PALAEONTOLOGICAL DESKTOP STUDY

Proposed Mainstream wind farm near Prieska, Pixley ka Seme District Municipality, Northern Cape Province

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June 2011

EXECUTIVE SUMMARY

The Mainstream Prieska wind farm study area to the southeast of Copperton, Northern Cape Province, is largely underlain by glacially-related sediments of the Dwyka Group (Karoo Supergroup) that are of Late Carboniferous to Early Permian age. Although interglacial mudrocks within the Dwyka beds elsewhere in the Northern Cape have yielded important fossil remains of fish, marine invertebrates, trace fossils, petrified wood as well as various microfossil taxa, much of the succession consists of essentially unfossiliferous tillites. Substantial portions of the study area are mantled in various types of Late Caenozoic superficial deposits – such as calcretes, surface gravels, alluvium and windblown sands - that are very sparsely fossiliferous at most. Small inliers of Precambrian basement rocks are generally highly metamorphosed or igneous intrusions and do not contain any fossils. The overall palaeontological sensitivity of the study area as a whole is therefore low to very low. It is concluded that the proposed Mainstream Prieska wind farm development is unlikely to pose a substantial threat to local fossil heritage. The impact significance of this project as far as palaeontological heritage is concerned is rated as LOW (negative). Therefore, pending the discovery of significant new fossil material here, no further specialist studies are considered to be necessary.

It is recommended that:

- The ECO responsible for the development should be aware of the possibility of important fossils being present or unearthed on site and should monitor all substantial excavations into fresh (*i.e.* unweathered) sedimentary bedrock for fossil remains;

- In the case of any significant fossil finds (*e.g.* vertebrate teeth, bones, burrows, petrified wood) during construction, these should be safeguarded - preferably *in situ* - and reported by the ECO as soon as possible to the relevant heritage management authority (SAHRA) so that any appropriate mitigation by a palaeontological specialist can be considered and implemented, at the developer’s expense;

- These recommendations should be incorporated into the EMP for the Mainstream Prieska wind farm project.

All specialist palaeontological work would have to conform to international best practice for palaeontological fieldwork (*e.g.* data recording, fossil collection and curation, reporting) and as far as possible should adhere to the minimum standards for palaeontological studies currently being developed by SAHRA.

1. INTRODUCTION & BRIEF

The company Mainstream Renewable Power is proposing to develop a series of three wind farms in the Northern Cape Province at sites near Noupoort, Prieska and Loeriesfontein. The size of each wind farm has yet to be determined and will be dependent on the size of the connection into the Eskom Grid. The present desktop report represents a scoping level study of palaeontological heritage within the Prieska wind farm study area and has been commissioned on behalf of the client by SIVEST Environmental Division, Johannesburg. Their contact details are:

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While technical details of the proposed wind farm development have yet to be finalized, for the most part these will not affect the main conclusions drawn from the present desktop study which is based on a broad palaeontological heritage assessment of the entire development area.

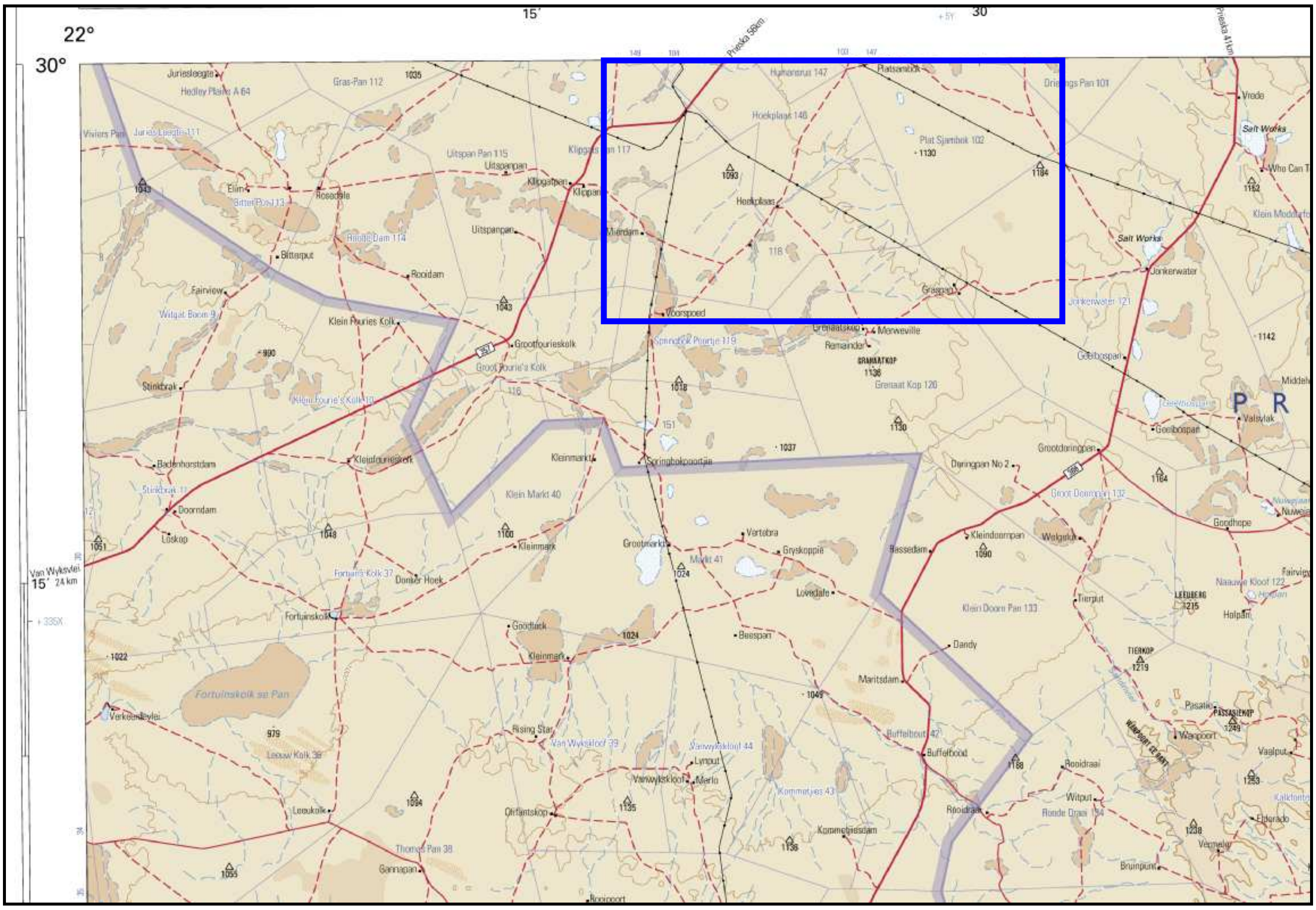


Figure 1: Extract from 1: 250 000 topographical map 3022 Britstown (Courtesy of The Chief Directorate of Surveys & Mapping, Mowbray) showing the *approximate* location of the proposed Mainstream wind farm c. 60 km southwest of Prieska and 12-20 km southeast of Copperton, Northern Cape (blue rectangle).

