geological events at the Limeworks. A discussion of the historical interpretations of these sites is presented along with preliminary reinterpretations and discoveries resulting from the current research. These results demonstrate a significant need to reinvestigate and reinterpret the BNL localities using a wider research perspective than previously employed. The localities described below form an initial stage of ongoing investigation that will provide new insight into the potential for multidisciplinary studies at the BNL. In turn, this renewed agenda will re-establish the significance of the BNL as preserving a rich record of fossil and artefact accumulations that span well beyond the time of *Australopithecus africanus* stretching from the Pliocene to the Holocene.

THE TYPE SITE

While the Taung Child's exact provenance was not recorded during its removal from what is now referred to as the 'Type Site' locality (Figs 1 & 2) its association to the remaining deposits has been reasonably well established as outlined below; especially when new chronological data are taken into account. It is also well established that three main sedimentological types of deposit exist at the Type Site: the Thabaseek Tufa itself; a fluvially deposited (although with some aeolian influence), pale reddish-brown to pink claystone and siltstone (here termed PCS after terminology of Hopley *et al.* 2013); and an aeolian, yellowish-red sandstone and siltstone (here termed YRSS after the terminology of Hopley *et al.* 2013) (Butzer *et al.* 1978; Partridge *et al.* 1991; Peabody 1954; Tobias *et al.* 1993). What is debated more is the mode of deposition of the various deposits at the Type Site and their relationship to each other (discreet carapace caves, a large solution cave or landscape surface), as also outlined below.

Hrdlička (1925) notes the associations of the skull with a 'pinkish deposit' based on the skull matrix and *in situ* deposits of what became known as the Hrdlička Site or Pinnacle. Peabody (1954) conducted extensive interviews with miners who were around at the time the Taung Child skull was extracted and confirmed that it came from a location between and slightly to the south of the two remnants (the easterly Hrdlička Pinnacle and westerly Dart Pinnacle; the later also termed the *Australopithecus* Pinnacle; Fig. 2; McKee & Tobias 1994; Partridge 2000) of the Thabaseek Tufa and associated sediments that were left in place by the mine manager. The term Dart Pinnacle is used here as it does not infer an origin for the skull itself.

A number of interpretations of the geological and fossil accumulations associated with these Type Site deposits have been proposed, although they all suggest they represent a cave of some sort, as suggested by the geologist



Figure 2. North-facing photograph of the Type Site, Dart and Hrdlička Pinnacles in the BNL. Locations of cores taken in 2012, the Dart deposits and the purported location of the Taung Child Skull are all shown.

Young in 1925 and Broom in 1946 ('Dart Cave', 'Hrdlička Cave', 'Australopithecus Cave' and 'Spiers' Cave'), typical of most early hominin fossil deposits on the southern African landscape during the Plio-Pleistocene, and certainly true for the case of younger sites of Equus Cave and Black Earth Cave (see below). The hypothesis that the tufa formations were riddled with later cave systems has been widely accepted in publications describing the Type Site (Broom 1946; Butzer 1974; McKee 1993b; McKee & Tobias 1994; Peabody 1954; Tobias 1985; Young 1925). However, different opinions exist as to the nature of the caves.

Hrdlička (1925) notes the fossil material he collected as having come from a pinkish deposit. He notes that fossil turtle (actually terrapin (Pelomedusidae)) and eggs collected by the lime miners came from what was termed the 'long cave', whereas the monkeys occurred only in the in-filled tunnels and one in particular. Kuhn *et al.* (2015) recently identified eggshells from these deposits as belonging to two different, granivorous and carnivorous, avian guilds (Numididae [helmeted guinea fowl] and Aquilinae [black eagle]), the last perhaps associated with the suggested accumulator of the Taung Child itself (Berger & Clarke 1995). Hrdlička (1925) also notes that the endocasts of these monkey skulls were formed of fine reddish fill. He further notes that the remains of the tunnel from which the Taung Child was recovered could be distinguished from the surrounding limestone (tufa) by the slightly more pinkish rock. He also notes that a photograph he tried to take failed, due to lack of sufficiently clear demarcation between the filling and the surrounding limestone. So, at this early stage Hrdlička (1925) noted the occurrence of three types of deposits, the tufa itself, a pinkish deposit associated with the Taung Child skull that was not easily distinguishable from the tufa and a reddish deposit associated with monkey skulls. He also seemed to note a difference in the size and shape of these deposits in the tufa, the pinkish deposits being part of a larger cave and the reddish sediments the infill of tunnels. Broom (1948) also noted such differences between fossils collected at different periods with much lighter matrix on some fossil specimens than others. He also notes that the lighter material appears to be associated with *Parapapio antiquus*, while the darker (sandy lime) deposits contain *Papio izodi*. This is the first suggestion of a major difference that might be temporal in nature.

Peabody (1954) also notes the occurrence of two phases of deposition (other than much younger Middle Stone Age bearing fill), in the '*Australopithecus* (Hrdlička) Cave': an earlier dry phase consisting of red sand and a later wet phase consisting of horizontal layers of pure lime intercalated with layers of red sandy limestone. He additionally notes that both contain fossils and differ from each other in terms of colour, matrices and preservation of fossils. Early thin section analysis by Peabody (1954) suggested little difference between these two deposits and the matrix of the Taung Child skull, except subtlety in grain size. Peabody (1954) also notes the apparent large size of this 'long cave'. Peabody (1954) concludes that the earlier dry phase consisting of massive red sandy limestone that is then overlain by a wet phase of pure lime with intercalated layers of red, sandy limestone. The supposed earlier dry phases contained small mammals, rodents, baboons, crab (Potamonautidae) and terrapin fossils, whereas the later wet phase just baboons and small antelope. The occurrence of terrapins and crabs in his dry phase seems strange when such fossils were not noted in his wet phase. Peabody (1954) notes that the younger wet phase has calcitie formation seen on the Taung Child, but not seen in the older red phase and thus associated the Taung Child with the younger wet phase. Peabody (1954) then notes two younger phases of deposition, a massive fossilless, red sandstone and Middle Stone Age bearing black earth.

Butzer (1974) undertook sedimentological analysis of Peabody's (1954) wet (Taung Child Matrix) and dry phases and described the dry phase as sand and the wet phase as clayey silt. He further noted that the tufa itself contains detrital grains in the form of clayey silt and that pink to reddish-yellow pockets of sediments are commonplace. Butzer (1974) suggests that the dry phase is pinkish sand with tufa clasts and is similar to other reddish deposits containing baboon fossils. This contrasts with the wet phase skull matrix, which is also pink, but more fine-grained and with a lot of veins of calcite. He suggests this is a derived soil mixed with aeolian sand and that it compares most closely with the younger Norlim Tufa rather than being an aeolian sand like most secondary tufa fills. Butzer (1974) notes for the first time that 'turtle' carapace came from the Taung Child matrix, suggesting that the aquatic fauna described by the miners likely came from the wet-phase of Peabody (1954), thus stating the opposite of Peabody (1954) in this regard, and the long cave deposit described by Hrdlička (1925). He also suggests that all the baboon and perhaps macrofauna come from the dry phase sand and thus it has little to do with the Taung Child period of deposition. He follows Peabody's (1954) view that the dry phase is older than the wet phase. However, Butzer (1980) later suggests that there is no sedimentological difference between samples in Peabody's (1954) so-called wet and dry phases and that these 'baboon sands' are distinct from the matrix of the Taung Child, despite terrapin fossils apparently occurring in both the Taung Child matrix and Peabody's 'dry phase'.

Partridge *et al.* (1991) undertook a further sedimentological study of the exposed deposits around the Dart and Hrdlička Pinnacles and the matrix associated with the Taung Child itself. As in the earlier studies, Partridge *et al.* (1991) define a pink fill consisting of silt (26%), sand (35%), and clay (39%), thus comparable to Peabody's (1954) wet phase and matrix of the Taung Child as described by Butzer (1974) and a Red Fill of silty sand (74%), potentially comparable to the dry phase of Peabody (1954); 'Baboon Sands' of Butzer (1974). Partridge *et al.* (1991) also note a difference in the preservation of fossils in the two deposits, as also noted by Peabody (1954). Partridge *et al.* (1991) note for the first time that the red phase has filled cavities eroded through the older pink phase, inverting the sequence of the wet and dry phases suggested by Peabody (1954) or at least the baboon sands and hominid matrix as termed by Butzer (1980) for Partridge *et al.*'s (1991) red and

pink fill. Partridge *et al.* (1991) also note the remarkable similarity of the pink phase from the Hrdlička Pinnacle and the matrix of the Taung Child skull, concluding that the Hrdlička Pinnacle pink deposit sampled was a remnant of a much larger cave system that included the Taung Child deposits.

McKee (1992; also in Tobias *et al.* 1993) was the first to suggest that more than one fossil-bearing 'deposit' (i.e other than the Hrdlička deposits that were the focus of attention prior to the 1990s) occurred in the Thabaseek Tufa, at the base of the Dart Pinancle (McKee 1993a). He suggests that this Dart deposit is older than the Hrdlička deposits (which were already shown to contain two deposits other than the tufa itself) because it grew from west to east. In contrast, Tobias *et al.* (1993) caution that previous studies (Young 1920; Peabody 1954; Butzer 1974, etc.) suggested that the Hrdlička deposits were part of a labyrinth cave system that may have formed across and through the layering and growth of the tufa. This is in contrast to McKee's (1993a) idea that caves always form as carapace caves close to the front of tufa growth. This indicates that McKee and Partridge (both authors on the Tobias *et al.* 1993 paper) obviously had differing views on the stratigraphy and formation of the Type Site deposits. Both may be true as the early work also talks of both caverns and tunnels. McKee & Tobias (1994) also suggest that the PCS deposits of the Dart Pinnacle are more in keeping with the reconstructed site from Peabody's (1954) interviews with miners and as recounted to Partridge *et al.* (1991) by the son of a miner from 1925.

Partridge expanded the results of his sedimentological study in Tobias *et al.* (1993) and further confirmed the conclusion defining a pink to light reddish-brown fill (Pink Fill; PCS) and a yellowish-red fill (YRSS; Red Fill) in the Hrdlička Pinnacle and a similar pink fill (PCS) in the newly discovered and excavated Dart deposits. He also again concluded that the similarity of the Taung Child skull matrix to pink deposits at the base of the Hrdlička pinnacle and suggested the skull came from those deposits. While this two-phase model of sediment types, and thus deposits, dominated prior to the 1990s, McKee (1993a,b; *et al.* 1994), during his excavations, attempted to define separate carapace caves infilled with these deposits. McKee (1993a) uses the fact that the sediments of deposit H-B (McKee & Tobias 1994 defines this as pink heavily calcified with interfingered decalcified, loose sandy red breccia; he also suggests it corresponds to Peabody's [1954] wet phase; 38-5b locality) do not cut across the tufa as might be expected with a solution cavity. He notes that a solution cavity (much younger MSA bearing Black Earth Pipe) did later intersect the H-B sediments cutting across the tufa beds, as is also the case for deposit H-A (Red Fill) that contains very eroded bones. McKee (1993a) also notes that bones extend from the sediment into the tufa in deposit H-E, a situation not compatible with a later solution cavity, but suggesting formation at a time close to the tufa itself. McKee (1993b) notes that only *Parapapio antiquus* was found in H-B, whereas in H-E only *Papio izodi* was found, suggesting some vertical temporal variation in the Hrdlička Pinnacle; despite his suggestion that horizontal, rather than vertical stratigraphy is most important. McKee & Tobias (1994) in a preliminary, and as yet only description of the deposits that they excavated in the early 1990s, note that H-E is also a pink deposit and that it is separated by a large amount of sterile red sand. This suggests that the vast majority of fossils recovered by the Wits excavations were from deposits containing pink fill, although the red fill contains fossils in areas. However, Tobias *et al.* (1993) note that both red and pink fill is found in 'deposit' H-B, which in itself suggests that either these two deposits are synchronous or that this 'deposit' has sampled deposits, and thus fossils, of different ages.

In the Dart A deposit, McKee (1993a) suggests that both carapace and solution caves occur. He notes in deposit D-D that the pink breccia is horizontally bedded. It is his firm view that the Taung Child comes from these pink Dart deposits and not from the Hrdlička Pinnacle as suggested by Partridge *et al.*'s (1991) work. McKee (1993) quite rightly suggests that similar sedimentological characters could be found in different caves of different time periods and points out inadequacies in Partridge's Member systems at sites such as Makapansgat (Latham *et al.* 1999, 2003). As such, it could be possible that both PCS and YRSS deposits were deposited in the Dart deposits and then in the Hrdlička deposits. However, our recent work (Hopley *et al.* 2013) suggests that these two deposits have different magnetic polarities (PCS and Tufa are normal polarity and YRSS is reversed) and thus could not be synchronous. Instead this suggests that PCS may have formed across the two pinnacles and subsequently eroded through by solution cavities and infilled with YRSS; as envisioned by Partridge *et al.* (1991). Partridge (2000) again firmly asserts his view of the occurrence of a cave across both deposits with two main fills, a pale reddish-brown clayey infilling of fluvial origin and the yellowish-red sandy aeolian deposit. He further asserts that the pink infill underwent dissolution and channelling before the younger red sediments were deposited but that cercopithecoid remains occurred in both deposits. The confusion over Peabody's wet and dry phase and associations to pinkish or reddish deposits seems to stem from the fact that in some areas the older 'pink phase' has sandier components that are redder in colour and as such likely sample the same older 'pink phase' as defined by Partirdge. This is confirmed in our preliminary work by these older pink fluvial deposits having a normal polarity and the younger aeolian red sandstone deposits having reversed polarity.

Recently, Hopley *et al.* (2013) have proposed an entirely different model for the formation of the Type Site deposits of the Dart and Hrdlička Pinnacles. This potentially explains much of the contrasting data from the previous work. Thin section work undertaken on the pink sediments of the Dart deposits indicates that it contains microfossils and features indicative of a palaeosol that would have formed in on open, rather than a cave environment. When this is combined with macrofossil evidence for terrapins, crabs, bird eggs, ground nesting bees (Parker *et al.* 2016) and the stems of reed plants as described by McKee & Tobias (1994) it suggests that the

normal polarity pink deposits (PCS) likely formed at the same time as the normal polarity tufa. This could be in the manner envisaged by McKee (1993a) with the deposits forming in a carapace cave. However, in other areas of the BNL similar pink deposits can clearly be seen to be layered within the Thabaseek Tufa and represent phases of landscape stability and erosion, as shown by the large number of tufa blocks within the deposits. Similar tufa clasts can be seen in the pink Dart deposits. In contrast, the reversed polarity yellowish-red sandstone (YRSS) later filled caves formed within both the tufa and PCS.

McKee (2015) responded to Hopley *et al.*'s (2013) model and argued that PCS is not a single unit but a reoccurring type. This is actually made clear by Hopley *et al.* (2013) where they describe the interbedded nature of PCS-like deposits in the Peabody Pinnacle. PCS should be considered a type of deposit, not a single unit. McKee (2015) notes that his deposits H-E and H-B are different from H-A despite the commonality of the pink carbonate. In fact, deposit H-A seems to consist of yellowish-red sediment based on our work and that would be more consistent with the later YRSS infill, not the older PCS. This explains the difference McKee (2015) notes in preservation of fossils. Overall McKee (2015) agrees that much of Hopley *et al.*'s (2013) model could be correct, but argues this to not be the case for the PCS fills of the Hrdlička pinnacle due to the shape of the deposits he excavated. Part of the issue is that McKee has provided only a very preliminary description of his excavations (in McKee & Tobais 1994) that makes it difficult to reconcile them against the *in situ* stratigraphy.

McKee (2015) continues to argue that the PCS deposits of the Dart Pinnacle, from which there is extensive evidence the Taung Child was recovered, are older than those of the Hrdlička Pinnacle. This is entirely possible as the tufa dips steeply between the Dart and Hrdlička Pinnacle and as such, McKee (2015) is correct that the PCS of the Dart deposits are likely older than the PCS of the Hrdlička Pinnacle, which are in turn older than the YRSS cave fill deposits across the two pinnacles. As described in Hopley *et al.* (2013) this would further mirror the interlayered nature of PCS and tufa within the Peabody Pinnacle. The similar normal polarity for PCS in both Dart and Hrdlička Pinnacles as well as the tufa suggests this all formed within the same polarity zone; perhaps 400 000 years of deposition based on the palaeomagnetic interpretation of Herries *et al.* (2013). All the evidence clearly shows that PCS formed synchronously with the tufa, whether it was as an open-air deposit or a carapace cave. The crab and terrapin fossils (now in the collections of the Ditsong National Museum of Natural History), eggshell, ground nesting bees and fossil reed stems suggest that these deposits perhaps formed around pools within the tufa during phases of active erosion, that would have punctuated phases of formation of the Thabaseek Tufa. Such pools can be seen today formed within the Blue Pool Tufa at the BNL. Such cycling of phases of tufa formation, landscape stabilization and erosion is well documented along the Ghaap Plateau escarpment (Butzer *et al.* 1978; Curnoe *et al.* 2006; Doran *et al.* 2015). Moreover, early descriptions of a 'long cave' (Hrdlička 1925) forming over a very wide area may also suggest it was not actually a cave, whereas, the early description of tunnels may relate to the YRSS cave fills.

As outlined above, the palaeomagnetic analysis of the Type Site deposits indicates that the tufa and PCS micrite both have a normal magnetic polarity, while the YRSS has a reversed magnetic polarity (Hopley *et al.* 2013). This adds further evidence that PCS and the tufa were formed synchronously as suggested by Hopley *et al.* (2013) and that YRSS formed through the two deposits later. While Delson (1988) and McKee (1993a) have suggested biochronological age estimates for the deposits of between 2.6 and 2.3 Ma, these are based on the assumed age of many of the South African sites before recent chronometric dating that has significantly revised the age of correlated sites in many cases (Herries *et al.* 2010, 2013). Therefore these direct dates should be considered more accurate than the older biochronological estimates, and the older estimates no longer used without a reanalysis of the biochronological data. While McKee (1993b) suggests that few fossils are associated with PCS and the Taung Child, our research suggests that a large number of fossils in the collections have a matrix identical to PCS that are deposited within the same magnetic polarity zone. Thus while the deposits and fauna might not be exactly the same age, having come from a later layer of PCS compared to the skull, the age difference is likely not great and a reassessed biochronology of this later deposit is likely to help assess the age of the polarity zone and Taung Child. Others fossils have both YRSS- and PCS-style matrix. These fossils also likely came from the older PCS deposits given they are partly encased in the older PCS and it is known that solution tubes later in-filled with YRSS eroded through both the tufa and PCS, and around fossils (Partridge *et al.* 1991). Until the detailed publication on the contexts of the Wits excavations is published there will always remain some degree of uncertainty in the association of fossils with mixed matrix to the older PCS or younger YRSS in the Hrdlička Pinnacle; whereas there is no issue with the association of the fossils from the Dart deposit to PCS.

Given the age of *Australopithecus africanus* in South Africa (3.03–2.01 Ma; Herries *et al.* 2013) it seems likely that the PCS deposit and the Taung Child were deposited during the Gauss Chron between 3.60 and 2.58 Ma, although perhaps more likely contemporary with the Makapansgat Limeworks between 3.03 and 2.58 Ma (Herries *et al.* 2013). If the Dart PCS is indeed older than the Hrdlička PCS then it might be that the Dart PCS fossils and Taung Child skull are closer to, or possibly older than, 3.03 Ma, making it one of the oldest, if not the oldest hominin in South Africa, whereas the fossils from Hrdlička PCS maybe closer to 2.58 Ma. The fact that the tufa and PCS formed at a similar time also means there is the likelihood that a uranium-lead date could be associated to the skull.

Prior biochronological analysis (Delson 1988; McKee 1993a) indicated that Taung likely formed at the same time as Sterkfontein Member 4 or between it and Swartkrans Member 1. Based on recent dates (Pickering *et al.* 2011;



Figure 3. Fossil-bearing breccia dump, fossils without tags (primate maxilla) as well as tags without associated fossils left by the 1988–1993 excavation team and found in an old warehouse at the BNL in 2010. This material has now been recovered and is under study.

Herries & Shaw 2011; Herries *et al.* 2013; Herries & Adams 2013) this would place the site around 2.6–2.0 Ma. Based on the polarity this is impossible, as deposits of this age would have to have a reversed polarity, like the YRSS deposits. An age in the earliest part of the Matuyama reversed polarity Chron (2.58–1.95 Ma) is thus likely a good age for the YRSS deposits. The older normal polarity deposits thus may have formed just prior to 2.6 Ma during the Gauss Normal Chron between Sterkfontein Member 4 and Makapnsgat Member 3

An extensive number of other well-preserved fossils, including many primates, were also recently discovered by our team abandoned in a large pile in the corner of an old storage shed at the BNL (Fig. 3). Tags associated with the fossils indicate they are from the 1988 to 1993 University of the Witwatersrand Medical School excavations with material represented from every year of excavation. Unfortunately many of these fossils have lost their association because the bags they were stored in have rotted away. However, we have started a programme to recover this material and have begun looking at the distinctive matrix of the fossils to associate them to either the PCS or YRSS depositions based on sedimentology and geochemistry. Many of these have pink (PCS) matrix and so the number of fossils available for an updated biochronology and to help reconstruct the environment in which the Taung Child lived is more extensive than previously thought. This, combined with research on previously accessioned material, is ongoing and will be the focus of future publications.

While almost all the PCS deposits have recorded a normal polarity and the YRSS deposits a reversed polarity there are a couple of exceptions. Some reversed polarity directions appear to occur in the top of the PCS deposits at the base of the Dart Pinnacle and this may suggest this deposit formed across the Gauss–Matuyama boundary at 2.58 Ma; however, this needs further confirmation, along with an analysis of tufa that is stratigraphically higher in the Dart Pinnacle, access to which is difficult due to a thick overburden of mining waste. Single normal and intermediate polarities were also recorded at the top of the Hrdlička Pinnacle. This deposit represents a series of stratified YRSS deposits (McKee & Tobias's, 1994 H-A deposit) and flowstone spelothem that has infilled a solution cavity at the top of the Pinnacle. It is possible that this deposit records a short normal polarity episode within the Matuyama Chron such as the Huckleberry Ridge event at ~2.05–2.01 Ma as recorded at Sterkfontein and Malapa (Herries & Shaw 2011; Pickering *et al.* 2011). The flowstone itself has been sampled for uranium-lead analysis and work is forthcoming. Further geochronological work is also being undertaken with electron spin resonance dating. Currently, the best age estimate for the Taung Child is between 3.03 and 2.58 Ma.

FORMATIONAL HISTORY OF THE BNL AND THE EXTENT OF THE THABASEEK TUFA

Since 2010 our investigations have primarily focused on the geology of the Type Site and consisted of sampling for palaeomagnetic analysis (Hopley *et al.* 2013), isotopic analysis (Doran *et al.* 2015), uranium-lead analysis, and the recovery of newly-excavated drill cores into the base of the Dart Pinnacle and through the length of the Hrdlička Pinnacle. These were undertaken to fully understand the complex depositional history of the Type Site. Partridge (2000) undertook similar core drilling of the Hrdlička

Pinnacle but never published a full description of those cores, which have yet to be re-located. Partridge (2000) recovered Precambrian basement rocks at a depth of >50 m from the top of the Hrdlička Pinnacle and inferred a broad 'L' shaped escarpment buried underneath the Thabaseek Tufa. In contrast, our cores, which were drilled adjacent to the core hole markers left by Partridge (2000) yielded different results. The underlying Precambrian shale was reached at a depth of 10.6 m below the base of the Dart Pinnacle and 48.5 m below the top of the Hrdlička Pinnacle. As the Hrdlička Pinnacle core is at an elevation of 7.5 m above the Dart Pinnacle core, the tufa is 30.4 m deeper where the Hrdlička Pinnacle is located, compared to where the Dart Pinnacle is located, despite only 62.3 m horizontal separation between the cores (Fig. 2). This indicates that there was a very steep and possibly a stepped escarpment (or valley) through or over which the Thabaseek river flowed, producing a >50 m thick succession of riverine, lacustrine, palustrine and pedogenic sediments. Our cores also suggest the depth of the tufa in the Hrdlička Pinnacle is at least 8.5 m deeper than estimated by Partridge (2000). The base of the cores consist of breccia that transition into shale. The edge of the Ghaap Plateau consists of a stepped escarpment where insoluable shale layers occur within the dolomite and the tufa seems to have formed over a similar steeply stepping escarpment as occurs at the BNL near Berger Cave and is similarly visible at Groot Kloof Locality D further down the escarpment, as well as at numerous places along the escarpment today (Butzer 1974; Curnoe *et al.* 2006). Between the Dart and Hrdlička Pinnacles, adjacent to the location of the 'Peabody Pyramid', the tufa can be seen to go from horizontal deposition, as seen all around the base of the Dart Pinnacle, to steeply dipping deposition (Hopley *et al.* 2013). This depositional change may mark this cliff edge. This is perhaps the best evidence to date that the tufa and PCS deposits in the Hrdlička Pinnacle may be younger than those in the Dart Pinnacle, as envisaged by McKee (1993a). Throughout the Hrdlička core numerous small cave conduits filled with more lightly consolidated yellowish-red sandy sediments occur consistent with the YRSS deposits (Fig. 4). Moreover, at a depth of approximately 40m the core hit an open void of 2.46 m, suggesting that a possible cavity exists near the base of the tufa. More detailed analysis of the core is ongoing to help understand the stratigraphy and palaeo-environment of the Thabaseek Tufa, as well as to date the entire sequence with palaeomagnetism and U-Pb.

Currently, the geological structure of the BNL is interpreted as a succession of lacustrine, riverine and palustrine tufas and calcretes modified by karstic processes as outlined by Peabody (1954), Butzer *et al.* (1978), Partridge (1985), McKee & Tobias (1994) and Hopley *et al.* (2013). Our recent survey work also suggests that previous interpretations regarding the layout and formation of the various tufa flows need revisiting. For example, Peabody (1954) argued that the Thabaseek Tufa was the oldest at Taung, however, the Norlim Tufa, into which Black Earth Cave is eroded, actually sits beneath the Thabaseek and was extensively eroded before the Thabaseek was deposited on top of it (Fig. 5). This major erosional contact can be seen along the northern and eastern edge of the North-East Quarry (Fig. 6). The two tufas are easily distinguished, as the Norlim Tufa has a grey colouration and greater inclusions, whereas the Thabaseek Tufa consists of purer calcium carbonate with a yellow to white colouration. The purer nature of the Thabaseek Tufa is the primary reason that it appears to have been mined more extensively. For the majority of the North East Quarry area the Thabaseek Tufa has been removed down to the contact with the Norlim Tufa, which was mined away in a few areas, such as to the south of Black Earth Cave. This has meant that Black Earth Cave itself was not mined away like many sites in the Thabaseek Tufa and remnants of the contact can also be seen near Quinney Cave in the northern part of the Eastern Quarry.

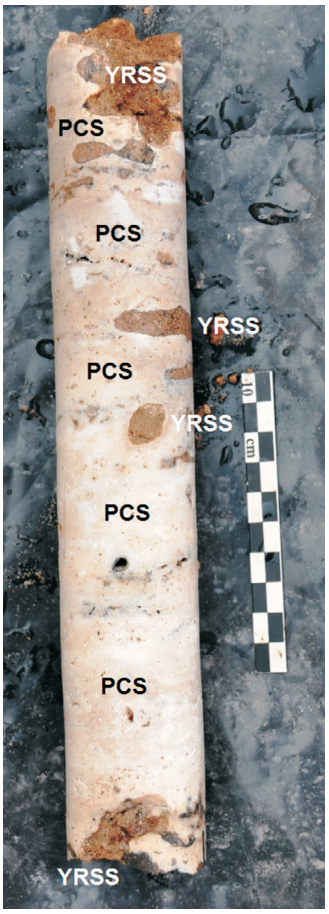

Figure 4. Part of the Hrdlička Pinnacle core showing the complexity of the stratigraphy. The pink PCS micrite contains tufa fragments from erosion of the underlying Thabaseek Tufa on an open landscape. The normal polarity PCS had obviously already become indurated, likely by later formation of the Thabaseek Tufa, before solution pockets were eroded through it and in-filled with later reversed polarity YRSS.

When Peabody (1954) visited the BNL, the extent of the mining of the tufa was at a much different stage to what it is today, as mining at the BNL continued until the 1970s. This may explain why these quite obvious contacts were not noted at the time and all subsequent researchers have followed Peabody's sequencing of the deposits (Butzer 1974; McKee 1993b; Partridge 2000; Tobias *et al.* 1993). However, Figure 3 of Peabody's Plate 2 (Peabody 1954, 976) seems to show the North-East Quarry in a similar state as today. Based on the data presented below and by

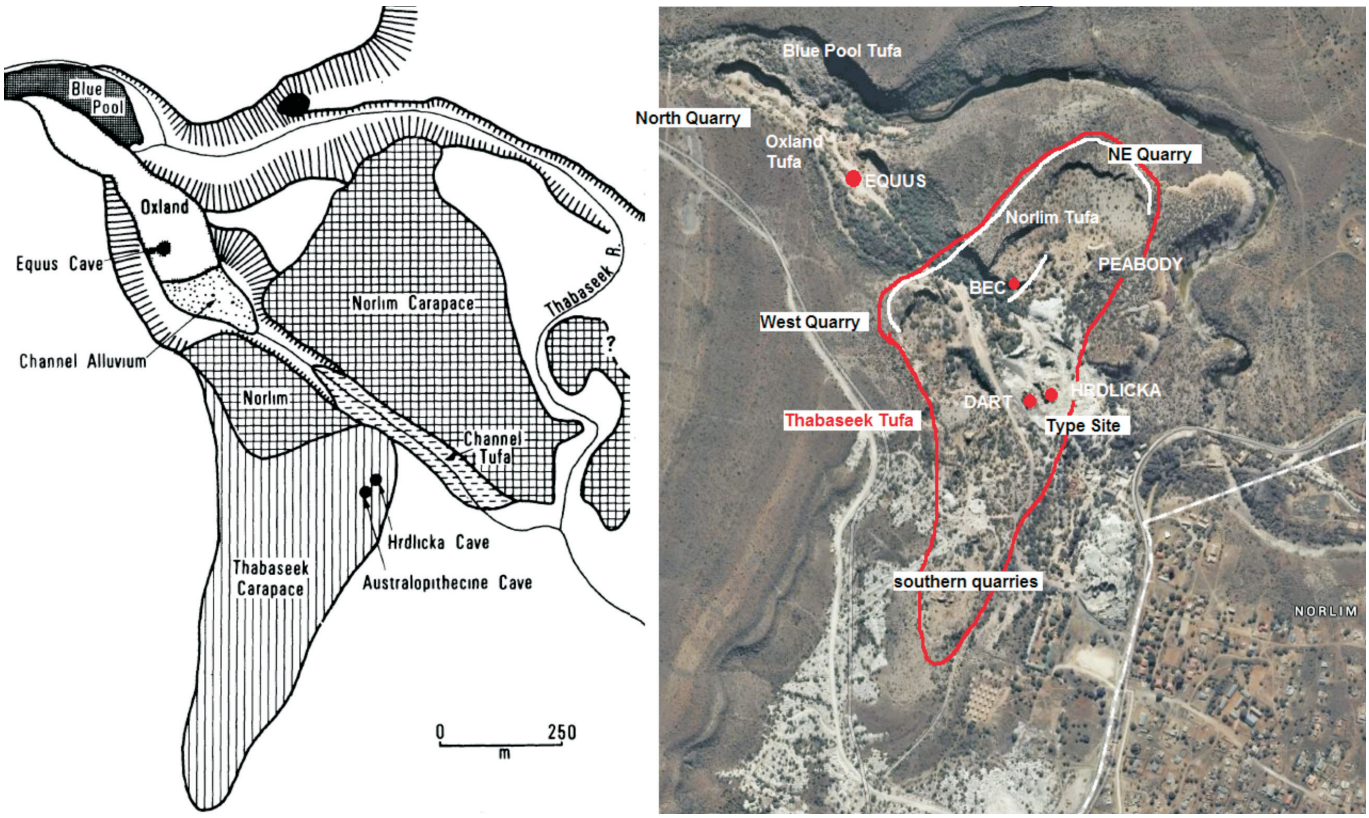

Figure 5. Sequencing of the Buxton-Norlim Limeworks tufa flows by Peabody (1954) and Butzer (1974) compared with 2014 Google Earth image showing the actual outline of the Thabaseek Tufa (red) and underlying Norlim Tufa (white). The locations of the Type Site (Dart and Hrdlička Pinnacles), Black Earth Cave (BEC) and Equus Cave are also shown.

Hopley *et al.* (2013) and Herries *et al.* (2013) the Thabaseek Tufa is considered to be terminal Pliocene to early Pleistocene in age and as such, the underlying Norlim Tufa could be considerably older. However, this does not mean that sites that are eroded within it, like Black Earth Cave, are older than the Pliocene as the geomorphic evolution of the palaeo-Blue Pool River caused it to cut through these older deposits and caused caves to be formed and in-filled within the Norlim Tufa much later.

Peabody (1954) also suggested that the Norlim Tufa occurred over the majority of what is now the North-East Quarry and also the northern part of the West Quarry. The Thabaseek Tufa is shown to occur exclusively in the Western Quarry, in the area of the Type Site and extending south to the Southern Quarries (Fig. 5), but not crossing the erosional feature that formed through the centre of the Norlim Tufa due to stream cutting by the palaeo-Blue Pool River when it was forming the Oxland Tufa; the same erosional episode that opened up Black Earth Cave. Peabody (1954) does not formally attribute tufa to the south of the North-East Quarry and across the River near Powerhouse Cave to a tufa phase, but Butzer (1974) does attribute this to the Norlim Carapace. Today the extent of the various tufas is impossible to determine as most of this area is covered by mining waste. However, the Peabody Pinnacle, which represents the southern extent of the North-West Quarry, shows evidence of only the Thabaseek Tufa, having similar interstratified pink micrites as noted at the Type Site (Hopley *et al.* 2013). This indicates either that the Norlim Tufa did not extend this far south, or that it remains buried beneath the North-West Quarry and the Peabody Pinnacle. Tracking its extent from just south of Black Earth Cave is impossible due to the occurrence of thick overlying mining waste. However, it is clear that the Thabaseek Tufa is much more extensive than previously suggested. It is also not the oldest tufa flow. The eroded nature of these tufas and the surrounding landscape since the Pliocene makes it difficult to identify their points of origin, but it is likely to have been to the Northeast of the BNL. At some point the river changed course significantly and broke through the escarpment where the road now connects the Western Quarry to the Northern Quarry. This episode also eroded a channel through both the Thabaseek and Norlim Tufas and eroded open Black Earth Cave. The Oxland Tufa formed and grew into the gap eroded through the escarpment. Part of the Oxland Tufa has been dated to ~230 ka (Vogel & Partridge 1984), similar to ages of ~250 ka for tufa from Groot Kloof, ~100 km to the southwest along the escarpment (Curnoe *et al.* 2006). This indicates that the cutting of this valley through the Thabaseek and Norlim Tufas occurred during or prior to the MIS7 interglacial. Speleothem within Black Earth Cave has produced U-Th ages in equilibrium, indicating an age of greater than 500 000 years, meaning that this flowstone must have formed before the BEC Valley was eroded through the Norlim and Thabaseek Tufas. After the deposition of the Oxland Tufa, the river again changed course, this time to the east, and eroded the rear side of the Oxland Tufa, forming the Blue Pools Tufa at sometime around 40–35 ka (Butzer *et al.* 1978). Caves such as Equus Cave then began to form within the end of the Oxland Tufa.



Figure 6. Erosion of the older Norlim Tufa before the deposition of the younger Thabaseek Tufa on the northeastern wall of the limeworks.

EQUUS CAVE

Equus Cave (EQC; Figs 1 & 7) is the next most well known site at the BNL. It is a solution cavity that opened within the western face of the ~230 ka Oxland Tufa (Butzer 1974, 1984; Butzer *et al.* 1978; Grine & Klein 1985; Klein *et al.* 1991; Peabody 1954). EQC was first excavated by Shackley & Beaumont in 1978, followed by Beaumont again in 1982, who identified four stratigraphic units (1A, 1B, 2A & 2B), approximately 250 cm in depth (Grine & Klein 1985; Klein *et al.* 1991). EQC has yielded over 30 000 fossil remains, as well as Middle Stone Age (MSA) and Later Stone Age (LSA) artefacts that are dated to the late Pleistocene and Holocene by radiocarbon dating and amino acid racemization (Johnson *et al.* 1997). The fossil accumulation is one of the largest in southern Africa spanning this time period, which has provided valuable



Figure 7. Excavations into rich archaeological talus slope deposits left at Equus Cave in 2012. The 1978 and 1982 excavations removed the entire area in the foreground and the excavation trenches were left open and have eroded extensively in the last 35 years. The wall to the right is part of the Oxland Tufa and is a wall of the now unroofed cave.

insight into environmental shifts that have occurred in southern Africa over perhaps the last 32 000 years (Grine & Klein 1985; Johnson *et al.* 1997; Klein 1986; Klein *et al.* 1991; Lee-Thorp & Beaumont 1995; Scott 1987, 1989, 2002; Sponheimer & Lee-Thorp 1999). The 13 human remains, comprised twelve isolated teeth and a fragmented mandibular corpus with two molars from EQC have provided an important biological perspective on the stasis in modern human dental variation and developmental growth patterns over the last 100 000 years (Grine & Klein 1985; Smith *et al.* 2006). However, the usefulness of these data has been limited by questions over the reliability of the dating of the site (Johnson *et al.* 1997). EQC stratigraphy and associated material has been a problematic issue since only three seemingly reliable dates from the uppermost unit have been produced, while samples from the lower units have yielded an erratic dating sequence with numerous inverted ages (Johnson *et al.* 1997; Hedges *et al.* 1995; Miller *et al.* 1992; Klein *et al.* 1991; Vogel *et al.*1986). Due to these difficulties we started new excavations at Equus Cave in 2012 with a view to reanalysing the stratigraphy and chronology of the site.

The dating for the EQC sequence is outlined in Table 1. Three coherent dates have been recovered from layer 1A, two of which were recovered from within hearth features. Charcoal from the top of the sequence dates it to 2544–2300 cal yrs[1] BP, while ostrich eggshell (OES) from the base of the sequence dates it to 8399–8050 cal yrs BP. A third sample of OES from just above the basal sample gave an age of 7576–7270 cal yrs BP. These dates suggest that layer A1 formed throughout much of the Holocene from ~8.5–2.4 ka. However, the two oldest dates are on ostrich eggshell (OES) and they do not take account of a possible Dead Carbon Fraction (DCF) occurring within the OES that could make the ages slightly older (Johnson *et al.* 1997). Given that this is a karst landscape, the OES can contain ancient, dead carbon absorbed from karstic rocks eaten by the ostriches to aid digestion.

Dates for layer 1B gave ages that are stratigraphically consistent with the 1A ages, with a date on tooth enamel from the top of the deposit of 11 618–10 754 cal yrs BP and a date of 13 871–13 446 cal yrs BP on OES from the base of the deposit. This would suggest that 1B dates to the Pleistocene to Holocene transition, however two other younger Holocene dates (~6.4–5.7 ka) on the inside and outside of the same OES fragment complicates this. While this variation may be due to a need for a DCF correction in these samples, with the site occurring at the contact between karst and non-karst landscape, and thus OES from ostriches eating carbonate and non-carbonate rocks, this latter sample is perhaps more a result of mixing from the overlying level 1A. Whether this is due to site formation processes (bioturbation, etc.) or excavation (OES falling out of the edge of the excavation wall) have caused potential mixing is a question that will remain unanswered. A third sample of OES from the top of level 1A was dated to 34 108–32 262 cal yrs BP and has been used to suggest significant bioturbation by Johnson *et al.* (1997).

