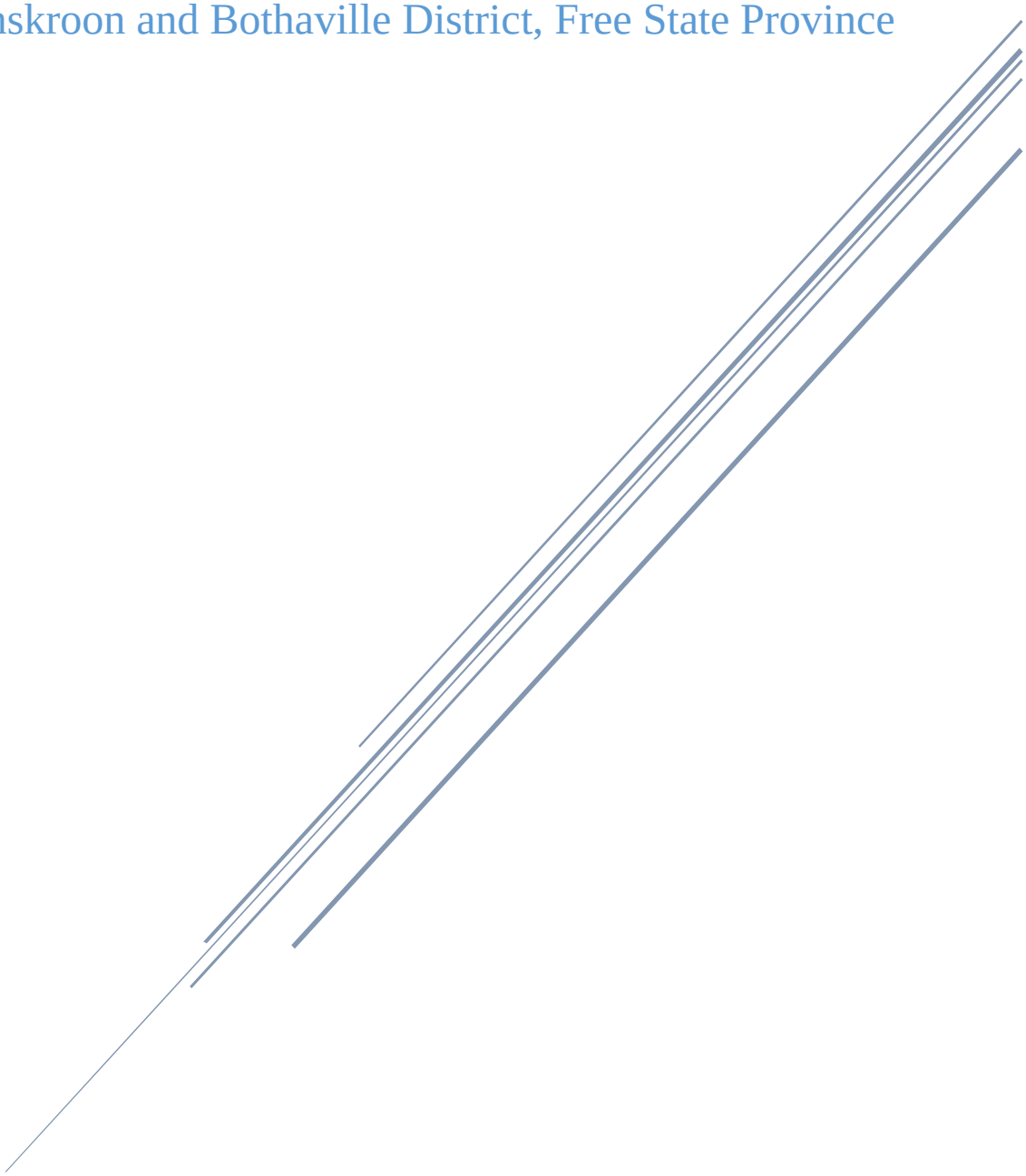
HERITAGE IMPACT ASSESSMENT FOR A DIAMOND PROSPECTING RIGHT APPLICATION

Viljoenskroon and Bothaville District, Free State Province



DKNR Consulting (Pty) Ltd
August 2018

APPLICATION FOR A DIAMOND PROSPECTING RIGHT ON THE FARMS WELTEVREDEN 130, BOSHOEK 466, WELVERDIEND 2016, STERKFONTEIN 474, JONKERSKRAAL 475, KLEIN JONKERSKRAAL 551 SITUATED IN THE MANISTERIAL DISTRICT OF VILJOENSKRRON AND BOTHAVILLE IN FREE STATE PROVINCE

DMR APLICATION REF NO: **FS 30/5/1/1/2/10477 PR.**

Prepared by:
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Prepared for:
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AUGUST 2018

EXECUTIVE SUMMARY

APPLICATION FOR A DIAMOND PROSPECTING RIGHT ON THE FARMS WELTEVREDEN 130, BOSHOEK 466, WELVERDIEND 2016, STERKFONTEIN 474, JONKERSKRAAL 475, KLEIN JONKERSKRAAL 551 SITUATED IN THE MANISTERIAL DISTRICT OF VILJOENSKRRON AND BOTHAVILLE IN FREE STATE PROVINCE

DMR APLICATION REF NO: FS 30/5/1/1/2/10477 PR.

DKNR Consulting (Pty) Ltd was appointed to undertake a heritage appraisal for a Diamond prospecting right application by Mashau Capital (Pty) Ltd. Fieldwork was done on 30 July and 08 August, 2018 on the area earmarked for prospecting which is 7 kilometres north-west of the Orkney city centre.

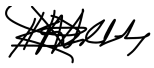
The assessment revealed graves and stone tool scatter and debris on one farm and these will be directly impacted by the prospecting. Based on the nature of the findings the report can rank the potential impact of prospecting as ranging from high to very low. As such the report can recommend that prospecting rights be granted subject to the adhesion and implementation of recommendation and mitigation measures set here. Graves are very sensitive and significant forms of living heritage and should be preserved for the value they aid to peoples' lives and their ideologies. As such their sensitivity is ranked as high.

The report, therefore, recommends the revision of terms and project objectives with respect to Weltevreden Farm. Overall prospecting will not impact negatively on the heritage or potential heritage on the proposed area of prospecting. Lithics identified are out of context and of low significance. The scatter is carried out of context by natural elements. However, these are indicative of a possibility of archaeology on the farm. As such great care and caution should be exercised. As such the reports recommends that the client gets a permit from the South Africa Heritage Resources Agency.

Declaration

I Elijah Dumisani Katsetse, of DKNR Consulting (Pty) Ltd, a professional member of the Association of Southern African Professional Archaeologists, and an accredited archaeologists, membership number 399 declare that I have no financial interest in the proposed prospecting. I was appointed as an independent professional to broker my professional expertise on the nature of project and potential impact it may have on heritage resources.

Name: **Elijah Dumisani Katsetse**, ASAPA, *professional member, 399*

Signature: 

Date: 20 August 2018

1. INTRODUCTION

The area on which prospecting is to take place is 7 kilometres north-west of the Orkney city centre. The area covers an estimated 3813 hectares. The area is constituted of 6 farms, Boshoek 466, Klein Jonkerskraal 551, Jonkerskraal 475, Sterkfontein 474 (three potions separately owned), Weltevreden 130, and Welverdiend 240 all in the Viljoenskroon and Bothaville District. The underlying rocks form part of the Plattberg Group, with the formation of the Allanridge and the Rietgat. The current project aims to explore the underlying geology of the Ventersdorp Group for Alluvial, Kimberlite/dyke Diamonds. Accordingly, Mashau Capital (Pty) Ltd has requested a cultural heritage survey to establish a baseline of known heritage sites in the area.

2. OBJECTIVES

The general aim of this cultural heritage appraisal is to record and document cultural heritage ruins and objects consisting of both tangible and intangible archaeological and historic artefacts, structures (including graves), settlements and oral traditions of cultural significance.

As such the terms of reference of this survey are as follows:

- Identify and provide a detailed description of all artefacts, assemblages, settlements and structures of an archaeological or historic nature located on the study area
- Estimate the level of significance of these remains in terms of their archaeological, historical, scientific, social, religious, aesthetics and tourism value,
- Assess any possible impact on the archaeological and historical remains within the area emanating from the proposed development activities, and
- Propose possible mitigation measures which will limit or prevent any impact provided that such action is necessitated by the development

3. PROPOSED PROJECT ACTIVITIES

The prospecting project aims to:

- Core drilling for sample testing according to the following terms on all the farms listed.

Farm name	Portions	SG	District
WELTEVREDEN 130	ALL	F03600000000013000000	VILJOENSKROON
BOSHOEK 466	ALL	F03600000000046600000	VILJOENSKROON
WELVERDIEND 216	ALL	F03600000000021600000	VILJOENSKROON
STERKFONTEIN 474	ALL	F03600000000047400000	VILJOENSKROON
JONKERSKRAAL 475	ALL	F00500000000047500000	BOTHAVILLE
KLEIN JONKERSKRAAL 551	ALL	F00500000000055100000	BOTHAVILLE

Figure 1. Table Detailing Project Plan.

4. STUDY AREA

The area proposed for prospecting is on the edge of the Vaal River which serves as a provincial border for Free State and the North-West Province. The study area fall within the Free State Province in the Viljoenskroon and Bothaville District. The study area is characterised by primary land uses such as agriculture and mining.

Currently, most of the area is either under cultivation (e.g. maize, ground nuts, sunflower etc.) or used for grazing. Other land uses include mining, game reserves and a lion farm. Crop farming would have impacted heavily on any cultural resources that may have existed in the area especially in the case Sterkfontein 474.

The Vaal River and water courses in general are often littered with Stone Age materials and rock engravings are also often found on river beds. Such occurrence have been noted and studied by earlier proponents and scholars in the field of archaeology.

5. LEGAL FRAMEWORK

Heritage Resources

The National Estate

The National Heritage Resources Act (No.25 of 1999) defines heritage resources of South Africa of cultural significance or other unique value(s) for contemporary people and society and for future benefactors that must as the current generation find fulfilment, enjoyment and also carry forward for generation to come as the national estate include but not limited to:

- Places, buildings, structures and equipment of cultural significance;
- Places to which oral traditions are attached or which are associated with living heritage;
- Historic, urban, cultural and natural landscapes of significance
- Natural, and geological sites of scientific and cultural significance;
- Archaeological and paleontological sites;
- Graves and burial grounds, including:
    - Sacred burial grounds
    - Ancestral graves
    - Graves of victims of conflict
    - Historic graves and cemeteries
    - Other human remains which are not covered in terms of the Human Tissue Act (No.65 of 1983)
- Sites of significance relating to the history of slavery in South Africa;
- Movable objects, including:
    - Objects recovered from the soils of the waters of South Africa, including archaeological, paleontological objects and meteorites and rare geological specimens
    - Objects to which oral traditions are attached or which are associated with living heritage
    - Ethnographic art and object
    - Military objects
    - Objects of decorative or fine arts
    - Objects of scientific or technological interest, and

- Books, records, documents, photographs positives and negatives, graphic, film or video material or sound recordings, excluding those that are public records as defined in Section 1(xiv) of the National Archives of South Africa Act (No.43 of 1996).

− Archaeological remains can be defined as human-made objects, which reflect past ways of life, deposited on or in the ground

− Heritage resources have lasting value in their own right and provide evidence of the origins of South African Society and they are valuable, finite, non-renewable and irreplaceable

− All archaeological remains, features, structures and artefacts older than 100 years and historic structures older than 60 years are protected by the relevant legislation, in this case the National Heritage Resources Act (NHRA) (Act No.25 of 1999) under Sections 34 and 35. The Act Makes archaeological impact assessment as part of an Environmental Impact Assessment (EIA) and the EMPR mandatory. This regulations are covered under Section 38 of the NHRA. No archaeological artefact, assemblage or settlement (site) may be removed or destroyed without the necessary approval from the South African Heritage Resources Agency (SAHRA).

− Cognisance will also be taken of the Mineral and Petroleum Resources Development Act (MPRD) (Act No.28 of 2002) and the National Environmental Management Act (NEMA) (Act No.107 of 1998) when making recommendations.

− Human remains older than 60 years are protected in the NHRA, with reference to Section 36. Human remains that are less than 60 years old are protected by the Regulations relating to the Management of Human Remains (GNR 363 of 22 May 2013) made in terms of the National Health Act No. 61 of 2003 as well as local Ordinances and regulations.

6. STUDY APPROACH/METHOD

Regional maps and other geographical information (ESRI shape file) were supplied by Mashau Capital (Pty) Ltd. In addition the most up-to-date Google Earth Images and topographic maps were used to indicate the survey area.

The strategy during the survey was to concentrate on certain areas within the general survey area. The survey area was accessed by existing tracks, and dirt roads with selected areas surveyed on foot.

