Palaeontological Impact Assessment for the proposed construction of three residential townships in Kroonstad, Free State Province

Desktop Study

For

Archaeological and Heritage Services Africa (Pty) Ltd

07 July 2019

Prof Marion Bamford
Palaeobotanist
P Bag 652, WITS 2050
Johannesburg, South Africa
Marion.bamford@wits.ac.za

Expertise of Specialist

The Palaeontologist Consultant is: Prof Marion Bamford
Qualifications: PhD (Wits Univ, 1990); FRSSAf, ASSAf
Experience: 30 years research; 22 years PIA studies

Declaration of Independence

This report has been compiled by Professor Marion Bamford, of the University of the Witwatersrand, sub-contracted by Archaeological and Heritage Services Africa (Pty) Ltd, 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

Signature: 

Executive Summary

A palaeontological Impact Assessment was requested for the proposed construction of three areas of residential housing, the Maokeng Housing Development, Kroonstad. To comply with 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 project.

The proposed sites lie on the sandstones and mudstones of the late Permian, Adelaide Subgroup, Beaufort Group, Karoo Supergroup. Although fossils have not been reported from this site there is a small chance that typical vertebrates of the *Pristerognathus, Tropidostoma*, *Cistecephalus* and *Dicynodon* Assemblage Zones could occur, as well as typical (but very infrequent) late *Glossopteris* flora plants, could occur in the sediments just below the surface. Surface exposures are likely to be very weathered. Therefore, a Fossil Chance Find Protocol should be added to the EMPr. Based on this information it is recommended that no palaeontological site visit is required unless fossils are revealed once excavations for foundations, roads, infrastructure, water, sewage and power have commenced. As far as the palaeontology is concerned the project can proceed.

Table of Contents

1. Background

This application is for the proposed development of three separate sections (Figure 1) for residential housing for the Maokeng Housing Development project, Kroonstad, Free State Province.

The project area is more than 10ha, therefore, in order to comply with 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 project.

Table 1: Specialist report requirements in terms of Appendix 6 of the EIA Regulations (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	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	Appendix A
ni	A reasoned opinion as to whether the proposed activity or portions thereof should be authorised	N/A
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	N/A
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 sites for the residential townships, Kroonstad, Free State Province, outlined in red. Map supplied by AHSA.

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

The site lies in the central sector of the Karoo Basin and the sediments are the alternating mudrocks and sandstones of the very thick, Adelaide Subgroup, Beaufort Group, Karoo Supergroup. They are late Permian in age with younger intrusive Jurassic-aged dolerite dykes occurring to the north and south (Figure 2, Table 2).

In this part of the Karoo Basin there are three formations in the Adelaide Subgroup, the basal Koonap Formation, then the Middelton Formation and the upper Balfour Formation (with five members, Rubidge, 2005; but now the Barberskrans Member is called the Ripplemead Member, Viglietti et al., 2017). This part of the Karoo Basin has not been as well studied as the western part and so the maps do not indicate which of the three formations is represented.

Large exposures of Jurassic dolerite dykes occur throughout the area. These intruded through the Karoo sediments around 183 million years ago at about the same time as the Drakensberg basaltic eruption.

