Palaeontological Impact Assessment for the proposed extension of Pit 8, Somkhele Mine, near Mtubatuba, KwaZulu Natal Province

Desktop Study

For

GCS Water & Environmental Consultants

19 January 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 GCS Water & Environmental Consultants, 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

Somkhele Anthracite Mine has been a fully operational anthracite mine since 2007 and is operated and owned by Tendele Coal Mining (Pty) Ltd. Is the intention of the owners of Somkhele Anthracite Mine to extend its existing Luhlanga opencast pit (Area 8) by approximately 18 ha. The proposed extension includes an increase in the footprint of the waste rock dump to 50 Ha. 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 development of a sand mining area.

Somkhele Mine is situated in the Vryheid Formation, Ecca Group, early to middle Permian in age and has reserves of coal and anthracite. Fossil plants of the Glossopteris flora have been recorded from road and rail cuttings and boreholes. Recent research on the nearby Emakwazini Formation has highlighted the unusual nature of this fossil deposit and so it is of interest to palaeontologists. Any fossil material will be visible and accessible once mining operations commence so it is strongly recommended that a monitoring programme and Fossil Chance Find Protocol are instituted in the EMPr. The mine's responsible person must check shales and mudstones (usually designated for a dump) regularly, save a sample of any fossils found and call a palaeontologist to collect and rescue a representative sample. This applies to the LoM.

Table of Contents

1. Background

Somkhele Anthracite Mine has been a fully operational anthracite mine since 2007 and is operated and owned by Tendele Coal Mining (Pty) Ltd. Is the intention of the owners of Somkhele Mine to extend its existing Luhlanga opencast pit (Area 8) by approximately 18 ha. The proposed extension includes an increase in the footprint of the waste rock dump to 50 ha.

The site of the proposed Area 8 opencast pit is 68 ha (680000 m²) in size hence it triggers section 38 (1) (c)(i) of the National Heritage Resources Act (NHRA), 1999 (Act No 25 of 1999), which refers to (c) any development or other activity which will change the character of a site — (i) exceeding 5 000 m² in extent. The mine falls within Reserve No. 3 (Somkhele 15822) of the Mtubatuba administrative district. The approximate midpoint of the proposed pit extension is at S28^{0}19'14.43"; E32^{0}04' 42.63".

A desktop palaeontological impact assessment was recommended for this proposed mine expansion 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). The PIA is presented here.

Table 1: Specialist report requirements in terms of Appendix 6 of the EIA Regulations (2014)

A specialist report prepared in terms of the Environmental Impact Regulations of 2014 must contain:	**Relevant section in report**
Details of the specialist who prepared the report	Appendix B
The expertise of that person to compile a specialist report including a curriculum vitae	Appendix B
A declaration that the person is independent in a form as may be specified by the competent authority	Page 1
An indication of the scope of, and the purpose for which, the report was prepared	Section 1
The date and season of the site investigation and the relevance of the season to the outcome of the assessment	N/A
A description of the methodology adopted in preparing the report or carrying out the specialised process	Section 2
The specific identified sensitivity of the site related to the activity and its associated structures and infrastructure	Section **Error! Reference source not found.** **Error! Reference source not found.**
An identification of any areas to be avoided, including buffers	N/A
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

A description of any assumptions made and any uncertainties or gaps in knowledge;	Section 5
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
Any mitigation measures for inclusion in the EMPr	N/A
Any conditions for inclusion in the environmental authorisation	N/A
Any monitoring requirements for inclusion in the EMPr or environmental authorisation	Section 8
A reasoned opinion as to whether the proposed activity or portions thereof should be authorised	N/A
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
A description of any consultation process that was undertaken during the course of carrying out the study	N/A
A summary and copies if any comments that were received during any consultation process	N/A
Any other information requested by the competent authority.	N/A

Figure 1: Google Earth map of the proposed expansion in Area 8 of Somkhele Anthracite

Mine. Grey indicates the heritage study area, the well-spaced contour lines indicate the dump and the closely spaced lines (north central) indicate the new pit. Map supplied by GCS.

