Palaeontological Impact Assessment for the proposed Dikgat sand mining project, Buffels River, Northern Cape Province

Desktop Study (Phase 1)

For

ASHA Consulting

17 December 2021

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Expertise of Specialist

The Palaeontologist Consultant: Prof Marion Bamford
Qualifications: PhD (Wits Univ, 1990); FRSSAf, ASSAf
Experience: 32 years research; 24 years PIA studies

Declaration of Independence

This report has been compiled by Professor Marion Bamford, of the University of the Witwatersrand, sub-contracted by ASHA Consulting, Muizenburg, South Africa. The views expressed in this report are entirely those of the author and no other interest was displayed during the decision making process for the Project.

Specialist: Prof Marion Bamford

Executive Summary

A Palaeontological Impact Assessment was requested for the proposed Dikgat sand mining operation on the Farm Dikgat 195/4, along the Buffels River, Northern Cape Province.

To comply with the regulations of the South African Heritage Resources Agency (SAHRA) in terms of Section 38(8) of the National Heritage Resources Act, 1999 (Act No. 25 of 1999) (NHRA), a desktop Palaeontological Impact Assessment (PIA) was completed for the proposed development.

The proposed site lies on the Quaternary alluvium and sands that are indicated as having zero palaeosensitivity. The sands are transported and may have entrapped fossils from farther upstream but they would be very fragmentary and of minimal scientific value. Nonetheless, they should have a moderate palaeosensitivity on the SAHRIS map. Therefore, a Fossil Chance Find Protocol should be added to the EMPr. Based on this information it is recommended that no further palaeontological impact assessment is required unless fossils are found by the developer/ environmental officer/ other designated responsible person once excavations/drilling/mining activities have commenced. As far as the palaeontology is concerned, the project should be authorised.

Table of Contents

1. Background

It is proposed to expand the sand mining operation on Farm Dikgat 195 in the channel of the Buffels River, Northern Cape Province (Figures 1, 2).

A Palaeontological Impact Assessment was requested for the Dikgat sand mining project. To comply with the regulations of the South African Heritage Resources Agency (SAHRA) in terms of Section 38(8) of the National Heritage Resources Act, 1999 (Act No. 25 of 1999) (NHRA), a desktop Palaeontological Impact Assessment (PIA) was completed for the proposed development and is reported herein.

Table 1: Specialist report requirements in terms of Appendix 6 of the EIA Regulations (amended 2017)

	A specialist report prepared in terms of the Environmental Impact Regulations of 2017 must contain:	**Relevant section in report**
ai	Details of the specialist who prepared the report	Appendix B
aii	The expertise of that person to compile a specialist report including a curriculum vitae	Appendix B
b	A declaration that the person is independent in a form as may be specified by the competent authority	Page 1
c	An indication of the scope of, and the purpose for which, the report was prepared	Section 1
ci	An indication of the quality and age of the base data used for the specialist report: SAHRIS palaeosensitivity map accessed – date of this report	Yes
cii	A description of existing impacts on the site, cumulative impacts of the proposed development and levels of acceptable change	Section 5
d	The date and season of the site investigation and the relevance of the season to the outcome of the assessment	N/A
e	A description of the methodology adopted in preparing the report or carrying out the specialised process	Section 2
f	The specific identified sensitivity of the site related to the activity and its associated structures and infrastructure	Section 4
g	An identification of any areas to be avoided, including buffers	N/A
h	A map superimposing the activity including the associated structures and infrastructure on the environmental sensitivities of the site including areas to be avoided, including buffers;	N/A
i	A description of any assumptions made and any uncertainties or gaps in knowledge;	Section 5
j	A description of the findings and potential implications of such findings on the impact of the proposed activity, including identified alternatives, on the environment	Section 4

k	Any mitigation measures for inclusion in the EMPr	Section 8, Appendix A
l	Any conditions for inclusion in the environmental authorisation	N/A
m	Any monitoring requirements for inclusion in the EMPr or environmental authorisation	Section 8, Appendix A
ni	A reasoned opinion as to whether the proposed activity or portions thereof should be authorised	Section 6
nii	If the opinion is that the proposed activity or portions thereof should be authorised, any avoidance, management and mitigation measures that should be included in the EMPr, and where applicable, the closure plan	Sections 6, 8
o	A description of any consultation process that was undertaken during the course of carrying out the study	N/A
p	A summary and copies if any comments that were received during any consultation process	N/A
q	Any other information requested by the competent authority.	N/A

Figure 1: Google Earth map of the proposed Dikgat Sand Mine on the Buffels River (green polygon) with relevant landmarks.

