Palaeontological Impact Assessment for the proposed re-alignment of the Kromfontein 132 kV powerline in support of the Vandyksdrift Central (VDDC) Project for South32 SA Coal Holdings (Pty) Ltd. Mpumalanga Province

Desktop Study

For

Jones and Wagener Engineering and Environmental Consultants

30 April 2019

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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 Jones and Wagener Engineering and Environmental Consultants, Johannesburg, 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

An Eskom powerline, the Kromfontein 132kV, needs to be realigned to accommodate the proposed additional infrastructural changes at Vandyksdrift Central (VDDC), Mpumalanga Province. South32 SA Coal Holdings (Pty) Ltd (South32) is the holder of an amended mining right for coal for Wolvekrans North and South Sections, south of Middelburg in the Witbank coalfield. As part of the request approved, to allow the opencast mining of the remaining No. 5, No. 4, No. 2 and No. 1 seams, some additional infrastructure is required and is addressed in a separate environmental authorisation application. The VDDC area falls within the footprint of historic underground mining operations at the old Douglas Colliery.

The Impact Risk Class is 2 as the Rating is 1.07 and falls in the range 1.1 – 2.0 which is low.

The project area falls in palaeontologically sensitive sediments (shales, mudstones and coal) of the early Permian Vryheid Formation in the Witbank coalfield. Coal seams are between 15-110m below the land surface that is covered by soils. It is very unlikely that any fossils would be impacted upon by the excavations required for the new route for the powerline poles because the fossils would occur in the shales associated with the coal seams and the fossils are rare and sporadic. Topsoils do not preserve fossils so there is no point in carrying out a site visit before excavations begin as any potential fossils would not be visible. Nonetheless, it is recommended that a Fossil Chance Find Protocol be included in the Environmental Management Programme (EMPr). Any further palaeontological assessment is only required once excavations have commenced and if the responsible person finds fossils.

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1. Background

Wolvekrans Colliery is an operational division of South32 SA Coal Holdings (Pty) Limited (South32). The mine is located between the towns of eMalahleni and Kriel, approximately 30 km south-east of the town of eMalahleni, in close proximity to the Duvha Power Station (Figure 1).

The Vandyksdrift Central (VDDC) section of Wolvekrans Colliery is located to the south of the Steenkoolspruit and Vandyksdrift North sections, and north of the Vandyksdrift South and Albion sections (mining has ceased at these two sections). The Olifants River determines the southern boundary of the VDDC mining section. The R544 and R575 provincial roads are located to the east and west of the Wolvekrans Colliery, respectively.

The VDDC section area falls within the footprint of historic underground mining operations at the old Douglas Colliery. In 2007, an amendment of the Environmental Management Programme Report (EMPR) for the Douglas Colliery operations was approved, to allow the opencast mining of the remaining coal seams. This is now referred to as the VDDC section to be opencast mined using dragline, and truck and shovel operations. Mining will commence in 2020.

Electricity for the VDDC section is supplied from Eskom's Klein Olifants 132 kV Substation, which feeds the Klein 132 kV Substation. The existing Kromfontein 132 kV powerline which connects the Klein Substation and the Kromfontein Substation, traverse the area to be opencast mined (Figures 1, 2) and therefore has to be relocated before opencast mining can commence.

Jones & Wagener Engineering and Environmental Consultants (J&W) has been appointed as an independent Environmental Assessment Practitioner (EAP) to undertake the application for Environmental Authorisation (EA) for the re-alignment of the Kromfontein 132 kV powerline. This application is undertaken by South32 in terms of a self-build agreement with Eskom. The EA will be transferred to Eskom on completion of the construction phase.

This document provides a detailed palaeontological impact assessment (PIA) by a professional palaeontologist as part of the Basic Assessment process to be undertaken in support of the EA application.