LITERATURE REVIEW

Additional information on the cultural heritage of the area was sourced from the following records:

- National Mapping Project, SAHRA
- SAHRIS online database
- Maps and Information supplied by the client
- Published and unpublished material on the area
- Existing Heritage Reports

INTERVIEWS

Mr Michael Fuller, Senior Security Manager, Weltevreden Mine

Mr Francois Huyssteen, Tenant on Sterkfontein 474 (Waterloo)

Mr Louwrens Vermeulen, Owner Sterkfontein 474

7. SITE SIGNIFICANCE AND IMPACT ASSESSMENT

Heritage assessment criteria and site grading

The NHRA (No. 25 of 1999) underlines the assessment criteria and the ranking of sites. The NHRA distinguishes sites in rank based on the following categories as stipulated under Section 7 of the Act:

Grade I: Heritage resources with exceptional qualities of special national value and importance

Grade II: Heritage resources with a regionalized or provincial significance based on their particularity to such scale(s)

Grade III: Heritage resources, although not afford national significance form the basis of identities of people and society at a very small scale, the local

SAHRA has further published various regulations including minimum standards: archaeological and paleontological components of impact assessment report in 2006 and updated requirements in 2012.

8. ASSUMPTIONS, RESTRICTIONS AND GAPS IN KNOWLEDGE

The survey has been influenced in part and largely by stakeholder relations and engagements. The broad study area as commissioned by the client could not be studied and only three farms, Weltevreden, Sterkfontein 474, Sterkfontein 474 (Waterloo) were surveyed on July 30 and August 8, 2018. Access to other farms was denied by property owners. One of the reasons given was that they did not allow people on the fields during harvesting. Further limitation, gaps and restriction pertains to the nature of moving landscapes (Bender 2002). Farms are dynamic and complex spaces that detail the history of dispossession, forced labour, ancestral land and are often associated with historic forms of heritage. Oral histories, traditions, graves and intangible aspects of heritage. Therefore, such heritage appraisal will require a thorough social consultative process which was not possible at this stage.

Specific issues that pertain to field survey and heritage reporting are listed as well,

- This report does not consider the paleontological potential of the area, however comments on it.
- On Weltevreden farm there are thorny bushes about one meter high which affected visibility
- The report does not cover areas not surveyed, Boshoek 466, Klein Jonkerskraal 551, Jonkerskraal 466, Sterkfontein 474 and Welvediend 216.

9. DESCRIPTION AND EVALUATION OF CULTURAL HERITAGE SITES

WELTEVREDEN FARM (Portion 1 and 2)

Archaeological and Historical Context

Stone tool scatters were identified along a narrow path that leads to the river. The material appeared to have been carried in run-off water and deposited on the side of the path. Such material are out of context. The presence of stone tool on the surface carried in run-off is indicative of possible subsurface material on the farm. The nature of the lithic and debris are suggestive of a Later Stone Age (LSA) period associated with hunting and gathering societies possibly San hunter-gatherers. The identifiable object is a stone flake made of volcanic rock, possibly andesite. The material were identified on Weltevreden 1, which is a smaller portion of the Weltevreden Mine. Weltevreden farm was divided into two portions for ease of interpretation and classification of finds. The two portions are separated by a dirt route as indicated on Figure 4 a and b.

Graveyards and Individual Graves

A graveyard with both marked and unmarked graves was identified on Weltevreden 1. The graveyard was identified with the assistance of Michael Fuller, who is a Senior Security Manager for Weltevreden Mine. In total about 30 graves were counted, but there is a possibility of more graves. Two possible unmarked graves were also identified on Weltevreden 2, also with Michael Fuller's assistance. Michael Fuller, previously lived on the Farm for 3 years and his knowledge of the place is credited both to his time there and the knowledge he received from a man he referred to as Thomas, who also lived and worked on the farm.

STERKFONTEIN 474 (WATERLOO)

Archaeological and Historical Context

No archaeological (Stone Age and Iron Age) or historical artefacts, assemblages, features, structures or settlements were recorded during the survey.

Graveyards and Individual Graves

No graves, graveyard or structures that resembled burial places were identified.

STERKFONTEIN 474

Archaeological and Historical Context

No archaeological (Stone Age and Iron Age) or historical artefacts, assemblages, features, structures or settlements were recorded during the survey.

Graveyards and Individual graves

No graves, graveyard or structures that resembled burial places were identified.

10. RECOMMENDATION AND CONCLUSIONS

The main aim of this heritage appraisal was to locate, identify, evaluate and document sites, objects and structures of cultural significance found in and on the farms earmarked for prospecting in order to assess the significance thereof and consider alternatives and plan for the mitigation of eminent impact.

Based on the assessment, from a cultural heritage perspective, it advised that the following is taken into consideration and cognisance is placed on the nature of the proposed prospecting. Given that all portions of the farms listed:

- Graves and the graveyard identified on Weltevreden Mine, portions 1 and 2 will be impacted on.
- Furthermore, farmhouses are both homes and forms of place attachment and constitute peoples livelihoods and this will also be impacted on.
- Graves are sensitive active forms of living heritage and should be avoided at all cost.
- As such it is recommended that the client revises prospecting plans for Weltervreden 130, that is prospecting should not be done areas with graves.

As such areas with graves and the graveyard should be fenced-off or a danger tape be used to mark-off such areas. However, in an event that these cannot not be avoided a social consultative process with all stakeholders should be constituted to negotiate terms for the relocation of the grave and a permit be acquired from the South African Heritage Resources Agency. However, this should be the last resort after all possibilities are explored and exhausted.

- The process to relocate and exhume graves should only be undertaken by a qualified individual or team of highly trained personnel on grave relocation and/or an undertaker with such skills and who has undertaken the process previously.

Grave relocation should be done under correct terms and conditions set out in the Management of Human Remains (GNR 363 of 22 May 2013) made in terms of the National Health Act No. 61 of 2003 as well as local Ordinances and regulations.

- However, the report does not recommend for such drastic measures, instead the report recommends for revised areas of prospecting for Weltevreden Farm were graves will and should be avoided.

The heritage reports based on the nature and character of the finds ranks the potential impact of prospecting as ranging from high to low. However, given that no archaeological and historical objects of significance identified on both divisions of Sterkfontein 474 (Waterloo and Sterkfontein), it is recommended that prospecting rights be granted following mitigation measures and recommendation set in this report. It is further recommended that the client, Mahsau Capital (Pty) Ltd obtain a permit from the South African Heritage Resources Agency following terms set in Section 36(3) of NHRA (No.25 of 1999)

Archaeological deposits usually occur on and below the ground level. Should archaeological artefacts or skeletal remains be revealed in the area during development activities, such activities should be halted, and a university or Museum be notified in order for an investigation and evaluation of the find(s) to take place (NHRA, 25 of 1999, Section 36(6)).

11. REFERENCES

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Bender, B. 2002. Landscapes on the move, *Journal of Social Archaeology vol.1, no1, pp.75−89.*

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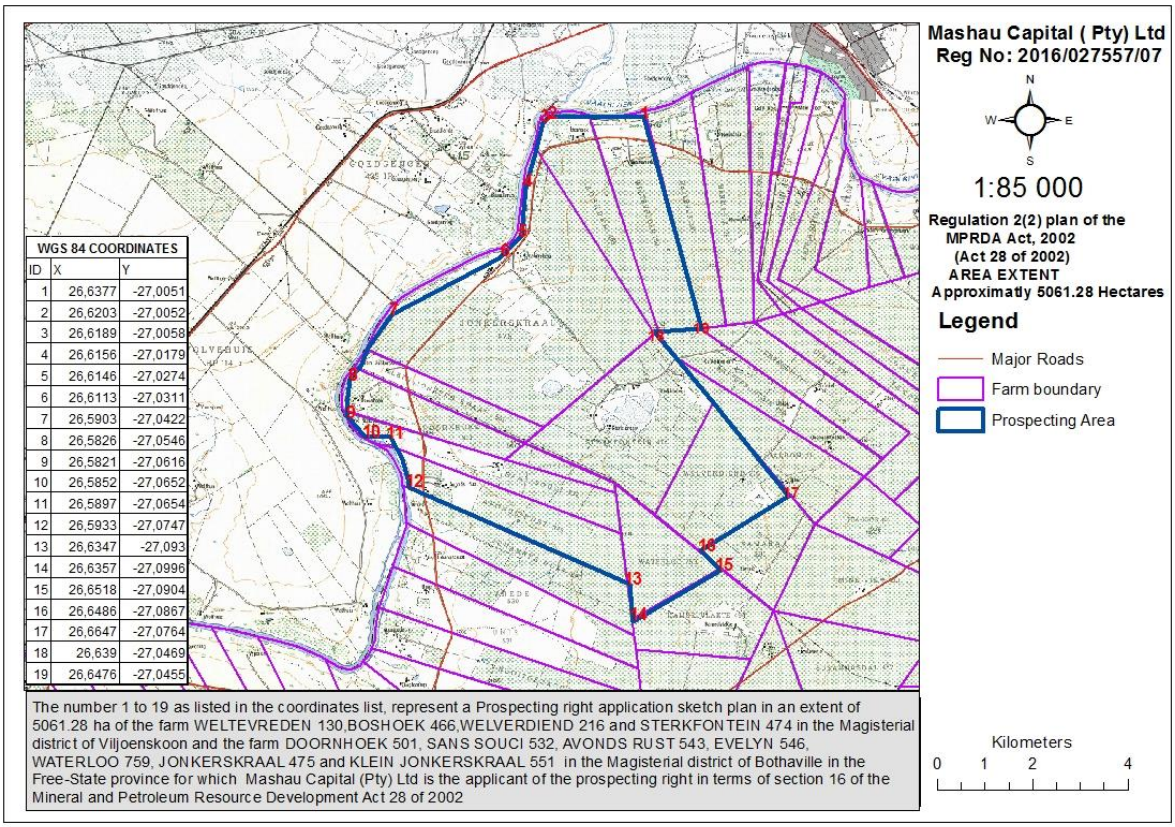
van Vollenhovem, A.C. 2011. A report on a baseline heritage assessment for Slatercoal exploration and mining project, close to Viljoenskroon, Free State Province, Unpublished Heritage Report. Rivonia, South Africa.

Vhufa Hashu Heritage Consultant cc. 2016. Archaeological and Heritage Impact Assessment for the Proposed Line from Viljoenskroon Munic Substation to Sewesco Substation in the Free State Province, Unpublished Heritage Report. Mbombela: South Africa.

12. IMAGES AND ILLUSTRATIONS



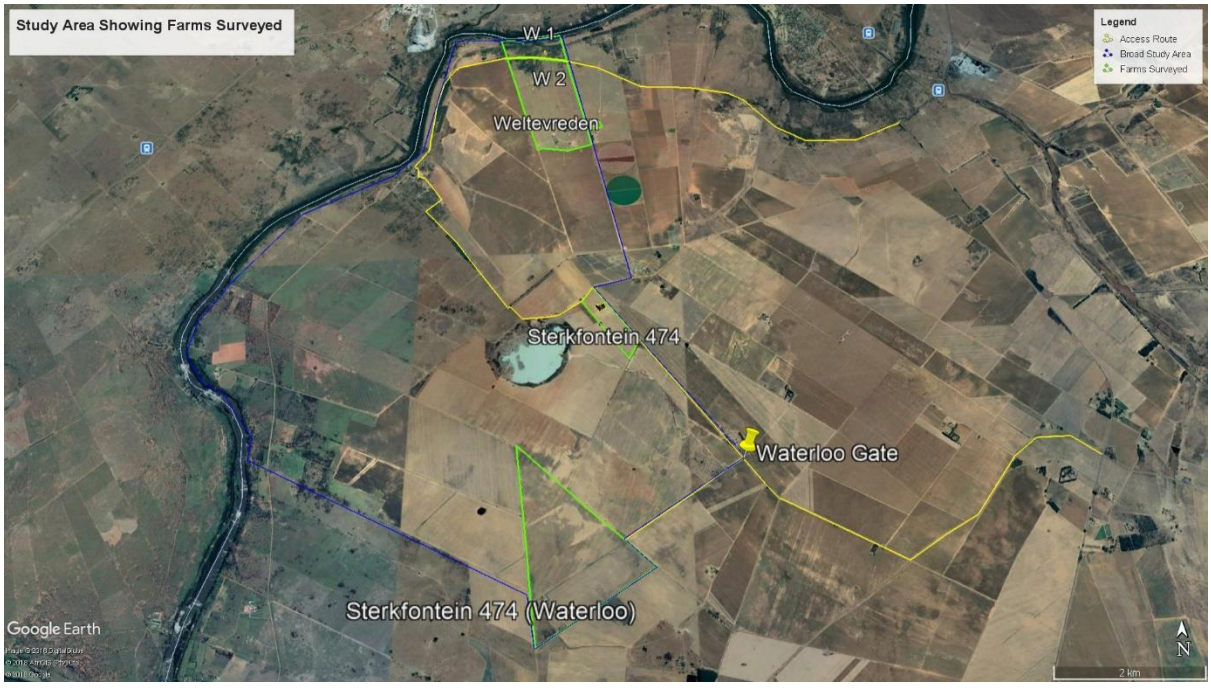
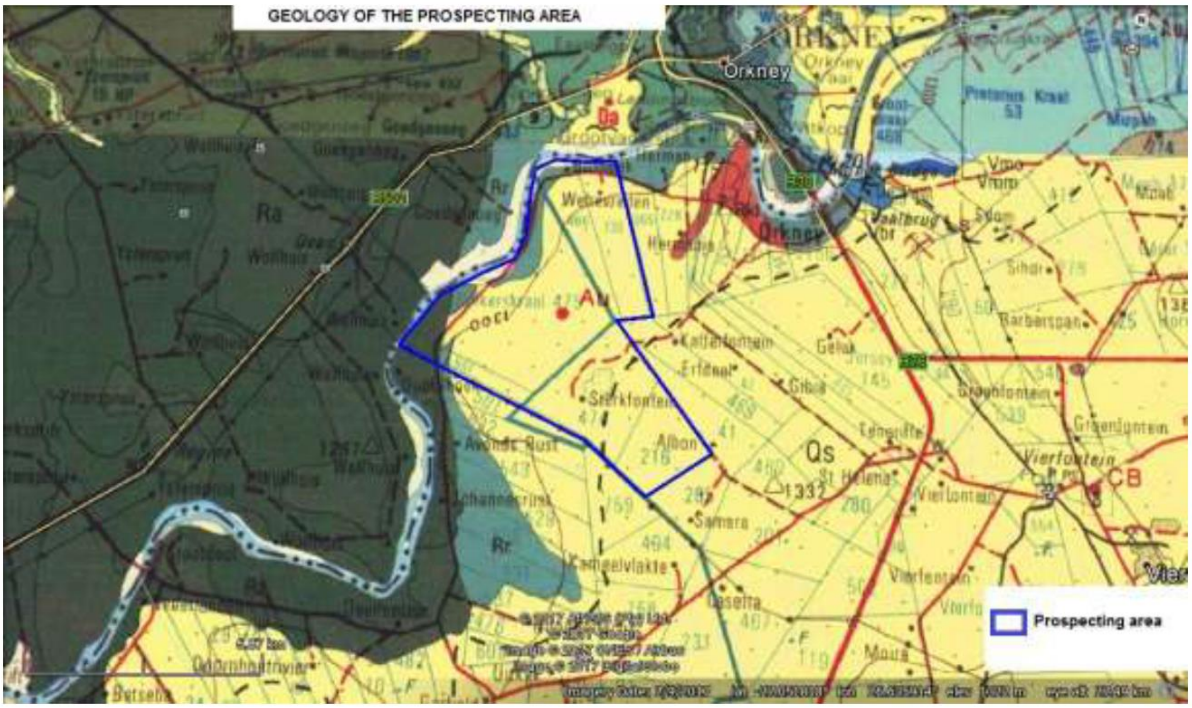