Figure 2: Google Earth satellite image of the study area to the southeast of the prieska CopperMine at Copperton showing the generally low, hilly relief and arid semi-desert setting. The prominent white line in the northwest is the R357 secondary road between Prieska and Van Wyks Vlei. Grey areas are Precambrian basement rocks and Dwyka Group tillites. Reddish areas are aeolian sands and alluvium.

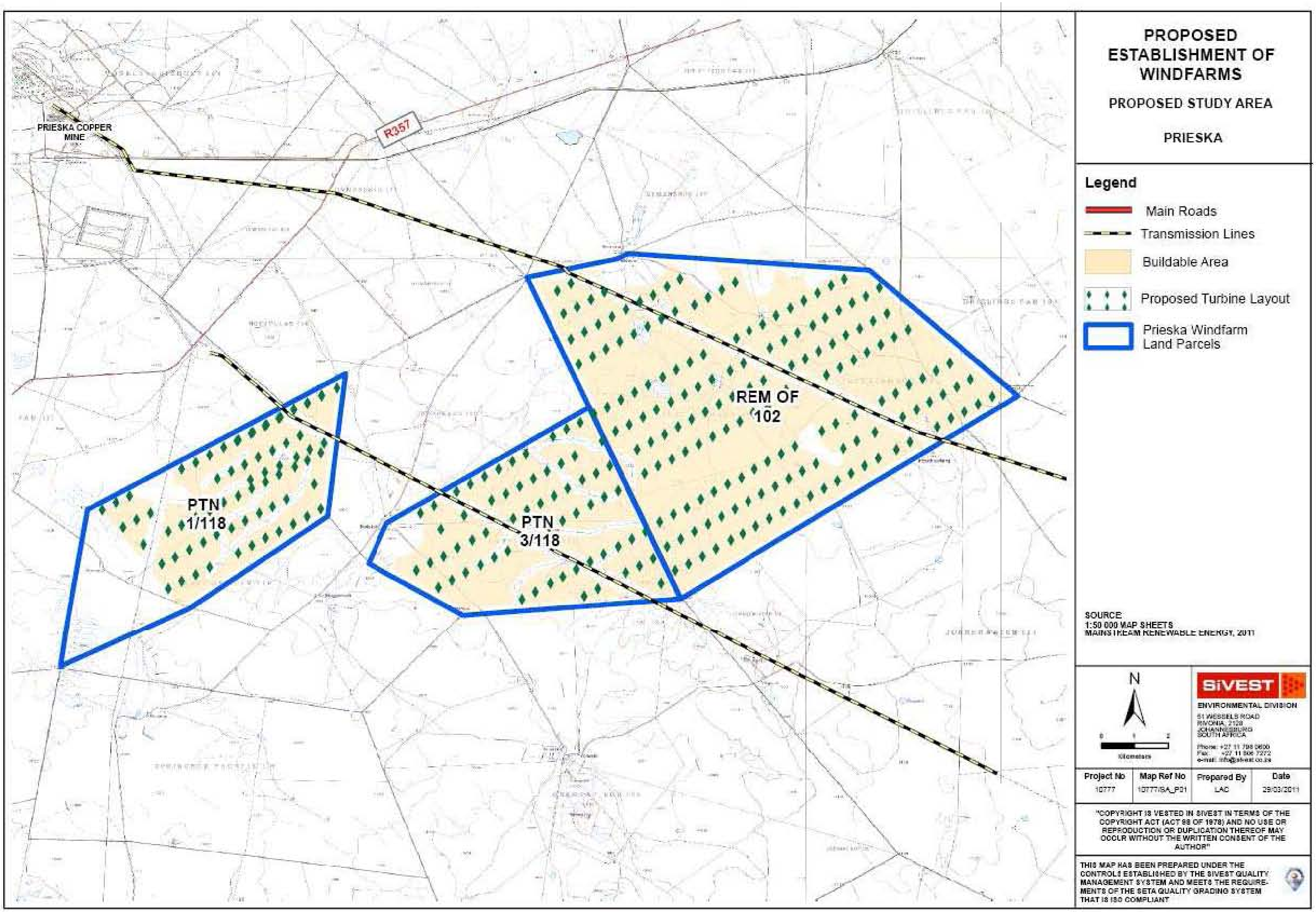
1.1. Location and extent of study area

The Mainstream wind farm study area is situated in a semi-arid desert region some 60 km southwest Prieska and 12 to 20 km southeast of the Prieska Copper Mine at Copperton, greater Pixley ka Seme District Municipality, Northern Cape Province (Figs. 1 and 2). The study area lies on the northern margin of sheet 3022 Britstown and consists of two separate sections (Fig. 3). It is approximately 12 980 hectares in size and comprises the following land parcels:

- **Remainder of the Farm Plat Sjambok No.102, Prieska** (7 238.42 hectares);
- **Portion 1 of the Farm Kaffirs Kolk No. 118, Prieska** (2 883.96 hectares);
- **Portion 3 of the Farm Kaffirs Kolk No. 118, Prieska** (2 857.40 hectares).

The boundaries of the western and eastern sections of the study area together with a provisional layout of the wind turbines are shown in map Fig. 3, kindly provided by SIVEST Environmental Division.

Figure 3 (following page): Map of the proposed Mainstream Prieska wind farm near Copperton showing boundaries of the land parcels concerned and a provisional wind turbine layout (Image kindly provided by SIVEST Environmental Division).


PROPOSED ESTABLISHMENT OF WINDFARMS
PROPOSED STUDY AREA
PRIESKA
Legend
Main Roads
Transmission Lines
Buildable Area
Proposed Turbine Layout
Prieska Windfarm Land Parcels
PRIESKA COPPER MINE
R357
REM OF 102
PTN 1/118
PTN 3/118
SOURCE:
1:50 000 MAP SHEETS
MAINSTREAM RENEWABLE ENERGY, 2011
N
SiVEST
ENVIRONMENTAL DIVISION
51 WESSELS ROAD
RIVONIA, 2128
JOHANNESBURG
SOUTH AFRICA
Project No
10777
Map Ref No
10777/SA_P01
Prepared By
LAC
Date
29/03/2011
"COPYRIGHT IS VESTED IN SIVEST IN TERMS OF THE COPYRIGHT ACT (ACT 98 OF 1978) AND NO USE OR REPRODUCTION OR DUPLICATION THEREOF MAY OCCUR WITHOUT THE WRITTEN CONSENT OF THE AUTHOR"
THIS MAP HAS BEEN PREPARED UNDER THE CONTROLS ESTABLISHED BY THE SIVEST QUALITY MANAGEMENT SYSTEM AND MEETS THE REQUIREMENTS OF THE SETA QUALITY GRADING SYSTEM THAT IS ISO COMPLIANT

1.2. Outline of proposed development project

As outlined in the provisional project description by SIVEST each of the three proposed Mainstream wind farms in the Northern Cape will include the following major components:

- **Wind Turbines:** The turbines have a hub height of 60-120 m and a rotor diameter of 70-130m. They will be connected to each other and to the substation using underground (1 m deep) medium voltage cables except where a technical assessment of the proposed design suggests that overhead lines are appropriate such as over rivers and gullies.