No dates exist for level 2A and those for 2B are again mixed. Bone and tooth enamel ages suggest 2B dates just prior to and into the Last Glacial Maximum (LGM) with ages of 20 043–19 204 cal yrs BP and 25 531–24 375 cal yrs BP. Another bone sample has an age of 10 800 ± 270 yrs BP despite coming from the base of the sequence, but this may be due to collagen degradation. In contrast OES samples give older dates of 31 861–30 765 cal yrs BP, consistent with the OES sample found within 1A; but also younger dates of 1090 ± 55 BP again suggestive of mixing of some kind. As such, it would seem that 2B is somewhere between 32 and 19 ka, perhaps with OES ages being too old due to a DCF correction being needed and bone samples perhaps being slightly too young due to some degree of diagenesis. Layer 2A is thus perhaps somewhere between 19 and 14 ka and LGM or slightly post LGM in age. In contrast, Johnson *et al.* (1997) suggest that the 2B-1A deposits formed over the last 16.6 ± 1.3 ka, which would be partly consistent with the bone, teeth, and charcoal chronology. Butzer *et al.* (1978) claimed that the lower stratigraphic units at EQC likely predate samples taken from 2 metres below the top of the Blue Pool Tufa that produced a minimum age of 32 700 ± 1190

[1]Radiocarbon dates were calibrated using OXCAL 4.1 and calibration curve ShCal13 (Hogg *et al.* 2013).

Table 1. Conventional radiocarbon ages and calibrated radiocarbon ages (using OXCal 4.2 and ShCal13 calibration curve; Hogg *et al.* 2013) for EQC (data from Vogel *et al.* 1986 and Johnson *et al.* 1997).

Level	Depth (cm)	Material	Sample no.	Conventional age	Calibrated age
1A	~5 (top)	OES	AA17267	29 210 ± 390 yrs BP	34 108–32 262 cal yrs BP
1A (hearth)	25	Charcoal	Pta-2452;	2390 ± 60 yrs BP	2544–2300 cal yrs BP
1A	~30	OES	AA-17266	6565 ± 90 yrs BP	7576–7270 cal yrs BP
1A (hearth)	45-53(base)	OES	Pta-2495;	7480 ± 80 yrs BP	8399–8050 cal yrs BP
1B	(Top) ~55	Tooth	Oxa-4276	9830 ± 120 yrs BP	11 618–10 754 cal yrs BP
1B	~55	OES	Pta-2789	5060 ± 60 yrs BP	5907–5643 cal yrs BP
1B	~55	OES	Pta-2791	5460 ± 70 yrs BP	6321–5996 cal yrs BP
1B	(base) ~80	OES	AA-5826;	11 870 ± 105 yrs BP	13 871–13 446 cal yrs BP
2B	~145	Bone	See Klein *et al.* 1991	16 300 ± 160 yrs BP	20 043–19204 cal yrs BP
2B	~145	OES	AA-17268	1090 ± 55 yrs BP	1065–897 cal yrs BP
2B	~155	OES	AA-5827	27 330 ± 340 yrs BP	31 861–30 765 cal yrs BP
2B	~190	Tooth	Oxa-4277	20 760 ± 220 yrs BP	25 531–24 375 cal yrs BP
2B	~220	Bone	Pta4051/57	10 800 ± 270 yrs BP	13 215–11 930 cal yrs BP

B.P. (Butzer *et al.* 1978: 40 007–34 579 cal yrs BP). While this interpretation is contentious due to a lack of any supporting stratigraphic evidence, the current geochronology for the site does fit this interpretation.

Climatic conditions corresponding to the deposition of the stratigraphic units discussed above have been derived through pollen analysis from hyaena coprolites (Scott 1987) and stable carbon isotopes (Lee-Thorp & Beaumont 1995). Palynological data suggest that Unit 2A and the top of 2B represents the coolest period of deposition, averaging 4°C cooler than present temperatures and was predominantly a grassland habitat (Beaumont *et al.* 1992; Johnson *et al.* 1997; Scott 1987). This would be consistent with an LGM age for these deposits as outlined by the chronology above. Warmer conditions began to gradually prevail throughout the top of Units 2A and 1B with the introduction of increased tree pollen in coprolites when compared to those found in Unit 2B, indicating shrubby, open *Acacia* savanna conditions (Scott 1987). Again, this would be consistent with a warming of the climate from the LGM to the beginning of the Holocene, as also suggested by the existing selective chronology. Finally, the shift towards modern rainfall and temperature patterns occurred in Holocene Unit 1A, in which the Kalahari Thornveld habitat that dominates the area today originated (Scott 1987). This seems to show a gradual change in climate from cooler towards warmer conditions as might be expected over the last 20 ka, as suggested by Johnson *et al.* (1997). However, Johnson *et al.* (1997) did not sample from the majority of the 2B unit, if at all, and as such older MIS3 deposits could still occur based on the current data.

One of the most significant aspects of EQC is the abundance of fossil remains, which have yielded over 30 000 taxonomically identifiable specimens to date (see Klein, Cruz-Uribe & Beaumont 1991 for review). Species representation within the stratigraphy of EQC seems to present an interesting point of differentiation between unit 1A, composed of exclusively extant taxa, and Units 1B–2B, which include three extinct species, Bond's springbok (*Antidorcas bondi*), the Cape zebra (*Equus capensis*), and the giant hartebeest (*Megalotragus priscus*) (Klein 1986; Klein *et al.* 1991). These species represent taxa of the Florisian Land Mammal Age, which went extinct between ~16 and 8 ka (Faith 2014), again consistent with a terminal Pleistocene chronology. Furthermore, Klein *et al.* (1991: 104) have found that the average body size of carnivores from Units 1B–2B are larger when compared to their modern analogues, which corroborates the cooler conditions (Bergmann's Rule) indicated by the palynological evidence discussed above and the dating.

The analysis of the fossil assemblages from EQC has been pivotal towards interpretations of site function (Klein 1986; Klein *et al.* 1991). For instance, the presence of ground bone points typical of the LSA, hearths, cut-marked bone and the rarity of hyaena (Pa*rahyaena brunnea* and *Crocuta crocuta*) coprolites from Unit 1A has firmly attributed the accumulation of these fossil remains to human occupation (Klein *et al.* 1991; Scott 1987). On the other hand, the scarcity of artefacts, the absence of hearths and cut-marked bone and the increase in hyaena coprolites in Units 1B–2B was used to suggest that hyaenas were the principal accumulators within the lower stratigraphy (Klein *et al.* 1991). While the hyaena occupation of EQC has dominated interpretations of the site within the last two decades, renewed investigations may potentially challenge this view. If the dating samples have been mixed so extensively, as suggested by Johnson *et al.* (1997), then this must also call into question the potential mixing of other material, including the fossil and archaeological remains. Central to this dilemma are issues surrounding the long-standing debates over the attribution of the EQC cultural material to a Middle Stone Age (MSA) or Later Stone Age (LSA) context (see Morris 1991).

While the LSA context of Unit 1A has been accepted due to the corroborated dating scheme discussed above, the age and archaeology of the lower stratigraphic units remains somewhat contentious, particularly for 2B. In fact, MSA artefacts have been reported from Units 1B–2B (Beaumont *et al.* 1984; Klein *et al.* 1991; McKee *et al.* 1995), which has supported a late Pleistocene age for these deposits (Butzer 1984). However, it has been suggested that the abraded nature of the MSA lithics when compared to the fresh appearance of the LSA material supports that the MSA was potentially washed in from an open-air site further upslope from the mouth of EQC (Klein *et al.* 1991; Morris 1991; Scott 1987). Scott (1987) mentions the possibility that all the archaeology of EQC might have entered into the cave in this manner. However, this point seems unlikely due to the lack of widespread abrasion amongst the archaeological assemblage, which is currently under study by one of the authors (M.V.C.). While recent studies have labelled EQC as an MSA site (see McKee *et al.* 1995; Smith *et al.* 2006), its archaeological context continues to be obscured by the lack of systematic description of any of the cultural material from the site. Moreover, the interpretation of how fossil assemblages from the lower stratigraphic units of EQC were accumulated, i.e. a hyaena accumulation, is based on a paucity of archaeological remains in Units 1B–2B (Klein, *et al.* 1991). While this hypothesis predominates the literature, without a detailed understanding of how artefacts are distributed throughout the stratigraphy, it is difficult to confirm given recent studies illuminating cave usage patterns by multiple species (including carnivores and bovids) in South Africa (Bountalis 2012; Bountalis & Kuhn 2014). In fact, the archaeological assemblage from the site, and notably the sharp unabraided nature of most of the assemblage, consisting of thousands of artefacts also calls into question the idea that Equus Cave is purely a carnivore accumulation as it is so often described. Thus, it is imperative to describe and classify the archaeological assemblages from EQC.

Current research

In 2012 our research team re-located the un-backfilled excavation trenches of the 1979 and 1982 field seasons, which had been subjected to widespread erosion of material out of the unconsolidated sections at the site. This task was also complicated as the excavation grid was oriented at 32 degrees negative from true north, which is twice the

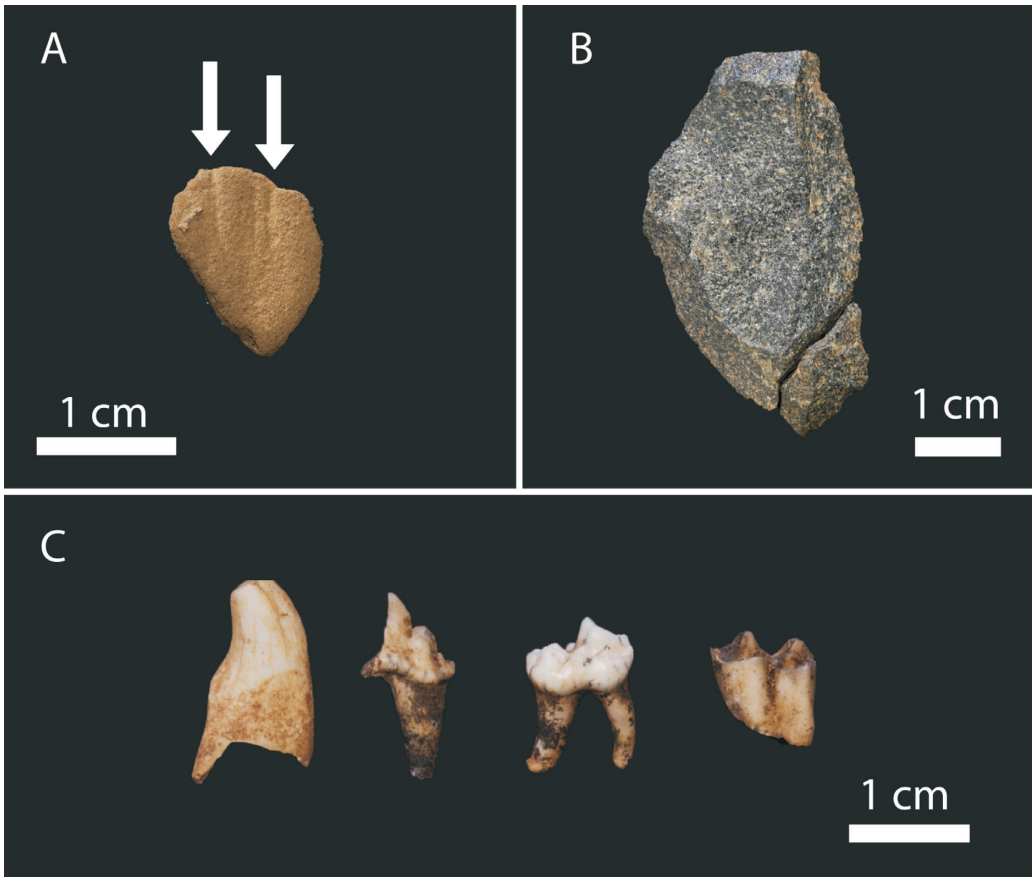

Figure 8. Remains recovered from Equus Cave. **A**, Ochre piece, arrows indicate areas possibly worked. **B**, Fresh lithic with break refit. **C**, Small teeth (Left to right: Hyaenidae canine, Canidae premolar, Mustelidae premolar, Bovidae molar).

local magnetic declination at the site. The main issue is that very little *in situ* deposits remain that can easily be excavated due to the steep and eroded nature of the site. We therefore began a 1 × 1 m excavation into a remnant of the talus cone of the cave, a feature that does not seem to have been previously excavated in any great detail.

This work has yielded a number new archaeological remains, which will aid in resolving the dispute over the presence of MSA tools at the site. Moreover, this new material includes *in situ*, possibly worked, ochre and extensive unweathered archaeological remains, including refitted material (Fig. 8) that is unlikely to have been washed into the site. This casts doubt on a purely non-human accumulation model, at least for this part of the site. In conjunction with the analysis of archaeological remains from the McGregor Museum (Kimberley, North West Province, South Africa) our research indicates that the cultural remains from EQC should strictly be affiliated with the LSA techno-complex. This ongoing analysis will be presented in detail elsewhere, which will serve as the first complete analysis of the archaeology from EQC.

Another important issue to be addressed is the loss of some archaeological material within the dumps of previous excavations, likely due to the sieving methodology (Shackley 1981). The loss of smaller teeth (see Fig. 8), generally less than 2 cm was established by excavation of the dumps of the earlier excavations in 2012. This work also showed that extensive amounts of charcoal occur in the deposits that may aid future radiocarbon dating work. In fact, numerous pieces of charcoal have so far been recovered from the *in situ* talus cone excavations and as such this is hoped to produce a robust chronology for the site independent of issues related to DCF offsets in dating OES and issues of collagen preservation in bone.

BLACK EARTH CAVE

The fossil deposits at Black Earth Cave (BEC; Fig. 9) were first noted by Peabody (1954), with excavated material sent off to the museum at the University of California Museum of Paleontology (UCMP) at Berkeley. To date this fossil material remains unpublished in detail, despite the fact that human remains were recovered. In addition, no dates have been published for the site. The site is eroded into the Norlim Tufa and was eroded through by waters draining from the formation of the Oxland Tufa (not the Thabaseek Tufa as suggested by Peabody (1954)). As such, it must have first formed prior to the formation of the Oxland Tufa at around 32 ka, although infill of the cave could have occurred after this. Peabody (1954) designated three galleries at BEC (A-C), however in the UCMP collections these are referred to as BEC1 (Gallery A; Peabody 38-14; UCMP V67279) and BEC 3 (Gallery B and C; Peabody 38-18; UCMP V67280). The small BEC2 (Peabody 38-17; UCMP V67281) collection in the UCMP is currently of unknown provenance (Justin Adams, pers. comm.).

In 2012, we surveyed the site and re-located Galleries A–C. The largest faunal collection at the UCMP is from BEC1 (A) but that site has been fully excavated of material and so no work can be done to assess its age other than directly dating fossils from UCMP or by stratigraphic

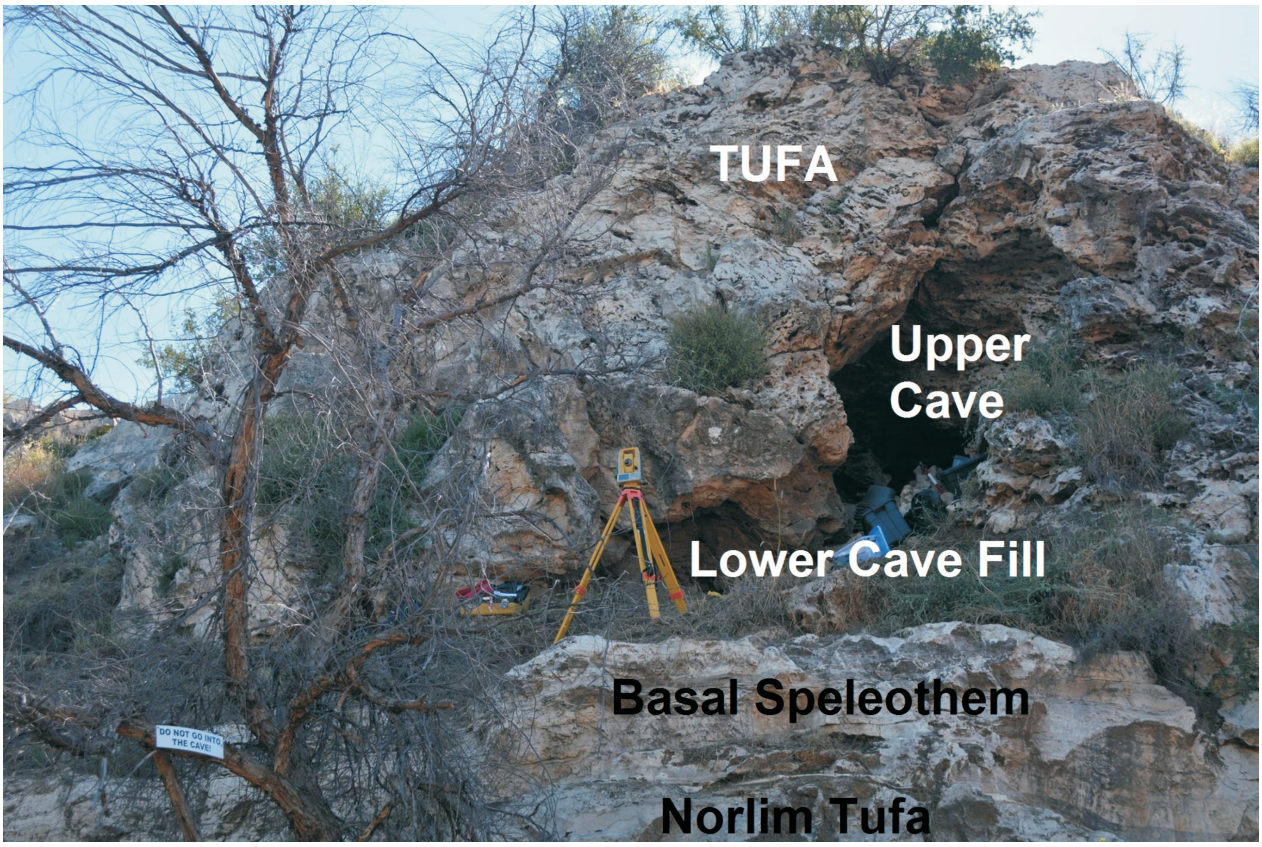

Figure 9. 2014 Excavations into the lower cave fill of Black Earth Cave gallery B. Basal flowstone speleothem >500 ka that was also discovered in 2012 is shown.

correlation. BEC1 (A) consisted of four stratigraphic zones with the upper fossil-bearing portion covering 150 cm: 1) the lowest layer consisting of sterile black clay after which the cave gets its name; 2) this is followed by 60 cm of rotted fossils in red and black streaky clay; 3) 60 cm of deposit with reddened bone and hyaena coprolites then follows from which the *Homo* fossils were recovered; 4) and is capped by 40 cm of dusty black earth, ash-bearing in parts and containing light coloured fossils and complete animal skulls.

The BEC3 Gallery C has a small trench in one side of it that may relate to Peabody's (1954) excavations. He noted few fossils from this deposit but the remaining *in situ* deposits are quite significant still. BEC3 Gallery B has also been mostly emptied, either by Peabody's excavations or due to other processes such as guano extraction and erosion. Peabody (1954) noted that most of the deposits were destroyed by mining prior to 1947 and suggested that at one time all three galleries were part of the same cave. Peabody (1954) describes the stratigraphy of Gallery B as consisting of the upper two levels of Gallery A, but with a confusing stratigraphy because of slumping and the collapse of a large roof block of tufa. The upper layer contained charred bone and a bone awl but no other evidence of human occupation. There was no evidence of the fallen tufa block as described by Peabody (1954) in Gallery B today and two clear stratigraphic layers can be seen that link to his descriptions from Gallery A and B. The inside of Gallery B contains a thin loose sediment containing abundant white fossil bone that is also scattered all over the walls and bare rock floor of the cavity. This is equivalent to the upper layers in Gallery A as described by Peabody (1954). A small section of darker earth with reddened bone occurred along the wall of the lower, exterior part of the cavity and correlates with the lower layers described for Gallery A, from which Peabody (1954) describes the only extinct species recovered from the site, that of a large horse, probably *Equus capensis* and suggesting a Pleistocene or very early Holocene age. This section disappeared beneath slumped earth that led down to the edge of the ledge that now marks the edge of the gallery. In 2014, we conducted *in situ* excavations into Black Earth Cave Gallery B at the base of this remnant section to recover datable material and explore the stratigraphy. This excavation revealed intact, *in situ* black clay and silt deposits with a number of articulated partial skeletons (one bovid and one carnivore) and a coprolite midden suggestive of a hyaena accumulation; again consistent with layer 2 of gallery A as described by Peabody (1954). No archaeology was noted and the base of the deposits was not reached. The fauna from the site is suggestive of carnivore accumulations and our excavations to date confirm this. A more detailed study of the fauna from this excavation is ongoing.

In 2012 we also identified a thick basal flowstone at the site for the first time, which is described by Peabody (1954; D in his figure 5) as the cave floor (Fig. 9). This flowstone is a few metres deeper than the current base of the excavations in gallery B and as such suggests there may be some significant depth and age to the deposits in that gallery. This flowstone also forms the ledge at the edge of Gallery B as described above. While BEC has generally been con-

Table 2. U-series isotopic and concentration data for Black Earth Cave, South Africa. All ages reported to 2σ error.

Sample name	U (ppm)	^{232}Th (ppb)	(^{230}Th/ ^{232}Th)	(^{230}Th/^{238}U)	(^{234}U/^{238}U)	Uncorr. age (ka)	Corr. age (ka)	Corr. initial (^{234}U/ ^{238}U)
BEC04	0.0356 ± 0.00003	21.3 ± 0.079	5.39 ± 0.05	1.062 ± 0.008	1.103 ± 0.003	299 ± 12	284 ± 22	1.275 ± 0.018
BEC05-A	10.6 ± 0.02	0.91 ± 0.013	35579 ± 571	1.005 ± 0.007	1.004 ± 0.001	>500	>500	n/a
BEC05-B	0.1308 ± 0.0001	1.54 ± 0.002	259 ± 0.92	1.003 ± 0.003	1.000 ± 0.002	>500	>500	n/a
BEC 11_T	0.3597 ± 0.0002	0.23 ± 0.001	5580 ± 22	1.175 ± 0.003	1.092 ± 0.001	>500	>500	n/a

Ratios listed in the table refer to activity ratios normalized to the corresponding ratios measured for the secular-equilibrium HU-1 standard. ^{230}Th ages are calculated using Isoplot/Ex 3.0 (Ludwig 2003). Non-radiogenic ^{230}Th correction was applied assuming non-radiogenic ^{230}Th/^{232}Th = 4.4 ± 2.2 × 10^{6} (bulk-earth value), and ^{238}U, ^{234}U, ^{232}Th and ^{230}Th are in secular equilibrium.

sidered to be late Pleistocene in age based on the fauna listed by Peabody (1954), preliminary uranium-thorium analysis yielded ^{238}U/^{230}Th ratios in equilibrium, indicating that this flowstone is older than 500 ka (Table 2). The base of the sequence has a normal magnetic polarity and so it may date to <780 ka, or perhaps as old as between 990 and 1.07 Ma. Further palaeomagnetic analysis is being undertaken to resolve the dating, along with uranium-lead dating of the sequence. One date on a secondary calcite infill within the main flowstone dates to 284 ± 22 ka and perhaps suggests the cave was still sealed at this time; just prior to the ~230 ka age for the formation of the Oxland Tufa, which caused the erosion through the Norlim Tufa that opened the cave to the surface. Regardless, it suggests that either a long period of time occurred between the deposition of the flowstone and the opening of the cave to allow sediments to in-fill or there is the possibility that much older deposits also occur within the cave. Excavations have so far progressed as far as a sterile looking 'Black Cave Earth' deposit but will continue in 2017.

DISCUSSION AND CONCLUSIONS

Our work at the BNL has so far concentrated on three of the 17 identified fossil sites, the Type Site, Equus Cave, and Black Earth Cave to develop a multidisciplinary understanding of the BNL and Taung World Heritage site. This is the beginning of a long programme of work to reconstruct the entire depositional history and age of the tufa flows and associated fossil and archaeological bearing deposits. This review highlights the lack of work done on many of the sites at the BNL and the many questions that remain unanswered. The current work at the BNL has already identified a number of issues with the stratigraphic work of Peabody (1954) and subsequent authors and shows that the Thabasek Tufa is not the oldest tufa flow at the site. It is also much more extensive than previously thought.

Our preliminary work at the Type Site suggests that the Taung Child (*Au. africanus*) skull is not associated with a cave but the older, PCS open air, Pliocene deposits that have an unusual aquatic fauna (crabs and terrapins). Our current best estimate for the age of the Taung Child is sometime between 3.03 and 2.58 Ma, making it contemporary with, or perhaps even slightly older than the *Au. africanus* remains from the Makapansgat Limeworks. Depending upon validity of recent work by Granger *et al.* (2015) with regard to the age of 'littlefoot', the Taung Child is one of, if not the oldest, hominin fossil in South Africa. A much larger number of fossils appear to be associated with this older PCS deposit than originally suggested and this makes reconstructing the environment at the time when the Taung Child was alive a distinct possibility. In addition we have begun the recovery and analysis of a large number of fossils that were abandoned at the BNL between 1988 and 1993. Abundant fossils also occur at the Type Site from the same period as Sterkfontein Member 4 and these did infill a series of fissure caves eroded through PCS and the tufa.

Renewed excavations at Equus Cave has recovered archaeological material, such as stone tools and utilized ochre, inconsistent with the current interpretation of the site as solely a hyaena den. Parts of the site do fit this pattern, but this new work suggests that carnivores and humans occupied the cave at different periods. Our work at EQC has also shown that a large number of smaller fossil elements (particularly teeth <2 cm) were lost in the excavation dumps from the 1970s and 1980s. The sampling at the site is thus biased towards larger elements, which can only be resolved through continued excavations. Furthermore, our work at Black Earth Cave has identified a thick basal flowstone for the first time that dates to >500 ka and suggests that the depth of that cave is much greater than previously expected. We have also re-located *in situ* deposits at BEC with no evidence to date for archaeological material, but evidence for hyaena occupation in the form of a coprolite midden. Partial skeletons were also recovered including that of a canid.

Together these results highlight the need for an ongoing research to reassess previous interpretations of the Taung World Heritage site. Furthermore, its localities preserve an important palaeontological and archaeological record of Pleistocene to Holocene transition that is rarely discussed. Thus the significance of the site ranges well beyond the discovery and the Taung Child skull discovered 90 years ago. To expand our understanding of the palaeo-scientific record preserved within the Taung localities, we employed a multidisciplinary approach that seeks a reinterpretation of previous conclusions about geological, geochronological, palaeontological and archaeological history of Taung. While the results of this renewed scientific agenda are preliminary, continued research will illuminate the importance of this site from the time of *Au. africanus* to recent hunter-gatherer occupations. The long record of time preserved within the various localities at Taung make it one of the most unique sites in southern Africa. Yet many of these localities remain unexplored and

thus 90 years after the discovery of *Au. africanus*, the true significance of Taung is still under examination.

Research conducted under SAHRA permit 80/09/10/028/51. We thanks the MEC for Environment in the North West Province for their continued support and access to the site.A.I.R.H. acknowledges funding from Australian Research Council Future Fellowship grant FT120100399. Initial fieldwork was supported in part by the Palaeontological Scientific Trust (PAST). Two seasons of fieldwork, laboratory analysis and core drilling were funded by National Geographic grants (8774-10 and 3212) awarded to P.J.H. Thanks to Francois Conradie and his team at Discovery Drilling for core extraction. Thanks also to students Rhiannon Stammers and Taylor Doran for their help in excavations at EQC. Grateful appreciation to editors Jonah Choiniere and Kieran McNulty and two anonymous reviewers whose comments greatly improved this manuscript.

REFERENCES

BEAUMONT, P.B., MILLER, G.H. & VOGEL, J.C. 1992. Contemplating old clues to the impact of future greenhouse climates in South Africa. *South African Journal of Science* **88**, 490–498.

BEAUMONT, P.B., VAN ZINDEREN BAKKER, E.M. & VOGEL, J.C. 1984. Environmental changes since 32 kyrs B.P. at Kathu Pan, Northern Cape, South Africa. **In**: Vogel, J.C. (ed.), *Late Cainozoic Palaeoclimates of the Southen Hemisphere*, 324–338. Rotterdam , Balkema.

BERGER, L.R., KEYSER, A.W. & TOBIAS, P.V. 1992. Galdysvale – first early hominid site discovered in S. Africa since 1948. *American Journal of Physical Anthropology* **92**, 107–111.

BOUNTALIS, A.C. 2012. *Cave usage and the implications of multiple taphonomic agents on a faunal assemblage.* MSc thesis, University of the Witwatersrand, Johannesburg.

BOUNTALIS, A.C. & KUHN, B.F. 2014. Cave usage by multiple taphonomic agents: issues towards interpreting the fossil bearing cave deposits in South Africa. *American Journal of Zoological Research* **2**(4), 55–61. DOI: http://dx.doi.org/10.12691/ajzr-2-4-1

BROOM, R. 1925a. On the newly discovered South African man-ape. *Natural History* **25**, 409–418.

BROOM, R. 1925b. Some notes on the Taungs skull. *Nature* **115**, 569.

BROOM, R. 1929. Note on the milk dentition of *Australopithecus*. *Proceedings of the Zoological Society of London* **99**(1), 85–88.

BROOM, R. 1930. The age of *Australopithecus*. *Nature* **125**, 814.

BROOM, R. 1934. On the fossil remains associated with *Australopithecus africanus*. *South African Journal of Science* **31**, 471–489.

BROOM, R. 1938. The Pleistocene anthropoid apes of South Africa. *Nature* **142**, 377–379.

BROOM, R. 1939. A preliminary account of the Pleistocene carnivores of the Transvaal caves. *Annals of the Transvaal Museum* **19**(3), 331–339.

BROOM, R. 1943. South Africa's part in the solution of the problem of the origin of man. *South African Journal of Science* **40**, 68–80.

BROOM, R. 1945. Age of the South African ape-man. *Nature* **155**, 389–390.

BROOM, R. 1946. The occurrence and general structure of the South African ape-men. *Transvaal Museum Memoir* **2**, 7–153.

BROOM, R. 1948a. The giant rodent mole, *Gypsohychus*. *Annals of the Transvaal Museum* **21**, 47–49.

BROOM, R. 1948b. Some South African Pliocene and Pleistocene mammals. *Annals of the Transvaal Museum* **21**, 47–49.

BUTZER, K.W. 1974. Paleoecology of South African Australopithecines: Taung revisited. *Current Anthropology* **15**(4), 367–382.

BUTZER, K.W. 1984. Late Quaternary environments on South Africa. **In**: Vogel, J.C. (ed.), *Late Cainozoic Palaeoclimates of the Southen Hemisphere*, 235–264. Rotterdam, Balkema.

BUTZER, K.W., STUCKENRATH, R., BRUZEWICZ, A.J. & HELGREN, D.M. 1978. Late Cenozoic paleoclimates of the Gaap Escarpment, Kalahari margin, South Africa. *Quaternary Research* **10**, 310–339.

CAMP, C.L. 1948. University of California African expedition – Southern section. *Science* **108**, 550–552.

CIPRIANI, L. 1928. Skull "*Australopithecus africanus*" Dart. *Archivio per l'Antropologia e la Etnologia* **57**, 1–29.

COOKE, H.B.S. 1990. Taung fossils in the University of California collections. **In**: Sperber, G.H. (ed.), *From Apes to Angels: Essays in Anthropology in Honor of Pillip V. Tobias,* 119–134. New York-Chichester-Brisbane-Toronto-Sigapore, Wiley-Liss.

CURNOE, D., HERRIES, A.I.R., BRINK, J., HOPLEY, P.J., VAN REYNVELD, K., HENDERSON, Z. & MORRIS, D. 2006. Discovery of middle Pleistocene fossil and stone tool-bearing deposits at Groot Klof, Ghaap Escarpment, Northern Cape Province. *South African Journal of Science* **102**, 180–184.

DART, R.A. 1925. *Australopithecus africanus*: the man-ape of South Africa. *Nature* **115**(2884), 195–199.

DART, R.A. 1948. The Makapansgat proto-human *Australopithecus prometheus*. *American Journal of Physical Anthropology* **6**, 259–283.

DELSON, E. 1988. Chronology of South African australopith site units. **In**: Grine, F.E. (ed.), *Evolutionary History of the "Robust" Australopithecines*, 317–324. New York, Aldine de Gruyter.

DORAN, T.L., HERRIES, A.I.R., HOPLEY, P.J., SOMBROEK, H., HELLSTROM, J.C., HODGE, E. & KUHN, B.F. 2015. Assessing the paleoenvironmental potential of Pliocene to Holocene tufa deposits along the Ghaap Plateau escarpment (South Africa) using stable isotopes. *Quaternary Research*. DOI: http://dx.doi.org/10.1016/j.yqres.2015.04.008

FAITH, J.T. 2014. Late Pleistocene and Holocene mammal extinctions on continental Africa. *Earth-Science Reviews* **128**, 105–121.

GRANGER, D.E., GIBBON, R.J., KUMAN, K., CLARKE, R.J., BRUXELLES, L. & CAFFEE, M.W. 2015. New cosmogenic burial ages for Sterkfontein Member 2 *Australopithecus* and Member 5 Oldowan. *Nature* **522**(7554), 85–88. DOI: http://dx.doi.org/10.1038/nature14268

GRINE, F.E. & KLEIN, R.G. 1985. Pleistocene and Holocene human remains from Equus Cave, South Africa. *Anthropology* **8**, 55–98.

HERRIES, A.I.R., PICKERING, R., ADAMS, J.W., CURNOE, D., WARR, G., LATHAM, A.G. & SHAW, J. 2013. A multi-disciplinary perspective on the age of *Australopithecus* in southern Africa. **In**: Reed, K.E., Fleagle, J.G. & Leakey, R.E. (eds), *Paleobiology of* Australopithecus, 21–40. Dordrecht, Springer.

HERRIES, A.I.R., CURNOE, D. ADAMS, J.W. 2009. A multi-disciplinary seriation of early *Homo* and *Paranthropus* bearing palaeocaves in southern Africa. *Quaternary International* **202**, 14–28.

HERRIES, A.I.R. & SHAW, J. 2011. Palaeomagnetic analysis of the Sterkfontein palaeocave deposits: implications for the age of the hominin fossils and stone tool industries. *Journal of Human Evolution* **60**(5), 523–539. DOI: http://dx.doi.org/10.1016/j.jhevol.2010.09.001

HOGG, A.G., HUA, Q., BLACKWELL, P.G., NJU, M., BUCK, C.E., GUILDERSON, T.P., HEATON, T.J., PALMER, J.G., REIMER, P.J., REIMER, R.W., TURNEY, C.S.M. & ZIMMERMAN, S.R.H. 2103. SHCal13 Southern Hemisphere calibration, 0–50,000 years cal BP. *Radiocarbon* **55**(4), 1889–1903.

HOPLEY, P.J., HERRIES, A.I.R., BAKER, S.E., KUHN, B.F. & MENTER, C.G. 2013. Beyond the South African cave paradigm – *Australopithecus africanus* from Plio-Pleistocene paleosol deposits at Taung. *American Journal of Physical Anthropology* **151**(2), 316–324. DOI: http://dx.doi.org/10.1002/ajpa.22272

HRDLIČKA, A. 1925. The Taungs Ape. *American Journal of Physical Anthropology* **8**, 379–392.

JOHNSON, B.J., MILLER, G.H., FOGEL, M.L. & BEAUMONT, P.B. 1997. The determination of late Quaternary paleoenvironments at Equus Cave, South Africa, using stable isotopes and amino acid racemization in ostrich eggshell. *Palaeogeography, Palaeoclimatology, Palaeoecology* **136**, 121–137.

KLEIN, R.G. 1986. Carnivore size and Quaternary climate change in southern Africa. *Quaternary Research* **26**, 153–170.

KLEIN, R.G., CRUZ-URIBE, K. & BEAUMONT, P.B. 1991. Environmental, ecological, and paleoanthropological implications of the Late Pleistocene mammalian fauna from Equus Cave, Northern Cape Province, South Africa. *Quaternary Research* **36**, 94–119.

KUHN, B.F., CARLSON, K.J., HOPLEY, P.J., ZIPFEL, B. & BERGER, L.R. 2015. Identification of fossilized eggshells from the Taung hominin locality, Taung, Northwest Province, South Africa. *Palaeontologia electronica* **18**(11A), 1–16.

LEE-THORP, J.A. & BEAUMONT, P.B. 1995. Vegetation and seasonality shifts during the Late Quaternary deduced from 13C/12C ratios of grazers at Equus Cave, South Africa. *Quaternary Research* **43**, 426–432.

McKEE, J.K. 2015. Return to the Taung Cave paradigm. *American Journal of Physical Anthropology* 2016 Feb; **159**(2): 348–351. DOI: 10.1002/ajpa.22883. Epub 2015 Nov 5.

McKEE, J.K. 1993a. Faunal dating of the Taung hominid fossil deposit. *Journal of Human Evolution* **25**, 363–376.

McKEE, J.K. 1993b. Formation and geomorphology of caves in calcareous tufas and implications for the study of the Taung fossil deposits. *Transactions of the Royal Society of South Africa* **48**(2), 307–322.

McKEE, J.K. 1994. Catalogue of fossil sites at the Buxton Limeworks, Taung. *Palaeontologia africana* **31**, 73–81.

McKEE, J.K., THACKERAY, J.F. & BERGER, L.R. 1995. Faunal assemblage seriation of southern African Pliocene and Pleistocene fossil deposits. *American Journal of Physical Anthropology* **96**, 235–250.

McKEE, J.K. & TOBIAS, P.V. 1990. New fieldwork at the Taung hominid site: 1988–1989. *American Journal of Physical Anthropology* **81**, 266–267.

McKEE, J.K. & TOBIAS, P.V. 1994. Taung stratigraphy and taphonomy: preliminary results based on the 1988–93 excavations. *South African Journal of Science* **90**(April), 233–235.

MORRIS, A.G. 1991. Biological relationships between Upper Pleistocene and Holocene populations in southern Africa. **In**: Bräuer, G. & Smith, F.H. (eds), *Continuity or Replacement: Controversies in* Homo sapiens *Evolution*, 131–143. Rotterdam, Balkema.

PARKER, J.F., HOPLEY, P.J., KUHN, B.F. 2016. Fossil Carder Bees' nest from the hominin locality of Taung, South Africa. *PLOS ONE* **11**(9): e0161198. DOI: 10.1371/journal.pone.0161198

PARTRIDGE, T.C. 1985. Spring flow and tufa accretion at Taung. **In**: Tobias, P.V. (ed.), *Hominid Evolution Past, Present and Future,* 171–187. New York, Alan R. Liss,

PARTRIDGE, T.C. 2000. Hominid-bearing cave and tufa deposits. **In**: Partridge, T.C. & Maud, P.R. (eds), *The Cenozoic in Southern Africa*, 100–125. Oxford Monographs on Geology and Geophysics. Oxford, Oxford University Press.

PARTRIDGE, T.C., BOLLEN, C.J., TOBIAS, P.V. & McKEE, J.K. 1991. New light on the provenance of the Taung Skull. *South African Journal of Science* **87**, 80–83.