Figure 2a & b. Basic Maps Showing Broad Study Area and Farms Surveyed.



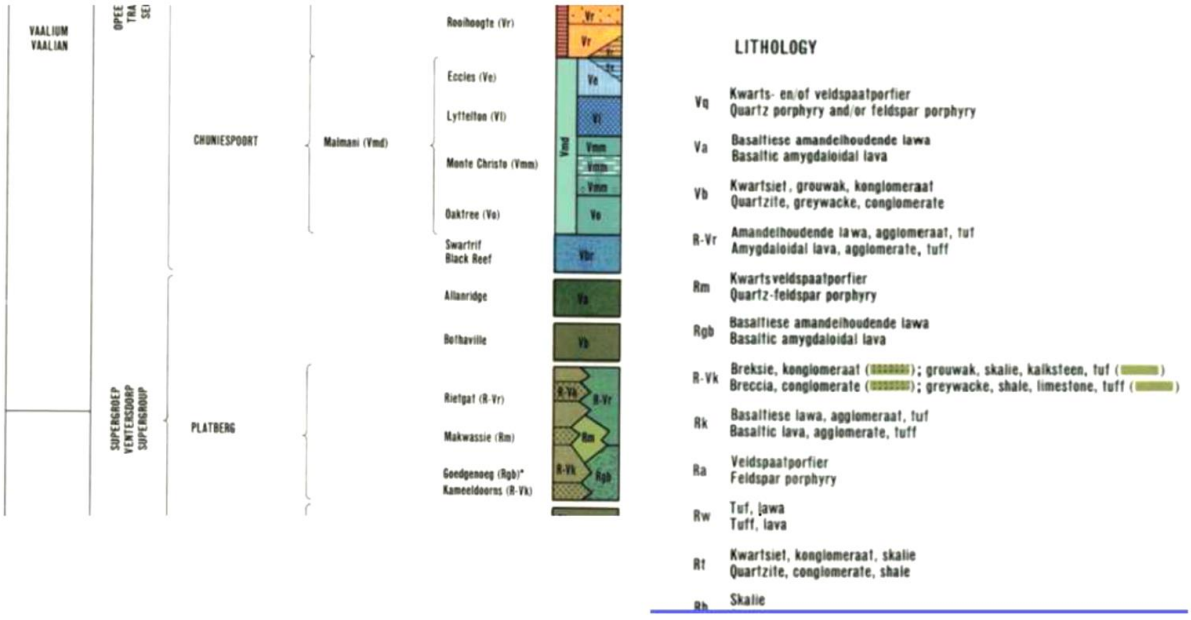


Figure 3a & b. Maps Showing Underlying Geology In The Study Area.

Figure 4a & b. Weltevreden Farms (1 & 2) and Observed Heritage Resources.

Figure 5a & b. Stone Scatter Carried in Run-off on Weltevreden 1.

Figure 6a & b. Graveyard and Clearly Marked Grave on Weltevreden 1.

Figure 7a & b. Possible Individual Graves on Weltevreden 2.

Figure 8 a & b. Old Mining Ruins on Weltevreden 2.

Figure 9a & b. Ruined Farm Compound on Weltevreden 2.

Figure 10 a & b. Decline Shaft Showing Date of Weltevreden Mine, Weltevreden 2.

Figure 11a & b. Tree Cluster Obscuring Abandoned Farm House, Sterkfontein 474.

Figure 12a & b. Farming Infrastructure Hidden inside Tree Cluster, Sterkfontein 474.

Figure 13a & b. Image Showing Activities on Sterkfontein 474.

Figure 14a & b. Harvested Fields, Sterkfontein 474 (Waterloo).

Figure 15 a & b. Boundary Line of Waterloo Looking East.

ADDENDUM 1: CURRICULUM VITAE OF ELIJAH DUMISANI KATSETSE

Elijah Dumisani Katsetse

1024 Tweefontein C2, Kwaggafontein 0458|elijahkatsetse@gmail.com |0737562086

Profile

I am a proactive heritage resource manager and researcher with proven skills in presentation and writing. I have problem solving and analytical skills to identify issues and challenges affecting the effective management and conservation of heritage resources and heritage library information. I always look to innovate and develop effective management tools to improve heritage preservation *in situ* and *ex situ*.

I have worked as a Student Research Assistant and Archaeological Collection Manager at the Rock Art Research Institute, University of the Witwatersrand and University of Pretoria respectively. I believe that the rich research history and output of these universities has prepared me for the work environment with necessary heritage research, management, and conservation skills. I have a thorough understanding and practical knowledge of the social, economic, and environmental aspects of heritage management and how these are infused in policy. This is supported by an understanding of heritage and environmental legislation enforcement and compliance issues facing the preservation and conservation of cultural and historical resources.

Education

University of the Witwatersrand, Johannesburg 2009–2011

***BSc.* Earth Sciences**

Courses Completed: Archaeology, Ancillary Mathematics & Statistics, Biology, Chemistry, and Geography

University of the Witwatersrand, Johannesburg 2012

***BSc.* Honours** (Archaeology)

University of the Witwatersrand, Johannesburg

2015

MSc. (Archaeology)

University of the Witwatersrand, Johannesburg

2016-to current

Doctor of Philosophy (Architecture)

Experience

Research Assistant, Rock Art Research Institute

01/December/ 2011–31/March/2014 Left to pursue Career in Heritage Research Management

- Worked on major rock art projects (International Rock Art Collaboration Project (Botswana, Mexico, Mozambique, and South Africa & The Makgabeng Project)
- Gained experience on rock art recording and documentation
- Data collection and management (Creating and maintaining Inventories)
- Conservation cleaning and management of museum objects
- *In situ* conservation cleaning (Makgabeng and Main Caves rock art sites)
- Archiving
- Gained extensive technical analysis skills working on Microsoft package (Office, Excel, Power Point etc...)
- Participated in general administrative duties on research project and departmental events (e.g. open days, and talks)
- Actively involved in the development (feasibility studies) and sustainability of rock art tourism in Makgabeng and Matsheng
- Participates in the development of new rock art conservation and management strategies

Volunteer, Yebo Gogga 2011

- Gained experience as a tour guide and exhibitor

Volunteer, Origins Centre 2011-2014

- Gained experience as a tour guide and exhibitor
- Conference and workshop usher

Volunteer, PGS Consulting and Grave Relocation 2012

- Participated in a mitigation excavation project of an Iron Age Site

Archaeological Collection Manager Intern, National Research Foundation

01/April/2014–30/March/2015 Left due to expiration of the contract

- Teaching assistant third year collection management course(University of Pretoria)
- Collection restoration
- collection recording and documentation
- Development systems to effectively manage the collection
- Collection appraisal
- General administration of the collection (quantification, loans, storage etc.)

Student Research Assistant, Rock Art Research Institute

01/April**/**2015–31/December/2015

- Bringing individual collections to similar curatorial standards
- Exploring ways of handling paper
- Maximizing long-term care and management of the paper archive

Associate Lecturer, University of the Witwatersrand, Johannesburg

01/January/2016–to current

Teaching

- Architectural Histories and Theories
- Settlements Through History

- Property Development (Heritage)
- Advanced History of Architecture and Urbanism

Research

- Histories of State Formation and Prehistoric Architecture
- Heritage Conservation, Planning and Management
- Archival Research and Management
- Economic Development and Heritage Management
- Landscape and Land-Use Planning
- Social History, Place-Making and Democratic Spaces

Administration

- General Administration
- Workflow Administration
- Library and Archives Working Group
- Curriculum Development
- Excursion Planning and Supervision

Wits Writing Centre Consultant, University of the Witwatersrand, Johannesburg

01/April/2017-to current

- Writing Consultant
- Writing and Reading as Modes of Thought
- Critical Thinking
- Curriculum Development

Skills

Communication and Interpersonal

- Gained experience in communicating with people at all level within the organization at the Rock Art research Institute.
- I have given numerous presentations as a student at all levels including as a Postgraduate.

Teamwork and Leadership

- I have participated in the organization of the Pan African Archaeological Association Conference held in 2014 at the University of the Witwatersrand.
- Worked within a team of student tasked with creating and building the website of the Pan African Archaeological Association as a data capture and uploaded the data onto the site.
- I chaired a non-governmental organization, The Vision of Success whose mission is community development.

Problem Solving Skills

- In my capacity as a collection manager I have addressed inconsistencies in recording and documentation strategies used and have made useful recommendation on their remedial.

Research and Technical Skills

- Data Collection (qualitative and quantitative methods)
- Data Processing Tools (ArcGIS, Google Earth, and QGIS, Photoshop)
- Microsoft Tools (Word, PowerPoint, Excel, Publisher)
- Report Writing
- Survey Techniques
- Environmental Monitoring Techniques

Achievements and Interests

Educational: I have received a university entrance scholarship (2009) from the University of the Witwatersrand and I have also been given an award for first class student (2011) in a course on the Fundamentals of Conservation Biogeography third year level.

- Obtained University Entrance Scholarship (Wits University)
- Year 2009
- Obtained ESRI ArcGIS 9.4.3 user certificate
- Year 2010
- Obtained First class student in Fundamentals of Conservation Biogeography III
- Year 2011
- Obtained NQF 4 (Basic Project Management) (Hudisa Business School)
- Year 2014

Research and Communication: I have given two papers in two different conferences. I presented my research proposal at a regional conference of the Association of Southern African professional Archaeologists (2013) and at the Pan Africa archaeological Association (2014) I presented the outcomes of my Masters Research project. I have recently being granted professional membership by The Association of Southern African Professional Archaeologists (ASAPA).

Interdisciplinary: my research interest extends to other fields such as geography, biogeography, and climatology. In particular I am interested in nature conservation and environmental and climate change.

Professional Membership: Association of Southern African Professional Archaeologists (ASAPA)

References

Name	Dr. Catherine Namono
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Organisation	University of the Witwatersrand, Johannesburg
Relationship	Colleague
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ADDENDUM 2: ARCHAEOLOGICAL AND HISTORIC SEQUENCE

Both the archaeological and historic sequences and context of the broad area are succinctly captured in previous heritage reports by van Vollenhoven (2011), Dreyer (2011), Mathoho (2016), and Rossouw (2017). The archaeological context captures both Stone Age and Later Stone Ages periods and further goes in to subdivide the sequences. The sequences are presented neatly to capture significance activities, process and points in time where marked changes are documented. The sequences are summarised as follows.

Concentrations of Early Stone Age (ESA) sites are usually on the flood plain of perennial rivers and may date to over 2 million years ago. These ESA open sites may contain scatters of stone tools and manufacturing debris and secondly, large concentrated deposits ranging from pebble tool choppers to core tools such as handaxes and cleavers. The earliest hominines who made these tools, probably not always actively hunted, instead of relying on opportunistic scavenging of meat from carnivore fill sites.