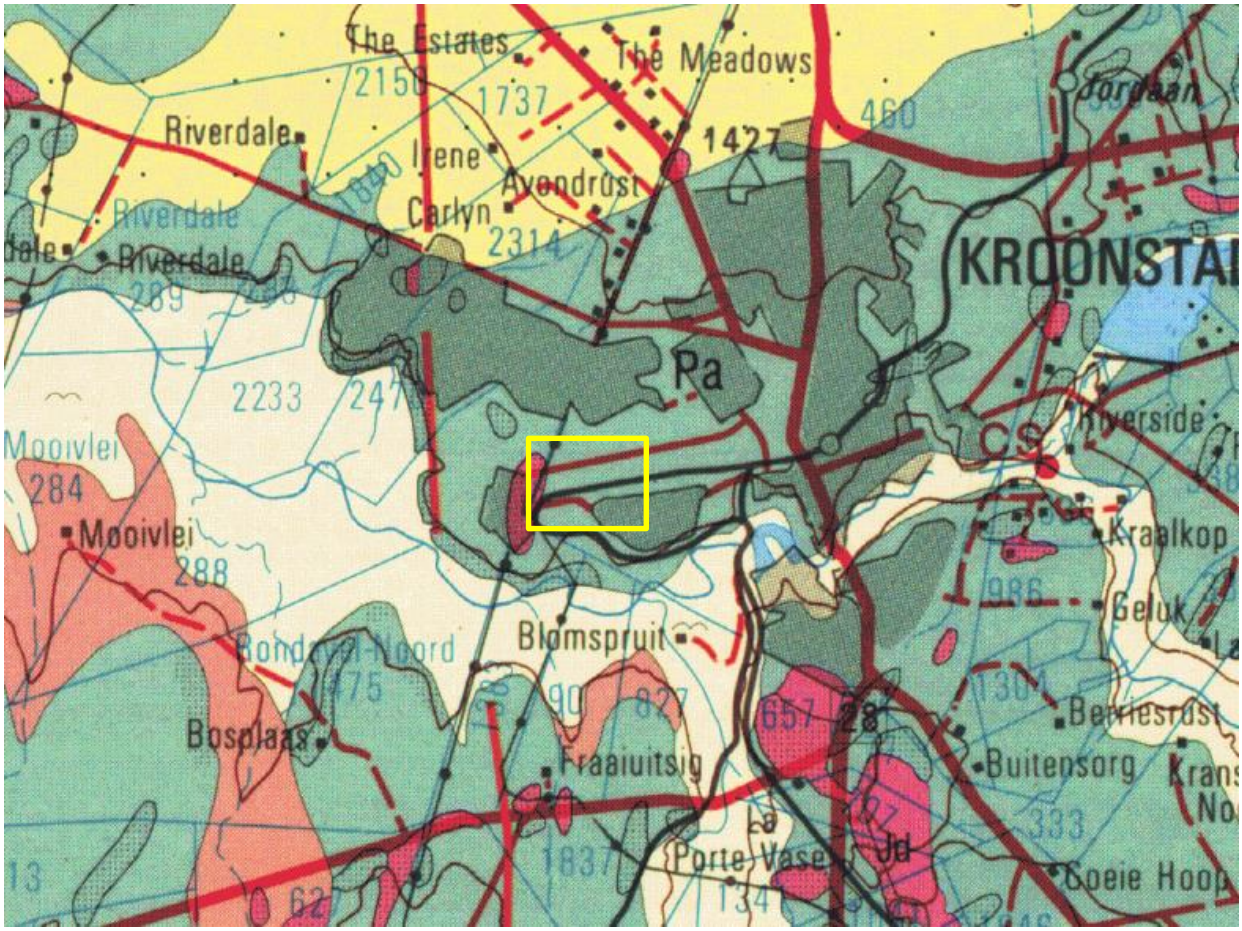

Figure 2: Geological map of the area around Kroonstad, The project site is indicated within the yellow rectangle. Abbreviations of the rock types are explained in Table 2. Map enlarged from the Geological Survey 1: 250 000 map 2000, 2726 Kroonstad.

Table 2: Explanation of symbols for the geological map and approximate ages (Barbolini et al., 2016; Johnson et al., 2006; Rubidge, 2005). SG = Supergroup; Fm = Formation; Ma = million years.

Symbol	Group/Formation	Lithology	Approximate Age
(white)	Quaternary alluvium	Alluvium	Last 2.5 Ma
Qs	Quaternary sand	Aeolian sand	Last 2.5 Ma
Jd	Jurassic	Dolerite dykes, intrusive	Jurassic, approx. 180 Ma
Pa	Adelaide Subgroup, Beaufort Group, Karoo SG.	Mudstones and sandstones	Late Permian (Guadalupian-Lopingian) ca 266-251 Ma
Pvo	Volksrust Fm, Eccca Group, Karoo SG.	Mudstone, sandstone, shale	Middle Permian

The Adelaide Subgroup is part of the eastern foredeep basin and was deposited in the overfilled or non-marine phase (Catuneanu et al., 2005) and so comprises terrestrial deposits. There are numerous fining-upward cycles, abundant red mudrocks and sedimentary structures that indicate deposition under fluvial conditions (Johnson et al.,

2006). Some of the lower strata probably represent a subaerial upper delta-plain environment and the generally finer grained materials are typical of meandering rather than braided rivers. Channel deposits are indicated by sandstones while overbank deposits are indicated by the mudstones (Johnson et al., 2006).

Intruding through these sediments are dolerite dykes that formed during the Jurassic Drakensberg basaltic eruptions.

i. Palaeontological context

The area proposed for development is underlain by geological sediments of the Adelaide Subgroup of the Beaufort Group (of very high paleontological sensitivity) and Jurassic Dolerite, which has zero paleontological sensitivity. According to the currently accepted biostratigraphy, the whole of the Adelaide Subgroup has been divided into eight Assemblage Zones based on the dominant or temporally exclusive vertebrate fossils (Rubidge et al., 1995; Rubidge, 2005). The zones are shown in Figure 3 below. If vertebrate fossils were common in this region and had been well mapped then the specific Assemblage Zone would have been indicated in the literature. Common names for the fossils that could occur here are fish, amphibians, reptiles, therapsids, terrestrial and freshwater tetrapods, as well as freshwater bivalves, trace fossils including tetrapod trackways and burrows. Where the vertebrates do not occur it is possible to find sparse to rich assemblages of vascular plants of the late *Glossopteris* Flora, including some petrified logs, and insects are also prevalent at some sites.

The Volksrust Formation occurs in the area and represents deeper water sediments. Fossil plants are extremely rare in this lithology and vertebrates are unknown.

Dolerites are intrusive and do not preserve any fossils, furthermore, they tend to destroy any fossils in their immediate vicinity. This project lies only on sediments of the Adelaide Subgroup, but it is unknown precisely which formation or which assemblage zone because no fossils have been recorded from this area. A doctoral student from Wits University is surveying the region around Kroonstad looking for fossils but to date only silicified woods have been found to the north east (unpublished; work in progress).