Figure 2: Google Earth map showing the extended Dikgat sand mining operation in the Buffels River valley and just south of the R355 shown by the green polygon.

2. Methods and Terms of Reference

The Terms of Reference (ToR) for this study were to undertake a PIA and provide feasible management measures to comply with the requirements of SAHRA.
The methods employed to address the ToR included:

1. Consultation of geological maps, literature, palaeontological databases, published and unpublished records to determine the likelihood of fossils occurring in the affected areas. Sources included records housed at the Evolutionary Studies Institute at the University of the Witwatersrand and SAHRA databases;
2. Where necessary, site visits by a qualified palaeontologist to locate any fossils and assess their importance (*not applicable to this assessment*);
3. Where appropriate, collection of unique or rare fossils with the necessary permits for storage and curation at an appropriate facility (*not applicable to this assessment*); and
4. Determination of fossils' representivity or scientific importance to decide if the fossils can be destroyed or a representative sample collected (*not applicable to this assessment*).

3. Geology and Palaeontology

i. Project location and geological context

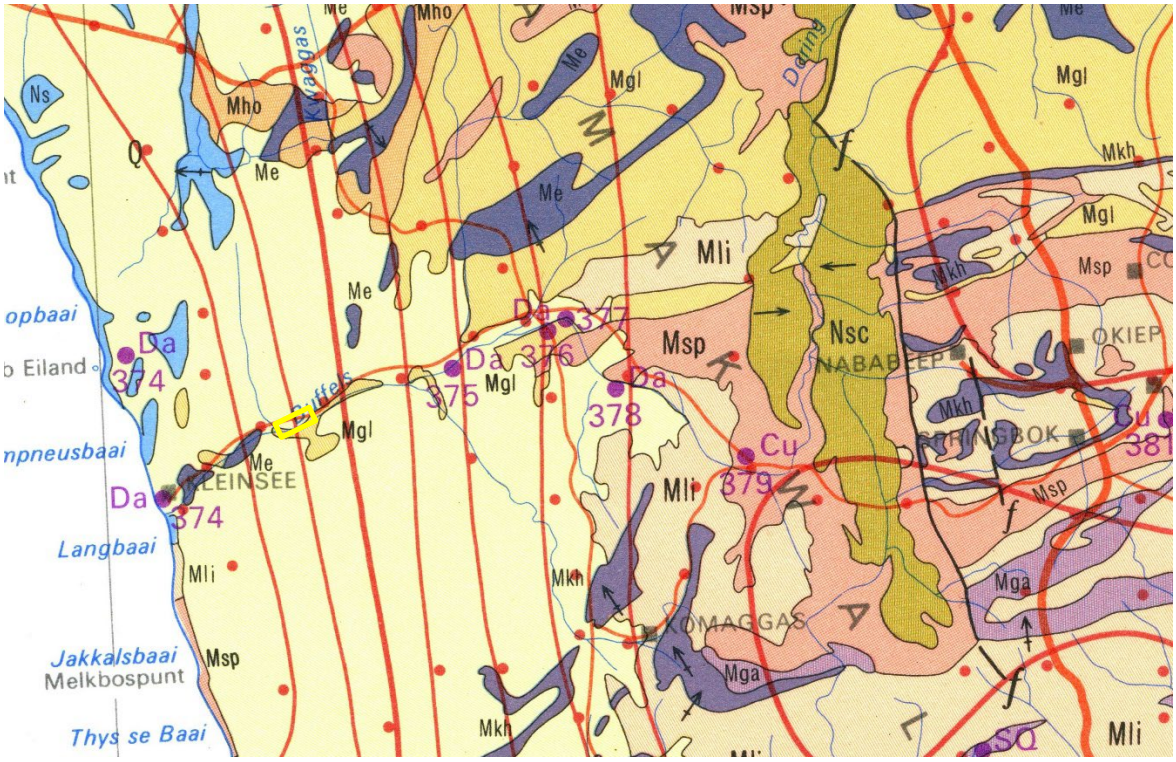

Figure 3: Geological map of the area around the Buffels River on Farm Dikgat 195. The location of the proposed project is indicated within the yellow rectangle. Abbreviations of the rock types are explained in Table 2. Map enlarged from the Geological Survey 1: 1 000 000 map.