2. Methods and Terms of Reference

The Terms of Reference (ToR) for this study were to undertake a Palaeontology Impact Assessment (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 (*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 location of the project lies on the north eastern margin of the Main Karoo Basin and includes the Late Carboniferous-Early Permian Dwyka Group, the Early to middle Permian Ecca Group (Pietermaritzburg, Vryheid, Volksrust Formations), Jurassic intrusive dykes, the the southern end of the Letaba Formation (Lebombo Group, Jurassic). Ecca Group shales, sandstones, mudrock and coals were deposited around the large inland sea that receded over time and are overlain by the Beaufort deposits that were the result of a shrinking sea and a shift from lacustrine to braided stream settings. Economically exploitable coal seams occur in the Vryheid Formation and these are the target of the mine expansion project in the Somkhele Anthracite Mine in Area 8.

The other older rocks in the region, to the east would not be affected by this development and will not be discussed further.

ii. Palaeontological context

The Pietermaritzburg dark silty mudrock and shales are the result of a major post-glacial transgression from the melting of the Dwyka ice sheets. Invertebrate trace fossils are present in some areas and no fossils have been recorded (Johnson et al., 2006). Overlying the

Pietermaritzburg Formation are the upward-coarsening cycles of the Vryheid Formation that are deltaic in origin. Fossil plants are fairly common and can be found in the shales and mudstones, usually associated with shale lenses and coal seams. Where plants are found, more often than not, no vertebrates are found. The overlying Volksrust Formation comprises grey to black silty shale with thin sandstone or siltstone lenses. It probably represents a transgressive open shelf sequence (Johnson et al., 2006) and fossils have not been recorded from this formation.

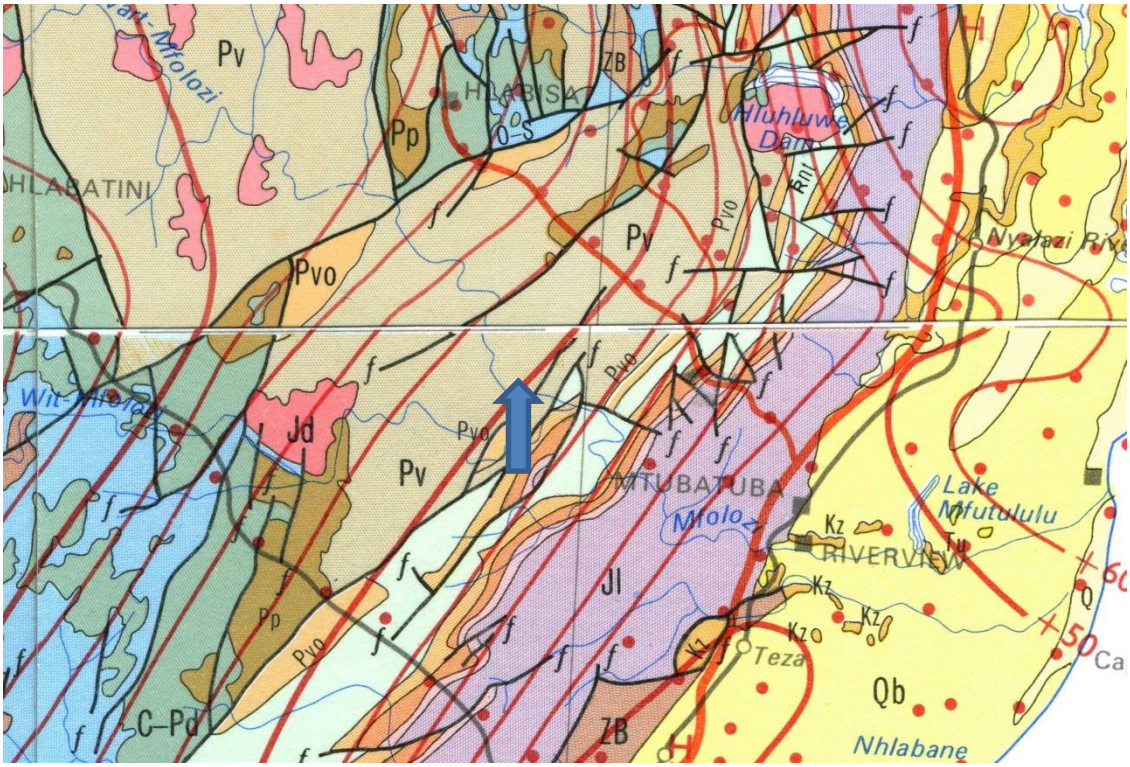

Figure 2: Geological map of the area around Mtubatuba and Somkhele Mine. The location of the proposed project is indicated with the arrow. Abbreviations of the rock types are explained in Table 2. Map enlarged from the Geological Survey 1: 1 000 000 map 1984.