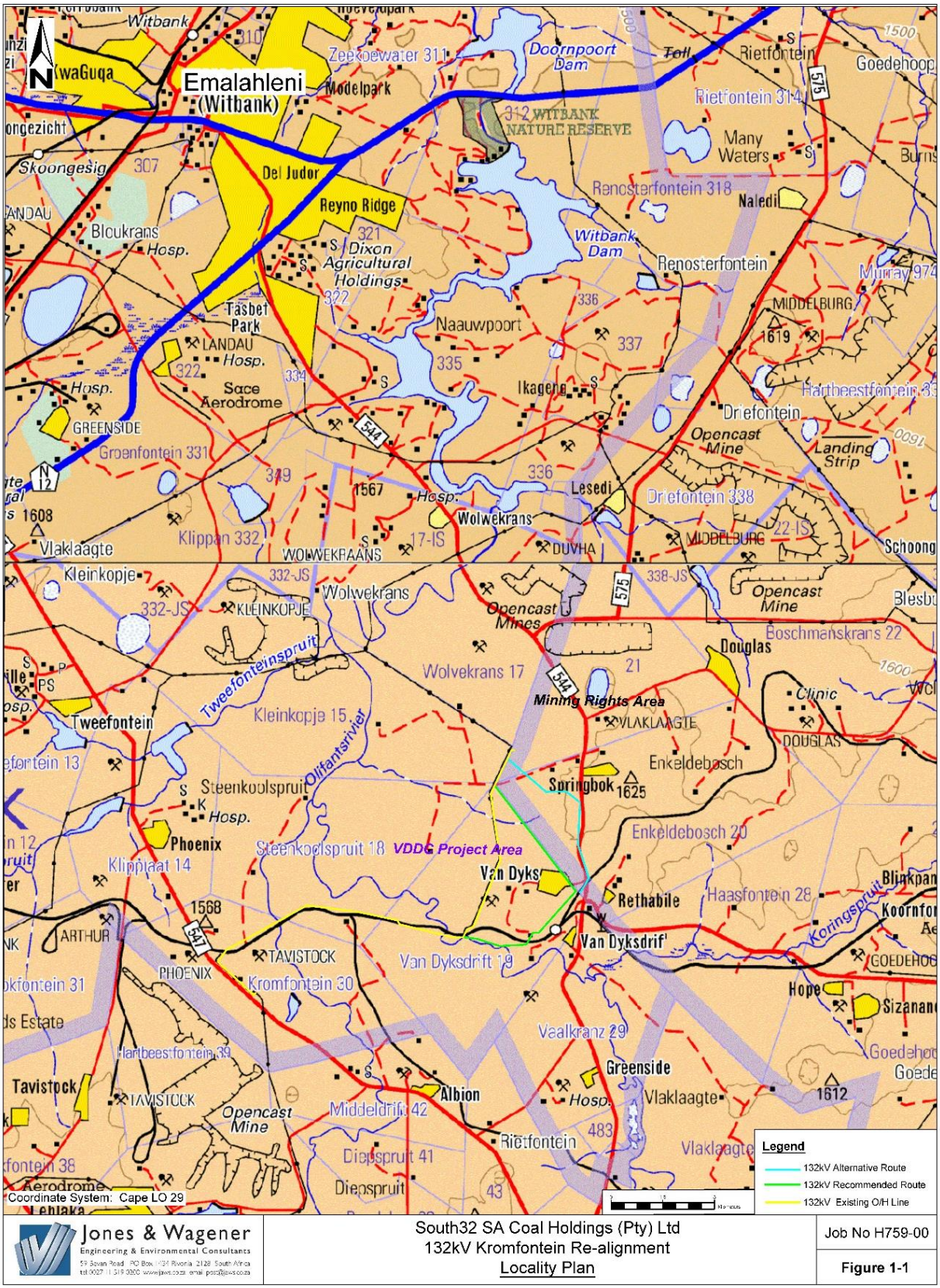

Figure 1: **General plan of the Wolvekrans Colliery with VDDC (Vandyksdrift Central) shown in purple relevant powerline routes turquoise, green and yellow. Map supplied by Jones and Wagener.**