Table 2: Explanation of symbols for the geological map and approximate ages (Cornell et al., 2006; Partridge et al., 2006). SG = Supergroup; Fm = Formation; Ma = million years; grey shading = formations impacted by the project.

Symbol	Group/Formation	Lithology	Approximate Age
Q	Quaternary	Alluvium, sand, calcrete	Neogene, ca 1.2 – 1 Ma
Tab	Alexander Bay Fm		Neogene, ca 2.5 Ma to present
Msp	Spektakel Suite	Aplogranite, porphyritic granite	Neoproterozoic ca 1060 Ma
Mli	Little Namaqualand Suite	Augen gneiss	Neoproterozoic ca 1200 Ma
Mgl	Gladkop Suite	Grey fine-grained gneiss	Neoproterozoic 2050 - 1700 Ma
Me	Aardvark and EenRiet Subgroup, Okiep Group	Schist gneiss, quartzite	
Mga	Garies Subgroup, Okiep Group	Biotite gneiss	

The proposed Dikgat sand mine lies in the Namaqua-Natal Province in the Namaqua section (Figure 3, Table 2). The Namaqua-Natal Province is a tectono-stratigraphic province and forms the southern and western boundary of the ancient Kaapvaal Craton, and extends below the Karoo Basin sediments to the south (Cornell et al., 2006). It comprises rocks that

were formed during the Namaqua Orogeny (mountain-building) some 1200 – 1000 million years ago. It has been divided by geologists into a number of terranes (similar lithology and bounded by shear zones). There are three main lithologic units used to separate the terranes as well as the shear zones but still there is some debate about the terranes (ibid). Very simply, the lithologic units are older reworked rocks, juvenile rocks formed during tectonic activities and metamorphosed, and intrusive granitoids.

According to Cornell et al. (2006) the five terranes are:
A - Richtersveld Subprovince (undifferentiated terranes)
B – Bushmanland Terrane (granites)
C – Kakamas Terrane (supracrustal metapelite ca 2000 Ma
D – Areachap Terrane (supracrustal rocks and granitoids)
E – Kaaien Terrane (Keisian aged metaquartzites and deformed volcanic rocks).

The project lies in the **Bushmanland Terrane** with its northern boundary against the Richtersveld Subprovince and the eastern boundary against the Kakamas Terrance (ibid). The Namaqua-Natal Province rocks are volcanic in origin and frequently metamorphosed. Several outcrops occur in the area and probably underlie the Gordonia sands.

Overlying many of these rocks are loose sands and sand dunes of the Gordonia Formation, Kalahari Group of Neogene Age. The Gordonia Formation is the youngest of six formations and is the most extensive, stretching from the northern Karoo, Botswana, Namibia to the Congo River (Partridge et al., 2006). It is considered to be the biggest palaeo-erg in the world (ibid). The sands have been derived from local sources with some additional material transported into the basin (Partridge et al., 2006). Much of the Gordonia Formation comprises linear dunes that were reworked a number of times before being stabilised by vegetation (ibid).

A narrow band of Neogene sediments along the West coast of southern Africa from Elands Bay in the south to Alexander Bay on the Orange River are informally (not SACS approved) called the West Coast Group as proposed by Roberts (1999). A number of rivers have incised through the underlying Gariep Supergroup metasediments and deeply weathered and kaolinised granitoids. Marine incursions and regressions during the Cretaceous and Tertiary have caused the repeated cutting and re-filling of these fluvial deposits and as a result their age ad correlation is very complex. Such deposits are rich in diamonds so have been studied (ref …..).

