

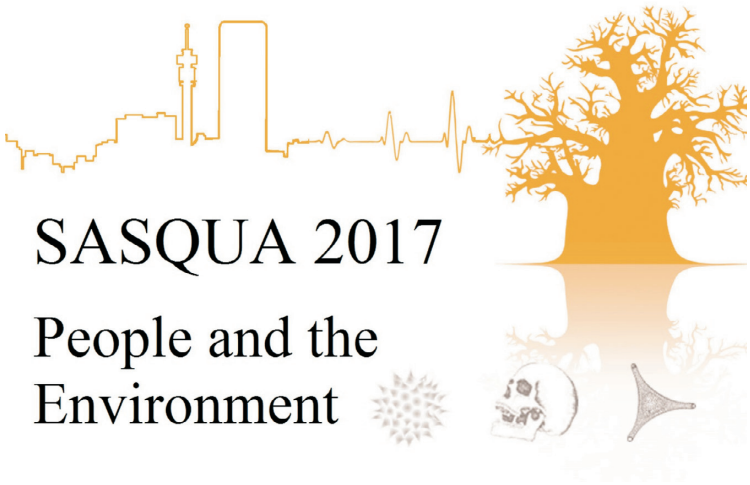
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Proceedings of the 21st Biennial Conference of the South African Society of Quaternary Research, Johannesburg, 3–7 April 2017

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Palaeontologia africana **52**: 1–45 — ISSN 2410-4418 [Palaeontol. afr.] Online only
Permanently archived on the 21th of July 2017 at the University of the Witwatersrand, Johannesburg, South Africa.
This item is permanently archived at: http://wiredspace.wits.ac.za/handle/10539/23008/

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Editorial

Research, Discussion and Debate in Southern African Quaternary Research in 2017

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Introduction

The Southern African Society for Quaternary Research (SASQUA) was established in the 1960s, and remains a vibrant community of Quaternary scientists including archaeologists, palaeoecologists, palaeoclimatologists, geomorphologists, chronologists and palaeoanthropologists (Bamford & Grab 2005). Considerable progress has been made by members of the community in reconstructing the environments, climates and human evolution of southern Africa spanning the Quaternary (Meadows & Finch 2016; Fitchett *et al.* 2017). A number of critical reviews of South African Quaternary palaeoscience have published over recent years (*cf.* Meadows 2015; Meadows & Finch 2016; Fitchett *et al.* 2017), but as with any developing discipline, the landscape continues to evolve rapidly. Conferences are critical fora for sharing state-of-the-art knowledge including: methodological developments, reconstructions for previously overlooked regions, and debates on interpretations and inferences. It is likewise critical to publish the conference outputs in the public domain. The South African Society of Quaternary Research (SASQUA) brings together many of the currently active Quaternary scientists conducting research in southern Africa. The conference delegates, although predominantly South African, include international scientists, allowing for a rich transfer of expertise and ideas. Of particular value to continued Quaternary research in South Africa is that a large proportion of the conference delegates are students, all of whom are engaged in exciting projects that pursue methodological advancement, address spatial and temporal gaps in the existing regional database, and who demonstrate a strong culture of skills development in the country. This special issue contains the extended abstracts of material presented in oral and poster presentations at the 2017 SASQUA conference, together with conference proceedings papers from a selection of delegates.

Historical overview

Quaternary palaeoenvironmental and palaeoclimatic reconstructions were initiated comparatively late in southern Africa, compared to work elsewhere in the world. Pioneering studies by Van Zinderen Bakker (1955), Martin (1959, 1968), Coetzee (1967) and Scott (1976, 1982), were challenged by the considerably rich and varied flora of the region and limited by uncertain chronologies. In recent years, studies have benefited from access to increasingly affordable, high-precision dating facilities, and large pollen, phytolith and diatom collections to facilitate the identification of proxies (Meadows 2014). Archaeological research in the region was initiated slightly earlier, with the establishment of the *South African Archaeological Bulletin* in 1960 (Bamford & Grab, 2005). Since then there have been numerous publications in local and international journals. Just one example is shown in Wadley's (2015) review of the Middle Stone Age innovations of southern Africa where she lists more than 57 sites, compared with a list of seven sites in 1999 by Deacon & Deacon (1999). Both archaeology and palaeoenvironmental studies have benefited tremendously from advances in dating techniques and capacity over the past half-century (Fitchett *et al.* 2017), and improvements in age-dating remain a popular topic at SASQUA conferences.

In the editorial for the *Quaternary International* special issue for the 2005 SASQUA Conference, Bamford & Grab (2005) tabulated the key themes spanned by papers presented at SASQUA conferences from 1993–2003 (Table 1). These themes were notably dominated by the fields of geomorphology, sedimentology and stratigraphy, topics which have over subsequent years received increasingly less attention. The conferences of 2001 and 2003 additionally had key focus areas in the domains of archaeology, palaeozoology, and dating and isotopic work. It is interesting to reflect a decade and a half later, on how many of these themes remain topics of continued innovation, debate and development within the community.

Table 1. Percentage contributions of papers from sub-disciplines, presented at SASQUA conferences from 1993–2003 (after Bamford & Grab 2005).

Year	Geomorphology/ sedimentology/ stratigraphy	Dating isotope work	Archaeology	Palaeozoology	Palaeobotany	Palaeoclimatology	Environmental multidisciplinary
1993	27	3	22	13	15	10	10
1995	45	4	7	4	7	11	45
1997	64	3	7	7	9	3	7
2001	53	13	3	12	3	3	16
2003	31	3	26	14	12	0	14

Current themes in South African Quaternary science

In comparison to the trends of 1993–2003 (Table 1), it is notable that none of the oral or poster presentations at SASQUA 2017 cover topics of geomorphology; the only work exploring sedimentology is presented by Morrissey *et al.* (this issue), investigating the palaeoenvironment of the Nahoon Point footprints on the basis of sedimentological evidence. A significant proportion of the work presented at this conference explores developments in Quaternary science methods and proxies. It is thus fitting that the plenary address, presented by Prof. Anson Mackay of University College London, explores novel developments in the use of $\delta^{18}O_{diatom}$ records from lake sediments to reconstruct hydrological variability (Mackay *et al.,* this issue). Applications of Foraminifera in palaeoenvironmental reconstructions of South Africa's shoreline (Strachan, this issue), FIB-SEM as a new method for examining pollen grain walls (House, this issue), and a comparison of palynological processing methods (Neumann *et al.,* this issue) comprise a few of these contributions. As is typical for SASQUA conferences, many of the presented works include new Quaternary palaeoenvironmental reconstructions, which for SASQUA 2017 span the Middle Stone Age through to the late Holocene. The conference also included a strong contingent of geologists and cultural archaeologists, providing a wealth of perspectives. Engaging in the diversity of delegates, a panel debate was scheduled to conduct inter-disciplinary discussion regarding the climatic conditions in South Africa during the Last Glacial Maximum (LGM). This contributes to the ongoing efforts of the SHeMax team to better understand LGM conditions in the southern hemisphere (Petherick *et al.* 2016). The outcome of this panel debate is summarized in a short communication (Fitchett *et al.* this issue).

The abstracts accepted for oral and poster presentations at SASQUA 2017 reflect a focus on South and southern Africa, as to be expected given the ambit of the conference (Fig. 1). There is a significant focus on palynology in the proceedings of SASQUA 2017, with the word 'pollen' used 76 times in the full collection of all accepted abstracts. Related subjects of 'climate', 'change', 'environment' and 'conditions' also feature among the frequently used words in the collection of abstracts, with a combined total of 208 mentions.

The way forward: sustaining Quaternary research and debate in South africa

While the large international conferences draw more attention to more people the disadvantage is that there is an overwhelming amount of information disseminated and unless the delegate is very focussed and disciplined in attending his selection of topics it results in a

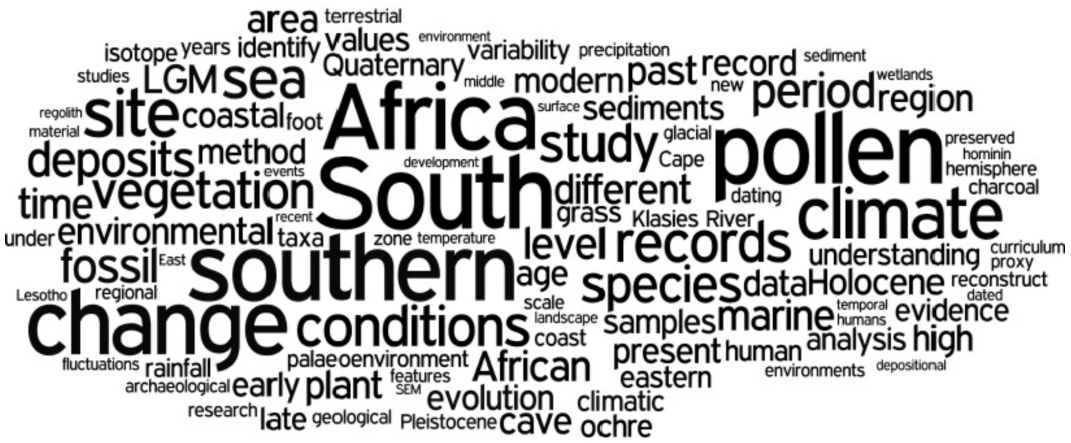


Figure 1. Word cloud demonstrating the proportional contribution of words used 10 times or more in the full collection of SASQUA 2017 abstracts.

case of 'in one ear and out of the other'. The advantage of smaller, more personal conferences is that the delegates are more likely to listen to talks outside of their normal selection and so learn something new but can also contribute new ideas from another field to the presenter. Thus, conferences such as SASQUA remain a vital enterprise in the training of the next generation of palaeoscientists, who will be increasingly local and diverse.

REFERENCES

BAMFORD, M.K. & GRAB, S.W. 2005. Highlights of Quaternary research in southern Africa, and proceeding forwards. *Quaternary International* **129**, 1–3

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

DEACON, H.J., DEACON, J. 1999. Human beginnings in South Africa: uncovering the secrets of the Stone Age. David Phillip, Cape Town.

FITCHETT, J.M., GRAB, S.W., BAMFORD, M.K. & MACKAY, A.W. 2017. Late Quaternary research in southern Africa: progress, challenges and future trajectories. *Transactions of the Royal Society of South Africa,* In press.

MARTIN, A.R.H. 1959. The stratigraphy and history of Groenvlei, a South African coastal fen. *Australian Journal of Botany* **7**, 142–167.

MARTIN, A.R.H. 1968. Pollen analysis of Groenvlei lake sediments, Knysna (South Africa). *Review of Palaeobotany and Palynology* **7**, 107–144.

MEADOWS, M.E. 2014. Recent methodological advances in Quaternary palaeoecological proxies. *Progress in Physical Geography* **38**(6), 807–817.

MEADOWS, M.E. 2015. Seven decades of Quaternary palynological studies in southern Africa: a historical perspective. *Transactions of the Royal Society of South Africa* **70**(2), 103–108.

MEADOWS, M.E. & FINCH, J.M. 2016. The history and development of Quaternary science in South Africa. *South African Geographical Journal* **98**(3), 472–482

PETHERICK, L., SHULMEISTER, J., KNIGHT, J. & ROJAS, M. 2016. SHeMax: the last glacial maximum in the southern hemisphere. *Quaternary Australasia* **33(**2), 32.

SCOTT, L. 1976. Preliminary palynological results from the Alexandersfontein Basin near Kimberley. *Annals of the South African Museum* **71**, 73–189.

SCOTT, L. 1982. A Late Quaternary pollen record from the Transvaal Bushveld , South Africa. *Quaternary International* **17**, 339–370.

VAN ZINDEREN BAKKER, E.M. 1955. A preliminary survey of the peat bogs of the alpine belt of northern Basotholand. *Acta Geographica* **14**, 413–422.

WADLEY, L. 2015. Those marvellous millennia: the Middle Stone Age of southern Africa. *Azania: Archaeological Research in Africa* **50**(2), 155–226.

Inter-disciplinary Discussion

Discussion on the Last Glacial Maximum in southern Africa

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Introduction

During the 21st Biennial Conference of the Southern African Society for Quaternary Research (SASQUA; April 2017), a panel debate was convened to discuss the state of science pertaining to the Last Glacial Maximum (LGM) in southern Africa. From a global perspective the LGM corresponds to the coldest phase of the last glacial cycle, and is a critical period to focus on as palaeoenvironmental data from this period allow for a better understanding of how large-scale climatic forcings translate to local and regional environments. Reconstructions of climatic conditions (temperature, moisture availability and seasonality) for this period are also essential for the robust evaluation of climate models. In southern Africa, key questions pertaining to the LGM period included the timing of the event as a whole and its coldest conditions, the overall climatic conditions during this period, the varied palaeoenvironmental evidence for the event, and the microscale geographic variation in palaeoenvironmental conditions. These questions are particularly pertinent in a southern African context, given the absence of undisputed glacial or periglacial evidence for the LGM. The aim of the panel debate was to discuss the context and significance of existing knowledge, and the pertinent avenues for future research in the region, into the Quaternary period generally and the LGM in particular. The panel comprised representatives from some of the key subdisciplines of southern African Quaternary science: archaeology (Prof. Amanda Esterhuysen), geology (Dr Hayley Cawthra), palaeoecology (Dr Lynne Quick), and palaeoanthropology and palaeoecology (Prof. Francis Thackeray). The panel was chaired by Prof. Jasper Knight, and convened by Dr Jennifer Fitchett and Prof. Marion Bamford. The debate was opened to the floor for interaction from the broader southern African palaeoscience community, as represented by SASQUA conference delegates.

Timing and climatic conditions of the LGM

Although a topic of contention across the southern hemisphere as a whole (*cf.* Petherick *et al*. 2016), the panel did not explicitly contest the conventional notion of the LGM in southern Africa at ~21 000 cal yr BP. It should be noted, however, that in most instances this timing was derived by a temporary absence of data, rather than positive evidence derived from different records. The absence of data across a number of proxies over the broad period 24 000–20 000 cal yr BP is interpreted to have resulted in part from the particularly cold climatic conditions at this time, suppressing the behaviour of surface river, soil and ecosystems, and inhibiting fossil preservation. The overlap in these periods of poor proxy record availability for a number of sites and for a range of proxies is notable, yet the absence of positive proxy evidence does preclude the inference of climatic conditions during the LGM, such as from regional lake or marine records.

Existing proxy data, from which palaeoclimatic and palaeoenvironmental reconstructions have been made for the LGM period, vary in their degree of predictive strength. Proxies such as isotopes have the capacity to quantitatively reconstruct past moisture and temperature regimes, but issues of isotopic contamination/overprinting are difficult to resolve and transfer functions may be subject to error and there is an absence of training sets. Most proxy evidence for the LGM period itself is derived either from sediment cores or archaeological sites, often requiring the interpretation of climatic conditions on the basis of regional vegetation change from pollen data and faunal assemblages from these sites. In order to make these somewhat qualitative inferences of past climate from plant fossil records more robust, reliance has been placed on statistical methods. While simple methods of factor analysis and principal components analysis can elucidate broad gradients in palaeoenvironmental data, they can seldom accurately decouple the moisture and temperature records or distinguish these from other local environmental factors. Where moisture records can be isolated, it becomes difficult to determine the relative importance of precipitation, evaporation and the seasonality of precipitation. More complex statistical approaches have been recently

proposed (*cf.* Chevalier *et al.* 2014), but there remains concern regarding the extent to which these can be applied to a broader range of locations and depositional environments, and the suitability in what are likely non-analogous conditions during the LGM. There was consensus among the panellists that any statistical approaches should be undertaken by experts with in-depth knowledge of both the proxy utilized, and the contemporary environment from which it was derived. Caution was raised, however, regarding an over-reliance on comparisons with the present, given both the magnitude of temperature departures during the LGM, the potential for non-analogous conditions during the LGM, and the rapid rate of contemporary climate change.

Palaeoclimatic evidence from southern Africa encompassing the LGM period consistently indicates an average temperature depression of >6°C, yet the precise value and land surface impact of this depression remains uncertain both spatially and temporally, as evaluated from different proxies. Moisture records are more clearly defined, yet indicate considerable spatial heterogeneity, including a moisture dipole within the contemporary winter rainfall zone. This moisture variability is posited to result from the increased influence of the southern westerlies during the LGM. However, there remain many outstanding questions relating to the dynamics and interactions of the temperate climate systems (the westerlies) and tropical moisture sources, and how these systems have influenced rainfall regimes across southern Africa during and since the LGM. Exploring climatic conditions leading into and out of the LGM was highlighted as a means to better understand why there are spatial and temporal variations in response, and why the LGM may be recorded differently based on different proxies.

Avenues for Future Research

An important component of the discussion was the identification of sites for targeted and integrated (multidisciplinary) research on the LGM. The Quaternary science research transects proposed by Chase & Meadows (2007), extending north, northeast and east of the WRZ, were raised as an important starting point, and there was consensus that these reflected regions of importance in better understanding climate variability throughout the LGM. However, it was noted that few palaeoenvironmental records exist in large areas of southern Africa, mainly due to low preservation potential. LGM-age material is commonly available at known archaeological sites, yet these have not been studied in great detail as the period does not reflect technological or cultural innovation periods of interest to archaeologists. It was thus proposed that research should endeavour to integrate the approaches of a range of Quaternary palaeosciences at these archaeological sites, to obtain fossil proxy evidence for the climates and environments of the LGM. There is also some debate about the timing and degree of sea-level changes, particularly in relation to coastal sites (Cawthra *et al.* 2016), but there is uncertainty on the extent to which these independent data can be correlated with other coastal sites or to inland sites.

It was concluded by panellists and SASQUA participants that while there is undoubtedly a clear need for continued research to refine our understanding of the timing and climate of the LGM, it is also important to revisit, re-date and reanalyse past datasets, in particular from key sites.

Acknowledgements

The SASQUA 2017 Conference, and J.F. and M.B. personally, were supported by funding from the DST/NRF Centre for Excellence in Palaeosciences.

References

CAWTHRA, H.C., COMPTON, J.S., FISHER, E.C., MACHUTCHON, M.R. & MAREAN, C.W. 2016. Submerged shorelines and landscape features offshore of Mossel Bay, South Africa. **In**: Harff, J., Bailey, G. & Lüth, F. (eds), *Geology and Archaeology: Submerged Landscapes of the Continental Shelf*, 219–233. London, Geological Society, Special Publications, **411**.

CHASE, B.M. & MEADOWS, M.E. 2007. Late Quaternary dynamics of southern Africa's winter rainfall zone. *Earth-Science Reviews* **84**(3), 103–138.

CHEVALIER, M., CHEDDADI, R. & CHASE, B.M. 2014. CREST (Climate REconstruction SofTware): a probability density function (PDF)-based quantitative climate reconstruction method. *Climate of the Past* **10**, 2081–2098.

PETHERICK, L., SHULMEISTER, J., KNIGHT, J. & ROJAS, M. 2016. SHeMax: the Last Glacial Maximum in the southern hemisphere. *Quaternary Australasia* **33**(2), 32–34.

Plenary Talk

Reconstructing hydrological variability using $\delta^{18}O_{diatom}$ records from lake sediments

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The oxygen isotope composition of diatom silica ($\delta^{18}O_{diatom}$) provides valuable information for palaeoclimate studies where carbonate proxies are either rare or absent in lake and ocean sediments. Unfortunately, mineral and rock fragments found alongside diatoms in most sediments can be problematic as the method used liberates oxygen from all components within the sediment, producing both high-frequency noise and low-frequency excursions that can resemble climate signals. Removal of contaminants used to rely on the combination of chemical leaching and physical separation techniques (e.g. sieving, density). This combination can be inefficient however, and often significant proportions of contaminants are still present in 'purified' diatom samples. Using electron optical imaging and X-ray fluorescence spectrometry on previously 'purified' diatom samples, we have developed a mass balance approach to identify the types and proportions of residual contaminants. By integrating this information with measured oxygen isotope ratios of the contaminants, it is then possible to remove contamination effects from the $\delta^{18}O_{diatom}$ record (Brewer *et al.* 2008; Wilson *et al.* 2014a). In this talk we will present palaeoenvironmental records of hydrological variability extracted from tectonic rift lake sediments in southern Siberia (Lake Baikal) and East Africa (Baringo-Bogoria basin). Each record is based on re-modelled $\delta^{18}O_{diatom}$values of diatom silica ($\delta^{18}O_{modelled}$), where the residual contaminants are identified and compensated for.

We will first of all present records of hydrological variability for both the Late Glacial–Holocene and the Last Interglacial periods in southern Siberia (Mackay *et al.* 2011; Mackay *et al.* 2013). $\delta^{18}O_{modelled}$interpretations are based on the balance between rivers with high $\delta^{18}O$ values, and rivers with low $\delta^{18}O$ values. Isotopic variability is related to latitudinal differences in precipitation which feed these rivers. The $\delta^{18}O_{modelled}$record suggests that rather moist conditions prevailed in southern Siberia during the latter stages of the Younger Dryas. Throughout the Holocene, episodes of low $\delta^{18}O_{modelled}$values are, in general, in good agreement with increases in percentage haematite-stained grains in North Atlantic sediments (indicative of ice-rafted debris events and changing patterns in Atlantic meridional overturning circulation (AMOC). Rivers with southerly catchments dominate fluvial input especially between *c.* 3.3 and 2 cal ka BP, concurrent with high precipitation in the Lake Baikal region. Last Interglacial (127.5–115 ka BP) $\delta^{18}O_{modelled}$ records of hydrological variability show that peak rain-fed discharge occurred *c.* 125.4 ka BP, shortly after July insolation maximum and initiation of Siberian soil development. Between 127 and 119.7 ka BP there are six marked fluctuations in $\delta^{18}O_{modelled}$ values, with a pacing of approximately 1.26 ± 0.3 ka, similar to fluctuations of within-lake productivity. Fluctuations in $\delta^{18}O_{modelled}$ values show good agreement with patterns in AMOC, indicative of strong teleconnections via the Westerlies between the North Atlantic and central Asia. We also compare variability in $\delta^{18}O_{modelled}$ values between the Last Interglacial and the Holocene from Lake Baikal sediments. Millennial-scale variability was significantly more stable during the Last Interglacial, possibly linked to diminished influence of freshwater discharge on AMOC during periods of higher, global mean temperatures.

Finally we present an analysis of Barsemoi diatomites from the East African Rift Valley which contain more than one source of contaminants (tephra and clay). In the Baringo-Bogoria basin, the well-dated sequence of diatomites and fluviolacustrine sediments documents the precessionally forced cycling of an extensive lake system between 2.70 Ma and 2.55 Ma. Here we employed multivariate analyses to develop a three end-member model to successfully resolve climate-driven changes in $\delta^{18}O_{modelled}$ in one of these diatomite sequences (Wilson *et al.* 2014a). $\delta^{18}O_{modelled}$ suggests a rapid onset and gradual decline of deepwater lake conditions, which exhibited millennial-scale cyclicity of ~1400–1700 yr, similar to late Quaternary Dansgaard-Oeschger events (Wilson *et al.* 2014b). These cycles are

thought to reflect enhanced precipitation coincident with increased monsoonal strength, suggesting the existence of a teleconnection between the high latitudes and East Africa during this period.

REFERENCES

BREWER, T.S., LENG, M.J., MACKAY, A.W., LAMB, A.L., TYLER, J.J. & MARSH, N.G. 2008. Unravelling contamination signals in biogenic silica oxygen isotope composition: the role of major and trace element geochemistry. *Journal of Quaternary Science* **23**, 321–330.

MACKAY, A.W., SWANN, G.E.A., BREWER, T.S., LENG, M.J., MORLEY, D.W., PIOTROWSKA, N., RIOUAL, P. & WHITE, D. 2011. A reassessment of late glacial–Holocene diatom oxygen isotope record from Lake Baikal using a geochemical mass-balance approach. *Journal of Quaternary Science* **26**, 627–634.

MACKAY, A.W., SWANN, G.E.A., FAGEL, N., FIETZ, S., LENG, M.J., MORLEY, D.W., RIOUAL, P. & TARASOV, P. 2013. Hydrological instability during the last interglacial in central Asia: a new diatom oxygen isotope record from Lake Baikal. *Quaternary Science Reviews* **66**, 45–54.