PEABODY, F.E. 1954. Travertines and cave deposits of the Kaap Escarpment of South Africa, and the type locality of *Australopithecus africanus* Dart. *Bulletin of the Geological Society of America* **65**, 671–706.

PICKERING, R., DIRKS, P.H.G.M., JINNAH, Z., DE RUITER, D.J., CHURCHILL, S.E., HERRIES, A.I.R., WOODHEAD, J.D., HELLSTROM, J.C. & BERGER, L.R. 2011. *Australopithecus sediba* at 1.977 Ma and implications for the origins of the genus *Homo*. *Science* **333**, 1421–1423.

PICKERING, R. & KRAMERS, J.D. 2010. Re-appraisal of the stratigraphy and determination of new U-Pb dates for the Sterkfontein hominin site, South Africa. *Journal of Human Evolution* **59**(1), 70–86. DOI: http://dx.doi.org/10.1016/j.jhevol.2010.03.014

SCOTT, L. 1987. Pollen analysis of hyena coprolites and sediments from Equus Cave, Taung, southern Kalahari (South Africa). *Quaternary Research* **28**, 144–156.

SCOTT, L. 1989. Climate conditions in southern Africa since the Last Glacial Maximum, inferred from pollen analysis. *Palaeogeography, Palaeoclimatology, Palaeoecology* **70**, 345–353.

SCOTT, L. 2002. Grassland development under glacial and interglacial conditions in southern Africa: review of pollen, phytolith and isotope evidence. *Palaeogeography, Palaeoclimatology, Palaeoecology* **177**, 47–57.

SHACKLEY, M. 1981. *Environmental Arhaeology.* London, George Allen & Unwin.

SMITH, T., OLEJNICZAK, A.J., TAFFOREAU, P., REID, D.J., GRINE, F.E. & HUBLIN, J-J. 2006. Molar crown thickness, volume and development in South African Middle Stone Age humans. *South African Journal of Science* **102**, 513–517.

SPONHEIMER, M. & LEE-THORP, J.A. 1999. Alteration of enamel carbonate environments during fossilisation. *Journal of Archaeological Science* **26**, 143–150.

TOBIAS, P.V. 1985, The former Taung cave system in light of contemporary reports and its bearing on the skull's provenance: early deterrents to the acceptance of *Australopithecus*. Paper presented at the Hominid Evolution: Past, Present and Future Proceedings of the Taung Diamond Jubilee, Johannesburg and Mmabatho, South Africa, 1985.

TOBIAS, P.V., VOGEL, J.C., OSCHADLEUS, H-D. & PARTRIDGE, T.C. 1993. New isotopic and sedimentological measurements of the Thabaseek deposits (South Africa) and the dating of the Taung hominid. *Quaternary Research* **40**, 360–367.

VOGEL, J.C. & PARTRIDGE, T.C. 1984. Preliminary radiometric ages for the Taung tufas. **In**: Vogel, J.C. (ed.), Late Cainzoic palaeoclimates of the southern hemisphere, 507–514. Rotterdam, Balkema.

YOUNG, R.B. 1925. The calcareous tufa deposits of the Cambell Rand, from Boetsap to Taungs Native Reserve. *Transvaal Geological Society of South Africa* **28**, 55–67.

Proceedings of the 19th Biennial Conference of the Palaeontological Society of Southern Africa, Stellenbosch, 5–9 July 2016

Table of Contents

ORGANIZERS AND ACKNOWLEDGEMENTS 31

PROGRAMME 32

KEYNOTE ADDRESS 34

Rogers, R. Twenty years of palaeontological adventure and discovery on the Great Red Island, Madagascar 34

PLENARY TALKS 35

Benson, R., Day, M.O., Rubidge, B., Butler, R., Carrano, M., Alroy, J. Tetrapod diversification and sampling in the Karoo Basin, and the world 35

Fernandez, V. Synchrotron radiation-based science 36

Roberts, E.M., Broderick, T., Munyikwa, D., O'Connor, P., Carrano, M., Dirks, P., Jinnah, Z., Stevens, N., Owusu Agyemang, P. Revisiting Jurassic–Cretaceous fossil localities in the Mana Pools Basin and Mid-Zambezi Rift, Zimbabwe: new discoveries and sedimentological and taphonomic insights 37

Rogers, K.C. Tiny titanosaurs: primary growth and early ontogeny in a very young sauropod from Madagascar 38

Farke, A.A. Digital palaeontology for outreach and education: moving from promise to practice 39

Braga, J., Thackeray, J.F. The Kromdraai Research Project: new discoveries 40

Dirks, P. About the landscape, caves and fossils in the Cradle of Humankind; what determines their presence 41

CONFERENCE ABSTRACTS 42

Abrahams, M., Bordy, E.M., Sciscio, L., Knoll, F. Tridactyl dinosaur trackways in the Lower Jurassic upper Elliot Formation near Lephoto village (Roma, Maseru District, Lesotho) 42

Anderson, H.M. Generic and specific concepts in Molteno and Gondwana palaeobotany 42

Anderson, J.M. Biodiversity and extinction 42

Angst, D., Chinsamy, A., Steel, L., Hume, J. Life history insights of the dodo from bone histology 43

Araújo, R., Fernandez, V., Polcyn, M.J., Fröbisch, J., Martins, R.M.S. The neuroanatomy, braincase and occiput in Gorgonopsia revealed by synchrotron microtomography 43

Bamford, M.K. The diversity of conifer woods from the Early Cretaceous Kirkwood Formation and palaeoenvironmental implications 44

Barbolini, N., Bamford, M.K., Rubidge, B.S. Glacial barriers to floral migration in the Permo-Carboniferous of Gondwana . . . 44

Beaudet, A., Dumoncel, J., de Beer, F., Durrleman, S., Gilissen, E., Oettlé, A., Subsol, G., Thackeray, F., Braga, J. Early hominin brain evolution: extracting palaeoneurological evidence from the fossil record 45

Benoit, J., Norton, L.A. A reappraisal of the capacity to envenom the bite in Euchambersia (Therocephalia, Therapsida) using µCT scanning 45

Bergh, E.W., Compton, J.S. Stratigraphy and depositional environment of Namibian continental shelf sediments as indicated by fossil foraminifera 46

Bergh, E.W., Naran, D., Taylor, W. The role of museums in palaeontological education 46

Bordy, E.M., Sciscio, L., Reid, M., Abrahams, M. A new theropod dinosaur footprint site in the Lower Jurassic Elliot Formation (Mafube, eastern Free State, South Africa): footprint preservation in a semi-arid fluvio-lacustrine setting 47

Botha-Brink, J., Huttenlocker, A. K., Smith, R. M. H., Prevec, R., Modesto, S.P., Viglietti, P. New data on the Permo-Triassic Boundary from the Karoo Basin of South Africa 47

Bowen, D., van der Linde, C., Dinis, Y., Muir, R.A., Bordy, E.M. Palaeoenvironment, stratigraphy and evolution of Mesozoic rift basins, onshore Outeniqua Basin, Western and Eastern Cape, South Africa 48

Browning, C., Gabbott, S., Zalasiewicz, J., Theron, J. A record of sedimentation of the Late Ordovician Soom Shale Member (Cedarberg Formation) from new borehole data in the Cedarberg region of South Africa 48

Butler, E., Botha-Brink, J., Abdala, N.F. A new gorgonopsian from the uppermost Daptocephalus Assemblage Zone, Karoo Basin of South Africa 49

Canoville, A., Chinsamy, A. Palaeobiological implications of the bone microstructure of pareiasaurs (Parareptilia) from the Karoo Basin, South Africa 49

©2017 Evolutionary Studies Institute, University of the Witwatersrand. This is an open-access article published under the Creative Commons Attribution 3.0 Unported License (CC BY 3.0). This license permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited. This item is permanently archived at: http://wiredspace.wits.ac.za/ handle/10539/22433/

Palaeontologia africana **51**: 27–85 — ISSN 2410-4418 [Palaeontol. afr.] Online only

Permanently archived on the 30th of April 2017 at the University of the Witwatersrand, Johannesburg, South Africa.

This item is permanently archived at: http://wiredspace.wits.ac.za/handle/10539/22433

Canoville, A., de Buffrénil, V., Laurin, M. Microanatomical diversity of amniote ribs · · · · · 49

Cazenave, M., Braga, J., de Beer, F., Hoffman, J.W., Macchiarelli, M., Oettlé, A., Thackeray, J.F. Cancellous network patterning and cortical bone distribution at the proximal femoral end in *P. robustus* · · · · · 50

Chapelle, K., Choiniere, J.N. Three-dimensional morphometric analysis of the cranial ontogeny of *Massospondylus carinatus* based on CT reconstructions · · · · · 50

Chinsamy, A., Cerda I., Powell, J. Vascularized, endosteal bone tissue in saltasaurine titanosaurs from Argentina · · · · · 51

Choiniere, J.N., Chapelle, K.E.J., Brusatte, S.L., Hendrickx, C., Norell, M.A. CT-based reconstruction of the skull of the basal maniraptoran *Ornitholestes hermanni* Osborn 1903 · · · · · 51

Clayton, K.E., McPhee, B.W., Penn-Clarke, C., Choiniere, J.N., Jinnah, Z. Trace and body fossils of the Triassic-Jurassic Elliot and Clarens formations in the Lebombo–Tshipise Basin, South Africa · · · · · 52

Cohen, B.F. Archaeological methods and practice: a multidisciplinary approach · · · · · 52

Couzens, R. A. Spatial modelling, formation and transformation of the Oldowan lithic artefact assemblages from Sterkfontein caves, South Africa · · · · · 52

Day, M. O., Rubidge, B.S., Abdala, F. A new burnetiamorph therapsid from the *Pristerognathus* AZ of South Africa and a proposed solution to their stratigraphic incongruence · · · · · 53

Dinter, C.M., Benson, R.B.J., McPhee, B.W., Choiniere, J.N. New associated basal sauropodomorph material from the Late Triassic lower Elliot Formation, Karoo Basin, Eastern Cape · · · · · 53

Dollman, K.N., Choiniere, J.N. A study on the cranial anatomy of Lower Jurassic crocodylomorphs *Protosuchus haughtoni* and *Litargosuchus leptorhynchus* using 3D digital models · · · · · 54

Duhamel, A., Rubidge, B.S., Benoit, J., Day, M. New burnetiid specimens add to understanding of *Biarmosuchian* taxonomy and ontogeny · · · · · 54

du Plessis A., le Roux, S.G. X-ray CT scanning at Stellenbosch University: palaeontological applications · · · · · 54

Durugbo, E.U., Olayiwola, M.A., Yussuph, W.I., Bankole, S. I., Oyelami, A. Biostratigraphic and sequence analysis of Well H1, from the central Niger Delta, Nigeria · · · · · 55

Engelbrecht, M., Steininger C., Val A., Kibii J.M. Taxonomic and taphonomic analyses of fossil fauna from a new deposit in Gondolin · · · · · 55

Galimberti, M., Wiltshire N. A reflection on the use of palaeosensitivity maps in heritage resources management · · · · · 56

Gess, R.W. Estuarine fish breeding grounds: a tale of two times · · · · · 56

Gess, R.W., Harris, C. Environmental and depositional setting of a low diversity lingulid brachiopod assemblage from the Witpoort Formation (Witteberg Group, Cape Supergroup) east of Grahamstown · · · · · 56

Govender, R., Avery, G., Chinsamy-Turan, A. Marine and terrestrial carnivore damage on Mio-Pliocene marine mammals from the west coast of South Africa · · · · · 57

Groenewald., G. Palaeontological Impact Assessments – opportunities for exploring new fossil sites · · · · · 57

Groenewald, D.P., Rubidge, B.S., Day, M.O. Preliminary findings: litho- and biostratigraphic analysis of the Lower Beaufort Group, Karoo Supergroup, in the central Free State Province, South Africa, and implications for the depositional history of a distal bulge · · · · · 57

Haarhoff, P.J. West Coast Fossil Park – past, present and future · · · · · 58

Hancox, P.J. The vertebrate fauna from the lower Burgersdorp Formation (*Cynognathus* Assemblage Zone – *Langbergia* subzone) of South Africa · · · · · 58

Harrison, B., Bordy, E.M., Taylor, W.L., Högström, A. Investigating the Ediacaran–Cambrian boundary in the Vanrhynsdorp Group, South Africa, and the Vestertana Group of Finnmark, northern Norway · · · · · 59

Haupt, T., Mapekula, L., Bordy, E.M., Sciscio, L. Sedimentological, geochemical and palaeontological assessments across the upper Elliot and lowermost Clarens formations, South Africa · · · · · 59

Hilbert-Wolf, H.L., Roberts, E.M., Mtelela, C., O'Connor, P.M., Stevens, N. Geochronological and stratigraphic correlations of new late Oligocene and late Miocene–Pliocene vertebrate-bearing successions in the Rukwa Rift Basin · · 60

Iqbal, S., Carlson, K. J., Abdala, F., Fernandez, V. The functional morphology of the Early Triassic non-mammaliaform cynodont *Thrinaxodon liorhinus* forelimb · · · · · 60

Jakata, K. CT scanning of fossils at the Evolutionary Studies Institute · · · · · 61

Jirah, S., Rubidge, B.S., Abdala, N.F. Middle Permian diversity of large herbivores: taxonomic revision of the Titanosuchidae (Therapsida, Dinocephalia) of the Karoo Basin, South Africa · · · · · 61

Kock, S. Tree growth rings as a palaeoclimate proxy for the Karoo Basin · · · · · 61

Kruger, A., Randolph-Quinney, P., Elliott, M. Spatial taphonomic reconstruction of the Dinaledi Chamber, Rising Star Cave, by the use of high resolution three-dimensional data collection · · · · · 62

Krummeck, D.W., Bordy, E.M. Update on the digital library of ichnofossils in the Karoo Supergroup, South Africa · · · · · 62

Krupandan, E., Chinsamy, A. The long bone histology of *Antetonitrus ingenipes*: basal sauropoda and the evolution of the sauropod-type growth strategy · · · · · 62

Lavin, J., Thomas, G. Proposed new Palaeontological Guidelines for the Western Cape · · · · · 63

Legendre, L.J., Guénard, G., Botha-Brink, J., Cubo, J. Palaeohistological evidence for ancestral high metabolic rate in archosaurs · · · · · 63

Lennox, S.J. Charcoal analysis from 58 and 49 000-year-old hearths at Sibudu: Implications for wood uses and the KwaZulu-Natal environment during the Middle Stone Age · · · · · 64

Mahabeer, K., Barbolini, N., Bamford, M.K. Palynology of the Permian Mucanha-Vuzi Coal Basin (Ecca Group, Karoo Supergroup), Tete Province, Mozambique 64

Mckay, I.J. What is happening in palaeosciences outreach and education in South Africa in 2016? 64

Mann, N.J., Stynder D.D. Using phytolith evidence to reconstruct the Middle Pleistocene vegetation community along the southwest coast of South Africa 65

Master, S. Alexander Logie du Toit's drawings of Alfred 'Gogga' Brown's collection of Stormberg plant fossils, and notes on the localities of several important vertebrate fossil holotypes from the Eastern Cape 65

Master, S. New historical information on the first vertebrate fossil discoveries from Lesotho in 1867, including the type locality of the cynodont therapsid *Tritylodon longaevus* 66

Master, S., Bordy, E.M. A new fossil termite nest from the uppermost Clarens Formation at Pafuri River camp, Venda, Limpopo Province, South Africa – Comparison with other occurrences in southern Africa 66

Matiwane, A., Prevec, R. Investigations of a *Glossopteris* flora near Sutherland: a new approach embracing morphometric and ecological aspects 67

Matthews, T., Measey, G. J. Palaeoclimatic implications of frog taxa from South African fossil sites 67

McPhee, B.W., Choiniere, J.N., Sciscio, L., Bordy, E.M. The largest dinosaur in the Karoo: what the Highland Giant is and is not 67

Montoya-Sanhueza, G., Chinsamy, A. Bone microstructure of two highly specialized subterranean rodents: *Bathyergus suillus* and *Heterocephalus glaber* (Bathyergidae) 68

Montoya-Sanhueza, G., Chinsamy, A., La Grange, L., Stynder, D. Hindlimb histology of the specialized climber, *Procavia capensis* (Hyracoidea; Paenungulata) 68

Mtelela, C., Roberts, E.M., Hilbert-Wolf, H., Stevens, N., O'Connor, P. Stratigraphy, palaeontology and continental ichnology of the late Cenozoic Lake Beds Successions, Rukwa Rift Basin, Tanzania 69

Mudau, M.A.M., Mckay, I. J. Producing a glossary to explain palaeontological terms in indigenous South African languages for palaeoscientists, outreach officers, teachers and learners 69

Muir, R., Bordy, E.M. Stratigraphic framework of the Kirkwood Formation in the southern Cape region, South Africa: invertebrate-based biostratigraphy and zircon geochronology 70

Neumann, F.H., Cawthra, H.C., Carr, A.S., Scott, L., Durugbo, E., Humphries, M.S., Cowling, R., Bamford,M.K., Musekiwa, C., MacHutchon, M. Palaeoenvironmental fluctuations during a terminal Oligocene–early Miocene transgression at the southwestern tip of Africa 70

Ngoloyi, N., Braga, J., Fourvel, J.B., Lans, B. The use of GIS and multi-scalar analysis tools to reconstruct the geomorphology of the fossil hominin sites and, to facilitate the understanding and interpretation of fossil hominin taphonomy in Kromdraai and the Cradle of Humankind 71

Norton, L.A., Abdala, F., Rubidge, B.S., Botha-Brink, J. Comparison of tooth replacement patterns of the Permo-Triassic epicynodonts *Cynosaurus* and *Galesaurs* 71

Parkinson, A.H. New ichnotaxa from Cooper's D, Cradle of Humankind, South Africa 72

Penn-Clarke, C.R., Rubidge, B.S., Jinnah, Z.A. The rise and fall of the Malvinokaffric Realm in South Africa: insights from palaeoenvironmental, biostratigraphic and sequence stratigraphic data 72

Phillips, C.A., Harris, J.W.K., Bamford, M.K. The palaeoenvironment (*c.* 1.6 Ma) of FxJj20 complex, Koobi Fora, Kenya, using phytoliths 73

Pickering, R. Frequency and duration of U-Pb dated flowstone growth intervals in South African early hominin caves reflect Early Pleistocene climate variability 73

Prevec, R. *Rigbya* revisited: a large new collection from KwaZulu-Natal confirms glossopterid affinities and associated *Glossopteris* leaf morphotype 73

Rammutla, R.T., Rubidge, B.S., Day, M.O. Lithology and palaeontology of the Ecca–Beaufort contact in the northern Karoo Basin 74

Redelstorff, R., Hine, P. New 'Guidelines for Palaeontological Permitting Policy' by SAHRA: what are the improvements? . . . 74

Reid, M., Bordy, E.M., Taylor W.L. Exploring an ophiuroid–stylophoran assemblage from the Devonian Voorstehoek Formation, Bokkeveld Group, Western Cape: taphonomy, palaeoecology and taxonomy 75

Rey, K., Amiot, R., Fourel, F., Abdala, F., Fluteau, F., Jalil N-E., Liu, J., Rubidge, B.S., Smith, R.M.H., Steyer. J-S., Viglietti, P.A., Wang, X., Lécuyer, C. Oxygen isotopes suggest elevated thermometabolism within multiple Permo-Triassic therapsid clades 75

Ritzman, T., Schoville, B. Seasonal exploitation of coastal resources in the Middle and Later Stone Age of southern Africa from comparative Cape fur seal (*Arctocephalus pusillus*) assemblages 76

Rogers, R., Curry Rogers, K., Carrano, M. Isotaphonomy in concept and practice: an exploration of vertebrate microfossil bonebeds in the Upper Cretaceous (Campanian) Judith River Formation, North-Central Montana 76

Rubidge, B.S., Day, M.O. The Middle Abrahamskraal Formation and the mystery of the *Eodicynodon–Tapinocephalus* Assemblage Zone transition 77

Sciscio, L., Bordy, E.M., McPhee, B.W., Choiniere, J.N. The first vertebrate burrow from the upper Elliot Formation (Early Jurassic), main Karoo Basin 77

Shelton, C., Chinsamy, A. Histovariability revealed in anteosaurid (Therapsida: Dinocephalia) limb bones 78

Singh, M., Barbolini, N. Preliminary report on the palynology of the Permian Mid-Zambezi Basin of Zambia 78

Smith, R.M.H., Sidor, C.A., Angielczyk, K.D., Nesbitt, S., Tabor, N. Taphonomy and sedimentary environments of mid-Triassic vertebrate accumulations, Lifua Member (Manda beds), Ruhuhu Basin, Tanzania · · · · · · · · · · · · 78

Staunton, C.K., Choiniere, J.N. The evolution of forelimb architecture in early sauropodomorphs · 79

Stratford, D. Increasing stratigraphic resolution within the *Australopithecus*-bearing Member 4 deposit, Sterkfontein · · · · · · · · 79

Stynder, D. An analysis of gross dental wear and dental breakage patterns to determine the dietary ecology of large-bodied carnivores from Langebaanweg 'E' Quarry · · · · · · · · · · · · · · · · · · ·



19th Biennial Conference of the Palaeontological Society of Southern Africa Stellenbosch, 5–9 July 2016

Organizers and acknowledgements

Major funding was provided by: NRF-KIC: National Science Foundation Knowledge Interchange and Collaboration funding and PAST: the Palaeontological Scientific Trust of Southern Africa.

Financial support was provided by: Stellenbosch University, The Department of Earth Sciences at Stellenbosch University, the Western Cape Gravel Monkeys with the Department of Earth Sciences at Stellenbosch University, the Western Cape Branch of the Geological Society of South Africa, the Society of Vertebrate Palaeontology, the DST/NRF Centre of Excellence in Palaeosciences at the University of the Witwatersrand.

Editors: Bordy, E.M., Viglietti, P., Carlson, K., Rubidge, B.S., Bamford, M.K., Smith, R.M.H., Botha-Brink, J., Abdala, N.F., Choiniere, J.N., Roberts, E.M., Dirks, P., Jinnah, Z., Chapelle, K.E.J., Prevec, R., Tucker, R.T., Shelton, C., Farke, A.A., McKay, I., Stratford, D., Braga, J.

Organizing Committee Chairs: Tucker, R.T., Choiniere, J.N., Chapelle, K.E.J., Jinnah, Z., Roberts, E.M. & Bamford, M.K.

Special Thanks go to: Choiniere, J.N., Bamford, M.K., Rubidge, B.S., Roberts, E.M., Jinnah, Z., Chapelle, K.E.J. and Prevec, R., for their continued support throughout the past two years during the preparation of this meeting. Furthermore, thanks go to the M.Sc. students of the Western Cape Gravel Monkeys at Stellenbosch University including: Walters, S., Rademen, Z., Jonk, L., along with many others for volunteering throughout the PSSA 2016 event.

We also wish to thank Triggerfish Brewery, Camberley Wines, Twaalf, Nooitgedacht Wine Farms, Darling Brewery, Stellenbrau and Blitz Braais for hosting our events.

The logo of the PSSA 2016 Conference and other sketches depict the integrations of the Western Cape Winelands and the Palaeontological Society of Southern Africa. All drafts were the production of palaeoartist Dr Owen Li of Petrified Pencils, NSW, Australia.

Programme

Monday July 4

Ice Breaker & Registration
Triggerfish Brewery (Somerset West)
Begins at 5:30 pm

Tuesday, July 5

7:45 am Prestart coffee

8:15 am *Opening Remarks*: Deputy Vice Chancellor Research Prof. Eugene Cloete

Symposium: New Approaches to Biostratigraphy in the Karoo Basin

8:45 am *Plenary Talk:* Dr Roger Benson
9:15 am Rubidge, B.S.
9:30 am Day, M.O.
9:45 am Viglietti, P.A.
10:00 am Jirah, S.
10:15 am Groenewald, G.

Tea 10:30–11:00 am

11:00 am Van den Brandt, M.J.
11:15 am Butler, R.
11:30 am Hancox, P.J.
11:45 am Muir, R.

Lunch 12:00–1:00 pm

General Session

1:00 pm Iqbal, S.
1:15 pm Master, S.
1:30 pm Norton, L.A.
1:45 pm Welman, J.
2:00 pm McPhee, B.W.
2:15 pm Dinter, C.M.

Tea 2:30–3:00 pm

3:00 pm Wiersma, J.

Symposium: Virtual Palaeontology

3:15 pm *Plenary Talk:* Dr Vincent Fernandez
3:45 pm Du Plessis A.
4:00 pm Jakata, K.
4:15 pm Reid, M.
4:30 pm Araújo, R.
4:45 pm Benoit, J.
5:00 pm Dollman, K.N.
5:15 pm Staunton, C.K.
5:30 pm Chapelle, K.E.J.
5:45 pm Choiniere, J.N.

Poster Session – 6.45 pm

Bowen, D.
Canoville, A.
Duhamel, A.
Durugbo, E.U.
Engelbrecht, M.
Galimberti, M.
Gess, R.W.
Haupt, T.
Master, S.
Montoya-Sanhueza G.
Rammutla, R.T.
Singh, M.
Stynder, D.
Thackeray, J.F.
Von Der Meden, J.
Zanolli, C.

Wednesday, July 6

7:45 am Prestart coffee
8:30 am Opening

Symposium: Sedimentary Influences on the Fossil Record

8:45 am *Plenary Talk:* Dr Eric Roberts
9:15 am Rogers, R.
9:30 am Sciscio, L.
9:45 am Hilbert-Wolf, H.L.
10:00 am Smith, R.M.H.
10:15 am Bordy, E.M.

Tea 10:30–11:00 am

11:00 am Mtelela, C.
11:15 am Abrahams, M.
11:30 am Bergh, E.W.
11:45 am Penn-Clarke, C.

Lunch 12:00–1:00 pm

1:00 pm Browning, C.
1:15 pm Clayton, K.E.

Symposium: Karstic Palaeontology

1:30 pm *Plenary Talk:* Dr Paul Dirks
1:45 pm Couzens, R.A.
2:00 pm Venter, C.
2:15 pm Pickering, R.

Tea 2:30–3:00 pm

3:00 pm Kruger, A.
3:15 pm Parkinson, A.H.
3:30 pm van Dijk, E.
3:45 pm Bamford, M.K.
4:00 pm Botha-Brink, J.
4:15 pm Matiwane, A.
4:30 pm Prevec, R.
5:00 pm Anderson, H.M.
5:15 pm Master, S.
5:30 pm Mahabeer, K.
5:45 pm Barbolini, N.

Conference Keynote Address

6:45 pm Prof. Raymond Rogers

ISSN 2410-4418 *Palaeont. afr.* (April 2017) **51**: 27–85

Thursday, July 7

7:45 am Prestart coffee

8:30 am Opening

Symposium: Hominin Evolution

8:45 am *Plenary Talk:* Dr Jose Braga

9:15 am Stratford, D.

9:45 am Ngoloyi, N.

10:00 am Zipfel, B.

10:15 am Cazenave, M.

Tea 10:30–11:00 am

11:00 am Phillips, C.A.

11:15 am Lennox, S.J.

11:30 am Ritzman, T.

11:45 am Krummeck, D.W.

Lunch 12:00–1:00 pm

Symposium: Palaeosciences, Education, and Outreach

1:00 pm *Plenary Talk:* Dr Andrew Farke

1:30 pm McKay, I.J.

1:45 pm Tawane, G.M.

2:00 pm Bergh, E.W.

2:15 pm Haarhoff, P.J.

Tea 2:30–3:00 pm

3:00 pm Mudau, M.A.M.

3:15 pm Wentzel, W.A.

3:30 pm Anderson, H.M.

General Session

3:45 pm Gess, R.W.

4:00 pm Matthews, T.

4:15 pm Harrison, B.

4:30 pm Stynder, D.D.

4:45 pm Mann, N.J.

5:00 pm Govender, R.

5:15 pm Neumann, F.H.

5:30 pm Cohen, B.F.

Friday, July 8

7:45 am Prestart coffee

8:15 am Opening Centre of Excellence, Palaeosciences Program Director Dr Christine Steininger

Symposium: Vertebrate Histology & Microanatomy

8:45 am *Plenary Talk:* Dr Kristina Curry Rogers

9:15 am Canoville, A.

9:30 am Shelton, C.

9:45 am Legendre, L.J.

10:00 am Krupandan, E.

10:15 am Chinsamy, A.

Tea 10:30–11:00 am

11:00 am Groenewald, G.

11:15 am Angst, D.

11:30 am Montoya-Sanhueza, G.

11:45 am Rey, K.

Lunch 12:00–1:00 pm

General Session

1:00 pm Lavin, J.

1:15 pm Redelstorff, R.

Biennial General Meeting

1:30 pm Prof. Marion Bamford, President's address

End of Conference Awards & Dinner

Begins at 6:30 pm

Saturday, July 9

Field Trip: Langebaan Fossil Park

Begins at 7:00 am

Keynote Address

Twenty years of palaeontological adventure and discovery on the Great Red Island, Madagascar

Professor Raymond Rogers

Geology Department, Macalester College, St. Paul, Minnesota, U.S.A.

Approximately 180 million years ago, the supercontinent Gondwana began to fragment into isolated landmasses. The island of Madagascar was initally positioned in the center of Gondwana, nestled between mainland Africa and India. But by ~85 million years ago powerful geological forces had left Madagascar isolated, as it is today, in the Indian Ocean. For the past 20 years, over the course of eight eventful expeditions, I have worked as the geologist and taphonomist for the Mahajanga Basin Project (MBP), a multinational, multi-institutional team of researchers devoted to exploring the fossil and rock records of Madagascar.

Over the years, the MBP team has documented an amazing menagerie of extinct animals, including fishes, frogs, turtles, lizards, snakes, crocodyliforms, nonavian dinosaurs, birds, and mammals. In this plenary talk we will explore some of the highlights of the MBP, including (1) a meat-eating dinosaur that practiced cannibalism (the theropod *Majungasaurus*), (2) baby dinosaurs, no bigger than a Golden Retriever, that grew to immense adult size (the sauropod *Rapetosaurus*), (3) pug-nosed, plant-eating crocodiles (*Simosuchus*), and bizarre little mammals (*Vintana*). We will also investigate why ancient Cretaceous rocks of Madagascar yield so many fantastic fossils. Interestingly, the majority of the exquisitely preserved vertebrate fossils of Madagascar show evidence of dying during stressful environmental episodes, such as droughts (drought is a major killing agent in Africa to this day). When the rains returned, the dead were entombed within debris flow deposits that shielded animal remains from destructive surface processes and ushered them into the fossil record.

Funding acknowledgement: Provided by National Science Foundation (EAR-0446488, EAR-1123642), the National Geographic Society (8597-09), and Macalester College.

Plenary Talk

Tetrapod diversification and sampling in the Karoo Basin, and the world

Benson, R.[1], Day, M.O.[2], Rubidge, B.[2], Butler, R.[3], Carrano, M.[4], Alroy, J.[5]

[1]*Department of Earth Sciences, University of Oxford, U.K.*

[2]*Evolutionary Studies Institute, University of the Witwatersrand, Johannesburg, South Africa*

[3]*School of Geography, Earth and Environmental Sciences, University of Birmingham, U.K.*

[4]*Department of Paleobiology, Smithsonian Institution, Washington DC, U.S.A..*

[5]*Department of Biological Sciences, Macquarie University, Sydney, Australia*

Biostratigraphy is a core application of fossil data, with wide utility across evolutionary biology and the earth sciences. Despite its long history, biostratigraphic research remains a dynamic field of investigation. High-resolution field studies continue to yield insight on the stratigraphic column. Parallel advances in global fossil occurrence databases (https://paleobiodb.org) and quantitative analytical methods are providing significant insights into the timing and causes of faunal turnover in deep time. The Karoo Basin of South Africa has become a model system for terrestrial biostratigraphy, containing thousands of tetrapod specimens, and contributing seminal information on major events in the evolution of terrestrial ecosystems. This includes extinction and recovery around the Middle/Late Permian transition. Preservation of fossil-bearing deposits is uneven in time and space. Furthermore, the available fossil record is unevenly sampled. These factors bias inferences of ancient biodiversity, and of speciation and extinction rates at both global and regional levels. Bias is more pervasive than commonly conceived, and even those studies that attempt to correct them have typically presented continuous, 'global' time series of fossil diversity, giving an inflated impression of our knowledge of deep time diversity. Using a near-complete database of Mesozoic–Palaeocene tetrapod occurrences, we show that there is no such thing as the 'global' fossil record. Instead, the record comprises patchily distributed regional windows on diversity. This will seem obvious to some palaeontologists, and provides an important message: that statistical analyses of global databases are only useful if they explicitly analyse this patchwork of regions. When analysed as such, the inferred pattern of Mesozoic tetrapod diversity appears relatively static, with low long-term rates of increase. This differs entirely from previous notions of substantial and unbounded diversification in Mesozoic tetrapods. A key role for high-resolution regional databases should be recognized. In this context, we present analysis of 3500 occurrences of Middle Permian–early Late Permian tetrapod fossils from the Karroo Basin. Sampling-informed measures indicate high extinction rates near the top of the *Tapinocephalus* AZ. Subsequent recovery was delayed: the *Pristerognathus* AZ is a protracted interval of low diversity, with high rates of origination only in its upper part. We anticipate that further documentation and study of the Karoo succession will continue to yield substantial further insights.

Plenary Talk

Synchrotron radiation-based science

Fernandez, V.

European Synchrotron Radiation Facility, 71 avenue des Martyrs, 38000 Grenoble, France

Synchrotron has become a more and more popular tool for palaeontological investigation since the advent of the 21st century. A synchrotron is simply a ring-shaped particle accelerator generating X-rays, surrounded by experimental hutches in which a variety of studies can be conducted. Most common in palaeontological investigations are the use of X-rays for computed tomography – that is producing 3D images from X-ray slices through a fossil. Although CT methods are available in labs worldwide, the synchrotron beam has distinct advantages, primarily in its intensity. This progressively opens the gate to observing matter in the nano-world at resolutions not previously achievable. With such assets, synchrotrons are optimized for use in a broad variety of applications, whether it is to understand how a material evolves under certain pressure and temperature conditions, or to visualize protein structure at the atomic level. While the European synchrotron was built to facilitate research from scientists of member countries, there has also been a growing interest from African researchers, notably in South Africa that joined the coalition in 2013 as scientific associate. With the growing synchrotron user community from African countries, a Steering Committee was elected at the end of 2015 to initiate the process leading to the construction of the first light source in Africa. By continuing to scan rare and unique fossils, progressively replacing crucial but invasive techniques (such as virtual histology) and keeping on learning other synchrotron techniques to apply them in our domain, African palaeontologists have an important role to play in the prospect to see a synchrotron emerge on their continent.

Plenary Talk

Revisiting Jurassic–Cretaceous fossil localities in the Mana Pools Basin and Mid-Zambezi Rift, Zimbabwe: new discoveries and sedimentological and taphonomic insights

Roberts, E.M.[1], Broderick, T.[2], Munyikwa, D.[3], O'Connor, P.[4], Carrano, M.[5], Dirks, P.[1], Jinnah, Z.[6], Stevens, N.[4], Owusu Agyemang, P.[1]

[1]*James Cook University, Australia*

[2]*Harare, Zimbabwe*

[3]*National Museums and Monuments of Zimbabwe (Natural History Museum)*

[4]*Ohio University, U.S.A.*

[5]*Smithsonian Institution, U.S.A.*

[6]*University of the Witwatersrand, South Africa*

Three expeditions were conducted between 2007 and 2010 in the Zambezi Valley, which focused on revisiting historic dinosaur fossil localities in the Mana Pools and Mid-Zambezi basins, northern Zimbabwe. In Mana Pools National Park, excavation of a spectacular Early Jurassic bonebed (laterally correlative to the bonebed excavated by M. Raath in the late 1970s) containing associated to partially articulated remains of *Syntarsus rhodesiensis* was conducted, and a number of other new fossil localities were discovered, including the site of a beautifully preserved partial skeleton of a small prosauropod dinosaur. Most of the jackets containing the dinosaur material have now been prepared (nearly doubling the amount of material known for *Syntarsus rhodesiensis*), and detailed analysis of the taphonomy and palaeobiology of both sites is underway. Additional exploration was conducted in the Chewore Safari Area, including mapping of a new large sauropod trackway along the Ntumbe River and discovery of abundant partially preserved fish fossils from the Ntumbe beds. Detailed sedimentological, biostratigraphic and provenance investigation of sites from both the Mana Pools and Chewore areas have now been completed, which yield new insights into the age, depositional environments, regional tectonics and palaeofluvial drainage evolution of the Mid-Zambezi Rift System. An update and summary of these findings will be presented.

Funding acknowledgement: We acknowledge the National Geographic Society-CRE and the Jurassic Foundation for supporting this research. We also acknowledge the University of Zimbabwe for their technical support and use of equipment and vehicle rental. James Cook University provided E.M.R. with a small faculty grant to conduct U-Pb detrital zircon geochronology.

Plenary Talk

Tiny titanosaurs: primary growth and early ontogeny in a very young sauropod from Madagascar

Rogers, K.C.

Departments of Geology and Biology, Macalester College, Minnesota, U.S.A.

Sauropods began their lives as tiny animals and exhibit an ontogenetic size difference between hatchlings and adults greater than that for any other terrestrial vertebrate. The lack of data for perinatal sauropods hampers our understanding of the strategies that allowed them to achieve such astounding changes in size. Here I describe a very young specimen of *Rapetosaurus krausei* that represents one of the smallest post-hatching sauropods yet recovered. The perinatal specimen is represented by associated elements from the forelimb, hindlimb, pelvic girdle, and vertebral column. Limb element lengths indicate that this very young juvenile stood ~35 cm at the hip, and may have weighed as little as ~25 kg. In spite of its very small body size, limb elements do not exhibit significant differences from later stage juvenile and adult morphology and generally scale isometrically as documented for other sauropod taxa. Bone histological and microCT data indicate that young *Rapetosaurus* grew very quickly, but that this fast growth coincided with an early onset of bone remodelling that extends into the mid-cortex of all sampled appendicular elements. LAGs and annuli are absent, but an intracortical zonation indicates a post-hatching growth hiatus similar to hatching lines in reptiles and neonatal lines in birds. *Rapetosaurus* hatching lines provide a lower limit for body size in this titanosaur. Remodelling may be related to a phylogenetic shift in titanosaur growth strategies, to biomechanical loading, to blood calcium homeostasis, or to a combination of all three. Epiphyseal regions comprise zones of calcified cartilage perforated by tubes lined with newly formed bone tissue. These zones are thinner than in other perinatal dinosaurs and could indicate relatively slow elongation of limb bones, but is inconsistent with observed rapid appositional growth and frequency of secondary remodelling. These data combined with the taphonomy and palaeoenvironmental context of the Maevarano Formation support the hypothesis that *Rapetosaurus* were nidifugous (precocial), probably not reliant on significant postnatal parental care, and died just a few weeks after hatching as a victim of Late Cretaceous drought stress in ancient Madagascar.

Plenary Talk

Digital palaeontology for outreach and education: moving from promise to practice

Farke, A.A.

Raymond M. Alf Museum of Paleontology, Claremont, CA 91711, U.S.A.