Table 2: Explanation of symbols for the geological map and approximate ages (Erikssen et al., 2006. Johnson et al., 2006; McCarthy et al., 2006; Robb et al., 2006; van der Westhuizen et al., 2006). SG = Supergroup; Fm = Formation.

Symbol	Group/Formation	Lithology	Approximate Age
Qb	Bluff, Beach and Port Durnford Fm	Aeolianite, sand, clay, limestone	Pliocene
Jd	Jurassic	Dolerite dykes, intrusive	Jurassic, approx. 180 Ma
Pvo	Volksrust Fm	shale	Middle Permian, Upper Ecca
Pv	Vryheid Fm	Shales, sandstone, coal	Early Permian, Middle Ecca
Pp	Pietermaritzburg Fm,	shale	Early Permian, Early Ecca
C-Pd	Dwyka Group	Shales, sandstones, mudstones	Late Carboniferous to Early Permian; ca 315-290 Ma
O-S	Natal Group	Quartzitic sandstone, arkose, shale	Ordovician-Silurian

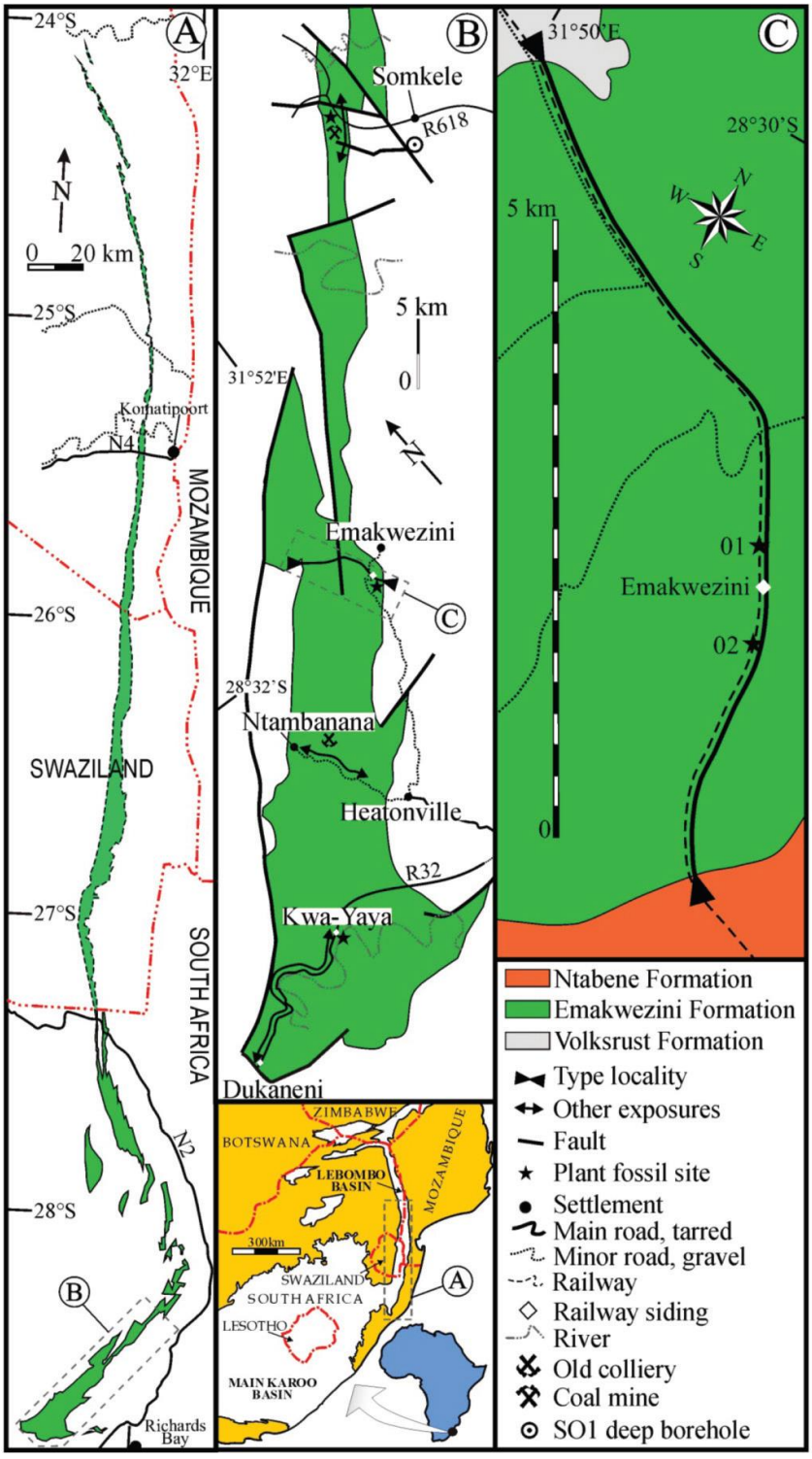

Figure 3: Emakwezini Formation outcrops in relation to Somkhele. Fig 1 of Bordy and Prevec (2015) type site.

Vryheid Formation coal flora fossils in southern Africa comprise typical Gondwana plants, namely a variety of *Glossopteris* leaves, rare fructifications, cordaitaleans, gymnosperms, lycopods, sphenophytes and ferns. In in some outcrops fossil plants can be abundant.

Coals themselves, and anthracite in particular, do not preserve fossils that are of interest to palaeobotanists because all the plant material has been compressed and altered by heat. No macroplants would be visible but in some cases, heat altered pollen and spores can be found in the layers. Fossil plant impressions, however, can be preserved in the mudstones and shales lenses that occur between the coal seams. As a general rule the finer the grain the better the preservation of the plant impressions.

Early work on fossil plants from railway cuttings and a borehole core by Etheridge (1902), Seward (1907) and Plumstead (1970) described a number of taxa, for example *Glossopteris* spp., *Ottokaria* sp., *Vertebraria indica*, *Schizoneura gondwanensis*, *Phyllotheca* spp. and *Dictyopteridium* in carbonaceous shales associated with coal seams. The latter two taxa were used by Plumstead (1070) to assign the Emakwezini Formation to the Upper Permian.