WILSON, K.E., LENG, M.J., MACKAY, A.W. 2014A. The use of multivariate statistics to resolve multiple contamination signals in the oxygen isotope analysis of biogenic silica. *Journal of Quaternary Science* **29**, 641–649.

WILSON, K.E., MASLIN, M.A., LENG, M.J., KINGSTON, J.D., DEINO, A.L., EDGAR, R.K. & MACKAY, A.W. 2014b. East African lake evidence for Pliocene millennial-scale climate variability. *Geology* **42**, 955–958.

Conference Abstracts

Holocene charcoal from Stratum 4 at Wonderwerk Cave, South Africa

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Wonderwerk Cave in the Kuruman Hills, Northern Cape Province, is an almost horizontal cavity in dolomite, about 140 m long, 11–26 m wide and 3–7 m high. The sediments in the cave preserve an almost continuous record of the last two million years and the cave has been occupied almost until the present day. It was first excavated in 1940 by B.D. Malan. From 1978 to 1996 Peter Beaumont carried out seven excavations in the cave but it is Excavation 1, near the stalagmite at the entrance of the cave, that is the focus of the current research project led by Profs Michael Chazan and Liora Kolska Horwitz (Horwitz & Chazan 2015). Francis and Anne Thackeray were instrumental in extracting most of the Holocene charcoal samples when they excavated the fauna from Excavation 1 (Thackeray 1983).

Archaeological excavations were done in squares and descending downwards and recofreded as strata based on the lithic artefacts recovered. Dense strata were subdivided into spits by various researchers. Charcoal and plant fragments have been recovered from the much older Oldowan layers (Strata 12 and 11), the Acheulean layers (9–5) where there is the first evidence of the controlled use of fire (Berna *et al.* 2012). The Holocene layers (strata 4–1) are extremely rich in charcoal and this is a preliminary report on the diversity of wood taxa represented by charcoals in Stratum 4.

Stratum 4 has been subdivided into eight sublayers. These have been variously dated but the most recent dates based on ostrich eggshell indicate a range in age from 10 550–12 200 cal yr BP at the base to 4300–5070 cal yr BP at the top (stable light isotopes, Lee-Thorp & Ecker 2015) and so represents a maximum length of time of about 7000 years. From proxy data from Wonderwerk the early and mid Holocene were moister than today and possibly because of increased summer rainfall (Horwitz & Chazan 2015). Pollen data from Tswaing, also Savanna biome but some 600 km to the northeast, also shows a wetter climate than today. By comparing the climate tolerances of the same modern species with the charcoal species identified it is possible to reconstruct the past climate.

Less than 5% of the charcoal samples have been studied to date but the common species that have been recognized so far are *Searsia lancea* (Anacardiaceae; karee), *Heteromorpha arborescens* (Apiaceae, parsley tree), *Ochna pulchra* (Ochnaceae, peeling bark ochna) and *Vitex mombassae* (Lamiaceae, smelly-berry fingerleaf). All except the last species are small trees with a widespread distribution in southern Africa, growing in a range of altitudes and soils and often associated with woodland, bushland and riverine habitats. *Vitex mombassae* occurs today in Mozambique and Zimbabwe but several other species occur in the Wonderwerk environs today. These Holocene woods indicate a moister environment than occurs in the Wonderwerk environs today. Only *Searsia lancea* occurs in the immediate environment today and was recorded from the underlying Stratum 5 (Bamford 2015) which implies that it is has a wide range of climate tolerance and is also a useful fuel wood. Other woods from Stratum 5 indicated that the climate was slightly wetter than today, and the preliminary complement from Stratum 4 indicate that the climate was even wetter than Stratum 5 times.

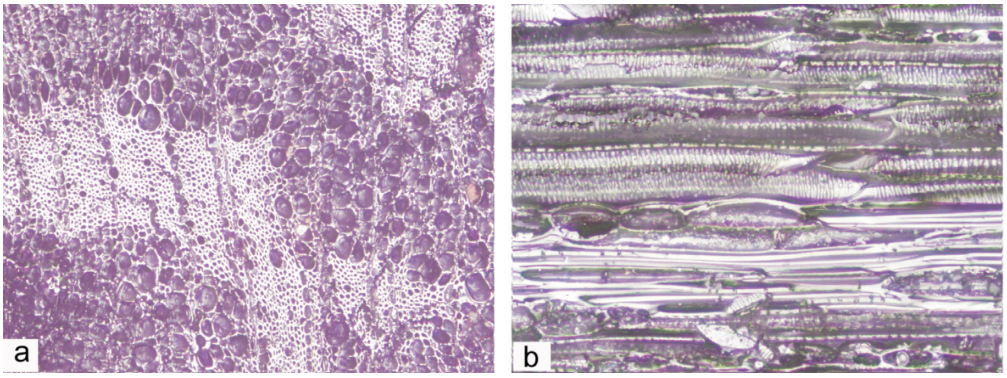


Figure 1. Photomicrographs of charcoal from Stratum 4d, sample M28-0-5cm-B, *Heteromorpha arborescens*. **a**, transverse section showing clustered vessels in a dendritic arrangement; **b**, tangential longitudinal section showing tracheids with spiral thickenings and uniseriate rays.

REFERENCES

BAMFORD,M.K. 2015. Charcoal from pre-Holocene Stratum 5, Wonderwerk Cave, South Africa. *Palaeoecology of Africa* **33**, 153–174.

BERNA, F., GOLDBERG, P., HORWITZ, L.K., BRINK, J., HOLT, S, BAMFORD, M. & CHAZAN, M., 2012, Microstratigraphic evidence for in situ fire in the Acheulean strata of Wonderwerk Cave, Northern Cape Province, South Africa. *PNAS Plus* **9**(20), E1215–E1220. DOI: 10/1073/pnas.1117620109

HORWITZ, L.K. & CHAZAN, M. 2015. Past and present at Wonderwerk Cave (Northern Cape Province, South Africa). *African Archaeological Review* **32**, 595–612.
LEE-THORP, J. & ECKER, M. 2015. Holocene environmental change at Wonderwerk Cave, South Africa: insights from stable light isotopes in ostrich egg shell. *African Archaeological Review* **32**, 795–811.
THACKERAY, A.I. 1983, Archaeological sites in the Kuruman Hills area. **In**: Humphries, A.J.B. & Thackeray, A.I. (eds), *Ghaap and Gariep. Later Stone Age Studies in the Northern Cape*, 33–47. Cape Town, South African Archaeological Society.

Rationalization of the Quaternary regolith depicted on the published 1:250 000 geological series maps covering South Africa

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Over a century of geological mapping by the former Geological Survey and the Council for Geoscience has produced seventy one, 1:250 000 geological series maps that depict lithostratigraphic and lithological units across South Africa. An assessment of the Cenozoic units on these map legends shows that both lithostratigraphic principles and lithological characterization has been used to portray regolith stratigraphic relationships. The focus of regional geological mapping has been to extrapolate bedrock lithostratigraphy without adequate attention to accurate characterization or mapping of the Cenozoic cover sediments and duricrusts. The lack of a systematic approach to regolith stratigraphy results in duplication of units and introduction of 'soil' cover onto maps in an unwarranted geological context. The lithostratigraphic framework for Cenozoic deposits was compiled by SACS (1980) with short descriptions of units included in the SACS (1994, 1998) stratigraphic lexicons. Formalization of Cenozoic lithostratigraphy has focused on the well-researched and mapped coastal plain deposits of the Algoa, Bredasdorp, Maputaland and Sandveld Groups (Roberts *et al.* 2006). Diverse Cenozoic regolith in the interior regions has been summarized by Partridge *et al.* (2006).

Compilation of the 1:250 000 geological map data to create a digital 'seamless' coverage has revealed the multiplicity of descriptions and diverse lithological combinations in commonly depicted sedimentary units such as alluvium, colluvium, calcrete, aeolian sand and mass movement deposits. Many of the Quaternary sediment types are associated with characteristic depositional structures or geomorphic landforms that have not been adequately represented on geological maps. A review of sites described in published literature is being undertaken to identify localities that can be used as representative type sites for the extrapolation and correlation of lithological and lithostratigraphic units across the 'seamless' digital 1:250 000 sheet coverage.

Due to the long periods associated with landscape formation and degradation and the localized preservation of ancient landsurface remnants, coupled with the dramatic terrain morphological and climate gradients across the diverse geology of South Africa, reliable correlation of remnant regolith units can only be achieved within limited areas. Given the close relationship between landforms or terrain morphology, climatic regime and regolith types it is likely that 'geomorphic province' delineation can be used to constrain the stratigraphic context of regolith across a similar range of bedrock geology, terrain and

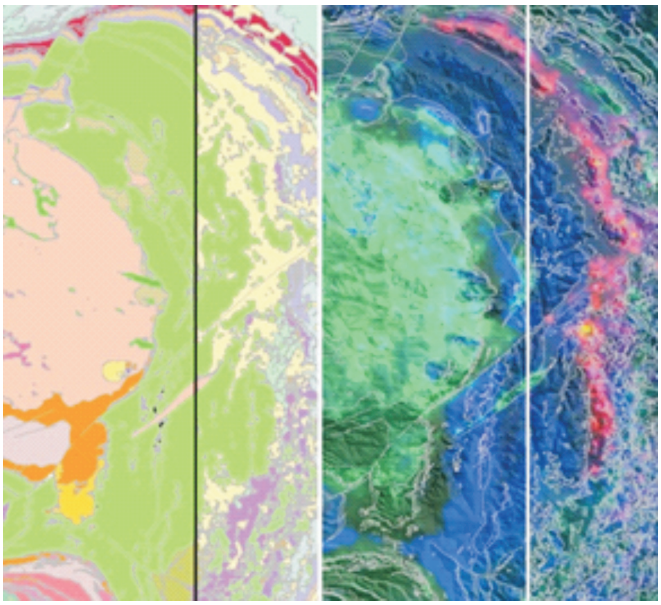


Figure 1. Compilation of adjacent geological map sheet data (left) showing different levels of representation of undifferentiated Quaternary sediments at the border between sheets 2428 Nylstroom and 2430 Pilgrim's Rest, compared with annotated satellite imagery of the same area (right) (after M. Brynard).

climatic conditions. The sparse distribution of reliably dated deposits limits the chronostratigraphic correlation of regolith across the interior regions of the country.

The rationalization process being undertaken by the authors involves comparison of mapped regolith polygons with digital satellite imagery that facilitates the identification of localities to be checked in the field along traverses across map sheets. Initial assessments have confirmed that representation of Quaternary cover is generally limited by the map scale which has resulted in 'lumping' of different sediments and depositional contexts. Sheetwash colluvial hillslope deposits and valley alluvium are not differentiated and raised alluvial terraces not adequately delineated. Representation of extensive pedogenic calcrete in the northern Karoo and Kalahari regions does not distinguish cementation of weathered bedrock and transported sediment host materials. The aeolian sand of the interior and coastal plains need to be better defined, particularly where extensive older, pedogenically modified aeolian sand sheet cover lacks dune depositional structures (cover sands). Recent mapping of landslides and widespread rockfall deposits must be incorporated on the digital maps. Representation of valley fill and hillslope colluvial accumulations tends to depict the extent of widespread gully erosion features rather than accurately delineate the infilled colluvial hollows. Differences in mapping regolith become apparent when the arid western parts and wetter eastern regions are compared. Thick bedrock weathering profiles or ferruginous duricrusts in the eastern hinterland are generally not mapped whereas thin surficial sediment cover is depicted as concealing bedrock over large parts of the northern and northwestern parts of South Africa.

In the past the publication of geological maps aimed to support mineral exploration and associated mining development across the country. However, the rationalization of Cenozoic regolith is essential in order to develop geological maps that better support applied geoscience in the spheres of natural geohazards, geotechnical problems, environmental degradation and agriculture as well as to aid mineral exploration beneath surficial cover.

REFERENCES

PARTRIDGE, T.C., BOTHA, G.A. & HADDON, I.G. 2006. Cenozoic deposits of the interior. **In**: Johnson, M.R., Anhaeusser, C.R., Thomas, R.J. (eds), *Textbook of South African Geology*, 585–604. Pretoria, Geological Society of South Africa and Council for Geoscience.

ROBERTS, D.L., BOTHA, G.A., MAUD, R.R. & PETHER, J. 2006. The coastal Cenozoic deposits. **In**: Johnson, M.R., Anhaeusser, C.R., Thomas, R.J. (eds), *Textbook of South African Geology*, 605–628. Pretoria, Geological Society of South Africa and Council for Geoscience.

SOUTH AFRICAN COMMITTEE FOR STRATIGRAPHY (SACS), 1980. *Stratigraphy of South Africa. Part 1. Handbook 8*, 603–628. Pretoria, Geological Survey.

SOUTH AFRICAN COMMITTEE FOR STRATIGRAPHY (SACS), 1994. *Lexicon of South African Stratigraphy, Part 1: Phanerozoic Units*. Pretoria, Council for Geoscience. 56 pp.

SOUTH AFRICAN COMMITTEE FOR STRATIGRAPHY (SACS), 1998. *Abridged Lexicon of South African Stratigraphy.* Pretoria, Council for Geoscience. 160 pp.

Reconstructing the palaeo-Agulhas Plain: clues from the continental shelf

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The South African continental shelf and low relief coastal plain comprise the submerged and emergent portions of a continuous feature, the degree of separation being dependent upon the relative sea level at any given time (Cawthra *et al.* 2015). This shelf varies considerably in width from the narrow sheared east coast margin to the broad passive margin of the south and west coasts. The resultant response in depositional systems contrasts accordingly and this is shown in the marine geophysical record.

Considering the magnitude of Quaternary sea-level fluctuations and the associated duration of glacials and interglacials, a vast proportion of these marine isotope stages have been dominated by lowered relative sea levels compared to the modern elevation. In this study, we examine the continental shelf, which can be considered key in understanding the palaeoenvironments when it was exposed as a vast coastal plain and in the aim to understand the transition from glacial to interglacial periods (Marean *et al.* 2014). Pleistocene sea-level fluctuations have repeatedly exposed the continental shelf and during the archaeological occupation of southern South Africa, and sea level was lower than the present for approximately 90% of this time with an associated coast of up to 95 km distant (Fisher *et al.* 2010).

The shoreline is a geologically, sedimentologically, climatically and biologically complex zone and Quaternary deposits preserved on mid-latitude coastlines have long been studied as indicators of past sea levels. With the rapid advancement in marine geophysical and hydrographic techniques, however, margin successions can be used to decipher sea-level changes and these deposits are increasingly being

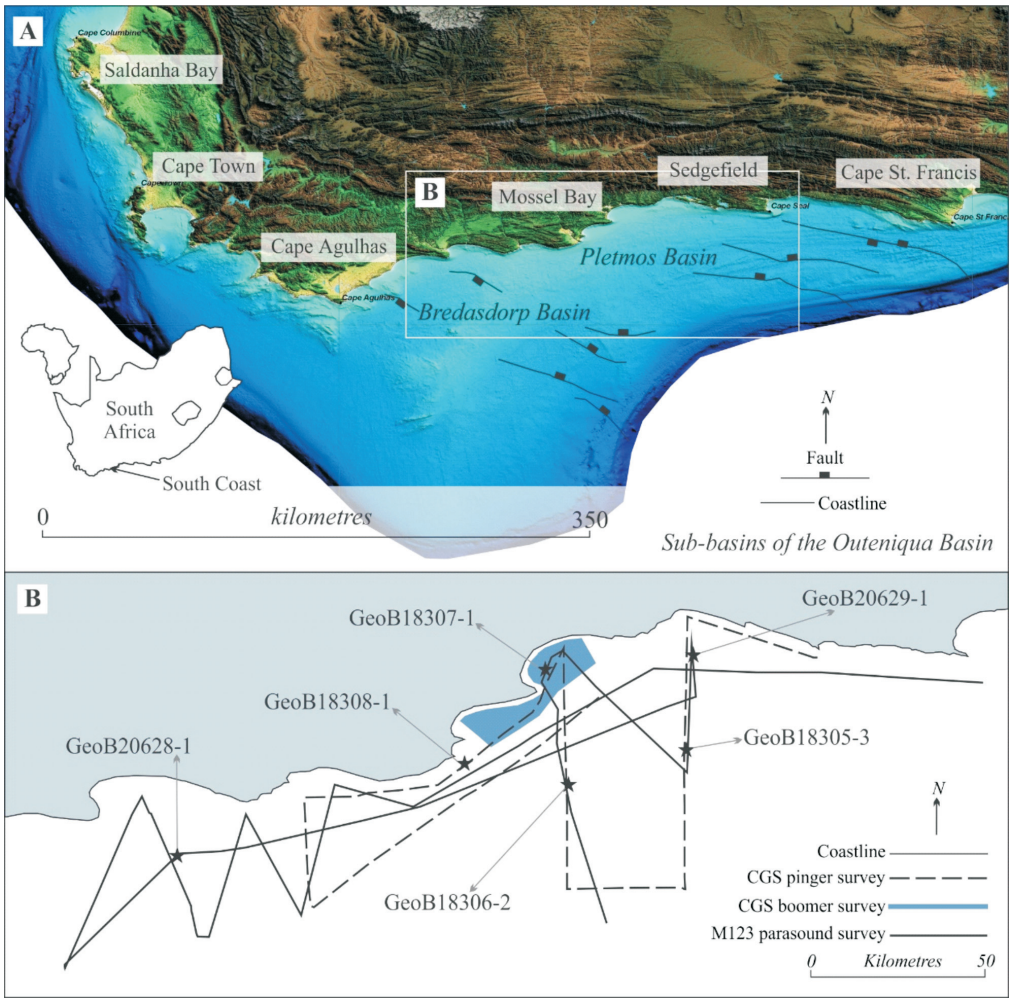


Figure 1. The focus of most of our work is centred on the southern coastal plain of South Africa. A series of geophysical and geological surveys have been carried out, including four seismic surveys, one hydrographic survey and three sampling expeditions (coring from the research vessel R/V Meteor, scuba diving offshore of the Great Brak River). The base bathymetry shown here is from de Wet (2013).

mapped and studied on continental shelves. We show that this relatively narrow littoral zone band migrates with falling sea levels onto what is now the continental shelf. Although the rate of erosion in the marine environment is typically high, preservation of fragments of palaeoshorelines in the offshore record allows a window of opportunity to map and unravel the sequence of events associated with sea-level regressions and subsequent transgressions. The shoreline/littoral zone region consists of numerous geomorphic features (clastic facies of dunes and beaches, lower energy back-barrier deposits, lacustrine deposits and estuarine deposits and the intertidal zone) and these are all preserved on the South African shelf. In addition, fluvial systems drain into the ocean basins at the shoreline. These features have been mapped on the south and east coasts using ultra-high-resolution marine geophysical instrument. In some cases we have 'ground-truthed' these deposits and sampled them by scuba diving, or they have been cored off the research vessel Meteor (e.g. Hahn *et al.*, under review). These offshore samples obtained from palaeocoastlines and within drowned river valleys have been dated by Optically Stimulated Luminescence and Radiocarbon techniques and we show that they extend in time from Marine Isotope Stage 7 (~250 000 years) to the present. They have been critically examined through sedimentary and geochemical analyses for fluctuations in rates of sea-level change, differences in sea-surface temperature, and a careful correlation to seismic stratigraphy. The relevance of these studies to Quaternary palaeoenvironments is demonstrated here through a South Coast case study. This work broadly presents a contribution to the knowledge on sea-level change from a South African perspective; the role of sedimentological deposits used in palaeoclimatic and palaeoenvironmental reconstructions; and the impact of a changing shoreline on our early *Homo sapiens* ancestors through time.

REFERENCES

CAWTHRA, H.C., COMPTON, J.S., FISHER, E. C., MACHUTCHON, M.R., MAREAN, C.W. 2015. Submerged terrestrial landscape features off the South African south coast. **In**: Harff, J., Bailey, G. & Lüth F. (eds), *Geology and Archaeology: Submerged Landscapes of the Continental Shelf,* 219–233. Special Publication of the Geological Society of London 411.

DE WET, W. 2013. *Bathymetry of the South African continental shelf.* Unpublished M.Sc. thesis, University of Cape Town, Cape Town.

FISHER, E.C., BAR-MATTHEWS, M., JERARDINO, A. & MAREAN, C.W. 2010. Middle and Late Pleistocene Paleoscape modeling along the southern coast of South Africa. *Quaternary Science Reviews* **29**, 1382–1398.
HAHN, A., ANDO, S., CAWTHRA, H.C., FRENZEL, P., KUGEL, M., MESCHNER, S., MOLLENHAUER, G., SEHEFUSS, E. & ZABEL, M. Under review. Environmental conditions and sea-surface temperature fluctuations during the Late Holocene in southernmost South Africa. Submitted October 2016 to the journal *Climate of the Past*.
MAREAN, C.W., CAWTHRA, H.C., COWLING, R.M., ESLER, K.J., FISHER, E.C., MILEWSKI, A., POTTS, A.J., SINGELS, E. & DE VYNCK, J. 2014. Stone Age People in a changing South African Greater Cape Floristic Region. **In**: Allsopp, N., Colville, J.F., Verboom, T. (eds), *Ecology and Evolution of Fynbos: Understanding Megadiversity*, 164–199. Oxford, Oxford University Press.

Palaeoshoreline depositional history from MIS 6 (Termination II) to MIS 3 on the southern margin of South Africa

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The major southern hemisphere landmasses ('far-field' locations) are important for understanding sea-level changes and offer the opportunity to reconstruct long-term eustatic sea-level fluctuations where tectonic stability can be demonstrated (Woodroffe & Horton 2005) and as a result, Pleistocene deposits on mid-latitude coastlines are useful indicators of past sea levels. Here, we describe a succession of subaerial to submerged Pleistocene deposits along the South African South Coast. The submerged units transect and sample a once exposed palaeoecosystem (the Palaeo-Agulhas Plain) and, thus, provide a window on this now submerged ecosystem. Palaeoshoreline deposits in this study comprise both palaeodunes and palaeobeaches extending to water depths of up to 55 m on the mid-shelf. Five sedimentary facies were identified and correlated to modern depositional environments of Mossel Bay, which include dune, upper shoreface, foreshore, intertidal swash and back-barrier settings. The stratigraphy and chronology of the succession preserves a record of initial deposition during Termination II (T-II) meltwater events preceding and leading to marine isotope stage (MIS) 5e, during multiple regressions between MIS 5d and MIS 4, and deposition at the end of MIS 4 and commencement of MIS 3, which is marked by Heinrich Event 6 (H6). Optically stimulated luminescence (OSL) ages obtained for ten samples from the raised deposits all form a single cluster of ages and compare to the stratigraphy of Carr *et al.* (2010). The lowermost and oldest dune unit date to 131 ± 7 ka. The ages obtained for the rest of the raised deposits, all dated to between 121 ± 7 ka and 118 ± 7 ka, suggest a rapid sequence of deposition during MIS 5e. The ages obtained for 12 samples from the submerged deposits (Cawthra *et al.* 2015) show a much longer time-span

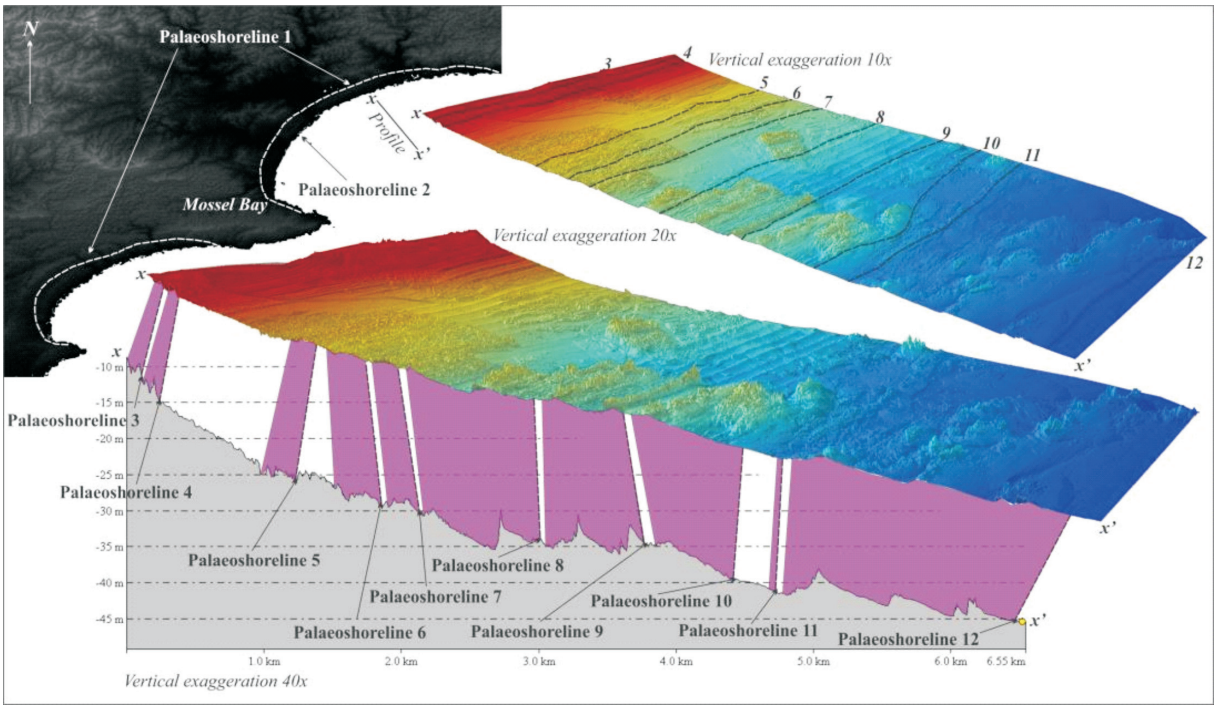


Figure 1. Bathymetry profile reveals 12 major palaeoshorelines, extending from the onshore (1) to the mid-shelf (12).

and form five discrete age clusters dating to ~130, ~110–115 (MIS 5c), ~95, ~80 and ~60 ka. Both regressive and transgressive depositional cycles are well preserved in the succession. The chronology and geological mapping indicates two highstands during MIS 5e at heights of 6.3 and 6.8 m above present-day mean sea level (MSL). In this study, we propose that sediments in this region, and other regions globally in similar settings, are deposited and preserved either during times of rapid sea-level movement, or oscillation around stadials and interstadials. Periods of relatively slow average rise or fall of sea level are represented by erosional planation surfaces.