Three-dimensional digitization of fossils has moved from a flashy novelty to a standard tool for palaeontological research. In addition to immediate research needs, digitization efforts are often promoted as beneficial for outreach and education, by allowing broader access to specimens in museum collections. Yet, it remains difficult to truly bring fossils to the masses. Despite the increasing variety of digitization methods, it can still be time-consuming and often expensive to model large numbers of specimens. Many important digitized fossils remain unavailable for broader access, variously due to researcher and museum desires to restrict distribution or technological difficulties in archiving and distributing data. Even when digital fossils are accessible, it takes effort to alert the public to their availability as well as to create meaningful educational opportunities around the specimens. Disparities in access to technology affect institutions, researchers, educators and the public alike. If digital fossils are to achieve their full potential as research and educational tools, solutions to all of these problems must be implemented. First and foremost, a culture shift within the scientific community is required to encourage and reward active sharing of digital data. Improvements in technological infrastructure, via websites such as MorphoSource, contribute positively to this. For usage in formal and informal education settings, access to technology (or creative work-arounds) is key. Furthermore, continued development of standards-based lesson plans using digital fossils is also necessary. Ongoing work by numerous parties shows considerable promise for expanding use of digital fossils in education and outreach.

Plenary Talk

The Kromdraai Research Project: new discoveries

Braga, J.[1], Thackeray, J.F.[2]

[1]*University of Toulouse, CNRS, France*

[2]*Evolutionary Studies Institute, University of the Witwatersrand*

The Plio-Pleistocene site of Kromdraai (Gauteng, South Africa) is of interest because the dentally and cranially more generalized states shown by some of its 27 hominins recovered until 2014 and not displayed by other southern African congenerics sampled thus far, may lie close to the origin of a putative *Paranthropus* monophyletic clade close to or before 2.3 Ma. However, current scenarios consider that *Paranthropus* did not occur in southern Africa prior to 2.0 Ma. Fieldwork undertaken since 2014 by the Kromdraai Research Project (KRP), as well as laboratory work on newly and previously discovered KB fossils, (i) demonstrate the much larger size of the Kromdraai site through the exposure of extensive and until then unexplored fossiliferous deposits; (ii) recovered as yet (until March 2016) more than 2000 identifiable macrovertebrate fossils, including 22 new hominins, all from the earliest part of the Kromdraai stratigraphic sequence from Member 1 to Member 3; (iii) established relative chronological relationships between Kromdraai A and B localities; (iv) initiated revised taxonomic, phylogenetic and taphonomic interpretations of the Kromdraai fossils by more precisely taking into account the context of their discovery (i.e. stratigraphic provenience or not), and by using computer-assisted 3D imaging methods and recent advances in 3D morphometry. These exciting new discoveries lead to increasing the timeline of hominins at this site, with the recognition of hominin-bearing sediments lower than Member 3 that might register a continuation from Sterkfontein Member 4 to the succeeding phases represented by Swartkrans Member 1 and Sterkfontein Member 5.

Funding acknowledgement: This work is supported by the Institut des Déserts et des Steppes, the French Ministry of Foreign Affairs, the CNRS and the NRF.

Plenary Talk

About the landscape, caves and fossils in the Cradle of Humankind; what determines their presence

Dirks, P.

Department of Geosciences, College of Science & Engineering, James Cook University, Townsville, Queensland 4811, Australia

Why do fossils end up in caves and why are they preserved? Is the chain of events that led to fossilization simply dependent on chance due to the occasional convergence of suitable circumstance, or is the process more specific, and in part systemic and predictable? The answer to these questions lies not simply in the behavioural patterns of the animals involved, and how they interacted with the landscape. There are also a range of physical processes, climate variability, landscape dynamics, and cave formation, as the most obvious ones, that influenced fossil deposition.

In this talk I would like to inspect the relationship between hominid fossil deposits and the caves and landscapes in the Cradle of Humankind (CoH) in which they occur, to determine to what degree the physical environment facilitated fossil formation, preservation and variations therein.Caves in the CoH occur in dolomite, and their formation and exposure is the result of erosion and tectonics. Cosmogenic isotope dating in the CoH indicate erosion rates of 2–3 m/Ma, and suggests that the caves are younger than 4 Ma. In combination with other dating techniques and knowledge of cave geometries it appears that most caves formed sometime between 2–3 Ma and, as the climate changed, may have been relatively inactive (except as fossil depositories) after that. Caves with macrofossils are not randomly distributed, but relate to a range of topographic and geological controls such as terrain roughness, slope direction, faulting and proximity to water sources, which allows for the construction of fossil prospectivity maps. Fossil deposits also appear to vary depending on their position on the landscape (e.g. breccia-dominated deposits away from river courses; mud-dominated deposits near river courses). New species like *A. sediba* and *H. naledi* come from non-traditional deposits and suggest a high degree of localized niche behaviour by hominins. Whilst fossil distribution can be linked to landscape-scale processes; fossil preservation is a function of the cave environment itself. Within individual caves, it can be observed that fossil deposits occur intermittently separated by depositional non-conformities commonly decorated with flowstone. Of particular interest is evidence of event horizons in the sedimentary sequence that link to fossil deposits and reflect sudden and dramatic changes to the cave environment. These changes could be externally driven (e.g. a climate event) or internal to the cave (e.g. chamber collapse). Of note are the association of fossil deposits with geological anomalies such as quartz veins or palaeomagnetic reversals.

Conference Abstracts

Tridactyl dinosaur trackways in the Lower Jurassic upper Elliot Formation near Lephoto village (Roma, Maseru District, Lesotho)

Abrahams, M.[1], Bordy, E.M.[1], Sciscio, L.[1], Knoll, F.[2,3]

[1]*Department of Geological Sciences, University of Cape Town, 7701 South Africa*

[2]*School of Earth, Atmospheric and Environmental Sciences, University of Manchester, Manchester, U.K.*

[3]*School of Earth Sciences, University of Bristol, Bristol, U.K.*

Footprint morphology (outline, shape, impression depth) is a principal feature used to interpret vertebrate tracks. The upper Elliot Formation is well known for the wealth of Early Jurassic footprint sites and their different morphologies. Recent fieldwork on previously reported but unstudied footprint localities within the Lower Jurassic upper Elliot Formation at Roma (Maseru District, Lesotho) has revealed approximately 40 footprints on a single 4 m^2 slab near Lephoto village. These tracks vary in size and make up thee distinct track-ways. Morphologically the footprints are tridactyl, with divergent curvature of the digits and pointy tips with some prints preserving digital pad impressions and claw marks. The tridactyl prints can be subdivided by size due to low morphological variation. These split the tracks into two groups, smaller (6 cm length) footprints and larger (16 cm length) footprints. Trackways illustrate three individuals walking in E–W and W–E directions. Although preservation of the slab and the associated sedimentological structures (e.g. ripple marks and dessication cracks) is good, it is unclear as to whether or not the footprints are true-tracks or under-tracks. The footprints can be attributed to theropod track-makers based on the following criteria: a) the absence of manus impressions which is suggestive of bipeds, b) the impressions are long rather than broad and c) the digits are asymmetrical, long and slender.

Funding acknowledgement: The financial support of the DST-NRF Centre of Excellence in Palaeosciences (CoE in Palaeosciences) and NRF Competitive Programme for Rated Researchers to E.M.B. towards this research is hereby acknowledged.

Generic and specific concepts in Molteno and Gondwana palaeobotany

Anderson, H.M.

Honorary Research Associate, Evolutionary Studies Institute, University of the Witwatersrand, Johannesburg

An historical perspective is provided of the development of the 'Palaeodeme' concept and its application to the study of fossil plants from the Molteno Formation as undertaken by John Anderson and myself. The palaeodeme was the subject of a presentation at the first PSSA meeting in the early 1970s. Now 45 years on we still have the same problems in palaeobotany and a novice researcher could well be asking the same question I once asked. How does one define the variable leaves of the genus *Dicroidium* – as one or as six genera and decide on a multitude of specific names? How does one communicate with researchers from the various Gondwana continents if the same definitions are not used? One may ask 'Is it of concern?' In solving problems of distribution, phylogeny, palaeoecology it is of great importance to use uniform taxonomy and nomenclature. According to present literature, *Umkomasia*, the female fruit of *Dicroidium* first appears in the Upper Permian of India (Chandra *et al.* 2008) and the last record is from the Lower Cretaceous of Mongolia (Shi *et al.* 1916). In my opinion these fruits have been incorrectly classified and are not *Umkomasia*. Therefore, even a simple question 'What is the first and last appearance of a genus?' can lead to very different answers. At present *Umkomasia*, originally based on a good collection of fossils with the affiliated male organs (*Pteruchus*) and the leaves (*Dicroidium*) is becoming a basket genus for any female fruit with somewhat similar cupule morphology found anywhere in the world.

Biodiversity and extinction

Anderson, J.M.[1,2]

[1]*Honorary Research Associate, Evolutionary Studies Institute, University of the Witwatersrand, Johannesburg*

[2]*Honorary Professor, Africa Earth Observatory Network (AEON), Nelson Mandela Metropolitan University, Port Elizabeth*

We are running a 12-part series on '*Biodiversity & Extinction*' in the school-kid magazine Supernova. Each part covers a major group of plants or animals on a two-page spread. And each aims to include the most recently published Timetree for the relevant group, along with sketches of typical members of the orders (or classes) covered. The focus, then, is on the known (and still unknown) global diversity of the group and on our ongoing human impact on that richness of life. The interdependent nature of all life, climate change and drifting continents is emphasized. The seven parts published to date are: Part 1, *Introduction*, 'from the printing press to biodiversity'; Part 2, *Flowering Plants*, that appeared at around 135 Ma in the

Early Cretaceous; Part 3, *Birds*, that appeared at around 150 Ma, in the Late Jurassic; Part 4, *Mammals*, that appeared at around 200 Ma, in the Late Triassic; Part 5, *Insects*, that appeared around 425 Ma, in the Late Silurian; Part 6, *Molluscs*, that appeared at around 540 Ma, near the Ediacaran–Cambrian boundary; and Part 7, *Hominins*, including the gorillas, chimpanzees and humans going back to around 10 Ma. From Parts 2 to 6, the roots of the Timetrees reach progressively further back in time from the Early Cretaceous to the Late Ediacaran. The idea is to end the series with Part 12, *Homo sapiens*, who appeared in the last wink of a geological eye (some 200 000 years ago) – and have had a devastating impact on the rest of life, setting alight the Sixth Extinction. For each part, we coauthor with two specialist scientists from the universities and research organizations around South Africa – thus involving a spreading authoritative network. Supernova is a South African magazine, based in Pretoria, that appears every 2 months. They target school kids between the ages of 9 and 14. Their mission is to 'make children aware of issues which affect them, their community, and their environment, by giving them tools and inspiration to become active and responsible world citizens.' Their aim is to filter into the school curriculum and to be used by 'educators as a classroom resource'. This meets our aims exactly in producing the series – and the further it spreads across Africa and beyond, the more those aims will be met.

Life history insights of the dodo from bone histology

Angst, D.[1], Chinsamy, A.[1], Steel, L.[2], Hume, J.[3]

[1]*Department of Biological Sciences, University of Cape Town, Private Bag X3, Rhodes Gift, 7701 South Africa*

[2]*Department of Earth Sciences, Natural History Museum, Cromwell Road, London SW7 5BD, U.K.*

[3]*Department of Life Sciences, Natural History Museum Cromwell Road, London SW7 5BD (Bird Group)*

Raphus cucullatus, the dodo, is a large extinct flightless bird endemic to the Indian Ocean island of Mauritius, that was first described at the end of the 16th century when sailors arrived on the island. By the end of the 17th century it was extinct due to human activities. Although this bird was contemporaneous with humans for several decades, we know hardly anything about its ecology. Since it is well recognized that the microscopic structure of fossil bones retains signals pertaining to various aspects of their biology, we conducted a histological analysis of various long bones of the dodo. Twenty-two bones (four femora, one humerus, twelve tibiotarsi and two tarsometatarsi) were obtained from the swamp, La Mare aux Songes in the southeastern part of Mauritius, while four tibiotarsi were obtained from various cave sites on the island. Our results were quite striking in that the histological structure of the bones from the swamp were well preserved, but the bones from the cave environments showed severe degradation of the histology. The majority of the bones presented a histological structure showing three distinctive layers: the outer circumferential layer and inner circumferential layer (i.e. the OCL, and ICL) composed of lamellar bone, which enclose a central layer of fibrolamellar bone. Three of our samples showed an incipient OCL, suggesting that they had just attained sexual maturity, while one of them was clearly still a juvenile. In some of our samples, lines of arrested growth were observed in the OCL, showing periodic arrests in growth, and in one thin section at least 6–7 growth marks were evident. Interestingly among our samples there are indications of medullary bone (and hence female birds), and histological features that are attributable to moulting. The bone histology of the dodo has given us unprecedented insight into various aspects of the life history of this recently extinct bird.

The neuroanatomy, braincase and occiput in Gorgonopsia revealed by synchrotron microtomography

Araújo, R.,[1] Fernandez, V.,[2] Polcyn, M.J.,[3] Fröbisch, J.,[4] Martins, R.M.S.[5]

[1]*Instituto de Plasmas e Fusão Nuclear (IST/UL), MfN, SMU, GEAL-ML*

[2]*European Synchrotron Research Facility*

[3]*Southern Methodist University*

[4]*Museu für Naturkunde*

[5]*Instituto de Plasmas e Fusão Nuclear (IST/UL), CENIMAT, GEAL-ML*

The internal structures of the braincase and occipital region in gorgonopsians so far obtained from serial grinding techniques are currently incompletely known. Gorgonopsians are key synapsid taxa for the understanding of the early steps of pre-mammalian evolution. A specimen of *Aloposaurus gracilis* (GPIT/RE/7124) collected from the upper Permian of South Africa was subjected to propagation phase-contrast X-ray synchrotron microtomography. The gorgonopsian braincase is particularly complex, especially in older individuals where extensive co-ossification and fusion occurred. Notably though, GPIT/RE/7124 is a juvenile specimen in which the sutures are clearly visible. The tomographies revealed the complex anatomy of braincase and occiput elements, but also of the osseous labyrinth, cranial nerves

and vasculature and brain endocast. The cerebellum is broader than the forebrain, resembling the condition of other non-mammalian therapsids. The floccular complex lobes are solely delimited by the supraoccipital, yet there is an embayment on the dorsal portion of the prootics forming a lateral inflation of the cerebellum. The hypophysis is divided ventrally into two laterally-positioned pituitary lobes that communicate with the single median internal carotid foramen anteriorly. The paths of some cranial nerves and vasculature could be discerned from the tomographies. The trigeminal nerve and the vena capitis medialis exit the brain endocast from between the pila antotica and the anterodorsal process. The vidian canal runs along the laterodorsal side of the parabasisphenoid. The internal carotids pierce the parabasisphenoid laterally and join in the median plan of the skull to exit anterior to the sella turcica. The osseous labyrinth is well preserved; however, the horizontal semicircular canal is not delimited by bone. The anterior and posterior semicircular canals are housed in the prootic, supraoccipital and opsithotic. The anterior semicircular canal is significantly larger than the posterior semicircular canal. The gorgonopsian brain endocast retains many 'reptilian' features, demonstrating its conservative anatomy in non-mammalian therapsids.

Funding acknowledgement: FCT/MEC through the EXPL/BIA-EVF/0665/2013 project and the SFRH/BPD/96205/2013 scholarship, by ESRF (proposal HG-23), PalNiassa Project.

The diversity of conifer woods from the Early Cretaceous Kirkwood Formation and palaeoenvironmental implications

Bamford, M.K.

Evolutionary Studies Institute, University of the Witwatersrand, Johannesburg, South Africa

The Kirkwood Formation, Uitenhage Group, outcrops in the Algoa and Gamtoos basins, Eastern Cape Province, and has been known since 1845. Discoveries of theropod, ornithopod and sauropod dinosaurs, a variety of invertebrate fossils and plants have been made over the years. The plants comprise ferns, cycads, cycadeoids and conifers. The large trunks exposed along the Bezuidenhouts river, among other sites, are poorly preserved but the charcoal fragments, represented in a 1m thick stratified parabreccia, are much better preserved. Silicified charcoal from Shamwari game reserve is also well preserved. Three genera are known from this formation but have not been described: *Agathoxylon*, *Brachyoxylon* and *Protocircoporoxylon*. A representative of the genus *Taxaceoxylon* is now added to the list. Based on these woods from a number of other sites worldwide it is possible to reconstruct the past environment for the Kirkwood Formation. *Agathoxylon* is the most common wood in Gondwana and occurred in all climate zones. *Brachyoxylon* ranges from the Early Jurassic to Early Cretaceous but is more common in summer wet environments, as is *Protocircoporoxylon* but its time range is limited to the Early Cretaceous. *Podocarpoxylon* has a long time range but did not occur in summer wet regions. *Taxaceoxylon* was restricted to warm temperate and winter wet environments. These woods imply a diversity of microhabitats rather than a long time range and rapidly fluctuating climate.

Glacial barriers to floral migration in the Permo-Carboniferous of Gondwana

Barbolini, N., Bamford, M.K., Rubidge, B.S.

Evolutionary Studies Institute and School of Geosciences, DST-NRF Centre of Excellence: Palaeontology, University of the Witwatersrand, Private Bag 3, WITS 2050, South Africa

The late Palaeozoic Ice Age (LPIA) is known to have had a drastic impact on biological, chemical and physical systems across Gondwana for up to 100 million years. Contemporary glaciation models now propose a more dynamic interplay of alternating glacial and interglacial cycles lasting between 1–8 million years, with ice centres waxing and waning diachronously across Gondwana. In the late Carboniferous and early Permian, southern Africa was largely enveloped by a multitude of ice sheets, ice caps, and alpine glaciers that extended to parts of South America and Antarctica. First appearance datums of many stratigraphically significant palynomorphs in the main Karoo Basin are delayed relative to other parts of Gondwana. The wide-ranging index taxon *Pseudoreticulatispora* (*Converrucosisporites*) *confluens* is present in deglaciation successions of Australia, Antarctica, South America, India, Oman and Saudi Arabia, but has never been recorded from South African deposits. However, *C. confluens* is present in the neighbouring Kalahari (Aranos) Basin of southern Namibia. The large glacial centre over the Cargonian Highlands separated the Kalahari from the Karoo Basin, and posed a significant geographic and climatic barrier that prevented successful dispersal and establishment of the parent plants of *C. confluens*, and possibly other plant taxa, in South Africa. This spatio-temporal variation of floras hinders global biostratigraphic correlations. Radiometric dating is useful for calibrating Permo-Carboniferous palynozones because

diachronous fluctuations in ice volume and palaeoclimate had a strong influence on plant migrations and extinctions. This resulted in differing stratigraphic ranges of continental floras across Gondwana.

Funding acknowledgement: The support of the DST/NRF Centre of Excellence in Palaeosciences (CoE in Palaeosciences) and NRF African Origin Platform towards this research is hereby acknowledged. Additional financial support was received from the Mellon Foundation, National Research Foundation, the Palaeontological Scientific Trust (PAST) and its Scatterlings of Africa Programmes, and the University of the Witwatersrand.

Early hominin brain evolution: extracting palaeoneurological evidence from the fossil record

Beaudet, A.,[1] Dumoncel, J.,[2] de Beer, F.,[3] Durrleman, S.,[4] Gilissen, E.,[5] Oettlé, A.[6], Subsol, G.[7], Thackeray, F.,[8] Braga, J.[9]

[1]*Department of Anatomy, University of Pretoria, South Africa*

[2]*UMR 5288 AMIS CNRS-Université de Toulouse Paul Sabatier, France*

[3]*South African Nuclear Energy Corporation, Pelindaba, South Africa*

[4]*INRIA, Sorbonne Universités, UPMC Université Paris 06, UMR S 1127, Inserm U 1127, UMR 7225 Aramis CNRS, ICM, Paris, France*

[5]*Department of African Zoology, Royal Museum for Central Africa, Tervuren, Belgium*

[6]*Department of Anatomy, University of Pretoria, South Africa*

[7]*ICAR Research-Team, LIRMM, UMR 5506 CNRS, Université de Montpellier, France*

[8]*Evolutionary Studies Institute, University of the Witwatersrand, Johannesburg, South Africa*

[9]*UMR 5288 AMIS CNRS-Université de Toulouse Paul Sabatier, France*

Tracking the early appearance of the derived *Homo*-like neuroanatomical features in the hominin fossil record should contribute the assessment of (i) the inter-taxic evolutionary relationships within the human lineage and (ii) the tempo and mode of the most critical endocranial changes (i.e. size increase, cortical reorganization). Indeed, based on the investigation of East and South African early hominin endocasts, Falk and colleagues (JHE, 2000) have suggested that the palaeoneuroanatomical features of *Australopithecus* are consistent with a potential ancestral condition to *Homo* as compared to the more ape-like *Paranthropus* pattern. Based on recent development of 3D imaging and modelling methods, we revised the endocranial morphoarchitectural pattern of three Pliocene *Australopithecus africanus* (STS 5, STS 60, Taung) and one Early Pleistocene *Paranthropus boisei* (OH 5) representatives with respect to the extant human ($n = 10$), chimpanzee ($n = 10$), and bonobo ($n = 10$) conditions. We combined a semi-automatic technique for extracting the sulcal pattern together with a landmark-free registration method based on deformations. Both local and global information provided by our morphometric approach are used to perform statistical classification and topological analysis of inter- and intra-specific variation. In association with a morphology of the frontal lobes that substantially differs from the non-hominin condition, the fossil hominin endocasts combine a global neural condition closer to *Pan* than to *Homo*. The *Australopithecus sulcal* pattern preserves both *Homo*- (i.e. the middle and superior frontal sulci organization) and *Pan*-like (i.e. the fronto-orbital sulcus) features. Additionally, our analyses support a relatively closer affinity between *Australopithecus/Homo* than between *Paranthropus/Homo*.

Funding acknowledgement: Supported by PRES of Toulouse, Midi-Pyrénées Region, French MAEDI and CNRS, AESOP+ programme. We are grateful for access to the HPC resources of CALMIP supercomputing centre (2015-P1440). We thank Stephany Potze, curator of the Palaeontology Section of the Ditsong National Museum of Natural History (Pretoria) and Little Company of Mary (Pretoria) for collection access and data acquisition. S. Benazzi for OH 5 record sharing.

A reappraisal of the capacity to envenom the bite in *Euchambersia* (Therocephalia, Therapsida) using *μ*CT scanning

Benoit, J.[1], Norton, L.A.[2]

[1]*Evolutionary Studies Institute & School of Anatomical Sciences, University of the Witwatersrand, Johannesburg, South Africa*

[2]*School of Geosciences, University of the Witwatersrand, Johannesburg, South Africa*

Euchambersia mirabilis is an iconic species of Permo-Triassic therapsid because of its unusually large external maxillary fossa associated with a ridged canine. This anatomy led to the commonly accepted conclusion that the large fossa accommodated a venom gland. Because *Euchambersia* is considered the earliest and most robustly supported case of a venomous terrestrial vertebrate, it usually serves as a model for the inference of envenoming capacity in other fossil species. However, a review of the literature demonstrates

inconsistencies in the interpretation of the morphology of the canine, which sheds some doubt about the hypothesis that *Euchambersia* was venomous. As such, we conducted a μCT scan-assisted reappraisal of the envenoming capacity of *Euchambersia*, with a special focus on the anatomy of the maxillary fossa and canine. This study included both known specimens of *Euchambersia*. It shows that the fossa, presumably for the venom-producing gland, is directly linked to the maxillary canal, which carries the trigeminal nerve (responsible for the sensitivity of the face). The peculiar anatomy of the maxillary canal suggests important modifications in the somatosensory system of the face. In addition, we describe for the first time the complete crown morphology of the incisiform teeth of *Euchambersia*; a replacement maxillary incisor, and an isolated incisor, possibly of mandibular origin. The upper incisor has a concave labial surface, whereas the isolated tooth is strongly recurved and bears lateral ridges. Together, these data support that the maxillary fossa could have housed a venom-producing gland, a specialized sensory organ, or both.

Funding acknowledgement: Thanks to K. Carlson, T. Jashashvili, and K. Jakata (Wits MicroCT facility) and F. Ahmed (BMNH, London) for performing the scans of the fossil material. This research was conducted with financial support of the DST/NRF Centre of Excellence in Palaeosciences, the NRF African Origins Platform, and Palaeontological Scientific Trust (PAST) and its Scatterlings of Africa Programmes. The support of the DST/NRF Centre of Excellence in Palaeosciences (CoE in Palaeosciences) towards this research is hereby acknowledged. Opinions expressed and conclusions arrived at, are those of the authors and are not necessarily to be attributed to the CoE in Palaeosciences.

Stratigraphy and depositional environment of Namibian continental shelf sediments as indicated by fossil foraminifera

Bergh, E.W.[1], Compton, J.S.[2]

[1]*Natural History Department, Iziko Museums of South Africa, Cape Town*

[2]*Department of Geological Sciences, University of Cape Town*

The Pleistocene-aged sediments on the Namibian continental shelf are rich in pelletal phosphorite containing a wide variety of biogenic grains including foraminifera. Vibracores from the central Namibian continental shelf to south of the Kunene River mouth were studied to determine the depositional history and palaeoenvironment of the area. Foraminiferal index species *Globoquadrina dehiscens* and *Globigerinoides bisphericus*, and Sr-age dating on foraminiferal tests from the northern shelf revealed a Middle Miocene age for foraminifera in olive-green mud units underlying pelletal phosphorite units. The contact between the olive-green mud units and overlying pelletal phosphorite units is sharp and erosional. Components above the contact were found to be reworked Late Miocene to Pleistocene in age. The final deposition of the pelletal phosphorite sand units took place in the Pleistocene confirmed by index species such as *Globorotalia inflata* and *Globorotalia truncatulinoides*. The water depth for the Miocene-aged foraminifera was greater than today and Pleistocene-aged foraminifera indicated shallower depths for that time period. Planktonic foraminifera and trace abundances of the ostracods *Henryhowella* and *Bairdoppilata* indicate subtropical warmer surface waters during the Miocene cooling slightly during the Quaternary.

Funding acknowledgement: National Research Foundation.

The role of museums in palaeontological education

Bergh, E.W.,[1] Naran, D.,[2] Taylor, W.[2]

[1]*Natural History Department, Iziko Museums of South Africa, Cape Town, and Department of Geological Sciences, University of Cape Town*

[2]*Education and Public Programmes Department, Iziko Museums of South Africa, Cape Town*

Museums are constantly redefining and questioning their role in society. These institutions are more than just a space to display strange, unusual and interesting objects. Museums such as the Iziko South African Museum have the benefit of extensive collections, public exhibitions and specialist scientists. The Museum's Education and Public Programmes and Natural History Departments work together to present fossil and evolution workshops to schools and tertiary institutions. The content of these workshops is aligned with the Curriculum Assessment Policy Statements (CAPS) at primary school and secondary school (grades 10 and 12) level. Workshops are also adapted for tertiary-level life sciences, environmental management and education students. The fossil and evolution workshops are presented by palaeontology curators and focus on fossil basics, the evolutionary record, continental drift and other geological topics. Tours within the Museum's fossil exhibitions are led by museum curators and educators to supplement the presentations. The workshops have shown that there is an important role for museums to assist

teachers and lecturers in educating students. The need for geology and basic palaeontology programmes may be greater at schools from disadvantaged backgrounds. A pre-workshop evaluation of one of the fossil workshops showed that less than 15% of learners had any idea of what a fossil was. This percentage increased by nearly 40% post-workshop. Other indicators recorded improvements on different scales for the various topics that were assessed. The success of these workshops in assisting learners to understand basic concepts are enhanced through interactive, hands-on activities that utilize museum specimens.

A new theropod dinosaur footprint site in the Lower Jurassic Elliot Formation (Mafube, eastern Free State, South Africa): footprint preservation in a semi-arid fluvio-lacustrine setting

Bordy, E.M., Sciscio, L., Reid, M., Abrahams, M.

Department of Geological Sciences, University of Cape Town, 7701 South Africa

Bipedal saurischian dinosaur tracks have been recently discovered in the Lower Jurassic Elliot Formation at Mafube Mountain Retreat (eastern Free State, South Africa). We studied over 80 tridactyl tracks on the bedding surface of a single sandstone bed that shows evidence for footprint preservation in an abandoned, high energy ephemeral stream, which is typical in semi-arid climates. The tracks show large shape variability over the length of the bed; however, these morphological differences are considered here to be mainly due to variations in the substrate rheology (e.g. moisture content) as opposed to differences in the trackmaker's foot anatomy, foot kinematics or recent, footprint modifying weathering processes on the exposed bedding surface. Desiccation cracks, invertebrate burrows, ripple marks, etc., preserved in association with and within some of the Mafube tracks suggest that the imprints are essentially contemporaneous and are true tracks rather than undertracks or erosional remnants. The best preserved footprints are therefore valuable not only for the interpretation of the palaeoenvironment (i.e. seasonally dry river channels) but also for taxonomic assessments, because some of them closely resemble the original anatomy of the trackmaker's foot. The Mafube ichnotaxa are assigned to *Eubrontes* and potentially *Grallator* ichnogenera and are linked to large and small tridactyl theropod trackmakers, possibly to *Dracovenator* and *Coelophysis* based on the following criteria: a) lack of manus impressions indicative of obligate bipeds; (b) long, slender digits, asymmetrical, tapering, (c) often ending in a claw impression or point, and (d) the prints being longer than broad.

Funding acknowledgement: The financial support of the DST-NRF Centre of Excellence in Palaeosciences and NRF Competitive Programme for Rated Researchers to E.M.B. towards this research is hereby acknowledged.

New data on the Permo-Triassic Boundary from the Karoo Basin of South Africa

Botha-Brink, J.[1], Huttenlocker, A.K.[2], Smith, R.M.H.[3], Prevec, R.[4], Modesto, S. P.[5], Viglietti, P.[3]

[1]*Karoo Palaeontology Department, National Museum, P.O. Box 266, Bloemfontein, South Africa*

[2]*Biology Department, University of Utah, Salt Lake City, UT 84112, Utah, U.S.A.*

[3]*Evolutionary Studies Institute, School for Geosciences, University of the Witwatersrand, Private Bag 3, WITS 2050, Johannesburg, South Africa*

[4]*Rhodes University and the Albany Museum, Grahamstown, South Africa*

[5]*Cape Breton University, Cape Breton, Nova Scotia, Canada*

The South African Karoo Basin preserves a detailed record of environmental and evolutionary changes associated with the Permo-Triassic Mass Extinction (PTME) that has been the focus of considerable research for decades. Currently, the Permo-Triassic boundary (PTB) is defined biostratigraphically by the last appearance of *Daptocephalus leoniceps* and *Lystrosaurus maccaigi*. Recently there has been much debate regarding this placement within the South African Karoo Supergroup. Recent research has resulted in claims that the vertebrate-defined PTME in South Africa is not synchronous with the extinction in the marine realm. This assertion has important implications for correctly interpreting and understanding the PTME in South Africa. Our ongoing fieldwork at PTB sites in the Free State, particularly on the farm Nooitgedacht 68, has yielded new information on the placing of this event. We present an updated lithostratigraphic log of the PTB at Nooitgedacht 68 that includes new *in situ* records of archosauromorphs and therapsids. For the first time, plants and an insect wing are recorded at the site, including lidgettonioid *Glossopteris* leaves and fragments of a fern species previously unknown from the Late Permian of South Africa. Isotope stratigraphy shows a negative excursion at the PTB, which is supported by preliminary data from therapsid enamel. A preliminary U-Pb date from detrital zircons using thermal

ionization mass spectrometry (TIMS) places a maximum age on the boundary fauna. We compare these data with coeval sites and use them to address the claim that the vertebrate-defined PTME in South Africa does not coincide with the marine PTME.

Funding acknowledgement: The National Research Foundation (UID 95980, 82605 to J.B-B.) is gratefully acknowledged for their support. The support of the DST/NRF Centre of Excellence in Palaeosciences (CoE in Palaeosciences) towards this research is hereby acknowledged.

Palaeoenvironment, stratigraphy and evolution of Mesozoic rift basins, onshore Outeniqua Basin, Western and Eastern Cape, South Africa

Bowen, D., van der Linde, C., Dinis, Y., Muir, R.A., Bordy, E.M.

Department of Geological Sciences, University of Cape Town, 7701 South Africa

The Mesozoic rift basins of the Western and Eastern Cape demonstrate a dichotomy in extant research. The Uitenhage Group sedimentary rocks and their palaeontological heritage in the Algoa Basin are well-researched, in contrast to poorly documented onshore compartments of the Oudtshoorn, Heidelberg, Gamtoos and Pletmos basins. This presents a problem in that current assumptions made about these rift compartments lack the stratigraphic context to accurately compare them with the Algoa Basin, which has a seemingly more fossiliferous sedimentary fill. Furthermore, without comprehensive synthesis of stratigraphic data from all these Mesozoic basins, the context of any palaeontological findings and their palaeoenvironments would be geographically and temporally limited. This research aims to provide that stratigraphic context by conducting ongoing sedimentological, geochronological, and palaeontological studies in these four lesser-studied Mesozoic basins. Detailed lithofacies and architectural element analyses have enabled the reconstruction of fluvial, lacustrine and coastal regimes in these rift compartments. Palaeontological findings have been noted, and together with sedimentological data, a rift sequence stratigraphic framework of these four basins is being compiled to better document their development. U-Pb dating of zircons from several tuffaceous beds would allow the refinement of the temporal relationships within these basins and their correlation to the Algoa Basin.

Funding acknowledgement: The financial support of the DST-NRF Centre of Excellence in Palaeosciences, SACCS and NRF African Origins Platform (grant #91601) to E.M.B. towards this research is hereby acknowledged.

A record of sedimentation of the Late Ordovician Soom Shale Member (Cedarberg Formation) from new borehole data in the Cedarberg region of South Africa

Browning, C.,[1] Gabbott, S.,[2] Zalasiewicz, J.,[2] Theron, J.[3]

[1]*Council for Geoscience, Department of Mapping Geology, Bellville, South Africa*

[2]*Department of Geology, Leicester University, LE1 7RH U.K.*

[3]*Department of Earth Sciences, Stellenbosch University, Private Bag X1, Matieland, 7602 South Africa*

The Late Ordovician glaciation–deglaciation is recorded in the South African Table Mountain Group (Cape Supergroup) by the Pakhuis and Cedarberg formations, respectively. The Cedarberg Formation, consisting of Soom Shale and Disa Siltstone Members, forms an upward coarsening cycle of sedimentation in a shallow marine setting and is overlain by the dominantly fluvial sandstones of the Goudini Formation. The Soom Shale Member is particularly significant as it represents the only Ordovician Konservat-Lagerstätte in southwestern Gondwana. A preliminary investigation of the sedimentary rocks revealed an unusual facies comprising coarse quartz grains that occur in clusters and aggregates within organic matter and intercalated within distal, laminated turbidites. This microfabric was tentatively linked to glacially derived loess which was either blown across seasonal sea ice or directly into the sea. To obtain new data on this unique facies, we drilled a 40 m stratigraphic core through the lower Cedarberg and upper Pakhuis formations on Holfontein farm (~25 km south of Clanwilliam). A detailed (mm-scale) sedimentological log, petrographic thin sections and Scanning Electron Microscope analysis were employed to quantify and interpret the sedimentary facies. Our preliminary results show that the unique laminated facies is well-developed throughout the Soom Shale and persists, albeit less prolifically, into the Disa Siltstone Member. To explain the origin of this unique facies, in this study we explore hypotheses, including: 1) loess-derived quartz fertilizing marine algal blooms and 2) an algal mat-bound seafloor trapping quartz grains.

Funding acknowledgement: National Geographic, Council for Geoscience, University of Leicester.

A new gorgonopsian from the uppermost *Daptocephalus* Assemblage Zone, Karoo Basin of South Africa

Butler, E.,[1] Botha-Brink, J.,[1] Abdala, N.F.[2]

[1]Karoo Palaeontology, National Museum, P.O. Box 266, Bloemfontein, 9300 South Africa

[3]Evolutionary Studies Institute and School of Geosciences, University of the Witwatersrand, South Africa

The gorgonopsian therapsids are well known in the Permian deposits of Africa, Russia, India and China. By the middle Late Permian these gorgonopsians become the dominant terrestrial predators of Gondwana and by the end of the Permian they were geographically widespread in southern Africa with a high taxonomic diversity. However, they did not survive the Permo-Triassic mass extinction some 252 million years ago. Here we describe the skulls and postcranial elements of a new species from South Africa. Although these specimens are the geologically youngest gorgonopsians known, they exhibit several basal characteristics, similar to the geologically older specimens from the *Eodicynodon* and *Tapinocephalus* Assemblage Zones. A comparison with Russian taxa reveals that the new species is similar to the gorgonopsian *Inostrancevia*, which is only known from Russia. The presence of palatal tuberosities and absence of palatal teeth compared to the Russian species suggests that, although closely related, the new material does not belong to the Russian genus. This new gorgonopsian has several implications for South African biostratigraphy and taxonomy, as well the global distribution of gorgonopsians during the Late Permian.

Funding acknowledgement: National Research Foundation: African Origins Platform (UID 82605).

Palaeobiological implications of the bone microstructure of pareiasaurs (Parareptilia) from the Karoo Basin, South Africa

Canoville, A.* Chinsamy, A.

University of Cape Town, Department of Biological Sciences, Rhodes Gift, South Africa.

**Present address: Steinmann Institute for Geology, Mineralogy and Paleontology, University of Bonn, Bonn, Germany*

Numerous morphological studies have been carried out on pareiasaurs; yet their taxonomy and biology remain incompletely understood. Earlier works have suggested that these herbivorous parareptiles had a short juvenile period as compared to the duration of adulthood. Several studies further suggested an aquatic lifestyle for these animals, but more recent investigations have proposed a fully terrestrial habitat. Bone palaeohistology is regarded as a powerful tool to assess aspects of tetrapod palaeobiology. Although this method has been extensively applied to the non-mammalian therapsids of the Karoo Basin of southern Africa, few studies have been conducted on pareiasaurs, which were abundant in the Middle and Late Permian continental ecosystems. The present study assesses intra and inter-specific histovariability of pareiasaurs and provides fresh insight into their palaeobiology, thereby permitting a re-evaluation of earlier hypotheses. Our sample comprises various skeletal elements and several specimens covering most of the taxonomic and stratigraphic spectrum of South African pareiasaurs, including large and basal forms from the Middle Permian, as well as small and more derived forms from the Late Permian. Our results suggest that the species diversity of the pareiasaurs of the *Tapinocephalus* Assemblage Zone may have been underestimated. Bone histology also confirms that these animals experienced a relatively rapid growth early in ontogeny. The growth later slowed down during adulthood, which appears to have been extended. Pareiasaur bone microanatomy is unusual for continental tetrapods, in having extremely spongious stylopod diaphyses. Rigorous palaeoecological interpretations are thus limited since no real modern analogue exists for these enigmatic animals.

Funding acknowledgement: Claude Leon Foundation.