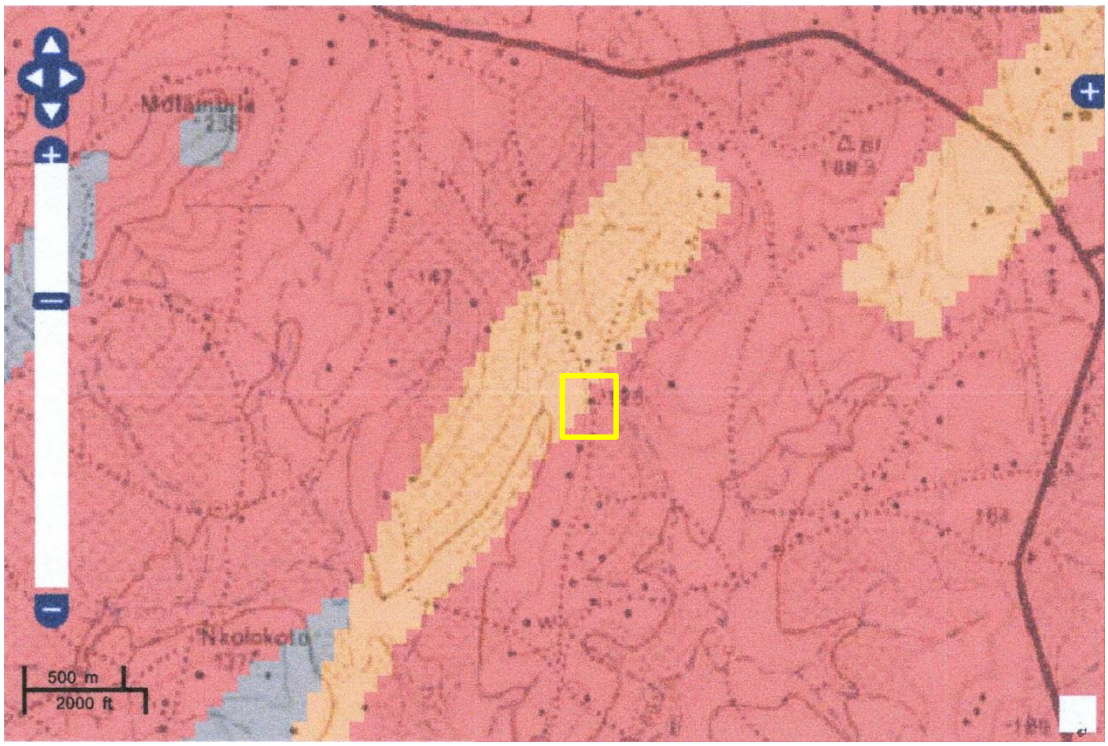

Figure 4: SAHRIS palaeosensitivity maps for the area around Somkhele Mine where the proposed expansion is located - shown within the yellow rectangle. Colours indicate the following degrees of sensitivity: red = very highly sensitive; orange/yellow = high; green = moderate; blue = low; grey = insignificant/zero.

More recent research by Bordy and Prevec (2008, 2015) has descriptions and updates of the plant taxonomy and the lithostratigraphy. They focussed on the Emakwazini Formation which conformably overlies the Volksrust Formation and unconformably underlies the Ntabene Formation. The Emakwazini Formation plant fossils indicate a middle to late Permian age and so it correlates with the Normandien Formation (and informal Estcourt Formation) of the

eastern and north-eastern and the Balfour Formation of the southern main Karoo Basin (Bordy and Prevec, 2008). They concluded that a very low energy, vegetated peat swamp isolated from sites of active clastic sedimentation is represented. Moreover, the flora is atypical of the South African Glossopteris flora and (Bordy and Prevec, 2015). This flora, therefore, requires further collection and study.

The palaeontological sensitivity of the area under consideration is presented in Figure 4, and indicates that the area is highly sensitive.

4. Impact assessment

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

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**	The Vryheid Fm contains fossil materials of plants. The impact would be high
	M	-
	L	..
	L+	-
	M+	-
	H+	-
DURATION	**L**	-
	M	-
	H	Where manifest, the impact will be permanent.

PART B: ASSESSMENT		
SPATIAL SCALE	**L**	Since only the possible fossils within the area would be fossil plants from the *Glossopteris* flora in the shales, the spatial scale will be localised within the site boundary.
	M	-
	H	-
PROBABILITY	**H**	**-**
	M	**There is a moderate chance of fossils occurring in the shales between the coal lenses BUT they can be sporadic and would not be evident until mining operations commence. A Chance Find Protocol should be added to the EMPr.**
	L	-