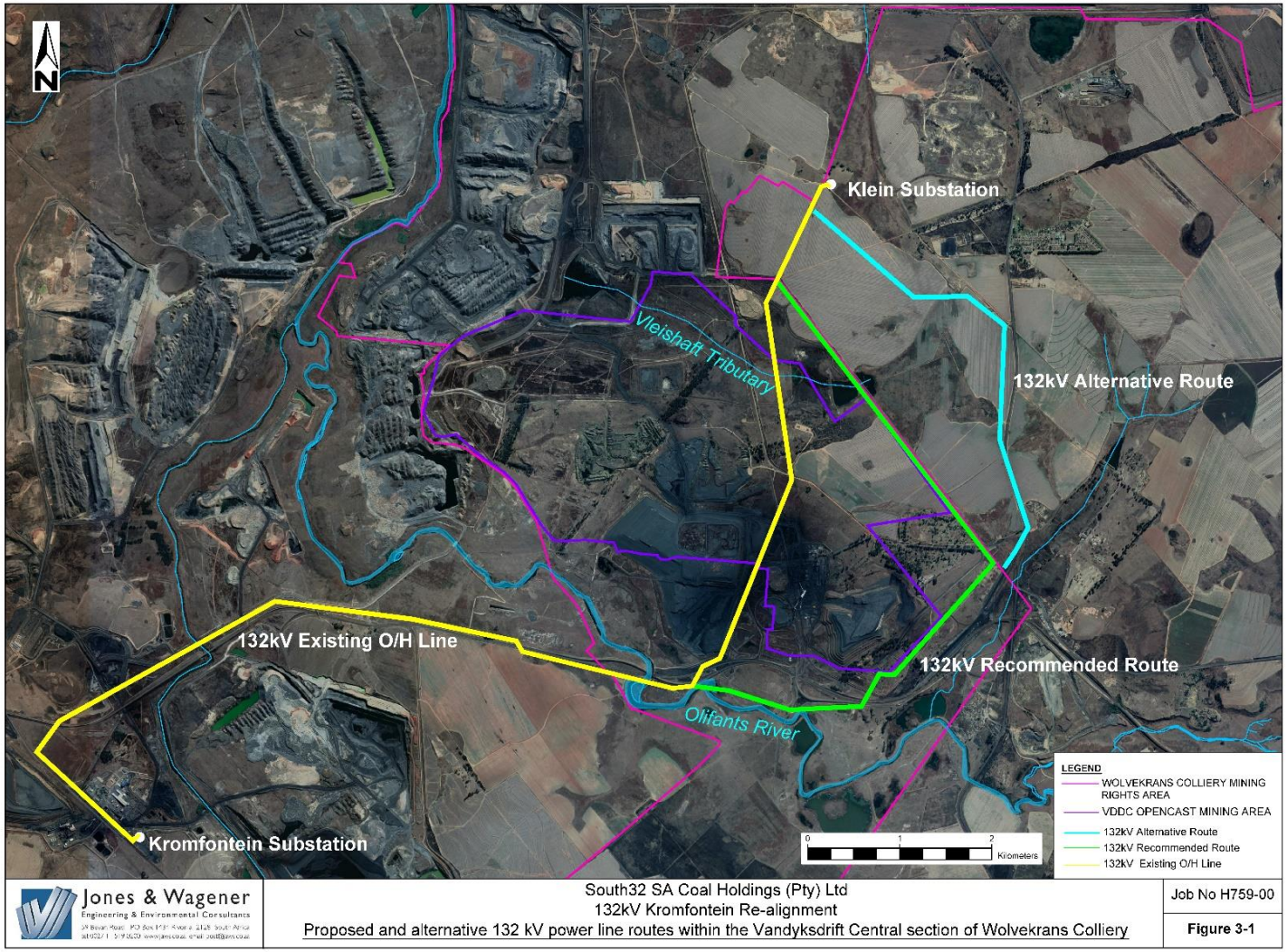

Figure 2: Google Earth map of the proposed powerline routes for the VDDC development

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 2014 must contain:	**Relevant section in report**
ai	Details of the specialist who prepared the report	Appendix A
aii	The expertise of that person to compile a specialist report including a curriculum vitae	Appendix A
b	A declaration that the person is independent in a form as may be specified by the competent authority	Page i
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	
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

	A specialist report prepared in terms of the Environmental Impact Regulations of 2014 must contain:	Relevant section in report
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

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;
3. Where appropriate, collection of unique or rare fossils with the necessary permits for storage and duration 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.

3. Geology and Palaeontology

i. Project location and geological context.

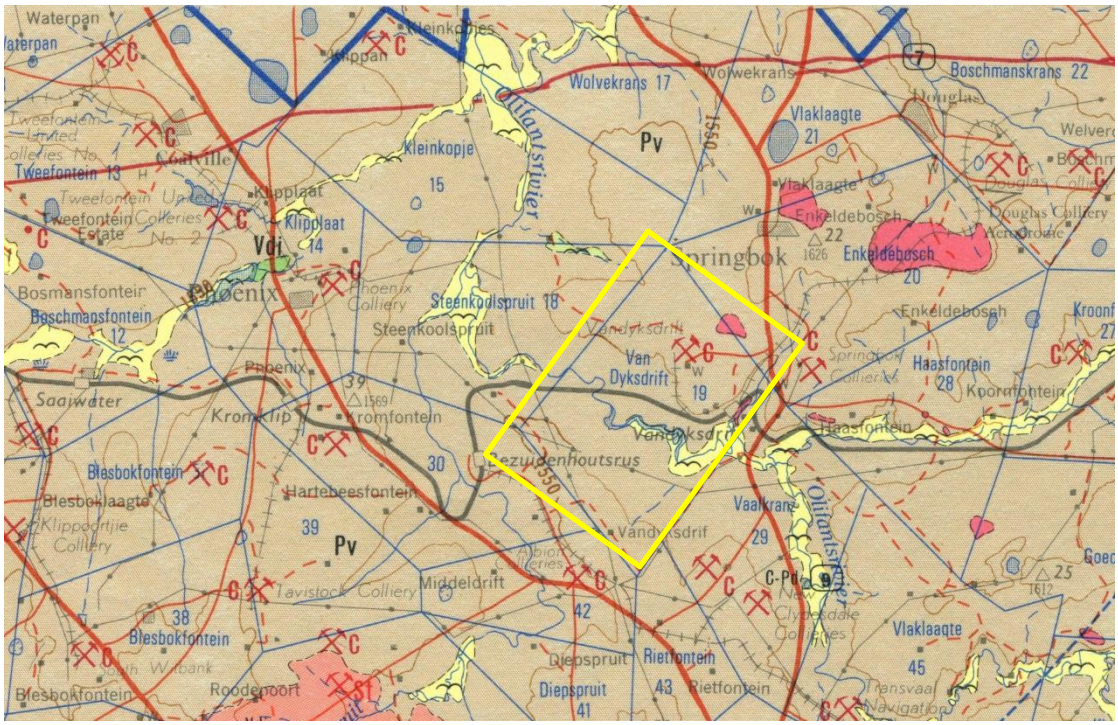

Figure 3: **Detailed geological map of the Vandyksdrift farm (within the yellow outline) and adjacent farms. Geological Survey 1:250 000 map 2628 East Rand 1996**