Microanatomical diversity of amniote ribs

Canoville, A.[1], de Buffrénil, V.[2], Laurin, M.[2]

[1]Steinmann Institute for Geology, Mineralogy and Palaeontology, University of Bonn, Bonn, Germany

[2]CR2P, Centre de Recherches sur la Paléobiodiversité et les Paléoenvironnements, Sorbonne Universités, CNRS/MNHN/UPMC, Paris, France

Numerous studies have documented long bone microanatomical diversity in tetrapods. Yet, the majority of previous works has focused on the appendicular skeleton. A relationship between limbbone microanatomy and lifestyle (e.g. aquatic, amphibious, terrestrial) has been uncovered and used for palaeoecological reconstructions. Relatively fewer comparative studies have focused on the microanatomy of the axial skeleton and its ecological signal. Here, we propose an extensive quantitative

study of the microanatomy of amniote ribs. Our sample comprises 155 species of extant amniotes and encompasses the taxonomic, ecological, and body size diversity of this group. We standardized our sampling location to the midshaft of mid-dorsal ribs. Transverse sections were obtained from classical petrographic methods, as well as from X-ray microtomography. Our analyses reveal that most of the microanatomical and size parameters of the ribs display a phylogenetic signal, an expected result also observed in amniote limb bones and vertebrae. We found a significant relationship between rib cortical thickness, global compactness and lifestyle. As for the vertebrae, the development of the spongiosa in the medullary region seems to be strongly correlated with size. This study is complementary to previous work conducted on long bones and vertebrae because it further documents bone inner architectural diversity and offers a better understanding of the general adaptation of the skeleton to environmental and biomechanical constraints.

Funding acknowledgement: Alexander von Humboldt Foundation.

Cancellous network patterning and cortical bone distribution at the proximal femoral end in *Paranthropus robustus*

Cazenave, M.[1], Braga, J.[2], de Beer, F.[3], Hoffman, J.W.[3], Macchiarelli, M.[4], Oettlé, A.[5], Thackeray, J.F.[6]

[1]*Department of Anatomy, University of Pretoria, South Africa, and UMR 5288 CNRS, Université Paul Sabatier, Toulouse, France*

[2]*UMR 5288 CNRS, Université Paul Sabatier, Toulouse, France, and Evolutionary Studies Institute, University of the Witwatersrand, Johannesburg, South Africa*

[3]*South African Nuclear Energy Corporation, Pelindaba, South Africa*

[4]*UMR 7194 CNRS, Muséum national d'Histoire naturelle, Paris, France, and Unité de Formation Géosciences, Université de Poitiers, France*

[5]*Department of Anatomy, University of Pretoria, South Africa*

[6]*Evolutionary Studies Institute, University of the Witwatersrand, Johannesburg, South Africa*

Compared with the extant human condition, some characteristics of the paranthropine proximal femur provide evidence for a gait-related adaptation resulting in relatively increased superoinferior bending loads at the femoro-pelvic complex. As also body shape in this extinct hominin differs in some way from the human bauplan, we expect the biomechanically-related cortico-trabecular signature imprinted at the coxo-femoral joint somehow reflects such differences in terms of site-specific structural arrangement. By means of X-ray microtomography the cancellous network properties and cortical bone topographic variation in four adult upper femoral ends from Swartkrans *P. robustus* samples: SK 82 and SK 97, likely males, and SK 3121 and SKW 19, likely females, were investigated. While relatively and absolutely denser, and also locally more contrasted, especially along the mediolateral axis, the cancellous network of *P. robustus* globally traces the human pattern. Interestingly, for their proportion of thinner struts, the likely sex-related differences expressed by the fossil specimens exceed the range measured in our comparative modern sample ($n = 9$). Similarly to the CT-based results provided by Ruff and Higgins (AJPA, 2013), we found superoinferior cortical bone asymmetry in the neck of SK 82 and SK 97 (S/I thickness ratio <1.0), and also confirm the finding that asymmetry in *P. robustus* is expressed at a lower degree than in extant humans. However, because of the higher resolution of our record, present estimates allowed for a subtler assessment of cross-sectional changes along the neck. Accordingly, they reveal that, at the midneck, *P. robustus* had more human-like proportions than previously observed.

Funding acknowledgement: We especially acknowledge B. Billing, L. Kgasi, D. Morris and S. Potze for access to fossil and comparative materials, K. Jakata for X-ray microtomographic acquisitions at Wits, and K. Carlson for scientific collaboration and data sharing (SKW 19). Research funded by the Erasmus Mundus AESOP and the AESOP+ programmes, the South African National Research Foundation (NRF) and Department of Science and Technology (DST), the French CNRS.

Three-dimensional morphometric analysis of the cranial ontogeny of *Massospondylus carinatus* based on CT reconstructions

Chapelle, K., Choiniere, J.N.

Evolutionary Studies Institute, University of the Witwatersrand, Johannesburg, South Africa

Understanding ontogenetic variation in dinosaurs is necessary because it informs taxonomic hypotheses, elucidates larger macroevolutionary patterns, and allows for the inference of behavioural traits such as parental care, feeding and locomotion. *Massospondylus carinatus* Owen 1854 is an emblematic South African basal sauropodomorph dinosaur and it presents an ideal study system for dinosaurian cranial

ontogeny because it has a range of referred specimens aged from hatchling to adult. This study reconstructs individual skull bones of a size series of *M. carinatus* using CT scans and qualitatively and quantitatively assesses the ontogenetic variation between these bones. The results show clear differences in the development between facial bones and braincase bones (both in the amount of growth and in the correlation between size and shape). Several morphological differences are also identified between juveniles and adults. There is a possibility that several species are represented in the *M. carinatus* sample, based on both the qualitative and quantitative assessments.

Funding acknowledgement: DST-NRF Centre of Excellence in Palaeontology, Palaeontological Scientific Trust (PAST) and its Scatterlings of Africa Programmes, University of the Witwatersrand.

Vascularized, endosteal bone tissue in saltasaurine titanosaurs from Argentina

Chinsamy, A.,[1] Cerda, I.,[2] Powell, J.[3]

[1]*Department of Biological Sciences, University of Cape Town, Private Bag X3, Rhodes Gift, 7700 South Africa*

[2]*CONICET, Instituto de Investigación en Paleobiología y Geología, Universidad Nacional de Río Negro, Museo Carlos Ameghino, Belgrano 1700, Paraje Pichi Ruca (predio Marabunta) 8300, Cipolletti, Río Negro, Argentina*

[3]*CONICET, Facultad de Ciencias Naturales Universidad Nacional de Tucumán, Miguel Lillo 205, (4000) Tucumán, Argentina*

Well-vascularized, endosteal bone in the medullary region of long bones of non-avian dinosaurs has been invoked as being homologous to avian medullary bone, a specialized tissue formed during ovulation. However, similar bone tissues are known to form in response to pathologies in modern birds and in non-avian dinosaurs, and have also been reported in an immature non-avian dinosaur. In the current study we describe the occurrence of well-vascularized endosteal bone tissue in three skeletal elements of saltasaurine titanosaurs from the Upper Cretaceous of Argentina: i) within the medullary cavity of a metatarsal, ii) inside a pneumatic cavity of a posterior caudal vertebra, iii) in intra-trabecular spaces in an osteoderm. Our results show that considering the criteria of location, origin (or development), and histology, these endosteally-derived tissues in these armoured sauropods could be described as either medullary bone or pathological bone. Additionally, we show that similar endosteally-formed well-vascularized bone tissue is quite widely distributed among non-dinosaurian archosauriforms, and is not restricted only to long bones, but can occur in the axial, and dermal skeleton. We propose that independent evidence is required to verify whether vascularized endosteal bone tissues in extinct archosaurs are pathological or reproductive in nature.

CT-based reconstruction of the skull of the basal maniraptoran *Ornitholestes hermanni* Osborn 1903

Choiniere, J.N.,[1] Chapelle, K.E.J.,[1] Brusatte, S.L.,[2] Hendrickx, C.,[1] Norell, M.A.[3]

[1]*Evolutionary Studies Institute, University of the Witwatersrand, Johannesburg, South Africa*

[2]*University of Edinburgh*

[3]*American Museum of Natural History*

More than 100 years after its discovery, the phylogenetic relationships of the theropod taxon Ornitholestes hermanni remain enigmatic. General consensus holds that *Ornitholestes* is important for understanding the early evolution of *Maniraptora*, the theropod group that includes birds and their agile, generally small bodied relatives. Confusion about this taxon's relationships is in part due to the crushed preservation of the holotype skull, AMNH 619. The crushing of the specimen obscures details such as the morphology of the braincase bones, which contain important character data. To better understand its anatomy, we CT-scanned the cranium of *Ornitholestes* and made 3D digital reconstructions using VG Studio Max. We present more complete descriptions of braincase bones, including the prootic and laterosphenoid, as well as previously unknown aspects of other skull bones, including the quadrate. These observations allow us to refine the phylogenetic position of *Ornitholestes* and to provide more precise diagnostic criteria for the species. Finally, we present a more accurate 3D model for what *Ornitholestes*' skull would have looked like.

Funding acknowledgments: This research was supported by the Richard Gilder Graduate School's Kalbfleisch and Gerstner Fellowship at the American Museum of Natural History, by the DST/NRF Centre of Excellence in Palaeosciences, by the Friedel Sellschop Award, and by the Palaeontological Scientific Trust (PAST) and its Scatterlings of Africa Programmes.

Trace and Body Fossils of the Triassic–Jurassic Elliot and Clarens formations in the Lebombo–Tshipise Basin, South Africa

Clayton, K.E.,[1] McPhee, B.W.,[2] Penn-Clarke, C.,[1] Choiniere, J.N.,[2] Jinnah, Z.[1]

[1]School of Geosciences, University of the Witwatersrand, Johannesburg, South Africa

[2]Evolutionary Studies Institute, University of the Witwatersrand, Private Bag 3, Johannesburg, 2050 South Africa

The Triassic–Jurassic aged rocks of the Karoo Supergroup are perhaps best known for assemblages of amphibian, crocodylomorph, dinosaurian and therapsid (cynodontid and mammaliamorph) fossils, in addition to an assortment of vertebrate and invertebrate ichnofossils. Recent re-evaluation of the palaeoenvironments of this succession in the Lebombo–Tshipise Basin has yielded both sauropodomorph dinosaur fossils from the Elliot Formation and invertebrate ichnofossils from the Elliot and Clarens formations. Previously discovered sauropodomorph dinosaur fossils from the Lebombo–Tshipise Basin were assigned to the now invalid '*Euskelousaurus browni*' in 2001. Preliminary comparative work on newly recovered manual elements suggests that this find either represents a new species of sauropodomorph, or informative, but currently unknown, elements from a known species. We present further comparisons of additional material and suggest taxonomic affinities for this material. Additionally presented are ichnofossils from a fine-grained sandstone unit at the Red Rocks locality, recently posited as Elliot Formation, but formerly considered as a member of the Clarens Formation. These ichnofossils appear to be networks within the casting medium, interpreted to be formed by burrowing communal arthropods. The overlying Early Jurassic Clarens Formation preserves *Arenicolites isp., Planolites isp., Entradichnus isp.,* in addition to dubious *Lockeia isp.* in medium-grained planar and low-angle cross bedded sandstones interpreted to be fluvial and aeolian dune foresets. These ichnofossils often occur together in pervasively bioturbated-and-soft-sediment-deformed horizons. These data suggest a perennially wet interdune environment; however, this ichnocoenosis contains elements of both *Scoyenia* and *Octopodichnus-Entradichus* ichnofacies, but differs from each in a paucity of arthropod trackways.

Funding acknowledgement: Centre of Excellence Palaeosciences and the University of Witwatersrand.

Archaeological methods and practice: a multidisciplinary approach

Cohen, B.F.

Department of Archaeology, University of Cape Town

The disciplines of archaeology and palaeontology cover a diverse array of fields from Stone Age lithic analysis to palaeoanthropology to dinosaur and therapsid research. Excavations and field collection of specimens is an essential component of fossil research – indeed it is one of the main draw cards of these disciplines. There are, however, many pitfalls to conducting field work and excavations. Each individual site is idiosyncratic and can present many unexpected obstacles and while there are numerous fundamental field processes or laboratory techniques common across the discipline as a whole, there are numerous specialized protocols inherent to particular localities. For example, the methodologies outlined by Shannon McPherron are highly effective in unconsolidated archaeological deposits, but are ineffective in for example, consolidated dinosaur beds where rock saws and jackhammers are the preferred excavation tools. All students of the palaeo-disciplines are exposed to and/or taught field methodologies, but their experiences are usually limited to local methodologies and they may be unaware of other equally relevant techniques. This work will investigate a variety of excavation methods and pitfalls with the aim of identifying ways in which excavations techniques and information may be improved across the discipline. Such methods may include improvements in field recording, publication of excavation information in the form of site reports, as well as the increased use of volunteers, amateurs and general outreach programmes. Other disciplines like geology, zoology and even oceanography utilize field methodologies and laboratory analyses that could greatly benefit our discipline. Thus an emphasis on increased multidisciplinary research is advised.

Funding acknowledgement: I would like to acknowledge funding by the National Research Foundation, Centre of Excellence in Palaeosciences, and the Palaeontological Scientific Trust.

Spatial modelling, formation and transformation of the Oldowan lithic artefact assemblages from Sterkfontein caves, South Africa

Couzens, R.A.

University of the Witwatersrand

The research project detailed here focuses on the formation of the underground artefact-bearing depos-

its of Member 5 (M5) at Sterkfontein Cave. Since the discovery of the first adult *Australopithecus* by Robert Broom in 1936, Sterkfontein has played an integral role in the palaeoanthropological sciences. *P. robustus* teeth have been excavated from M5 as well as the most complete and oldest Oldowan assemblage in southern Africa. Much research has been done at Sterkfontein over the last 80 years to clarify the complexity of karst stratigraphy and its relationship with the artefacts and fossils. In M5 there has been only a traditional, basic approach to lithic analysis. My examination seeks to assess the site wholly and more accurately than ever before. The aim of this study is to determine how the lithic and geological elements of M5 relate to one another using a high-resolution 3-D, GIS approach. Powerful Micro CT scanning was used to quantify lithic abrasion using a 3-D technique; a Geographic Information System (GIS) was subsequently used to place artefacts within a 3-D representation of M5. Quantifying lithic abrasion and, thus, exploring the extent of sediment reworking in M5 will better explain how the site came to be defined as a secondary depositional environment. Currently very little literature exists for the study of lithics at a microscopic level; here I present some of my preliminary methods and findings. My methodology is easy to replicate *en masse* and should prove beneficial in future lithic studies.

A new burnetiamorph therapsid from the *Pristerognathus* AZ of South Africa and a proposed solution to their stratigraphic incongruence

Day, M.O., Rubidge, B.S., Abdala, F.

Evolutionary Studies Institute, School of Geosciences, University of the Witwatersrand, Private Bag 3, WITS 2050, Johannesburg, South Africa

Burnetiamorphs are a group of Permian basal therapsids that are currently best known from the main Karoo Basin of South Africa but with representatives from European Russia, Zambia and Tanzania. Within the Permian of South Africa, burnetiamorphs have been reported from all biozones except the Guadalupian-aged *Eodicynodon* and *Pristerognathus* Assemblage Zones (AZs) and discoveries over the past decade have increased the number of known genera to 10. While this has provided additional data for determining relationships, a problem remains: the continued recovery of the oldest burnetiamorph genera within the family Burnetiidae, the most distal and derived subclades of the Burnetiamorpha. In 2011 the snout of a burnetiamorph was discovered in the Poortjie Member of the Teekloof Formation north of Merweville, within strata assigned to the *Pristerognathus* AZ. This prompted a review of burnetiamorph phylogeny involving the assembly of most known specimens and a critical revision of morphological characters. The results suggest that the *Pristerognathus* AZ specimen is a new taxon, which is most closely related to the Russian *Niuksenitia sukhonensis*. Our phylogeny also suggests that the oldest burnetiamorphs, *Bullacephalus* and *Pachydectes*, are not burnetiids but basal burnetiamorphs. Similarities in palatal structure also link *Bullacephalus* and *Pachydectes* with *Hipposaurus*, a contemporaneous non-burnetiamorph from the *Tapinocephalus* AZ. This change makes the newly proposed burnetiamorph tree significantly more congruent with the stratigraphic appearance of its constituent taxa and allows for diversification of the clade after the Wordian.

Funding acknowledgement: The authors would like to acknowledge the Palaeontological Scientific Trust (PAST) and its Scatterlings of Africa programmes for kindly funding field research, the NRF African Origins Platform, as well as the DST/NRF Centre of Excellence in Palaeosciences (CoE-Pal) for financial support to M.O.D.

New associated basal sauropodomorph material from the Late Triassic lower Elliot Formation, Karoo Basin, Eastern Cape

Dinter, C.M.[1], Benson, R.B.J.[2], McPhee, B.W.[1], Choiniere, J.N.[1]

[1]*University of the Witwatersrand*

[2]*University of Oxford*

South Africa's Late Triassic–Early Jurassic Elliot Formation is well known for its fossils of basal sauropodomorph dinosaurs in its upper strata. Despite more than a century of study, however, sauropodomorphs from the lower parts of the formation remain poorly known due to fossil scarcity or are represented by material of uncertain provenance and association. We present a new, associated sauropodomorph specimen from the middle of the lower Elliot Formation. The material represents a single animal, and includes axial and appendicular bones. We present a preliminary description of the new specimen, and analyse its phylogenetic relationships by incorporating it into a data matrix of basal sauropodomorph dinosaurs. Our preliminary results show that the specimen is not *Blikanasaurus* or *Plateosauravus*, two of the better known lower Elliot sauropodomorph taxa. It possibly represents a previ-

ously unknown species of *Melanorosaurus*. The discovery of an articulated lower Elliot sauropodomorph with precise provenance data helps us to refine our biostratigraphic interpretations for the Late Triassic.

Funding acknowledgement: We would like to thank NRF for their generous contribution to this research project.

A study on the cranial anatomy of Lower Jurassic crocodylomorphs *Protosuchus haughtoni* and *Litargosuchus leptorhynchus* using 3D digital models

Dollman, K.N., Choiniere, J.N.

Evolutionary Studies Institute, University of the Witwatersrand, Johannesburg, South Africa

Crocodiles, alligators and gharials are all members of a much larger and more ecologically diverse clade Crocodylomorpha, which originated in the Late Triassic. The cranial anatomy of early crocodylomorphs, particularly their braincase and palate, remains enigmatic even after nearly a century of anatomical investigation. These structures have significant implications for phylogeny, biological functionality, and homology of a variety of features within the larger crocodylomorph tree. We Micro-CT scanned and developed 3D digital models of the skulls of the basal crocodylomorphs *Protosuchus haughtoni* (Protosuchidae), and *Litargosuchus leptorhynchus*(Sphenosuchia) from the upper Elliot Formation in South Africa. 3D digital modelling allowed for the most complete and detailed anatomical descriptions of these skulls to date. This study highlights the usage of digital modelling as an investigatory tool in anatomical studies. We amended the cranial characters of basal crocodylomorphs in a large phylogenetic dataset. We analysed this dataset and provided a revised evolutionary hypothesis for the earliest members of the group.

Funding acknowledgement: We would like to thank the DSTNRF Centre of Excellence and the Palaeontological Scientific Trust for the funding that has made this research possible.

New burnetiid specimens add to understanding of biarmosuchian taxonomy and ontogeny

Duhamel, A.[1], Rubidge, B.S.[2], Benoit, J.[2], Day, M.[2]

[1]*École Normale Supérieure de Lyon and Université Claude Bernard Lyon 1, Lyon, France*

[2]*Evolutionary Studies Institute and School of Geosciences, University of the Witwatersrand, Johannesburg, South Africa*

The Biarmosuchia (Sigogneau-Russell, 1989) is a poorly known group of Middle to Late Permian therapsids (Broom, 1905). Currently the taxon comprises 16 genera from different regions of Pangea (South Africa, Malawi, Zambia, Tanzania, Zimbabwe and Russia) which are classified into four families : Biarmosuchidae (Olson, 1962), Hipposauridae (Watson and Romer,1956), Ictidorhinidae (Broom, 1932) and Burnetiidae (Broom, 1923). Although there are sixteen genera, most of them are represented by only one specimen, with the result that we have no understanding of ontogenic development. Even though Biarmosuchia are currently considered to be a monophyletic group, the phylogenetic position and the ontogeny of the individual genera is not yet well understood. New cranial material of *Lemurosaurus* (Broom, 1949), including a juvenile, increases the sample size of the genus to four individuals, making this the best represented burnetiid and offers new possibilities to understand biarmosuchid taxonomy and ontogenetic development. Evolution of the proportions of *Lemurosaurus* throughout its ontogenetic development and implications for burnetiid systematics will be discussed.

Funding acknowledgement: This research was conducted with financial support of the DST/NRF Centre of Excellence in Palaeosciences, the NRF African Origins Platform, the Palaeontological Scientific Trust (PAST) and its Scatterlings of Africa Programmes, the AMI programme from the CROUS of Lyon, France, and the Explo'RA sup programme from the Rhône-Alpes region, France. We aknowledge the assistance of Charlton Dube and Sifelani Girah with preparation, and the Council for Geosciences (Pretoria), National Museum (Bloemfontein) and Iziko Museums (Cape Town) for the loan of specimens.

X-ray CT scanning at Stellenbosch University: palaeontological applications

du Plessis A., le Roux, S.G.

CT Scanner Unit, Central Analytical Facilities, Stellenbosch University, Stellenbosch, South Africa

X-ray computed tomography (CT) scanning is a well-known technique embraced by the palaeontological community worldwide, and encompasses synchrotron CT, laboratory macro, micro and nanoCT

devices and the associated advanced 3D image processing software and procedures. In this talk we outline the capabilities of the open access Stellenbosch University CT Scan Facility (www.sun.ac.za/ct-scanner), focusing on palaeontological examples. We specifically highlight the advantages of multiscale CT investigations, the potential of nanoCT and challenges in data analysis. Some unique methods for improving image quality of fossil scans embedded in rock are briefly discussed, for the very special case of Karoo fossils.

Funding acknowledgement: The Stellenbosch CT facility is funded by users on an hour by hour basis. We therefore thank and acknowledge all our users.

Biostratigraphic and sequence analysis of Well H1, from the central Niger Delta, Nigeria

Durugbo, E.U.[1], Olayiwola, M.A.[2], Yussuph, W.I.[3], Bankole, S. I.[4], Oyelami, A.[5]

[1]*Department of Biological Sciences, Redeemer's University, P.M.B. 230, Ede, Osun State, Nigeria*

[2]*Natural History Museum, Obafemi Awolowo University, Ile-Ife, Osun State, Nigeria*

[3]*Biostratigraphy Department, Earthprobe Nigeria Limited, Lagos, Nigeria*

[4]*Department of Geology, University of Lagos, Akoka, Lagos, Nigeria*

[5]*Palynology Unit, Global Energy Resources Limited, Lagos, Nigeria*

The sequence analysis of well H1(4100–12898 ft) dated Middle Eocene to Middle Oligocene from the Central Niger Delta have broadened our knowledge of the prevailing palaeoenvironments and vegetation around the Niger Delta in the early Tertiary. The logs indicated the presence of two lithostratigraphic units: the continental Benin Formation (4100–7820 ft) and the Upper Agbada Formation (7820–12898 ft) composed of alternating sand and shale intervals. The Benin Formation was barren of foraminifera and nannofossils, the palynological data revealed moderate counts of pollen and spores especially typical diagnostic Nigerian Eocene and Oligocene taxa. Four 3rd Order Maximum Flooding Surfaces characterized by marker shales, high faunal abundances and diversities were delineated and dated 35.9, 36.8, 38.0 and 39.45 Ma. The increased occurrence of *Retibrevitricolporites ibadanensis* and Base continuous occurrence of *Arecipites exilimuratus* at 5500 and 7160 ft defined the Early/Middle Oligocene and Late Eocene/Early Oligocene boundaries. Furthermore, the FDO *Nonion oyae* (*Nonion* sp. 8) at 7860 ft; FDO *Brizalina ihuoensis* at 7880 ft, HO: *Coccolithus formosus* at 8160 ft coupled with the FDO: *Doualaidites laevigatus* at 9160 ft, HO: *Helicosphaera lophata* at 9640 ft all indicated the penetration of Late Eocene. The FDO *Uvigerina hourqi* (*Uvigerina* cf. *topilensis*) delineated the Middle /Late Eocene boundary at 10 240 ft. The Middle Eocene is confirmed by the FDO *Chiloguembelina martini* at (12 780 ft), Acme *Uvigeriella-sparsicostata* at (11 580 ft) and the common presence of *Doualaidites laevigatus*. The palaeoenvironments fluctuated between Coastal Deltaic to Middle Neritic based on pollen and foraminiferal data.

Taxonomic and taphonomic analyses of fossil fauna from a new deposit in Gondolin

Engelbrecht, M.,[1] Steininger C.,[1] Val A.,1 Kibii J.M.[2]

[1]*Evolutionary Studies Institute, University of the Witwatersrand*

[2]*National Museums of Kenya*

The Plio-Pleistocene palaeocave site of Gondolin is located on the edge of the Cradle of Humankind near Hartebeestpoort Dam, 4 km SW of the town of Broederstroom. Gondolin is one of several early hominin fossil-bearing cave sites in South Africa. Historically, only three short excavations were conducted by Vrba in 1979, Menter in 1999 and Adams in 2006 respectively. In June of 2015, a fourth phase of excavation was initiated by Dr Job Kibii. This poster outlines the methods that will be used to study the bone assemblage recovered from a fourth excavation, into a deposit that consists of decalcified, *in situ* sediments, which lie in close proximity to Vrba's excavations. Given the proximity of the newly excavated deposit to Vrba's excavation (GD2), we hypothesize that the faunal assemblage recovered from itis similar (taxonomically and taphonomically) to the one from GD2. The main aims of this research are to conduct a taxonomic and taphonomic analysis of the 3000 macrovertebrate fossil fauna specimens excavated in June 2015. A taxonomic list of the macrofauna from this deposit will be compiled, together with a thorough taphonomic analysis of the assemblage, in order to identify possible bone modifiers and accumulators. Atentative age estimate will be made based on faunal correlations. The results will be compared and contrasted to the previously studied faunal assemblages from Gondolin 1 and 2, as well as to other Plio-Pleistocene assemblages within the Cradle of Humankind

Funding acknowledgement: NRF (Innovation) and PAST (Palaeontological Scientific Trust).

A reflection on the use of palaeosensitivity maps in heritage resources management

Galimberti, M., Wiltshire N.
Cedar Tower Services, Plumstead, South Africa

Cedar Tower Services (CTS) developed a new heritage management product called the 'Heritage Screener' in 2014. It is a fast and convenient tool that maps and summarizes heritage resources surveyed within proposed development areas and makes proactive recommendations to guide developers to minimize or avoid creating negative impacts on heritage resources. Palaeontological heritage features prominently in the range of resources taken into account for Heritage Screeners. The development and release of the national palaeosensitivity maps on the South African Heritage Resources Information System (SAHRIS) has significantly improved the ability of heritage practitioners to predict the impact of developments on fossils. These maps are publicly accessible on the web and they have raised the awareness of fossil heritage in a very short time. CTS has interpreted the fossil sensitivities for a number of development applications based on the SAHRIS palaeosensitivity maps. By working with the data on a daily basis we noted a number of issues which, if addressed in a coordinated fashion, will improve the quality and value of the tool. These issues are discussed along with suggestions for action. While the community of palaeontologists working in Cultural Resources Management in South Africa is small, the discipline is increasingly gaining recognition. The maintenance, debate and update of the SAHRIS palaeosensitivity maps is an important forum which brings heritage managers, impact assessors and researchers into the same space to share their findings. We therefore hope this is taken even further with bolder approaches to protecting palaeontological heritage by meaningfully integrating data derived from research institutions and palaeontological impact assessments.

Estuarine fish breeding grounds: a tale of two times

Gess, R.W.
Albany Museum, Grahamstown, an associate of Rhodes University, and partner in the South African NRF DST Centre of Excellence in Palaeontology

Estuarine systems comprise partially enclosed coastal water bodies which are either permanently or periodically open to the sea and within which there is variable salinity due to mixture of marine and fresh water, typically supplied by rivers. Commonly estuaries exhibit exceptionally high levels of primary and secondary production, though abrupt fluctuations in salinity, water temperature, dissolved oxygen and turbidity, which make them challenging environments. Relatively inaccessible regions of estuaries provide attractive nursery areas for those taxa that can tolerate environmental fluctuations. Although many species spend their entire lifecycles in estuaries approximately 40% of fish species in modern southern African estuaries are marine species that enter as early juveniles and return to the sea when mature. Estuaries are therefore vital for many marine fish lifecycles. Carbonaceous metashales of the ±360 mya (latest Devonian) Witpoort Formation (Witteberg Group, Cape Supergroup) Waterloo Farm lagerstätten are interpreted as having been deposited in a quiet embayment of a back-barrier lagoonal estuary. More than 500 vertebrate derived specimens, systematically collected over several decades, represent both complete and incomplete growth series, providing evidence for variable use of estuaries as fish nurseries. As in recent estuaries, certain taxa (including both arthrodire and antiarch placoderms) spent their entire life cycle within the estuarine environment whereas others (including the coelacanth, *Serenichthys*) only inhabited the estuary as juveniles and subadults. Additional taxa (including gyracanthid acanthodians), only represented by remains of large adults, may have entered the estuary to feed on juvenile fish or may have been washed in postmortem from adjacent environments.

Funding acknowledgement: This research was funded by the NRF DST CoE Palaeontology.

Environmental and depositional setting of a low diversity lingulid brachiopod assemblage from the Witpoort Formation (Witteberg Group, Cape Supergroup) east of Grahamstown

Gess, R.W., Harris, C.
Albany Museum, Grahamstown

Lingulid brachiopod impressions have been recovered from three widely spaced localities along a laterally extensive, fine grained carbonaceous metashale horizon within the lower Witpoort Formation (Witteberg Group, Cape Supergroup). At two of these localities they are extremely abundant, occurring as virtually monospecific invertebrate assemblages. A possible second species of lingulid is the only other species represented. Occasional terrestrial plant stems are preserved on the same bedding planes. Poor

sorting of shells, their large size range and their lack of damage suggests minimal transport before deposition on bedding surfaces, perhaps during erosive episodes. Some specimens that occur in near vertical orientation are interpreted as having been preserved in their infaunal life position. Lingulids have previously been reported from taxonomically more diverse marine invertebrate communities of the underlying Weltevrede Formation (Witteberg Group) and the Bokkeveld Group. The presence of entirely lingulid brachiopod constituted communities is conventionally considered indicative of a shallow marine environment with sufficient fresh water input to exclude taxa less tolerant of variable salinity. The above reported occurrence is interpreted as evidence for a fauna associated with mud flats formed from organic-rich fine-grained sediment discharged from an adjacent open river mouth. It represents the stratigraphically youngest record of brachiopods in the Cape Supergroup.

Funding acknowledgement: This project has been funded by SANRAL which has enabled the collection and study of fossil material exposed during mitigation of the N2 in 2015/'16.

Marine and terrestrial carnivore damage on Mio-Pliocene marine mammals from the west coast of South Africa

Govender, R.,[1] Avery, G.,[1] Chinsamy-Turan, A.[2]

[1]Iziko Museums of South Africa, Natural History Department, P.O. Box 61, Cape Town, 8000 South Africa

[2]University of Cape Town Biological Sciences, Private Bag X3, Rhodes Gift, Cape Town, 7701 South Africa

Marine mammal fossils, including seals and cetaceans, from the West Coast span the Late Miocene to Early Pliocene (7–5 Ma). During the taxonomic analysis of seal and cetacean skeletal remains, we identified a variety of bite marks that could be attributed to marine and terrestrial predators/scavengers. Thus far, the marine carnivores have been identified as sharks with and without serrated teeth. The results show that white and mako sharks were feeding on carcasses at sea, but whether or not the sharks were scavenging or actively hunting cetaceans and seals was not possible to determine. Skeletal damage by large and small terrestrial carnivores is linked to bears, hyaenas, wolverines, canids, felids and viverrids. The evidence lends support to the proposition that carcasses of cetaceans and seals were beached along the shorelines of the Early Pliocene lagoon/estuary, where they became accessible to terrestrial scavengers.

Funding acknowledgement: The Langebaanweg Cetacean Project was initially funded by the Claude Leon Foundation Postdoctoral Fellowship through R.G. from January 2010 to August 2011. The terrestrial carnivore damage analysis is funded by NRF/AOP through R.G.'s current project: Mio-Pliocene marine mammal palaeoecology and palaeoenvironment reconstruction.

Palaeontological Impact Assessments – Opportunities for exploring new fossil sites

Groenewald., G.

Market Street, Clarens, Free State, South Africa

Palaeontological Impact Assessments (PIAs) have been requested more regularly since the increase in formal recognition of this important part of the geological history of southern Africa.The request for PIAs are based on the Palaeontological Sensitivity Map of South Africa that is available on the website of the South African Heritage Resources Authority (SAHRA) and developers are compelled to ask for at least desktop surveys in all areas where fossils might be present in the rock sequence on sites of new developments. In this relatively short presentation the focus will be on the valuable information gathered through these PIA studies and how discoveries of previously unknown fossil localities are the direct result of these requests for Palaeontological Investigation in areas that would otherwise not have been thought of as important in terms of Palaeontological Heritage. The sites that are of particular interest include, for example The Ingula Pumped Storage Scheme of Eskom Holdings (Pty) Ltd, the Amatola Water Reticulation Scheme; the Water Recultation Scheme at Tsomo in the Eastern Cape; the Sendawo Photo-Voltaic Development near Vryburg. Case studies will be presented as part of the very short discussion on the value of these finds for future studies of the palaeontology of South Africa.

Preliminary findings: Litho- and biostratigraphic analysis of the Lower Beaufort Group, Karoo Supergroup, in the central Free State Province, South Africa, and implications for the depositional history of a distal bulge

Groenewald, D.P., Rubidge, B.S., Day, M.O.

Evolutionary Studies Institute, University of the Witwatersrand, Johannesburg, South Africa

The Ecca–Beaufort contact has been the subject of ongoing research, and stratigraphic collecting in the

lower Beaufort has revealed a northward younging of this boundary and associated faunal changes. Few extensive lithological markers are present for basin-wide stratigraphic correlation in the Beaufort Group and stratigraphic correlation of Beaufort Group strata around the basin has largely relied upon the eight SACS approved vertebrate biozones. The *Daptocephalus* (formerly *Dicynodon)* Assemblage Zone (AZ) is the only Permian biozone present north of the town Philippolis in the southern Free State. Recent fieldwork in the Jagersfontein district resulted in the recovery of faunal elements of the *Pristerognathus* AZ. Fossils probably assignable to *Daptocephalus* AZ taxa have been recovered in lower Beaufort Strata only 40 km to the east and no fossils of the *Tropidostoma* and *Cistecephalus* AZs have been found in the area to date, suggesting that in this part of the basin middle Permian rocks of the *Pristerognathus* AZ are directly overlain by the Late Permian deposits of the *Daptocephalus* AZ. Based on recently published dates of the Permian Beaufort biozones, this indicates a possible depositional hiatus of Late Permian Beaufort deposition lasting four million years or that a later period of erosion was experienced by this part of the basin. Both of these possibilities lend support to the reciprocal stratigraphic depositional model for the Karoo Basin. Fossil specimens collected during field work were prepared and identified in order to determine the presence and extent of the *Tropidostoma* and *Cistecephalus* AZs in the study area.

Funding acknowledgement: The financial assistance of the National Research Foundation (NRF) towards this research is hereby acknowledged. Opinions expressed and conclusions arrived at, are those of the authors and are not necessarily to be attributed to the NRF. The authors also acknowledge the financial support of the Palaeontological Scientific Trust (PAST), Johannesburg, South Africa.

West Coast Fossil Park – Past, present and future

Haarhoff, P.J.

West Coast Fossil Park

In the 1950s, the Chemfos mining company started mining phosphate at Langebaanweg and in 1958 the first fossil remains were discovered. Expansion of the mining activities in the 1960s revealed huge deposits of fossils and the South African Museum, under the leadership of Dr Brett Hendey, started an intensive research project on these deposits. With the halt in mining operations in 1993, it was decided not to follow the normal closure procedure that would have rehabilitated the mine for agricultural use, but rather to implement a programme that would ensure the preservation of the fossils of the area. Thus in 1996 the West Coast Fossil Park (WCFP) project commenced in a joint venture between the mining company Samancor (the holding company for Chemfos) and the South African Museum (now part of Iziko Museums of South Africa) and in 2005 the WCFP Trust was formed. The present challenge is to ensure that the WCFP is sustained and preserved in perpetuity as a fossil site and to take advantage of the unique opportunities that it provides for research, tourism, environmental education and other activities. The WCFP has an important role in stimulating economic and social upliftment on the West Coast and is currently engaged in a major facilities upgrade project funded by the NLC. This presentation will provide an overview of the development of the Park and will include a summary of the research programme.

Funding acknowledgement: Primary funders of the WCFP are: NLC, Bhp Billiton.

The vertebrate fauna from the lower Burgersdorp Formation (*Cynognathus* Assemblage Zone – *Langbergia* subzone) of South Africa

Hancox, P.J.

Evolutionary Studies Institute, School of Geosciences, University of the Witwatersrand, Private Bag 3, WITS 2050, Johannesburg, South Africa

The lower Burgersdorp Formation (Beaufort Group) records a rich and diverse Lower Triassic (Upper Olenekian) aged fauna that is referred biostratigraphically to the Langbergia subzone of the *Cynognathus* Assemblage Zone. The macrofauna of the *Langbergia* subzone comprises a relatively high diversity of temnospondyl amphibians, which are also the most abundant fossils, found. Taxa include the mastodonsaurids *Kestrosaurus dreyeri* and *K. kitchingi*, *Parotosuchus haughtoni*, the trematosuchid *Trematosuchus sobeyi* and the brachyopid *Bathignathus poikilops*. The associated amniote fauna includes the erythrosuchid archosauriform *Garjainia madiba*, eucynodont teeth, the cynodonts *Cynognathus craternotus* and *Langbergia modisei*, the therocephalian *Microgomphodon oligocynus*, the enigmatic diapsid *Palacrodon browni*, and as of yet undescribed procolophonoids. Despite extensive collecting no dicynodonts are documented from this subzone. Evidence of a diverse actinopterygian, sarcopterygian and chondrichthyan fish fauna exists in the form of thousands of isolated cranial bones, teeth and scales. At present, however, only the actinopterygian *Saurichthyes*, the dipnoan *Ptychoceratodus* and the chondrichthyan *Lissodus* are

documented in the literature. Thousands of vertebrate coprolites of various morphologies have also been collected, which contain fish scales and vertebrate bone. The remaining microvertebrate fauna remains undescribed; however, the discovery of this diverse microvertebrate fauna is important, as previously only the Czatkowice quarry in Poland and the Arcadia Formation in Australia have produced Early Triassic microvertebrate remains. Gaining a better understanding of this recovery fauna is important, as it is at this time that the radiation of life following the end Permian mass extinction begins.

Investigating the Ediacaran–Cambrian boundary in the Vanrhynsdorp Group, South Africa, and the Vestertana Group of Finnmark, northern Norway

Harrison, B.,[1] Bordy, E.M.,[1] Taylor, W.L.,[1] Högström, A.[2]

[1]*Department of Geological Sciences, University of Cape Town, 7701 South Africa*

[2]*Tromsø University Museum, UiT the Arctic University of Norway, N-9037 Tromsø, Norway*

The Vanrhynsdorp Group of South Africa is a thick fluvio-marine siliciclastic succession with minor carbonates that contains the Precambrian–Cambrian boundary. The age of the Vanrhynsdorp Group is poorly constrained and the stratigraphic position of the boundary within the succession remains unresolved. New detrital zircon dating in one of the middle units (lowermost Besonderheid Formation) yielded a maximum depositional age of 524 to 528 Ma. Additionally, trace fossil evidence suggests that the lowermost units are Upper Ediacaran while the bulk of the upper units are Lower Cambrian. The Group correlates with the world-famous Nama Group of southern Namibia as well as the Vestertana Group of Finnmark, northern Norway, both of which feature diverse Ediacaran–Cambrian fossils. This project focuses on the lithostratigraphy, sedimentology, micropalaeontology and chronostratigraphy of the lower Vanrhynsdorp Group that is believed to encompass the critical Precambrian–Cambrian boundary. Micropalaeontological correlation studies may help resolve stratigraphic problems regarding the position of the Precambrian–Cambrian boundary in South Africa and northern Norway. Our aims are to: 1) determine the stratigraphic location and nature of the Ediacaran–Cambrian boundary, 2) refine the sedimentological interpretation of the units by undertaking sedimentary facies analysis, 3) characterize the micropalaeontology in comparison to the Vestertana Group, and 4) separate detrital zircons from the coarse-grained siliciclastics and tuffaceous layers for dating purposes using Laser Ablation ICPMS.