REFERENCES

CARR, A.S., BATEMAN, M.D., ROBERTS, D.L., MURRAY-WALLACE, C.V., JACOBS, Z. & HOLMES, P.J. 2010. The last interglacial sea-level high stand on the southern Cape coastline of South Africa. *Quaternary Research* **73**, 351–363.

CAWTHRA, H.C., COMPTON, J.S., FISHER, E.C., MACHUTCHON, M.R. & MAREAN, C.W. 2015. Submerged terrestrial landscape features off the South African south coast. **In**: Harff, J., Bailey, G.& Lüth F. (eds), *Geology and Archaeology: Submerged Landscapes of the Continental Shelf*, 219–233. Special Publication of the Geological Society of London 411.

WOODROFFE, S.A. & HORTON, B.P. 2005. Holocene sea-level changes in the Indo-Pacific. *Journal of Asian Earth Sciences* **25**(1), 29–43.

Late-Quaternary pollen inferred environments of Ntsikeni Wetland, KwaZulu-Natal, South Africa

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Wetlands are considered great palynological archives. Pollen does not preserve well in dry oxidizing conditions but preserves better in wetter climates (Scott *et al.* 2012; Fitchett *et al.* 2016). The Ntsikeni wetland, KwaZulu-Natal, is one of the largest high altitude (~1700 m asl) wetlands in southern Africa, and is still relatively undisturbed. It was declared a Ramsar site in February 2010 and has little alteration to its hydrological and ecological character, therefore providing good potential for microfossil preservation. As the fossil pollen records assist with data on past climate and climate change it warrants investigation into the record's genesis and development.

A total of 81 samples were obtained from a 300 cm deep core, extracted from Ntsikeni wetland using a Russian corer in 2015. Five radiocarbon AMS dates were obtained, constraining the profile to 25 000 cal yr BP to present. A total of 34 pollen taxa were identified, with 27 occurring at a frequency of greater than 2% throughout the core. Using CONISS (Constrained Incremental Sum of Squares) four distinct pollen zones were identified: NT4 from 300 cm to194 cm (~25 000–13 100 cal yr BP); NT3 from 192 cm to 161 cm (~13 000–10 800 cal yr BP); NT2 from 140 cm–84 cm (~9 000–4300 cal yr BP); and NT1 from 82 cm–30 cm (~4200–650 cal yr BP). Principal component analysis was used as the primary ordination method to determine trends in the data. Principal component two accounts for 16.07% of the variability in the pollen distribution, and distinctly separates semi-aquatic and wetland species, with negative scores from dry-climate taxa including grass and succulents with high positive scores. The palaeoenvironmental reconstruction identifies periods of change between wetness and dryness throughout all four zones, based on the key species for principle component two. There are also indications of change in temperature based on the fluctuating amount of taxa present during the different zones as species diversity increases with temperatures as conditions become more tolerable.

Within zone NT4 there are fluctuations between wetter and dryer periods, as denoted by the change in relative abundance of Cyperaceae *versus* Poaceae. From ~25 000–20 000 cal yr BP there is a change from wet to dry, followed by a wet period from 19 000–17 000 cal yr BP, which is once again followed by a dry period ~27 000–15 000 cal yr BP. Towards the top of NT4 the conditions become wet again from

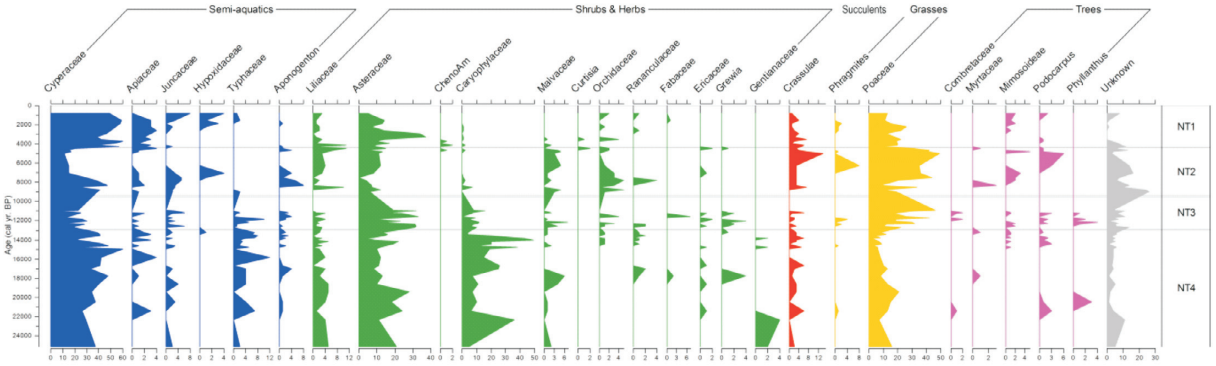


Figure 1. Pollen diagram for Ntsikeni Wetland illustrating environmental variability throughout past ~25 000 cal yr BP.

~14,900–13,100 cal yr BP. The relative abundance of Poaceae in NT3 indicates a dry period from ~13 000–9000 cal yr BP, whereas NT2 has two different periods, the first from ~9100–8500 cal yr BP indicating a wet period then from ~8,400–4,300 cal yr BP, illustrating dryer conditions. The final zone, NT1, primarily indicates wetter conditions for the entire time frame as principal component two species, semi-aquatic plants, increase in average abundance.

The study indicates notable similarities with the nearby Mahwaqa Drakensberg site nearby (Neumann *et al.* 2014), especially in terms of pollen zonation and the indicator species present at key time intervals (Scott & Nyakale 2002). As one of the few continuous pollen records which spans both the Holocene-Pleistocene boundary and the Last Glacial Maximum, this study presents a key piece in the southern African late Quaternary puzzle.

ACKNOWLEDGEMENTS

We would like to thank The Palaeontological Scientific Trust (PAST), Johannesburg, South Africa, for the financial support to attend SASQUA 2017 conference.

REFERENCES

FITCHETT, J.M., MACKAY, A.W., GRAB, S.W.& BAMFORD, M.K. 2016. Holocene climatic variability indicated by a multi-proxy record from southern Africa's highest wetland. *The Holocene*. DOI: 0959683616670467.

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**, 665–681.

SCOTT, L.& NYAKALE, M. 2002. Pollen indications of Holocene palaeoenvironments at Florisbad spring in the central Free State, South Africa. *The Holocene* **12**, 497–503.

SCOTT, L., NEUMANN, F.H., BROOK, G.A., BOUSMAN, C.B., NORSTRÖM, E. & METWALLY, A. 2012. Terrestrial fossil-pollen evidence of climate change during the last 26 thousand years in southern Africa. *Quaternary Science Reviews* **32**, 100–118.

MIS6 to MIS3 environmental change on the south coast of South Africa as indicated by phytolith analysis at Pinnacle Point

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The south coast of South Africa has received continuous investigation of its palaeoclimatic, palaeoenvironmental and palaeoanthropological history for a variety of reasons. Three climatic zones are present in southern Africa: the western winter rainfall zone (WRZ), eastern summer rainfall zone (SRZ) and wedged in between there is the all-year rainfall zone (YRZ). This rainfall seasonality is responsible for the grass photosynthetic pathway distribution resulting in C_3 grasses dominating in the WRZ and C_4 grasses dominating in the SRZ, while the YRZ present a mix of C_3 and C_4 grasses. These zones have shifted, however, because of the variations in the Inter-Tropical Convergence Zone (ITCZ) to a greater or lesser extent. These climatic shifts might have affected the distribution of plant resources and, therefore, human distribution. The south coast of South Africa is located in the Greater Cape Floristic Region, the world's most diverse extratropical flora, both in terms of richness and endemism. It is also an important geographical location for paleaoanthropological research focused on the origins and evolution of modern humans and the appearance of a modern human behaviour in relation to the climatic and environmental changes occurring during the Middle and Late Pleistocene in South Africa. These changes on climate conditions might have also affected the distribution of vegetation types and biomes and therefore might have influenced the availability of vegetal resources for past hunter-gatherers (Marean *et al.* 2014).

The archaeological complex of Pinnacle Point (PP), in Mossel Bay, is formed by a series of coastal caves and rock-shelters with human occupations since the Middle Stone Age. The work presented here uses phytoliths – amorphous silica particles that formed in epidermal cells of plants – from the archaeological deposits of two sites at PP, cave 13B (PP13B) (Albert & Marean 2012) and site 5-6 (PP5-6), to investigate environmental changes at the centre south coast of South Africa during the Middle and Late Pleistocene (marine isotope stage – MIS 6 to MIS 3). One-way ANOVA and a *post hoc* Tukey honest significant differences (HSD) tests were performed on the dataset in order to identify specificities in the distribution of plant types, grass photosynthetic pathways through GSSCs and phytolith indices between StratAggs from PP13B and PP5-6. The phytolith results were later compared to other palaeo-archives available from the south coast.

Phytoliths in the archaeological sediments of Pinnacle Point were interpreted as the product of both the

selection habits of people and the vegetation within the collection radius of the people inhabiting the site. And thus, the relative abundance of phytoliths must be considered a merged product of human behaviour and local vegetation.

The main outcome of this study is the big change observed in the record, where grasses were scarce in some stratigraphic aggregates (StratAggs) of PP13B, while they were abundant in most of the StratAggs from PP5-6. At first glance, this may seem indicative that between ~160–90 ka, grasses might have been less common in the immediate surroundings of Pinnacle Point, and that something significant changed in the environment such that after 90 ka grasses were regularly abundant in the immediate surroundings of the cave.

For the latter phases of MIS6 the speleothem and the micro- and macromammal PP records are suggestive of the presence of extensive grasslands in the now submerged Palaeo-Agulhas Plain (Rector & Reed 2010; Braun 2014). Conversely, this was not detected in the phytolith record, which was representative of the presence of some sort of shrubby vegetation occurring in the vicinity of PP13B and this might have been the area preferred for plant foraging practices by the inhabitants of PP during MIS6. The plant phytolith assemblage during MIS5 points towards a mosaic of habitats that might have occurred through time where fynbos, thicket/forests and some sort of vegetation with high grass content as could be grassy fynbos or renosterveld. During MIS4 the phytolith record at PP5-6 was indicative of the presence of a fynbos-thicket mosaic vegetation where C_3 grasses dominated although C_4 grasses were also well represented and this is also supported by other palaeo-archives recorded from the south coast (Bar-Matthews *et al.* 2010; Quick *et al.* 2014). Finally, despite only one sample dating to MIS3 was interpreted, the plant phytolith assemblage was similar to that recorded during MIS6, indicative of a shrubby/forest vegetation occurring in the vicinity of Pinnacle Point.

In conclusion, the changes observed in the phytolith record from Pinnacle Point deposits might be indicative of vegetation movements according to climate changes and sea-level fluctuations, in a continuous regional mosaic of habitats.

REFERENCES

BAR-MATTHEWS, M., MAREAN, C.W., JACOBS, Z., KARKANAS, P., FISHER, E.C., HERRIES, A.I.R., BROWN, K., WILLIAMS, H.M., BERNATCHEZ, J., AYALON, A. & NILSSEN, P.J. 2010. A high resolution and continuous isotopic speleothem record of paleoclimate and paleoenvironment from 90 to 53 ka from Pinnacle point on the south coast of South Africa. *Quaternary Science Review* **29**, 2131–2145.

BRAUN, K. 2014. *Influence of the Agulhas Current on the Terrestrial Climate of South Africa as Derived from Speleothems. GSI/26/201*, Jerusalem, Geological Survey of Israel.

MAREAN, C.W., CAWTHRA , H.C., COWLING, R.M., ESLER, K.J., FISHER, E., MILEWSKI, A., POTTS, A.J., SINGELS, E. & DE VYNCK, J. 2014. Stone age people in a changing South African Greater Cape Floristic Region. **In**: Allsopp, N., Colville, J.F. & Verboom, T. (eds), *Fynbos: Ecology, Evolution, and Conservation of a Megadiverse Region*, 164–199. Oxford, Oxford University Press.

QUICK, L.J., MEADOWS, M.E., BATEMAN, M.D., KIRSTEN, K.L., MÄUSBACHER, R., HABERZETTL, T. & CHASE, B.M. 2015. Vegetation and climate dynamics during the last glacial period in the fynbos-afrotemperate forest ecotone, southern Cape, South Africa. *Quaternary International* **404**, 136–149.

RECTOR, A. & REED, K. 2010. Middle and late Pleistocene faunas of Pinnacle Point and their paleoecological implications. *Journal of Human Evolution* **59**(3-4), 231–233.

Rain, disease and the death of a chief

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The natural environment is often regarded as a static backdrop against which the events of history play out, and yet within African belief systems drought and disease are symptoms of greater socio-political forces at play. In this study we consider how rainfall, malaria, African horse sickness and the importation of a Friesian bull from Holland contributed to the downfall of the Ndebele Chief Mugombane in 1854/55.

In the mid-19th century, the Kekana Ndebele under the leadership of Mugombane, occupied large tracts of land around Mokopane, Limpopo Province. The chief's capital lay about 7 km south of Mokopane, within an arid to semi-arid area at the northern extent of a large floodplain wetland (Tooth & McCarthy 2007). The wetland was formed, in part, through the discharge of sediment, from tributaries to the north of Mokopane, slowing and obstructing the river's flow (McCarthy *et al.* 2011). The wetland provided a measure of security by offering a reliable source of water and graze for livestock (Higgins *et al.* 1996). However, these resources made the area attractive to Dutch settlers (Boers), who repeatedly tried to appropriate the Kekana's land. In September 1854, in a coordinated act of resistance, the Ndebele, under chiefs Mugombane (Kekana) and Mapela (Langa) attacked a number of Boers after which the Kekana took refuge in a cave. The Boers retaliated and, after trying unsuccessfully to extricate the Kekana from the cave, placed them under siege (Esterhuysen *et al.* 2009).

The material evidence from the siege exposed a complex web of spiritual and physical relationships that played a role in the collapse of the Kekana Ndebele chiefdom. In this paper we show how Mugombane,

who survived the siege, was strategically invested in the ability of his diviners to portend and bring rain, because the onset of summer rains posed a threat to the Boers who had limited defence against horse sickness and malaria. Seasonally late rain however, occasioned an extended siege, and the death of thousands of Mugombane's followers. While the siege exposed the chief spiritually and economically, we further argue that the independent but coincident arrival of a Friesian bull carrying a virulent strain of contagious bovine pleuropnemonia (CBPP) in the Cape Colony in 1854 (Amanfu 2009), that spread northward rapidly, killing thousands of cattle, was the proverbial last straw that resulted in the chief being politically unseated through ritual suicide.

REFERENCES

AMANFU, W. 2009. Contagious bovine pleuropnemonia (lungsickness) in Africa. *Onderstepoort Journal of Veterinary Research* **76**, 13–17.

ESTERHUYSEN, A.B., SANDERS, V.M. & SMITH, J.M. 2009. Human skeletal and mummified remains from the AD1854 siege of Mugombane, Limpopo, South Africa. *Journal of Archaeological Science* **36**, 1038–1049.

HIGGINS, S.I., COETZEE, M.A.S., MARNEWECK, G.C. & ROGERS, K.H. 1996. The Nyl River floodplain, South Africa, as a functional unit of the landscape: a review of current information. *African Journal of Ecology* **34**, 131–145.

McCARTHY, T.S., TOOTH, S., JACOBS, J., ROWBERRY, M.D., THOMPSON, M., BRANDT, D., HANCOX, J., MARREN, P.M., WOODBORNE, S. & ELLERY, W.N. 2011. The origin and development of the Nyl River floodplain wetland, Limpopo Province, South Africa: trunk–tributary river interactions in a dryland setting. *South African Geographical Journal* **93**, 172–190.

TOOTH, S. & McCARTHY, T.S. 2007. Wetlands in drylands: geomorphological and sedimentological characteristics, with emphasis on examples from southern Africa. *Progress in Physical Geography* **31**, 3–41.

Accidental science: fossil pollen evidence to dispute the classification of *Chrysocoma ciliata* as an invasive in the eastern Lesotho Highlands

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Considerable academic discussion and policy development has surrounded the management of *Chrysocoma ciliata* L. (Asteraceae, syn. *C. tenufolia*) in the eastern Lesotho highlands. The necessity for the management of the population size and dispersion of this shrub species derives from its status as an invasive, presumed to have been introduced into the eastern Lesotho highlands region by cattle herders within the last century (Killick 1978; Grundling *et al.* 2015). Historical botanical records in Lesotho are scarce, so the origins of this species in the region are as yet uncertain. The classification as an invasive is based on the contemporary abundance of these shrubs in overgrazed areas throughout the highlands, and the rapid colonization of this species in degraded wetlands (Grab & Deschamps 2004). The species is confirmed to have existed within the arid Karoo region of South Africa throughout the late Quaternary, and is hypothesized to have been transported eastwards through the western Lesotho lowlands with the movement of cattle into the eastern Lesotho highlands for year-round grazing.

Fossil pollen records are seldom explored with the intention to dispute the status of a species as invasive: in most instances such findings occur by coincidence when a supposed invasive is found in material older than the proposed timing of introduction (Van Leeuwen *et al.* 2005). This study, initiated to reconstruct the Holocene palaeoenvironmental history of the Sani Pass region in eastern Lesotho, inadvertently uncovered evidence for the sporadic presence of *Chrysocoma ciliata* throughout the record spanning ~6000 cal yr BP to present (Fig. 1). In so doing, this record refutes claims that the species was introduced to the eastern

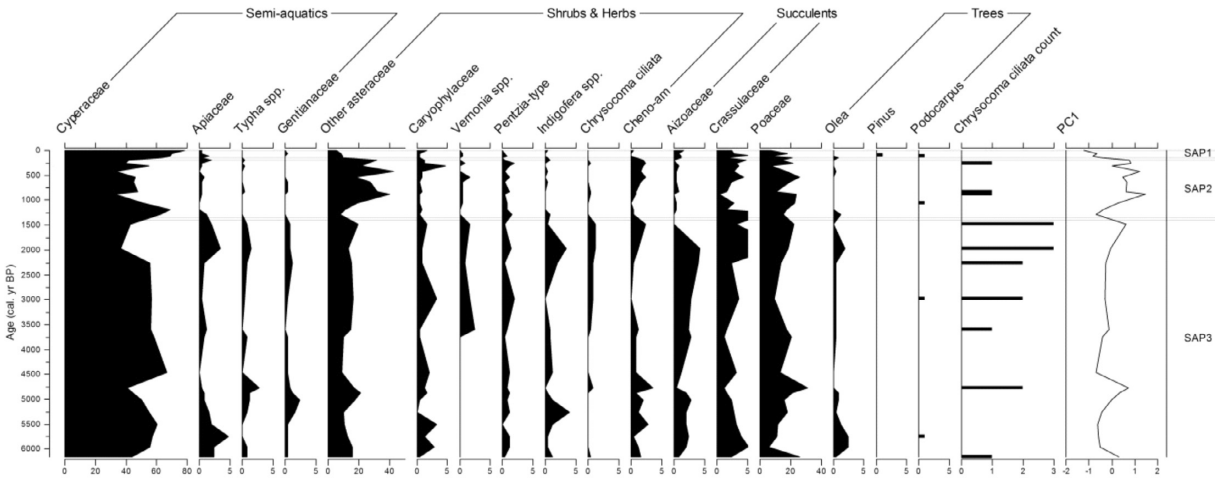


Figure 1. Pollen diagram for Sani Pass revealing the intermittent presence of *Chrysocoma ciliata* throughout the 6000 year record.

Lesotho highlands anthropogenically within the past 100 years, and the narrow definition of *Chrysocoma ciliata* as a Karoid invasive in Lesotho. The intermittent appearance of this species in the pollen record, however, indicates that it is climate sensitive, colonizing the wetlands under conditions unsuitable to other plant species. This has important applications for the environmental management policies pertaining to this species, as it evidently has been nested within the botanical community of the region for thousands of years.

Although proven not to have been anthropogenically introduced into the region within the last century, it remains possible that the species may have inadvertently been anthropogenically transported into the eastern Lesotho highlands at some point prior to 6000 cal yr BP. Archaeological evidence confirms Stone Age occupation dating to 80 000 yr BP, with considerable seasonal migration both within the eastern Lesotho Highlands, and to adjacent lower altitude sites in western Lesotho and South Africa (Carter 1976). Until it is possible to prove or dispute the presence of *Chrysocoma ciliata* in the fossil record prior to 80 000 yr BP, the species could tentatively be classified as an archaeophyte invasive. Such a title might well, however, then apply to many other species within the region, warranting considerable future efforts to identify and analyse temporally-continuous records for the region, sufficiently long to pre-date Stone Age occupation.

REFERENCES

CARTER, P. 1976. The effects of climatic change on settlement in eastern Lesotho during the Middle and Later Stone Age. *World Archaeology* **8**, 197–206.

GRAB, S.W. & DESCHAMPS, C.L. 2004. Geomorphological and geoecological controls and processes following gully development in alpine mires, Lesotho. *Arctic, Antarctic and Alpine Research* **36**(1), 49–58.

GRUNDLING, P.L., LINSTRÖM, A., FOKKEMA, W. & GROOTJANS, A.P. 2015. Mires in the Maluti Mountains of Lesotho. *Mires and Peat* **15**(9), 1–11.

KILLICK, D.J.B. 1978. Notes on the vegetation of the Sani Pass area of the southern Drakensberg. *Bothalia* **12**(3), 537–542.

VAN LEUUWEN, J.F.N., SCHÄFER, H., VAN DER KNAAP, W.O., RITTENOUR, T., BJÖRCK, S. & AMMANN, B. 2005. Native or introduced? Fossil pollen and spores may say. An example from the Azores Islands. *NEOBIOTA* **6**, 27–34.