The geological context of the project is shown in **Figure 3** and the symbols used on the geological maps is explained in **Table 2**.

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

Symbol	Group/Formation	Lithology	Approximate Age
Jd	Jurassic Dolerite Dyke	Intrusive dolerite	Jurassic ca 183 Ma
Pv	Vryheid Fm, Ecca Group, Karoo SG	Sandstone, shale, coal	Lower Permian, Middle Ecca
C-Pd	Dwyka Group, Karoo SG	Tillite, sandstone, mudstone, shale	Upper Carboniferous, Early Permian 295-290 Ma

The 132 kV powerline re-alignment project is in the southern part of the Witbank Coalfield where there are typically all five coal seams and sometimes several layers of No 4 seam (Snyman, 1998). They are overlain by soils for 5-10m from the land surface, and below them sandstones, shales and siltstones. In this coalfield the various coal seams occur anywhere between 15m below surface down to 110m. Between the coal seams are bands of sandstones, shales and siltstones.

ii. Palaeontological context

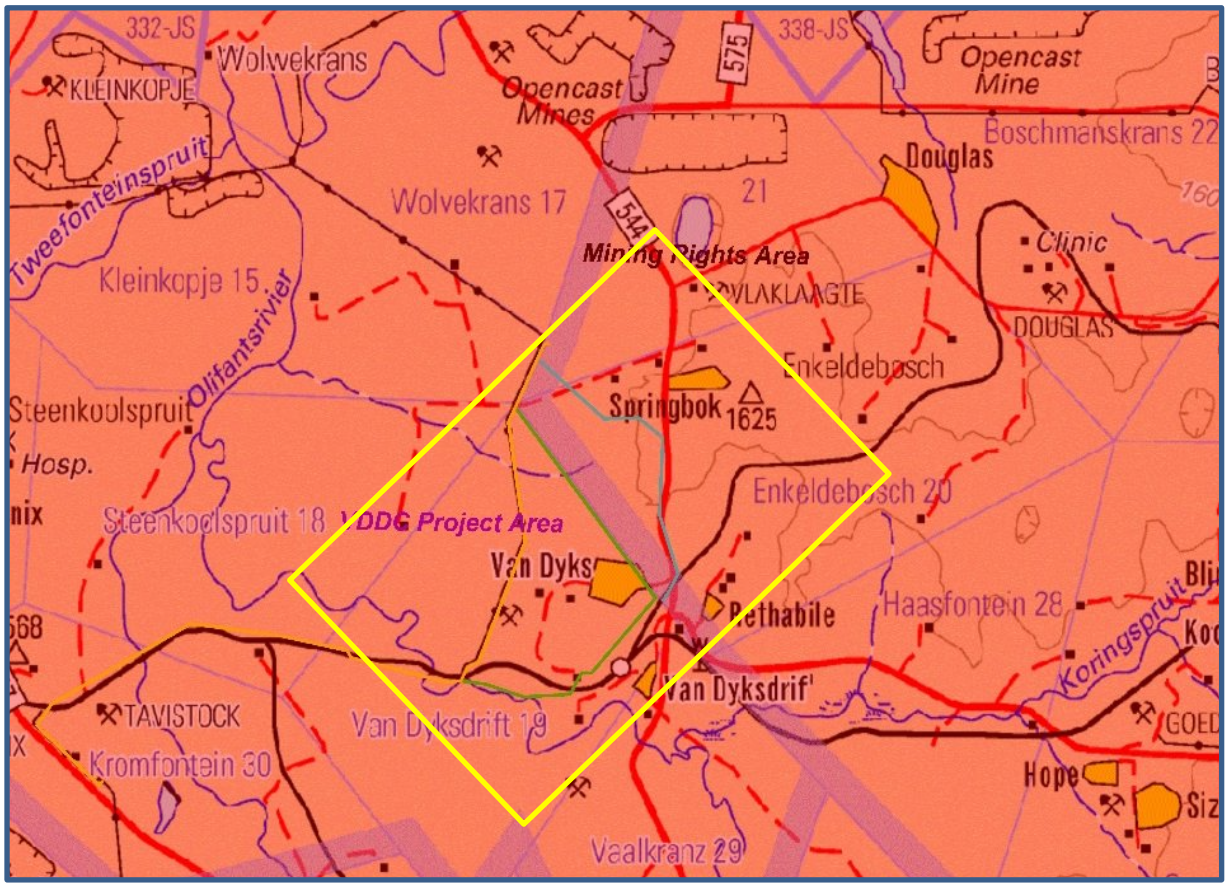

Figure 4: **SAHRIS palaeosensitivity map of the region around Vandyksdrift Central of the Wolvekrans Colliery, Mpumalanga (yellow rectangle). The proposed powerline routes are all the highly sensitive (red) area. Colours indicate the following degrees of sensitivity: red = very highly sensitive; orange/yellow = high; green = moderate; blue = low; grey = insignificant/zero (accessed April 2019).**

The 132 kV powerline re-alignment project is situated in a well-established coal mining area with economically productive coal seams. While coal *per se* does not preserve any recognisable fossil plant material because it has been altered and compressed by high temperatures and pressures, impressions of the coal flora can be found in the shales and mudstones between the coal lenses. Typical coal flora plants are the seed fern *Glossopteris*, various lycopods, sphenophytes and ferns, with rare early gymnosperms.

The sediments in this area are the middle Ecca Group Vryheid Formation sandstones, shales and coals. Based on the palynological record the Vryheid Formation is 269-265 million years old and equivalent to the Wordian stage of the Guadalupian Epoch (Barbolini et al., 2016). The macroplant flora does not assist with age constraints but the Vryheid Formation taxa are listed in Appendix A. Vertebrates are seldom found to occur with fossil plants as the preservation conditions are different and vertebrate fossils are extremely rare at this time.

4. Impact assessment

The criteria and rating scales for the impact assessment are given in **Table 3** to **Table 7**. The results are summarised below for the palaeontology impact:

- Significance = 2 (Impact is of a low order and therefore likely to have little real effect)
- Spatial scale = 1 (Isolated Sites / proposed site. The impact will affect an area no bigger than the corridor / site)
- Temporal scale = 5 (Permanent. The environmental impact will be permanent)