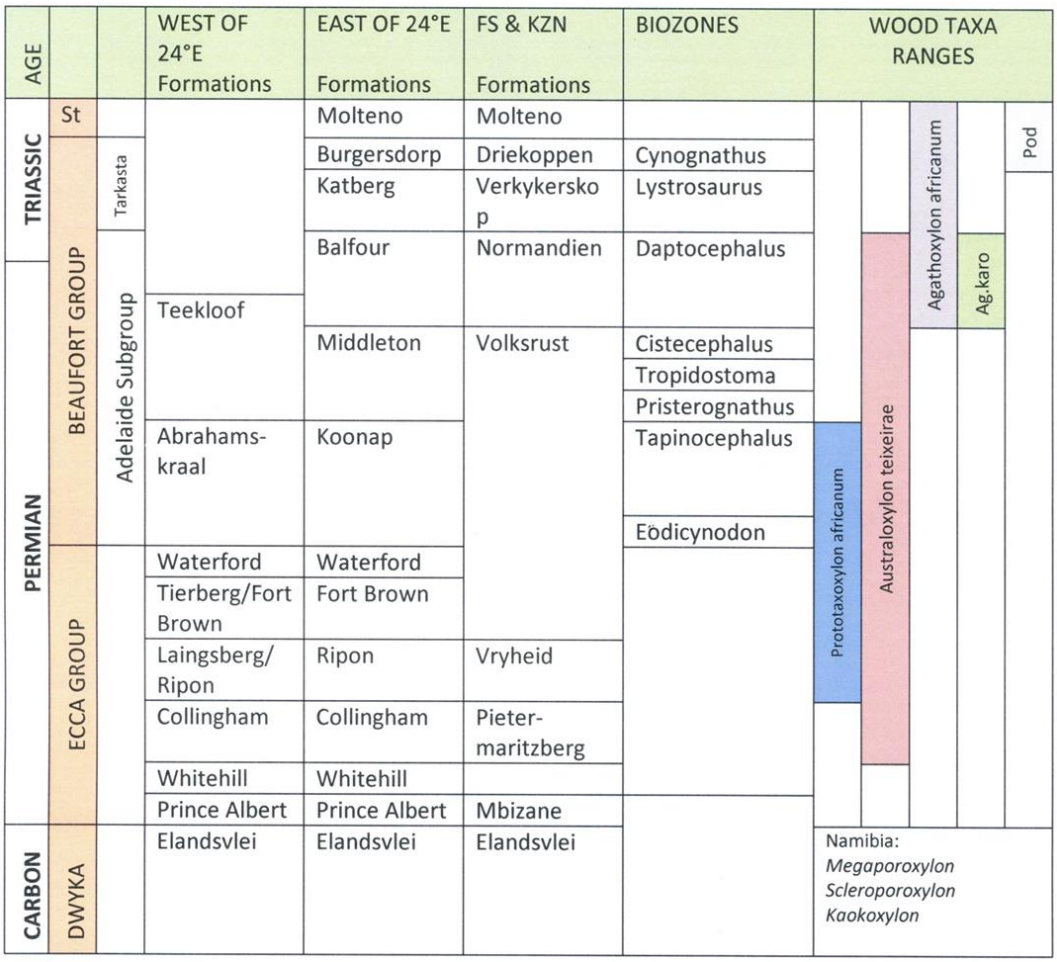

Figure 3: Karoo lithology, formations and vertebrate biozones based on Rubidge et al., 1995; Rubidge 2005; wood zones based on Bamford 2016.

Vertebrate fossils are fairly common in the Adelaide Subgroup in certain parts of the Karoo Basin and have been used to subdivide the strata into biozones (Rubidge et al., 1995; Day et al., 2015). The lower part of the Middleton Formation is in the *Pristerognathus* Assemblage Zone, the middle part is in the *Tropidostoma* Assemblage Zone and the upper part in the *Cistecephalus, Daptocephalus* and *Lystrosaurus* Assemblage Zones. The Balfour Formation corresponds to the *Dicynodon* Assemblage and is overlain by the *Lystrosaurus* Assemblage Zone. Lists of genera composition for each of the Assemblage Zones are provided in Appendix A, but in general the fauna is composed of anapsids (no temporal openings in the skull) and synapsids (single pair of lateral temporal skull openings; more like mammals). The common genera are *Pristerognathus, Diictodon, Tropidostoma, Cistecephalus, Aucalephalus* and *Oudenodon.*

Fossil plants also occur in the Adelaide Subgroup and they are from the *Glossopteris* flora and include leaf impressions of *Glossopteris*, early gymnosperms, lycopds, sphenophytes, ferns and silicified wood (see list in Appendix A).