- **Access Roads:** These will be 10 m wide gravel roads from the site onto the public road. An internal road network to the turbines and other infrastructure will include turning circles for large trucks, passing points and culverts over gullies and rivers. Existing roads will be upgraded.

- **Power lines & electrical substation:** Depending on the size of the site, the power capacity limit, as well as the number of wind turbines to be accommodated, the transmission lines could have a voltage of 66 kV (smaller wind farms) or 132 kV (larger wind farms). In Prieska, both connection points exist and one option for the 30 MW project will be breaking the 66 kV line crossing the site. A new substation (approx. 90 x 120 m) and a transformer to the existing 132 kV and 66 kV Eskom grid will be built, preferably close to the transmission lines. The connection from the substation to the Eskom grid line will be an overhead line and pole. Its length will be dependent on the location of the substation relative to the 66 kV and/or 132 kV line.

- **Wind farm control room:** The operations and maintenance building will be single storey, of maximum area 5,000 m^2, with warehouse / workshop space and access, office, telecoms space, security and ablution facilities as required. These should be situated preferably close to the substation.

- **Other infrastructure:** This includes fencing, if required, as well as a permanent wind measuring mast of 70 m – 100 m height.

- **Temporary construction lay-down area:** A 10,000 m^2 lay-down area will consist of an access route and a 2,250 m^2 compound for the installation of turbines, including an office for all contractors.

1.3. Potential implications of this project for fossil heritage

The proposed Mainstream wind farm to the southeast of Copperton is located in an area of Bushmanland that is underlain by potentially fossiliferous sedimentary rocks of the Dwyka Group (Karoo Supergroup) that are of Permocarboniferous age. The construction phase of the development will entail substantial excavations into the superficial sediment cover (soils *etc*) and also into the underlying bedrock. These include excavations for the turbine foundations, buried cables (*c*. 1 m deep), any new gravel roads and transmission line pylons. In addition, sizeable areas of bedrock may be sealed-in or sterilized by associated infrastructure such as any hard standing areas for the wind turbines, a large lay-down area (this is temporary, however), ancillary buildings (*e.g.* an operations and maintenance building) as well as the new gravel road system. All these developments may adversely affect potential fossil heritage within the study area by destroying, disturbing or permanently sealing-in fossils that are then no longer available for scientific research or other public good. Once constructed, the operational and decommissioning phases of the wind energy facility will not involve further adverse impacts on palaeontological heritage.

1.4. Scope of work

The Scope of Work for this scoping level desktop study of palaeontological resources within the wind farm study area has been defined by SIVEST (Environmental Division). The report is to be based on:

1. An analysis of the stratigraphy, age and depositional setting of fossil-bearing units;
2. A review of all relevant palaeontological and geological literature, including geological maps, and previous palaeontological impact reports;
3. Data on the proposed development provided by the developer (*e.g.* location of footprint, depth and volume of bedrock excavation envisaged);
4. Where feasible, location and examination of any fossil collections from the study area (*e.g.* museums).

The scoping level report is to include the following:

1. An outline of the development project;
2. An outline of the relevant legislation;
3. An illustrated, fully-referenced review of palaeontological heritage within study area;
4. Identification and ranking of highlights and sensitivities to development of fossil heritage within the study area;
5. Specific recommendations for further palaeontological mitigation (if any);
6. Recommendations and suggestions regarding fossil heritage management on site, including conservation measures as well as promotion of local fossil heritage (*e.g.* for public education, schools)
7. An outline of experience of heritage practitioner and statement of independence.

1.5. Approach to this study

The present report represents a scoping level desktop study of palaeontological heritage within the Mainstream Prieska wind farm study area. This development falls under Section 38 (Heritage Resources Management) of the South African Heritage Resources Act (Act No. 25 of 1999). The various categories of heritage resources recognised as part of the National Estate in Section 3 of the Heritage Resources Act include, among others:

- geological sites of scientific or cultural importance
- palaeontological sites
- palaeontological objects and material, meteorites and rare geological specimens

Minimum standards for the palaeontological component of heritage impact assessment reports are currently being developed by SAHRA. The latest version of the SAHRA guidelines is dated May 2007.

This palaeontological specialist report provides an assessment of the observed or inferred palaeontological heritage within the study area, with recommendations for specialist palaeontological mitigation where this is considered necessary. The report is based on (1) a review of the relevant scientific literature, (2) published geological maps and accompanying sheet explanations, (3) previous palaeontological impact assessments in the Prieska region by the author, as well as (4) the author's extensive field experience with the formations concerned and their palaeontological heritage.

In preparing a palaeontological desktop study the potentially fossiliferous rock units (groups, formations *etc*) represented within the study area are determined from geological maps. The known fossil heritage within each rock unit is inventoried from the published scientific literature, previous palaeontological impact studies in the same region, and the author's field experience (Consultation with professional colleagues as well as examination of institutional fossil collections may play a role here, or later following fieldwork during the compilation of the final report). This data is then used to assess the palaeontological sensitivity of each rock unit to development (Provisional tabulations of palaeontological sensitivity of all formations in the Western, Eastern and Northern Cape have already been compiled by J. Almond and colleagues; *e.g.* Almond & Pether 2008). The likely impact of the proposed development on local fossil heritage is then determined on the basis of (1) the palaeontological sensitivity of the rock units concerned and (2) the nature and scale of the development itself, most notably the extent of fresh bedrock excavation envisaged. When rock units of moderate to high palaeontological sensitivity are present within the development footprint, a field-based assessment by a professional palaeontologist is usually warranted.

1.6. Assumptions and limitations

The accuracy and reliability of palaeontological specialist studies as components of heritage impact assessments are generally limited by the following constraints:

1. Inadequate database for fossil heritage for much of the RSA, given the large size of the country and the small number of professional palaeontologists carrying out fieldwork here. Most development study areas have *never* been surveyed by a palaeontologist.

2. Variable accuracy of geological maps which underpin these desktop studies. For large areas of terrain these maps are largely based on aerial photographs alone, without ground-truthing. The maps generally depict only significant ("mappable") bedrock units as well as major areas of superficial "drift" deposits (alluvium, colluvium) but for most regions give little or no idea of the level of bedrock outcrop, depth of superficial cover (soil *etc*), degree of bedrock weathering or levels of small-scale tectonic deformation, such as cleavage. All of these factors may have a major influence on the impact significance of a given development on fossil heritage and can only be reliably assessed in the field.

3. Inadequate sheet explanations for geological maps, with little or no attention paid to palaeontological issues in many cases, including poor locality information.

4. The extensive relevant palaeontological "grey literature" - in the form of unpublished university theses, impact studies and other reports (*e.g*. of commercial mining companies) - that is not readily available for desktop studies.