Eastern South African provenance study: a toolbox for interpreting inorganic and organic marine *versus* terrestrial signals

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Major questions concerning the mechanisms controlling eastern South African climate still persist: both a synchrony with northern as well as southern hemispheric changes has been suggested along with a variety of factors controlling and interlinking eastern South African hydrology, climate and ocean circulation (Dupont *et al.* 2011; Schefuß *et al.* 2011; Ziegler *et al.* 2013; Simon *et al.* 2015). In order to understand

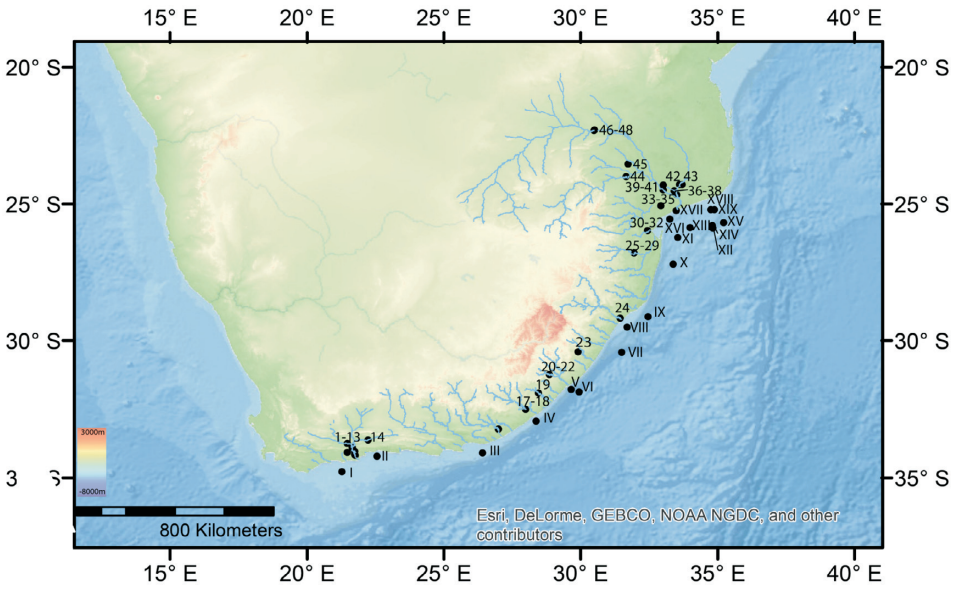


Figure 1. The topography and bathymetry of southern Africa as well as relevant drainage systems plotted with the sampling locations relevant to this study. Terrestrial sampling site are indicated with arabic numbers and marine core top locations with latin numbers.

these mechanisms efforts to retrieve suitable marine archives have recently intensified (e.g. Meteor cruise M102, M123 and IODP Exp.361). Additionally, a detailed understanding of the signals recorded by various proxies is needed to interpret these records adequately. For this purpose we have performed a source to sink study in which we compare the signals of various proxies (pollen, biomarkers, rock fragments and heavy minerals as well as bulk geochemistry) on recent samples of the continent to the marine realm. Riverine and surface marine samples were compared along the entire South African East coast extending towards the Limpopo River in southern Mozambique (Fig. 1). We observe a good correspondence in the suite of proxies encountered in the fluvial samples with their adjacent marine deposits. Nevertheless all proxy-indicators reflect variations in the onshore setting: Elemental and mineralogical composition reflect the catchment geology with a dominance of Cape and Karoo sedimentary rocks in the south and Transvaal Craton metamorphic and igneous rocks in the north. The Mediterranean and mountain shrubland vegetation (C3 vegetation) in the Cape and Drakensberg regions changes to a mixed C4/C3 signal further north in the subtropical grasslands/savanna and is reflected by leaf wax δ13C composition and pollen assemblages (Mucina & Rutherford 2006). Leaf wax δD signatures are indicative of increasing rainfall amounts towards the north from a subtropical into a tropical climate regime. Despite the influence of the strong Agulhas current along the studied shelf we detect a minimal change in the sedimentological, mineralogical, geochemical and palynological fingerprint from the terrestrial to the marine realm. Despite the evident differences in transport and depositional characteristics between proxies, we note a general comparability of all studied parameters. On a global scale, these findings may be relevant as basis for adequate proxy interpretation in marine archives.

REFERENCES

DUPONT, L.M., CALEY, T. KIM, J.H., CASTAÑEDA,I.. MALAIZÉ,B. & GIRAUDEAU, J. 2011. Glacial-interglacial vegetation dynamics in south eastern Africa coupled to sea surface temperature variations in the Western Indian Ocean. *Climate of the Past* **7**(4), 1209–1224.

MUCINA, L.& RUTHERFORD, M. 2006.*The Vegetation of South Africa, Lesoto and Swaziland. Strelitzia 19*. Pretoria, South African National Biodiversity Institute.

SIMON, M.H., ZIEGLER, M., BOSMANS, J., BARKER, S., REASON, C.J.C. & HALL, I.R. 2015. Eastern South African hydroclimate over the past 270,000 years. *Scientific Reports* **5**, 18153.

SCHEFUß, E., KUHLMANN, H., MOLLENHAUER,G., PRANGE, M.& PÄTZOLD, J. 2011. Forcing of wet phases in southeast Africa over the past 17,000 years. *Nature* **480**, 509–512.

ZIEGLER, M., SIMON, M.H., HALL, I.R., BARKER, S., STRINGER, C. & ZAHN, R. 2013. Development of Middle Stone Age innovation linked to rapid climate change. *Nature Communications* **4**, 1905.

Palaeoenviromental change and ochre use in the southern Cape during the Late Pleistocene

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Ochre assemblages provide a way to explore some of the behavioural and cognitive changes that took place during the Late Pleistocene – a time of significant behavioural developments, and important cognitive implications for *Homo sapiens* and Neanderthals. This study compares two important Middle Stone Age (MSA) sites on the southern Cape coast, Blombos Cave (100–72 ka) and Klipdrift Shelter (66–59 ka). Both sites contain large ochre assemblages, including ground, scraped and engraved ochre pieces (Henshilwood *et al.* 2001, 2014; Watts 2009). Notably, in the *c.* 100 ka levels at Blombos, ochre-processing kits were found (pictured), which demonstrate that people in the MSA were preparing and storing ochre-rich substances.

Ochre collection and use is ubiquitous at Middle Stone Age and Middle Palaeolithic sites. A wide range of artefacts associated with ochre are also found during the late Pleistocene: grindstones, shell beads, ochre paint and powder, worked bone and stone tools. These finds shed light on ways that ochre was processed and used in the past, but interpretations of how the powder was used and *why* ochre was processed are at times contentious. Ochre pieces bearing engraved 'designs' and the preferential use of bright-red and shiny (micaceous) ochre have resulted in symbolic interpretations of the uses of ochre. However, ochre has many functional applications. This makes ochre a useful tool with which to explore behavioural evolution that is closely linked with changing environments.

This study explores ochre collection and use at Blombos and Klipdrift in relation to environmental fluctuations. The two sites are 45 km apart and span a period of ~40 000 years. Palaeoenvironments possibly had a significant effect on social behaviour in the Late Pleistocene, influencing subsistence strategies and population density and could have influenced mobility around the landscape allowing or restricting access to raw materials (Ziegler *et al.* 2013). Faunal, speleothem and isotope data reflect significant fluctuations in vegetation, aridity, rainfall, and sea temperature over this time period (Roberts *et al.* 2016). We



Figure 1. Ochre-processing toolkit from *c.* 100 ka levels at Blombos Cave, southern Cape, South Africa (image: C. Henshilwood).

consider changes in the collection of ochre types, in the application of ochre powder, and in the ways ochre was processed within the context of environmental changes. Raw material choices over time appear to be influenced by sea-level changes which restricted/allowed access to sources. Periods of resource intensification and greater mobility around the landscape coincide with periods of increased ochre collection and use at the sites. Access to resources and mobility across the landscape would have impacted group fluidity and social networks possibly affecting how cultural items, such as ochre, were used.

REFERENCES

HENSHILWOOD, C.S., SEALY, J.C., YATES, R.J., CRUZ-URIBE, K., GOLDBERG, P., GRINE, F.E., , KLEIN, R.G., POGGENPOEL, C., VAN NIEKERK, K.L. & WATTS, I. 2001. Blombos Cave, southern Cape, South Africa: preliminary report on the 1992–1999 excavations of the Middle Stone Age levels. *Journal of Archaeological Science* **28**(5), 421–448.

HENSHILWOOD, C.S., VAN NIEKERK, K.L., WURZ, S., DELAGNES, A., ARMITAGE, S., RIFKIN, R., DOUZE, K., KEENE, P., HAALAND, M., REYNARD, J., DISCAMPS, E. & MIENIES, S. 2014. Klipdrift Shelter, southern Cape, South Africa: preliminary report on the Howiesons Poort levels. *Journal of Archaeological Science* **45**, 284–303.

ROBERTS, P., HENSHILWOOD, C., VAN NIEKERK, K., KEENE, P., GLEDHILL, A., REYNARD, J., BADENHORST, S. & LEE-THORP, J. 2016. Climate, environment and early human innovation: stable isotope and faunal proxy evidence from archaeological sites (98–59ka) in the southern Cape, South Africa. *PLOS ONE* **11**(7). DOI: doi.org/10.1371/journal.pone.0157408.

WATTS, I. 2009. Red ochre, body painting, and language: interpreting the Blombos ochre. **In**: Botha, R.& Knight, C. (eds), *The Cradle of Language*, 62–92. Oxford, Oxford University Press.

ZIEGLER, M., SIMON, M.H., HALL, I.R., BARKER, S., STRINGER, C. & ZAHN, R. 2013. Development of Middle Stone Age innovation linked to rapid climate change. *Nature Communications* **4**, 1905. DOI: doi.org/10.1038/ncomms2897.

FIB-SEM: A new method for examining pollen grain walls and palaeontological specimens in 3D

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The typically distinctive and elaborate external structures and sculpturing of pollen grains have proved to be reliable characteristics when formulating classification systems for flowering plants. Pollen wall sculpturing is often highly characteristic and consistent within taxa and is also considered to be conservative in that fossil pollen can often be related to pollen of an extant taxon due to closely shared morphological features (Walker 1974). This makes the study of pollen, or palynology, an attractive field applicable to taxonomy and systematics.

The internal pollen wall, from which the external sculpturing is derived, exhibits complex and diverse characteristics, but difficult and cumbersome methods are required to examine these interior layers. An investigation of the internal structure of the pollen grain wall was conducted in order to identify features or characters of potential taxonomic value (House & Balkwill 2013). The Acanthaceae were selected for this purpose as members of this family are interesting from a palynological perspective in that they encompass a wide range of morphological pollen structures from supposedly primitive, right through to more advanced types. In addition, the diverse characteristics of the external pollen grain walls have traditionally been used for taxonomy and classification purposes in this family.

In order to examine internal pollen wall ultra-structure, an innovative microscopy technique involving precise cross-sectioning or slicing of pollen grains at a pre-selected position using a focused ion beam-scanning electron microscope (FIB-SEM), was explored, yielding data of taxonomic importance

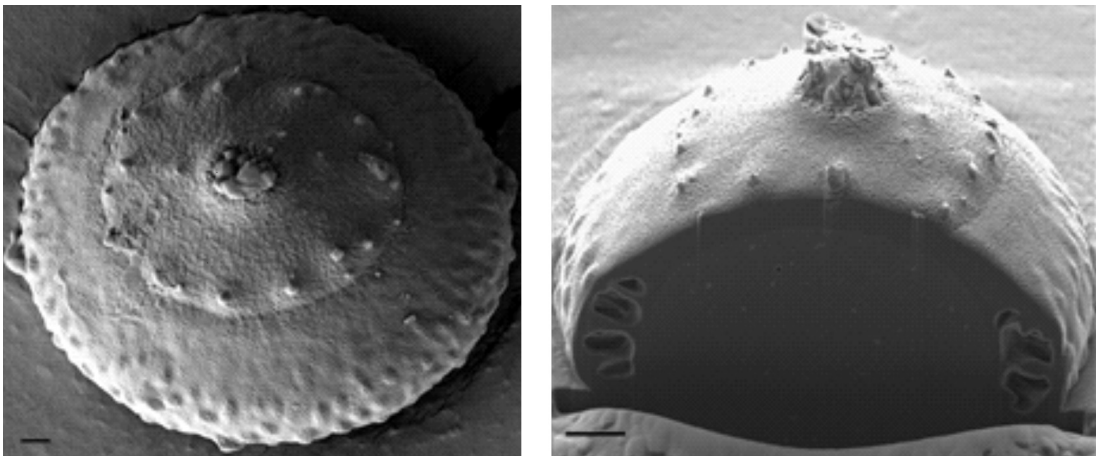


Figure 1. External view of a whole pollen grain of *Isoglossa glandulosa* and a cross-section of the same grain cut by FIB-SEM. Scale bars = 3 μm.

(House & Balkwill 2016). In addition to sample preparation being fairly simple, the FIB-SEM proved to be an extremely effective tool for affording high resolution, three-dimensional views for investigating internal pollen wall structures (Fig. 1). Results obtained with this technique allow one to identify between distinct features which could otherwise appear similar when viewed as thin cross-sections or surface scans, supplementing data gained from more conventional methods of microscopy such as light microscopy (LM), transmission electron microscopy (TEM) and scanning electron microscopy (SEM).

The application of FIB-SEM to fossilized specimens is still in its infancy, with only a few studies – mostly involving the Cretaceous period – having been made thus far. The technique has been applied to palaeopalynological specimens in order to establish ancestral forms of early flowering plants using fossil spores and pollen and to reconstruct external sculpturing and internal wall structure for identification and taxonomic purposes (Villanueva-Amadoz *et al.* 2012). These data add to the understanding of long-term changes and variability taking place in palaeoenvironments. Furthermore, the ultrastructural organization of cuticles and substomatal cavities in fossil leaves have also been analysed (Sender *et al.* 2017). Researchers now believe this technique will allow them to estimate the volume of the substomatal cavity. It is possible that a comparative study in structures used for gaseous exchange in fossil plants may increase our understanding of changing atmospheric palaeoenvironments. These studies highlight the potential this technique affords for reconstructing Quaternary and older environments by assisting in the identification of species and even inferring atmospheric conditions such as carbon dioxide concentrations based on stomatal densities and structure.

As the FIB-SEM becomes more widely available and its demand increases for biological sciences, it is highly likely that future nano-morphological studies could be important sources of data for Quaternary studies, increasing our knowledge and understanding of palaeoclimates, palaeoenvironments and palaeoecology.

REFERENCES

HOUSE, A. & BALKWILL, K.. 2013. FIB-SEM: an additional technique for investigating internal structure of pollen walls. *Microscopy and Microanalysis* **19**, 1535–1541.

HOUSE, A. & BALKWILL, K. 2016. Labyrinths, columns and cavities: new internal features of pollen grain walls in the Acanthaceae detected by FIB-SEM. *Journal of Plant Research* **129**, 225–240.

SENDER, L.M., ESCAPA, I., BENEDETTI, A., CYNEO, R. & DIEZ, J.B. 2017. Exploring the interior of cuticles and fossil compressions by FIB-SEM milling and image microscopy. *Journal of Microscopy* (under review).

VILLANUEVA-AMADOZ, U., BENEDETTI, A., MENDEZ, J., SENDER, L.M. & DIEZ, J.B. 2012. Focused ion beam nano-sectioning and imaging: a new method in characterization of palaeopalynological remains. *Grana* **51**, 1–9.

WALKER, J.W. 1974. Evolution of exine structure in the pollen of primitive angiosperms. *American Journal of Botany* **61**, 891–902.

The use of historical documentary sources to reconstruct rainfall on the South African Highveld

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'It rained continuously .... and men and frogs alike are happy'

(*Goldfields Times,* 13 December 1887)

Historical documentary sources can be used to reconstruct climatic information for the pre-instrumental period (Nash & Adamson 2014). Sources such as newspapers, journal entries, letters, farm records and ship's log books have been used to reconstruct climatic information for the recent past (Kelso & Vogel 2007; Nash & Adamson 2014; Nash *et al.* 2015). This method can be particularly useful in South Africa where the

consistent collection of measured meteorological data only began in the early 20th century. The usefulness of a particular documentary resource will depend on the nature of that source. Newspapers can be particularly useful, as they are regular publications, often with the same author, reporting on the changes in the weather. Using the South African Highveld around Johannesburg and Pretoria as an example, this paper examines the potential for using written documentary sources to reconstruct rainfall patterns for a period of 10 years prior to the first available rainfall data. Multiple historical documentary sources were consulted.Many of the early newspapers of the region, *The Transvaal Advertiser*, *The Transvaal Argus and Commercial Gazette*, *The Digger's News* had regular references to the weather. Difficulties related to access to water, sanitation, transport, farming and food supply at the rapidly expanding mining camps of early Johannesburg were narrated in detail. The particular aim of this research is to identify early droughts and wet years. These are subsequently compared to historical El Niño–Southern Oscillation low phase events. A critique of the usefulness of particular documentary sources is also presented (Nash & Adamson 2014). This research forms part of a larger southern African regional project aiming to collect archival references to weather, rainfall, seasonality and extreme climatic events (Neukom *et al.* 2012). These are then centrally captured onto the *ENSO Africa* database administered by the University of Brighton. At a later stage the intention is to use this database for larger scale, regional, precipitation analysis.

REFERENCES

KELSO, C.& VOGEL, C. 2007. The climate of Namaqualand in the nineteenth century. *Climatic Change* **83**(3), 357–380.

NASH, D.J. & ADAMSON, G.C.D. 2014. Recent advances in the historical climatology of the tropics and subtropics. *Bulletin of the American Meteorological Society* **95**, 131–146.

NASH, D.J, PRIBYL, K., KLEIN, J., ENDFIELD, G.H., KNIVETON, D.R. & ADAMSON, G.C.D. 2015. Tropical cyclone activity over Madagascar during the late nineteenth century. *International Journal of Climatology* **35**(11),3249–3261.

NEUKOM, R., NASH, D.J., ENDFIELD, G.H., GRAB, S.W., GROVE, C.A., KELSO, C., VOGEL, C.H. & ZINKE, J. 2014. Multi-proxy summer and winter precipitation reconstruction for southern Africa over the last 200 years. *Climate Dynamics* **42**, 9–10.

NICHOLSON, S.E., D. KLOTTER, D. & DEZFULI, A.K. 2012. Spatial reconstruction of semi-quantitative precipitation fields over Africa during the nineteenth century from documentary evidence and gauge data. *Quaternary Research* **78**, 13–23.

Towards an understanding of the Last Glacial Maximum in the southern hemisphere

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Traditionally the Last Glacial Maximum (LGM) is thought to have extended across the period ~24–18 kyr, with variations in continental ice volume being driven largely by northern hemisphere summer insolation minima. However, many records from across the southern hemisphere indicate a gradual recession from minimum conditions starting at or after ~30 kyr BP, which is significantly earlier than the widely accepted global LGM, as defined by sea ice extent and $\delta^{18}O$ maxima (~21.5–18 kyr BP) recorded in Antarctic ice cores (e.g. Rother *et al.* 2014). It has also been suggested that the LGM was not uniformly cool and dry, but may have been characterized by millennial-scale variability (Petherick *et al.* 2008). The current state of knowledge of climatic variability in the southern hemisphere for the period 35–15 kyr BP is essentially based on robust records from New Zealand, relatively few records from Australia, and even fewer from South America and southern Africa. Irrespective of this patchy spatial coverage, a key issue is that palaeoclimatic records from the LGM are not uniformly preserved in all environments, and there has been very little work integrating records of different types, which has inhibited our understanding of Earth System responses to climate forcing (Alloway *et al.* 2007). This INQUA-funded project, called SHeMax (Southern Hemisphere Last Glacial Maximum), aims to develop a greater understanding of the timing and nature of the LGM in the southern hemisphere. In order to achieve this, proxy data archived in marine and terrestrial records from different settings in the southern hemisphere will be analysed for the broad period 35–15 kyr BP, encompassing the termination of the last glacial cycle, and the traditionally accepted timing of the global LGM. Greater knowledge of decadal and millennial scale climatic and environmental variability across the southern hemisphere, and whether or not these changes are in phase with Antarctica, is crucial for providing input for the validation of palaeoclimate models and for better understanding of palaeo-circulation patterns and the dynamics of monsoon and El Niño–Southern Oscillation phases.

Here we present a summary review of the current state of knowledge, including possible differences in the timing of the onset and termination of the LGM, as well as the severity of the LGM, as is recorded in different locations in the southern hemisphere, including South America, southern Africa, Australia, New

Zealand, South Pacific islands and Southern Ocean islands. Key research problems, in no particular order, include the following:

(1) The potential role of northern hemisphere insolation forcing (and/or cryosphere system feedbacks) on southern hemisphere climate is unclear and likely varied throughout the extended LGM period. This is particularly the case with respect to variations in the position of the intertropical convergence zone and monsoon strength and extent into (for example) northeast Australia;
(2) High-resolution ice cores from Antarctica show quite different conditions than glacial records from the mid-latitudes (e.g. Tasmania) and low-latitudes (e.g. Papua New Guinea). Also, some Antarctic Isotope Maxima can be correlated with biological records from New Zealand, whereas others cannot;
(3) In all regions, there are presently significant west–east precipitation gradients that are controlled by atmospheric circulation patterns. It is unclear to the extent to which such gradients existed in the past, related to changes in synoptic-scale circulation, although evidence from southern Africa suggests migration in the inland penetration of the winter rainfall zone;
(4) Fluvial records especially in Australia have been used to reconstruct palaeo-precipitation, but there is uncertainty on the role of ecosystems and land surface properties on river system responses, in particular in semi-arid areas, and the role of atmospheric circulation patterns (e.g. blocking high pressure cells) in changing precipitation tracks;
(5) Biological proxy records have been used to derive mean annual temperatures, but many records such as oxygen isotopic ratios within emu eggs in southern Australia may reflect seasonal and not annual forcings;
(6) Biological data (in particular pollen and microfossils) used for calculations of palaeo-precipitation and palaeo-temperature are often not based on robust transfer functions and training datasets, and errors in palaeoclimate reconstruction are not well quantified;
(7) Dating control and correlation is problematic. There are large variations in carbonate dissolution effects and radiocarbon reservoir ages in the Southern Ocean, which are not well understood and which may have implications for establishing reliable radiocarbon chronologies. In addition, changes to southern hemisphere cosmogenic production rates and associated scaling factors mean that changes in cosmogenic-based chronologies from dated LGM moraine limits have implications for calibration and tuning of glacier–climate models.

In the SHeMax project, records from high-resolution marine and coastal sediments, lake sediments, speleothems, ice cores, glacial moraines, dunes and fluvial systems will be compared to produce a synthesis of climatic variability and explore the premise of an extended LGM in the southern hemisphere (Rother *et al*. 2014). The spatial focus will be ~20–80°S, which will allow investigation into teleconnections between the mid- and high latitudes. In addition to the synthesis of environmental conditions, drivers and/or triggers of climatic variability will also be explored, and results will be compared to model simulations for the LGM.

REFERENCES

ALLOWAY, B.V., LOWE, D.J., BARRELL, D.J.A., NEWNHAM, R.M., ALMOND, P.C., AUGUSTINUS, P.C., BERTIER, N.A.N., CARTER, L., LITCHFIELD, N.J., McGLONE, M.S., SHULMEISTER, J., VANDERGOES, M.J., WILLIAMS, P.W. & NZ-INTIMATE MEMBERS. 2007. Towards a climate event stratigraphy for New Zealand over the past 30 000 years (NZ-INTIMATE project). *Journal of Quaternary Science* **22**, 9–35.

HUFFMAN, G.J., ADLER, R.F., BOLVIN, D.T. & GU, G. 2009. Improving the global precipitation record: GPCP Version 2.1. *Geophysical Research Letters* **36**, L17808. DOI: 10.1029/2009GL040000.

PETHERICK, L., McGOWAN, H. & MOSS, P. 2008. Climate variability during the Last Glacial Maximum in eastern Australia: evidence of two stadials? *Journal of Quaternary Science* **23**, 787–802.

ROTHER, H., FINK, D., SHULMEISTER, J., MIFSUD, C., EVANS, M. & PUGH, J. 2014. The early rise and late demise of New Zealand's last glacial maximum. *Proceedings of the National Academy of Sciences* **111**, 11630–11635.