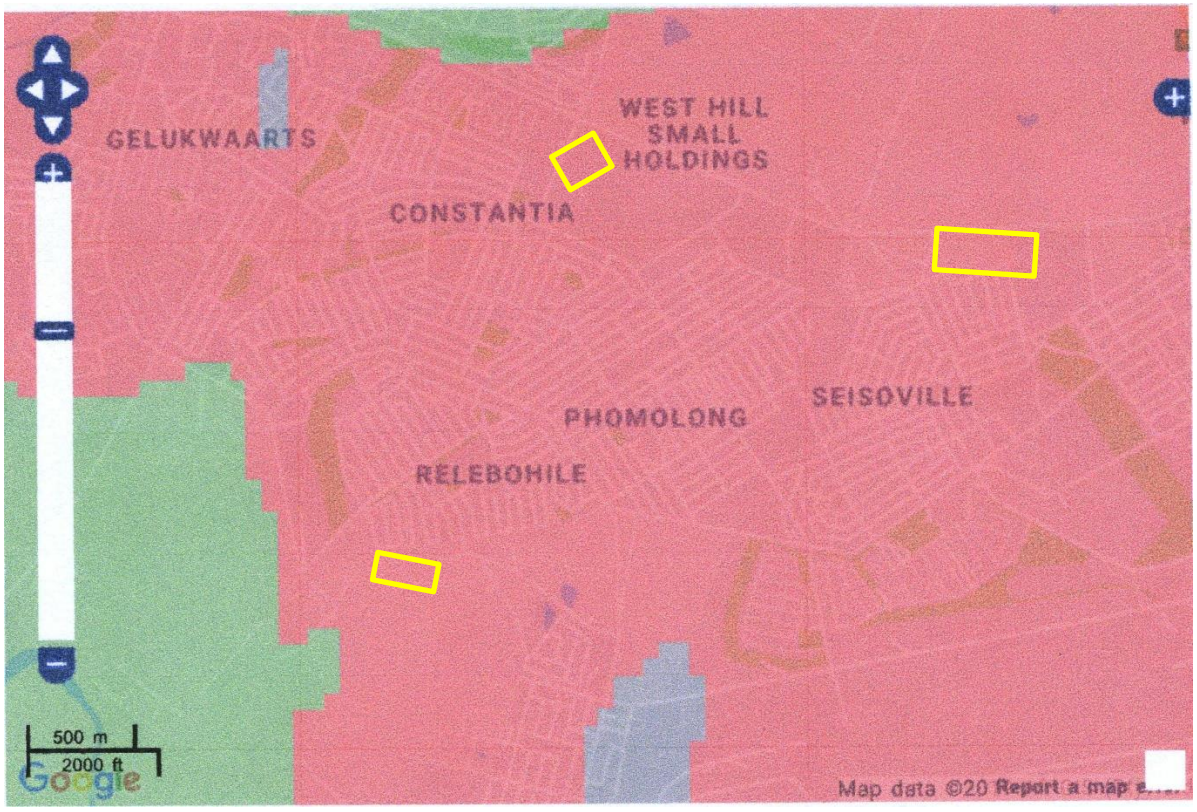

Figure 4: SAHRIS palaeosensitivity map for the sites for the proposed residential townships in Kroonstad indicated within the yellow rectangles. Colours indicate the following degrees of sensitivity: red = very highly sensitive; orange/yellow = high; green = moderate; blue = low; grey = insignificant/zero.

The area has been disturbed from previous urban and agricultural activities so any surface fossils are likely to be very weathered (naturally) or destroyed by previous activities. Along the streams there could be downcutting into underlying sediments that contain vertebrates or fossil plants (they are seldom found together). There is, however, a very small chance that fossil vertebrates or plants could be found where new excavations are made for the foundations, utilities and access roads.

From the SAHRIS map above the area is indicated as very highly sensitive (red; Figure 3) so a desktop assessment is being reported upon here. No fossils have been reported from the area but there is a small chance that fossil vertebrates or plant fragments could occur in the building area. Fossils are not likely to be seen on the land surface because of extensive weathering that has formed soils, and previous agricultural or urban activities (Figures 5-8).

4. Impact assessment

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

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	There is a small chance that fossil vertebrates or plants occur in the Adelaide Subgroup sandstones and mudstones but any surface occurrences would have been disturbed by previous agricultural and urban activities. The impact would be very unlikely.
	L+	-
	M+	-
	H+	-
DURATION	**L**	-
	M	-
	H	Where manifest, the impact will be permanent.
SPATIAL SCALE	**L**	Since only the possible fossils within the area would be a variety of vertebrates or fossil plants from the *Glossopteris* flora in the mudstones and sandstones, the spatial scale will be localised within the site boundary.
	M	-
	H	-

PART B: ASSESSMENT		
PROBABILITY	H	-
	M	-
	L	It is unlikely that any fossils would be found in the surface sediments but there may be vertebrates or plant fragments in the underlying mudstones. No surface fossils are likely to be found. Therefore, 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 development footprint. Underlying rocks of the Middleton Formation, Adelaide Subgroup, Beaufort Group, namely the mudstones, might preserve fossil vertebrates or plants but this will be evident once excavations commence. Although no fossils have been recorded from the town of Kroonstad, there is a small chance that fossils from the upper Permian Adelaide Subgroup may be disturbed so a Fossil Chance Find Protocol has been added to this report (Section 8). Taking account of the defined criteria, the potential impact to fossil heritage resources is 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 dolomites, sandstones and mudstones are typical for the country and could contain fossil vertebrates or plant material. The Jurassic dolerite dykes would not preserve any fossils.

6. Recommendation

Based on experience and the lack of any previously recorded fossils from the area, it is unlikely that any fossils would be preserved on the surface. There is a very small chance that fossil vertebrates or plant fragments may occur in the Adelaide Subgroup mudstones, so a Chance Find Protocol should be added to the EMPr: if fossils are found once excavations for foundations have commenced then they should be rescued and a palaeontologist called to assess and collect a representative sample, with a relevant permit from SAHRA.

7. References

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Viglietti, P.A., Rubidge, B.S., Smith, R.M.H., 2017. Revised lithostratigraphy of the upper Permian Balfour and Teekloof Formations of the Beaufort Group, South Africa. South African Journal of Geology 120, 45-60.

8. Chance Find Protocol

Monitoring Programme for Palaeontology – to commence once the excavations for foundations for the buildings, utilities and roads begin.