- Probability = 2 (Unlikely)
- Degree of certainty = High.

When the results are inserted into the following formula to obtain the impact risk the rating:

$$\textit{Impact Risk} = \frac{(\text{SIGNIFICANCE} + \textit{Spatial} + \text{Temporal})}{3} \times \frac{\text{Probability}}{5}$$

$(2 + 1 + 5)/3 \times 2/5 = 1.066$

Impact risk class 2 = Low.

Table 3: Quantitative rating and equivalent descriptors for the impact assessment criteria

RATING	SIGNIFICANCE	EXTENT SCALE	TEMPORAL SCALE	PROBABILITY
1	VERY LOW	Isolated corridor / proposed corridor	Incidental	Practically impossible
2	LOW	Study area	Short-term	Unlikely
3	MODERATE	Local	Medium-term	Could happen
4	HIGH	Regional / Provincial	Long-term	Very likely
5	VERY HIGH	Global / National	Permanent	It's going to happen / has occurred

Table 4: Description of the significance rating scale

RATING		DESCRIPTION
5	VERY HIGH	Of the highest order possible within the bounds of impacts which could occur. In the case of adverse impacts: there is no possible mitigation and/or remedial activity which could offset the impact. In the case of beneficial impacts, there is no real alternative to achieving this benefit.
4	HIGH	Impact is of substantial order within the bounds of impacts, which could occur. In the case of adverse impacts: mitigation and/or remedial activity is feasible but difficult, expensive, time-consuming or some combination of these. In the case of beneficial impacts, other means of achieving this benefit are feasible but they are more difficult, expensive, time-consuming or some combination of these.
3	MODERATE	Impact is real but not substantial in relation to other impacts, which might take effect within the bounds of those which could occur. In the case of adverse impacts: mitigation and/or remedial activity are both feasible and fairly easily possible. In the case of beneficial impacts: other means of achieving this benefit are about equal in time, cost, effort, etc.
2	LOW	Impact is of a low order and therefore likely to have little real effect. In the case of adverse impacts: mitigation and/or remedial activity is either easily achieved or little will be required, or both. In the case of beneficial impacts, alternative means for achieving this benefit are likely to be easier, cheaper, more effective, less time consuming, or some combination of these.
1	VERY LOW	Impact is negligible within the bounds of impacts which could occur. In the case of adverse impacts, almost no mitigation and/or remedial activity is needed, and any minor steps which might be needed are easy, cheap, and simple. In the case of beneficial impacts, alternative means are almost all likely to be better, in one or a number of ways, than this means of achieving the benefit. Three additional categories must also be used where relevant. They are in addition to the category represented on the scale, and if used, will replace the scale.
0	NO IMPACT	There is no impact at all - not even a very low impact on a party or system.