The Neogene “West Coast Group” comprises the basal Alexander Bay Formation that extends along the length of the coast, the overlying southerly Curlew Formation. Overlying but synchronous aeolian deposits form dunes of loose sands or cemented aeolianites. Three members comprise the Alexander Bay Formation and are distinguished by their height above the present sealevel (packages) and marine shell components. The lower Kleinsee Member (90m package) is very thin and composed of shelly, gravelly, sandy mud and Isognomon fossil shells (Roberts et al., 2006). The Avontuur Member (50m package) represents lower shoreface bands of coarse gravel, fine sand, sand and mud, with fossil burrows and shells of Donax spp. The upper Hondeklip Bay Member (30m package) represent the proximal lower shoreface to upper shoreface sands, gravels. These sands

were deposited as trough crossbedding lanes, ripples and minor dunes and form the thickest layers in the Alexander Bay Formation. The component sequences of the Alexander Bay Formation are transgressed and truncated by younger, high energy beach deposits, the Curlew Strand Formation, and comprise calcified to unconsolidated sandy to gravelly deposits. These are up to 12m above sealevel and can contain marine shells similar to those along the coast today (Roberts et al., 2006.

Ages of these strata are uncertain but have been suggested to be middle Miocene for the Kleinsee Member, Mio-Pliocene for the Avontuur Member, Late Pliocene for the Hondeklip Member and Plio-Holocene for the Curlew Strand Formation (Roberts et al., 2006).

ii. Palaeontological context

The SAHRIS palaeosensitivity map for block 2917 appears to be based on the 1: 1 000 000 geological map rather than the 1:25 000 and the West Coast Group strata are not distinguished from the Quaternary Kalahari Group sediments. The low resolution map provided by Roberts et al. (2006; Fig 1) shows that the West Coast Group sediments extend inland roughly 30 km at Kleinzee so we can assume that Dikgat which is about 5km inland along the Buffels River will be within the West Coast Group zone. However, the Buffels River has cut down through the Neogene shoreline facies and the valley will be filled with sands and alluvium from upstream, probably Gordonia Formation and younger transported sediments. Since it is not known exactly which sediments are in the Dikgat sand mining site, a Fossil Chance Find Protocol should be added.

The palaeontological sensitivity of the area under consideration is presented in Figure 4. The site for mining is in the Quaternary sands and alluvium in the riverbed, possibly sourced from the Gordonia Formation. Since these sands have been transported they would not contain any fossils in primary context. They might have included fragments of more robust fossils such as bones or silicified woods from farther upstream. When and if the river flows the stones, bones and fragments would be tumbled and washed downstream so their occurrence would be very rare and unpredictable. The SAHRIS palaeosensitivity map indicates that the area is of zero sensitivity (Figure 5) but should be moderate because fossils can be transported from farther inland. No fossils were seen on the surface by the archaeologist during his site survey.

The older granites of the Little Namaqualand Suite are of volcanic origin and would not preserve any fossils.

Figure 4: SAHRIS palaeosensitivity map for the site for the proposed Dikgat Sand mine project shown within the yellow rectangle. Background colours indicate the following degrees of sensitivity: red = very highly sensitive; orange/yellow = high; green = moderate; blue = low; grey = insignificant/zero.