1. The following procedure is only required if fossils are seen on the surface and when excavations commence.
2. When excavations begin the rocks and must be given a cursory inspection by the environmental officer or designated person. Any fossiliferous material (plants, insects,

wood, bone) should be put aside in a suitably protected place. This way the building activities will not be interrupted.

3. Photographs of similar fossil plants must be provided to the developer to assist in recognizing the fossil plants in the shales and mudstones (for example see Figure 4, 5). 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 developer/environmental officer/engineers 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 the site inspections by the palaeontologist will not be necessary.
8. If no fossils are found and the excavations have finished then no further monitoring is required.

Appendix A – Lists and Examples of upper Permian fossils

Middleton Fm / Pristerognathus Assemblage Zone (AZ)		
Group	***Vertebrate Genera***	**Plant Genera (# species)**
Captorhinida	*Pareiasaurus*	Mosses: *Buthelezia* (1) Sphenophytes: *Sphenophyllum, Raniganjia, Phyllotheca, Schizoneura* (6) *Sphenopteris* (1) *Glossopteris*: minimum: 11 leaf types, 6 fructifications Cordaitales: *Noeggerathiopsis* (1) Conifers?: *Taeniopteris*, *Pagiophyllum*, *Benlightfootia* (3) *Australoxylon* (1) *Prototaxoxylon* (1)
Eosuchia	*Youngina*	
Dicynodontia	*Tropidostoma* *Endothiodon* *Cistecephalus* *Pristerodon* *Diictodon* *Emydops* *Rachiocephalus*	
Gorgonopsia	*Gorgonops* *Lycaenops* *Cyonosaurus*	
Therocephalia	*Ictidosuchoides* *Ictidosuchops*	

Middleton Fm / Tropidostoma AZ		
Group	***Vertebrate Genera***	**Plant Genera (# species)**
Captorhinida	*Pareiasaurus*	Mosses: *Buthelezia* (1) Sphenophytes: *Sphenophyllum, Raniganjia, Phyllotheca, Schizoneura* (6) *Sphenopteris* (1)
Eosuchia	*Youngina*	
Dicynodontia	*Tropidostoma* *Endothiodon* *Cistecephalus* *Pristerodon*	

	Diictodon *Emydops* *Rachiocephalus*	*Glossopteris*: minimum: 11 leaf types, 6 fructifications Cordaitales: *Noeggerathiopsis* (1) Conifers?: *Taeniopteris*, *Pagiophyllum*, *Benlightfootia* (3) *Australoxylon* (1) *Prototaxoxylon* (1)
Gorgonopsia	*Gorgonops* *Lycaenops* *Cyonosaurus*	
Therocephalia	*Ictidosuchoides* *Ictidosuchops*	
Middleton Fm/Cistecephalus AZ		
Captorhinida	*Pareiasaurus* *Anthodon* *Owenetta*	Conifer woods: *Agathoxylon* (2), *AustraIoxylon* (1)
Eosuchia	*Youngina*	
Dicynodontia	*Endothiodon* *Cistecephalus* *Pristerodon* *Diictodon* *Emydops* *Aulacacephalodon* *Rachiocephalus* *Platycyclops* *Oudenodon* *Dinanomodon*	
Gorgonopsia	*Gorgonops* *Arctognathus* *Lycaenops* *Cyonosaurus* *Prorubidgea* *Rubidgea* *Dinogorgon* *Clelandina*	
Therocephalia	*Ictidosuchoides* *Ictidosuchops*	
Balfour Fm / Dicynodon		
Captorhinida	*Pareiasaurus* *Milleretta* *Millerosaurus* *Anthodon* *Spondyloestes* *Owenetta*	
Eosuchia	*Youngina* *Saurostemon*	
Dicynodontia	*Pristerodon* *Diictodon* *Dicynodon* *Emydops* *Aulacocephalodon* *Oudenodon* *Pelanomodon*	

	Dianomodon
Biarmosuchia	*Rubidgina* *Burnettia* *Ictidorhinus* *Lemurosaurus*
Gorgonopsia	*Lycaenops* *Cyonosaurus* *Prorubidgea* *Leontocephalus* *Broomicephalus* *Rubidgea* *Dinogorgon* *Clelandrina* *Paragalerhinus*
Therocephalia	*Ictidosuchoides* *Ictidosuchops* *Theriognathus* *Homodontosaurus* *Scaloporhinus* *Scaloposuchus* *Nanictidops* *Akidnognathus* *Lycideops* *Cerdops* *Promosuchorhynchus* *Tetracynodon* *Moschorhinus*
Cynodontia	*Procynosuchus* *Cynosaurus* *Nanictosaurus*
(Balfour Fm) Katberg Lystrosaurus	
Captorhinida	*Owenetta* *Procolophon*
Eosuchia	*Heleosuchus* *Paliguana* *Noteosuchus* *Prolacerta* *Aenigmasaurus* *Proterosuchus*
Dicynodontia	*Myoaurus* *Lystrosaurus*
Therocephalia	*Tetracynodon* *Moschorhinus* *Scaloposaurus* *Ericiolacerta* *Olivieria* *Regisaurus* *Zorillodontops*
Cynodontia	*Thrinaxodon* *Galesaurus*

	Platycraniellis

Table 4: Lists of fossil vertebrates and plants that have been recorded from the Middleton and Balfour Formations, Adelaide Subgroup, Beaufort Group, Karoo Supergroup of South Africa. (Source: Anderson and Anderson, 1985; Rubidge et al., 1995).