Table 5: Description of the spatial scale

RATING		DESCRIPTION
5	Global/National	The maximum extent of any impact.
4	Regional/Provincial	The spatial scale is moderate within the bounds of impacts possible and will be felt at a regional scale (District Municipality to Provincial Level). The impact will affect an area up to 50km from the proposed site / corridor.
3	Local	The impact will affect an area up to 5km from the proposed route corridor / site.
2	Study Area	The impact will affect a route corridor not exceeding the boundary of the corridor / site.
1	Isolated Sites / proposed site	The impact will affect an area no bigger than the corridor / site.

Table 6: Description of the temporal rating scale

RATING		DESCRIPTION
1	Incidental	The impact will be limited to isolated incidences that are expected to occur very sporadically.
2	Short-term	The environmental impact identified will operate for the duration of the construction phase or a period of less than 5 years, whichever is the greater.
3	Medium term	The environmental impact identified will operate for the duration of life of the project.
4	Long term	The environmental impact identified will operate beyond the life of operation.
5	Permanent	The environmental impact will be permanent.

Table 7: Description of the degree of probability of an impact occurring

RATING	DESCRIPTION
1	Practically impossible
2	Unlikely
3	Could happen
4	Very likely
5	It's going to happen / has occurred

Based on the nature of the project, the surface soils will be excavated to a depth of several metres for the powerline pole or pylon foundations. Since the whole area is indicated as very highly sensitive on the SAHRIS palaeomap (red; **Figure 4**), a Fossil Chance Find Protocol must be added to the EMPr. Although there is no chance of finding fossils in the topsoil, there is a small chance that fossils could occur in the shales above the coal seams that are about 15m below the surface. The foundations for the poles could penetrate to a depth of 3m below the land surface. Taking account of the defined criteria, the potential impact to fossil heritage resources is low. Nonetheless, a Chance Find Protocol should be added to the EMPr given that there are fossiliferous sediments below ground and associated with the coal seams.

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 shales, mudrocks and coal seams could contain impressions of leaves of the *Glossopteris* flora in the associated shales BUT these would not be preserved in the surface soils or coarse sandstones. It is unknown if fossil plants occur in any of the sediments above the coal seams. Vertebrate fossils are extremely rare during the early Permian and seldom occur with fossil plants. Although no fossils have been recorded from this region, there is a small chance that they could, so a Chance Find Protocol should be included (see appendix A and photographs of fossil plants).

6. Recommendation

Since the whole area of this project is palaeontologically sensitive a monitoring programme and Chance Find Protocol should be included in the EMPr that should come into effect once excavations for the project commence. Topsoils do not preserve fossils so there is no point in carrying out a site visit before excavations begin as any potential fossils would not be visible. If recognisable fossils are found by the responsible person monitoring the excavated sediments, then a palaeontologist should be called to assess them.

As far as the palaeontology is concerned the proposed development can go ahead. Any further palaeontological assessment would only be required after excavations for the pole foundations have commenced and if fossils are found by the geologist or environmental personnel.

7. References

Aitken, G. 1994. Permian palynomorphs from the Number 5 Seam, Ecca Group, Witbank Highveld Coalfields, South Africa. Palaeontologia africana 31: 97-109.

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.

Barbolini, N., Bamford, M.K., Rubidge, B., 2016 Radiometric dating demonstrates that Permian spore-pollen zones of Australia and South Africa are diachronous. Gondwana Research 37, 241-251.

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.

Rubidge BS (ed). 1995. Biostratigraphy of the Beaufort Group (Karoo Supergroup). South African Committee for Stratigraphy Biostratigraphic Series 1. Council for Geoscience, South Africa.

Snyman, C.P., 1998. Coal. In: Wilson, M.G.C., and Anhaeusser, C.P., (Eds) The Mineral Resources of South Africa: Handbook, Council for Geosciences 16, 136-205.

Appendix A – Chance Find Protocol and examples of fossil plants from the Vryheid Formation

Monitoring Programme for Palaeontology – to commence once the project excavations begin for the powerline poles.

1. The following procedure is only required if and when deep excavations (below topsoil and alluvium commence. The surface activities most likely would not impact on the fossil heritage as the coal and any associated fossil plants are below ground.
2. In the event that shales and mudstones are cut through, they must be given a cursory inspection by a designated person. Any fossiliferous material should be put aside in a suitably protected place.
3. Photographs of similar fossil plants must be provided to assist in recognizing the fossil plants in the shales and mudstones (for example see Figure 5 and 6). This information will be built into the project's training and awareness plan and procedures.
4. On a regular basis, the responsible person should examine a representative sample to determine the presence of fossil plants and take digital photographs of them to send to a qualified palaeontologist/ palaeobotanist sub-contracted for this project to get an opinion on their scientific value.
5. Fossil plants that are considered to be of good quality or scientific interest by the palaeobotanist must be removed, catalogued and housed in a suitable institution where they can be made available for further study. Before the fossils are removed, a SAHRA permit must be obtained. Annual reports must be submitted to SAHRA as required by the relevant permits.
6. If any underground inspection is deemed necessary then the normal safety procedures, must be followed by the palaeontologist and associated mine employees.
7. If no good fossil material is recovered, then the site inspections by the palaeontologist will not be necessary.