Middles Stone Age (MSA) sites also occur on flood plains, but are also associated with caves and rock shelters. Sites usually consist of large concentration of knapped stone flakes such as scrappers, points and blades and associated manufacturing debris. Tools may have been hafted but organic materials, such as those used in hafting seldom preserve. Limited drive-hunting activities are also associated with this period.

Sites dating to the Later Stone Age (LSA) are better preserved in rock shelters, although open sites with scatters of mainly stone tools occur. Well-protected deposits in shelters allow for stable conditions that result in the preservation of organic material such as wood, bone, hearths, ostrich eggshell beads and even bedding material. By using San ethnographic data a better understanding of this period is possible. South African rock art is also associated with the LSA.

The landscape has a broad historical significance as a sight of skirmishes, conflict, contact and cultural exchanges during colonial times. Accordingly Dreyer (2011) has described both the Free State and neighbouring Provinces (Northern Cape and North West) as a terrain for deadly skirmishes. This a place where Early European missionaries ventured into the interior during the 19th century. It is also important to note the significance of the Anglo-Boer War (1900-1902) battlegrounds in the Free State, Northern and Eastern Cape.

Conflict during the contact period also affected Bantu Farming communities in the area, the Sotho-Tswana speaking people. Conflict was both external and internal in Bantu Farming communities. The effects of Mfecane or Difecane was also felt in the interior.

ADDENDUM 3: PALEONTOLOGICAL HERITAGE

According to Almond and Pether (2009: 1) a site or development specific impact assessment on paleontological heritage is inadequate and a counter-productive exercise. Almond and Pether (2009: 1) further state that paleontological impact assessment should be done employing the palaeotechnical report as a baseline which should be read in conjunction with geological maps. This approach is believed to be effective in aiding developers, heritage manager, and environmental impact assessors to evaluate the potential impact of proposed developments on fossil heritage (Groenewald & Groenewald n.d.). As such this heritage appraisal will adopt the methodology proposed by Almond and Pether (2009) and support this stance with previous paleontological Assessment on the broad study area of Bothaville and Viljoenskroon. Below are heritage reports on the paleontological heritage of the region.

PALEONTOLOGICAL INPUT

SAHRA PALAEOTECHNICAL REPORT

PALAEONTOLOGICAL HERITAGE OF THE FREE STATE

Brandwag Rock Golden Gate Highlands National Park. Photograpgh: Gideon Groenewald

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GENERAL INTRODUCTION

The core purpose of this SAHRA palaeotechnical report (PTR) is to briefly but comprehensively document the palaeontological heritage resources in South Africa in an accessible and useful format. Following the request by SAHRA, the report is presented in the form of two sections. The first section outlines the general geological history of South Africa and the second section provides a more detailed, geological history of the Free State, Gauteng, North West, Limpopo and Mpumalanga Provinces with specific reference to the palaeontological sensitivity of geological formations and their importance to the development of life through 3600 million years of time in Earth history.

The first section summarises the geological history of South Africa and gives a very brief description of the six major events that shaped the Earth over time. The known and predicted fossil heritage within all the major fossiliferous stratigraphic units (formations, groups etc) that crop out in South Africa are presented on a map that relates directly to the composite geological map of South Africa where mapping was done on a 1:250 000 scale. The palaeontological sensitivity of geological units was allocated sensitivity ratings on a five point scale: very high sensitivity, high sensitivity, moderate sensitivity, low sensitivity and very low sensitivity (Table 1). When used in conjunction with published geological maps, this report can be used by heritage managers and environmental impact assessors, as well as private developers, to rapidly evaluate the potential impact of proposed developments on fossil heritage. (Please note that this scheme is provisional, and will need to be modified in the light of discussions with heritage managers and palaeontological colleagues). Early assessment of palaeontological sensitivity – preferably at the NID or BID phase - is highly advantageous for developers and heritage managers alike, as well as providing the best safeguard for fossil heritage.

The second section of the report consists of concise summaries of the geological history of the Free State, North West, Gauteng, Limpopo and Mpumalanga Provinces. The geological history is specifically related to the development of life as it is recorded in the fossil content of the geological formations. A colour coded palaeontological sensitivity map is provided for each province, with colours referring to the five sensitivity classes described in Table 1. The maps must be read in conjunction with a tabular database for each individual province. The database for each province explicitly relates palaeontological heritage to well-defined stratigraphic units – normally successions of sedimentary rocks – rather than to known fossil sites. This is because a site-specific approach is normally inappropriate for assessing the potential impact of new developments on fossil heritage. The best predictors of fossil heritage at any unstudied locality are the stratigraphic units present there. An undue emphasis on fossil sites (eg map showing all known localities) would be counterproductive since it would give the misleading impression that areas between known sites are less palaeontologically sensitive than the sites themselves. Furthermore, a site specific database could not be made freely available since it would undoubtedly endanger localities of scientific importance.

Despite the comparatively good legal protection offered to palaeontological heritage in South Africa by the current legislation, hitherto this aspect of natural heritage has been largely ignored by developers and professional heritage managers alike. In part this stems from pervasive ignorance

about the extent of fossil resources in this country, as well as a widespread confusion between palaeontological and archaeological heritage.

LEGISLATIVE FRAMEWORK

Fossil heritage in South Africa is protected, with important exceptions, by the **National Heritage Resources Act of 1999** (NHRA, Act 25 of 1999). This act replaces the earlier National Monuments Act of 1969 (Act 28 of 1969). Under the new act, fossils are treated as a category of heritage – *palaeontological heritage* - and are regarded as part of the National Estate (NHRA, 1999, p14 and section 32.1(a)).

Definitions

The NHRA does not define the term "fossil" but does offer its own definition of the term "palaeontological" which might be reasonably taken to circumscribe all fossil heritage:

(xxxi) "palaeontological" means any fossilised remains or fossil trace of animals or plants which lived in the geological past, other than fossil fuels or fossiliferous rock intended for industrial use, and any site which contains such fossilised remains or traces (NHRA, 1999, p. 10)

Formal Protections

SAHRA and PHRAs must identify those places with qualities so exceptional that they are of special significance and must investigate their desirability as National and Provincial Heritage Sites, including sites of exceptional palaeontological significance. Any person may submit a nomination to SAHRA for a place to be declared a National Heritage Site or to the provincial heritage resources authority for a place to be declared a Provincial Heritage Site.

27. (18) No person may destroy, damage, deface, excavate, alter, remove from its original position, subdivide or change the planning status of any heritage site without a permit issued by the heritage resources authority responsible for the protection of such site.

Palaeontological objects can be listed as "Heritage objects" in terms of section 32 of the NHRA, (1999), however this requires a formal process.

32. (1) An object or collection of objects, or a type of object or list of objects, whether specific or generic, that is part of the national estate and the export of which SAHRA deems it necessary to control, may be declared a heritage object, including—

(a) objects recovered from the soil or waters of South Africa, including archaeological and **palaeontological objects**, meteorites and rare geological specimens;

General Protections

The import of foreign cultural property into South Africa is prohibited and requires evidence of permission from the country of origin.

33. (1) No person may import into South Africa any foreign cultural property other than through a customs port of entry, and the export permit or other permission issued in the country of origin of such object must be produced to a customs officer before import to South Africa is effected or allowed.

According to the NHRA it is illegal to own, collect, damage or destroy South African fossils without a permit (NHRA, 1999, 35, p58). Such permits would usually be granted only to qualified palaeontologists or other heritage specialists. It is also illegal to buy or sell South African fossils.

35. (1) Subject to the provisions of section 8, the protection of archaeological and palaeontological sites and material and meteorites is the responsibility of a provincial heritage resources authority: Provided that the protection of any wreck in the territorial waters and the maritime cultural zone shall be the responsibility of SAHRA.

(2) Subject to the provisions of subsection (8)*(a)*, all archaeological objects, palaeontological material and meteorites are the property of the State. The responsible heritage authority must, on behalf of the State, at its discretion ensure that such objects are lodged with a museum or other public institution that has a collection policy acceptable to the heritage resources authority and may in so doing establish such terms and conditions as it sees fit for the conservation of such objects.

(3) Any person who discovers archaeological or palaeontological objects or material or a meteorite in the course of development or agricultural activity must immediately report the find to the responsible heritage resources authority, or to the nearest local authority offices or museum, which must immediately notify such heritage resources authority.

(4) No person may, without a permit issued by the responsible heritage resources authority—
(a) destroy, damage, excavate, alter, deface or otherwise disturb any archaeological or palaeontological site or any meteorite;

(b) destroy, damage, excavate, remove from its original position, collect or own any archaeological or palaeontological material or object or any meteorite;

(c) trade in, sell for private gain, export or attempt to export from the Republic any category of archaeological or palaeontological material or object, or any meteorite; or

(d) bring onto or use at an archaeological or palaeontological site any excavation equipment or any equipment which assist in the detection or recovery of metals or archaeological and palaeontological material or objects, or use such equipment for the recovery of meteorites.

Provincial Heritage Authorities

The NHRA provides for the setting up of Provincial Heritage Resources Agencies (PHRAs) to manage most aspects of fossil heritage including, for example, permits and database management. However, some key issues (*eg* export and destruction permits) are dealt with at a national level by SAHRA (South African Heritage Resources Agency), based in Cape Town. In practice, several provinces have yet to establish PHRAs backed up by appropriate palaeontological expertise. Palaeontological heritage in these provinces is entirely managed by SAHRA. The provinces in which palaeontology is still managed by SAHRA include;

- Mpumalanga
- Northern Cape
- North West Province
- Gauteng
- Limpopo Province

- Free State Province

The following provinces have PHRAs competent in management of palaeontological heritage;

- Eastern Cape: EC PHRA (S. Mokhanya: smokhanya@ecphra.co.za)
- KZN: Amafa (A. Van de Venter-Radford: amafaddps@amafapmb.co.za)
- Western Cape: HWC (T. Smuts: tsmuts@westerncape.gov.za)

GEOLOGICAL HISTORY OF SOUTH AFRICA

1 Introduction

The geological history of South Africa spans a total of at least 3.6 billion years and includes some of the major tectonic events that shaped the Earth since the very early formation of this unique Planet. Several leading scientists have devoted their professional careers to the study of the geological history of this part of the world and comprehensive summaries of their work are contained in four recent publications(Tankard et al (1982), MacRae (1999), McCarthey and Rubidge (2005) and Johnson et al (2006)). A comprehensive summary of research in the Pliocene, Pleistocene and Holocene (4,5Ma to the present) cave deposits in the Cradle of Humankind provides an understanding of the palaeoenvironment as well as the development of humans over time (Hilton-Barber and Berger, 2002).

The aim of this document is to give the average reader a very brief idea of the geological history of Southern Africa, with the specific aim of introducing readers to the important impact that the geological development of the region had on the development and evolution of life during the past 3.6 billion years. For more detailed information the reader is referred to the above mentioned publications as well as a wealth of other publications.

The geological history of South Africa is best summarized in chronological order according to the internationally accepted geological time scale as presently used by the South African Committee for Stratigraphy (SACS) and used in recent publications of the Geological Society of South Africa in Johnson et al (2006).

The geological timescale is basically divided into three major Eons, namely the extremely old (older than 2500 million years) Archaean Eon, the Proterozoic Eon (2500 to 545 million years ago) and the Phanerozoic Eon (545 million years ago to today). The Eons are subdivided into different Era, for example the Palaeozoic (545 to 250ma), the Mesozoic (250 to 65ma) and the Cenozoic (65ma to today) which in turn is subdivided into Periods, with more well known terms such as the Permian (300 to 250ma), Triassic (250 to 200ma), Jurassic (200 to 145ma) Cretaceous (145 to 65ma), Tertiary (65 to 1,8ma) and the Quaternary (1,8 ma to today). The Tertiary and Quaternary Periods are further subdivided into Epoch, or Series, with terms such as for example Miocene (23 to 7ma) and Pliocene (7 to 1,8ma) in the Tertiary. The Quaternary is divided into the Pleistocene (1,8ma to 10 000 years ago) and Holocene (10 000 years ago to today). The constant upgrading of the geological timescale has lead to the fact that specific dates assigned to these time intervals can differ, depending on the specific version of the timescale used by a specific author. The dates used in this report are from Johnson et al (2006).

Geological events have distinct features, which in many cases also have distinct relationships with the palaeontological heritage that is preserved in the rock record. Six major stages of geological development, spanning more than 3600 million years, are reflected in the rock record of South Africa.