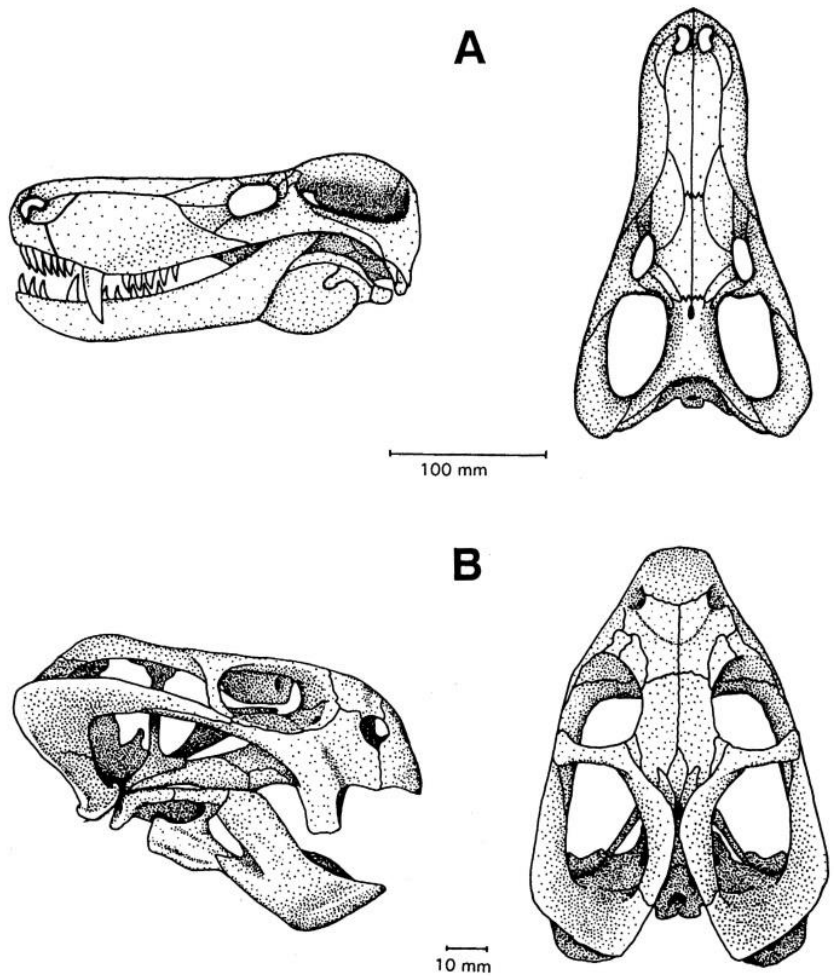

Figure 5: *Pristerognathus* (A) and *Diictodon* (B) (from Rubidge et al., 1995)