Table A1: List of Vryheid Formation flora and fauna (Aitken, 1994; Anderson & Anderson, 1985; Barbolini et al., 2016; Plumstead, 1969; Rubidge et al., 1995).

Flora - macroplants	Flora – microfossils	Fauna
Azaniodendron fertile, Cyclodendron leslii, Sphenophyllum hammanskraalensis, Annularia sp., Raniganjia sp., Asterotheca spp., Liknopetalon enigmata, *Glossopteris* > 20 species, *Hirsutum 4 spp., Scutum 4 spp., Ottokaria 3 spp., Estcourtia sp., Arberia 4 spp., Lidgetonia sp., Noeggerathiopsis sp. Podocarpidites sp*	*Protohaploxypinus microcarpus Praecolpatities sinuous Microbaculispora trisina Striatopodocarpites cancellatus Striatopodocarpites fusus Pseudoreticulatispora pseudoreticulata Pseudoreticulatispora confluens* Taeniate bisaccate pollen	*Mesosaurus* in the lowest part

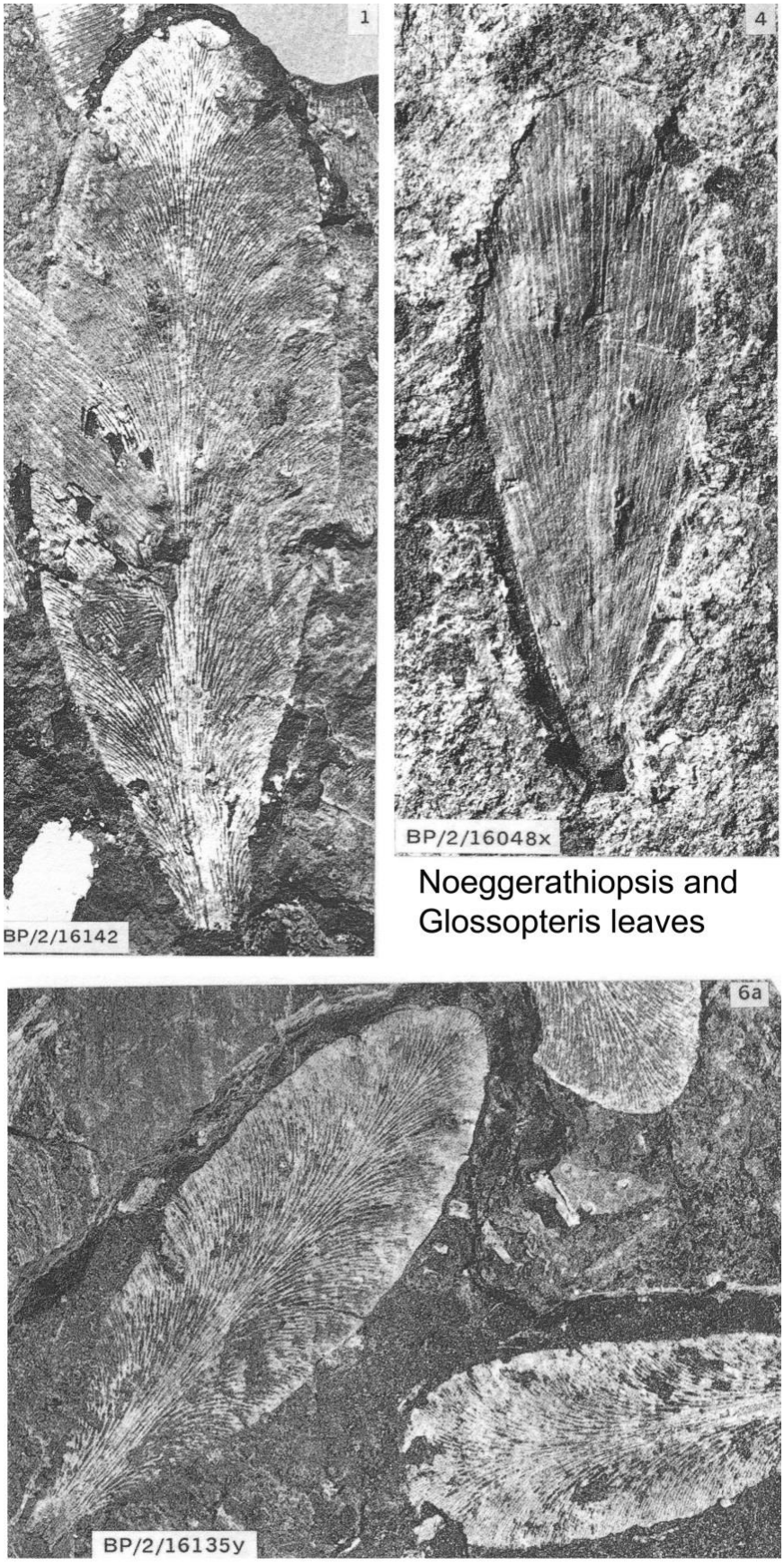

Figure A1: **Examples of fossils from the Vryheid Formation, *Glossopteris* sp. and *Noeggerathiopsis* sp.**