Re-evaluating the Last Glacial Maximum in southern Africa

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The Last Glacial Maximum (LGM) record in southern Africa is different to that of many other areas of the southern hemisphere, because only restricted cirque glaciers existed and thus there is neither a geomorphic signature nor a chronostratigraphic and regional-scale marker that represents the LGM. As such, the LGM in southern Africa is marked by sparsely-distributed, proxy, non-glacial records that tend to have low temporal resolution and/or poor or insecure dating control. The two most complete records spanning the period ~35–15 ka are from Tswaing Crater and Wonderkrater but these are located relatively close to each other on the Highveld. Other records mainly from coastal locations are of shorter time spans. A key assumption is that the LGM is the period of greatest cold (Stone 2014), but this is related to the proxy

type being considered and the validity of any transfer function or statistical relationship between the proxy record and interpreted palaeotemperature. A key limitation is that different proxy records reflect different aspects of climate in combination and thus may not necessarily be comparable, and the variable spatial and temporal resolutions of these records, and an absence of records in large areas of the interior of southern Africa, mean that correlation between records is problematic. This limits the extent to which synoptic-scale climate reconstructions can be made for the LGM period, which in turn limits the potential to evaluate different forcings on land surface/environmental responses. Here, we critically examine the basis on which the LGM is evaluated from different proxy records in southern Africa, the different assumptions involved and deductions of LGM temperature/precipitation values, and whether a 'southern African LGM' existed. This contrasts with previous, narrow viewpoints of the timing and significance of the regional LGM (e.g. Stone 2014). We also consider different viewpoints of the onset (maximal age) and termination (minimal age) of the LGM in the wider context of the southern hemisphere. The limited available evidence suggests that, within the period ~35–15 ka, several climatic phases existed in southern Africa (e.g. Thackeray 1987), with cool and moist conditions existing prior to 35 ka, followed by a cool and dry maximal LGM, with increased temperature and moisture availability thereafter. However, the spatial and temporal patterns of climate changes during this period and across southern Africa are not well resolved, and there are large areas of the region with no records at all. This is a significant limitation on our present ability to reconstruct LGM climates. Likewise, changes in precipitation seasonality are also unknown, although this is believed to be a significant component of the precipitation signal in LGM records, but this is as yet not well quantified (Thackeray & Fitchett 2016). In many areas of southern Africa where biological or geochemical (speleothem) records are sparse, sedimentological and geomorphological records (such as river terrace deposits, palaeosols, coversands) also have potential to inform on LGM climates. Advances in cosmogenic dating also mean that age of burial/exposure can be measured, and erosion/weathering rates calculated, which can allow for consideration of long-term landscape change processes (e.g. Keen-Zebert *et al.* 2016). To develop a fuller understanding of LGM climates and environments in southern Africa, two key research thrusts are needed: (1) the use of more innovative isotopic, geochemical and sedimentary environmental proxies, in particular from areas with sparse data coverage; and (2) climate modelling constrained by radiometric ages and associated temperature/moisture conditions that are interpreted from proxy records. The limitations of existing records and their climatic interpretations have hampered regional correlations and an understanding of synoptic-scale climate dynamics during the LGM.

REFERENCES

KEEN-ZEBERT, A., TOOTH, S. & STUART, F.M. 2016. Cosmogenic ^{3}He measurements provide insight into lithologic controls on bedrock channel incision: examples from the South African interior. *Journal of Geology* **124**, 423–434.

STONE, A.E. 2014. Last Glacial Maximum conditions in southern Africa: are we any closer to understanding the climate of this time period? *Progress in Physical Geography* **38**, 519–542.

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

THACKERAY, J.F. & FITCHETT, J.M. 2016. Rainfall seasonality captured in micromammalian fauna in Late Quaternary contexts, South Africa. *Palaeontologia africana* **51**, 1–9.

Marine reservoir correction ΔAR, for south and east coasts of South Africa

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Quaternary palaeoenvironmental conditions in southern Africa remain relatively unknown due to the spatially and temporally fragmented nature of available evidence. The reconstruction of longer-term palaeoclimatic changes is important because, due to its latitudinal position, southern Africa is exposed to dynamics of both tropical and temperate climate regimes (Carr *et al.* 2006). Furthermore, the region's juxtaposition in relation to the warm Agulhas and cool Benguela currents leads to complex ocean–atmosphere interactions that impact climate significantly. Indeed, the volume and quality of research into reconstruction of palaeoenvironmental conditions in the Quaternary of the region has increased markedly within the last decade in response to the recognition of its significance. Reconstructions are based on more traditional proxies, such as pollen and diatoms from wetland and lake sediments, as well as novel evidence, including a range of biological and chemical characteristics of rock hyrax middens. While such reconstructions have greatly improved understanding of environmental changes in the region during the Quaternary, the establishment of reliable chronologies which are crucial for every palaeoenvironmental reconstruction remain a key challenge for sedimentary sequences (Wündsch *et al.* 2016).

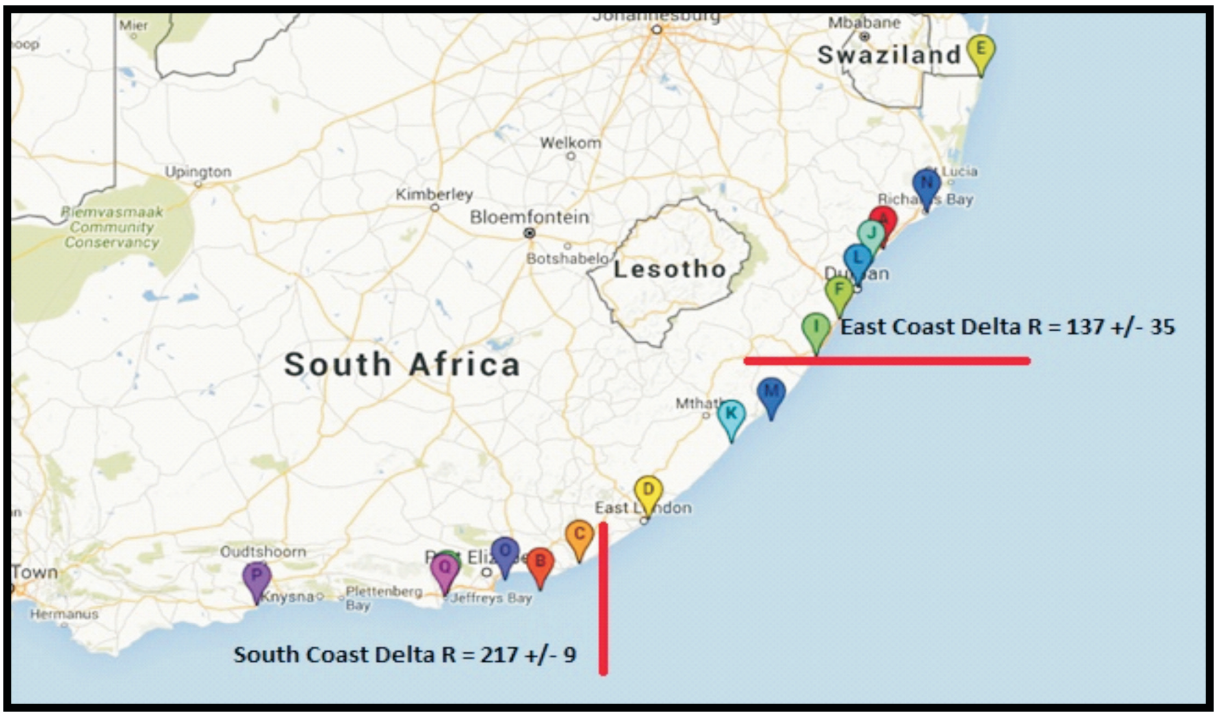


Figure 1. Map showing Delta R values for the south and east coasts determined by this research.

The RAIN project (Regional Archives for Integrated iNvestigations) is a multidisciplinary and multi-institutional collaboration that aims to explore evidence from terrestrial and offshore sediments of changing climate and associated environmental conditions during the late Quaternary in southern Africa (Haberzettl 2014). Several studies that link terrestrial and marine records to reconstruct palaeoclimates in the region have ensued, and therefore need to consider reservoir corrections (e.g. Wündsch *et al.* 2016a).

Central to such studies is obtaining accurate age determination of the samples and therefore a reliable chronology. This paper aims to approximate the marine reservoir effect for the southeast coastal region of South Africa as a step to better contextualizing results of the numerous Late-Quaternary palaeo-environmental studies currently under way. Reimer & Reimer (2001) remarked on the lack of reservoir correction data for most of Africa, and until now there are very few such studies (Dewar *et al.* 2012; Wündsch *et al.* 2016). Dewar *et al.* (2012) highlighted the need to conduct a regional reservoir correction study on the south coast of South Africa similar to the one they carried out for the west coast. The results reported here therefore respond to the need for additional ΔAR values for the oceans around the African continent. The paper presents results of radiocarbon dating on 15 known-age (pre-1950) shell samples in order to derive a marine reservoir correction for coastal regions of South Africa for which hitherto there has been an inadequate database to enable radiocarbon age adjustment on sediments from coastal and marine sources. The samples yield results for two distinctive zones relating to the south and east coasts of South Africa and represent a sound dataset on which to base ΔAR values for a stretch of coastline extending over 1500 km between Richards Bay and Mossel Bay. These results will help to contextualize geochronologies for samples found in the region.

ACKNOWLEDGEMENTS

We would like to acknowledge Palaeontological Scientific Trust (PAST) for their support in presenting this research at the SASQUA 2017 conference.

REFERENCES

CARR A., THOMAS, D.S., 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, Palaeoclimatology, Palaeoecology* **239**(1), 147–165.

DEWAR, G., REIMER, P., SEALY, J.& WOODBORNE, S. 2012. Late-Holocene marine radiocarbon reservoir correction for the west coast of South Africa. *The Holocene* **22**(12), 1481–1489.

HABERZETTL, T., BAADE, J., COMPTON, J., DAUT, G., DUPONT, L., FINCH, J., FRENZEL, P., GREEN, A., HAHN, A., HEBBELN, D. & HELMSCHROT, J. 2014. Paleoenvironmental investigations using a combination of terrestrial and marine sediments from South Africa – The RAIN (Regional Archives for Integrated iNvestigations) approach. *Zentralblatt für Geologie und Paläontologie* **I**, 55–73.

REIMER, P.J. & REIMER, R.W. 2001. A marine reservoir correction database and on-line interface. *Radiocarbon* **43**(2A), 461–463.

WÜNDSCH, M., HABERZETTL, T., MEADOWS, M.E., KIRSTEN, K.L., KASPER, T., BAADE, J., DAUT, G., STONER, J.S. & MÄUSBACHER, R. 2016. The impact of changing reservoir effects on the 14 C chronology of a Holocene sediment record from South Africa. *Quaternary Geochronology* **36**, 148–160.

The inclusion of Evolution and Palaeontology in the Life Sciences Curriculum: Is this an opportunity for Quaternary Research?

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Prior to 1994 evolution was not covered in the school curriculum due to the government of that era's policy of National Christian Education which excluded the coverage of topics that were considered 'unchristian'. One of the priorities of the post-1994 government was the reform of the education system which included the introduction of a new curriculum which led finally, in 2008 (Saunders and Ngxola 2009) to the inclusion of the topics of 'evolution', 'human evolution' and palaeontology in the Life Sciences (Biology) curriculum. The coverage of the these topics is detailed in the formal Curriculum Assessment Policy Statements (Department of Education 2011) and includes: the evidence for evolution, Lamarckism, Darwinism, punctuated equilibrium, artificial selection, speciation, and examples of evolution and natural selection in present times. With regard to human evolution there are topics like anatomical differences/similarities between chimpanzees and human, the fossil evidence, cultural evidence (e.g. tool making), genetic evidence, 'Out of Africa Hypothesis', African origins of modern humans, East African fossil sites, fossils, and scientists, southern African fossil sites, fossils and scientists and different cultural and religious explanations for the origin and development of life on earth. Not only is the coverage substantial, but it is taken seriously given that the evolution topics cover 25% of the final year of the Grade 12 Curriculum and also represent an important part of the final 'school leaving' matric exam. This inclusion of evolution in the Grade 12 Curriculum is complimented by the inclusion of palaeontology into the Grade 10 Curriculum, where for the first time in the Life Sciences Curriculum (and possibly in the entire South African School Curriculum) we have specific mention of the 'Geological Time Scale', mass extinctions, the 6th extinction, changes in sea level, climate change, and methods of dating fossils. Arguably these palaeontology topics are some of the fundamental concepts which underlie the Quaternary sciences.

One might think that the substantial inclusion of evolutionary and palaeontological content in the school curriculum would be a tremendous boost for the historical sciences such as Quaternary research; however, superficially, perhaps, it may appear that there has been no effect. The South African public is generally very conservative and a recent Media 24 survey revealed that less than 50% of South Africans accept that humans evolved from other species, well in keeping with international trends for the USA and the developing world (Miller 2006). Natural history museums in South Africa and the Cradle of Humankind continued to struggle to attract visitors (DST 2011) and there are numerous anecdotal reports that teachers have many concerns and difficulties about the teaching of this new topic. While there are no recent publications on the matter, early concerns were documented by Sanders & Ngxola (2009).

This paper argues that despite this apparent initial lack of impact, the curriculum reform has had an effect and South Africans are now more informed and interested in the palaeosciences than ever. Evidence for this comes from the enormous and unprecedented interest from the South African public in exhibitions of reconstructions of dinosaurs and ice age animals. In addition, there was the huge interest shown in the discovery of *Homo naledi* which appeared to spark interest in other finds, including South African dinosaur fossils. Also, there is the surprising knowledge shown by Wits students, in a National Science Week Survey, of fossil finds such as Mrs Ples and acceptance of evolution (McKay 2014) which many of them reported as having learnt about at school. Can it be argued that a reform in the school curriculum has sparked off an interest in both learners and their families, in topics that they were never really exposed to before?

It seems possible to conclude, therefore, that despite the slowness and many imperfections in the curriculum reform process, it is having a positive impact, and will continue to have a positive impact on the knowledge and interest of the public in the palaeosciences, and represents a real opportunity for attracting more funds and skilled students into the field of Quaternary research.

REFERENCES

DEPARTMENT OF BASIC EDUCATION. 2011. National Curriculum Statement, Curriculum and Assessment Policy Statement, Further Education and Training Phase, Life Sciences.

DEPARTMENT OF SCIENCE AND TECHNOLOGY. 2011. South African Strategy for the Palaeosciences.

McKAY, I.J. 2014. Investigation into University of the Witwatersrand Students, opinions and knowledge of science and technology issues: inparticular their beliefs about earth sciences and evolution and palaeontology icons like Mrs Ples. Paper Presented at the 16th SAASTEC Conference held at the Nelson Mandela Bay Science & Technology Centre, Uitenhage, Eastern Cape, from the 17–20 November 2014.

MILLER, J.D., SCOTT, E.C., OKOMATO, S. 2006. Public acceptance of evolution. *Science* **313**, 765–766

SAUNDERS, M. & NGXOLA, M. 2009. Addressing teachers' concerns about teaching evolution. *Journal of Biological Evolution* **43**, 121–128

Glacial–interglacial and ENSO-driven environmental variability in southeast Africa

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The mechanisms controlling past climate variability and the associated environmental impact in subtropical southeast Africa remain poorly understood, due primarily to the semi-arid climate resulting in a lack of long, continuous, terrestrial palaeoenvironmental archives. A continuous 8.8-m long core extracted from the Mfabeni coastal peatland (on the Maputaland Coastal Plain; Fig. 1) provides a unique opportunity to reconstruct environmental conditions over the past 30 000 years (30 ka).

Here we present carbon ($\delta^{13}C_{wax}$) and hydrogen isotope (δD_{wax}) data from plant leaf-wax *n*-alkanes from Mfabeni in order to estimate both past vegetation type (C_3 tree *vs* C_4 grass), and hydrological variability. We use the relative abundance of mid- to long-chain *n*-alkanes (P_{aq}) to elucidate the relative amount of aquatic vs terrestrial plant-derived matter as an indicator of water level changes. Additionally, we use the carbon isotopic composition of bacterial hopanes (δC_{hop}) to infer changes in terrestrial methane cycling.

Our data indicate that glacial–interglacial changes were a major control on past climate variability in southeast Africa. Low P_{aq} values reveal the dominance of terrestrial plants and emergent macrophytes suggesting drier than present conditions during the Last Glacial Maximum (LGM; *c.* 21 ka). This is supported by enriched δD_{wax} values, which suggest a decrease in rainfall during this time. Enriched $\delta^{13}C_{wax}$ values suggest that the vegetation during the LGM was dominated by C_4 grasses which is supported by palynological data indicating the presence of dry grassland (Finch & Hill 2008). In addition, enriched $\delta^{13}C_{hop}$ values during the LGM indicate a lack of methanogenesis, likely related to relatively cold and dry conditions (Pancost *et al.* 2007).

The Holocene is characterized by higher water levels evidenced by higher P_{aq}, suggesting an increase in submerged aquatic macrophyte input. This is supported by depleted δD_{wax} values, which signify increased rainfall intensity. Depleted $\delta^{13}C_{wax}$ values suggest that vegetation was dominated by C_3 trees, consistent with an expansion of *Podocarpus* forest during the Holocene (Finch & Hill 2008). A switch to more depleted Holocene $\delta^{13}C_{hop}$ values indicate an elevated rate of methanogenesis, which may result from warmer and wetter conditions (Pancost *et al.* 2007).

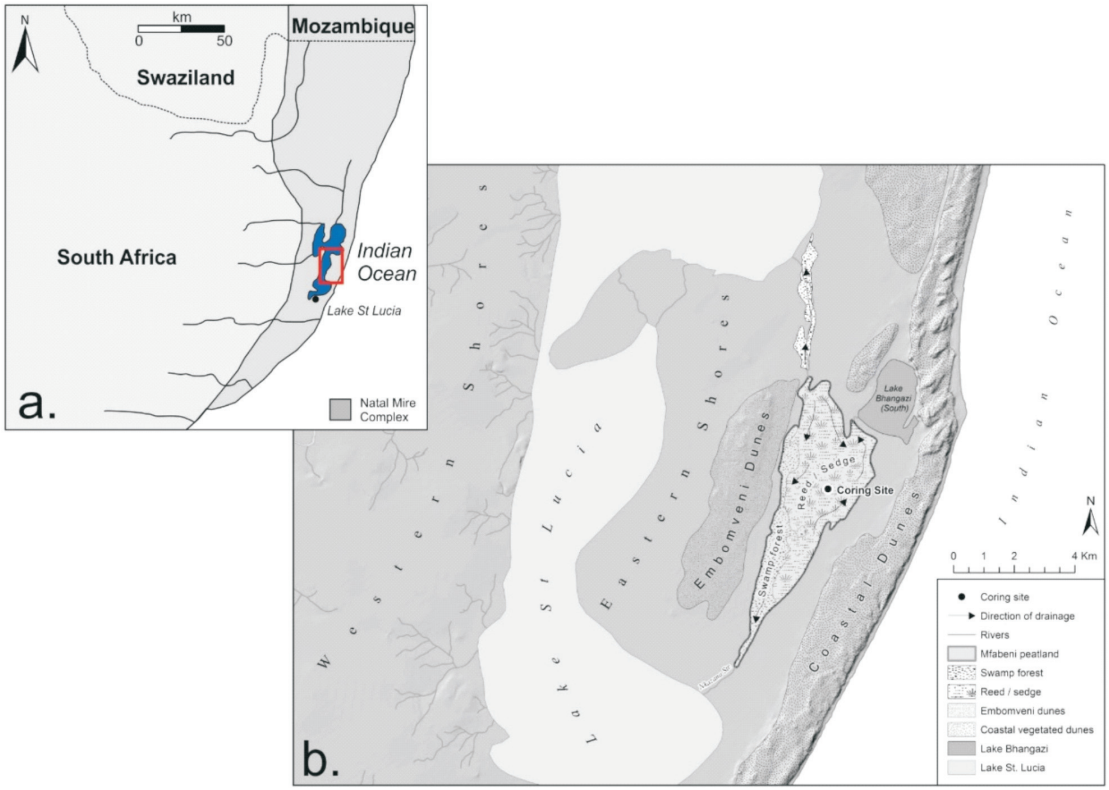


Figure 1. The location of Mfabeni Peatland, South Africa. The red box in map (**a**) highlights the study region shown in map (**b**), and is adapted from (Baker *et al.* 2014). Map (**b**) is courtesy of Brice Gijsbertsen, UKZN Cartography Unit.

Two abrupt arid events are evident at Mfabeni at around 3 ka and from 1.5 ka until the present-day, where δD_{wax}, $\delta^{13}C_{wax}$ and $\delta D^{13}C_{hop}$ values are enriched and emergent C_4 plants dominate (lower P_{aq}). These events coincide with two prominent increases in ENSO (El Niño–Southern Oscillation) intensification (Tudhope *et al*. 2001). El Niño-related warm sea-surface temperature anomalies in the southwestern Indian Ocean lead to reduced penetration of Indian Ocean moisture into South Africa due to a reduced land–sea temperature contrast and consequently reductions in rainfall on the continent (Reason & Rouault 2002).

As climate models predict a potential doubling in the occurrence of extreme ENSO events in response to future anthropogenic global warming, we expect increased drought occurrence in southeast Africa with possibly severe socio-economic consequences.

REFERENCES

BAKER, A., ROUTH, J., BLAAUW, M. & ROYCHOUDHURY, A.N. 2014. Geochemical records of palaeoenvironmental controls on peat forming processes in the Mfabeni peatland, Kwazulu Natal, South Africa since the Late Pleistocene. *Palaeogeography, Palaeoclimatology, Palaeoecology* **395**, 95–106.

FINCH, J.M. & HILL, T.R. 2008. A late Quaternary pollen sequence from Mfabeni Peatland, South Africa: reconstructing forest history in Maputaland. *Quaternary Research* **70**(3), 442–450.

PANCOST, R.D., STEART, D.S., HANDLEY, L., COLLINSON, M.E., HOOKER, J.J., SCOTT, A.C., GRASSINEAU, N.V. & GLASSPOOL, I.J. 2007. Increased terrestrial methane cycling at the Palaeocene-Eocene thermal maximum. Nature **449**(7160), 332–335.

REASON, C.J.C. & ROUAULT, M. 2002. ENSO-like decadal variability and South African rainfall. *Geophysical Research Letters* **29**(13), 11–16.

TUDHOPE, A.W., CHILCOTT, C.P., McCULLOCH, M.T., COOK, E.R., CHAPPELL, J., ELLAM, R.M., LEA, D.W., LOUGH, J.M. & SHIMMIELD, G.B. 2001. Variability in the El Niño-Southern Oscillation through a Glacial–Interglacial cycle. *Science* **291**(5508), 1511–1517.

The palaeoenvironmental context of the Nahoon Point footprints: preliminary results

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In 1964, three human footprints and the tracks of at least three other species of vertebrate organisms were found preserved in coastal aeolianite at Nahoon Point (East London, Eastern Cape, South Africa). Analysis of the human footprints has indicated that they were produced by a young anatomically-modern *Homo sapiens* individual (Roberts 2008). The footprint-bearing aeolianite has recently been dated by the optically-stimulated luminescence (OSL) method to 120–128 ka, which falls within Marine Isotope Substage (MIS) 5e (130–115 ka) (Jacobs & Roberts 2009). Past research at Nahoon Point has focused on dating the footprints, identifying the species responsible for the faunal trackways, and analysing the anatomical details preserved in the human footprints (Roberts 2008). Apart from a general description of the geomorphological features associated with the footprint site (Mountain 1966; Roberts 2008), and a description of the lithostratigraphy of the Nahoon Formation near the site (Le Roux 1989), there has been no attempt to reconstruct the physical environment of Nahoon Point at the time the footprints were produced. Consequently, the environmental context of human occupation at Nahoon Point during MIS 5e is poorly known.