Based on the nature of the project, surface activities may impact upon the fossil heritage if preserved in the development footprint. The geological structures suggest that the rocks are the correct age and type to preserve fossil plants of the Glossopteris flora but it is unknown at which depths they may occur or how abundant they would be. Although the South African coal flora plants have been fairly well studied, the Somkhele is a particularly interesting flora because it is atypical, possibly represents the late Permian time and is well preserved when found. Since there is a moderate to high chance that fossils from the Vryheid Formation may be disturbed a Fossil Chance Find Protocol has been added to this report. Taking account of the defined criteria and survey of the literature, the potential impact to fossil heritage resources is significant.

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, shales and sands are typical for the country and do contain fossil plant, insect, invertebrate and vertebrate material. From the survey of the published literature it is very likely that fossils will be encountered at one or more levels during mining operations.

6. Recommendation

Based on experience and the published literature there is a good chance of finding fossil plants of the Glossopteris flora that are of great palaeobotanical interest because of their good preservation, as recorded in core and surface collections, and the time period that they represent. This will not be confirmed until mining operations commence as surface fossils would be weathered but below ground fossils, if and where they occur, are likely to be well preserved (see illustration by Bordy and Prevec, 2008, reproduced her in Appendix A). Therefore, a Chance Find Protocol must be added to the EMPr and the mining geologist, environmental officer and other designated personnel must regularly check the shales and mudstones for fossils, rescue them and call a palaeobotanist to collect a sample (with an AMAFA permit) and house them in a recognised local institution for further study. This monitoring process must continue for the life of the mine.