Funding acknowledgement: The financial support of the DST-NRF Centre of Excellence in Palaeosciences and the Norwegian Research Council (NFR) through the Digermulen Early Life Research Group towards this research is hereby acknowledged.

Sedimentological, geochemical and palaeontological assessments across the upper Elliot and lowermost Clarens formations, South Africa

Haupt, T., Mapekula, L., Bordy, E.M., Sciscio, L.

Department of Geological Sciences, University of Cape Town, 7701 South Africa

The upper Elliot and Clarens formations encapsulate the Early Jurassic geological history in the main Karoo Basin of southern Africa. The transition from the upper Elliot Formation into the overlying Clarens Formation has been known for its steadily increasing aridity from semi-arid to desert-like conditions. In an attempt to reconstruct the palaeoenvironment and understand the broader geological and climatic changes over this critical interval, sedimentological logs were constructed and samples for geochemical analyses were taken both from the upper Elliot lake deposits, known to be anoxic and often containing conchostraca, as well as the transition between the upper Elliot and Clarens formations. This study reports on the provisional results of the investigations at farms Belmont, Rhodes and Westerford in the Ladybrand and Clocolan districts of South Africa in order to provide quantitative data for palaeoclimatic changes over this critical interval in the Early Jurassic. Major and trace elements of the samples were analysed using X-ray fluorescence and induction-coupled plasma emission spectrometry. Results calculated using the chemical index of alteration (CIA) method show a restricted but linear spread with low range of CIA values indicating semi-arid conditions. In addition, X-ray diffraction (XRD) analysis of clay minerals has been conducted in order to determine the rock provenance and further elucidate the palaeoclimatic conditions. Integration of field- and lab-based techniques offers potential for new knowledge on the Early Jurassic history of the Earth, which has been known for an overall humidification trend in several studies outside southern Africa.

Funding acknowledgement: The financial support of the DST-NRF Centre of Excellence in Palaeosciences, NRF African Origins Platform and CPRR to E.M.B. towards this research is hereby acknowledged.

Geochronological and stratigraphic correlations of new late Oligocene and late Miocene–Pliocene vertebrate-bearing successions in the Rukwa Rift Basin

Hilbert-Wolf, H.L.[1], Roberts, E.M.[1], Mtelela, C.[2], O'Connor, P.M.[3], Stevens, N.[3]

[1]*James Cook University*

[2]*University of Dar Es Salaam*

[3]*Ohio University*

Nearly a decade of palaeontological and geological investigations of the Rukwa Rift Basin in southwest Tanzania have led to the discovery of richly fossiliferous Cretaceous and late Oligocene vertebrate-bearing strata. Here we report the discovery of the first confirmed late Miocene–Pliocene vertebrate-bearing deposits in the Rukwa Rift, as well as a series of newly identified late Oligocene deposits to the east of the well-known Nsungwe Formation type area in the Songwe Valley. The discovery of a new late Miocene–Pliocene unit in the rift, which we assign to the base of the Lake Beds Sequence, is significant because it represents the only known fossil-bearing deposit of this age exposed in the western branch of the East African Rift System between lakes Edward and Malawi. Preliminary investigation has resulted in the discovery of numerous fossiliferous horizons, with faunal remains consisting of abundant fish, some turtle and crocodilian elements, as well as rare mammalian remains, including those of hippopotami and large ungulates. We have dated two volcanic tuffs within the sequence via LA-ICPMS U-Pb zircon geochronology, constraining the major vertebrate fossil localities. The Rukwa Rift Basin has been affected by recent tectonic inversion along the basin margins, and the isolated and varied sedimentary exposures and difficult-to-recognize alkaline volcanics make dating and correlation challenging. However, careful geological mapping, in combination with applying multiple dating methods and Sm-Nd isotopic fingerprinting of tuffs is proving to be a powerful approach for deciphering the complex stratigraphy and correlating isolated exposures and fossil localities across the basin.

Funding acknowledgement: We acknowledge Heritage Rukwa Tanzania Limited for funding geochronology analytical work and for logistical assistance, and the Tanzanian Petroleum Development Corporation for making samples available. We thank the Tanzanian Commission for Science and Technology and the Tanzanian Antiquities Unit for logistical support in the field. Fieldwork was supported by the National Science Foundation (BCS_1127164; EAR_1349825) and the National Geographic Society (Committee for Research and Exploration). This project was also funded by the AAPG Suzanne Takken Memorial Grant, and we are grateful to the AAPG Grants-in-Aid Program for this support.

The functional morphology of the Early Triassic non-mammaliaform cynodont *Thrinaxodon* liorhinus forelimb

Iqbal, S.,[1] Carlson, K.J.,[2] Abdala, F.,[1] Fernandez, V.[3]

[1]*Evolutionary Studies Institute, University of the Witwatersrand, WITS 2050, Johannesburg, South Africa*

[2]*Department of Anthropology, Indiana University, Bloomington, Indiana, U.S.A.*

[3]*European Synchrotron Radiation Facility, 71 rue des Martyrs, 38000, Grenoble, France*

The non-mammaliaform cynodont, *Thrinaxodon liorhinus*, is one of the best known fossils in the transition to mammals, and has been a key taxon in understanding the evolution of therapsids. The species is abundant in the South African Karoo Basin and is one of the best represented taxa immediately after the Permian–Triassic mass extinction event. One of the key adaptive behaviours that may have aided in their survival of the extinction was fossorialism. Usually, evidence for this comes in the form of numerous fossils of *Thrinaxodon* having been found in burrows or in a curled-up position. Direct evidence for burrowing capability; however, can come from the functional morphology of *Thrinaxodon* limbs. The present study investigates the internal and external structure of the *Thrinaxodon* forelimb by quantitatively comparing it to forelimb structure of a variety of reptiles characterized by different behavioural patterns, to a fossorial mammal, and to other cynodonts. The study employs geometric morphometric analyses, forelimb metric indices, torsion and cortical thickness of humeri in order to determine the extent to which, the *Thrinaxodon* forelimb functionally and structurally resembles that of a fossorial mammal versus a reptile. Results of the study tease apart the extent to which the *Thrinaxodon* forelimb illustrates structural modifications and prove that the morphology is close to that of fossorial mammals with minimal similarities to digging reptiles. This study provides direct anatomical evidence that the limb configuration of *Thrinaxodon* indicates the non-mammalian forelimb form had begun to show similarities to the mammalian form.

Funding acknowledgement: The Palaeontological Scientific Trust (PAST), National Research Foundation (NRF).

CT scanning of fossils at the Evolutionary Studies Institute

Jakata, K.

Evolutionary Studies Institute, University of the Witwatersrand, Johannesburg, South Africa

Computed tomography has become one of the main methods used in palaeoscience to study fossil materials. The technique uses X-rays to allow researchers to acquire a three-dimensional image of the specimen, observe the internal structure non-destructively and to take measurements. However, some of the fossils have inclusions with relatively higher density compared to other elements in the matrix or bone material. This has the effect of reducing contrast between the matrix and the bone whilst introducing bright regions in the acquired images. We will be discussing the scanning of such specimens and other CT artefacts such as noise, and movement.

Funding acknowledgement: Centre for Excellence in PalaeoSciences, Evolutionary Studies Institute, University of the Witwatersrand.

Middle Permian diversity of large herbivores: taxonomic revision of the Titanosuchidae (Therapsida, Dinocephalia) of the Karoo Basin, South Africa

Jirah, S., Rubidge, B.S., Abdala, N.F.

Evolutionary Studies Institute, University of the Witwatersrand, Johannesburg, South Africa

Dinocephalians are a group of therapsids that constitute a significant part of the Middle Permian tetrapod biodiversity. They comprise six families, four of them, anteosauridae, titanosuchidae, tapinocephalidae and styracocephalidae, occur in South Africa. Three of these families (anteosauridae, styracocephalidae and tapinocephalidae) have recently undergone taxonomic revisions by various researchers except for the family titanosuchidae, which has been neglected and the current taxonomy has not changed since 1969. Currently the family titanosuchidae comprises two genera and nine species (*Titanosuchus ferox*, *Jonkeria boonstrai*, *J. haughtoni, J. ingens, J. koupensis, J. parva, J. rossouwi, J. truculenta* and *J. vanderbyli*). This project is an enquiry into the validity of these species and involves first hand examination of the majority of the known (well preserved) specimens of the group to evaluate the morphological features proposed to characterize the different members of the titanosuchidae. In addition, aspects relating to ontogenetic development and sexual dimorphism would also be a target of this study. Together with the recent taxonomic work on anteosaurids, styracocephalids and tapinocephalids, this research project will give a comprehensive picture of dinocephalian diversity in the Middle Permian of South Africa. Taxonomic clarification of groups represented in the fauna is a basic prerequisite for any project aiming to explorethe diversity changes and extinctions of terrestrial faunas from the Middle Permian.

Funding acknowledgement: We would like to thank the Palaeontological Scientific Trust (PAST), NRF African Origins Platform and CoE Palaeosciences for their financial support.

Tree growth rings as a palaeoclimate proxy for the Karoo Basin

Kock, S.

University of the Witwatersrand, Jan Smuts Ave, Johannesburg, 2000 South Africa

Very few dendroclimatology studies have been done on the *Agathoxylon* wood specimens found in the Permian to Jurassic Beaufort Group and overlying Molteno and Elliot formations of the Karoo Supergroup in the main Karoo Basin of South Africa. Preliminary analyses of these gymnosperm wood specimens reflect a variable palaeoclimate that may be the result of palaeoenvironmental conditions in the immediate area or the area's distance from the coast. The study will look at five anatomical features of 60 Karoo fossil wood specimens from outcrops in the Free State to reconstruct the palaeoclimate of this area over 60 million years from Mid-Permian to Early Jurassic times. The anatomical features include: the presence/absence of tree growth rings, width of the growth rings, annual width variations of adjacent growth rings, presence/absence of false and traumatic rings and the portions of early wood and late wood in each growth ring. The features will be used as an indicator of the seasonality of the palaeoclimate, favourability of growing conditions, regularity of the length of the growing season/environmental stresses and the occurrence of extreme climatic conditions. Fossil wood specimens at/near the P-Tr boundary will also be studied and compared to woods from other parts of the Karoo Basin to see whether their tree growth rings reflect extreme climatic conditions that can be associated with the P-Tr mass extinction event. Finally, intra-ring growth analysis will be used to determine whether the trees had evergreen or deciduous habits.

Funding acknowledgement: NRF Grant holder-linked Student Support through my supervisor, Prof. Marion Bamford.

Spatial taphonomic reconstruction of the Dinaledi Chamber, Rising Star Cave, by the use of high-resolution three-dimensional data collection

Kruger, A.[1], Randolph-Quinney, P.[2], Elliott, M.[1]

[1]*Evolutionary Studies Institute, University of the Witwatersrand, Johannesburg, South Africa*

[2]*Department of Anatomy, University of the Witwatersrand Medical School, Johannesburg, South Africa*

The Dinaledi Chamber in the Rising Star Cave (Cradle of Humankind, South Africa) has yielded approximately 1550 specimens of hominin remains to date, representing a minimum of 15 individuals. The excavation environment within the cave represented an exceptionally difficult and dangerous recovery challenge where conventional methods of high-resolution spatial data retrieval would have been exceptionally cumbersome. Through the innovative use of white-light photogrammetry and laser scanning at scales ranging from landscape level down to the level of individual bone fragments, data collected with these methods push boundaries of both technology and image reconstruction as applied to the analysis of taphonomy, palaeoenvironment and skeletal morphology. Here we review the use of these technological solutions in the Dinaledi excavation, and show applications that help us to understand the spatial distribution of remains, possible disarticulation or disaggregation processes in the site, and the association of taphonomic signatures with spatial position of hominin elements. The findings from the spatial data are an important input parameter in understanding how the bodies entered the Dinaledi Chamber. These high-resolution data integration methods create a foundation for further work on understanding site formation processes for the Dinaledi Chamber and other parts of the Rising Star cave system.

Funding acknowledgement: Funding for this project was provided by the National Research Foundation, L.R. Berger Foundation for Exploration, the Lyda Hill Foundation and National Geographic Society. Additional funding was provided by the DST-NRF Centre of Excellence in Palaeosciences.

Update on the digital library of ichnofossils in the Karoo Supergroup, South Africa

Krummeck, D.W., Bordy, E.M.

Department of Geological Sciences, University of Cape Town, 7701 South Africa

The Karoo Supergroup in southern Africa boasts a stratigraphic record that: a) contains evidence for the end-Permian and end-Triassic mass extinction events, ~252 and ~200 Ma ago, respectively; and b) is rich in trace and osteological fossil assemblages. Ichnofossils are important in capturing the biotic changes associated with these events and can provide unique insights into the interactions among organisms and their sustaining ecosystems. To date, no consolidated South African ichnotaxa database exists, and thus the spatiotemporal distribution and abundance of the Karoo ichnites are unknown. We are creating a Karoo ichno-database using primarily the digital reappraisal of various museum collections in South Africa. Photogrammetry has been a sustainable technique, because it requires simple tools (camera) and skills (photography, basic computer literacy) that form part of the general ichnological and geological practice. Photogrammetry has been relatively efficient in the digital 3D modelling of larger trace fossils (e.g. vertebrate burrows). However, smaller inchnofossils require more specialised photographic equipment such as macro lenses and photostacking rigs, making the technique less practical for producing digital 3D models. Laser scanning is effective for converting small ichnites into digital 3D models; however, it requires specialized, less affordable equipment. We propose that, for small trackways and traces, the data collection should focus on capturing the variations in these highly repetitive structures with the aid of techniques that involve semi-automated, statistical descriptions. Our ultimate aim is to utilize the data in the ichnological applications of deep learning algorithms, especially those that are equipped with graphical user interfaces.

Funding acknowledgement: The financial support of the NRF African Origins Platform and CPRR to E.M.B. towards this research is hereby acknowledged.

The long bone histology of *Antetonitrus ingenipes*: basal sauropoda and the evolution of the sauropod-type growth strategy

Krupandan, E., Chinsamy, A.

Department of Biological Sciences, University of Cape Town, Private Bag X3, Rhodes Gift, 7701 South Africa

Analysis of the long bone microstructure of *Antetonitrus ingenipes* fills a crucial gap in our understanding of the growth dynamics of sauropodomorph dinosaurs. Basal Sauropodomorpha are largely characterized by zonal bone tissue; in contrast, more derived sauropod taxa show a shift towards continuous, uninterrupted growth, characterized by fibrolamellar bone with lines of growth either absent or only present

in the outer circumferential layer. While *Mussaurus patagonicus* shows an increase in growth relative to more basal sauropodomorphs, *Antetonitrus* shows us that the histology of the first true sauropods exhibits an increase in growth rate coupled with intermittent growth lines. Growth lines are not restricted to the outer margin of the compacta (i.e. late ontogeny), indicating that the fully uninterrupted growth seen in more derived sauropods, such as the Nam Phong sauropod, had not yet developed – even in larger sampled individuals. Growth patterns in the youngest individuals exhibit uninterrupted fibrolamellar bone, similar to that of the older individuals, bar the lack of growth marks. Occurrence of growth marks are decoupled from bone size, indicating a level of developmental plasticity in this taxon. Modulations in the pattern of vascular channel arrangements throughout the cortex may indicate periods of resource strain, but the lack of consistency in these modulations indicate this is not likely due to seasonal fluctuations in resource availability. Bands of radial fibrolamellar bone in two samples are interpreted as evidence of disease. While exhibiting highly vascularized, azonal fibrolamellar bone throughout the cortex, as in more derived sauropods, *Antetonitrus* lacks the restriction of growth marks to the outer cortical margin considered diagnostic of Sauropoda.

Funding acknowledgement: NRF/DST Innovation Grant, Palaeontological Scientific Trust (PAST), Harry Crossley Foundation Doctoral Research Grant.

Proposed new Palaeontological Guidelines for the Western Cape

Lavin, J., Thomas, G.

Heritage Western Cape, South Africa

Following a meeting between key stakeholders in the palaeontological community, as well as representatives of the various national and provincial heritage authorities in July 2014, various issues were raised regarding the requirements of Palaeontological permitting under the National Heritage Resources Act (NHRA 25 of 1999). These issues arose from a conflict between requirements under the act, as well as expectations and relevant needs from research palaeontologists in the field. Following the 2014 meeting, the various needs and requirements have been incorporated into a set of guidelines that address many of the issues raised. Heritage Western Cape is in the process of adopting these guidelines in an effort to better facilitate palaeontological research in the Western Cape. The guidelines are intended to help interpret the NHRA in a way that better suites the research approach of a field palaeontologist, and in a legal sense, to move the field of Palaeontology into a position where legal requirements better mirror the needs of palaeontological methodology.

Funding acknowledgement: Western Cape Government, Department of Cultural Affairs and Sport.

Palaeohistological Evidence for ancestral high metabolic rate in archosaurs

Legendre, L.J.[1], Guénard, G.[2], Botha-Brink, J.[1], Cubo, J.[3]

[1]*Department of Palaeontology, National Museum, 36 Aliwal St., Bloemfontein, 9302 South Africa*

[2]*Université de Montréal, Département de Sciences Biologiques, Succursale Centre-Ville, Montréal, QC H3C 3J7, Canada*

[3]*Université Pierre et Marie Curie, Institut des Sciences de la Terre de Paris, 4 place Jussieu, 75005 Paris, France*

Archosaurs are a clade of vertebrates that includes birds, crocodiles, and numerous fossil groups. This clade has long been a matter of debate among palaeontologists concerning the evolution of its thermometabolism. The classical hypothesis considers that only modern birds are truly endotherms (i.e. able to produce their own body heat), whereas all other archosaurs are ectotherms (i.e. relying on the external environment to maintain their body at a high temperature). Bone histology allows the study of several traits linked to thermometabolism, otherwise impossible to estimate on fossil specimens. However, no quantitative estimation of metabolic rate has ever been performed on fossils using bone histological features. Here we performed statistical predictive modelling in a phylogenetic context using a sample of vertebrates and a set of bone histological features to estimate metabolic rates of fossil archosauromorphs. We used the recently published method called Phylogenetic Eigenvector Maps (PEM) to express phylogenetic relationships between species as independent variables in our models. Our results show that Mesozoic theropod dinosaurs exhibit metabolic rates close to those of modern birds, and that most fossil archosaurs share an ancestral metabolic rate higher than that of extant ectotherms. This derived metabolic rate was acquired at a more inclusive level of the phylogenetic tree, among non-archosaurian archosauromorphs. These preliminary results also highlight the difficulties of assigning a given heat production strategy (i.e. endothermy, ectothermy) to an estimated metabolic rate value,

and confirm findings of previous studies that the definition of the endotherm/ectotherm dichotomy may be ambiguous.

Funding acknowledgement: This work was supported by the Université Pierre et Marie Curie (Paris) and the French Centre National de la Recherche Scientifique (UMR 7193), and the National Research Foundation of South Africa (UID 91602) and Palaeontological Scientific Trust (PAST) and its Scatterlings of Africa Programmes.

Charcoal analysis from 58 and 49 000-year-old hearths at Sibudu: implications for wood uses and the KwaZulu-Natal environment during the Middle Stone Age

Lennox, S.J.

Evolutionary Studies Institute, School of Geosciences, University of the Witwatersrand, Private Bag 3, Johannesburg, South Arica

Sibudu cave was occupied by hunter gatherer groups of modern humans. The site includes technological industries from approximately 77 ka to 35 ka, distinguished by specific stone tool types. The environmental conditions have previously been elucidated from studies of well-preserved botanical remains. Archaeological charcoal specimens, from hearths on three of the occupation floors, were analysed for information about wood selection and use. Charcoal was identified by means of reflected light. Taxa identified, such as *Afrocarpus/Podocarpus* spp., confirmed that the coldest, driest phase of occupation was at approximately 58 ka. Bushveld woods, including five *Acacia* types, have been identified in charcoal from MOD layer. The vegetation mosaic was different from today's coastal forest and savanna near Sibudu. The vegetation succession since ~58 ka and ~49 ka represents an increase in savanna at the expense of forest. Charcoal from poisonous *Spirostachys africana* occurs in one hearth in each of the three layers and suggests that the wood was selected deliberately and burnt for insecticidal smoke or other medicinal purposes. This is supported by the occurrence in one hearth, in one layer, of *Tarchonanthus parvicapitulatus* charcoal.

Funding acknowledgement: The support of the NRF and the Palaeontological Scientific Trust (PAST) and its Scatterlings of Africa Programmes towards this research is acknowledged.

Palynology of the Permian Mucanha-Vuzi Coal Basin (Ecca Group, Karoo Supergroup), Tete Province, Mozambique

Mahabeer, K., Barbolini, N., Bamford, M.

Evolutionary Studies Institute, University of the Witwatersrand, Private Bag 3, WITS 2050, Johannesburg, South Africa

A significant amount of palynological work has been carried out on southern African coals but very few studies have focused on coal seams in Mozambique. This study investigated the palynology of the Mucanha-Vuzi Basin in the Tete Province, Mozambique. A total of 32 samples were examined from three boreholes. Standard acid preparation was carried out and 15 samples were productive. The palynomorphs were mostly fragmented and darkly coloured but 36 species were positively identified. Biostratigraphic correlation, age determination, thermal maturity and palaeoenvironmental reconstruction were the objectives of the study. An abundance of saccate pollen allowed a strong correlation to be made between the Mucanha-Vuzi samples and those from the Witbank/Highveld coalfields of South Africa. Correlation with the Waterberg and Pafuri coal-bearing basins (MacRae, 1988) was also possible due to the same dominant species being present. Based on these correlations, the Mucanha-Vuzi Basin samples were determined to be Lopingian (late Permian). The thermal maturity of the palynomorphs was determined to be 4–6 according to the Thermal Alteration Scale of Batten (1980). The palaeoenvironment was reconstructed based on parent floras of the palynomorphs, and this indicated a fluctuating climate with warm wet cycles dominating in the late Permian. Palynology is a powerful tool for analysing past ecosystem changes, and accordingly more research should be undertaken in areas such as Mozambique, where macrofloral and -faunal remains are extremely rare.

Funding acknowledgement: Postgraduate Merit Award from the University of the Witwatersrand Grantholder-Linked Student Support from the NRF.

What is happening in palaeosciences outreach and education in South Africa in 2016?

Mckay, I.J.

Education and Outreach, Evolutionary Studies Institute, University of the Witwatersrand

It is relatively easy for those involved in palaeontological research in South Africa to tell you who else is

doing research in their particular field, where they are working, what their qualifications are and what there outputs are in terms of number of publications and citations. The situation, however, is not so easy with regard to Palaeoscience education and outreach. This paper presents the results of a mainly internet based survey – using Survey Monkey, follow up e-mails and telephone calls to summarize the state of palaeosciences outreach and education in South Africa in 2016. All the NRF funded Palaeoscience Centre of Excellence (CoE) institutions are being surveyed as well as a number of non-CoE organizations also doing palaeosciences outreach including the McGregor Museum, the Cradle of Humankind and the Durban Museum of Natural History. The survey intends to find out what programmes are being offered, what audience and what size audience they are reaching, how successful the presenters of the programmes rate them and what the biggest obstacles that they face when presenting programmes. The survey will also find out what education resources are being using when presenting their programmes, such as posters and casts, and what resources they need. Also, what are the qualifications of the presenters and what remuneration are they receiving. The purpose of this survey is to establish a baseline for palaeosciences outreach and education in South Africa with the goal of identifying joint projects that can be used to develop it sustainably in the future.

Using phytolith evidence to reconstruct the Middle Pleistocene vegetation community along the southwest coast of South Africa

Mann, N.J., Stynder D.D.

University of Cape Town, Rhodes Gift, Cape Town, 7701 South Africa

The southwest coast of South Africa is home to a unique fynbos-dominated plant community that is characterized by a mix of low-growing shrub, succulent and geophyte species. Unlike plant communities in the rest of southern Africa, grasses (comprising primarily C3 taxa) and indigenous trees in this region are conspicuously rare. Low primary productivity with respect to grasses in particular has resulted in very low levels of ungulate biomass and diversity. Vegetative conditions may have been significantly different in the past however. While today the indigenous ungulate community is typified by small-bodied browsing and mixed feeding bovid species, a diversity of large-bodied ungulates dominated the region's faunal community during the Pleistocene. It has been proposed that the presence of these large ungulates, indicates a significantly grassier past for this region. To investigate this hypothesis further, we analysed grass silica short-cell phytoliths extracted from Middle Pleistocene fossil soil horizons in the archaeological excavations at Elandsfontein. Our results suggest that grasses (C3 and to a lesser extent C4 taxa) were indeed more abundant than they are in the contemporary environment. This notwithstanding, grass does not appear to have dominated the environment as some have suggested, since non-grass plant taxa were equally well represented. Overall, these results support the existence of a rich mosaic C3-dominated plant community and confirm previous findings that the Elandsfontein Middle Pleistocene environment was highly productive.

Funding acknowledgement: NRF.

Alexander Logie du Toit's drawings of Alfred 'Gogga' Brown's collection of Stormberg plant fossils, and notes on the localities of several important vertebrate fossil holotypes from the Eastern Cape

Master, S.

Economic Geology Research Institute, School of Geosciences, University of the Witwatersrand, Private Bag 3, WITS 2050, Johannesburg, South Africa.

Alfred Gogga Brown (born England, 1834), an amateur fossil collector and naturalist, settled in Aliwal North (Eastern Cape) in 1859, living there until his death in 1920 (Drennan, M.R., n.d., *Gogga Brown*). He is best known for his vertebrate fossil discoveries from the Stormberg mountains where he had made six journeys by 1868, traversing >650 km in total. Twelve fossil reptiles, three fossil fishes, and a temnospondyl amphibian were named after him. Brown is less well known for his fossil plant collection, which was, nevertheless, one of the best and most beautiful in the country (Drennan). Vertebrate palaeontologist T.H. Huxley, upon receiving a box of 350 mostly plant fossils, was unimpressed, referring to them as vegetable remains (letter to R.I. Murchison, 2.10.1866). However, one of Brown's plant specimens was described by palaeobotanist A.C. Seward, and named *Odontopteris browni*. Alexander Logie du Toit (1878–1948), pioneering advocate of continental drift, and widely regarded as South Africa's greatest geologist, was also a good palaeobotanist. Among his papers (UCT, BC722.D), there is an undated sketchbook, containing sketches by du Toit of plant fossils, collected by Brown, occurring in soft yellow sandstones (Molteno Formation) near Aliwal North, and Herschel. Among the plants illustrated are:

Callipteridium stormbergense; Danaeopsis(?), *Pterophyllum, Ginkgo* (or *Baiera*?), *Noeggerathiopsis*(?). Du Toit sketched these fossils during a visit to Brown in Aliwal North, and he also made notes on the detailed localities of holotype fossils collected by Brown, of *Euskelosaurus browni* Huxley 1867, *Batrachosuchus browni* Broom 1903, and *Karoomys browni* Broom 1903.

Funding acknowledgments: S.M. is grateful to the School of Geosciences, University of the Witwatersrand, for funding his attendance at the PSSA 2016 conference.

New historical information on the first vertebrate fossil discoveries from Lesotho in 1867, including the type locality of the cynodont therapsid *Tritylodon longaevus*

Master, S.

EGRI, School of Geosciences, University of the Witwatersrand, Private Bag 3, WITS 2050, Johannesburg, South Africa

In the 1870s, Richard Owen of the British Museum received vertebrate fossils from Basutoland (Lesotho), sent to him by medical doctor Hugh Exton from Bloemfontein, Orange Free State, and he published an illustrative catalogue of these in 1876. In 1884, he described from this collection a Triassic mammal – *Tritylodon longaevus* (an important cynodont therapsid or mammal-like reptile). New information has been found concerning the discovery, locality, stratigraphic position, and discoverers of the Basutoland vertebrate fossils, in two letters sent to Dr Alexander Logie du Toit by the 80-year-old David Draper in 1929. Draper revealed in these letters that the fossils were found during a raiding party by horse commandos from the Orange Free State during the Basuto War of 1867. The then 18-year-old Draper assisted Dr Exton with collecting vertebrate fossils from the Upper Red Beds (i.e. upper Elliot Formation, Karoo Supergroup, of Lower Jurassic age) not far below their contact with overlying Cave Sandstones (Clarens Formation), at a site whose location he pointed out on a map (present day Thaba Tso'eu). The incidents regarding the Basutoland fossil discovery had not been recorded before in the biographies of Hugh Exton and David Draper, who both later became illustrious geologists. The discovery of fossils by Exton and Draper in 1867 was the first find of any fossils in Basutoland, and predated discoveries of plant fossils associated with coal seams, described by Richard Bright in 1873 and 1874, which were previously thought to have been the first fossils found there.

Funding acknowledgment: I am grateful to the School of Geosciences, University of the Witwatersrand, for funding my attendance at the PSSA 2016 conference.

A new fossil termite nest from the uppermost Clarens Formation at Pafuri River camp, Venda, Limpopo Province, South Africa – Comparison with other occurrences in southern Africa

Master, S.[1], Bordy, E.M.[2]

[1]*EGRI, School of Geosciences, University of the Witwatersrand, Private Bag 3, WITS 2050, Johannesburg, South Africa*

[2]*Department of Geological Sciences, University of Cape Town, Cape Town, South Africa*

A new ichnofossil locality, interpreted to contain fossil termite nests, has been discovered in the Lower Jurassic Clarens Formation of the Karoo Supergroup, at Pafuri River camp, NE Venda (S22°25.34′; E21°02.17′), Limpopo Province, South Africa. The ichnofossils are found stratigraphically in the uppermost Clarens Formation, directly below the contact with the ~183 Ma Karoo basalts (Lebombo Group). The ichnofossils are positively-weathering structures, which stand out in sharp contrast to the uniform cream-coloured, well-sorted, medium-grained aeolian sandstones which form the host rocks. They consist of a tangled mass of intertwined tubules, and tube-like cavities, 0.5–1 cm in diameter. These traces are confined to irregular elliptical sandstone structures (L: 48 cm; W: 25 cm) that are better cemented and less susceptible to erosion than the surrounding sandstone, which is more friable. Another elliptical structure (L: 16 cm; W: 10 cm) is connected to a tube that is 2.5–3 cm wide and 28 cm long. Other isolated, similar-sized tubes are present in the outcrop. The interiors of the tubes and elliptical structures are oxidized and pink in colour, while their peripheries are bleached paler than the host sandstones, indicating strong diagenetic reduction around these structures. Overall, the structures resemble fossil termite nests and associated structures described previously from other parts of the Clarens Formation in southern Africa (Bordy *et al.* 2004 – *Palaios* 19: 68–78; Bordy *et al.* 2009 – *SAJS* 105: 356–362).

Funding acknowledgment: S.M. is grateful to the School of Geosciences, University of the Witwatersrand, for funding his attendance at the PSSA2016 conference. E.M.B. acknowledges financial support of the DST-NRF Centre of Excellence in Palaeosciences and various NRF programmes (AOP, CPRR, IFFRR). Opinions expressed and conclusions arrived at are those of the authors only.

Investigations of a *Glossopteris* flora near Sutherland: a new approach embracing morphometric and ecological aspects

Matiwane, A.[1], Prevec, R.[1,2]

[1]*Geology Department, Rhodes University, Artillery Road, Grahamstown, 6140 South Africa*

[2]*Albany Museum, Grahamstown, South Africa*

Glossopteris leaves are one of the most common and easily recognized fossils in the Permian of the Karoo Basin, but they are morphologically conservative and taxonomic approaches to species differentiation have been varied, relying on visual estimations of relatively plastic characteristics such as shape, length etc. Species identification has therefore proven to be subjective, inconsistent and extremely challenging. Here, we consider new approaches involving morphometric and ecological techniques with the aim of establishing a standardized methodology for the leaf taxonomy of this group. A new flora from the Ouberg Pass (near Sutherland), has been selected as the subject for this study, and will contribute towards the greater goal of establishing a reliable biostratigraphic framework for *Glossopteris* floras of the Permian of the Karoo Basin. The middle Permian is particularly poorly understood in terms of palaeofloras in South Africa. Previous records have been allochthonous fragments, or floras lacking conclusive stratigraphic and temporal constraints. The Ouberg Pass lies in the southern Karoo Basin, rich in fossil records of terrestrial vertebrates of the *Tapinocephalus* Assemblage Zone, and these together with multiple ash dates in the immediate area provide excellent context for this study of a well-preserved, middle Permian parautochthonous flora.

Funding acknowledgement: The support of the DST/NRF Centre of Excellence in Palaeosciences (CoE in Palaeosciences) and the African Origins Platform (AOP) towards this research is hereby acknowledged.

Palaeoclimatic implications of frog taxa from South African fossil sites

Matthews, T.,[1] Measey, G.J.[2]

[1]*DST-NRF Centre of Excellence in Palaeosciences, Iziko South African Museum, 25 Queen Victoria Street, Cape Town, 8000 South Africa*

[2]*Centre for Invasion Biology, Department of Botany and Zoology, Natural Sciences Building, University of Stellenbosch, South Africa*

Frogs are useful palaeoclimatic indicators as they are sensitive to climate change and, in particular, to shifts in variables such as temperature and moisture due to their semi-permeable skins, unshelled eggs, biphasic lifestyles, and the fact that the timing of breeding is driven by environmental cues. Fossil frog assemblages may potentially provide information on rainfall, seasonality, the types of water bodies available, and also the terrestrial environment (vegetation and substrate) as a number of frog species are independent of water during various periods of their lifecycles. The results from an analysis of fossil frog assemblages from the archaeological west coast Holocene site of Dunefield Midden (DFM) and the much older 5.1 Mya palaeontological site of Langebaanweg (LBW) are presented. DFM provides information on some of the agents/agencies which led to the accumulation of microfauna at the site, while the LBW frog fauna provides evidence for substantial rainfall at 5.1 Mya at the southwestern tip of Africa, and also provides new and compelling evidence for a summer rainfall regime, or of at least significant summer rainfall during the Early Pliocene. Preliminary taxonomic and palaeoenvironmental results from the frog fauna from Coopers Cave (1.9–1.6 Ma), situated approximately 45 km northwest of Johannesburg in the Cradle of Humankind, are presented.

Funding acknowledgments: The support of the DST-NRF Centre of Excellence in Palaeosciences (CoE in Palaeosciences), and the National Research Foundation (NRF), towards this research is hereby acknowledged. G.J.M. thanks the DST-NRF Centre of Excellence for Invasion Biology for their support.

The largest dinosaur in the Karoo: what the Highland Giant is and is not

McPhee, B.W.,[1] Choiniere, J.N.,[1] Sciscio, L.,[2] Bordy, E.M.[2]

[1]*Evolutionary Studies Institute, University of the Witwatersrand, Private Bag 3, Johannesburg, 2050, South Africa*

[2]*Department of Geological Sciences, University of Cape Town, 7701 South Africa*

In 1994 Prof. James Kitching discovered an assemblage of massive dinosaur bones while prospecting in the Elliot Formation near Clarens at one of the key sites for the Lesotho Highlands Water Project. Almost two decades later, *in situ* material from the same assemblage was relocated on Beginsel farm (Free State) by a team from Wits University. In addition to the vertebrae, ulna and pedal ungual originally collected by Kitching, we have recovered a partial sacrum and femur, as well as additional dorsal and caudal vertebral

material. This assemblage (informally known as the Highland Giant) represents a sauropodomorph dinosaur of appreciably larger size than any previously known specimen from deposits close to the global Triassic–Jurassic boundary. Despite the 20 years since its initial discovery, the taxonomic affinities and stratigraphic provenance of the Highland Giant remain enigmatic. Originally thought to be a giant biped from Late Triassic beds of the lower Elliot Formation, our recent investigations securely place it within the upper Elliot Formation and suggests a close relationship with the large-bodied supposedly quadrupedal lower Elliot genus *Antetonitrus*. In-depth analyses of the stratigraphic and phylogenetic relationships of the Highland Giant and a quantitative estimate of its body mass and general proportions are presented. This allows for guided speculation about the locomotory habits of this intriguing animal. These concerns also have bearing on the way in which ecological partitioning of the increasingly arid upper Elliot palaeoenvironment encouraged the taxonomically and morphologically diverse assemblage of large-bodied herbivores now recognized.

Funding acknowledgement: B.W.M. is supported by an NRF African Origins bursary to Bruce Rubidge and a DST/NRF Centre of Excellence in Palaeosciences postgraduate bursary.

Bone microstructure of two highly specialized subterranean rodents: *Bathyergus suillus* and *Heterocephalus glaber* (Bathyergidae)

Montoya-Sanhueza, G., Chinsamy, A.

Department of Biological Sciences, University of Cape Town, Cape Town, Private Bag X3, Rhodes Gift, 7701 South Africa

African molerats are a large group of strictly subterranean rodents endemic to the sub-Saharan region, and occurring in a wide range of habitats. An important ecofunctional difference among bathyergids is the way they dig underground; *Cryptomys*, *Fukomys*, *Georychus*, *Heliophobius* and *Heterocephalus* are chisel-tooth diggers, so they use mostly their incisors during digging, while *Bathyergus* is a scratch digger, being the only one showing long digging claws in fore- and hindlimbs. Majority of the studies on the fossorial adaptations of mammals have focused on macrostructural features of the musculoskeletal system, whilst little attention has been given to their bone microstructure. In the current study, we compared the adult femoral and humeral (midshaft) histology of the smallest bathyergids (weighing ~35 g), *Heterocephalus glaber*, with that of the largest, *Bathyergus suillus* (>2 kg). Both species have thick cortical walls, and have similar humeral microanatomy, although in *H. glaber* is more ellipsoidal. The femoral microanatomy differs, being more elliptical in *B. suillus*, likely due to differences in the extension of third trochanter along the midshaft. The histodiversity is higher in *B. suillus*, showing a stratified cortex with distinct layers of endosteal and periosteal bone, e.g. lamellar, parallel-fibred, woven, compact course cancellous and fibrolamellar bone. The cortex of *H. glaber* is mostly composed of parallel-fibred bone. Vascularization is more developed in *B. suillus*. These histological differences are likely due to size, shape and mechanical function. Further quantitative research of the bathyergid skeleton is needed to understand interrelationships between bone microstructure and bone shape.