This study focuses on understanding the palaeoenvironmental context of the Nahoon Point footprint site using an integrated geoarchaeological approach. This involves contextualising evidence for human occupation within the contemporary physical environment and ecosystems, and is based on sedimentological and stratigraphic analysis of the aeolianite strata (and other relevant sedimentary features including possible trace fossil prints) using both field and laboratory-based techniques. *In situ* stratigraphic logging and sedimentary analysis was conducted for 20 profiles along several kilometres of coastline at and around Nahoon Point. Bulk samples were analysed for carbonate content, density, particle size distribution, particle shape (overall shape and surface texture), and primary and secondary minerals. These data provide information on depositional and post-depositional processes including the environmental conditions under which aeolianite cementation took place.

Preliminary results of this ongoing study suggest there were several distinct environmental phases during the formation of aeolianite at Nahoon Point. The stratigraphic sequence at the point (Fig. 1) includes both marine and terrestrial facies, and indicates a succession of phases in which different depositional and diagenetic processes were in operation at and near the footprint site. The sequence is dominated by several different aeolianite facies which were formed during periods in which the stability/mobility of the dunes (as evidenced by the presence or absence of rhizoliths and the angle and thickness of bedding structures) varied.

The lowermost facies in the terrestrial sequence, a cross-laminated aeolianite, was formed during a period of relatively high sediment mobility. The overlying cross-bedded aeolianite, and the facies characterized by cross-bedded aeolianite with large and numerous rhizoliths which follows it, suggest that the dunes became more stable with growth of land plants. Changes in sediment texture and the degree and

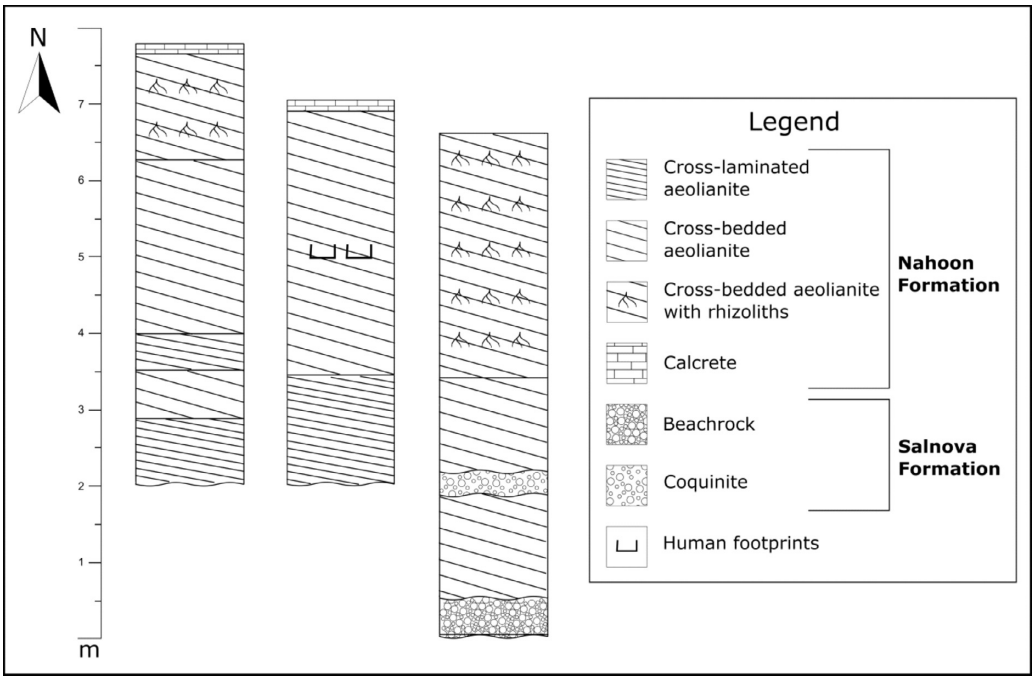


Figure 1. Example stratigraphic logs for three of the south-facing profiles recorded at Nahoon Point. The terrestrial facies are assigned to the Nahoon Formation, while the marine deposits form part of the Salnova Formation. The scale is in metres above the base of the third profile.

nature of cementation within the aeolianite facies indicate changes in environmental conditions over shorter temporal scales. Similar patterns to those observed at the point are visible in the exposures of the Nahoon Formation throughout the study area.

The major driver of the phases discussed above is likely to have been sea-level fluctuations during late MIS 6 and MIS 5e, resulting in changes in sediment supply, nearshore wind regime and groundwater table position. The alternating marine and terrestrial facies within some logged stratigraphic profiles provide evidence for several transgressive–regressive cycles.

The information gained from the ongoing analysis of sediment properties, stratigraphy and trace fossils will be used to reconstruct environmental conditions and palaeogeography during MIS 5e at Nahoon Point. This will be compared to regional archaeological evidence for human presence during the Middle Stone Age (encompassing MIS 5e). Nahoon Point is one of a handful of archaeological and palaeontological sites that preserve evidence for human occupation of coastal environments during this period.

REFERENCES

JACOBS, Z. & ROBERTS, D.L. 2009. Last Interglacial Age for aeolian and marine deposits and the Nahoon fossil human footprints, southeast coast of South Africa. *Quaternary Geochronology* **4**, 160–169.

LE ROUX, F.G. 1989. Lithostratigraphy of the Nahoon Formation (Algoa Group). *South African Committee for Stratigraphy, Lithostratigraphic Series* **9**. Pretoria, Geological Survey.

MOUNTAIN, E.D. 1966. Footprints in calcareous sandstone of Nahoon Point. *South African Journal of Science* **66**, 103–111.

ROBERTS, D.L. 2008. Last Interglacial hominid and associated vertebrate fossil trackways in coastal eolianites, South Africa. *Ichnos* **15**, 190–207.

Tracing the origin of southern African biomes – the Miombo woodland from the early Miocene until modern times

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Our aim is to compare Quaternary palynological records from southern Africa to Neogene records in order to understand the evolution of the remarkably diverse vegetation on the subcontinent and the

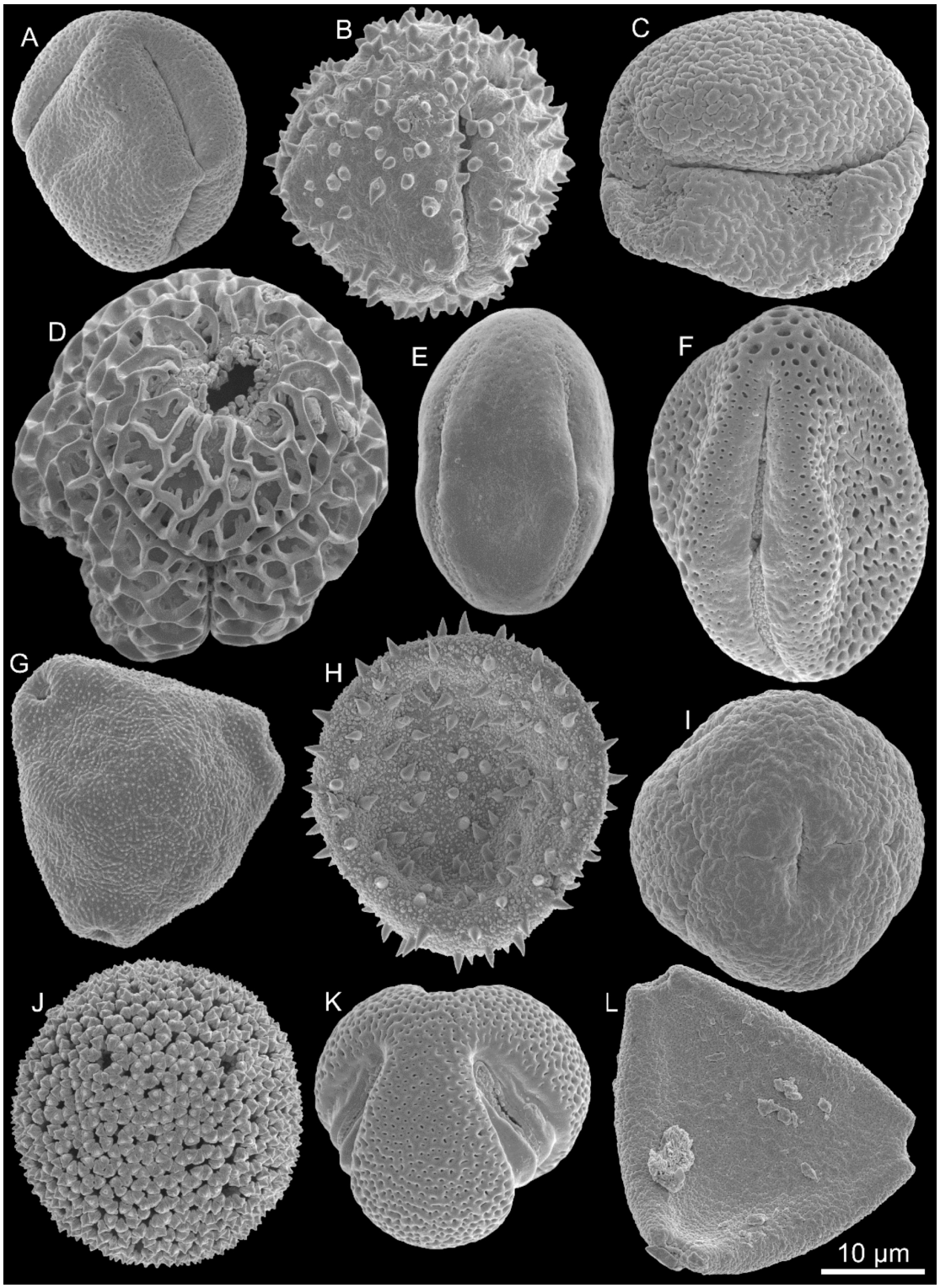


Figure 1. SEM micrographs of fossil pollen from the early Miocene of Saldanha Bay (South Africa). **A**, Rhizophoraceae. **B**, Viscaceae. **C**, Araceae. **D**, Winteraceae. **E**, Sapotaceae. **F**, Vitaceae. **G**, Casuarinaceae. **H**, Picrodendraceae. **I**, Ericaceae. **J**, Thymelaeaceae. **K**, Euphorbiaceae. **L**, Proteaceae.

evolution of its distinctive biomes. An early Miocene marine core from Saldanha Bay to the north of Cape Town reveals a diverse palynoflora with mangrove elements (Rhizophoraceae), subtropical forest dominated by Podocarpaceae, palms and dicotyledons including basal angiosperms like Winteraceae, proto-fynbos with Proteaceae, Ericaceae and Restionaceae, riparian/swamp forest and wetland taxa. The assemblage reflects a diverse flora during a major transgression most probably during the early Miocene as dated by dinoflagellates (Roberts *et al.* 2017, fig. 1). However, one of the most peculiar findings is evidence of a subtropical woodland with Combretaceae, Burseraceae (*Commiphora*-type) and even *Brachystegia* (*Peregrinipollis nigericus*) at Saldanha Bay. Woodland, albeit with often different taxa, is known already from the interior of the subcontinent during the early Palaeogene (Scholtz 1985) but was

hitherto unknown from the Miocene of the Cape region. In order to track down botanical affinities of the Saldanha Bay taxa we apply a method combining SEM and LM images and compare fossil pollen to recent pollen taxa. A comparison of the woodland taxa to modern pollen types revealed similarities to pollen spectra known from Quaternary deposits, e.g. from the Zambezi catchment (Dupont & Kaufmann 2017), or southern central Mozambique (McWethy *et al.* 2016). In southern Mozambique a mosaic of Ericaceae heathlands and montane podocarp forest exists, whereas the coastal area is characterized by coastal forest and *Rhizophora*-dominated mangroves under the influence of a monsoonal climate influenced by the warm Agulhas current. Another distinct modern vegetation unit in that region is Miombo woodland where its main constituent, insect-pollinated *Brachystegia* sp., is notably under-represented in pollen profiles due to low pollen productivity. Apparently, the Saldanha Bay taxa often share the same families with the vegetation in southeastern Africa and might have their most recent counterpart in that region – although we are aware that such comparisons are highly tentative for many reasons (uncertain botanical affinities of fossil pollen, broader ecological range of taxa during the Neogene). This underlines our hypothesis that the Saldanha Bay vegetation during the early Neogene developed under completely different climatological conditions than the current regional vegetation. Probably a monsoonal climate, which was quite similar to the climate experienced along the Indian Ocean coastal belt nowadays with high precipitation and pronounced summer rainfall, supported a lush growth of ferns. We suggest that Miombo woodland might have developed during the Palaeogene in the Cape during the early Miocene but disappeared later in this epoch, coincident with the development of a more arid, winter rainfall climate under the influence of a strengthening cool Benguela current. During the Quaternary, Miombo woodland occupied an extensive region in south-central Africa with a centre in the Zambezi region, with only a tiny representation in the extreme northeast of South Africa. Miombo woodland retracted during the glacials in a regionally varying pattern and spread during warmer interglacials (McWethy *et al.* 2016, Dupont & Kuhlmann 2017).

REFERENCES

DUPONT, L.M. & KUHLMANN, H. 2017. Glacial-interglacial vegetation change in the Zambezi catchment. *Quaternary Science Reviews* **155**, 127–135.

McWETHY, D.B., NEUMANN, F.H., STEINBRUCH, F., RYAN, C.M. & VALSECCHI, V. 2016. Late Quaternary vegetation development and disturbance dynamics from a peatland on Mount Gorongosa, central Mozambique. *Quaternary Science Reviews* **137**, 221–233.

ROBERTS, D.L., NEUMANN, F.H., CAWTHRA, H.C., CARR, A.S., SCOTT, L., DURUGBO, E.U., HUMPHRIES, M.S., COWLING, R.M., BAMFORD, M.K., MUSEKIWA, C. & MACHUTCHON, M. 2017. Palaeoenvironments during a terminal Oligocene or early Miocene transgression in a fluvial system at the southwestern tip of Africa. *Global and Planetary Change,* In press.

SCHOLTZ, A. 1985. The palynology of the upper lacustrine sediments of the Arnot Pipe, Banke, Namaqualand. *Annals of the South African Museum* **95**, 1–109.

Advantages of the 'Calgon' method – Comparison of three different palynological processing methods for Miocene clays and non-HF processing of clastic sediments from a Holocene marine core

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Two case studies were conducted in order to evaluate non-HF processing of clastic sediments with consecutive heavy-liquid separation (sodium polytungstate) for both terrestrial and marine archives.

Case study 1: Three palynological processing methods (H_2O_2, HF, $(NaPO_3)_6$) (Riding & Kyffin-Hughes 2006, 2011) where applied to Miocene clays of the clay pit Adendorf near Bonn, which were known to contain numerous, well-preserved palynomorphs (Nitz 2014). All three methods were followed by heavy-liquid separation (sodium polytungstate), sieving with 10 μm respectively 250 μm grids and slide preparation in glycerine jelly (see Fig. 1). The reason for carrying out this test series is the fact that the most common method (HF) presents considerable health risks. A detailed cost and time calculation was compiled in order to identify the most efficient method. The HF method was most time intensive, both HF and H_2O_2 have to be handled with special care, whereas $(NaPO_3)_6$ is considered a harmless substance. All three methods are roughly comparable under palynological aspects (number of pollutants, pollen percentages), although for a verification more tests would be necessary to assure statistical significance. In terms of costs the H_2O_2 method is much more expensive than the other two methods, whereas the $(NaPO_3)_6$) method is the cheapest. Consequently, the $(NaPO_3)_6$) method proved to have a number of advantages in comparison to the other tested methods (Franke 2014).

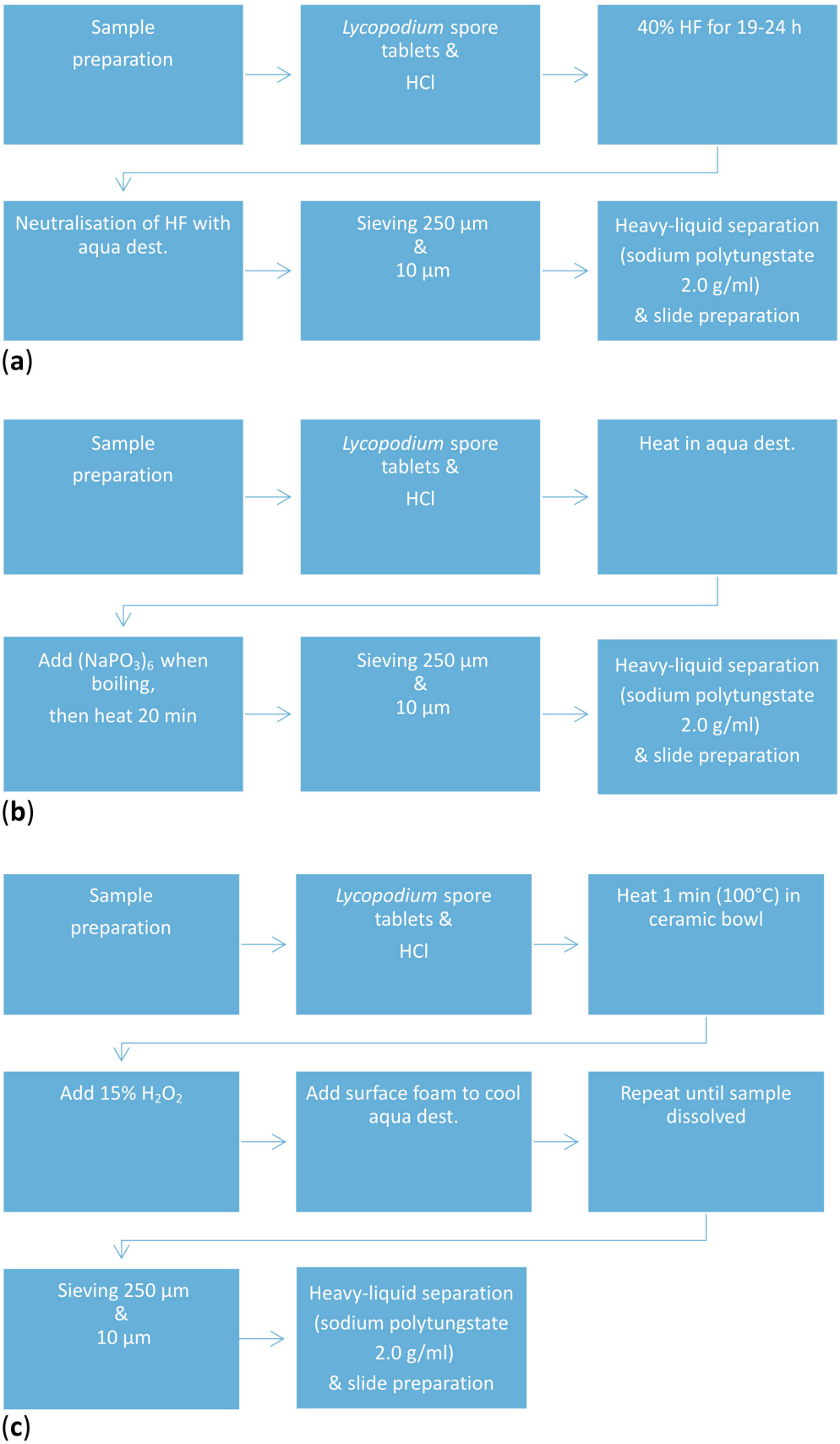


Figure 1. **a**, Preparation with HF. **b**, Preparation with $(NaPO_3)_6$. **c**, Preparation with H_2O_2.

Case study 2: Clayey (fine) sandy sediments from a Holocene marine core taken during a METEOR cruise offshore eastern South Africa in the frame of the RaiN2 project (Regional Archives for Integrated iNvestigations) (Zabel *et al.* 2016) were processed applying the $(NaPO_3)_6$) method followed by heavy-liquid separation with a density of 2 g/ml and sieving with 10 μm and 250 μm grids respectively and slide preparation. A moderate to low pollen concentration was obvious, but the number of *Lycopodium*

spores was also suspiciously low. After heavy-liquid separation (density 2 mg/l), probably due to gravity effects and trapped palynomorphs under abundant clastics, many palynomorphs and *Lycopodium* spores (added to calculate the pollen concentration) were found in the heavy fraction and caused the loss in the light fraction. In order to concentrate especially the pollen and spores, the residue was subject to a 2nd heavy-liquid separation with a density of 2.1 g/ml. Two consequences were observed: firstly, the concentration of palynomorphs and *Lycopodium* spores increased strongly and secondly, beautifully preserved silicate microfossils, including sponge spicules, silicoflagellates and diatoms were available for analysis. Although the 2nd heavy-liquid separation was more time consuming, the obvious advantages in the current case justify additional work and expense.

We tested and improved the $(NaPO_3)_6$) method for our lab in case study 1, and add valuable information, e.g. about time and cost expenses to earlier studies, e.g. by Riding & Kyffin-Hughes (2006, 2011). We also show how effective heavy-liquid separation with sodium polytungstate can be for concentrating palynomorphs in case study 2, with the secondary effect of making silicate microfossils available for study.

ACKNOWLEDGEMENTS

We thank Matthias Zabel and Enno Schefuss (MARUM, RAiN2) for the allowance to use sediments from core GeoB20610-2 for the current study.

REFERENCES

FRANKE, J.N. 2014. *Comparison of three palynological preparation methods on the basis of Miocene sample in a clay pit at Adendorf, Germany.* B.Sc. thesis, University of Münster, Münster.

NITZ, V.L. 2014. *Paläoökolgie und Sedimentologie des miozänen Profils von Adendorf in der südlichen Niederrheinischen Bucht*. M.Sc. thesis, University of Münster, Münster.

RIDING, J.B. & KYFFIN-HUGHES. J.E. 2006. Further testing of a non-acid palynological prepatation procedure. *Palynology* **30**, 69–87.

RIDING, J.B. & KYFFIN-HUGHES, J.E. 2011. A direct comparison of three palynological preparation techniques. *Review of Palaeobotany and Palynology* **167**, 212–221.

ZABEL, M. & CRUISE PARTICIPANTS 2016. Climate archives in coastal waters of southern Africa – Cruise No. M123 – February 3 – February 27, 2016 – Walvis Bay (Namibia) – Cape Town (Rep. of South Africa). METEOR-Berichte, M123, 50 pp., DFG-Senatskommission für Ozeanographie.

Updating modern pollen rain from southern Africa as a tool for the reconstruction of past vegetation and climate change

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Southern Africa is considered a particularly sensitive area in terms of long-term climate change as well as an important region for the appearance of cultural innovations among early groups of *Homo sapiens* signifying potential new social behaviours in the *Middle Stone Age* and *Later Stone Age* cultures. Several hypotheses linking environmental variability, population expansion and dispersal have been proposed to explain behavioural changes (e.g. Marean *et al.* 2007). However, few reliable palaeoclimatic records exist from the sub-Saharan region and comparisons between proxies from different archives remain still difficult and often contradictory.

In particular, fossil pollen data used as vegetation and climate indicators are complex in this region because of the high taxonomic diversity and high range of climatic distribution. Studying the relationships between present-day pollen assemblages, vegetation and climate (e.g. Cao *et al* 2014) along with the analysis of high temporal resolution and well-dated marine pollen sequences is crucial to reconstruct past vegetation and climate changes at millennial and long-term time scales. Comparison of marine pollen sequences with terrestrial environmental archives provides a clear picture of the local environments where humans have evolved.

Here we propose an updated calibration of modern pollen–vegetation–climate relationships based on large modern pollen samples database for the southern African region. In addition to the previously published 31 surface samples from the southwestern part (Urrego *et al.* 2015) and the 150 surface samples collected between 22 S and 35 S from the African Pollen Database (Gajewski *et al.* 2002), we are compiling other published data and analysing a new set of modern pollen surface samples. New samples have been collected from the Limpopo River catchment area in Pullen Nature Reserve near Nelspruit and Ga-Moraba hill close to the archaeological site of Bushman Rock Shelter. These samples consist of mossy patches, soils and water bodies where pollen deposition and preservation were likely. Statistical analyses using detrended correspondence analysis (DCA) and canonical correspondence analysis (CCA) combined with bioclimatic data from Wordclim (Hijmans *et al.* 2005) are used to visualize the bioclimatic environmental effects on the distribution of vegetation. Finally, GIS software will be used to map the

distribution and pollen abundance for the main taxa that characterize the different biomes of southern Africa by interpolating values through the natural neighbour method. The process of updating this record will allow us to apply the calibration to the new high temporal resolution pollen record from marine core MD96-2098 collected off the Orange River estuary for reconstructing potential rapid climate changes that affected the western part of southern Africa through the Middle and Later Stone Age.