The six major stages of development can be summarized as follows:

- Early crustal development during the Archaean Eon, including the greenstone belts such as the Barberton Greenstone Belt. The greenstone belts are areas of tectonism, magmatism and sedimentation that occurred on a more ancient stable piece of continental crust known as the Kaapvaal Craton. These rocks contain evidence of very early life in the form of unicellular organisms and bacteria.
- Increasing stability of the crust to allow for volcano-sedimentary sequences such as the Witwatersrand and Ventersdorp Supergroups to accumulate during the latter part of the Archaean Eon.
- In part contemporaneous with the above, collision of crustal plates to yield metamorphic belts such as the Limpopo Metamorphic Belt and the deposition of sediments in large basins, forming such depositions as the Transvaal Supergroup and the emplacement of large plutonic intrusions such as the Bushveld Complex. During this period Southern Africa was also struck by a meteorite that measured up to 10km in diameter, creating the Vredefort Impact Crator. The sedimentary rocks contain evidence of abundant algal growth in the form of Stromatolites.
- Accretion of depositional basins, such as the Waterberg, Soutpansberg and Olifantshoek basins in the north, Damara and Gariep in the west and the Malmesbury basin in the south. These sediments were deformed and metamorphosed at different times (for example during the Namaqua-Natal Metamorphic Belt) with the accretion of continental plates to the Kaapvaal Craton during the Proterozoic Eon.
- Amalgamation of continental plates to form the Gondwana supercontinent on which extensive intracratonic basins (for example the Karoo Basin) developed during the Palaeozoic and Mesozoic Eras of the Phanerozoic Eon. This period represents a major explosion of life forms and is of extreme importance for the palaeontological heritage of South Africa.
- Fragmentation of Gondwana, accompanied by the extrusion of great volumes of basaltic and rhyolitic magma during the early Mesozoic Era of the Phanerozoic Eon. Extensive deposits of sedimentary rocks accumulated during the later Phanerozoic Eon, known as the Cenozoic Era. These rocks contain important palaeontological evidence of the development of life, including the very important fossilized remains of Mankind.

2 Geological History of Southern Africa

The geological history of southern Africa is briefly discussed in terms of the chronological sequence of events that shaped this part of the world. All the major geological events have been described in several comprehensive publications. For the purpose of this document, specific attention is given to those geological processes that had some influence on the development of life. These units will be of specific importance to the palaeontological heritage of South Africa.

2.1 Ancient continental blocks and the Earliest Forms of Life

The Kaapvaal Craton is one of the oldest single pieces of stable continental crust on Earth (McCarthy and Rubidge, 2005; Johnson et al, 2006) and dates back to the Archaean Eon up to 3600 million years ago. This geological treasure underlies a large part of South Africa and holds evidence of the formation of extremely old crustal plates. The rocks that contain information about these ancient times are best exposed as the Barberton Supergroup in the Barberton Mountain Land, where exposures of ancient cherts contain the remains of spherical, single-celled cyanobacteria. These fossils are between 3300 and 3500 million years old and belong to the Archaean Eon (MacRae, 1999). Although these fossils are extremely small (1 micron in diameter) and not visible with the naked eye, they play a very important role in the story of life and therefore are of extreme importance to the palaeontological heritage of South Africa.

2.2 Archaean Sedimentary and Volcanic deposits

The later part of the Archaean Eon was dominated by a series of geological events that lead to the deposition of large quantities of sedimentary and volcanic rocks in what is today known as the Dominion Group, Witwatersrand and Ventersdorp Supergroups and the Pongola Supergroup. These rocks date from 3080 to 2700Ma and are interpreted to have been deposited in local basins that formed on the Kaapvaal Craton, possibly during the same time that the Kaapvaal Craton collided with the Zimbabwe Craton in the north (Johnson et al., 2006).

Due to very high gold reserves found in them, the Witwatersrand Supergroup is probably to most famous group of rocks in South Africa. This group of mainly sedimentary rocks were deposited in a foreland basin which resulted from the collision of the Kaapvaal Craton with the Zimbabwe Craton (Johnson et al, 2006). These rocks have also attracted the attention of palaeontologists when recent discoveries conclusively indicated that some of the gold deposits were concentrated by biological processes associated with lichens that populated the sedimentaryenvironments (Mac Rae, 1999). This interpretation therefore indicates that more advanced forms of life were present at 2900 to 2700Ma, much earlier than was previously believed.

Advanced algal structures, known as stromatolites, have also been described from the Pongola Supergroup. This confirms the importance of these sedimentary sequences in the palaeontological heritage of South Africa.

2.3 Late Archaean to Proterozoic Events

During the late Archaean Eon conditions on the Kaapvaal Craton was more stable, leading to the deposition of thick deposits of carbonaceous sediments in extensive shallow basins that today forms the Transvaal Supergroup of rocks. The dolomites that dominate the lower part of the Supergroup (Malmani Subgroup of the Chuniespoort Group in the north and Cambell Rand Subgroup of the Ghaap Group in the south western part of the basin) contain some excellent examples of stromatolites, ranging from centimetre scale to several tens of meters in size. These structures, that are a result of algal growth in shallow water, indicate a very rich growth of algae that would have caused an enrichment in the amount of oxygen in the atmosphere, which in turn would have led to the precipitation of large thicknesses of banded iron formation in the overlying groups of rock sequences (Penge Iron Formation in the Chuniespoort Group and Asbestos Hill Subgroup in the Ghaap Group). The precipitation of iron oxide is probably closely related to the biological processes of cyanobacteria (MacRae, 1999).

The presence of stromatolites and micro-fossils in the rocks of the Transvaal Supergroup is of high palaeontological significance. Reports of other possible “trace fossils structures” from rocks of the Transvaal Supergroup might lead to some very important discoveries of advanced life forms in the lower Proterozoic in the future. The importance of these rock units for the palaeontological heritage of South Africa must not be underestimated.

Two other important geological events that happened during the Proterozoic Eon are the intrusion of the Bushveld Igneous Complex at about 2050Ma and the massive impact of an asteroid at Vredefort at 2023Ma, making it the oldest impact structure on Earth. Although no fossils are directly associated with these events, they are important for the possible influence that they would have had on the development of life on the planet. The fact that most of the life forms on Earth were very primitive at the time reduces the actual impact of these two events (McCarthy and Rubidge, 2005).

2.4 Accretion of Depositional Basins during the Proterozoic Eon

Commencing around 1900Ma, shallow-water marine sediments represented by limestones, dolomites quartzites and mudstones, accumulated in the west, depositing rocks of the Olifantshoek Supergroup. At the same time, rocks of the Waterberg and Soutpansberg Groups in the north were also deposited in local extension basins. The Waterberg and Soutpansberg Groups contain the Earth’s oldest red beds, indicating deposition under an atmosphere that contained free oxygen. Up to this point in time, oxygen produced by cyanobacteria was consumed by iron and manganese dissolved in the oceans and precipitated as banded iron formations (McCarthy and Rubidge, 2005). Although minor

indications of possible algal mats have been recorded from these sediments, no major fossil finds have been recorded to date.

Several intrusive events, including the better known Pilansberg Complex, took place during this time, about 1300Ma. These events did not have noticeable impacts on the primitive life of the time.

During a collision event on the southern margin of the Kaapvaal Craton 1750Ma, the Namaqua-Natal Metamorphic Belt was formed but no fossils have up to date been recorded from this sequence. Towards the west the Gariep Basin developed, characterised by shallow marine shelf environments with stromatolitic algal reefs and clean quartz sand deposits (Johnson et al, 2006). Similar conditions probably prevailed in the south where the Malmesbury and related groups were deposited. Very little is known about the fossil content of these rocks and a gap of at least 1950 million years in palaeontological evidence in our knowledge of life on Earth is indicated by MacRae (1999).

2.5 Late Proterozoic and Phanerozoic Developments

The late Proterozoic Eon (600Ma to 500Ma) saw the making of the Gondwana supercontinent and represents a time of incredible diversification of life on Earth (MacRae, 1999; McCarthy and Rubidge, 2005 and Johnson et al, 2006). Accretion of continental blocks led to the folding and deformation of rocks along the margins of the old continents. The Pan-African event (550Ma) encompasses the welding together of the old continents (McCarthy and Rubidge, 2005) and lead to the development of high mountain ranges along what is now the southern Cape as well as the West Coast of South Africa. Sediments from the mountains on the West Coast accumulated in a shallow basin, resulting in the deposition of the Nama Group. The Nama Group of sediments contain some of the best, if not the best examples of some of the oldest multicellular invertebrate animals in the world (Mac Rae, 1999). Rocks of this group also contain very good examples of trace fossils that indicate an age of 543Ma for the boundary between the Proterozoic and the Phanerozoic (also known as the Precambrian/Cambrian boundary) (MacRae, 1999).

During the early Phanerozoic Eon (or early Palaeozoic Era) Southern Africa was the keystone for the early Gondwana Supercontinent and aborted drifting produced elongate troughs along the southern and eastern margins of South Africa , leading to the deposition of the Ordovician to Carboniferous (500Ma to 325Ma) Cape Supergroup and Natal Group of rocks (Jonson et al, 2006). The Cape Supergroup sediments contain a wealth of organisms with hard outer skeletons (MacRae, 1999; McCarthy and Rubidge, 2005), rendering it as one of the palaeontological treasure houses of South Africa.

By mid-Carboniferous times (325Ma) shortening and buckling of the crust lead to the deformation of the Cape Supergroup rocks whilst most of the interior of South Africa was covered in thick ice sheets due to the drifting of this part of Gondwana past the South Pole. Melting of the ice sheets and downwarp to the north of the now actively building Cape Fold

Mountain Range, lead to the deposition of the Karoo Supergroup from 325 to 180 million years ago. Rocks of the Dwyka Formation (glacial deposit), Ecca Group (mainly deep water sediments in the south and deltaic sediments with extensive coal beds in the north), Beaufort Group (mainly fluvial to lacustrine deposits) and Stormberg Group (mainly fluvial, playa lakes and desert deposits) was deposited in a foreland basin that extended far to the north of the Cape Fold Belt. Sedimentation was terminated at about 180 Ma with the extensive eruption of basaltic lava during deposition of the Drakensberg Formation and the Lebombo Group lavas up to 150Ma during the Jurassic Period (MacRae, 1999; McCarthy and Rubidge, 2005; Johnson et al, 2006). The Karoo Supergroup is internationally known for the extreme wealth of palaeontological information relating to the development of life on land, both in the Plant and Animal Kingdoms (MacRae, 1999; McCarthey and Rubidge, 2005). Of specific importance is the evidence for the development of reptiles, mammal-like reptiles, mammals and dinosaurs (MacRae, 1999; McCarthy and Rubidge, 2005). The rocks of the Karoo Supergroup contain a very important part of the palaeontological heritage of South Africa.

2.6 The Break-up of Gondwana and Late Phanerozoic Events

Towards the end of the Mesozoic Era the final break-up of Gondwana lead to the formation of numerous fault-bound basins on the continental margin of Southern Africa during the Cretaceous Period (150Ma to 65Ma). Although most of these deposits are preserved in off-shore basins off the coast of South Africa, the Algoa Basin is particularly well known for the wealth of fossil material from the Kirkwood Formation (including dinosaur remains) and the Sundays River Formation (rich in marine vertebrates, invertebrates and trace fossils) of the Uitenhage Group (Johnson et al, 2006). The most important palaeontological information on conditions that prevailed in the interior of South Africa comes from crater lakes of volcanoes and specifically Kimberlite pipes that erupted during the Cretaceous (McCarthy and Rubidge, 2005).

Apart from the extensive terrestrial deposits of the Kalahari Group in the Kalahari Basin, Cenozoic deposits are largely confined to coastal areas where very rich assemblages of marine fossils (KwaZulu-Natal and Eastern and Western Cape coasts) are recorded (MacRae, 1999; Johnson et al, 2006). These assemblages contribute significantly to the Palaeontological Heritage of the country.

Finally, the Cenozoic Era (65Ma to today), reflects climatic changes, changes in the geomorphology of South Africa and the presence of fossil hominins in certain cave and spring deposits that contributed significantly to the understanding of the evolution of modern man (MacRae, 1999; Hilton-Barber and Berger, 2002; McCarthy and Rubidge,, 2005; Johnson et al, 2006).

3 Conclusion

The geological history of Southern Africa spans at least 3.6 billion years of time and includes several major geological events that not only shaped the geological formation of the area, but had profound impacts on the development of life on Earth. Most of the ancient Archaean and Proterozoic rock sequences contain only very primitive forms of life whereas the rock units that date back to the late Proterozoic and specifically the Phanerozoic, contain some of the richest treasure houses of fossils in the world. Fossils from these younger units bear witness to the development of higher forms of life, including the development of mammals from reptiles and also the development of humankind from very early ancestors.

4 References

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GEOLOGICAL HISTORY OF THE FREE STATE PROVINCE

1 Introduction

The geological history of the Free State Province spans a total of 3600 million years, including some of the major events that lead to the deposition of a wealth of economically important sequences of rocks. Although most of the Archaean and Proterozoic-aged rocks are much more known for their mineral wealth, rather than their palaeontological importance, the more recent Phanerozoic deposits and specifically the Late Palaeozoic and Mesozoic aged rock units (300 to 145 million years old) are of significant palaeontological importance. Cenozoic deposits are not yet well studied, but significant finds are known from specific sites where very important fossils were recorded. These, at the moment, isolated sites are of importance in the study of the evolution of life during the last 4.5 million years. This includes the important discoveries of fossilized remains of *Homo sapiens* and the study of the development of human ancestors.