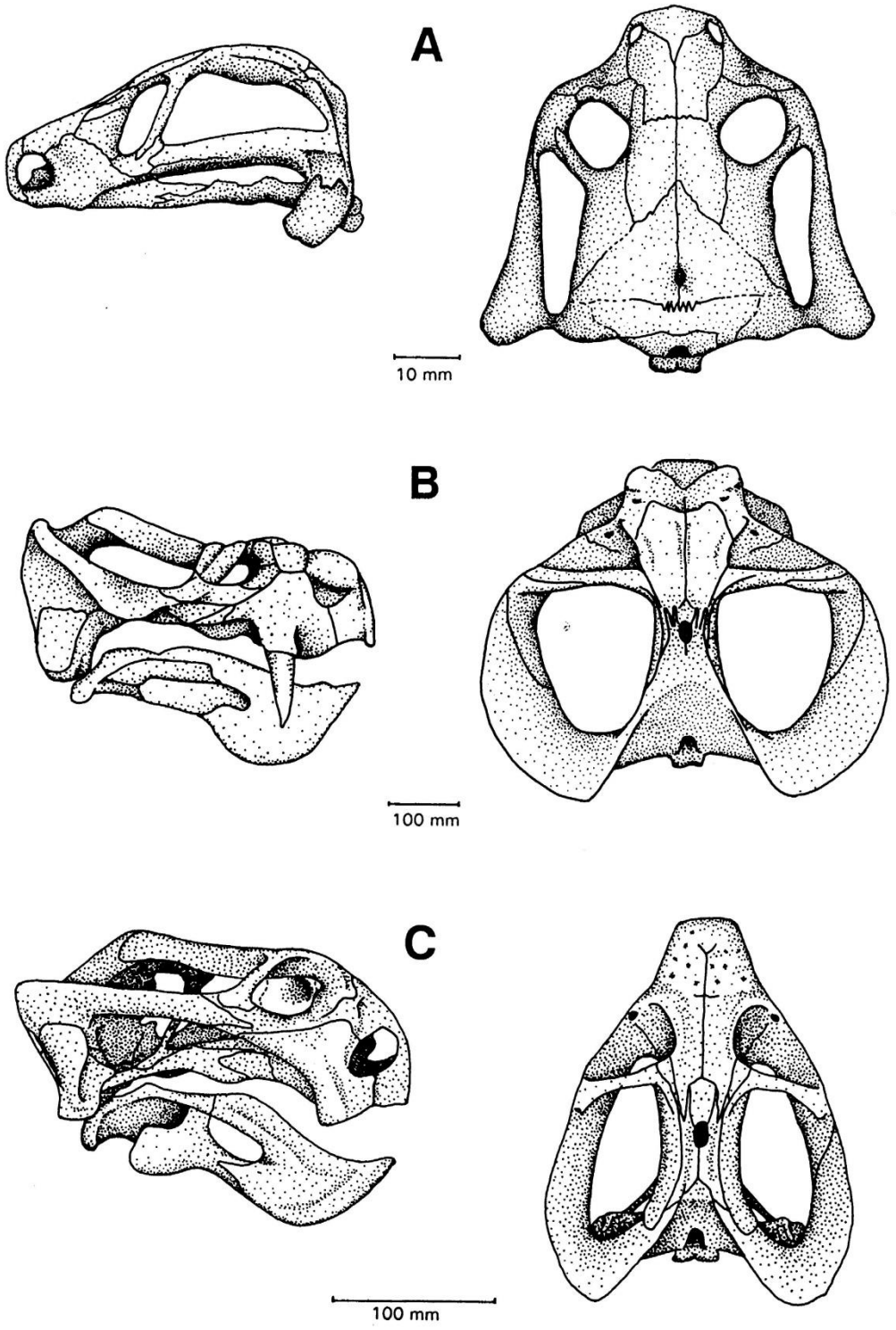

Figure 6: *Cistecephalus* (A), *Aulacephalus* (B) and *Oudenodon* (C) (from Rubidge et al., 1995).

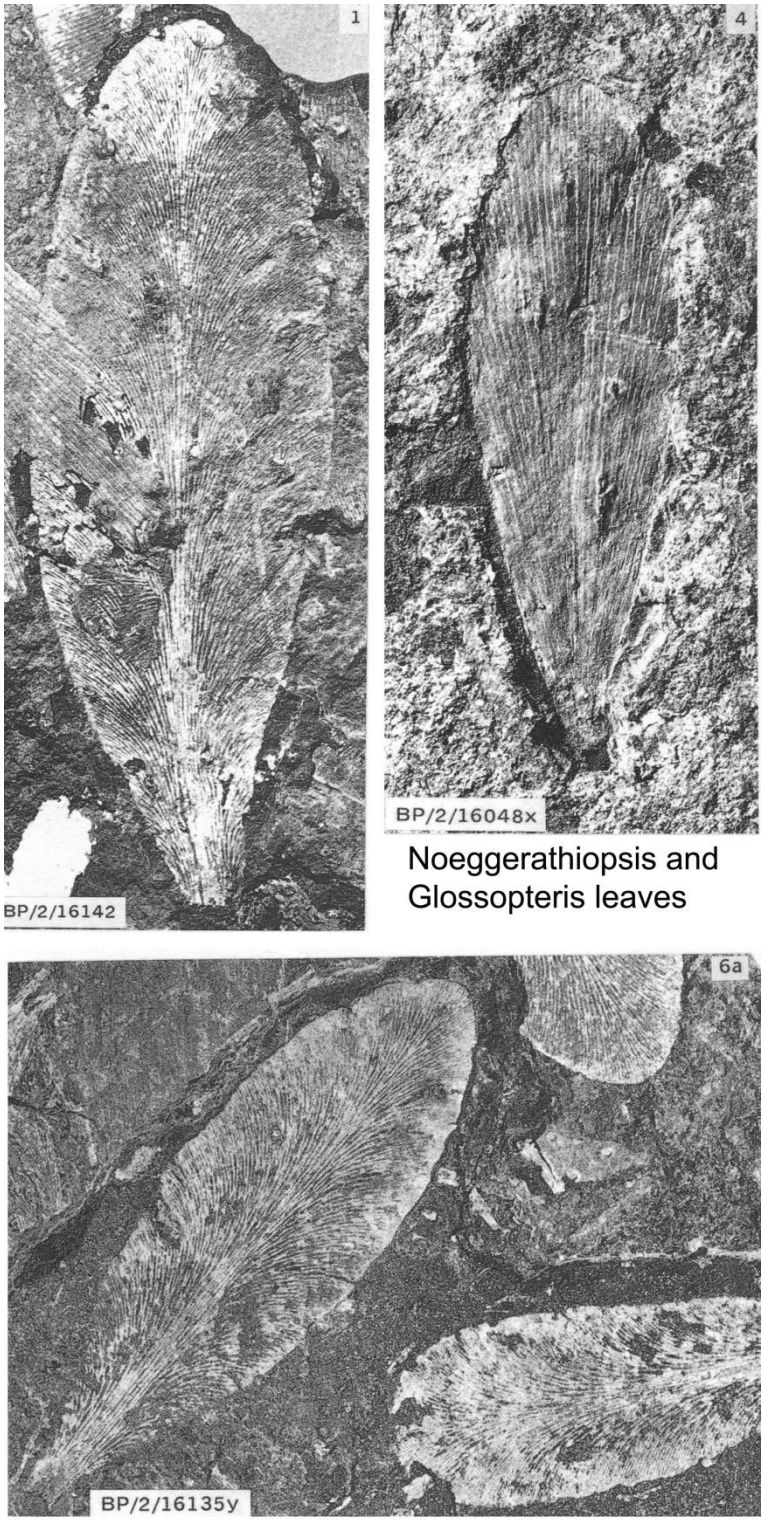

Figure 7: Fossil plants from the Permian of South Africa.