Hindlimb histology of the specialized climber, *Procavia capensis* (Hyracoidea; Paenungulata)

Montoya-Sanhueza, G.[1], Chinsamy, A.[1], La Grange, L.[2], Stynder, D.[2]

[1]*Department of Biological Sciences, University of Cape Town, Private Bag X3, Rhodes Gift, 7701 South Africa*

[2]*Department of Archaeology, University of Cape Town, Private Bag X3, Rondebosch, 7701 South Africa*

Bone development in mammals is mostly known for domestic cursorial animals, but, there is a gap in our understanding of how other lifestyles affect bone growth. Hyracoids are small ungulates adapted for rock and tree climbing; they have feet with elastic and rubbery pads on the soles, which constitute a particular locomotor adaptation in mammals. Their crouched and high-fulcrum posture typical of small mammals involves specific mechanical loads (e.g. stress and momentum) in the musculoskeletal system. Thus, microstructural differences are expected when compared to similar-sized organisms with extended limbs. In this preliminary study we explore the mid-diaphyseal hindlimb histology of three individuals of *Procavia capensis* (Procaviidae) representing a relative ontogenetic series. The femur and tibia show a modelling pattern established by a fibrolamellar scaffold followed by symmetrical periosteal apposition of parallel-fibred and lamellar bone tissues. As in other terrestrial mammals, the medullary cavity expands as a result of considerable endosteal resorption as the animal grows. The femoral microanatomy changes slightly from an elliptical cross-sectional shape to a more circular shape, while the tibia changes more

drastically from circular to highly ellipsoidal. All bones analysed were well vascularized and remodelling was present from early stages of ontogeny. Dense Haversian tissue was observed in the tibia of the adult. Such changes in bone geometry and histology may be correlated with shifts in locomotor patterns during ontogeny. This pilot study represents the first histological assessment of the long bone growth in Hyracoidea and highlights areas for future research.

Stratigraphy, palaeontology and continental ichnology of the late Cenozoic Lake Beds Successions, Rukwa Rift Basin, Tanzania

Mtelela, C.,[1] Roberts, E.M.,[2] Hilbert-Wolf, H.,[2] Stevens, N.,[3] O'Connor, P.[3]

[1]*University of Dar es Salaam, Tanzania*

[2]*James Cook University, Australia*

[3]*Ohio University, U.S.A.*

We present the first detailed sedimentological investigation and palaeontological survey of the late Cenozoic Lake Beds succession of the Rukwa Rift Basin, Tanzania. Work over four field seasons revealed a complex unconformity bounded, stratigraphic succession with isolated fossiliferous exposures of highly variable ages, between late Miocene and late Quaternary. Our work provides the basis for subdividing the poorly understood Lake Beds into a three-fold stratigraphy, which includes: (1) a basal, richly fossiliferous upper Miocene–Pliocene lower unit; (2) a lithologically complex, and as yet poorly understood, lower to middle Pleistocene (?) middle unit; (2) and an extensive, well exposed upper unit. Biostratigraphy, geochronology and establishment of a formal stratigraphic nomenclature is currently underway in all three units. The lower Lake Beds have two distinct members: a poorly fossiliferous lacustrine lower member; and a richly fossiliferous, fluvial-floodplain dominated upper member. The middle Lake Beds are characterized by a series of isolated exposures, many fault bounded, throughout the southern end of the rift. As of yet, these deposits have only yielded plant macrofossils and trace fossils. The middle unit is characterized by localized lacustrine (including carbonate), volcaniclastic alluvial fan, and fluvial-floodplain facies. Overlying the middle Lake Beds, is a thick succession of late Pleistocene–Holocene volcanic-rich, locally fossiliferous alluvial to deep-water lacustrine strata. The upper Lake Beds record a spectacular continental ichnofauna, as well as abundant isolated fish remains, and isolated larger vertebrate macrofossils. Detailed analysis reveals six discrete depositional sequences that record climate-driven lake cyclicity (±70 m fluctuations) over the last 50 Ka.

Funding acknowledgement: We acknowledge Petroleum Development Corporation (TPDC) and Heritage Oil Rukwa Tanzania Ltd for funding this project. This research was also supported by the US National Science Foundation (EAR_1349825, BCS_1127164), the National Geographic Society (CRE), and the postgraduate research fund from James Cook University.

Producing a glossary to explain palaeontological terms in indigenous South African languages for palaeoscientists, outreach officers, teachers and learners

Mudau, M.A.M., Mckay, I.J.

Director Education and Outreach, Evolutionary Studies Institute, University of the Witwatersrand

Traditionally, palaeosciences outreach has been conducted in English and Afrikaans which has resulted in calls to translate outreach materials into more official languages. Here we describe a new project creating a basic glossary of palaeontological terms used in school education in some of South Africa's indigenous African official languages. The terms and definitions chosen for translation have been taken from evolution and palaeontology sections of popular South African Natural Science and Life Science textbooks and are therefore currently very much in use in our education system, and are also more likely to be at the appropriate level for South African learners. In the beginning we are focussing on the languages of IsiZulu, Tshivenda, and Sesotho and are hoping to find partners who will translate IsiXhosa for us. We hope that this glossary will be used as a resource by school teachers, palaeoscientists and outreach officers. We foresee that it will be most useful for nursery school teachers and primary school teachers whose learners may not understand English at all, as well as for high school English second language learners who struggle to understand biological terms but will still need to write their exams in English. A major problem we have encountered is that most palaeontological terms such as 'fossils' simply do not exist in indigenous African languages, and the words required in definitions like 'Marambo a khale are tomboni' in Tshivenda are ambiguous. Ultimately we also would like to produce a simple pamphlet on South African palaeontology, in our four chosen languages.

Stratigraphic framework of the Kirkwood Formation in the southern Cape region, South Africa: invertebrate-based biostratigraphy and zircon geochronology

Muir, R., Bordy, E.M.

Department of Geological Sciences, University of Cape Town, 7701 South Africa

The Jurassic–Cretaceous Kirkwood Formation, which forms part of the fluvio-lacustrine sedimentary fill of the rift basins along the southern continental margin of Africa, consists of mudstone, sandstone, sporadic conglomerate and tuffaceous layers. It also contains a diverse non-marine biota comprising fossil flora, charophytes, invertebrates, reptiles and mammalians. Despite the rich fossil heritage preserved, none of the terrestrial fossils are sufficiently age diagnostic to accurately date the Kirkwood Formation. A Valanginian age is commonly accepted; however, this is entirely based on the foraminifera found in the overlying Sundays River Formation and poorly understood Colchester Member of the Kirkwood Formation. This age may not be accurate because the contact between the Kirkwood and Sundays River formations has not been fully resolved. Additionally, the known age of the thin Colchester Member cannot be extrapolated through the entire Formation. In order to improve the chronostratigraphic framework of the Kirkwood Formation, this study aims to both refine the palaeoenvironmental conditions during its deposition and establish the age of the tuffaceous layers using U-Pb LA-ICPMS and CA-TIMS dating methods on detrital zircons. Preliminary U-Pb LA-ICPMS zircon ages from primary tuffaceous layers range from 172 ± 3 Ma to 130 ± 3 Ma confirming the suspected diachronous nature of the Kirkwood Formation. The integration of these, and additional dates, with biostratigraphic work will provide information about both the geological evolution of the rift system and biological evolution of life during the Jurassic–Cretaceous transition.

Funding acknowledgement: The financial support of the DST-NRF Centre of Excellence in Palaeosciences, SACCS and NRF African Origins Platform (grant #91601) to E.M.B. towards this research is hereby acknowledged.

Palaeoenvironmental fluctuations during a terminal Oligocene–early Miocene transgression at the southwestern tip of Africa

Neumann, F.H.,[1] Cawthra, H.C.,[2] Carr, A.S.,[3] Scott, L.,[4] Durugbo, E.,[5] Humphries, M.S.,[6] Cowling, R.,[7] Bamford, M.K.,[8] Musekiwa, C.,[2] MacHutchon, M.[2]

[1]*Forschungsstelle für Paläobotanik, Münster, Germany*

[2]*Marine Geoscience Unit, Council for Geoscience, Bellvillle, South Africa*

[3]*Department of Geography, University of Leicester, Leicester, U.K.*

[4]*Department of Plant Sciences, University of the Free State, Bloemfontein, South Africa*

[5]*Department of Biological Sciences, Redeemer's University, Ede, Osun state, Nigeria*

[6]*Molecular Sciences Institute, School of Chemistry, University of the Witwatersrand, Johannesburg, South Africa*

[7]*Centre for Coastal Palaeosciences, Nelson Mandela Metropolitan University, Port Elizabeth, South Africa*

[8]*Evolutionary Studies Institute, University of the Witwatersrand, Johannesburg, South Africa*

A multi-proxy study from an offshore core in Saldanha Bay spans the Palaeogene–Neogene transition. It consists of fluvio-paludal sediments that provide perspectives on fluvial deposition, ecosystems, and sea-level history. Offshore seismic data illuminate the control of bedrock topography on Cenozoic stratigraphy and provide evidence of relative sea level as low as –100 m during the early Oligocene. A 3D landscape reconstruction reveals hills, plains and ananastomosing river. A Chattian to early Miocene age for these diments is suggested by dinoflagellate taxa. Pollen indicates subtropical vegetation including mangroves, lianas and vines, evergreen arboreal elements, palms and ferns. The forested environment implies high precipitation, probably reduced seasonal drought and a stronger contribution of summer rainfall. From the topography, sedimentology and palynology we hypothesize Podocarpaceae-dominated forests, proto fynbos, swamp/riparian forests with palms and other angiosperms along the water courses. Subtropical woodland-thicket with Combretaceae and *Brachystegia* developed possibly on the coastal plains. Mangroves with Rhizophoraceae and associated ferns were restricted to estuaries. Typical Gondwanan elements, which became extinct during the Neogene in South Africa, e.g. Araucariaceae, prevailed. Fungal elements were recovered with charred particles suggesting fires. The marine microfossils (dinoflagellate cysts, microforaminiferal linings), pollen and spores, together with various organic and inorganic geochemical proxy data suggest a gradual glacio-eustatic sea-level rise which

began during a late Oligocene warming phase, keeping pace with wetland sedimentation. The sequence sheds light on southern hemisphere biogeography and regional climate during the Palaeogene–Neogene transition, enabling comparison and correlation with marine and terrestrial records on other Gondwanan continents.

The use of GIS and multi-scalar analysis tools to reconstruct the geomorphology of the fossil hominin sites and, to facilitate the understanding and interpretation of fossil hominin taphonomy in Kromdraai and the Cradle of Humankind

Ngoloyi, N.[1], Braga, J.[1], Fourvel, J.B.[2,3], Lans, B.[4,5]

[1]*Université Toulouse III Paul Sabatier Anthropologie Moléculaire et Imagerie de Synthèse, 37 Allées Jules Guesde, 31073 Toulouse cedex 3, France*

[2]*Université Toulouse Jean Jaurès, Travaux et Recherches Archéologiques sur les Cultures, les Espaces et les Sociétés, 5 Allées Antonio Machado, 31058 Toulouse Cedex 9, France*

[3]*Department of Communication Sciences, Central University of Technology, 20 President Brand Street, Westdene, Bloemfontein, South Africa*

[4]*Université Bordeaux Montaigne, Laboratoire ADESS CNRS UMR 518556 Rue de la Croix de Monjous, 33170 Gradignan, France*

[5]*Department of Environmental, Water & Earth Science, Tshwane University of Technology (TUT), Staatsartillerie Road, Pretoria West, South Africa*

The application of Geographic Information System (GIS) tools in archaeology has become an increasingly valuable approach for the visualization and interpretation of fossil hominin sites, as well as for the study of their geomorphological contexts at a more regional scale. This research explores the use of multi-dimensional efforts to create a 3D representation and, to generate a complete digital record of the Kromdraai B (KB) site and the 'Cradle of Humankind'. The main objective of the study is to demonstrate the series of geological changes at different scales, the geometry of the fossiliferous deposits at KB and the taphonomy of fossilized Plio-Pleistocene hominins, ultimately providing an archive documenting the palaeoenvironments of Kromdraai. With the application of modern, innovative methods such as multi-image photogrammetry from land and drone imagery, remote sensing, terrestrial and close range laser scanning and micro-computed tomography (microCT); a multi-scalar analysis of various aspects of the study site is provided. An accessible web interface comprising a database incorporating the findings of the study, the progression of the excavation and relevant metadata will be created for the benefit of both academics and the general public. This presentation will discuss the usefulness of adopting a four-tiered approach (3D modelling, image processing and the use of GIS and remote sensing) towards the understanding of fossil taphonomy in different study sites and, the importance of disseminating information through a virtual environment. Preliminary results showing the integration of 3D point cloud data and photogrammetry documenting the changes in the Kromdraai excavation operation from 2014 to 2016 will also be presented.

Funding acknowledgement: Erasmus Mundus Programme (European Commission), Evolutionary Studies Institute (University of the Witwatersrand, South Africa), Centre National de la Recherché Scientifique (CNRS-France), French Ministry of Foreign Affairs.

Comparison of tooth replacement patterns of the Permo-Triassic epicynodonts *Cynosaurus* and *Galesaurus*

Norton, L.A.,[1] Abdala, F.,[1] Rubidge, B.S.,[1] Botha-Brink, J.[2]

[1]*Evolutionary Studies Institute, University of the Witwatersrand, Johannesburg, South Africa*

[2]*Department of Karoo Palaeontology, National Museum, and Department of Zoology and Entomology, University of the Free State, Bloemfontein, South Africa*

Cynosaurus suppostus and *Galesaurus planiceps* were small non-mammaliaform cynodonts from the late Permian and Early Triassic of South Africa. Eight specimens of *Galesaurus* and five of *Cynosaurus* were scanned using micro-computed tomography. This was undertaken in order to establish the size, number and positions of unerupted teeth relative to functional teeth, in order to determine the patterns and rates of tooth replacement in the two taxa. Results showed that in both genera the incisor and postcanine teeth were replaced in an alternating pattern. Replacement maxillary canines erupt anterior to the functional canine, whereas mandibular replacement canines erupt posterior to the functional one. For *Galesaurus*, replacement of the maxillary canines took place at an earlier stage than replacement of the mandibular canines. In both genera, the largest specimens showed no signs of replacement activity associated with

the canines. This suggests a finite number of replacement generations associated with the canine teeth. Furthermore, the canine teeth of the largest specimens of *Galesaurus* remain open-rooted. Both genera showed an increase in the number of teeth in the postcanine series through ontogeny, with the possible retention of the first postcanine tooth. For *Cynosaurus* the maxillary series showed an increase from 7 to 10 postcanines and the mandibular from 9 to 10; whereas in *Galesaurus* the maxillary and mandibular postcanine series showed an increase from 9 to 12 and 11 to 15, respectively. Despite the difference in morphology and number of postcanine teeth, the manner in which the series was replaced is very similar between *Cynosaurus* and *Galesaurus*.

Funding acknowledgement: This research was made possible by an NRF PDP bursary awarded to L.A.N. Thanks to K. Carlson, T. Jashashvili, and K. Jakata (Wits MicroCT facility) for performing the scans of the fossil material.

New ichnotaxa from Cooper's D, Cradle of Humankind, South Africa

Parkinson, A.H.

Evolutionary Studies Institute, School of Geosciences, University of the Witwatersrand, Private Bag X3, WITS 2050, South Africa

This presentation will detail the first comprehensive description and analysis of trace fossils produced by insects on bone from a faunal assemblage in the Cradle of Humankind, South Africa. A total of 9500 bone fragments from Cooper's D were visually inspected for evidence of insect trace fossils. Fifty-three specimens with insect traces were identified and analysed using optical microscopy at low magnifications. Analysis revealed frass and coprolites preserved on some bones, and nine morphologically distinctive traces. Circular boreholes associated with a crescent-shaped excavation are attributed to a new ichnotaxa. Ellipsoidal surface borings (pupation chambers) are assigned to a new ichnospecies of Cubiculum. Evidence suggests that traces were produced by more than one agent at different stages during the taphonomic process. Modification either took place whilst bones were sub-aerially exposed, at the point of final deposition, or post-burial of the remains. These two new ichnotaxa represent the first ichnotaxa described in bone from the Cenozoic of Africa.

Funding acknowledgement: DST/NRF Centre of excellence in Palaeosciences, Evolutionary Studies Institute, University of the Witwatersrand, South Africa.

The rise and fall of the Malvinokaffric Realm in South Africa: insights from palaeoenvironmental, biostratigraphic and sequence stratigraphic data

Penn-Clarke, C.R.,[1] Rubidge, B.S.,[2] Jinnah, Z.A.[1]

[1]*School of Geosciences, University of the Witwatersrand, Johannesburg*

[2]*Evolutionary Studies Institute, University of the Witwatersrand, Johannesburg*

The Malvinokaffric Realm is a Silurian to Middle Devonian (Eifelian) high latitude polar-to-subpolar palaeobiogeographic realm of southwestern Gondwana characterized by a low-diversity fauna comprising several genera and species of endemic brachiopods and molluscs, in addition to certain phacopid trilobites, of which calmonids are unique. Conularids, tentaculitids and hyolthids are abundant, whilst bryozoans and corals are rare. Rhynchonellid brachiopods, stromatoporoids, conodonts, ammonoids and graptolites are absent making correlation of Malvinokaffric Realm successions tenuous. Closure of the Realm is recognized by admixture with warm-water Old World Realm fauna. The appearance of trans-Atlantic brachiopods, *Tropidoleptus* sp. and *Rhipidothyris* sp., typically mark this event. Their appearance in South America is coincident with a global warming trend and transgression possibly related to the global Kačák Event transgression and extinction at the end of the Eifelian. In South Africa, the Malvinokaffric Realm is restricted to the Rietvlei-Baviaanskloof formations (Table Mountain Group) and the Bokkeveld Group (Gydo to Waboomberg formations). *Riphidothyris* sp. and *Tropidoleptus* sp. are present in the Karoopoort and Wagendrift formations (Witteberg Group), implying a Givetian age for the Bidouw and Weltevrede Subgroup. Palaeoenvironmental, biostratigraphic and sequence stratigraphic research on the Bokkeveld Group suggests that the Malvinokaffric Realm is contained within two second-order transgressions with maximum flooding surfaces in the Gydo and Waboomberg formations. Closure of the Realm and the Eifelian–Givetian boundary coincides with a regressive surface of marine erosion or paraconformity near the Waboomberg–Wupperthal contact, suggesting a protracted regressive phase prior to transgression of the Klipbokkop Formation and admixture with Old World Realm Fauna.

Funding acknowledgement: DST-NRF CoE in Palaeosciences, Palaeontological Scientific Trust.

The palaeoenvironment (*c.* 1.6 Ma) of FxJj20 complex, Koobi Fora, Kenya, using phytoliths

Phillips, C.A.,[1] Harris, J.W.K.,[2] Bamford, M.K.[3]

[1]*Evolutionary Studies Institute, University of the Witwatersrand*

[2]*Department of Anthropology, Rutgers University*

[3]*Evolutionary Studies Institute, University of the Witwatersrand*

Phytoliths are opal silica shapes of plant cells formed during a plant's lifetime. They can survive millions of years of deposition and be taxonomically distinctive to plant type. Their presence can be used to determine how vegetation changes over time and as such are a valuable tool in the reconstruction of palaeoenvironments. We analysed samples collected from palaeosols within FxJj20 East site at Koobi Fora in northwest Kenya (dated 1.6 Ma). Globular echinate phytoliths, associated with palm trees, were the most dominant morphotype encountered which corroborate findings of fossilized palm tree trunks in this region. Other phytolith morphotypes detected are found in parts of tropical dicotyledonous trees and shrubs, and grasses. Although grass phytoliths found occur in both C3 and C4 grasses, as a combination (rondels, saddles and trapeziforms), they are more associated with C4 grasses in drier, lowland areas. Aridification occurred in this region 2.5–1.8 Ma which resulted in an expansion of C4 grasses. How dominant each plant type was in this palaeoenvironment 1.6 Ma, remains unknown, as this is not reflected by relative abundances of phytolith morphotypes detected in palaeosols. This preliminary work is the first systematic examination of phytoliths at this site and indicates that hominins would have encountered and utilized both open areas and those with more shrubs/trees forming a mosaic across the landscape.

Funding acknowledgement: Many thanks to The Leverhulme Trust, Claude Leon Foundation and DST/NRF Centre of Excellence in Palaeosciences who provided funding for this work to take place.

Frequency and duration of U-Pb dated flowstone growth intervals in South African early hominin caves reflect Early Pleistocene climate variability

Pickering, R.

Department of Geological Sciences, University of Cape Town

The Cradle of Humankind (CoH) in South Africa is home to a rich collection of early human (hominin) fossils, preserved in dolomite caves. Flowstones, horizontally bedded layers of calcium carbonate, are ubiquitous features at all sites and serve the dual utility of providing ages for the fossilferous sediments sandwiched between them (via U-Pb dating) and as indicators of past climate regimes by their presence alone, being associated with increased effective precipitation. We present a dataset of 28 U-Pb dated flowstones from 8 caves across the CoH, 14 new ages and 14 published ages, a number of which have been re-calculated, yielding greater precision. To solve the problem of necessarily large uncertainties on individual ages, we use a kernel density estimate to sum together the U-Pb age data into a single record of flowstone growth intervals (FGIs). This record spans from 3.2–1.3 Ma, with four major FGIs identified and interpreted as wet phases. The time periods interceding the FGIs are interpreted as drier phases. It is during these phases that the fossiliferous sediments accumulate in the caves, suggesting that these deposits in fact have a 'dry phase' bias and that the South African hominin and faunal record is only sampling these drier intervals.

Funding acknowledgement: The Australian Research Council DECRA scheme, grant number: DE12010-12504.

Rigbya revisited: a large new collection from KwaZulu-Natal confirms glossopterid affinities and associated *Glossopteris* leaf morphotype

Prevec, R.[1,2]

[1]*Department of Earth Sciences, Albany Museum, and Rhodes University, Somerset St., Grahamstown, 6139*

[2]*Evolutionary Studies Institute, University of the Witwatersrand, Private Bag 3, WITS, 2050*

Rigbya arberioides, a typical seed-bearing fructification of the Upper Permian floras of South Africa, is a widespread taxon that has been found in *Glossopteris*-dominated floras of Australia and Antarctica. The distinctive fan-shaped, dichotomizing fertile branch system of *Rigbya* is in contrast to the more typical, capitate fructifications of the Dictyopteridiaceae that have been found in direct, organic attachment to midrib of *Glossopteris* leaves. Additionally, the long, slender pedicels and axillary attachment of *Rigbya*

fructifications have apparently precluded the preservation of fructifications in organic connection to stems and leaves. For these reasons, the botanical affiliations of *Rigbya* have been a source of debate. However, careful examination of well-preserved material housed in South African collections demonstrates a clear morphological link between fructifications of the Arberiaceae, Dictyopteridiaceae, Lidgettoniaceae and Rigbyaceae, suggesting that these organs are all glossopterid, and represent modified branching axes, rather than the traditionally-held view that they are leaf homologues. A fossil locality in KwaZulu-Natal has produced an exceptionally well-preserved, large and informative Upper Permian fossil plant collection, containing over 100 specimens of *Rigbya*, along with a comprehensive representation of the associated glossopterid foliage. This provides further evidence of the glossopterid affinities of this taxon, and confirms a leaf association first proposed by Anderson and Anderson (1985).

Funding acknowledgement: The support of the following funding bodies is gratefully acknowledged: DST/NRF Centre of Excellence in Palaeosciences (CoE in Palaeosciences), the NRF African Origins Platform, the Palaeontological Scientific Trust (PAST), Rhodes University and the University of the Witwatersrand.

Lithology and Palaeontology of the Ecca–Beaufort contact in the northern Karoo Basin

Rammutla, R.T., Rubidge, B.S., Day, M.

Evolutionary Studies Institute and School for Geosciences, University of the Witwatersrand, Johannesburg.

The position and lithological nature of the contact between the Ecca and Beaufort groups of the Karoo Basin has been a subject of dispute for some time. More recently there is consensus that the lithological position of the contact is signified by a palaeoenvironmental change from subaqueous delta plain conditions in the case of the Ecca to a continental fluvial environment for the Beaufort. The contact is currently mapped at the top of the Waterford Formation of the Ecca Group in the southern, western, central and extreme northeastern parts of the basin while the lithological nature of the contact in the northern part of the basin is still uncertain, largely because of the lack of good outcrops. This study documents the lithology and palaeontological occurrences of the Ecca–Beaufort contact in the northern Karoo Basin between the towns of Frankfort and Newcastle. Localities for lithological study were selected based on a Google Earth analysis of outcrops that fall within the area. The main goal of the project is to establish the absence or presence of lithofacies which characterize the Waterford Formation in the study area, as these facies are known to be present in the central Free State and also in the Estcourt area of KwaZulu-Natal, as well as to determine palaeontological occurrences. We report on the lithofacies present in the study area and assess the significance of our findings for Karoo Basin development modelling.

Funding acknowledgement: We acknowledge financial assistance for this project from DST/NRF Centre of Excellence in Palaeosciences, the NRF African Origins Platform, and the Palaeontological Scientific Trust (PAST) and its Scatterlings of Africa Programmes.

New 'Guidelines for Palaeontological Permitting Policy' by SAHRA: what are the improvements?

Redelstorff, R., Hine, P.

South African Heritage Resources Agency, Cape Town, South Africa

The South African Heritage Resources Agency (SAHRA) is a statutory body that was created to implement the National Heritage Resources Act (NHRA) No. 25 of 1999 and it is responsible for the coordination of the identification and management of the National Estate. The implementation of the provisions of the NHRA relating to permitting has been biased towards archaeological standards and techniques, in particular with regard to excavation and collection practices. This has resulted in it being applied only with difficulty to palaeontological research and excavation/collection methods. The previous 'Policy and Guidelines for the Management of Archaeological and Palaeontological Heritage Resources, and Meteorites', implemented in September 2006, is in the process of being reviewed and divided into three different policies to address issues and methods specific to each field. The new 'Guidelines for Palaeontological Permitting Policy' addresses permits with regard to research and development-led applications. Research permits are needed for excavation and collection, destructive analysis/sampling as well as temporary and permanent export for analytical, exhibition or educational purposes. SAHRA, as the national body, coordinates permits for all provinces except those three that are declared functional, i.e. Amafa (KwaZulu-Natal), ECPHRA (Eastern Cape) and HWC (Western Cape), as well as export permits for material from the entire country (including EC, KZN and WC provinces). In an effort to work more closely with

the functional PHRAs and to address the needs of palaeontological research, the main new improvement is that a Formation/Group Collection Permit was approved. This and other improvements within the new Policy Guidelines will be presented.

Exploring an ophiuroid–stylophoran assemblage from the Devonian Voorstehoek Formation, Bokkeveld Group, Western Cape: taphonomy, palaeoecology and taxonomy

Reid, M., Bordy, E.M., Taylor W.L.

Department of Geological Sciences, University of Cape Town, 7701 South Africa

The Emsian Voorstehoek Formation (Ceres Subgroup, Bokkeveld Group, Cape Supergroup) is richly fossiliferous and contains typical cool to cold-water benthic biota (e.g. brachiopods, trilobites, crinoids) from the Malvinokaffric Realm of SW Gondwana. Palaeontological and sedimentological features of the Voorstehoek Formation suggest that deposition took place in a shallow marine environment within a storm-influenced, proximal offshore transition zone in the Early Devonian. We excavated a 5 cm thick layer at a study site in the Western Cape, and through the use of micro-CT scans, found complete ophiuroids associated with rare stylophorans. Taphonomic analyses of this ophiuroid–stylophoran assemblage suggest a marine obrution deposit, which formed due to the rapid burial that smothered both autochthonous and allochthonous taxa of the benthic community during high-energy storms. This uniquely preserved, mixed assemblage provides a taphonomic window into the marine ecosystems of the Early Devonian, including the structure of a benthic community within the Malvinokaffric Realm of SW Gondwana. The current project aims to extend the micro-CT scanning for a much large portion of the fossil-rich obrution bed to generate a computerized 3D model that would allow a more detailed taphonomic analysis of the bed. This includes the determination of the degree of fossil articulation, fossil orientation and faunal counts without damaging the delicate echinoderm fossils and primary sedimentary features. Furthermore, the ability to digitally dissect the fossil-rich bed can reveal organisms that would have otherwise been missed or destroyed using traditional, mechanical fossil preparation techniques.

Funding acknowledgement: The financial support of the DST-NRF Centre of Excellence in Palaeosciences towards this research is hereby acknowledged.

Oxygen isotopes suggest elevated thermometabolism within multiple Permo-Triassic therapsid clades

Rey, K.,[1] Amiot, R.,[2] Fourel, F.,[2] Abdala, F.,[3] Fluteau, F.,[4] Jalil N-E.,[3] Liu, J.,[6] Rubidge, B.S.,[3] Smith, R.M.H.,[3] Steyer. J-S.,[5] Viglietti, P.A.,[3] Wang, X.,[6] Lécuyer, C.[1]

[1]Ens de Lyon, CNRS, UMR 5276 LGL-TPE, F-69622, Villeurbanne, France, 2, Rue Raphaël Dubois, 69622 Villeurbanne Cedex, France

[2]Univ Lyon, Université Lyon I, Ens de Lyon, CNRS, UMR 5276 LGL-TPE, F-69622, Villeurbanne, France, 2, Rue Raphaël Dubois, 69622 Villeurbanne Cedex, France

[3]Evolutionary Studies Institute and School of Geosciences, University of the Witwatersrand, WITS 2050, Johannesburg, South Africa

[4]Institut de Physique du Globe de Paris, I rue Jussieu, F-75005 Paris, France

[5]Centre de Recherches en Paléobiodiversité et Paléoenvironnements, UMR 7207 CNRS-MNHN-UPMC, Laboratoire de Paléontologie, CP 38, 8 Rue Buffon, 75005 Paris, France

[6]Key Laboratory of Vertebrate Evolution and Human Origins of Chinese Academy of Sciences, Institute of Vertebrate Paleontology and Paleoanthropology, Chinese Academy of Sciences, Beijing 100044, China

Nowadays, birds and mammals are the only true endothermic homeothermic animals. They produce and regulate their internal temperature quite independently from ambient environmental temperatures. Whereas birds likely inherited their thermophysiology from their dinosaur ancestors, the oldest definitive evidence of mammal endothermy dates back to the Middle Jurassic. However, anatomical clues suggest an older origin, during the Triassic or the Permian. We analysed apatite stable oxygen isotope compositions of a representative sample of Permo-Triassic therapsids to investigate the origin and timing of mammal thermoregulation. All main clades of Eutherapsida were sampled (Dinocephalia, Anomodontia, Gorgonopsia, Therocephalia and Cynodontia). By comparing the $\delta^{18}O_p$ values of therapsid bone and tooth apatites with those of coexisting tetrapods of various ecologies and physiologies (terrestrial and semi-aquatic parareptiles, semi-aquatic stereospondyl and terrestrial archosauriforms), thermoregulatory strategies estimated from body temperature differences are proposed. Our results indicate that

amongst the Dicynodontia, Induan Lystrosauridae and Anisian and Camian Kannemeyeriiformes may have acquired elevated thermometabolism. A similar result has been obtained in the Cynodontia clade within Anisian Cynognathia and Rhaetian Mammaliaformes. Our results indicate that mammalian thermoregulation possibly originated from the Epicynodontia group during the middle late Permian. It appears that the timing of acquisition of elevated thermometabolism in amniotes coincides with major global climatic and environmental fluctuations that may have acted as a selective pressure during the origin of mammal endothermy.

Funding acknowledgement: This work was supported by a French project [NSU of the Centre National de la Recherche Scientifique, the Palaeontological Scientific Trust (PAST) and its Scatterlings of Africa Programmes, National Research Foundation (NRF) and DST/NRF Centre of Excellence in Palaeosciences. A.R. and W.X. were supported by the National Basic Research Program of China (2012CB821900), and L.J. by the National Basic Research Program of China (2012CB821902).

Seasonal exploitation of coastal resources in the Middle and Later Stone Age of southern Africa from comparative Cape fur seal (*Arctocephalus pusillus*) assemblages

Ritzman, T., Schoville, B.

Department of Archaeology, University of Cape Town, Private Bag X1, Rondebosch, 7701 South Africa

Modern human behaviour – marked by increases in cognitive ability, including symbol use, complex technologies, and advanced subsistence strategies – appear as early as 160 ka, but become more widespread after 100 ka. Arguments about seasonal exploitation of resources have been central to the debate about how, when, and in what context this behaviour emerged. For example, comparisons of Cape fur seal (*Arctocephalus pusillus*) remains from coastal sites in South Africa have been used to suggest that Later Stone Age (LSA) foragers, unlike those living in the preceding Middle Stone Age (MSA) period, strategically-targeted coastal sites during seasons when seals were more abundant. Although methods for establishing seasonality from archaeological seal mandibles have been evaluated by previous researchers, specific predictions for differences in MSA and LSA seal assemblages have not been rigorously tested. To investigate these unresolved issues, this study addresses two questions: (1) Are comparative samples of seal remains adequate to address the question of seasonality? and (2) Do comparisons of archaeological and comparative samples demonstrate the predicted differences between LSA and MSA suggested by prior research? These questions are evaluated using resampling techniques and mortality assemblage simulation modelling. The results indicate that the comparative samples may be useful for assessing seasonality, but do not support the contention that differences existed between the seasonal strategies of LSA and MSA peoples. The findings are discussed in terms of the appearance of behavioural modernity in southern Africa, particularly in relation to the evolution of seasonal variation in foraging.

Isotaphonomy in concept and practice: an exploration of vertebrate microfossil bonebeds in the Upper Cretaceous (Campanian) Judith River Formation, north-central Montana

Rogers, R.[1], Curry Rogers, K.[1,2], Carrano, M.[3]

[1]*Geology Department, Macalester College, Saint Paul, Minnesota 55105, U.S.A.*

[2]*Biology Department, Macalester College, Saint Paul, Minnesota 55105, U.S.A.*

[3]*Department of Paleobiology, Smithsonian Institution, Washington, DC 20013, U.S.A.*

Vertebrate microfossil bonebeds (VMBs) are commonly studied to recover otherwise rarely found small-bodied taxa, and to document relative abundance and species richness in ancient vertebrate communities. Taphonomic analyses of size and shape data from VMBs have generally found them to be non-isotaphonomic, and outcomes of 'strict' statistical tests of isotaphonomy suggest that potential for palaeoecological reconstruction in a broad comparative sense is limited. Given the general lack of clarity with regard to the definition of 'strict' isotaphonomic comparability, and the likelihood of significant variability within taphonomic systems, it is not surprising that sensitive statistical tests highlight variations among VMBs. Six VMB localities representing two distinct palaeoenvironments of the Upper Cretaceous Judith River Formation were rigorously sampled and compared to evaluate potential biases. The significant distinctions in size and shape reported in most previous comparative studies of VMBs are not developed in the Judith River VMB data set. Few defining distinctions are evident in comparisons of bioclast size and shape in surface collections, and site-to-site similarities are compelling among sieved subsamples. With one diagenetic outlier culled from the comparative sample, seven of ten potential comparisons yield indistinguishable or marginal results for size, and all are statistically indistinguishable from a shape frequency

perspective ($P \leq 0.01$). The case for isotaphonomy among Judith River VMBs is strong, whether based on graphical comparisons or evaluated in the 'strict' statistical sense. This bodes well for studies of palaeoecology, particularly in relation to investigations of faunal membership and community structure in Late Cretaceous wetland ecosystems.

Funding acknowledgement: Funding provided by National Science Foundation (EAR-1052673), Bureau of Land Management, and Macalester College.

The Middle Abrahamskraal Formation and the mystery of the *Eodicynodon–Tapinocephalus* Assemblage Zone transition

Rubidge, B.S., Day, M.O.

Evolutionary Studies Institute, University of the Witwatersrand, Johannesburg

The Abrahamskraal Formation, which reaches a maximum thickness of 2500 m, is the lowermost formation of the Beaufort Group and has been subdivided into several lithostratigraphic members, which have not yet received SACS recognition. The rich diversity of Middle Permian tetrapods has resulted in the official recognition of two vertebrate biozones, the *Eodicynodon* and *Tapinocephalus* Assemblage Zones (AZ). The *Eodicynodon* AZ comprises at least the lower 700 m of the formation and *Tapinocephalus* AZ makes up the rest, but the contact between the two is unsure . Fossil assemblages from the Abrahamskraal Formation primarily comprise a diverse number of dinocephalians, pareiasaurs and small dicynodonts. Recent research indicates that 80% of species have their Last Appearance Datum near the top of the Abrahamskraal Formation, which represents the transition from the *Tapinocephalus* AZ to the succeeding *Pristerognathus* AZ. This interval has been dated to the late Capitanian and represents the recovery from the Guadalupian extinction and the rise of the Lopingian fauna. While the stratigraphic distribution of the Upper Abrahamskraal Formation tetrapod taxa is now relatively well understood, the upper limit of the *Eodicynodon* Assemblage Zone is still not defined and biostratigraphic resolution of the middle portion of the Formation has not yet been achieved, largely because of the paucity of fossils. Recent fieldwork reveals that dinocephalians and pareiasaurs are more abundant than dicynodonts in the upper Leeuvlei and lower Koornplaats members, whereas in the lower Combrinkskraal Member (the lowermost member of the Abrahamskraal Formation) dicynodonts are more abundant and there are no pareiasaurs.

Funding acknowledgment: This work was supported by the University of the Witwatersrand, the DST/NRF Centre of Excellence in Palaeosciences, the NRF African Origins Platform, and the PPalaeontological Scientific Trust (PAST) and its Scatterlings of Africa Programmes.

The first vertebrate burrow from the upper Elliot Formation (Early Jurassic), main Karoo Basin

Sciscio, L.[1], Bordy, E.M.[1], McPhee, B.W.[2], Choiniere, J.N.[2]

[1]*Department of Geological Sciences, University of Cape Town, 7701 South Africa*

[2]*Evolutionary Studies Institute, University of the Witwatersrand, Private Bag 3, WITS 2050, Johannesburg, South Africa*

A semi-elliptical burrow cast was found on the farm Edelweiss 698 (Free State, South Africa) in the Lower Jurassic upper Elliot Formation (Stromberg Group, Karoo Supergroup) of the main Karoo Basin. The horizontal and vertical diameters of the burrow cast are ~18.4 and 6.5 cm, respectively. This semi-horizontal, straight to slightly sinuous tunnel is ~50 cm long with a ramp angle of <5°. The tunnel lacks branching, terminal chamber, or associated fossil bones. The massive burrow cast consists of medium sandstone that shows faint horizontal lamination in one of the burrow cast segments. The burrow cast is hosted in maroon, fine-grained pedogenically altered crevasse splay sandstone that is 10–20 cm thick and is under- and overlain by a massive, red, bioturbated floodplain mudstone unit with large scale (>20 cm) desiccation cracks, invertebrate trace fossils, calcareous rhizocretions, and spherical to elongated carbonate nodules. These and other associated sedimentary features provide evidence for a semi-arid fluvio-lacustrine palaeoenvironment during the burrowing activity. Based on comparisons to fossil and modern burrows, this burrow cast is tentatively interpreted as a vertebrate burrow, and appears to be the first report of vertebrate burrowing activity within the Elliot Formation in southern Africa. The ancient burrow architect has yet to be identified. However, given the size of the burrow and the occurrence of similar-sized fossil cynodont therapsids that inhabited the main Karoo Basin in the earliest Jurassic, the potential burrow maker may be tentatively linked to the Cynodontia (e.g. *Pachygenelus* – an advanced tritheledontid).

Funding acknowledgement: L.S. is funded by a DST/NRF Centre of Excellence in Palaeosciences postdoctoral bursary.

Histovariability revealed in anteosaurid (Therapsida: Dinocephalia) limb bones

Shelton, C., Chinsamy, A.