2 Significant Palaeontological features in the Free State Province

2.1 Archaean and Proterozoic Eons

Rocks belonging to the Archaean and Proterozoic Eons contain fossils of ancient life in the form of unicellular organisms such as cyanobacteria. None of these fossils have up to now, been described from the ancient rocks in the Free State, and any recording of these organisms will be significant.

The oldest rocks in the Free State Province are associated with the basement granites of the Vredefort Dome. Although not of palaeontological interest, the Vredefort Dome represents a significant geological event of about 2023 million years ago as will be discussed later in this section.

Examples of cyanobacteria have been described from the gold bearing conglomerates of the Witwatersrand Supergroup that crops out towards the north of the Vredefort Dome and is also mined at great depths close to Welkom (MacRae, 1999). These are significant recordings as it gives a possible indication of very early life forms, possibly ancient lichen growths that existed up to 2900 million years ago. These structures are not visible to the naked eye and recording of the fossils will only be possible when electron microscope work is done on the rocks.

Stromatolites have been interpreted as ancient examples of modern algal mats as early as 1933 (MacRae, 1999). These structures have been recorded from borehole data in the Rietgat Formation of the Ventersdorp Supergroup in the Free State Province and any recordings from similar aged rocks in the Province will be of palaeontological significance.

Very good examples of stromatolites have been described from the Malmani Subgroup of the Chuniespoort Group of the Transvaal Supergroup, near Pretoria in Gauteng where these structures were studied in detail by scientists such as Young, Bart Nagy and Murray Macgregor since 1974 (MacRae, 1999). These structures are pronouncedly associated with dolomites of the Malmani Subgroup of the Chuniespoort Group. Outcrops of dolomites of the Chuniespoort Group and

Malmani Subgroup are associated with the deformation rings of the Vredefort Dome in the northern Free State Province. Stromatolite structures are significant indicators of palaeoenvironments and provide evidence of algal growth between 2640 and 2432 million years ago (MacRae, 1999).

Stromalites have also been reported in many of the sediments of the Pretoria Group and it is possible that these structures will be present in outcrops of these rocks in the northern Free State. These structures therefore contribute significantly to the palaeontological heritage of the Free State Province. Informal reports of "sedimentary structures" that might have a biogenic origin have been reported from sedimentary rocks in the Pretoria Group of the Transvaal Supergroup (Colin MacRae, pers comm 2014). If these structures are indeed biogenic in origin, it will be some of the oldest recordings of more advanced multicellular (metazoan) life in the history of life on Earth, 2200 million years ago.

As mentioned earlier, a significant geological event that is recorded in the northern border regions of the Free State Province caused the formation of the Vredefort Dome. This geological feature is interpreted as the largest meteorite impact crater on Earth, caused by a meteorite of at least 10km in diameter that hit the Earth 2023 million years ago (Johnson et al, 2006). Because of its unique formation, the Vredefort Dome region has been declared a World Heritage Site. Due to the very primitive forms of life that existed at the time, this event seems to have had little effect on the evolution of life, mainly due to the fact that the cyanobacteria could survive the adverse environmental conditions for extensive periods of time (McCarthy and Rubidge, 2005).

The dolomites of the Transvaal Supergroup underlie the well-known "Cradle of Humankind" World Heritage Site in Gauteng Province and extend towards the south where outcrops of the dolomites are present in the northern Free State. Deposits of Cenozoic aged cave breccia associated with sinkholes and karst formations contains the fossilized remains of plants and animals, including the remains of the ancestors of man (MacRae, 1999; Hilton-Barber and Berger, 2002) These Cenozoic formations are not mapped out on the geological maps and for this reason the entire outcrop area of dolomites in the Chuniespoort Subgroup is allocated a high palaeontological significance.

2.2 Phanerozoic Eon

The base of the Phanerozoic Eon is known for the sudden explosion of diversity of life (MacRae, 1999; McCarthy and Rubidge, 2005). There are no outcrops of rocks that date from the lower or early Phanerozoic (Cambrian, Ordovician, Silurian and Devonian) and the first deposits of this age are the Carboniferous to Permian-aged Dwyka Formation, also termed the Bizane Formation in some parts of the Karoo Basin. Although some significant fossils have been recorded from the Dwyka Formation, the rock unit is allocated a moderate palaeontological sensitivity.

The Permian Ecca Group sediments are well-known for the wealth of fossils present in the sequence of sandstone and mudstone. In the western Free State the Prins Alfred Formation represents a marine environment and although fossils are rare, examples of low diversity marine fauna as well as rare petrified wood and trace fossils have been recorded. The overlying Whitehill Formation is of particular interest to palaeontology, with examples of Mesosaurid reptiles, rare cephalochordates, variety of palaeoniscoid fish, small eocarid crustaceans, arthropods (*Notocaris tapscotti*), insects, low diversity of trace fossils (e.g. king crab trackways, possible shark coprolites), palynomorphs, petrified wood and other sparse vascular plant remains (*Glossopteris* leaves, lycopods etc) being recorded. In

fresh outcrop the rock unit is black in colour due to high carbon content of the mudrocks. The high carbon content is probably derived from phytoplankton blooms that occurred during the time of deposition. Also restricted to the western parts of the Free State Province and overlying the Whitehill Formation, are mudstones of the Tierberg Formation. Fossils are rare, but include disarticulated microvertebrate remains, sponge spicules, spare vascular plants and trace fossil assemblages.

In the north-eastern Free State, the Ecca Group consists of the lower Pietermaritzburg Formation, the Vryheid Formation and upper Volksrust Formation. The Pietermaritzburg Formation rarely forms good outcrops and fossils are rare and difficult to find. A moderate palaeontological sensitivity is allocated to this formation.

The overlying Vryheid Formation is the main coal producing formation in South Africa and is of very high palaeontological significance. A wealth of fossils is recorded from this formation, including rich fossil plant assemblages of the Permian *Glossopteris* Flora. Abundant, low diversity trace fossils, rare insects, possible conchostracans, non-marine bivalves and fish scales have also been reported from this formation (MacRae, 1999). The overlying Volksrust Formation consists of a monotonous sequence of grey shale and fossils are significant, but rarely recorded. Fossils include rare temnospondyl amphibian remains, invertebrates, minor coals with plant remains, petrified wood, and low-diversity marine to non-marine trace fossil assemblages.

Overlying the Ecca Group is the late Permian to early Triassic Beaufort Group of sediments that is in turn subdivided into a lower Adelaide Subgroup and upper Tarkastad Subgroup. The Adelaide Subgroup consists of a sequence of sediments ranging from Permian aged lower deltaic environments through meandering fluvial environments to early Triassic lacustrine deposits (McCarthy and Rubidge, 2005; Johnson et al, 2006). A diverse fossil collection of terrestrial and freshwater tetrapods from the *Pristerognathus* to *Dicynodon* Assemblage Zones (amphibians, true reptiles, synapsids – especially therapsids), palaeoniscoid fish, freshwater bivalves, trace fossils (including tetrapod trackways) andsparse to rich assemblages of vascular plants (*Glossopteris* Flora, including spectacular petrified logs) as well as insects have been described from these geological formations. The Adelaide Subgroup contains the richest Permo-Triassic tetrapod fauna from Pangaea / Gondwana and key evidence for evolution of mammalian characters among therapsids. Continental evidence of the Late Permian Mass Extinction Event is recorded from Bethulie in the southern part of the Free State. The northern outcrop area contains mainly fossils of the *Dicynodon* Assemblage Zone (MacRae, 1999; McCarthy and Rubidge 2005). The upper part of the Adelaide Subgroup consists mainly of a sequence of Traissic aged lacustrine and playa lake deposits with a very rich fossil assemblage of plants and animals that either survived the Permian Mass Extinction Event or developed shortly after the event took place (MacRae, 1999; McCarthy and Rubidge, 2005). The fossil assemblage includes petrified wood, tetrapod faunas of the *Lystrosaurus* Assemblage Zone (dicynodonts, cynodonts, therocephalians, procolophonids, archosaurs etc), including rich lacustrine biotas of amphibians and fish as well as trace fossils including vertebrate burrows and coprolites (MacRae, 1999).

Overlying the Adelaide Subgroup is the Triassic aged Tarkastad Subgroup, consisting of a lower arenaceous Katberg Formation (Katberg Formation in the northeast) and red argillaceous Burgersdorp Formation (Driekoppen Formation in the northeast)(Johnson et al, 2006). The Katberg

Formation contain fossils of the Lystrosaurus Assemblage Zone, with a rich assembly of animal and plant fossils (MacRae, 1999) whilst the Burgersdorp Formation is known to contain the richest known Early Triassic freshwater fauna fossil record in the world. The fossil record includes petrified wood, tetrapod faunas of the *Cynognathus* Assemblage Zones (dicynodonts, cynodonts, therocephalians, procolophonids, archosaurs etc) including rich lacustrine biotas of amphibians and fish as well as trace fossils including vertebrate burrows and coprolites (MacRae, 1999; McCarthy and Rubidge, 2005). Overlying the Beaufort Group is the Stormberg Group, consisting of the Molteno, Elliot and Clarens Formations.

The Molteno Formation overlies the Beaufort Group and consists of a sequence of coarse-grained glittering sandstone and khaki-coloured mudstone that was deposited in a braided river, fluvial environment. The Molteno Formation contains an extremely rich fossil flora (ferns, horsetails, gymnosperm including conifers, ginkgophytes, cycads, seed ferns etc), silicified woods and palynormphs (MacRae, 1999; McCarthy and Rubidge, 2005). Apart from important insect fauna, animal fossils are very sparse, including rare fish, conchostracans, bivalves as well as invertebrate trace fossils and dinosaur tracks. Rare trackways do provide some of the earliest indirect evidence for the first dinosaurs to appear in the South African fossil record (MacRae, 1999; McCarthy and Rubidge, 2005).

The Elliot Formation consists of a sequence of red mudstone and subordinate sandstone that was deposited in an arid, braided river and playa lake environment. The formation contains one of richest Late Triassic to Early Jurassic dinosaur faunas in the world, containing key data on early diversification of the dinosaurs. Several important new dinosaur taxa have recently been discovered in the Free State.

Rich fossil reptile fauna dominated by early dinosaurs (principally sauropodomorphs like Massospondylus and “Euskelesaurus”) fossils also include ornithischians, rare theropods and crocodilomorphs as well as rare amphibians, turtles, fish, advanced mammal-like reptiles (cynodont therapsids) and early mammals. Other fossil elements include petrified wood, phyllopod crustaceans (conchostacans or “clam shrimps”), insects, and trace fossils, principally tetrapod trackways, root casts and possible termitaria (MacRae, 1999; McCarthy and Rubidge, 2005). The lower Elliot Formation is associated with the Late Triassic aged “Euskelesaurus” Range Zone, whilst the upper Elliot Formation is associated with the Early Jurassic *Massospondylus* Range Zone. In a unique find in the Golden Gate Highlands National Park, the upper Elliot Formation has yielded the oldest known dinosaur eggs (*Massospondylus* eggs) in the world.

The Jurassic aged Clarens Formation overlies the Elliot Formation and consists primarily of aeolian (wind-blown) sands, minor playa lake, ephemeral stream deposits, basaltic lava flows with an interfingering relationship with overlying Drakensberg Group lavas. The Clarens Formation was deposited in a desert environment and, although rare, contains examples of silicified wood, plant remains, freshwater crustaceans, primitive bony fish, invertebrate trace fossils, rare dinosaurs such as *Massospondylus*, crocodylomorphs, advanced cynodonts, including early mammals (e.g. *Erythrotherium*), trackways of dinosaurs and mammals, coprolites and eggshell fragments. Many fossils are associated with temporary lake deposits, interpreted as belonging to the upper part of *Massospondylus* range zone.

The Clarens Formation is capped by the Jurassic aged Drakensberg Group that consists of mainly basaltic lava and minor pyroclastic intrusions that terminated the deposition of material into the Karoo Basin. In the lower part of the group, thin aeolian sandstones are interbedded with the basalt. The presence of these sandstone units in the lower part of the Drakensberg Group indicate that sand was blown in from areas that were not covered in basalt flows. Fossils are primarily associated with these sandstone beds in the dominantly basaltic lava unit. Thousands of dolerite sill and dyke structures that cut the Karoo sedimentary sequence are associated with the Drakensberg Group volcanic episode. The dolerite intrusions are the remnants of the magma flows that fed the volcanoes of the Drakensberg Group. A moderate palaeontological sensitivity is allocated to the Drakensberg Group.

Significant fossil finds in the Free Sate are recorded from Cenozoic aged superficial deposits at specific localities such as Florisbad, Cornelia and others. These deposits can contain a wealth of palaeontological data and have been allocated a very high palaeontological sensitivity. The fossils recorded from specific sites include bones and teeth of mammals (e.g. proboscideans, rhinos, bovids, horses, micromammals, early Homo (*Homo heidelbergensis*); Cornelian and Florisian Mammal Age faunas), reptiles, fish, freshwater molluscs, petrified wood, trace fossils (e.g. termitaria), rhizoliths and diatom floras. Fauna is generally sparse but locally very rich and is of very high significance to the study of life during the Cenozoic, specifically the study of the development of early man (MacRae, 1999; McCarthy and Rubidge, 2005).