5. Absence of a comprehensive computerized database of fossil collections in major RSA institutions which can be consulted for impact studies. A Karoo fossil vertebrate database is now accessible for impact study work, however.

In the case of palaeontological desktop studies without supporting field assessments these limitations may variously lead to either:

(a) *underestimation* of the palaeontological significance of a given study area due to ignorance of significant recorded or unrecorded fossils preserved there, or…

(b) *overestimation* of the palaeontological sensitivity of a study area, for example when originally rich fossil assemblages inferred from geological maps have in fact been destroyed by tectonism or weathering, or are buried beneath a thick mantle of unfossiliferous "drift" (soil, alluvium *etc*).

Since most areas of the RSA have not been studied palaeontologically, a palaeontological desktop study usually entails *inferring* the presence of buried fossil heritage within the study area from relevant fossil data collected from similar or the same rock units elsewhere, sometimes at localities far away. Where substantial exposures of bedrocks or potentially fossiliferous superficial sediments are present in the study area, the reliability of a palaeontological impact assessment may be significantly enhanced through field assessment by a professional palaeontologist.

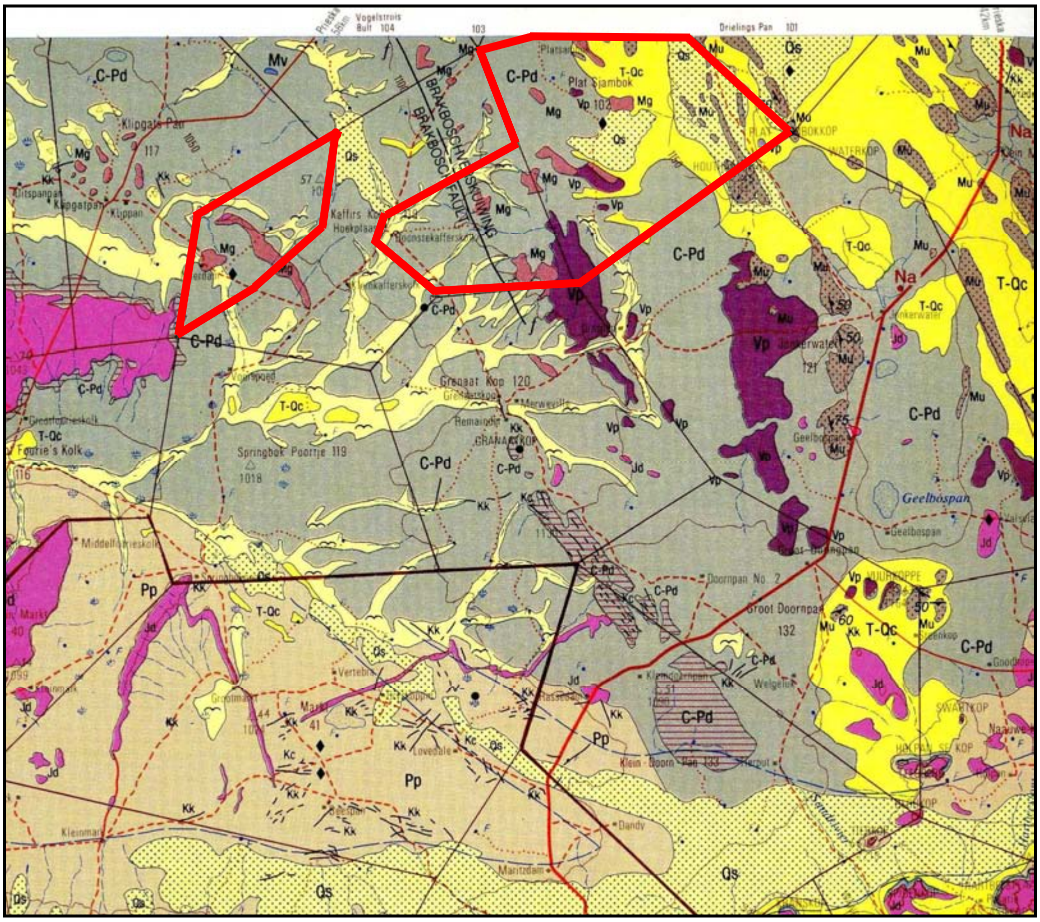


Figure 4: Extract from the 1: 250 000 geology sheet 3022 Britstown (Council for Geoscience, Pretoria) showing the *approximate* outline of the two separate sections of the wind farm study area to the southeast of Copperton (red polygons).

The main geological units represented here are:

PRECAMBRIAN BASEMENT (NAMAQUA-NATAL METAMORPHIC PROVINCE)

Mu (grey with dots) = Uitdrai Formation (Brulpan Group)
Vp (purple) = Spioenkop Formation (Marydale Group)
Mg (reddish-brown) = unnamed igneous rocks

PERMOCARBONIFEROUS DWYKA GROUP

C-Pd (grey) Mbizane Formation

LATE CAENOZOIC SUPERFICIAL DEPOSITS

T-Qc (yellow) = calcretes
pale yellow with "flying bird" symbol = alluvium
Qs (pale yellow with dots) = aeolian (wind-blown) sands (Gordonia Formation, Kalahari Group)

2. GEOLOGICAL BACKGROUND

Satellite images (Fig. 2) as well as 1: 50 000 topographical maps (3022AB Springbokportjie, 3022BA Jonkerwater) show that the Mainstream wind farm study area comprises broadly flat-lying, terrain lying at *c*. 1000 to 1100 m amsl with numerous low *koppies* and rocky ridges. This region forms part of the low-relief Kaiingveld of eastern Bushmanland. Drainage is limited to small, intermittently active streams and pans. In the western sector there is a net flow towards the west into old Tertiary drainage systems rather than the Orange River to the north.

The geology of the study area southeast of Copperton is shown on 1: 250 000 sheet 3022 Britstown (Council for Geoscience, Pretoria) (Fig. 4). In addition to the relevant sheet explanation by Prinsloo (1989) the geotechnical report by Bok (2011) also provides useful geological information. There is as yet no sheet explanation published for the 1: 250 000 Prieska sheet that borders the northern edge of the wind farm study area.

2.1. Precambrian basement rocks

The oldest rocks within the study area are various small, isolated inliers of Early to Late Precambrian (Archaean to Proterozoic) high grade metamorphic and intrusive igneous rocks belonging to the **Namaqua-Natal Metamorphic Province**. They include outcrops of (1) schists and quartzites of the **Uitdraai Formation** (**Mu**) within the **Brulpan Group**; (2) various Archaean (> 2.5 Ga) metamorphic rocks of the **Spioenkop Formation** (**Vp**) within the **Marydale Group**; and various unnamed granites, gabbros and pegmatites of ill-defined Mokolian age (*i.e.* Mid Proterozoic, between 1000 and 2050 Ma) that are indicated on the map as **Mg** (Prinsloo 1989, Slabbert *et al.* 1999, Potgieter & Botha 1982, Brandl *et al.* 2006, Cornell *et al.* 2006). These basement rocks were last metamorphosed some one billion or so years ago (1 – 1.2 Ga) and since they are entirely unfossiliferous they will not be considered further here.