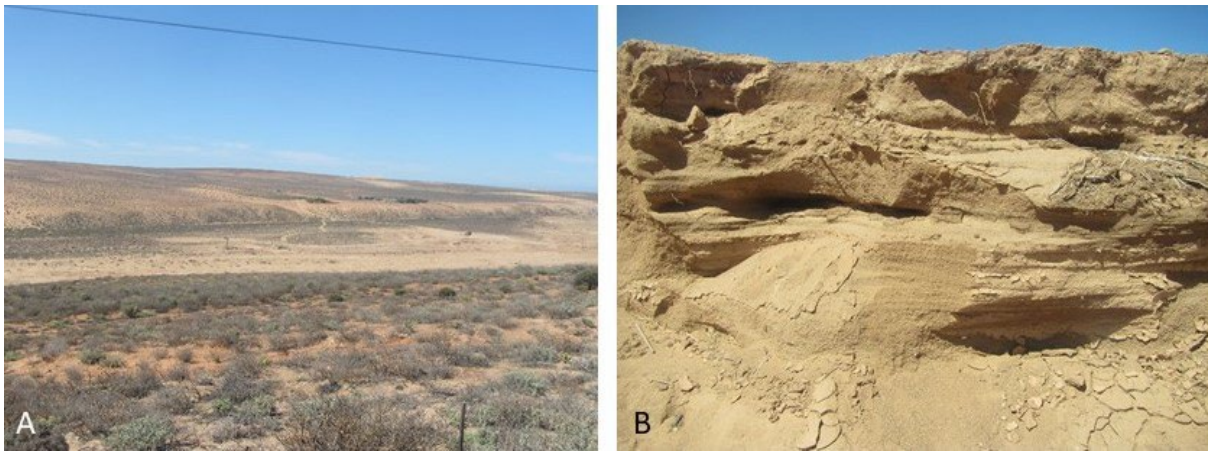

Figure 5: Photographs taken by the archaeologist (Dr Orton). A – general view of the mining area. B – the sand banks are composed of fine to coarse-grained sands.

4. Impact assessment

An assessment of the potential impacts to possible palaeontological resources considers the criteria encapsulated in Table 3:

TABLE 3A: CRITERIA FOR ASSESSING IMPACTS

PART A: DEFINITION AND CRITERIA		
Criteria for ranking of the SEVERITY/NATURE of environmental impacts	**H**	Substantial deterioration (death, illness or injury). Recommended level will often be violated. Vigorous community action.
	M	Moderate/ measurable deterioration (discomfort). Recommended level will occasionally be violated. Widespread complaints.
	L	Minor deterioration (nuisance or minor deterioration). Change not measurable/ will remain in the current range. Recommended level will never be violated. Sporadic complaints.
	L+	Minor improvement. Change not measurable/ will remain in the current range. Recommended level will never be violated. Sporadic complaints.
	M+	Moderate improvement. Will be within or better than the recommended level. No observed reaction.
	H+	Substantial improvement. Will be within or better than the recommended level. Favourable publicity.
Criteria for ranking the DURATION of impacts	**L**	Quickly reversible. Less than the project life. Short term
	M	Reversible over time. Life of the project. Medium term
	H	Permanent. Beyond closure. Long term.
Criteria for ranking the SPATIAL SCALE of impacts	**L**	Localised - Within the site boundary.
	M	Fairly widespread – Beyond the site boundary. Local
	H	Widespread – Far beyond site boundary. Regional/ national
PROBABILITY (of exposure to impacts)	**H**	Definite/ Continuous
	M	Possible/ frequent
	L	Unlikely/ seldom

TABLE 3B: IMPACT ASSESSMENT

PART B: ASSESSMENT		
SEVERITY/NATURE	**H**	-
	M	-
	L	Quaternary sands do not preserve fossils but might entrap them; so far there are no records from the area of plant or animal fossils in this region so it is very unlikely that fossils occur on the site. The impact would be negligible.
	L+	-
	M+	-
	H+	-
DURATION	**L**	-
	M	-
	H	Where manifest, the impact will be permanent.
SPATIAL SCALE	**L**	Since the only possible fossils within the area would be transported and fragmentary plants from farther upstream in the sands, the spatial scale will be localised within the site boundary.
	M	-
	H	-
PROBABILITY	**H**	**-**
	M	**-**
	L	It is extremely unlikely that any fossils would be found in the loose sand that will be mined. Nonetheless, a Fossil Chance Find Protocol should be added to the eventual EMPr.

Based on the nature of the project, surface activities may impact upon the fossil heritage if preserved in the project footprint. The geological structures suggest that the sand is either the wrong kind or is transported. Furthermore, the material to be mined is sand and this does not preserve fossils because it is aerobic. Since there is an extremely small chance that fossils may have been transported from farther upstream and be disturbed a Fossil Chance Find Protocol has been added to this report. Taking account of the defined criteria, the potential significance of impacts to fossil heritage resources is extremely low.

5. Assumptions and uncertainties

Based on the geology of the area and the palaeontological record as we know it, it can be assumed that the formation and layout of the granites, gneisses, sandstones and sands are typical for the country. Only the sands and alluvium might contain transported and fragmentary fossils, but the sands of the Quaternary period would not preserve fossils in situ.

6. Recommendation

Based on experience and the lack of any previously recorded fossils from the proposed mining area, it is extremely unlikely that any fossils would be preserved in the transported sands of the Quaternary. There is a very small chance that fossils may occur in the river bed but these would be rare and of minimal scientific value, therefore a Fossil Chance Find Protocol should be added to the EMPr. If fossils are found by the miners or environmental officer, or other responsible person once mining has commenced then they should be rescued and a palaeontologist called to assess and collect a representative sample.