Superficial deposits of Quaternary and Tertiary age can contain important fossils. In most cases the superficial deposits consist of windblown sand associated with the “Gordonia” Formation of the Kalahari Group towards the west and northwest in the Northern Province and Northwest Province. The Gordonia Formation is a specific formation of the Kalahari Group and the term should not be used for undifferentiated windblown sand that covers the western part of the Free State Province. The superficial deposits are allocated a moderate palaeontological sensitivity due to the fact that many fossiliferous rocks might be covered in a thin layer of soil or windblown sand, where fossils are invariably found in small erosion gullies where the topsoil or windblown sand has been removed by erosion.

Alluvial deposits are those deposits that are associated with water courses and rarely contain fossils. Where fossils do occur it is normally in abundance. These deposits are allocated a low palaeontological sensitivity where the developer must report any fossil finds.

3 Conclusion

The Free State Province is underlain by some of the most valuable geological formations in the world, including the Witwatersrand Supergroup (gold ore resources). The ancient sediments of the Witwatersrand Supergroup and the Transvaal Supergroup contain significant micro-fossils as well as stromatolite structures associated with ancient life forms. The fossils are of importance to the understanding of the development of life and it is essential that good examples of the structures be recorded and, if possible, be preserved as part of the palaeontological heritage of South Africa.

The Permian Ecca Group contains significant plant fossils. These fossils provide us with unique opportunities to study ancient ecosystems and are allocated a very high palaeontological

Significance. The most significant fossils in the Free State Province are associated with Permian to Jurassic aged deposits of the Karoo Supergroup, including the Ecca Group, Beaufort Group and Stormberg Group. These deposits are allocated a very high palaeontological significance and represent one of the richest assemblages of vertebrate, invertebrate and plant fossils in the world.

4 References

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PALAEONTOLOGICAL SIGNIFICANCE/VULNERABILITY OF ROCK UNITS	
The following colour scheme is proposed for the indication of palaeontological sensitivity classes. This classification of sensitivity is adapted from that of Almond et al 2008.	
RED	Very High Palaeontological sensitivity/vulnerability. Development will most likely have a very significant impact on the Palaeontological Heritage of the region. Very high possibility that significant fossil assemblages will be present in all outcrops of the unit. Appointment of professional palaeontologist, desktop survey, phase I Palaeontological Impact Assessment (PIA) (field survey and recording of fossils) and phase II PIA (rescue of fossils during construction) as well as application for collection and destruction permit compulsory.
ORANGE	High Palaeontological sensitivity/vulnerability. High possibility that significant fossil assemblages will be present in most of the outcrop areas of the unit. Fossils most likely to occur in associated sediments or underlying units, for example in the areas underlain by Transvaal Supergroup dolomite where Cenozoic cave deposits are likely to occur. Appointment of professional palaeontologist, desktop survey and phase I Palaeontological Impact Assessment (field survey and collection of fossils) compulsory. Early application for collection permit recommended. Highly likely that aPhase II PIA will be applicable during the construction phase of projects.
GREEN	Moderate Palaeontological sensitivity/vulnerability. High possibility that fossils will be present in the outcrop areas of the unit or in associated sediments that underly the unit. For example areas underlain by the Gordonia Formation or undifferentiated soils and alluvium. Fossils described in the literature are visible with the naked eye and development can have a significant impact on the Palaeontological Heritage of the area. Recording of fossils will contribute significantly to the present knowledge of the development of life in the geological record of the region. Appointment of a professional palaeontologist, desktop survey and phase I PIA (ground proofing of desktop survey) recommended.
BLUE	Low Palaeontological sensitivity/vulnerability. Low possibility that fossils that are described in the literature will be visible to the naked eye or be recognized as fossils by untrained persons. Fossils of for example small domal Stromatolites as well as micro-bacteria are associated with these rock units. Fossils of micro-bacteria are extremely important for our understanding of the development of Life, but are only visible under large magnification. Recording of the fossils will contribute significantly to the present knowledge and understanding of the development of Life in the region. Where geological units are allocated a blue colour of significance, and the geological unit is surrounded by highly significant geological units (red or orange coloured units), a palaeontologist must be appointed to do a desktop survey and to make professional recommendations on the impact of development on significant palaeontological finds that might occur in the unit that is allocated a blue colour. An example of this scenario will be where the scale of mapping on the 1:250 000 scale maps excludes small outcrops of highly significant sedimentary rock units occurring in dolerite sill outcrops. Collection of a representative sample of potential fossiliferous material recommended.

GREY	Very Low Palaeontological sensitivity/vulnerability. Very low possibility that significant fossils will be present in the bedrock of these geological units. The rock units are associated with intrusive igneous activities and no life would have been possible during implacement of the rocks. It is however essential to note that the geological units mapped out on the geological maps are invariably overlain by Cenozoic aged sediments that might contain significant fossil assemblages and archaeological material. Examples of significant finds occur in areas underlain by granite, just to the west of Hoedspruit in the Limpopo Province, where significant assemblages of fossils and clay-pot fragments are associated with large termite mounds. Where geological units are allocated a grey colour of significance, and the geological unit is surrounded by very high and highly significant geological units (red or orange coloured units), a palaeontologist must be appointed to do a desktop survey and to make professional recommendations on the impact of development on significant palaeontological finds that might occur in the unit that is allocated a grey colour. An example of this scenario will be where the scale of mapping on the 1:250 000 scale maps excludes small outcrops of highly significant sedimentary rock units occurring in dolerite sill outcrops. It is important that the report should also refer to archaeological reports and possible descriptions of palaeontological finds in Cenozoic aged surface deposits.

EON	ERA	Period	Supergroup/ Sequence	Group	Subgroup	Formation	Member	Lithology	Fossil Heritage	Comments
PHANEROZOIC			ALLUVIAL DEPOSISTS			mmm; Several symbols used for alluvium (Qa), colluvium and scree (Q17)		Recent sandy and clayey deposits along water courses	Wide range of fossils possible, including mammalian bones and teeth, tortoise remains, ostrich egg etc	Alluvial deposits associated with recent water courses of main rivers and streams. These sediments are presently not well studied and records of fossil occurrences are mainly associated with archaeological reports
	Caenozoic		CAENOZOIC SUPERFICIAL DEPOSITS (Q) Quaternary (1.6 to 0 Ma)			Q; Qs; Q-s; Qw; Qd; Qg Diamondeferous gravel (Qa) Masotcheni (Qm); River Terrace Gravel (Qg)		Aeolian sand, alluvium, colluvium, spring tufa (calcareous) and sinter (siliceous), lake deposits, peats, pedocretes or duricrusts (calcrete, ferricrete), soils and gravel	Very wide range of possible fossil remains, though these are often sparse, such as: mammalian bones and teeth, tortoise remains, ostrich eggshells, non-marine mollusc shells, ostracods, diatoms and other microfossil groups, trace fossils (e.g. calcretised termitaria, rhizoliths, burrows, vertebrate tracks), freshwater stromatolites, plant material such as peats, foliage, wood, pollens	Extensive alluvial and colluvial deposits are not well studied. Refer to archaeological publications for possible reference to important fossil assemblages from these units.
			MAINLY CALCRETES			Qc; Q16; T12; Q-c		Calcrete , pandune and surface limestone		
			Superficial Deposits Not mapped on 1:250 000 scale Predominantly Pleistocene to Recent (1.6 to 0 Ma			Examples: Cornelia (T-Qc); Florisbad		Terrestrial sediments, including diatomite (diatom deposits), spring deposits, pedocretes, calcareous tufa and other cave deposits, peats, soils and gravel	Bones and teeth of mammals (e.g. proboscideans, rhinos, bovids, horses, micromammals, early Homo (Florisbad Man (*Homo heidelbergensis*)); Cornelian and Florisian Mammal Age faunas), reptiles, fish, freshwater molluscs, petrified wood, trace fossils (e.g. termitaria), rhizoliths, diatom floras. Fauna generally sparse but locally very rich.	Scattered records with many areas being poorly studied (e.g. from ancient drainage systems). Key examples include sites at Cornelia, Uitzoek, Erfkroon, Florisbad, Vlakkraal and several sites where Orange River Gravels are preserved
	Mesozoic	Jurassic - Cretaceous	KIMBERLITES AND OTHER POST KAROO IGNEOUS ROCKS Diamond symbol			Kimberlites		Kimberlite pipes and other alkaline intrusions	No crater lake sediments and therefore no fossil biotas preserved. Fossiliferous crater lake deposits are known from the Northern Cape and in Botswana	
		Jurassic	KAROO SUPERGROUP			Dolerite (Jd; J-d)		Intrusive dolerites (dykes, sills), associated diatremes (i.e. vent of explosive volcano) Early Jurassic (c. 183 Ma)	No fossils recorded	Karroo-Ferrar magmatic activity – major igneous intrusions, basaltic volcanism - possibly associated with Early Jurassic mass extinction event (183 Ma)
		Early Jurassic (c. 183 Ma)		DRAKENSBERG (Jd)		Drakensberg (Jdb) Pyroclastics (Jp)		Basaltic lava flows with minor interbedded terrestrial sandstones, mudrocks, pyroclastics (tuffs, agglomerates etc)	Charred tree trunks, other plant fossils (horsetails, conifers, cycads, bennettititales, roots, pollens), trackways (small mammals, dinosaurs, invertebrates including arthropods, molluscs), rare vertebrate skeletal remains (bones, fish, possible amphibian remains, early mammals), crustaceans (conchostracans, notostracans, malacostracans, ostracods), insect wings, molluscs. No crater lake sediments of Drakensberg volcanoes preserved.	
		Early Jurassic (c. 183 Ma)		STORMBERG		Clarens (TRc; Jc)		Aeolian (wind-blown) sands, minor playa lake, ephemeral stream deposits, basaltic lava flows interfingering relationship with overlying Drakensberg Group lavas.	Silicified wood, plant remains, freshwater crustaceans, primitive bony fish, invertebrate trace fossils, rare dinosaurs (e.g. *Massospondylu* s), crocodylomorphs, advanced cynodonts including early mammals (e.g. *Erythrotherium*), trackways of dinosaurs and mammals, coprolites, eggshell fragments. Many fossils associated with temporary lake deposits. Upper part of *Massospondylus* Range Zone	
		Triassic to Early Jurassic				Elliot (Tre; e; K4r)		Red mudstone and subordinate fine-grained sandstone. Arid, meandering and braided-river red beds with some permanent river and playa lake deposits locally	Rich fossil reptile fauna dominated by early dinosaurs (principally sauropodomorphs like *Massospondylus* , *"Euskelesaurus"*), ornithischians, rare theropods) and crocodilomorphs as well as rare amphibians, turtles, fish, advanced mammal-like reptiles (cynodont therapsids) including early mammals. Other fossil elements include petrified woods, phyllopod crustaceans (conchostacans or "clam shrimps"), insects, and trace fossils, principally tetrapod trackways, root casts, possible termitaria. Lower Elliot Fm *"Euskelesaurus"* Range Zone, Late Triassic Upper Elliot Fm *Massospondylus* Range Zone, Early Jurassic. Oldest known dinosaur eggs (*Massospondylus*) with embryos (Golden Gate National Park).	One of richest Late Triassic to Early Jurassic dinosaur faunas in the world – key data on early diversification of the dinosaurs. Several important new dinosaur taxa discovered recently in the Free State.
		Late Triassic				Molteno (TRm; K4m; m)		Glittering coarse-grained sandstone and subordinate khaki coloured mudstone. Perennial braided fluvial sediments with thin coals	Extremely rich fossil flora (ferns, horsetails, gymnosperm including conifers, ginkgophytes, cycads, seed ferns etc), silicified woods, palynormphs. Apart from important insect fauna, animal fossils very sparse, including rare fish, conchostracans, bivalves as well as invertebrate trace fossils and dinosaur tracks. Rare trackways provide some of the earliest indirect evidence for first dinosaurs.	Richest Triassic floras in the World (Dicroidium Flora of Gondwana).
		Triassic		BEAUFORT	Tarkastad (TRt; t)	Burgersdorp (TRb; K3u; b) Driekoppen (TRd)		Red mudstone and subordinate fine-grained sandstone. Arid, meandering and braided-river red beds with some permanent river and lake deposits locally	Petrified wood, tetrapod faunas of the Cynognathus Assemblage Zones (dicynodonts, cynodonts, therocephalians, procolophonids, archosaurs etc), including rich lacustrine biotas of amphibians, fish; trace fossils including vertebrate burrows, coprolites.	Richest known Early Triassic freshwater fauna in World
						Katberg (TRk; K3m) Verkykerskop (TRv)		Braided and meandering fluvial sandstones and mudrocks, lake deposits	Petrified wood, tetrapod faunas of the Lystrosaurus Assemblage Zone (dicynodonts, cynodonts, therocephalians, procolophonids, archosaurs etc), including rich lacustrine biotas of amphibians, fish; trace fossils including vertebrate burrows, coprolites	
					Adelaide (Pa, Pn; Pne, K3l)	Balfour (Pb) Normandien (Pa; Pn; Pne) Estcourt (Pe, Pes)	Palingkloof/ Harrismith	Brightly coloured mudstone and siltstone. Playa lake deposits associated with arrid braided river environments	Petrified wood, tetrapod faunas of the Lystrosaurus Assemblage Zone (dicynodonts, cynodonts, therocephalians, procolophonids, archosaurs etc), including rich lacustrine biotas of amphibians, fish; trace fossils including vertebrate burrows, coprolites	
	Palaeozoic						Schoondraai	Meandering river channel sandstone	Diverse terrestrial and freshwater tetrapods of *Pristerognathus* to Dicynodon Assemblage Zones (amphibians, true reptiles, synapsids – especially therapsids), palaeoniscoid fish, freshwater bivalves, trace fossils (including tetrapod trackways), sparse to rich assemblages of vascular plants (*Glossopteris* Flora, including spectacular petrified logs), insects Richest Permo-Triassic tetrapod fauna from Pangaea / Gondwana	Key evidence for evolution of mammalian characters among therapsids Continental record of Late Permian Mass Extinction Events (e.g. Bethulie) Northern outcrop area mainly Dicynodon Assemblage Zone
							Rooinek	Meandering river channel sandstone		
							Frankfort	Coarse-grained sandstone and carbonaceous shale, deltaic deposits	Trace Fossils, plant fossils of *Glossopteris*	