2.2. Permocarboniferous Dwyka Group

The greater part of the study area by far is underlain by glacially-related sediments of the **Dwyka Group** (Karoo Supergroup) of Permocarboniferous age (**C-Pd**). The geology of the Dwyka Group has been summarized by Visser (1989), Visser *et al.* (1990) and Johnson *et al.* (2006), among others. The Dwyka Group sediments along the north-western margin of the Main Karoo Basin in particular have been reviewed by Visser (1985). In Dwyka times the Prieska – Copperton area lay within a basement high region between the Sout River Valley in the west and the Prieska Basin in the east. This area is referred to as the Kaiing Hills or Kaiing Veld Region by Visser and is characterized by a relatively thin Dwyka succession (normally < 50m). This mainly comprises massive clast-rich diamictites and clast–poor argillaceous diamictites (“boulder shale”) overlain by a thin zone of laminated dropstone argillite with outsized clasts composed mainly of quartzite and gneiss (Visser 1985 and Figs. 5 and 6 herein). Note the presence of an isolated peak (monadnock) of Proterozoic basement rocks to the southeast of Copperton shown in Fig. 5. Ice transport directions initially towards the south and later towards the southwest are reconstructed by Visser (1985, his fig. 17).

Detailed observations by Prinsloo (1989) on the Dwyka beds on the northern edge of the Britstown 1: 250 000 sheet are relevant to the Copperton study area. Good surface outcrops of the Dwyka beds are rare here due to extensive cover by thin surface gravels. Massive tillites at the base of the Dwyka succession were deposited by dry-based ice sheets in deeper basement valleys. Later climatic amelioration led to melting, marine transgression and the retreat of the icesheets onto the continental highlands in the north. The valleys were then occupied by marine inlets within which drifting glaciers deposited dropstones onto the muddy sea bed (“boulder shales”). The upper Dwyka beds are typically heterolithic, with shales, siltstones and fine-grained sandstones of deltaic and / or turbiditic origin. These upper successions are typically upwards-coarsening and show extensive soft-sediment deformation (loading and slumping). Varved (rhythmically laminated) mudrocks with gritty to fine gravely dropstones indicate the onset of highly seasonal climates, with warmer intervals leading occasionally even to limestone precipitation.

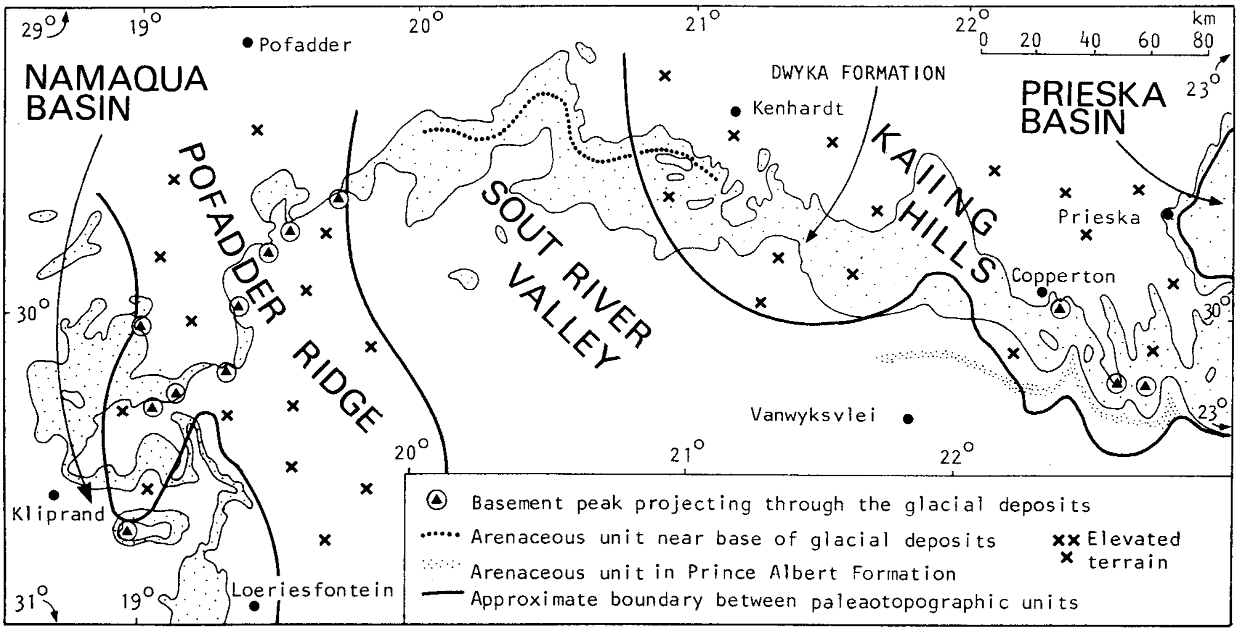


Figure 5: Reconstruction of the topography along the northern margin of the Karoo Basin in Dwyka times showing location of the Prieska-Copperton area on a basement high (From Visser 1985).

According to maps in Visser *et al.* (1990) and Von Brunn and Visser (1999) the Dwyka rocks in the Prieska-Copperton area close to the northern edge of the Main Karoo Basin belong to the **Mbizane Formation**. This is equivalent to the Northern (valley and inlet) Facies of Visser *et al*. (1990). The Mbizane Formation, up to 190m thick, is recognized across the entire northern margin of the Main Karoo Basin where it may variously form the whole or (as here) only the *upper* part of the Dwyka succession. It is characterized by its extremely heterolithic nature, with marked vertical and horizontal facies variation (Von Brunn & Visser 1999). The proportion of diamictite and mudrock is often low, the former often confined to basement depressions. Orange-tinted sandstones (often structureless or displaying extensive soft-sediment deformation, amalgamation and mass flow processes) may dominate the succession. The Mbizane-type heterolithic successions characterize the thicker Dwyka of the ancient palaeovalleys cutting back into the northern basement rocks.

Levels of tectonic deformation in the Copperton study region are generally low; no bedding dips are indicated on the geological map but the eastern section of the study area is traversed by the major NNW-SSE trending Brackbosch Fault (Fig. 4).

The Dwyka tillites and mudrocks are generally recessive weathering, generating landscapes of low relief that typify much of the Bushmanland region. Outside and to the west of the study area the Dwyka Group rocks are intruded by Early Jurassic (183 ± 2 Ma) igneous intrusions of the **Karoo Dolerite Suite** (**Jd**) (Duncan & Marsh 2006). The basic sills and dykes will have thermally metamorphosed or baked the adjacent Dwyka country rocks.