7. References

Anderson, J.M., Anderson, H.M., 1985. Palaeoflora of Southern Africa: Prodromus of South African megafloras, Devonian to Lower Cretaceous. A.A. Balkema, Rotterdam. 423 pp.

Bordy, E.M., Prevec, R. 2008. Sedimentology, palaeontology and palaeo-environments of the Middle (?) to Upper Permian Emakwezini Formation (Karoo Supergroup, South Africa). South African Journal of Geology 111, 429-458.

Bordy, E., Prevec, R., 2015. Lithostratigraphy of the Emakwezini Formation (Karoo Supergroup), South Africa. South African Journal of Geology 118.3, 307-310. doi:10.2113/gssajg.118.3.307

Etheridge, R. Jr. 1903. The fructification of *Schizoneura australis*, Etheridge fil. Geological Survey of New South Wales Record, 7, 234-235.

Johnson, M.R., van Vuuren, C.J., Visser, J.N.J., Cole, D.I., Wickens, H.deV., Christie, A.D.M., Roberts, D.L., Brandl, G., 2006. Sedimentary rocks of the Karoo Supergroup. 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 461 – 499.

Plumstead, E.P., 1969. Three thousand million years of plant life in Africa. Geological Society of southern Africa, Annexure to Volume LXXII. 72pp + 25 plates.

Plumstead, E.P. 1970. Recent progress and the future of palaeobotanical correlation in Gondwanaland. In: S.H. Haughton (Ed). Proceedings 2nd IUGS Symposium on Gondwana Stratigraphy and Palaeontology. Council For Scientific and Industrial Research, South Africa, 139-144

Robb, L.J., Brandl, G., Anhaeusser, C.R., Poujol, M., 2006. Archaean Granitoid Intrusions. 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 57-94.

Seward, A.C. 1907. On a collection of Permo-Carboniferous plants from the St. Lucia (Somkele) Coal-field, Zululand, and from the Newcastle District, Natal. Transactions of the Geological Society of South Africa, 10, 81-89.

Van der Westhuizen, W.A., de Bruiyn, H., Meintjes, P.G., 2006. The Ventersdorp Supergroup. 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 187-208.

8. Chance Find Protocol

Monitoring Programme for Palaeontology – to commence once the excavations for infrastructure begin and mining operations commence.

1. The following procedure is required from the commencement of any operations on site and must continue through the life of the mine.
2. When excavations and mining begin the rocks and must be given a cursory inspection by the geologist, environmental officer or designated person. Any fossiliferous material (plants, insects, bone, coal) should be put aside in a suitably protected place. This way the mining 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 9, 10). 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 or environmental officer 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 an AMAFA 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. Annual reports by the palaeontologist must be sent to AMAFA (only if permits have been obtained).
8. If no fossils are found and the excavations and coal mining operations have finished then no further monitoring is required.