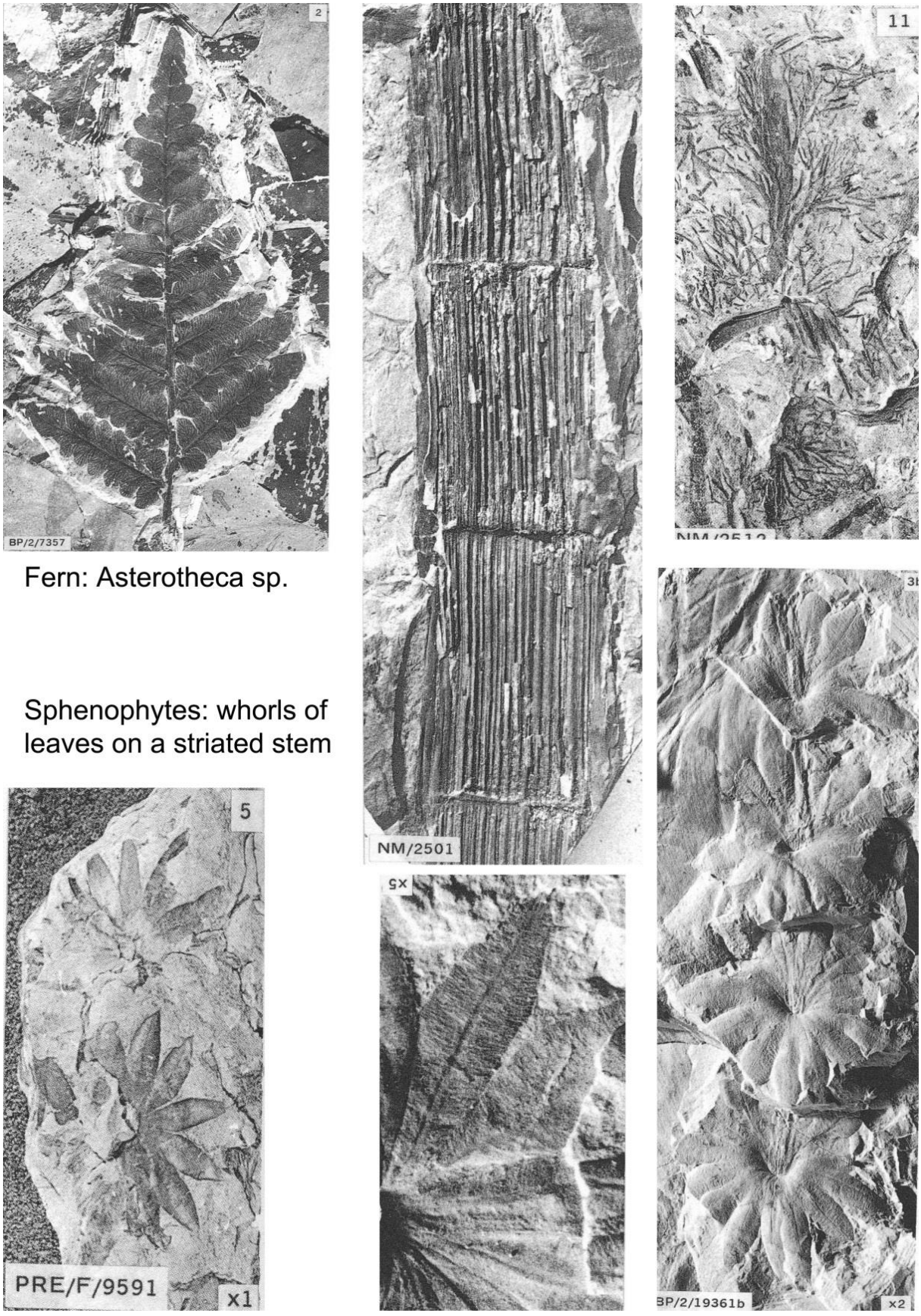

Figure A2: **Examples of ferns and sphenophytes (horsetails) from the Vryheid Formation.**

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	5	2
Masters	8	1
PhD	10	2
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 – current Assistant editor
Guest Editor: Quaternary International: 2005 volume
Member of Board of Review: Review of Palaeobotany and Palynology: 2010 – current
Cretaceous Research: 2014 - current

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
- 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 January 2019 peer-reviewed journals or scholarly books: over 125 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)