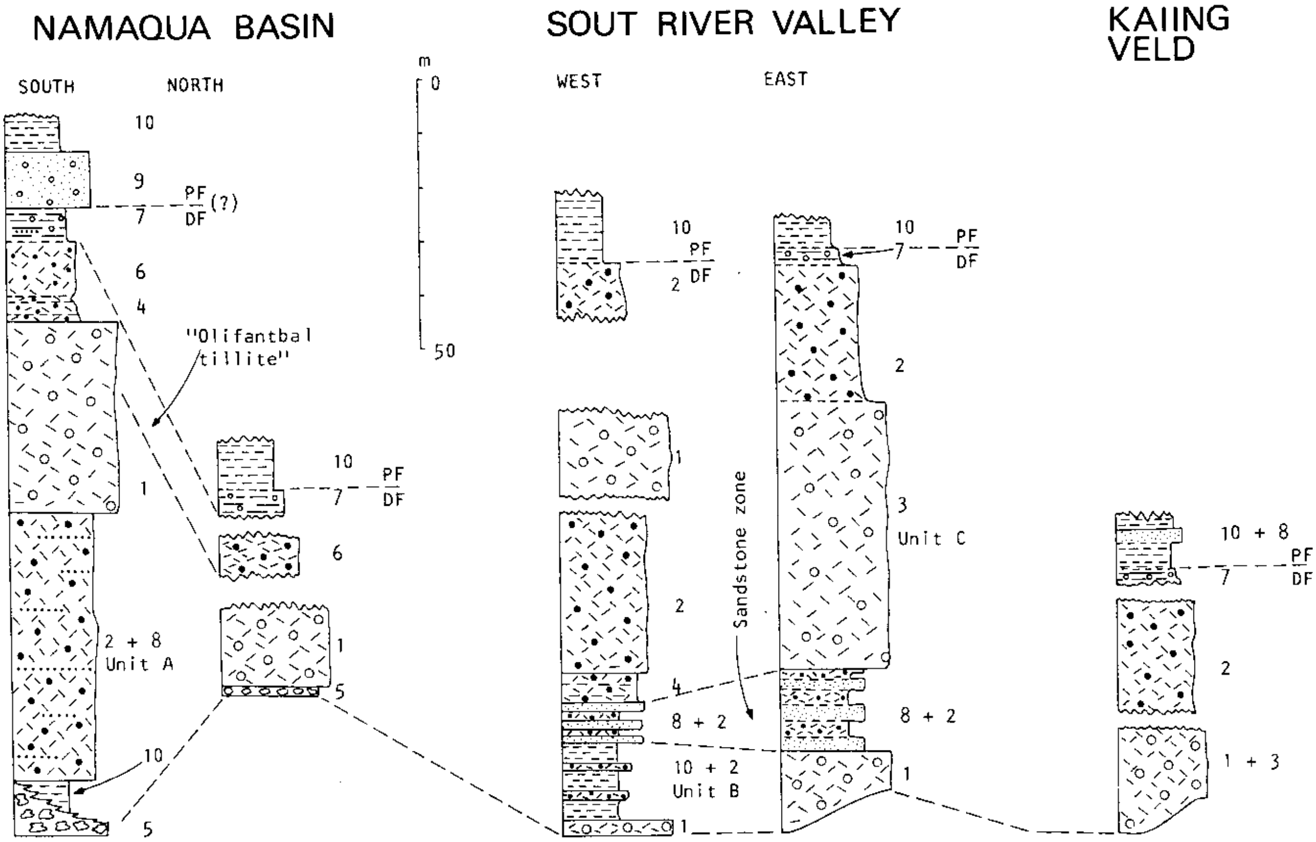


Figure 2

Regional stratigraphic sequences of the Dwyka Formation between Loeriesfontein and the Doringberg Range with the lithofacies indicated by numbers. 1. Massive clast-rich arenaceous diamictite. 2. Massive clast-poor argillaceous diamictite ("boulder shale"). 3. Massive diamictite (undifferentiated). 4. Bedded diamictite. 5. Brecciated basement rocks (local tillite). 6. Massive carbonate-rich diamictite ("olifantbal tillite"). 7. Dropstone argillite ("varved shale"). 8. Fine- to coarse-grained sandstone. 9. Pebbly sandstone. 10. Dark grey to black, micaceous shale and mudstone. Lithological units numbered A, B, and C will be referred to in the text. DF = Dwyka Formation, PF = Prince Albert Formation (see Fig. 1 for location of regions).

Figure 6: Stratigraphic logs through the Dwyka Group along the northern margin of the Main Karoo Basin. The short Kaaing Veld log on the RHS, dominated by diamictite facies, is most relevant to the Copperton area (From Visser 1985).

2.3. Late Caenozoic superficial deposits

In many areas the Precambrian and Palaeozoic bedrocks are mantled with a variety of **superficial deposits** or "drift", most of which are unconsolidated and are probably of Late Caenozoic (Quaternary to Recent) age (Prinsloo 1989, Slabbert *et al.*1999). The drift units shown on the 1: 250 000 geological map include (1) a range of Late Tertiary to Recent **calcretes** (pedogenic limestones) that typically form from carbonate-rich groundwaters in semi-arid climates, for example in the neighbourhood of the Dwyka tillite and dolerite intrusions; (2) gravelly to silty **alluvium** associated with ephemeral water courses and pans, as well as (3) patches of wind-blown or aeolian sands which have been assigned by some authors to the **Gordonia Formation** of the **Kalahari Group** (**Qs**). In addition, a thin mantle of surface gravels – many downwasted from the Dwyka Group – covers large areas of Precambrian and Palaeozoic bedrock.

The geology of the Late Cretaceous to Recent Kalahari Group is reviewed by Thomas (1981), Dingle *et al.* (1983), Thomas & Shaw 1991, Haddon (2000) and Partridge *et al.* (2006). The Gordonia Formation dune sands are considered to range in age from the Late Pliocene / Early Pleistocene, dated in part from enclosed Middle to Late Stone Age stone tools (Dingle *et al*., 1983, p. 291). Note that the recent extension of the Pliocene - Pleistocene boundary from 1.8Ma back to 2.588 Ma would place the Gordonia Formation entirely within the Pleistocene Epoch. The thickness of the Kalahari sands in the study region is uncertain. At the latitude of Copperton (*c*. 30° S) Gordonia Formation sands less than 30m thick are likely to be the main or perhaps only

Kalahari sediments present (*cf* isopach map of the Kalahari Group, fig. 6 *in* Partridge *et al*., 2006). These unconsolidated sands might be locally underlain by thin surface gravels equivalent to the Obobogorop Formation, formed from down-wasted (residual) or water-transported clasts weathered out of the Dwyka tillites, as well as by calcretes of Pleistocene age or younger (*cf* Mokalanen Formation).

3. PALAEONTOLOGICAL HERITAGE

The fossil heritage within each of the major sedimentary rock units that are represented within the Noupoort wind farm study area is outlined here. Note that the Precambrian metamorphic and igneous basement rocks are entirely unfossiliferous and are not considered further here.