7. References

Braun, J., Guillocheau, F., Robin, C., Baby, G., Jelsma, H., 2014. Rapid erosion of the Southern African Plateau as it climbs over a mantle superswell, Journal of Geophysical Research; Solid Earth 119, 6093–6112. doi:10.1002/2014JB010998

Cornell, D.H., Thomas, R.J., Moen, H.F.G., Reid, D.L., Moore, J.M., Gibson, R.L., 2006. The Namaqua-Natal Province. In: Johnson, M.R., Anhaeusser, C.R. and Thomas, R.J., (Eds). The Geology of South Africa. Geological Society of South Africa, Johannesburg / Council for Geoscience, Pretoria. Pp 325-379.

De Wit, M.C.J., 1999. Post-Gondwana drainage and the development of diamond placers in western South Africa. Economic Geology, 94, 721-740.

Netterberg, F., 1969. The interpretation of some basic calcrete types. South African Archaeology Bulletin 24, 117-122.

Partridge, T.C., Botha, G.A., Haddon, I.G., 2006. Cenozoic deposits of the interior. In: Johnson, M.R., Anhaeusser, C.R. and Thomas, R.J., (Eds). The Geology of South Africa. Geological Society of South Africa, Johannesburg / Council for Geoscience, Pretoria. Pp 585-604.

Roberts, D.L., Botha, G.A., Maud, R.R., Pether, J., 2006. Coastal Cenozoic deposits. In: Johnson, M.R., Anhaeusser, C.R. and Thomas, R.J., (Eds). The Geology of South Africa. Geological Society of South Africa, Johannesburg / Council for Geoscience, Pretoria. Pp 605-628.

8. Chance Find Protocol

Monitoring Programme for Palaeontology – to commence once the mining activities begin.

1. The following procedure is only required if fossils are seen on the surface and when mining commences.
2. When excavations begin the rocks and must be given a cursory inspection by the environmental officer or designated person. Any fossiliferous material (shells, burrows, plants, insects, bone, wood) should be put aside in a suitably protected place. This way the project activities will not be interrupted.
3. Photographs of similar fossils must be provided to the developer to assist in recognizing the fossil plants, vertebrates, invertebrates or trace fossils in the shales and mudstones (for example see Figure 6, 7). This information will be built into the EMP's training and awareness plan and procedures.
4. Photographs of the putative fossils can be sent to the palaeontologist for a preliminary assessment.
5. If there is any possible fossil material found by the environmental officer/miners then the qualified palaeontologist sub-contracted for this project, should visit the site to inspect the selected material and check the dumps where feasible.
6. Fossil plants or vertebrates that are considered to be of good quality or scientific interest by the palaeontologist must be removed, catalogued and housed in a suitable institution where they can be made available for further study. Before the fossils are removed from the site a SAHRA permit must be obtained. Annual reports must be submitted to SAHRA as required by the relevant permits.
7. If no good fossil material is recovered then no site inspections by the palaeontologist will be necessary. A final report by the palaeontologist must be sent to SAHRA once the project has been completed and only if there are fossils.
8. If no fossils are found and the excavations have finished then no further monitoring is required.

Appendix A – Examples of fossils from the Quaternary sands

Figure 6: Examples of fossils from fluvial or lacustrine Quaternary sediments.