REFERENCES

CAO, X.Y., HERZSCHUH, U., TELFORD, R.J. & NI, J. 2014. A modern pollen–climate dataset from China and Mongolia: assessing its potential for climate reconstruction. *Review of Palaeobotany and Palynology* **211**, 87–96.

GAJEWSKI, K., LÉZINE, A.M., VINCENS, A., DELESTAN, A.& SAWADA, M. 2002. Modern climate–vegetation–pollen relations in Africa and adjacent areas. *Quaternary Science Review* **21**(14), 1611–1631.

HIJMANS, R.J., CAMERON, S.E., PARRA, J.L., JONES, P.G. & JARVIS, A. 2005. Very high resolution interpolated climate surfaces for global land areas. *International Journal of Climatology* **25**, 1965–1978.

MAREAN, C.W., BAR-MATTHEWS, M., BERNATCHEZ, J., FISHER, E., GOLDBERG, P., HERRIES, A., JACOBS, Z., JERARDINO, A., KARKANAS, P., MINICHILLO, T., NILSSEN, P.J., THOMPSON, E., WATTS, I. & WILLIAMS, H.M. 2007. Early human use of marine resources and pigment in South Africa during the Middle Pleistocene. *Nature* **449**, 905–908.

URREGO, D. H., SÁNCHEZ GOÑI, M. F., DANIAU, A. L., LECHEVREL, S.& HANQUIEZ, V. 2015. Increased aridity in southwestern Africa during the warmest periods of the last interglacial. *Climate of the Past* **11**, 1417–1431.

Mineralogical and geochemical study of fringing lunette dunes sediments from the western Free State Panfield, South Africa

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The western Free State Panfield has the highest concentration of pans in South Africa, with densities of up to 16 ha/km^2. Like pans elsewhere, pans in this area have fringing lunette dunes. Lunette dunes are located on the southern and southeastern pan margins, and this is in agreement with palaeoatmospheric wind circulation in this region (Holmes *et al.* 2008). Previous studies (Holmes *et al.* 2008; 2012; Rabumbulu & Holmes 2012) in this area include *in situ* sedimentological analysis of lunette sediments and a detailed optically stimulated luminescence (OSL) dating sequence of exposed faces of lunette dunes. X-ray fluorescence (XRF) and X-ray powder diffraction (XRD) research was carried out in order to determine the origin, provenance, evolution and maturity of sediments from lunette dunes in the western Free State Panfield.

This study contributes to a better understanding of the chronological record for the study region and comparison of the different lunettes in the area in terms of age, development and origin of sediments. Seventy sediment samples were collected from exposed faces of lunettes from four sites (pans). Standard 5g pellets were prepared from the homogenized sample for total elements oxide composition XRF and chemical index of alteration (CIA) values were calculated using this equation; $Al_2O_3/(Al_2O_3 + CaO + Na_2O + K_2O) \times 100$. Geochemical differences between sediments indicate differences in chemical weathering intensities, which is indicative of past climate conditions. A higher CIA value occurred when most of the alkali and alkaline earth elements had been removed and therefore suggesting strong chemical weathering. Higher intensity of chemical weathering in some sediments indicate availability of moisture which can be associated with warmer humid phases. Lunettes that are presently closer to ephemeral drainage lines have the highest CIA values. The minerology of all the dunes, from different sites and within a site, suggests that all the sediments are different, indicating either differences in terms of evolution of these features or source of sediments.

REFERENCES

HOLMES, P.J., THOMAS, D.S.G., BATEMAN, M.D., WIGGS, G.F. & RABUMBULU, M. 2012. Evidence for land degradation from aeolian sediment in the west-central Free State Province, South Africa. *Land Degradation & Development* **23**, 601–610.

HOLMES, P.J., BATEMAN, M.D., THOMAS, D.S.G., TELFER, M.W., BARKER, C.H. & LAWSON, M.P. 2008. A Holocene–late Pleistocene aeolian record from lunette dunes of the western Free State Panfield. *Holocene* **18**(8), 1193–1205.

RABUMBULU, M. & HOLMES, P.J. 2012. Depositional environments of the Florisbad Spring site and surrounds: a revised synthesis. *South African Geographical Journal* **94**(2), 191–207.

A 13 ka pollen and isotope record from alluvial deposits in a Fynbos–Succulent Karoo ecotone near Uniondale, Western Cape, South Africa

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The Eastern and Western Cape border region has several valley fills with organic layers and sandy deposits, some of which have been freshly exposed by floods in 2007. Occasional floods continue to erode

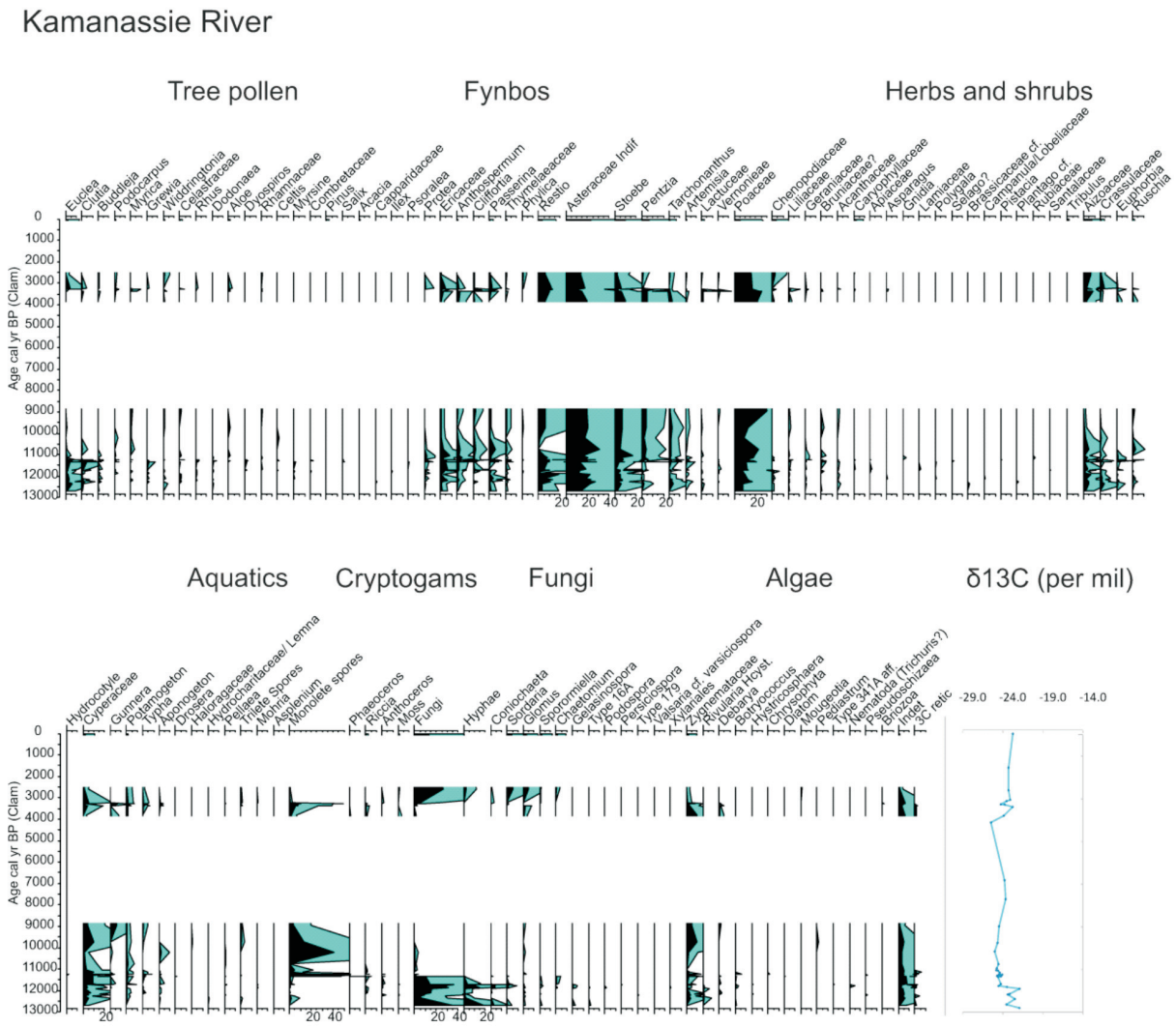


Figure 1. Pollen diagram of the alluvial section at the Kamanassie River, Uniondale, with non-pollen palynomorphs and carbon isotope ratios.

the deposits and will eventually destroy them. We dated an exposed section near Uniondale by radiocarbon and OSL dating and studied pollen and isotopes to investigate the past environments of this region from where very few palaeoclimate records are available (e.g. Martin 1967; Scholtz 1985; Quick 2015). The material contains pollen, fern spores, fungal spores, algae, phytoliths, burnt-grass phytoliths, microscopic charcoal, and coprophile spores. The section is in Succulent Karoo vegetation, fed by a mountain stream originating in Fynbos. Pollen from the basal layers of Younger Dryas age, *c.* 13 ka, consists of a relatively high proportion of Asteraceae and some woody plant pollen like *Euclea*. This phase ends *c.* 11.7 ka with increasing Restionaceae and other fynbos elements (Ericaceae, *Passerina* and *Cliffortia*) (Fig. 1). Up to this time the organic matter consisted of relatively enriched isotope values suggesting some C_4 in the vegetation. Moderate numbers of grass and succulent pollen can presumably account for this. Grass and Asteraceae (including *Stoebe* type) pollen increased and Restionaceae declined at *c.* 10.5 ka. The grass component now possibly included some C_3 species as more depleted carbon isotope values were found. The rest of the fynbos elements and succulents (e.g. *Ruschia*) still persisted but all these declined at *c.* 10 ka. Afterwards grass pollen increased markedly together with a moderate return of Restionaceae pollen up to *c.* 9 ka after which the record is interrupted by poor pollen preservation. Carbon isotope values remained relatively depleted by 8 ka but gradually became moderately enriched *c.* 7.3 to 6.8 ka suggesting the return of some C_4 plants possibly due to dry conditions that prevented pollen preservation. The available organic matter then showed a decline in isotope values at *c.* 4.1 ka to the most depleted of the section suggesting predominantly C_3 vegetation. Afterwards at *c.* 3.8–2.5 ka, the isotope values became more enriched again while grasses, Asteraceae and Restionaceae pollen became prominent indicating a return of some C_4 species under warm, presumably summer rain conditions. The uppermost section had poor pollen preservation and the low number of available samples shows reduced organic matter tentatively suggesting that conditions generally remained the same until the 20th century.

REFERENCES
MARTIN, A.R.H. 1968. Pollen analysis of Groenvlei lake sediments, Knysna (South Africa). *Review of Palaeobotany and Palynology* **7**, 107–144.
SCHOLTZ, A. 1986. *Palynological and Palaeobotanical Studies in the Southern Cape*. Stellenbosch, University of Stellenbosch.
QUICK, L.J., MEADOWS, M.E., BATEMAN, M.D., KIRSTEN, K.L., MAUSBACHER, R., HABERZETTL, T. & CHASE, B.M. 2015. Vegetation and climate dynamics during the last glacial period in the fynbos-afrotemperate forest ecotone, southern Cape, South Africa. *Quaternary International* **404**, 136–149.

Why so long in the tooth: A springbok's perspective on hominin evolution?

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Thirty years on from Vrba's (1985) Turnover Pulse Hypothesis, we re-examine the potential role of climate and human evolution in southern Africa. Vrba stressed the faunal species and turnover in southern Africa indicated warmer forested conditions were superseded by cooler, drier, grassland-dominated conditions. To test this highly-influential theory, we approach the problem from a different angle. What do diets of a successful herbivore species show over the period 2.8–0.8 Ma? Springbok, an abundant survivor of the palaeovegetation and palaeoclimatic changes of the Plio-Pleistocene, co-occurs with hominins at Sterkfontein and Swartkrans. Additionally there are several species present, suggesting possible adaptations to the changing habitats and vegetation conditions over the temporal period where significant changes in vegetation appeared to accompany faunal turnover as well as the disappearance of *Australopithecus africanus*, and the subsequent appearance of early *Homo* and *Paranthropus*.

We use the full range of dental proxies – microwear, mesowear, isotopes and phytolith sampling – to deduce in great detail, the dietary changes of a single surviving lineage, that of the springbok (*Antidorcas*). We examine all known specimens of the genus, and all specimens assigned to the various species (the ancestral *A. recki*, *A. bondi*, *A. australis* and *A. marsupialis*). The taxonomic assignment to species level for these assemblages presents a challenge, as does the complexity of cave stratigraphy.

Preliminary findings indicate:

1) The buccolingual width of dentition for *Antidorcas* sp., *A. marsupialis* and *A. bondi* significantly differs between Member deposits suggesting longer-term adaptation to changing conditions.
2) *A. bondi* consistently falls into the lower relief dental mesowear categories, as would be expected of a typical grazer. *A. marsupialis* shows less variation in diet than in dentition assigned to *Antidorcas* sp. or *Antidorcas australis/marsupialis*. This suggests *A. australis* has a distinct diet, and potentially goes some way to confirming *A. australis* as a separate species. The levels of variation in *A. marsupialis'* diets increases through time.
3) From microwear analysis, *A. recki* is shown to be a browser at Sterkfontein Member 4, with variation in diet subsequently increasing towards a mixed feeding signal. *A. marsupialis* shows the highest EpLsar (anisotropy) values of all *Antidorcas* species, a trend that increases through time, consistent with an increased grazing component to the diet. Modern *A. marsupialis* adopts a mixed feeding diet. This variation through time is potentially reflective of vegetation abundance or availability, or due to faunal community factors (such as prey risk and competition). *A. marsupialis'* ability to adapt its diet allows for its survival.

Preliminary evidence supports Vrba's Turnover Pulse Hypothesis. Ancestral *A. recki* shows higher levels of browse and later *A. marsupialis* shows greater levels of graze. Clearly, springbok survival was due to the ability of this mixed feeder to adapt to changing vegetation conditions. In turn, we can use these data to infer the types of palaeovegetation changes experienced by our hominin ancestors. Hominins, unlike herbivores (Lee-Thorp *et al.*1994), would not fully reflect the palaeovegetation conditions, but bovid dentition can be used as an informative proxy. *Antidorcas marsupialis* (extant springbok), as a mixed feeding antelope is a faithful reflector of palaeovegetation conditions of the temporal and geographic area. This project is the first to allow us to examine and reconstruct palaeovegetational signals experienced through time at the important hominin region of the Cradle of Humankind, South Africa, for this temporal period. It will also enable us to compare results from a range of proxies to evaluate their utility in exploring past habitats.

REFERENCES
DEMENOCAL, P.B. 2011. Climate and human evolution. *Science* **331**(6017), 540–542.
LEE-THORP, J.A., VAN DER MERWE, N.J. & BRAIN, C.K., 1994. Diet of *Australopithecus robustus* at Swartkrans from stable carbon isotopic analysis. *Journal of Human Evolution* **27**(4), 361–372.
STEININGER, C.M. 2012. *The dietary behaviour of early pleistocene bovids from Cooper's Cave and Swartkrans, South Africa*. Ph.D. thesis, University of the Witwatersrand, Johannesburg.
VRBA, E.S. 1985. Environment and evolution: alternative causes of the temporal distribution of evolutionary events. *South African Journal of Science* **81**, 229–236.

Investigations into the use of underground storage organs at Border Cave, South Africa, before 100 000 years ago

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Fruits, nuts, seeds, wood and underground corms, tubers and rhizomes were necessities for hunter-gatherers during the Stone Age, yet they seldom preserve archaeologically in southern African Middle Stone Age (MSA) sites. Although it is generally charcoal from fires in hearths that is preserved, there are other and exception cases of plant preservation. Evidence from Sibudu implies that people were familiar with medicinal plants in the MSA (Wadley 2015) and at Boomplaas and Klasies River, burned plant material indicates that geophytes may have been cooked and eaten (Wadley 2015: 197). This interpretation is supported by finds of carbohydrate-rich corms at another MSA site, Strathalan Cave B (Wadley 2015). Here, we investigate evidence for much earlier use of underground storage organs (USOs), at Border Cave, South Africa. We describe the methods used in our investigations and the difficulty of making positive identifications, and we outline future strategies.

Border Cave is in the Ingwavuma district of northern KwaZulu-Natal, on the border of Swaziland and South Africa. The cave has been extensively excavated in the past, but apart from a few preliminary plant identifications (Anderson 1978), little attention has until now been given to botanical remains from the site. An exception is the work on identifications of poison residues derived from plants younger than 40 000 years old (40 ka) (d'Errico *et al.* 2012). However, Border Cave occupations might have begun as early as 250 ka ago and the material from the 4 WA (White Ash) layers examined here have been dated by Electron Spin Resonance on tooth enamel to 115 ± 8, 113 ± 5 and 168 ± 5 ka (Grün *et al.* 2003).

Fragments of vegetative parenchymatous tissue from plant parts such as roots, tubers, corms, bulbs and rhizomes (referred to as geophytes or USOs) are frequently not recognized in archaeobotanical assemblages. When they are recognized, they are identified according to external morphology, if it is preserved, and by internal anatomy (vascular tissue in particular) observed at high magnification under scanning electron microscopy (SEM). This combined approach was applied to the 22 USOs recovered from 4 WA.

For the external morphological identification of the archaeological USOs, plant vouchers were consulted at Herbaria and modern plants were collected, charred and compared to the ancient samples. Size, shape, root position, surface features and detail visible under reflective magnification up to ×40, were recorded. These attributes, observed on 14 of the USOs, matched those of the rhizomes in the genus *Tulbaghia*, a monocotyledon belonging to the Alliaceae or onion family (Fig. 1).

However, SEM examination of the vascular structure of modern and ancient material could not confirm the *Tulbaghia* identification and furthermore, it suggested that the ancient material resembled the rhizome of a dicotyledonous plant. We are thus faced with a conundrum, and much work ahead: in order to



Figure 1. Modern carbonized *Tulbaghia violace* rhizome (left) and carbonized rhizome from Border Cave, 4WA (right). Scale bar = 1 cm (images: Lyn Wadley).

identify the early USOs at Border Cave we need to increase our reference collection of USOs to find a plant that matches both the morphology and the vascular tissue of the material from Border Cave.

Even though we are not yet able to identify the remains to a specific genus or species, the presence of the USOs at Border Cave over 100 000 years ago makes a significant contribution to our knowledge about plant use at that time. The USOs would have been brought into the cave by humans and the intriguing questions are what they might have been used for and if processing by roasting, which likely caused their carbonization, was deliberate.

REFERENCES

ANDERSON, J. 1978. Provisional comments on fossil leaves and seeds from Border Cave. **In**: Beaumont, P.B. *Border Cave*, 518–530. Ph.D. thesis, University of Cape Town, Cape Town.

D'ERRICO, F., BACKWELL, L., VILLA, P., DEGANO, I., LUCEJKO, J., BAMFORD, M.K., HIGHAM, T.F.G., COLOMBINI, M.P. & BEAUMONT, P.B. 2012. Early evidence of San material culture represented by organic artifacts from Border Cave, South Africa. *Proceedings of the National Academy of Sciences of the United States of America* **109**(33), 13214–13219.

GRÜN, R., P.B. BEAUMONT, P.V. TOBIAS & S.M. EGGINS. 2003. On the age of the Border Cave 5 human mandible. *Journal of Human Evolution* **45**, 155–167.

WADLEY, L. 2015. Those marvellous millennia: the Middle Stone Age of southern Africa. *Azania: Archaeological Research in Africa* **50**(2), 155–226.

A look into the past: A Holocene palaeoenvironmental reconstruction of the Okavango source wetlands in Angola

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Palaeoepalynology is the study of organic microfossils, including pollen and spores which are preserved in sedimentary rock as well as peat bogs and wetlands (Traverse 2007). Studying the pollen and spores enables us to reconstruct past climates as well as allow us to determine the past temperature and rainfall giving clues to the workings of ecosystems and their coping mechanisms. Understanding climate and environmental change is vital in the anthropogenic age, since humans in some way or another are directly affected by a change in surrounding environmental conditions. Tracking climate change enables us to gain a more valuable understanding of the past and how ecosystems dealt with change. This aids in predicting future climatic conditions. Fossil pollen serves as a useful proxy record of past vegetation, and in turn, the climate records extending from the contemporary to the early Permian period.

This study which is initiated to reconstructing the Holocene palaeoenvironmental history of the source wetlands to the Okavango Delta, aims to use fossil pollen and radiocarbon dating to record the dominant



Figure 1. Locality map of the sediment core collection sites, Cuito and Cuanavale, in Angola.

shifts in vegetation which occurred during the Holocene, and establish the likely climate drivers of such changes, with particular consideration to the periods in which substantial change occurred. Sediment core samples were extracted from two sites, namely Cuanavale and Cuito, illustrated in Fig. 1, ranging in depths of 40– 100 cm. The cores were subsampled at a 2 cm resolution for pollen analysis and 4 g of sample from particular depths in the cores for AMS radiocarbon dating. Pollen deposited in the sediment layers were extracted using a variety of chemical treatments. These two particular wetlands are sources of water influx into the Okavango. Analysis of the pollen counts from these high-resolution cores may reveal information relating to the formation and development of wetlands, the local environments surrounding them, and major climatic events that occurred during the period being studied.

This study is part of the National Geographic Okavango Wilderness project, which is currently being conducted in Angola, Namibia and Botswana. Rivers from the Angolan highlands drain into the Okavango Delta, and then enter the Ntetwe and Sowa pans of the Makgadikgadi–Okavango–Zambezi rift depressions (Ringrose *et al.* 2005). Local rainfall and inflow from the Angolan highlands causes annual flooding in the Okavango. This hydrological system is sensitive to change making it very susceptible to anthropogenic impacts such as fire, land-use change, and the introduction of invasive species. To improve conservation methods of the delta, an understanding of the spatial and temporal aspects of the palaeoclimate is necessary to gain insight into the mechanisms of the Okavango and its source wetlands.

The resultant qualitative and quantitative study of the palaeoclimate of the two source wetlands in Angola will contribute to the broader understanding of regional climate change during the Holocene. This will facilitate in more effective approaches towards the management of current ecosystems, especially within the context of a southern African developing country where there is great reliance on the Okavango and source wetlands (Smith *et al.* 2003; Jones *et al.* 2009; Huntsman-Mapila *et al.* 2005).

ACKNOWLEDGEMENTS

We would like to acknowledge and thank PAST for their generous funding towards our conference attendance.

REFERENCES

HUNTSMAN-MAPILA, P., KAMPUNZU, A.B., VINK, B. & RINGROSE, S. 2005. Cryptic indicators of provenance from the geochemistry of the Okavango Delta sediments, Botswana. *Sedimentary Geology* **174**(1), 123–148.

JONES, P., BRIFFA, K., OSBORN, T., LOUGH, J., VAN OMMEN, T., VINTHER, B., LUTERBACHER, J., WAHL, E., ZWIERS, F., MANN, M., SCHMIDT, G., AMMANN, C., BUCKLEY, B., COBB, K., ESPER, J., GOOSSE, H., GRAHAM, N., JANSEN, E., KIEFER, T., KULL, C., KÜTTEL, M., MOSLEY-THOMPSON, E., OVERPECK, J., RIEDWYL, N., SCHULZ, M., TUDHOPE, A., VILLALBA, R., WANNER, H., WOLFF, E. & XOPLAKI, E. 2009. High-resolution palaeoclimatology of the last millennium: a review of current status and future prospects.*The Holocene* **19**(1), 3–49.

SMITH, J., KLEIN, R. & HUQ, S. 2003. *Climate Change: Adaptive Capacity and Development.* London, Imperial College Press.

TRAVERSE, A. 1994. Palynofloral geochronology of the Brandon Lignite of Vermont, USA. *Review of Palaeobotany and Palynology* **82**(3-4), 265–297.