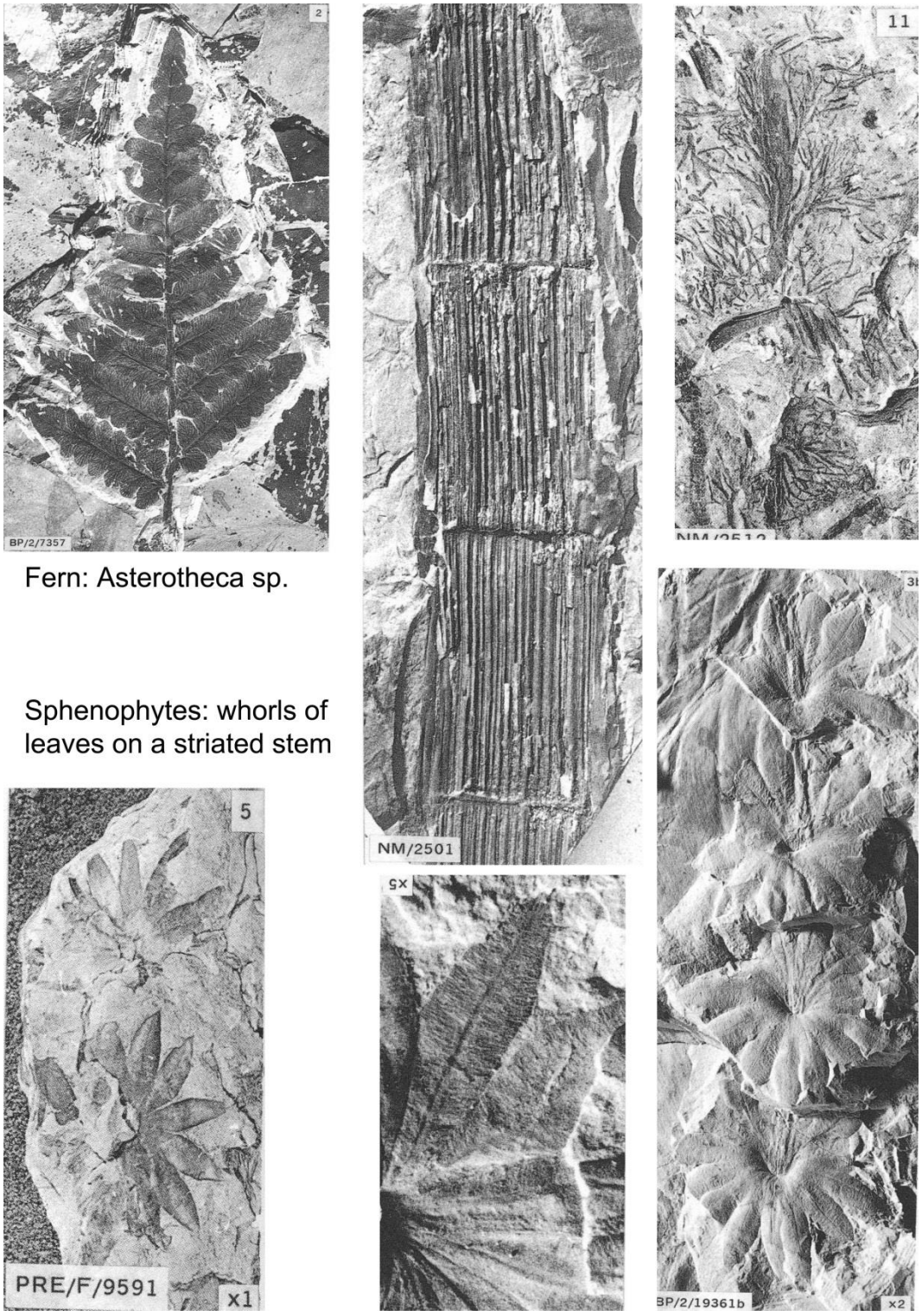

Figure 8: More examples of fossil plants from the Permian of South Africa.

Appendix B – Details of specialist

Curriculum vitae (short) - Marion Bamford PhD
January 2019

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 – 1984 to present
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	6	1
Masters	8	1
PhD	10	3
Postdoctoral fellows	9	3

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 onwards – Assistant editor
Guest Editor: Quaternary International: 2005 volume
Member of Board of Review: Review of Palaeobotany and Palynology: 2010 –
Cretaceous Research: 2014 -

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
- Amandelbult 2018 for SRK
- 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
- SARAO 2018 for Digby Wells
- Ventersburg B 2018 for NGT
- Hanglip Service Station 2018 for HCAC
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xi) Research Output

Publications by M K Bamford up to January 2019 peer-reviewed journals or scholarly books: over 125 articles published; 5 submitted/in press; 8 book chapters.
Scopus h index = 27; Google scholar h index = 30;
Conferences: numerous presentations at local and international conferences.

xii) NRF Rating

NRF Rating: B-2 (2016-2020)
NRF Rating: B-3 (2010-2015)
NRF Rating: B-3 (2005-2009)
NRF Rating: C-2 (1999-2004)