3.1. Fossil heritage within the Dwyka Group

The generally poor fossil record of the Dwyka Group (McLachlan & Anderson 1973, Anderson & McLachlan 1976, Visser 1989, Visser *et al*., 1990, Visser 2003, Almond & Pether 2008) is hardly surprising given the glacial climates that prevailed during much of the Late Carboniferous to Permian Periods in southern Africa. However, most Dwyka sediments were deposited during periods of glacial retreat associated with climatic amelioration. Sparse, low diversity fossil biotas from the Mbizane Formation in particular mainly consist of arthropod trackways associated with dropstone laminites and sporadic vascular plant remains, while palynomorphs (organic-walled microfossils) are also likely to be present within finer-grained mudrock facies. Glacial diamictites (tillites or "boulder mudstones") are normally unfossiliferous but do occasionally contain fragmentary transported plant material as well as palynomorphs in the fine-grained matrix. There are interesting records of limestone glacial erratics from tillites along the southern margins of the Great Karoo (Elandsvlei Formation) that contain Cambrian eodiscid trilobites as well as archaeocyathid sponges. Such derived fossils provide important data for reconstructing the movement of Gondwana ice sheets (Cooper & Oosthuizen 1974, Stone & Thompson 2005).

A limited range of marine fossils are associated with the later phases of several of the four main Dwyka deglaciation cycles (DSI to DSIV), especially in the Kalahari Basin of southern Namibia but also in some cases within the Main Karoo Basin in South Africa (Oelofsen 1986, Visser 1989, 1997, Visser *et al*. 1997, Bangert *et al*. 1999, Stollhofen *et al*. 2000, Almond 2008). These deglaciation sequences are estimated to have lasted five to seven million years on average (Bangert *et al*. 1999). A range of stenohaline (*i.e.* exclusively salt water) invertebrate fossils indicates that fully marine salinities prevailed at the end of each sequence, at least in the western outcrop area (Namibia, Northern Cape). These invertebrates include echinoderms (starfish, crinoids, echinoids), cephalopods (nautiloids, goniatites), articulate brachiopods, bryozoans, foraminiferans, and conulariids, among others. Primitive bony fish (palaeoniscoids), spiral "coprolites" attributable to sharks or eurypterids, as well as wood and trace fossils are also recorded from mudrock facies at the tops of DSII (Ganikobis Shale Member), DS III (Hardap Member) and DSIV (Nossob Shale Member, as well as base of the Prince Albert Formation (Ecca Group) in southern Namibia and, in the last case at least, in the Northern Cape near Douglas (McLachlan and Anderson 1973, Veevers *et al*. 1994, Grill 1997, Bangert *et al*. 1999, Pickford & Senut 2002, Evans 2005). The Ganikobis (DSII) fauna has been radiometrically dated to *c*. 300 Ma, or end-Carboniferous (Gzhelian), while the Hardap fauna (DSIII) is correlated with the *Eurydesma* transgression of earliest Permian age (Asselian) that can be widely picked up across Gondwana (Dickens 1961, 1984, Bangert *et al*. 1999, Stollhofen *et al*. 2000). The distinctive thick-shelled bivalve *Eurydesma*, well known from the Dwyka of southern Namibia, has not yet been recorded from the main Karoo Basin, however (McLachlan and Anderson 1973). The upper part of DSIV, just above the Dwyka / Ecca boundary in the western Karoo Basin (*i.e.* situated within the basal Prince Albert Formation), has been radiometrically dated to 290-288 Ma (Stollhofen *et al*. 2000).

Low diversity ichnoassemblages dominated by non-marine arthropod trackways are widely associated with cold water periglacial mudrocks, including dropstone laminites, within the Mbizane Formation in the Main Karoo Basin (Von Brunn & Visser, 1999, Savage 1970, 1971, Anderson 1974, 1975, 1976, 1981, Almond 2008, 2009). They are assigned to the non-marine / lacustrine *Mermia* ichnofacies that has been extensively recorded from post-glacial epicontinental seas and large lakes of Permian age across southern Gondwana (Buatois & Mangano 1995, 2004). These Dwyka ichnoassemblages include the arthropod trackways *Maculichna*, *Umfolozia* and *Isopodichnus*, the possible crustacean resting trace *Gluckstadtella*, sinuous fish-fin traces (*Undichna*) as well as various unnamed horizontal burrows. The association of these interglacial or post-glacial ichnoassemblages with rhythmites (interpreted as varvites generated by seasonal ice melt), the absence of stenohaline marine invertebrate remains, and their low diversity suggest a restricted, fresh- or brackish water environment. Herbert and Compton (2007) also inferred a freshwater depositional environment for the Dwyka / Ecca contact beds in the SW Cape based on geochemical analyses of calcareous and phosphatic diagenetic nodules within the upper Elandsvlei and Prince Albert Formations respectively. Well-developed U-shaped burrows of the ichnogenus *Rhizocorallium* are recorded from sandstones interbedded with varved mudrocks within the upper Dwyka Group (Mbizane facies) on the Britstown sheet (Prinsloo 1989; Fig. 7 herein). Similar *Rhizocorallium* traces also described from the Dwyka Group of Namibia (*e.g.*the Hardap Shale Member, Miller 2008). References to occurrences of the complex helical spreiten burrow *Zoophycos* in the Dwyka of the Britstown sheet and elsewhere (*e.g.* Prinsloo 1989) are probably in error, since in Palaeozoic times this was predominantly a shallow marine to estuarine ichnogenus (Seilacher 2007).

Scattered records of fossil vascular plants within the Dwyka Group of the Main Karoo Basin record the early phase of the colonisation of SW Gondwana by members of the *Glossopteris* Flora in the Late Carboniferous (Plumstead 1969, Anderson & McLachlan 1976, Anderson & Anderson 1985 and earlier refs. therein). These records include fragmentary carbonized stems and leaves of the seed ferns *Glossopteris* / *Gangamopteris* and several gymnospermous genera (*e.g. Noeggerathiopsis, Ginkgophyllum*) that are even found within glacial tillites. More “primitive” plant taxa include lycopods (club mosses) and true mosses such as *Dwykea*. It should be noted that the depositional setting (*e.g.* fluvial *versus* glacial) and stratigraphic position of some of these records are contested (cf Anderson & McLachlan 1976). Petrified woods with well-developed seasonal growth rings are recorded from the upper Dwyka Group (Mbizane Formation) of the northern Karoo Basin (*e.g.* Prinsloo 1989) as well as from the latest Carboniferous of southern Namibia. The more abundant Namibian material (*e.g. Megaporoxylon*) has recently received systematic attention (Bangert & Bamford 2001, Bamford 2000, 2004) and is clearly gymnospermous (pycnoxylic, *i.e.* dense woods with narrow rays) but most cannot be assigned to any particular gymnosperm order.