Foraminifera: A tool for palaeoenvironmental analysis along South Africa's coastline

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Coastal evolution is cumulative, and therefore the present coastal landscape is the result of past coastal processes and landforms (Masselink & Gehrels 2014). It is vital to understand how South Africa's coastline has responded to relative sea-level change, so that future changes can be predicted. For this reason there is a need for high-resolution studies, which may reveal a clear picture of coastal sea-level changes through time. Salt-marsh foraminifera are distributed according to the vertical zonation concept, and thereby considered to be accurate proxies for reconstructing the characteristics and timing of past sea levels (Scott & Medioli 1978). This research explores the application of intertidal salt-marsh foraminifera as sea-level indicators along the southern African coastline. It further describes the development of a regional transfer function and assesses its performance in reconstructing sea-level change. Three permanently open estuarine environments were selected for this study, Kariega and Keiskamma along the eastern coastline, and Knysna along the southern coastline.

Multivariate ordination was used to examine the correlation between living foraminiferal assemblages and environmental parameters. It was established that elevation was the key environmental variable governing the distribution of salt-marsh foraminifera at the Keiskamma and Knysna estuaries. Salinity had a significant but opposite influence to elevation at the Keiskamma Estuary. At Knysna Estuary, pH was the secondary driver of foraminiferal composition. The contemporary intertidal environments at Keiskamma and Knysna estuaries were described in relation to the zonation of foraminifera across each salt marsh. Cluster analysis was performed to separate foraminifera into salt-marsh zones. Whilst the composition and vertical ranges of assemblage zones vary between sites, we suggest that South African

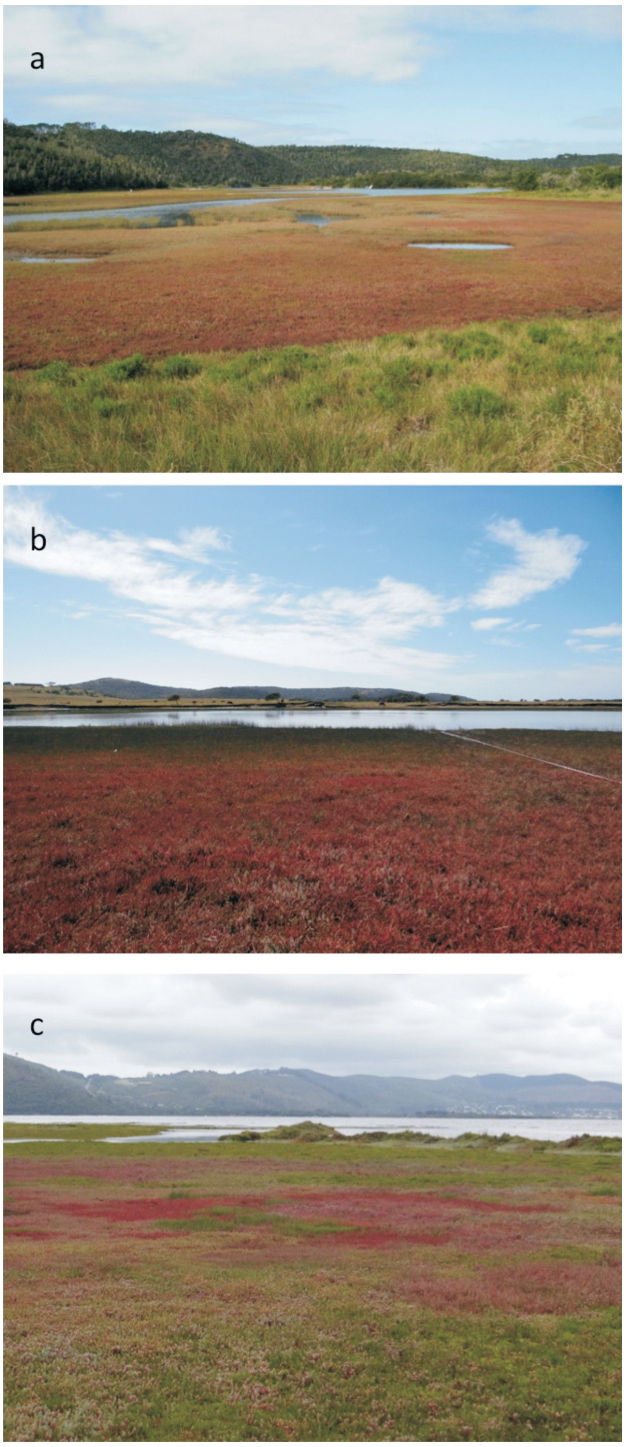


Figure 1. Study sites along the southeast coast of South Africa. **a**, Kariega Estuary; **b**, Keiskamma Estuary; **c**, Knysna Estuary.

salt marshes can be classified according to four broad subdivisions. The mudflats have the most diverse assemblages, consisting predominately of calcareous species. *Ammonia* spp., dominates the lower marsh zone followed by *Miliammina fusca*, which dominates the middle to lower marsh vegetated zone. The high marsh zone is characterized by the high abundance of *Trochammina inflata*.

Modern training datasets from the selected study sites were used to investigate the suitability of local *versus* regional datasets for reconstructing recent sea-level trends. The results suggest that a regional transfer function using weighted averaging models is suitable for the analysis of fossil material, producing sea-level reconstructions with an error of ±0.22 m. Sea-level records from far field sites offer important constraints on the timing and amplitude of global sea-level changes and improve our understanding of the driving mechanisms behind the late Holocene sea-level change. The regional transfer function has the potential to link short-term instrumental records with longer-term relative sea-level reconstructions, advancing research into past sea-level fluctuations along the South African coastline, and provide a baseline understanding of the nature and causes of sea-level variation. Intertidal salt-marsh foraminifera

provide South African sea-level studies with an indicator that is reliable and can be used at multiple sites, allowing for comparisons between studies.

REFERENCES

MASSELINK, G. & GEHRELS, R. (eds). 2014. *Coastal Environments and Global Change*. Chichester, John Wiley & Sons.

SCOTT, D.S. & MEDIOLI, F.S. 1978. Vertical zonations of marsh foraminifera as accurate indicators of former sea-levels. *Nature* **272**(5653), 528–531.

Oxygen isotope ratios of *Turbo sarmaticus* molluscan opercula from Late Pleistocene archaeological deposits, Klasies River, South Africa

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Klasies River (KR) is a cave complex situated on the Tsitsikamma coast, west of Port Elizabeth in South Africa.The sites were excavated by Ronald Singer and John Wymer (1982), and by Hilary Deacon (1995), yielding Late Pleistocene remains of 'anatomically modern *Homo sapiens*' and evidence for the exploitation of marine resources within the last 125 000 years before present (Thackeray 1988). Molluscs include the alikreukel (*Turbo sarmaticus*), an edible gastropod with well preserved opercula which have been analysed for oxygen isotope ratios (delta 18O) that relate to changes in both sea level and sea temperatures. In an initial study, Shackleton (1982) analysed approximately 200 KR samples from 17 specimens, and demonstrated seasonal variability in delta O18. Additional delta 18O data for just a few selected *T. sarmaticus* opercula were reported by Deacon *et al.*(1988).In this study we report results obtained from 30 specimens from Klasies River, and interpret the results in the context of global sea-level changes, sea temperatures and chronology associated with marine isotope stages (MIS). On the basis of the marine mollusc evidence presented here, we recognize at least three sub-stages of MIS 5 (5a, 5b, 5c), associated with MSA I and MSA II deposits. We consider that the Howiesons Poort deposits are associated with parts of MIS 4 and 3, including the warmest component of MIS 3, and thatMSA III deposits are associated with younger episodes of MIS 3.

REFERENCES

DEACON, H.J. 1995. Two Late Pleistocene-Holocene archaeological depositories from the southern Cape, South Africa. *South African Archaeological Bulletin* **50**, 121–131.

DEACON, H.J., TALMA, A.S. & VOGEL, J.C. 1988. Biological and cultural development of Pleistocene people in an Old World southern continent. **In**: Prescott, J.R. (ed.), *Early Man in the Southern Hemisphere.* Supplement to Archaeometry: Australian studies: S23–S31. Adelaide, University of Adelaide.

SHACKLETON, N.J. 1982. Stratigraphy and chronology of the Klasies River Deposits: oxygen isotope evidence. **In**: Singer, R. & Wymer, J. (eds), *The Middle Stone Age at Klasies River Mouth in South Africa*, 194–199. Chicago, Chicago University Press.

SINGER, R. & WYMER, J. (eds). 1982. *The Middle Stone Age at Klasies River Mouth in South Africa.* Chicago, Chicago University Press.

THACKERAY, J.F. 1988. Molluscan fauna from Klasies River, South Africa. *South African Archaeological Bulletin* **43**, 27–32.

Early systematic coastal foraging and cultural complexity at Klasies River main site

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The coastal area of the Cape is well known for its cave sites that were inhabited by humans throughout the Late Pleistocene and Holocene. For this reason the area features prominently in debates on the evolution of anatomical modernity, the origins of modern or complex behaviour and landscape use. Klasies River main site, situated on the Tsitsikamma coast is one of the sites that provide a particularly strong signal of occupation on the south Eastern Cape coast. Main site contains extensive Late Pleistocene deposits dating to between ~120 and 55 000 and, after an lengthy hiatus, Holocene deposits that date to between 4800 and 2300 years ago (Wurz 2012; Nami *et al.* 2016). The thick sediment pile, originally extending to a height of 20 metres, formed in and against the caves and overhangs, caves 1, 1A, 1B and 2, that comprise main site. These deposits contain the fossil and cultural remains of fisher-hunter-gatherers in characteristic stacked shell middens, including abundant shellfish, fauna and stone artefacts.

The stratigraphy of the site consists of a number of members (Deacon 2008), from the bottom to the top, the 1,5 m thick Light Brown Sand (LBS) member, the 10 m Shell and Sand (SAS) member, the 0.5 m Rock Fall (RF) member, the 2 m Upper member, the 0.5 m White Sand (WS) member, capped by the *c.* 2 m Late Holocene Later Stone Age member. In this paper the focus is on the earliest stratigraphic members dating to between *c.* 120 and 90 000 years ago, the LBS member, and the lower part of the SAS member. These members preserve a large collection of fossil remains of anatomically modern humans of variable morphology (Grine *et al.* 2017). Their subsistence patterns reflect a true coastal economy as high densities of shellfish, fish and a preponderance of marine mammals such as seal occur (Wurz 2012). The subsistence

patterns varied somewhat in relation to the fluctuating climate and environments in MIS 5. The LBS member, for example, relates to an open and marshland environment and the lower SAS member to a more closed environment. Even so, interglacial conditions prevailed and coastal resources remained a significant part of the diet.

Klasies River main site was repeatedly selected as an occupational site during MIS 5, leading to a deposition thickness of *c.* 10 metres. This is one of the most extensive MIS 5 deposits in Africa. Clues for the preference of the site during this time range may be found in the highly productive palaeoenvironment that might have been a biodiversity hotspot in the past, as it is today (Wurz 2012). The coastal resources were systematically used and exploited in a regular, recurrent planned way. New results for example confirm that the *Perna perna* (brown mussel) represent the main shellfish type exploited in large quantities throughout MIS 5. The coastal resources provided a 'dense and predictable' resource base. This, in turn, may have played a role in both the development of prosociality and heightened levels of interpersonal violence (Marean 2016) of the MIS 5 communities from this area. Indeed, some of the early human fossils from Klasies River are burnt and have cutmarks.This has been associated with either interpersonal violence, or ritual behaviour (Deacon 2008). The social implications of artefacts such as scored ochre and notched bone from MIS 5 levels at Klasies River main site will also be explored.They reveal extended production chains and it might be that they played a role in the changing social relations associated with increased population densities in the south-Eastern Cape at this time.

REFERENCES

DEACON, H.J. 2008. The context of the 1967-8 sample of human remains from Cave 1 Klasies River Main Site. *South African Archaeological Society Goodwin Series*, 143–149.

GRINE, F.E., WURZ, S.& MAREAN, C.W. 2017.The Middle Stone Age human fossil record from Klasies River Main Site. *Journal of Human Evolution* **103**, 53–78

MAREAN, C.W. 2016. The transition to foraging for dense and predictable resources and its impact on the evolution of modern humans. *Philosophical Transactions of the Royal Society B* **371**(1698), 20150239.

NAMI, H.G., DE LA PEFIA, P., VÁSQUEZ, C.A., FEATHERS, J. & WURZ, S. 2016. Palaeomagnetic results and new dates of sedimentary deposits from Klasies River Cave 1, South Africa. *South African Journal of Science* **112**(11-12), 1–12.

WURZ, S. 2012. The significance of MIS 5 shell midddens on the Cape coast – a lithic perspective from Klasies River and Ysterfontein 1. *Quaternary International* **270**, 61–69.

Evolution of the hominin foot in the Quaternary

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The 2.6 million years of the Quaternary represents the time during which recognizable human relatives existed. Of all the evolutionary specializations that define the human species, the foot is considered to be one of the most important and is pivotal in allowing the evolution of arguably the most critical defining character of the hominins – bipedalism (Susman 1983). Reconstructing the transition to bipedality is key to understanding early hominin evolution. Morton's (1935) synthesis of foot evolution argues that the foot of a common ancestor of modern humans and African apes is intermediate between *Pan* and *Hylobates* and the foot of a hypothetical hominin ancestor is intermediate between that of gorilla and modern humans. However, these hypotheses were formulated before the fossil record contained early hominin pedal material. Up until 2008, there were only four known relatively complete fossil foot assemblages, and of these, two fell within the Quaternary, most notably OH 8 from Olduvai, Tanzania, attributed to *Homo habilis* (Leakey 1960). The study of this assemblage resulted in varying interpretations and much debate. A number of significant fossil foot bones have subsequently been recovered from East Africa, South Africa, Georgia and the island of Flores, Indonesia, bringing the fossil foot record to 12 significant specimens, more than half of which fall within the Quaternary, representing the recent evolution of the foot (Fig. 1).

The increasing number of pedal elements in the hominin fossil record has led some to suggest that there may have been greater diversity in early human bipedalism than previously thought (Harcourt-Smith & Aiello 2004). The varying interpretations based on this material, together with changing theoretical insights and analytical approaches are reviewed here within the context of the remarkable new discoveries of *Australopithecus sediba* and *Homo naledi* (Zipfel *et al.* 2011; Harcourt-Smith *et al.* 2015). These shed new light on the evolution of the foot and have important implications for our understanding of hominin bipedal diversity. This also provides a surprising look at what can only be described as a transitional foot in *A. sediba* (as in most other fossil feet) where the calcaneus is ape-like and the talus derived, and a virtually modern human foot in *H. naledi* suggesting that the foot evolved a human-like bipedalism well before brain capacity increased and hominins abandoned arboreal locomotor strategies. There is evidence, at least in the lateral component of the foot of most pre-human hominins, that the biomechanical pattern is very similar to that of modern humans with a tendency towards a stable calcaneo-cuboid joint. This, however, may not have been the case in the medial column of the foot, as a mosaic pattern of hominin foot

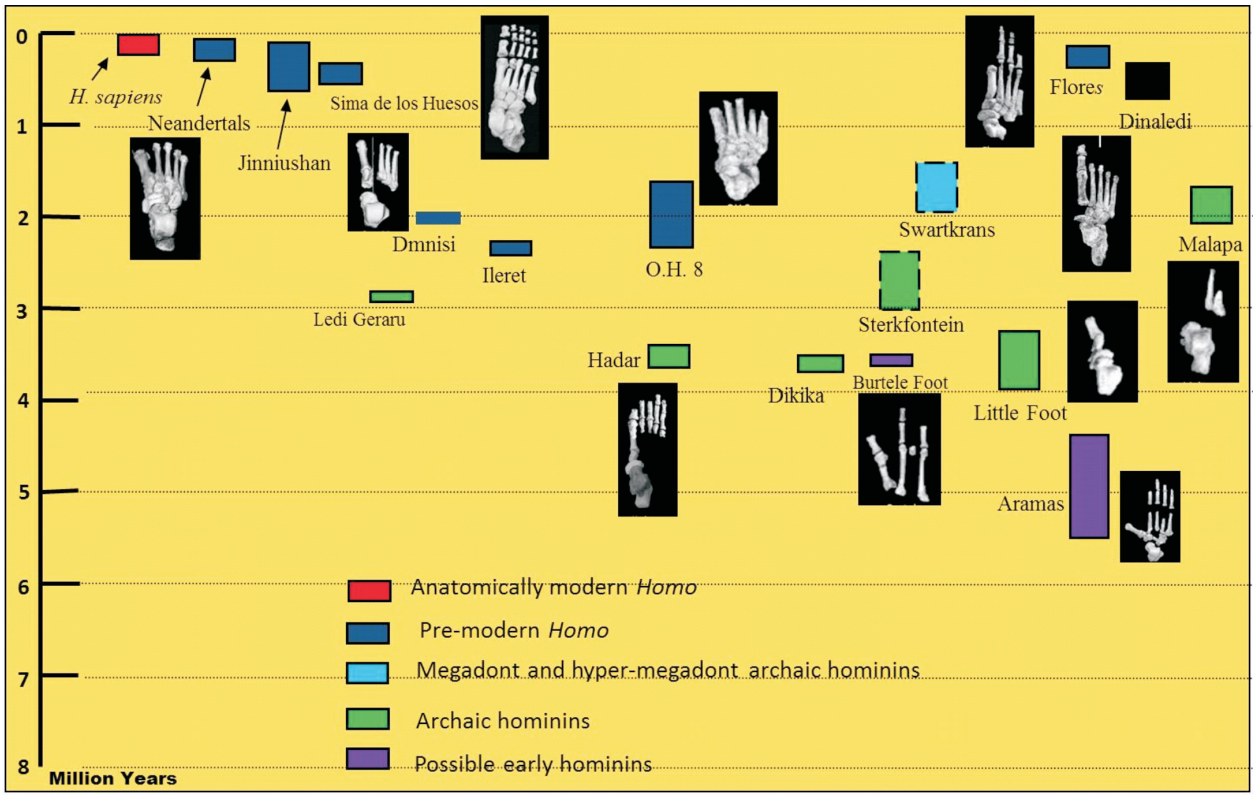


Figure 1. Temporal distribution of known fossil hominin feet. The hatched areas indicate localities where a number of isolated pedal elements have been recovered but do not represent comprehensive foot assemblages.

evolution and function has been suggested. The results of a number of studies may support the hypothesis of an increased calcaneo-cuboid stability having been an early evolutionary event in the history of terrestrial bipedalism.

Given the combination of features, and comparisons to both older and younger fossils, homoplasy is implied in the acquisition of bipedal adaptations in the hominin foot, and draws into question the descendant relationship of these hominins from one candidate ancestor, *Australopithecis afarensis*.

REFERENCES

HARCOURT-SMITH, W. & AIELLO, L.C. 2004. Fossils, feet and the evolution of human bipedal locomotion. *Journal of Anatomy* **204**, 403–416.

HARCOURT-SMITH, W.E.H., THROCKMORTON, Z., CONDON, K., ZIPFEL, B., DEAN, A., DRAPEAU, M., CHURCHILL, S.E., BERGER, L.R. & DESILVA, J.M. 2015. The foot of *Homo naledi*. *Nature Communications* **6**, 8432. DOI: 10.1038/ncomms9432.

LEAKEY, L.S.B. 1960. Recent discoveries at Olduvai Gorge. *Nature* **188,** 1050–1052.

SUSMAN RL.1983. Evolution of the human foot: evidence from Plio-Pleistocene hominids. *Foot Ankle* **3**, 365–376.

ZIPFEL, B., DESILVA, J., KIDD, R.S., CARLSON, C., CHURCHILL, S. & BERGER, L.R. 2011. The foot and ankle of *Australopithecus sediba*. *Science* **333,** 1417–1420.

Preliminary results for an analysis of charcoal from the Later Stone Age at Klasies River cave 1

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The Klasies River main site is situated on the coast of the densely vegetated, well-watered Tsitsikamma area, southern Cape. Main site is comprised of four caves (caves 1, 1A, 1B and 2) which were cut into the sandstone cliff at different elevations. The sequence is renowned for an extensive archaeological record that dates from the Late Pleistocene well into the Holocene. Klasies River main site is well known for the early fossil evidence of anatomically modern humans and their behaviour, and for the successful adaptation of fisher-hunter-gatherer groups from the Middle Stone Age into the Final Later Stone Age. Investigation into the environmental and climatic conditions associated with the Later Stone Age deposits has been limited. In this study, charred remnants of woody vegetation from Klasies River cave 1 were analysed to obtain a better understanding of the environment associated with the Later Stone Age occupation during the late Holocene.

Several physical factors define the Klasies River landscape. These include the coastal geographical location of the area, the underlying geological substrates as well as variable atmospheric elements which

include mild temperatures and non-seasonal precipitation. The interplay of these variables through time is imprinted in the local biotic elements of the environment such as woody vegetation. The current vegetation around Klasies River main site is predominantly thicket, Afrotemperate forest and coastal vegetation types with few fynbos elements (Van Wijk *et al.*, in press). These vegetation types populate the landscape in many growth forms such as shrubs, trees, creepers, geophytes and grasses. Shrubs and trees occur densely at different altitudes around the site, under different microclimatic conditions associated with the topography of the area. These are adapted to a non-seasonal supply of precipitation and can endure harsh salty winds. Woody taxa which tolerate specific environments may be used to identify specific dominant climatic conditions (February 1992); such taxa were identified in this study.

The archaeological charcoal remains were excavated from the occupational units of the Upper Midden of the Later Stone Age deposit in cave 1. This deposit is currently dated to *c.* 2300 BP. A total of four layers (spits) were excavated and charcoal and seeds were recovered. During laboratory analysis, a reflective light source in a stereomicroscope with up to ×500 objective lenses was used to analyse the microscopic anatomical features of the charcoal samples. The features were then captured into micrographs using Analysis and Extended Focal Image Software for comparative analysis. The woody taxa from the first two layers of the deposit have been identified.

Archaeological charcoal remains were identified mainly against a comparative collection created from shrub and tree species of the present Klasies landscape. Comparative woody taxa were sampled within a one kilometre radius of the main site. These were used to understand the community of shrubs and trees that tolerate the present climatic conditions. Other comparative collections used during the study include wood samples from the east and interior of southern Africa (Kromhout 1975; Allott 2006) as well as an online international database for wood and charcoal identification (http://insidewood.lib.ncsu.edu). Some of the taxa identified so far include *Searsia lancea*, *Podocarpus latifolius*, cf. *Protorhus longifolia*, *Sideroxylon inerme*, *Grewia occidentalis*, *Passerina* sp., *Nuxia* sp. and cf. *Hibiscus tiliaceus*. Preliminary observations indicate that the Klasies landscape during the late Holocene supported a considerably different vegetation population than today.

Although a significant number of woody taxa identified so far also occur in the Klasies landscape today, the presence of woody taxa such as cf. *H. tiliaceus* and *P. longifolia* suggest that the environmental conditions which occurred in this area during the late Holocene may be partly comparable to the present climatic conditions in the eastern and interior parts of southern Africa. These observations as well as further analysis of the charcoal and seed assemblage contributes new data on the palaeoenvironment of the southern coast in the late Holocene.

ACKNOWLEDGEMENTS

This conference presentation was funded by The Palaeontological Scientific Trust (PAST).

REFERENCES

ALLOTT, L.F. 2006. Archaeological charcoal as a window on palaeovegetation and wood-use during the Middle Stone Age at Sibudu Cave. *South African Humanities* **18**(1), 173–201.

FEBRUARY, E. 1992. Archaeological charcoals as indicators of vegetation change and human fuel choice in the Late Holocene at Elands Bay, Western Cape Province, South Africa. *Journal of Archaeological Science* **19**, 347–354.

KROMHOUT, C.P. 1975. 'n Sleutel vir die mikroskopiese uitkenning van die vernaamste inheemse houtsoorte van Suid Afrika. *South African Department of Forestry* **50**, 79–171.

VAN WIJK, Y., TUSENIUS, M.L., RUST, R., COWLING, R.M. & WURZ, S. 2017. Modern vegetation in the Klasies River cultural landscape. *Plant Ecology and Evolution*, In press.

INSIDEWOOD DATABASE http://insidewood.lib.ncsu.edu/ which follows the terminology of IAWA Hardwoods.

WHEELER, E.A., BAAS, P. & GASSON, P.E. (eds). 2007. IAWA list of microscopic features for hardwood identification. *IAWA Bulletin* **10**(3), 219–332.