Department of Biological Sciences, University of Cape Town, Private Bag X3, Rhodes Gift, 7701 South Africa

Anteosauridae (Therapsida: Dinocephalia) is a family of carnivorous basal synapsids that flourished as the dominant terrestrial predators during the Guadalupian, (Middle Permian: *Tapinocephalus* Assemblage Zone) between 270 and 260 million years ago. The current study focuses on the microstructure of nine anteosaurid elements from three individuals (three ulnae, two radii, two femora, and two fibulae). Until now, the most recent study to be published on anteosaurid bone histology comes from 1973 in which Armand de Ricqlès analysed a large distal humerus, and found the cortex consisted of a moderately vascularized (circumferential) lamellar zonal bone. The results from the femur of our largest individual somewhat correspond to these earlier findings with the exception that fibrolamellar bone (FLB) occurs in localized regions. The material from the medium-sized individual consists of longitudinal FLB and has the best record of growth. The third individual consists of a proximal ulna, and histological analysis suggests that it is from a much older individual that has reached skeletal maturity. Furthermore, its histology is similar to both the large and medium-sized individual. Histovariability is evident in the nine sampled bones, and it appears the femur contains the best record of life history data.

Funding acknowledgement: Claude Leon Foundation.

Preliminary report on the palynology of the Permian Mid-Zambezi Basin of Zambia

Singh, M., Barbolini, N.

Evolutionary Studies Institute, University of the Witwatersrand, South Africa

Palynology is the study of pollen and spores and is most useful for stratigraphic correlations, coal and oil explorations, and the reconstruction of palaeoenvironments. This is achieved by studying the palynomorphs and identifying all the taxa of a particular study area. The aim of this particular study is to analyse pollen from the mid-Zambezi Basin in Lusitu, Zambia and correlate the identified taxa with other microfloral assemblages in the main Karoo Basin of south-central Africa. The prediction is that the palynology of Lusitu is likely to correlate with assemblages of the Karoo supergroup which are of Permian age based on macrofauna and flora as well as the microfloral studies that were undertaken by John Utting during the 1970s. The extraction techniques for palynomorphs are adapted from Phipps and Playford (1984). Slides were studied under an Olympus bx51 microscope and identification and counting of the palynomorphs is in progress. The flora will be compared with floras from the main Karoo Basin, Brazil and Argentina.

Funding acknowledgement: NRF AOP programme.

Taphonomy and sedimentary environments of mid-Triassic vertebrate accumulations, Lifua Member (Manda beds), Ruhuhu Basin, Tanzania

Smith, R.M.H.,[1,2] Sidor, C.A.,[3] Angielczyk, K.D.,[4] Nesbitt, S.,[5] Tabor, N.[6]

[1]*Evolutionary Studies Institute, University of the Witwatersrand, Johannesburg, South Africa*

[2]*Iziko South African Museum, Cape Town, South Africa*

[3]*Burke Museum and Department of Biology, University of Washington, Seattle, U.S.A.*

[4]*Field Museum of Natural History, Chicago, U.S.A.*

[5]*Virginia Polytechnic Institute and State University, Blacksburg, Virginia, U.S.A.*

[6]*Roy A. Huffington Department of Earth Sciences, Southern Methodist University, Dallas, U.S.A.*

Four recent expeditions to southwestern Tanzania investigated strata of the Ruhuhu Basin as part of a project aimed at understanding the biogeographic structure of vertebrate communities across southern Pangea during the Permian and Triassic. New data relating to the climate, sedimentary environments and burial history of tetrapod fossils in the mid-Triassic Lifua Member of the Manda beds are reported here. Two bone-bearing intervals have been defined – one in the lowermost Lifua containing rare multitaxa bonebed-type occurrences, and the second midway through the succession containing multiple skeletons of the same taxon. Both bone-bearing levels are in overbank redbed facies deposited on the flanks of low-sinuosity rivers that flowed from the Ruhuhu rift scarps into a series of subsiding basins under warm, seasonally-wet climate. The lower bonebed-type occurrence, only discovered in 2014, contains a large

dicynodont (*Dolichuranus*), large cynodonts (*Cynognathus*), and a number of small archosauromorhs. It is associated with massive pedogenically-mottled sandy siltstone overlying a 2 m-thick medium-grained, trough-cross bedded channel sandstone. At the top of this interval a chaotic melange of semi-articulated, disarticulated and reworked bones occurs at the base of a laminated sandstone interpreted as a distal crevasse splay. Similar floodplain-hosted multitaxa bonebeds have been reported from age-equivalent *Cynognathus* AZ (subzone B) strata in the South African Karoo Basin. Most vertebrate collections from Manda beds derive from mid-Lifua bone accumulations associated with floodplain scour troughs and deflation hollows that, at times, held standing water. Outcropping as isolated patches of calcified overbank mudrocks, they contain multiple articulated and semi-articulated archosauromorph (*Asilisaurus*) and herbivorous cynodont (*Scalenodon*) skeletons. We propose that increased mean annual rainfall raised the water tables resulting in vegetated semi-permanent water bodies in all the floodplain depressions and the preferred habitat for herbivorous dicynodont, cynodont and archosauromorph populations. The distinctive change in faunal assemblage and taphonomic style between lower and mid Lifua strata suggests increasingly wetter climatic conditions in this part of Pangea from early to mid-Triassic similar to the *Cynognathus* AZ of the main Karoo Basin of South Africa.

Funding acknowledgement: NSF DBI-0306158 (to K.D.A.), NSF EAR-1337569 (to C.A.S.), NSF EAR-1337291 (to K.D.A.).

The evolution of forelimb architecture in early sauropodomorphs

Staunton, C.K., Choiniere, J.N.

Evolutionary Studies Institute, University of the Witwatersrand, Johannesburg, South Africa

The evolutionary history of Sauropodomorpha is currently hypothesized to record a change from small-bodied, bipedal animals to large-bodied quadrupedal animals. Such major changes in locomotory strategy must necessitate shifts in morphology. We investigated the shape changes that occur in the humerus bone of various sauropodomorphs at key muscle insertion points, as a proxy for understanding the changing role of the forelimb in locomotion. To do this, we made 3D models of a variety of sauropodomorph humeri using photogrammetry and analysed the shift in positions of landmarks using geometric morphometric techniques. We find distinct changes in the morphology of the humerus from more basal to more derived sauropdomorpha. These changes likely result from a shift in gait from bipedal in the more basal animals to quadrupedal in the more derived animals as well as the limb architecture being constrained due to an increase in the size of these animals overtime.

Funding acknowledgement: Centre of Excellence – Palaeosciences, Palaeontological Scientific Trust (PAST), University of the Witwatersrand.

Increasing stratigraphic resolution within the *Australopithecus*-bearing Member 4 deposit, Sterkfontein

Stratford, D.

School of Geography, Archaeology and Environmental Studies, University of the Witwatersrand

Member 4 at Sterkfontein is currently the world's richest repository of *Australopithecus* fossils. The ancient cave infill accumulated into a large underground chamber within the Sterkfontein karst system between about 2.6 and 2.0 million years ago, and documents an important window of environmental and hominid evolution. De-roofed by lime-miners in the early 20th century, the fossil-rich sediments were exposed to the landscape surface and excavated by Alun Hughes under the direction of Philip Tobias. Despite recognition of four beds within the Member 4 deposit by Tim Partridge, the sediments were excavated as a single unit with no recording of stratigraphic features. As such, interpretations of site formation, taxonomic diversity, taphonomy and palaeoenvironments have been varied, and generally limited to low-resolution inter-member comparisons. This paper presents results from a renewed effort to increase stratigraphic resolution to the Member 4 deposit and focusses on the formation history of the infill. Previous studies have proposed Member 4 accumulated from a single entrance throughout its formation history, developing in a single massive talus. Careful mapping of clast fabric has revealed a more complex formation history. Despite extensive post-depositional modification through erosion, collapse and subsidence, the residual fabric patterns indicate distinct depositional phases with multiple openings accumulating sediments from different directions through the formation of Member 4. Situating the fossil assemblages within the new stratigraphic model will enable taphonomic, hominid and palaeoenvironmental data to be associated for the first time within a relative chronostratigraphic framework.

An analysis of gross dental wear and dental breakage patterns to determine the dietary ecology of large-bodied carnivores from Langebaanweg 'E' Quarry

Stynder, D.
University of Cape Town

Gross dental wear/breakage patterns may serve as proxies for establishing the dietary behaviours of carnivores. Analysed across a fossil carnivore guild, this type of data can inform on aspects of guild structure, particularly niche separation and inter-specific competition. I analysed the gross dental wear/breakage patterns of carnivore teeth from the South African early Pliocene locality of Langebaanweg (LBW). The early Pliocene is an important period in the evolutionary history of Africa's carnivores, as it was at this time that the continent's carnivore guild began to develop its modern structure. As one of the few African localities to preserve a relatively complete early Pliocene carnivore fossil record, LBW provides a window into this critical period. For this study, dental wear was characterized as (1) light; (2) light–moderate; (3) moderate; (4) moderate–heavy; or (5) heavy. Pre-mortem breakage was also recorded. Analysis indicates similar patterns of dental wear across all carnivore families, with light to light–moderately worn teeth being most prevalent. This suggests that irrespective of family, LBW carnivores died mostly in their prime and that competition levels were low. Moderate–heavy to heavily worn teeth, as well as teeth exhibiting pre-mortem breakage, are almost exclusively those of hyaenids. The incidence of heavily worn teeth, however, is much lower amongst LBW hyaenids than extant bone-cracking hyaenids. This supports the hypothesis that Mio-Pliocene hyaenids were not bone specialists. Preliminary results suggest that patterns of gross dental wear/breakage patterns can provide ecological information about the LBW carnivore guild, justifying a more comprehensive study.

Funding acknowledgement: funding from an NRF grantholder bursary is hereby acknowledged.

Dental microwear texture analysis of the early Pliocene African bear *Agriotherium africanum*

Stynder D.D.,[1] Donohue, S.L.,[2] DeSantis, L.R.G.,[3] Schubert, B.W.,[4] Ungar, P.S.[5]
[1]*University of Cape Town (UCT)*
[2]*San Diego Natural History Museum*
[3]*Vanderbilt University*
[4]*East Tennessee State University*
[5]*University of Arkansas*

Agriotherium africanum, which was originally discovered in 1965 at the South African early Pliocene site of Langebaanweg (LBW), represents the first pre-Pleistocene ursid to be identified in sub-Saharan Africa. Ever since its discovery, it has generated scientific interest due to its relatively unusual morphology. While resembling extant ursids in overall form, it displays certain adaptations, particularly those related to feeding ecology, that are absent or rare in extant ursids. With regard to its skull, the muzzle is relatively short and broad, the zygomatic arches are particularly wide, and the neurocranium features a high sagittal crest. The P4 and maxillary molars possess pointed, high crowned buccal cusps that are coupled with reductions of the lingual cusps, forming what could be regarded as a shearing complex that functioned as a 'second carnassial'. These morphological features have long been considered indicative of a hypercarnivorous lifestyle. Recently, a study of tooth root morphology of *A. africanum* has challenged its characterization as a hypercarnivore. In particular, questions were raised about its ability to consume large bones on a regular basis. Here we report on microwear texture analysis of *A. africanum* M1s and M2s. In contrast to morphological evidence, dental microwear textures (DMT) can inform directly on the mechanical properties of foods eaten. Results show that *A. africanum* consumed significantly more hard foods – most likely bone – than extant omnivorous ursids. The hypothesis of hypercarnivory can therefore not be ruled out just yet, for this early Pliocene African bear.

Use of media platforms as tools to initiate community engagement

Tawane, G.M.
Evolutionary Studies Institute, University of the Witwatersrand, Johannesburg, South Africa

Homo naledi was discovered by explorers at the Cradle of Humankind in the Rising Star cave in 2013. Working together with a team of scientists, the species was announced in September 2015. The discovery and the announcement experienced a huge amount of media coverage. Media avenues ranging from television, radio, press, and online platforms were utilized to cover the announcement. The coverage

lasted for weeks to follow, with news trending across the entire media platform. This guaranteed momentum, as one article in the media is usually not enough to spread the intended communication. The success of the launch of the *Homo naledi* announcement was a result of all parties working together, from scientists and media houses. This strong interaction between scientists and the media resulted in an announcement that positively spilled over as a community engagement exercise. In addition to sharing the announcement via media house, the original fossils were placed on display and made accessible to the public. This garnered visitor numbers in excess of 250 000 and has proven very successful as an outreach avenue. The ripple effect saw the general public enquiring more about heritage sites and being interested in learning more about their heritage, and their origins.

Hominin evolution: sigma taxonomy in relation to palaeoanthropology and the lack of clear boundaries between species

Thackeray, J.F.

Evolutionary Studies Institute, University of the Witwatersrand, Johannesburg, South Africa

Hublin (2014) has highlighted a problem relating to 'the limits of a paleontological species'. This problem may be approached using a morphometric method of the kind developed by Thackeray, recognizing that boundaries between species such as *Australopithecus* and *Homo* are not necessarily clear. The method has been applied to cranial measurements obtained initially from modern conspecific vertebrate species, using least squares linear regression to quantify the degree of scatter around a regression line associated with the general equation $y = mx + c$, where m is the slope and c is the intercept. Thackeray *et al.* (1997) reported central tendency of the log-transformed standard error of the m-coefficient, known as 'log se_m', based initially on pairwise comparisons of conspecific specimens in museum collections of extant taxa. Central tendency has been confirmed with larger samples, associated with a mean log se_m value of –1.61 (Thackeray, 2007; Thackeray and Dykes, 2015). This log se_m value has been hypothesized to be an approximation for a biological species constant (T), expressed through geographical space and evolutionary time, associated with a statistical (probabilistic) definition of a species that could be applied to fossils, including specimens attributed to *Australopithecus* and early *Homo* (Thackeray, 2007). Log se_m values have potential for assessing probabilities of conspecificity, and can be used in the context of 'sigma taxonomy', without assuming clear boundaries between species. 'Sigma' relates to 'S' in the context of a spectrum of variation between taxa in the context of evolutionary time and geographical space.

Funding acknowledgement: National Research Foundation, French Embassy, AESOP.

Cranial morphology of *Embrithosaurus schwarzi* (Parareptilia, Pareiasauria), and a taxonomic and stratigraphic reassessment of the South Africa Middle Permian pareiasaurs

Van den Brandt, M. J., Rubidge, B.S., Abdala, N.F.

Evolutionary Studies Institute, University of the Witwatersrand, Johannesburg, South Africa

Pareiasaurs were abundant large, herbivorous parareptiles of the Middle and Late Permian with a global distribution. During the Middle Permian, they comprised 25% of the terrestrial tetrapod fauna, second to dicynodonts and dinocephalians which each make up 30 % of the fauna. The most basal pareiasaurs are found only in the Middle Permian of South Africa, suggesting that this important taxon had a Gondwanan origin. Despite their relative abundance, most pareiasaurs are poorly known, including the large Middle Permian South African taxa that went extinct at the end of the *Tapinocephalus* Assemblage Zone. Historically, unabated naming of new species created taxonomic confusion until Lee (1995, 1997) conducted a much needed alpha-taxonomic reorganization of all pareiasaurs, reducing the Middle Permian South African group from 11 to 4 species (*Bradysaurus baini*, *B. seeleyi*, *Embrithosaurus schwarzi* and *Nochelesaurus alexanderi*). However, this revision of Lee's did not include detailed anatomical descriptions of the *Tapinocephalus* Assemblage Zone forms. We present the first detailed cranial description and interpretive figures of *Embrithosaurus schwarzi*, including a taxonomic reassessment of all Middle Permian pareiasaurs and updated diagnoses for each valid species. These updated diagnoses have been used to re-identify all identifiable specimens of pareiasaurs from the *Tapinocephalus* Assemblage Zone, stored in South Africa, as well as a few holotypes in London. The re-identification allowed for accurate biostratigraphic and geographic range determination for the Middle Permian species.

Funding acknowledgement: DST Centre of Excellence in Palaeontology Masters Bursary, Palaeontological Scientific Trust (PAST), National Research Foundation – Innovation Masters.

Biogeography antecedes plate tectonics

Van Dijk, E.
Stellenbosch, South Africa

Thomas Henry Huxley in 1870 in his Presidential Address to the Geological Society of London compared the Miocene mammals of Europe and North America and concluded that there had been a dry-land connection between the two regions because nowhere else had there been ancestrally similar fossils discovered. Slides are presented which illustrate chronologically, stages in the concept of the Origin of Continents and Oceans based on the finding of similar organisms in regions now separated.

Palaeoenvironmental analysis of Plio-Pleistocene cave deposits from the Cradle of Humankind using stable light isotope analysis of speleothems

Venter, C.,[1] Steininger, C.,[1] Stratford, D.[2]
[1]Evolutionary Studies Institute, School of Geosciences, University of the Witwatersrand, Private Bag 3, WITS 2050
[2]School of Geography, Archaeology, and Environmental Studies. University of the Witwatersrand, Private Bag 3, WITS 2050

During the Plio-Pleistocene, the Earth experienced a period of gradual cooling, leading to a decrease in atmospheric temperature and increased seasonality. This resulted in the aridification of large parts of Africa, and this is believed to have encouraged human evolution and innovation. Palaeoenvironmental analyses using sediment deposits in the Cradle of Humankind have been used to understand the timing and intensity of this aridification by determining how changes in environmental conditions and seasonal cycles (including temperature and precipitation) affected the South African landscape and human evolution. These changes are recorded within the carbon and oxygen isotopic signatures of speleothems, which have precipitated within the Sterkfontein Caves system. The aim of this study is to understand the degree to which modern speleothems represent the modern climate and environment. Samples of modern speleothems from different areas of the Sterkfontein Caves were used to obtain modern temperature, precipitation and vegetation data from stable light carbon and oxygen isotope analyses. Some preliminary results will be presented here. This data was then compared to modern climatic and environmental records. The stable light isotope analysis should reveal patterns in the oxygen and carbon isotopes present in the speleothem samples, which can be related to changes in local climate during the precipitation of these modern speleothems from drip water sources. This would provide evidence of the reliability of speleothems as palaeoclimate proxies, which is influenced by climaticchanges regarding precipitation, atmospheric temperatures and variations in the overlying vegetation.

Funding acknowledgement: The financial assistance of the National Research Foundation (NRF) towards this research is hereby acknowledged. Opinions expressed and conclusions arrived at, are those of the authors and are not necessarily to be attributed to the NRF.

A new litho- and biostratigraphic framework for the latest Permian (Balfour and Teekloof formations) Karoo Basin of South Africa: implications for basin development

Viglietti, P.A.[1], Rubidge, B.S.[1], Smith, R.M.H.[1,2]
[1]Evolutionary Studies Institute, School for Geosciences, University of the Witwatersrand, Private Bag 3, WITS 2050, Johannesburg, South Africa
[2]Iziko South African Museum, P.O. Box 61, Cape Town, 8000 South Africa

A revised stratigraphic framework is proposed for the latest Permian *Dicynodon* Assemblage Zone (DiAZ). Within this new framework the Balfour Formation's Barberskrans Member (BM) correlates with the Oudeberg Member. A new unit, informally named the Upper Balfour sandstones (UB) replaces the BM. The uppermost Teekloof Formation's Javanerskop Member is also documented as a mappable arenaceous unit. The Musgrave Grit was also documented but only near Bloemfontein. These locally persistent sandstone horizons do not correlate temporally across the Karoo Basin and northward thinning is also documented in the UB. Moreover, three index fossils that currently define the DiAZ (*Dicynodon lacerticeps*, *Theriognathus microps*, and *Procynosuchus delaharpeae*) appear below its lower boundary and disappear below the PTB, and coevally with the appearance of *Lystrosaurus maccaigi*. Thus the base of the DiAZ is redefined, and the revived *Daptocephalus leonice*ps is re-established as the index fossil for the newly proposed *Daptocephalus* Assemblage Zone (DaAZ). A Lower and Upper DaAZ subdivision satisfies the

appearance of *L. maccaigi*. Wetter floodplain conditions prevailed in the Lower DaAZ than in the Upper DaAZ, and the faunal changes documented at this transition may reflect early onset of the climatic changes associated with the end-Permian mass extinction event. Northward thinning of strata suggests the end-Permian extinction event is not fully represented throughout the basin. Orogenic loading/unloading events are identified by two fining-upward cycles in DaAZ strata, and separated by a single diachronous third-order subaerial unconformity (SU). Flexural tectonics meant that sediment progradation northwards was out of phase with the south, preserving an incomplete northern stratigraphic record.

Funding acknowledgement: African Origins Platform (NRF, AOP), DST-Centre of Excellence for Palaeosciences (DST-CoE), Palaeontological Scientific Trust (PAST).

The micromorphology and U-Pb dating of Elandsfontein carbonates: implications for the mid-Pleistocene hominin occupation and the palaeoenvironment

Von Der Meden, J., Pickering, R.

Department of Geological Sciences, University of Cape Town

The Elandsfontein dune fields, situated on the West Coast of South Africa, have preserved unique geological features, as well as an abundance of fossils and artefacts, from the mid-Pleistocene (Braun *et al.* 2013). The fossils, which include those of large grazers such as hippopotamus, elephant and buffalo, indicate that during this period the climate and vegetation was different to present-day conditions and conducive to hominin occupation. The Quaternary sediments mainly comprise aeolian sand deposits and a carbonate-rich/calcrete layer. These calcretes, outcropping as laterally discontinuous pedestals scattered across the dune field, consist of concentric layers of hard, resistant micrite, and less-resistant layers of quartz-rich sand. Flow marks, desiccation cracks and fossilized spring eyes, suggest palaeo spring activity and a supply of fresh groundwater to the area. Current research is focused on the micromorphology of these calcretes together with stable isotope analysis and U-series dating, aiming to contribute to the further understanding of the palaeoenvironments of the area, as well as relating the dated carbonate pedestals to the archaeological excavation sites.

Funding acknowledgement: The NRF African Origins Platform, grant number: AOP150924142990.

Phylogenetic analysis based on braincases of early theropods, coelurosaurs, birds and maniraptorans

Welman, J.,[1] James, F.C.[2]

[1]*Biology Department, Sefako Makgatho Health Sciences University, MEDUNSA, 0204 South Africa*

[2]*Department of Biological Science, Florida State University, Tallahassee, Florida 32306, U.S.A.*

In this paper we (i) discuss some variation in the theropod braincase; (ii) review the published phylogenetic analyses of theropod dinosaurs; (iii) conduct a braincase-based phylogenetic analysis of the earliest birds, early archosauromorphs and a range of theropods. In addition to comparative anatomical evidence, embryological information can be integrated with direct evidence from fossils to test homologies. This integrative approach confirms that the pharyngo tympanic system in early theropods has been derived from the pouch of Rathke. Such a derived system is present in *Syntarsus* (*Megnaposaurus*) and *Allosaurus*. In *Compsognathus* and *Alioramuson* the other hand, the pharyngo tympanic system is present in the plesiomorphic form, closely resembling the pouch of Rathke in *Euparkeria* and *Proterosuchus*. In early theropods a fenestra pseudorotunda is present that is situated posterior to the ossified posterior basicapsular commisura that forms a crista interfenstralis that separates it from the fenestra ovalis. In birds, the function of dampening soundwaves in the perilymph is done by a neomorph avian fenestra rotunda separated from a neomorph fenestra ovalis by the promontorium which represents the ossified anterior basicapsular commisura. The condition of the middle ear of *Tyrannosaurusis* unclear.

Bringing fossils back to life at the Fossil Park through our education programmes

Wentzel, W.A.

Educator, West Coast Fossil Park

The aim of our Education Programme is to stimulate interest in fossils by investigating aspects of the palaeo environment 5 million years ago, and relating it to the present environment. Subject matter is linked to the school curriculum and covers a variety of components, including Environmental Education,

Biodiversity, Citizen Science and Conservation. Carefully planned hands-on activities have been developed to stimulate curiosity and to create awareness of our present environment, while opening a window to the past by relating these activities to the past environment of the West Coast Fossil Park.This presentation will demonstrate how Basic Science method is introduced informally to the learners by teaching them to record their observations, labelling of the samples, evaluating the samples and drawing conclusions from the activity which has been done.

Funding acknowledgement: Bhp Billiton, NLC – main sponsors of the WCFP.

The biogeography of Late Cretaceous ankylosaurid dinosaurs: implications for ankylosaurid diversity in Western North America

Wiersma, J.,[1] Irmis, R.[2]

[1]*James Cook University, Earth Sciences, Townsville, Queensland, Australia*

[2]*University of Utah, Geology and Geophysics, Salt Lake City, Utah, U.S.A.*

Global and regional fluctuations in sea level and climate during the Late Cretaceous strongly influenced the biogeographic distribution of non-marine faunas from Asia to western North America (Laramidia), including ankylosaurid dinosaurs. These dispersal events may have been triggered by short-lived regressions, producing an ephemeral Beringian land bridge that allowed for intercontinental dispersal to take place. Episodic transgressions repeatedly inundated this Beringian land bridge and prevented continuous faunal dispersal. Fossil evidence from the Early Cretaceous of Asia yields some of the earliest ankylosaurid dinosaurs (e.g. *Shamosaurus*), suggesting an Asian origin for the clade Ankylosauridae, with one or more dispersal events to North America. Currently, two distinct clades of Late Cretaceous ankylosaurid dinosaurs are known from Laramidia. The oldest occurrence of northern Laramidian ankylosaurids (*Scolosaurus, Dyoplosaurus*) are recorded from the middle Campanian stage (~77 Ma) of the Dinosaur Park Formation of Canada, whereas the younger, southern Laramidian clade, first appears at ~76 Ma in the upper Campanian Kaiparowits Formation of Utah. To investigate how the biogeography of these clades relates to sea level change during the Late Cretaceous, we utilized temporal calibrated phylogenies in combination with biogeographic modelling, and the most recent eustatic sea level data, to reconstruct dispersal, extinction, and vicariance events for the clade Ankylosauridae. These data suggest at least two intercontinental, three intracontinental, and a single vicariance event during Santonian and Campanian times (~86–77 Ma). These results support the hypothesis of distinct northern and southern biogeographic provinces for ankylosaurid dinosaurs during the upper Campanian in Laramidia.

Funding acknowledgement: Geological Society of America Bureau of Land Management (BLM) National Landscape Conservation System, University of Utah Department of Geology and Geophysics Graduate Student Travel Grant.

Australopith- or *Homo*-like? Investigating the taxonomic status of SK 27 (Swartkrans, South Africa) through its inner tooth structural signature

Zanolli, C.,[1] Braga, J.,[1] de Beer, F.,[2] Hoffman, J.W.,[2] Macchiarelli, R.,[3] Thackeray, F.[4]

[1]*Laboratoire AMIS, UMR 5288 CNRS, University of Toulouse, France*

[2]*South African Nuclear Energy Corporation, Pelindaba, South Africa*

[3]*UMR 7194 CNRS, Muséum National d'Histoire Naturelle, Paris, France, and Département Géosciences, Université de Poitiers, France*

[4]*Evolutionary Studies Institute, University of the Witwatersrand, Johannesburg, South Africa*

SK 27 represents a partially crushed juvenile cranium that was found in 1949, in the Hanging Remnant of the Member 1 of Swartkrans. Biochronology and U-Pb isotopic dating of its provenance stratigraphic unit coincide to an age of *c.* 1.8 Ma. The specimen preserves the LI2, Ldm2, LM1, and RM1, the unerupted LP4 and LM2, small crown and root fragments representing the I1s, the RC and the Rdm2, as well as the isolated LC and LP3. Formerly attributed to *Paranthropus robustus*, SK 27 is now considered as more likely representing early *Homo*, usually classified as *H. habilis*, but recently attributed to a possibly distinct southern African endemic taxon, *H. gautengensis*. In order to noninvasively extract from this problematic specimen additional morphostructural information suitable for clarifying its taxonomic status and phylogenetic relationships, the specimen SK 27 was imaged by X-ray microtomography and compared with similar evidence from Indonesian *H. erectus*, North African *H. heidelbergensis*, as well as with *Au. africanus* and *P. robustus* representatives from the South African hypodigm. Besides the virtual exploration and GM analysis of the premolar and molar enamel–dentine junction, we primarily focused on molar crown tissue proportions and enamel thickness distribution pattern. Our 3D analyses of the

internal tooth crown structural organization of SK 27 substantially differs from the average *P. robustus* condition, but show a combination of primitive (australopithecine-like) and derived (*Homo*-like) features. The taxonomic status of this controversial specimen remains contentious, pointing to the need for complementary analyses extended to additional taxa, including *Au. sediba*.

Funding acknowledgement: Research was funded by the National Research Foundation (NRF) and the Department of Science and Technology (DST) of South Africa, the programme 'A European and South African Partnership on Heritage and Past+' (AESOP+), and the French CNRS.

Fossil hominin collections of the University of the Witwatersrand: composition, curation and access

Zipfel, B.

Evolutionary Studies Institute, University of the Witwatersrand, Johannesburg, South Africa

The Phillip V. Tobias hominin collections of the University of the Witwatersrand began with the discovery of the Taung skull in 1924, holotype of *Australopithecus africanus*, followed by numerous discoveries primarily from Sterkfontein and Makapansgat. Other hominin discoveries followed from Border Cave, Drimolen, Gladysvale, Cooper's Cave and others. With the discovery of 'Little Foot' in 1998, the first complete australopithecine skeleton from South Africa, and subsequent substantial discoveries from Malapa (2008) and Dinaledi (2013), the nature of the collections changed. The number of specimens rose from 900 in 2007 to almost 3000 in 2016; a substantial number in terms of hominins. These collections now include a number of almost complete skeletons and several holotypes, unprecedented in South African palaeoanthropology. With this rapid growth, the existing repository had become too small; a new, state of the art hominin laboratory and vault was established at the university's Evolutionary Studies Institute. This new facility now houses the largest hominin collection in the world, containing a substantial record of human evolution. In order to maximize these resources, individual access to students and scientists is encouraged, innovative international workshops are held and scientific teams established to ensure efficient and timely publication in high impact journals. These projects provide a strong case on how primary source materials can be curated, catalogued and studied within the spirit of open access and scientific best practices.

Funding acknowledgement: National Research Foundation (NRF), Palaeontological Scientific Trust (PAST).

STYLE GUIDE FOR AUTHORS — REVISED 2016

GENERAL

Palaeontologia africana publishes papers in the field of palaeontological research and in related branches of the earth sciences. Copies are available for purchase individually or in sets. Back copies of volumes 1–48 are available electronically at the address below and in hard copy upon request at variable rates depending on shipping costs. Beginning with volume 49, *Palaeontologia africana* is available online only in pdf format at the following permanent address: http://wiredspace.wits.ac.za/handle/10539/13253. Direct all enquiries to:

The Editor
Palaeontologia africana
Evolutionary Studies Institute
University of the Witwatersrand
Private Bag 3
WITS 2050
South Africa
Telephone: [+27-11] 717-6690/6682
Fax: [27-11] 717-6694
E-mail: jonah.choiniere@wits.ac.za

Submission of a manuscript for publication will be taken to indicate that the material is original and has not been submitted for publication elsewhere.

Authors reserve copyright for their articles. Manuscripts are published under the Creative Commons Attribution 4.0 Unported License (CC BY 4.0; https://creativecommons.org/licenses/by/4.0/). This license permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited. Manuscripts and illustrations should be submitted to the following e-mail address: palaeontologia.africana@gmail.com

PREPARATION AND SUBMISSION OF MANUSCRIPTS

Manuscripts

Manuscripts must be submitted electronically, and formatted to fit on one side of A4 size paper in double spacing throughout and with margins at least 25 mm wide all around. All pages must be numbered consecutively in the centre of the top margin, beginning with page 1 on the title page.

The text should be saved in either .doc, .docx, or .rtf format, with a file name that clearly identifies at least the lead author and keywords from the title.

Layout

Except in the case of short communications and technical reports, manuscripts should normally be divided into appropriate conventional sections set out in the following order: title, abstract, introduction, body of text (subdivided as appropriate), acknowledgements, references, figure legends, tables.

Title

The title should be concise and should reflect the contents clearly. Names of new biological taxa proposed in the manuscript should not be included in the title. If the title is long a suitable abbreviated running title must be provided.

The title must be followed on a separate line by the authors' name/s and institutional address/es. Institutional affiliations, mailing addresses, and e-mail addresses of all authors must be provided. In multi-authored contributions, the institutional address and e-mail of each individual must be linked to the relevant name using superscript numbers.

Abstract

An informative abstract not exceeding 300 words must be provided. This section is to be omitted in Technical Reports.

Keywords

At least five keywords should be provided immediately after the abstract.

Introduction and main text

The manuscript should be divided as appropriate into conventional sections (e.g. Introduction, Materials and Methods, Results, Discussion).

Acknowledgements

Authors should include only those acknowledgements that are truly warranted.

References

References are listed at the end of the manuscript, beginning on a new page. Under this heading, authors must list only published works that have been cited in the text.

Unpublished works, even those that are 'in press', must not be included unless full bibliographic details can be provided, including pagination. However, formal theses and dissertations, even though unpublished, may be listed provided full details are supplied; this must include reference to the institution where the master copy is lodged. Work that is 'in preparation' and 'personal communications' may be referred to in the text, but must not be included in the list of references.

The list of references must be arranged alphabetically, then chronologically, according to the layout of the examples below. **An Endnote™ style is available for authors to download at the following address: http://hdl.handle.net/10539/17375** Leave one blank line between each reference, and do not indent or otherwise format each entry. The layout sequence is:

(i) Author's name(s) and initials (in uppercase only). In the case of multi-authored manuscripts, successive authors' names should be separated by commas, with an ampersand (&) between the penultimate and last name;
(ii) Year of publication (not in brackets). If more than one paper by the same author is listed for the same year, successive entries must be designated by placing the letters a, b, c, etc., after the year of publication;
(iii) Full title of paper. Use capitals only for the first letter and for proper names. Generic and specific names must be italicized, unless such names themselves fall within an italicized title, in which case the names should be in regular (non-italic) script;
(iv) Full (*unabbreviated)* title of journal, book or other source, in italics. Book titles should be followed by the edition (if other than the first), the place of publication and the name of the publisher.
(v) Volume specification of journal: i.e. series (if applicable), volume number (in bold), part number (if any) in brackets, pagination (first and last page).

Examples of reference citations (to save space, the blank line between successive entries has been omitted):

ANDERSON, H.M. 1976. *A revision of the genus* Dicroidium *from the Molteno Formation.* Unpublished Ph.D. thesis, University of the Witwatersrand, Johannesburg.

ANDERSON, H.M. & ANDERSON, J.M. 1970. A preliminary review of the biostratigraphy of the uppermost Permian, Triassic and lowermost Jurassic of Gondwanaland. *Palaeontologia africana* **13**, 1–22.

CROMPTON, A.W. 1962. On the dentition and tooth replacement in two bauriamorph reptiles. *Annals of the South African Museum* **46**(9), 231–255.

HOPSON, J.A. & BARGHUSEN, H.R. 1986. An analysis of therapsid relationships. **In**: Hotton, N., MacLean, P.D., Roth, J.J. & Roth, E.C. (eds), *The Ecology and Biology of Mammal-like Reptiles,* 159–168. Washington, Smithsonian Institution Press.

ROMER, A.S. 1966. *Vertebrate Palaeontology* (3rd edn). Chicago, University of Chicago Press.

ROMER, A.S. 1973. Permian reptiles. **In**: Hallam, A. (ed.), *Atlas of Palaeobiogeography,* 159–168. Amsterdam, Elsevier.

VAN DER MERWE, N.J., LEE-THORP, J.A., THACKERAY, J.F., HALL-MARTIN, A., KRUGER, F.J., COETZEE, H., BELL, R.H.V. & LINDEQUE, M. 1990. Source-area determination of elephant ivory by isotopic analysis. *Nature* **346**, 744–746.

PERIERA, L.M. 2009. The Wits Online Phytolith Database. University of the Witwatersrand, Johannesburg, South Africa. Online at: http://web.wits.ac.za/Academic/Science/GeoSciences/BPI/Research/WOPD/ (accessed 15 February 2010).

Reference citations in the text should give the name of the author and the date on each occasion, and substitutes such as *op. cit., loc. cit.* should not be used, e.g. 'Smith & Jones (1943) suggested that ...', '... extinction rates (Smith & Jones 1972) and other factors ...'. In the text, successive references by the same author should be separated by commas, and those of different authors by semi-colons: (Brain 1990, 1991; Hughes 1961; Smith & Jones 1972). Please note we use the standards of the International Commission on Stratigraphy for spelling and capitalization of chronostratigraphic intervals.

Headings

Three orders of headings are used.

FIRST ORDER, printed in bold capitals and left-aligned.
Second order, printed in bold upper and lower case and left-aligned.
Third order, printed in upper and lower case italics and left-aligned.

Headed sections and paragraphs should not otherwise be numbered or lettered in the manuscript.

Tables

Tables must be set out on separate sheets, with second-order headings for each. They are numbered consecutively in arabic numerals (e.g. Table 1, Table 2). Please indicate the position of each table by notation in the text (e.g. "<<Insert Table X here>>").

When referring to Tables in the text the word 'Table' is spelt out in full and given a capital initial letter, e.g. Table 2.

Figure legends

Figure legends should be placed at the end of the body text, after References. When referring to figures in the text the word is abbreviated with a capital initial letter, e.g. Figs 2–4. Please format as follows:

Figure X. Text. **A**, text. **B**, text. **C**, text. Scale bar(s) equal: A, 1 cm; etc.

Illustrations

All illustrations are termed Figures (the word is to be spelt out in full with a capital initial letter), and they are numbered consecutively with arabic numerals. *Palaeontologia africana* now only accepts electronic figures, although in exceptional cases the authors may petition the Editor to allow hard copy figure submission.

Please mark the position of figures by inserting the following identifier at an appropriate position in the body text: "<<Insert Figure X here>>".

All illustrations should be designed for same-size printing or slight reduction in the final form. Maximum printed sizes for figures are as follows: full page, height 245 mm width 175 mm; column width 87 mm. Tip-ins and fold-outs will require special arrangements with the editor and will incur additional costs.

For initial submission, .pdf, .jpeg, .png figures with resolution of 150 dpi are acceptable. Upon acceptance, authors will be asked to provide high-resolution 300 dpi (black and white or colour photographic images) or 600dpi (mixed line and photographic images), or 1200dpi (line art) .tif, .wmf, .eps, .pdf or .png figures. A guide to preparing high-quality figures is available from the Editor. Lettering and label lines should be added in a vector editor such as Adobe Illustrator or Inkscape. Colour illustrations welcomed at no cost to the author(s).

Scale should be represented by suitably labelled scale bars of appropriate size, with the units of measurement specified in the caption; avoid reference to magnification in captions.

Graphs should preferably in one of the vector (not bitmap) formats (.eps, .wmf, .svg, .emf, or .pdf). Diagrams prepared in Excel should be saved in one of the following formats: .wmf, .emf, .eps, .pdf, .svg.

Print-quality digital images may be submitted on CD-ROM or via FTP sites such as Dropbox.com or Wetransfer.com.

Numerical data

The metric system (SI units) is to be used throughout for all numerical data. If there is good reason for using units other than metric, the SI metric equivalents must be given in brackets. Authors should familiarize themselves with the standard abbreviations of SI metric units; non-standard abbreviations are not acceptable.

ACCEPTANCE OF PAPERS

All manuscripts offered to the Editor are submitted to two or more referees for critical appraisal, and the substance of the referees' comments is forwarded to the author in the event that the manuscript is rejected or requires revision. The Editor will advise the author whether or not the manuscript is accepted for publication.

If the manuscript is accepted, one set of proofs (usually page proofs) will be submitted to the author for careful checking and these must be returned as soon as possible. The cost of any additions or major alterations to the text at proof stage may be charged to the author. Further proofs may be submitted to the author if the Editor considers it to be necessary or desirable.