Appendix A – examples of fossils from the Vryheid Formation

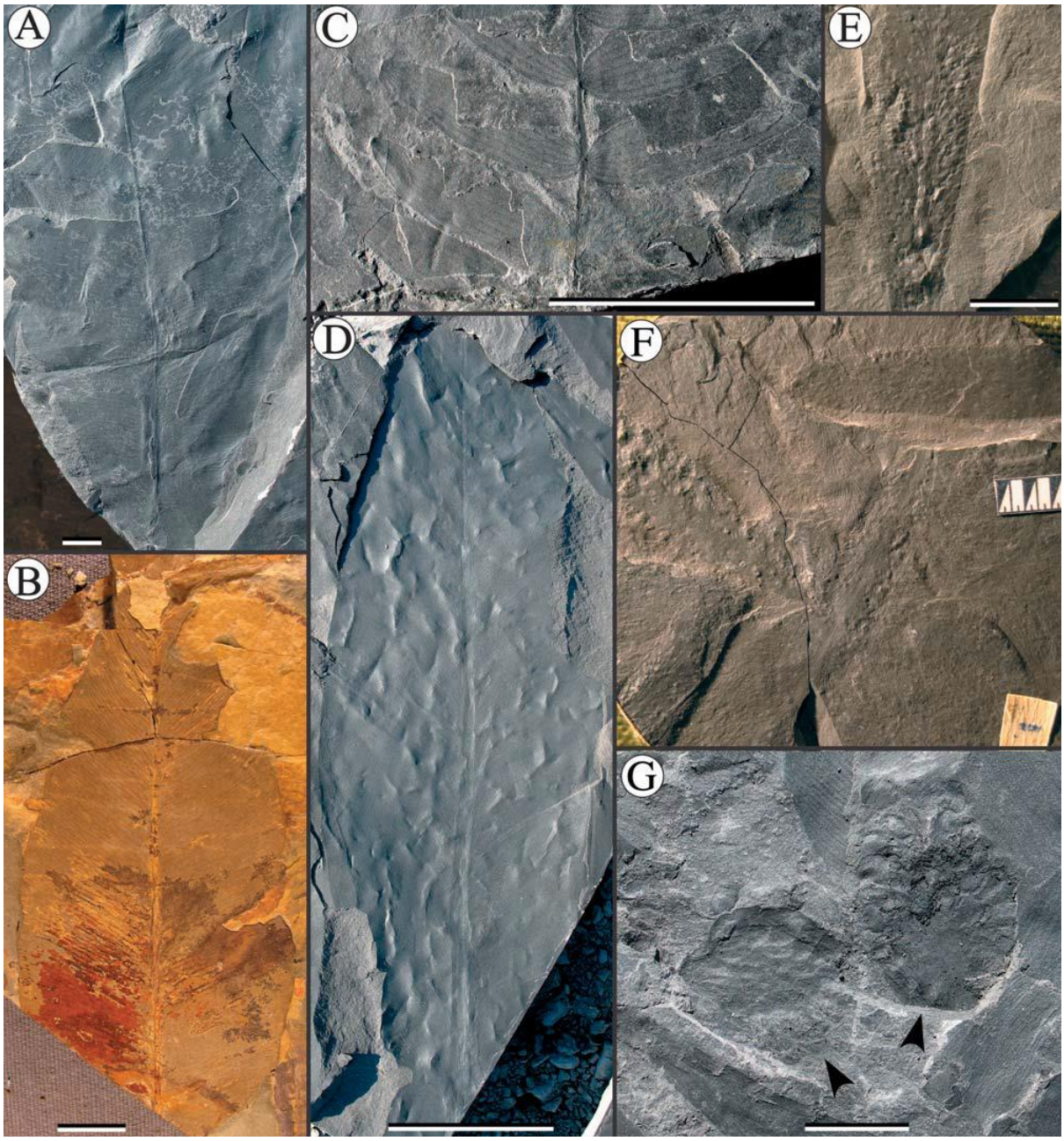

Figure 5: Taken from Bordy and Prevec, 2008, Plate III. (A and B) distinctive *Glossopteris* morphotypes included by Anderson and Anderson (1985) within their palaeo-species *Estcourtia bergvillensis*, found at both Kwa-Yaya [B; KY 72], and Somkhele Mine [A; SM 01]; note that the Somkhele specimen is double the size of the leaf from Kwa-Yaya; (C) an unusually well-preserved specimen of the sphenopsid *Schizoneura gondwanensis* from Somkhele Mine, with multiple foliar lobes in attachment [SM 02; scale bar = 50 mm]; (D) Glossopteris morphotype from Somkhele Mine [SM 03; scale bar = 50 mm]; (E and F) impression fossils from the SO1 borehole at Somkhele, described by Plumstead (1970) as *Dictyopteridium*. Note the abundance of oviposition scars, particularly along the midrib, in the specimen in E, which is the basal portion of a small Glossopteris leaf; (G) adjacent specimens of the ovuliferous glossopterid fructification *Ottokaria* sp. (arrows). Scale bars = 10 mm unless otherwise specified. Square brackets contain the temporary field numbers of the specimens.

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
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 – 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
- 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
-

xi) Research Output

Publications by M K Bamford up to June 2018 peer-reviewed journals or scholarly books: over 120 articles published; 5 submitted/in press; 8 book chapters.
Scopus h index = 26; 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)