EON	ERA	Period	Supergroup / Sequence	Group	Subgroup	Formation	Member	Lithology	Fossil Heritage	Comments
PHANEROZOIC	Palaeozoic	Permian	KAROO SUPERGROUP	ECCA (Pe)		Volksrust (Pvo)		Basinal dark mudrocks with phosphatic / carbonate / sideritic concretions, minor coals Offshore shelf, but possibly also nearshore / lacustrine / lagoonal deposits	Rare temnospondyl amphibian remains, invertebrates (bivalves, insects), minor coals with plant remains, petrified wood, organic microfossils (acritarchs), low-diversity marine to non-marine trace fossil assemblages Late Permian *Cistecephalus* Assemblage Zone biotas	
						Vryheid (Pv)		Deltaic mudrocks and sandstones, locally coastal and fluvial deposits, with occasional coal seams (Ecca "Coal Measures")	Rich fossil plant assemblages of the Permian *Glossopteris* Flora (lycopods, rare ferns and horsetails, abundant glossopterids, cordaitaleans, conifers, ginkgoaleans), rare fossil wood, diverse palynomorphs. Abundant, low diversity trace fossils, rare insects, possible conchostracans, non-marine bivalves, fish scales.	Globally important fossil floras from Middle Permian Gondwana. Seriously under-collected in recent years, despite ongoing mining for coal
						Pietermaritzburg (Pp)		Dark Grey Shale	Trace Fossils very rare	
						Tierberg (Pt, K2u)		Dark grey shale. Offshore non-marine mudrocks with distal turbidite beds, prodeltaic sediments	Disarticulated microvertebrate remains (e.g. fish teeth, scales), sponge spicules, spare vascular plants (leaves, petrified wood), moderate diversity trace fossil assemblages (as below plus variety of additional taxa such as large ribbed pellet burrows, arthropod scratch burrows, *Siphonichnus* etc)	Ecca Sea traces are among most diverse and best preserved non-marine ichnofaunas from Gondwana. Doubtful stromatolites also recorded
					Undifferentiated Whitehill and Prince Albert (Ppw-Pe6)	Whitehill (Pw)		Black, carbonaceous, pyrite bearing shale within minor volcanic ashes (tuff), ferruginous carbonate nodules. Mudrocks distinctively weathers white on the surface. Deposition largely by suspension settling in a young, underfilled foreland basin. Regarded as a distall equivalent of the Vryheid Formation in the north.	Mesosaurid reptiles, rare cephalochordates, variety of palaeoniscoid fish, small eocarid crustaceans, arthropods (*Notocaris tapscotti*) , insects, low diversity of trace fossils (e.g. king crab trackways, possible shark coprolites), palynomorphs, petrified wood and other sparse vascular plant remains (*Glossopteris* leaves, lycopods etc). High carbon content of mudrocks is probably derived from phytoplankton blooms.	Anoxic quiet-water bottom conditions promoted frequent preservation of intact skeletons of animal life. Distinctive Ecca Sea fauna also found in South America – early historical evidence for Gondwana supercontinent. Coeval with Ecca Coal Measures of Gauteng, KZN (Vryheid Fm).
						Prince Albert (Ppr)		Marine to hyposaline basin plain mudrocks, minor volcanic ashes, phosphates and ironstones, post-glacial mudrocks at base	Low diversity marine invertebrates (bivalves, nautiloids, brachiopods), palaeoniscoid fish, sharks, fish coprolites, protozoans (foraminiferans, radiolarians), petrified wood, palynomorphs (spores, acritarchs), non-marine trace fossils (especially arthropods, fish, also various "worm" burrows), possible stromatolites, oolites.	Transition from marine to brackish salinities early in history of epicontinental Ecca Sea. Marine body fossils rare (e.g. Douglas area). Biogenic origin of "stromatolites" within carbonate rocks needs confirmation.
		Carboniferous		DWYKA (C-Pd)		Mbizane (Pmb)		Tillite, massive and stratified diamictite, massive carbonate-enriched diamictite, conglomerate, sandstone and mudstone facies. Glacial deposits in a marine environment.	Most of the fossils recorded from the mudstone facies and include spores, polen, plant remains, arthropod trackways and fish trails have been recorded.	
		Devonian								
		Silurian								
		Ordovician								
		Cambrian								
PROTEROZOIC	Namibian		INTRUSIVE ROCKS (N)			Holfontein Dolerite (Nh)		Dolerite	No fossils recorded	
	Mokolian		MOKOLIAN INTRUSIONS Mpi (pale green) Pienaars River Complex Mdw (green) Dwarsfontein Complex Mka Kaffirskraal Complex Mdi – diabase dykes	F(purple); Ma; s; di; Mk; Mm; Mn; Mr				Various igneous intrusives Middle Proterozoic	No fossils recorded. Some of these intrusions are related to the Pilansberg Alkaline Province	
	Vaalian		PROTEROZOIC IGNEOUS INTRUSIONS MAFIC INTRUSIONS Diabase (Vdi; V-di) GRANITOID INTRUSIONS Baviaanskranz (Vbk) Schurwedraai ((Vsg)			Winddam wehrlite (Vw), Vbg, Vdi, Vbd (Ve; Vhy; Vq; Vbk; Vsg)		Intrusive igneous rocks. Diabase and granitoids	No fossils recorded	
			TRANSVAAL	PRETORIA		Magaliesberg (Vmg)(Vlm)		Coastal sandstones with mudrocks	Microbial mat structures (Desiccated mats sometimes resemble trace fossils)	ALERT FOR POTENTIALLY FOSSILIFEROUS LATE CAENOZOIC CAVE BRECCIAS WITHIN "TRANSVAAL DOLOMITE" OUTCROP AREA (breccias not individually mapped) Controversial records of 2.2 Ga "trace fossils"
						Silverton (Vsi)		Marine mudrocks with minor carbonates, volcanic rocks (Machadodorp Member)	Stromatolites	
						Daspoort (Vda; Vdp)		Alluvial, fluvial and deltaic sandstones and mudrocks, marine sediments incl. carbonates in east	Stromatolites.	
						Strubenkop (Vs; Vst)		Shale and tuff	No fossils recorded	
						Dwaalheuwel (Vdw, Vhd)		Alluvial sandstones; conglomerates and mudrocks	No fossils recorded	
						Hekpoort (Vh)		Volcanics (basalts, pyroclastics) with minor lacustrine shales	No fossils recorded	
						Boshoek (Vb)		Sandstones, conglomerats, diamictite (alluvial fans, slumps)	No fossils recorded	
						Timeball Hill (Vt; Vti)	Klapperkop (Vkp)	Lacustrine and fluvio-deltaic mudrocks with diamictite, conglomerates, quartzite, minor lavas	Stromatolites.	
						Rooihoogte (Vt)		Basal breccio-conglomerates, quartzites, mudrocks, carbonates (alluvial fan, lakes, karst infill)	No fossils recorded	
				CHUNIESPOORT	Malmani (Vmz; Vmd)	Littleton (Vl)		Dark, chert poor dolomite	Stromatolites. Range of shallow marine to intertidal stromatolites (domes, columns etc), organic-walled microfossils (e.g. cyanobacteria) in siliciclastics (carbonaceous shales), cherts or carbonates	
						Monte Christo (Vmm; Vmo)		Chert rich, stromatolitic carbonates (limestones / dolomites), minor secondary cherts, mudrocks including carbonaceous shales		
						Oaktree (Vmo; Voa)		Chert poor stromatolitic carbonates (limestones / dolomites), minor secondary cherts, mudrocks including carbonaceous shales		
						Black Reef (Vbr)		Siliciclastic sediments (mature sandstones plus minor mudrocks, conglomerates) deposited during a fluvial to shallow marine transition	Stromatolites. Possible equivalent of Black Reef Fm in N. Cape (Vryburg Formation) contains stromatolitic carbonates	
			INTRUSIVE ROCKS (Ve)			Intrusive rocks (Ve; Vdi; Vhy; Vq)		Metapyroxenite, epidiorite	No fossils recorded	
ARCHAEAN										

EON	ERA	Period	Supergroup/ Sequence	Group	Subgroup	Formation	Member	Lithology	Fossil Heritage	Comments
ARCHAEAN	Randian		VENTERSDORP			Allanridge (Ra)		Predominantly lavas with minor metasediments (fluvial and lacustrine conglomerates, breccias, minor shales, carbonates, cherts)	Possible stromatolites	
						Bothaville (Rb; Rbt)				
				PLATBERG		Ra; Rb; Rm; Rma; Rgb; Rka; Rkm; Rka1; Rka2		Predominantly lavas with minor metasediments (fluvial and lacustrine conglomerates, breccias, minor shales, carbonates, cherts)	Lacustrine stromatolites reported in carbonates,of Rietgat Formation (Platberg Group); possible organic-walled microfossils in cherts. LIP (Large Igneous Province) with voluminous eruptions of basaltic and other lavas. Stromatolites recorded from borehole cores. Any surface occurrences would be of considerable interest.	
						Rietgat (Rr; Rrg; Rrg2)		Predominantly lavas with minor metasediments (fluvial and lacustrine conglomerates, breccias, minor shales, stromatolitic carbonates, cherts)	Lacustrine stromatolites reported in carbonates,of Rietgat Formation (Platberg Group); possible organic-walled microfossils in cherts. LIP (Large Igneous Province) with voluminous eruptions of basaltic and other lavas.	Stromatolites recorded from borehole cores. Any surface occurrences would be of considerable interest.
						Rm; Rgb; Rkm			Possible stromatolites	
				KLIPRIVIERSBERG (Rk)		Rk; Ral; Rmk		Predominantly lavas with minor metasediments (fluvial and lacustrine conglomerates, breccias, minor shales, carbonates, cherts)	Possible stromatolites	
			INTRUSIVE ROCKS (Rs)			Selika Suite (Rs)		Intrusive igneous rocks.	No fossils recorded	
			WITWATERSRAND (Rw)	CENTRAL RAND	Turffontein (Rt)	Klerksdorp (Rkl) Elsburg (Re)		Mainly quartzites conglomerates (braided fluvial), pyritic sands, minor shales, volcanics, debris-flow diamictites	Thin layers of carbonaceous material (kerogen / bitumen) possibly represent ancient microbial mats, but this material probably has an abiogenic origin (e.g. precipitation of inorganic carbon due to irradiation by radioactive uranium minerals) Main source of Wits gold (beds of quartzose, pyritic fluvial conglomerates or "banket" that are known as "reefs"). Evidence for earliest known glaciations on Earth (Government Subgroup (Rg))	
						Booyens (Rbo)		Shale		
					Johannesburg (Rjo)			Mainly quartzites conglomerates (braided fluvial), pyritic sands, minor shales, volcanics, debris-flow diamictites		
				WEST RAND	Rj; Rg; Rh	Rc; Ro; Ror;		Marine shelf quartzites, shales, rare conglomerates, banded iron formation (BIF), volcanics, fluvial sediments, several diamictites		
				DOMINION (Rd)				Highly-metamorphosed volcanics (mafic / intermediate / felsic) and minor clastic sediments (palaeosols, braided fluvial seds). Thin outcrop area at base of Wits succession. 3.074 Ga Archaean	No fossils recorded	
			NEOARCHAEAN TO MESOPROTEROZOIC MAFIC ULTRAMAFIC INTRUSIONS N.B. Not marked on 1: million map			Rs		Sills, dykes in core and collar of Vredefort Dome Diorites, dolerites, gabbros etc	No fossils recorded	
	Swazian		VREDEFORD DOME	PARYS GRANITE (Zp)				Granite gneiss, impact related granitoids (granofels) in core of major impact structure, relicts of highly metamorphosed volcano-sedimentary succession Including impact melts (Vredefort Granophyre 2.023 Ga)	No fossils recorded	
						Blaauboschpoort (Zb)				
				INLANDSEE GNEISS (Zi)						
						Steynskraal (Zs)				
				ARCHAEN GRANITE GNEISS (ZA) ; 223						