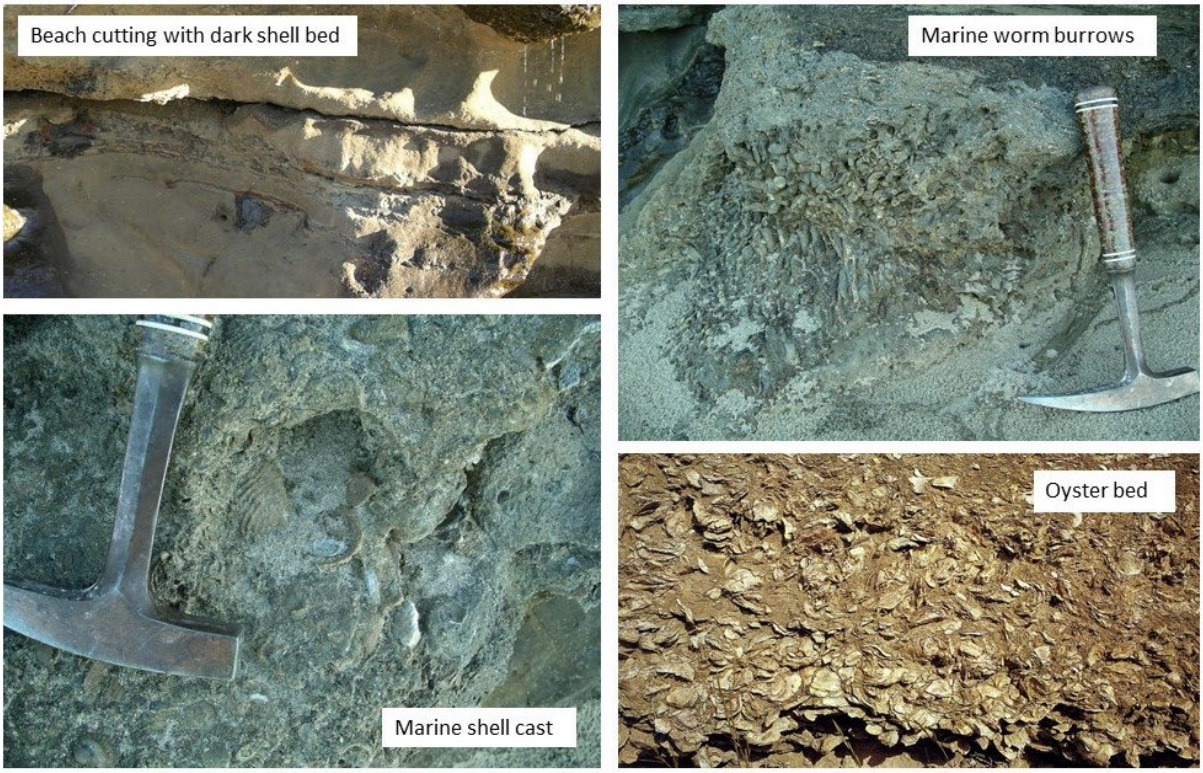

Figure 7: Examples of Quaternary shoreline marine fossils.

Appendix B – Details of specialist

Curriculum vitae (short) - Marion Bamford PhD
July 2021

I) Personal details

Surname	:	**Bamford**
First names	:	**Marion Kathleen**
Present employment	:	Professor; Director of the Evolutionary Studies Institute. Member Management Committee of the NRF/DST Centre of Excellence Palaeosciences, University of the Witwatersrand, Johannesburg, South Africa-
Telephone	:	+27 11 717 6690
Fax	:	+27 11 717 6694
Cell	:	082 555 6937
E-mail	:	marion.bamford@wits.ac.za ; marionbamford12@gmail.com

ii) Academic qualifications

Tertiary Education: All at the University of the Witwatersrand:
1980-1982: BSc, majors in Botany and Microbiology. Graduated April 1983.
1983: BSc Honours, Botany and Palaeobotany. Graduated April 1984.
1984-1986: MSc in Palaeobotany. Graduated with Distinction, November 1986.
1986-1989: PhD in Palaeobotany. Graduated in June 1990.

iii) Professional qualifications

Wood Anatomy Training (overseas as nothing was available in South Africa):
1994 - Service d'Anatomie des Bois, Musée Royal de l'Afrique Centrale, Tervuren, Belgium, by Roger Dechamps
1997 - Université Pierre et Marie Curie, Paris, France, by Dr Jean-Claude Koeniguer
1997 - Université Claude Bernard, Lyon, France by Prof Georges Barale, Dr Jean-Pierre Gros, and Dr Marc Philippe

iv) Membership of professional bodies/associations

Palaeontological Society of Southern Africa
Royal Society of Southern Africa - Fellow: 2006 onwards
Academy of Sciences of South Africa - Member: Oct 2014 onwards
International Association of Wood Anatomists - First enrolled: January 1991
International Organization of Palaeobotany – 1993+
Botanical Society of South Africa
South African Committee on Stratigraphy – Biostratigraphy - 1997 - 2016
SASQUA (South African Society for Quaternary Research) – 1997+
PAGES - 2008 –onwards: South African representative
ROCEEH / WAVE – 2008+
INQUA – PALCOMM – 2011+onwards

vii) Supervision of Higher Degrees

All at Wits University

Degree	Graduated/completed	Current
Honours	11	0
Masters	10	4
PhD	11	4
Postdoctoral fellows	10	5

viii) Undergraduate teaching

Geology II – Palaeobotany GEOL2008 – average 65 students per year
Biology III – Palaeobotany APES3029 – average 25 students per year
Honours – Evolution of Terrestrial Ecosystems; African Plio-Pleistocene Palaeoecology; Micropalaeontology – average 2-8 students per year.

ix) Editing and reviewing

Editor: Palaeontologia africana: 2003 to 2013; 2014 – Assistant editor
Guest Editor: Quaternary International: 2005 volume
Member of Board of Review: Review of Palaeobotany and Palynology: 2010 –

Review of manuscripts for ISI-listed journals: 25 local and international journals

x) Palaeontological Impact Assessments

Selected – list not complete:

- Thukela Biosphere Conservancy 1996; 2002 for DWAF
- Vioolsdrift 2007 for Xibula Exploration
- Rietfontein 2009 for Zitholele Consulting
- Bloeddrift-Baken 2010 for TransHex
- New Kleinfontein Gold Mine 2012 for Prime Resources (Pty) Ltd.
- Thabazimbi Iron Cave 2012 for Professional Grave Solutions (Pty) Ltd
- Delmas 2013 for Jones and Wagener
- Klipfontein 2013 for Jones and Wagener
- Platinum mine 2013 for Lonmin
- Syferfontein 2014 for Digby Wells
- Canyon Springs 2014 for Prime Resources
- Kimberley Eskom 2014 for Landscape Dynamics
- Yzermyne 2014 for Digby Wells
- Matimba 2015 for Royal HaskoningDV
- Commissiekraal 2015 for SLR
- Harmony PV 2015 for Savannah Environmental
- Glencore-Tweefontein 2015 for Digby Wells
- Umkomazi 2015 for JLB Consulting
- Ixia coal 2016 for Digby Wells
- Lambda Eskom for Digby Wells
- Alexander Scoping for SLR
- Perseus-Kronos-Aries Eskom 2016 for NGT
- Mala Mala 2017 for Henwood
- Modimolle 2017 for Green Vision
- Klipoortjie and Finaalspan 2017 for Delta BEC
- Ledjadja borrow pits 2018 for Digby Wells
- Lungile poultry farm 2018 for CTS
- Olienhout Dam 2018 for JP Celliers
- Isondlo and Kwasobabili 2018 for GCS
- Kanakies Gypsum 2018 for Cabanga
- Nababeep Copper mine 2018
- Glencore-Mbali pipeline 2018 for Digby Wells
- Remhoogte PR 2019 for A&HAS
- Bospoort Agriculture 2019 for Kudzala
- Overlooked Quarry 2019 for Cabanga
- Richards Bay Powerline 2019 for NGT
- Eilandia dam 2019 for ACO
- Eastlands Residential 2019 for HCAC
- Fairview MR 2019 for Cabanga

- Graspan project 2019 for HCAC
- Lieliefontein N&D 2019 for EnviroPro
- Skeerpoort Farm Mast 2020 for HCAC
- Vulindlela Eco village 2020 for 1World
- KwaZamakhule Township 2020 for Kudzala
- Sunset Copper 2020 for Digby Wells
- McCarthy-Salene 2020 for Prescali
- VLNR Lodge 2020 for HCAC
- Madadeni mixed use 2020 for EnviroPro
- Frankfort-Windfield Eskom Powerline 2020 for 1World
- Beaufort West PV Facility 2021 for ACO Associates
- Copper Sunset MR 2021 for Digby Wells
- Sannaspos PV facility 2021 for CTS Heritage
- Smithfield-Rouxville-Zastron PL 2021 for TheroServe

xi) Research Output

Publications by M K Bamford up to July 2021 peer-reviewed journals or scholarly books: over 150 articles published; 5 submitted/in press; 10 book chapters.
Scopus h-index = 30; Google scholar h-index = 35; -i10-index = 92
Conferences: numerous presentations at local and international conferences.