Borehole cores through Dwyka mudrocks have yielded moderately diverse palynomorph assemblages (organic-walled spores, acanthomorph acritarchs) as well as plant cuticles. These mudrocks are interbedded with diamictites in the southern Karoo as well as within Dwyka valley infills along the northern margin of the Main Karoo Basin (McLachlan & Anderson 1973, Anderson 1977, Stapleton 1977, Visser 1989, Anderson & Anderson 1985). Thirty one Dwyka palynomorph species are mentioned by the last authors, for example. Anderson’s (1977) Late Carboniferous to Early Permian Biozone 1 based on Dwyka palynomorph assemblages is characterized by abundant *Microbaculispora*, monosaccate pollens (*e.g. Vestigisporites*) and nontaeniate bisaccate pollens (*e.g. Pityosporites*) (Stephenson 2008). Prinsloo (1989) mentions stromatolitic limestone lenses within the uppermost Dwyka Group in the Britstown sheet area. These may be comparable to interglacial microbial mats and mounds described from the Ganikobis Shale Member (DSII) of southern Namibia by Grill (1997) and Bangert *et al.* (2000).

Although a wide range of fossils are now known from the Dwyka Group, most sediments assigned to this succession are unfossiliferous (with the possible exception of microfossils). The overall palaeontological sensitivity of the Dwyka Group is therefore rated as low (Almond & Pether 2008). Any interglacial mudrocks and heterolithic successions (*i.e.* interbedded sandstones and mudrocks) are worth investigating for fossils, however. Since the Prieska-Copperton area lay on a basement high in Dwyka times (Fig. 4), interglacial mudrocks are unlikely to be well represented here. Late-glacial or post-glacial mudrocks, such as those containing a fairly rich shelly fossil record at Douglas in the Northern Cape (McLachlan & Anderson 1973) have been lost to erosion in the Prieska region.

Figure 7: Large U-burrows of the ichnogenus *Rhizocorallium* in ripple-marked sandstones of the upper Dwyka Group, Britstown sheet area (From Prinsloo, 1989).

3.2. Fossil heritage within the Late Caenozoic superficial deposits

The "drift deposits" of the Karoo and Bushmanland regions of South Africa have been comparatively neglected in palaeontological terms. However, they may occasionally contain important fossil biotas, notably the bones, teeth and horn cores of mammals as well as remains of reptiles like tortoises. Good examples are the Pleistocene mammal faunas at Florisbad, Cornelia and Erfkroon in the Free State and elsewhere (Wells & Cooke 1942, Cooke 1974, Skead 1980, Klein 1984, Brink, J.S. 1987, Bousman *et al.* 1988, Bender & Brink 1992, Brink *et al*. 1995, MacRae 1999, Meadows & Watkeys 1999, Churchill *et al*. 2000 Partridge & Scott 2000). Other late Caenozoic fossil biotas from these superficial deposits include non-marine molluscs (bivalves, gastropods), ostrich egg shells, trace fossils (*e.g.* calcretised termitaria, coprolites), and plant remains such as peats or palynomorphs (pollens, spores) in organic-rich alluvial horizons (Scott 2000) and siliceous diatoms in pan sediments. In Quaternary deposits, fossil remains may be associated with human artefacts such as stone tools and are also of archaeological interest (*e.g.* Smith 1999 and refs. therein). Stone artefacts of Pleistocene and younger age may additionally prove useful in constraining the age of superficial deposits such as gravelly alluvium and pedocretes within which they are occasionally embedded.

The fossil record of the Kalahari Group is generally sparse and low in diversity. The Gordonia Formation dune sands were mainly active during cold, drier intervals of the Pleistocene Epoch that were inimical to most forms of life, apart from hardy, desert-adapted species. Porous dune sands are not generally conducive to fossil preservation. However, mummification of soft tissues may play a role here and migrating lime-rich groundwaters derived from the underlying Dwyka Group may lead to the rapid calcretisation of organic structures such as burrows and root casts. Occasional terrestrial fossil remains that might be expected within this unit include calcretized rhizoliths (root casts) and termitaria (*e..g Hodotermes*, the harvester termite), ostrich egg shells (*Struthio*) and shells of land snails (*e.g. Trigonephrus*) (Almond 2008, Almond & Pether 2008). Other fossil groups such as freshwater bivalves and gastropods (*e.g. Corbula, Unio*) and snails, ostracods (seed shrimps), charophytes (stonework algae), diatoms (microscopic algae within siliceous shells) and stromatolites (laminated microbial limestones) are associated with local watercourses and pans. Microfossils such as diatoms may be blown by wind into nearby dune sands (Du Toit 1954, Dingle *et al*., 1983). These Kalahari fossils (or subfossils) can be expected to occur sporadically but widely, and the overall palaeontological sensitivity of the Gordonia Formation is therefore considered to be low. Underlying calcretes might also contain trace fossils such as rhizoliths, termite and other insect burrows, or even mammalian trackways. Mammalian bones, teeth and horn cores (also tortoise remains, and fish, amphibian or even crocodiles in wetter depositional settings) may be expected occasionally expected within Kalahari Group sediments. However, no fossil records of Pleistocene mammals are listed in the study region in the review by Klein (1984).

4. CONCLUSIONS & RECOMMENDATIONS

The Mainstream Prieska wind farm study area to the southeast of Copperton is largely underlain by glacially-related sediments of the Dwyka Group (Karoo Supergroup) that are of Late Carboniferous to Early Permian age. Although interglacial mudrocks within the Dwyka beds elsewhere in the Northern Cape have yielded important fossil remains of fish, marine invertebrates, trace fossils, petrified wood as well as various microfossil taxa, much of the succession consists of essentially unfossiliferous tillites. Substantial portions of the study area are mantled in various types of Late Caenozoic superficial deposits – such as calcretes, surface gravels, alluvium and windblown sands - that are very sparsely fossiliferous at most. Small inliers of Precambrian basement rocks are generally highly metamorphosed or igneous intrusions and do not contain any fossils. The overall palaeontological sensitivity of the study area as a whole is therefore low to very low. It is concluded that the proposed Mainstream Prieska wind farm development is unlikely to pose a substantial threat to local fossil heritage. The impact significance of this project as far as palaeontological heritage is concerned is rated as LOW (negative). Therefore, pending the discovery of significant new fossil material here, no further specialist studies are considered to be necessary.

It is recommended that:

- The ECO responsible for the development should be aware of the possibility of important fossils being present or unearthed on site and should monitor all substantial excavations into fresh (*i.e.* unweathered) sedimentary bedrock for fossil remains;

- In the case of any significant fossil finds (*e.g.* vertebrate teeth, bones, burrows, petrified wood) during construction, these should be safeguarded - preferably *in situ* - and reported by the ECO as soon as possible to the relevant heritage management authority (SAHRA) so that any appropriate mitigation by a palaeontological specialist can be considered and implemented, at the developer’s expense;

- These recommendations should be incorporated into the EMP for the Mainstream Prieska wind farm project.

All specialist palaeontological work would have to conform to international best practice for palaeontological fieldwork (*e.g.* data recording, fossil collection and curation, reporting) and as far as possible should adhere to the minimum standards for palaeontological studies currently being developed by SAHRA.

5. ACKNOWLEDGEMENTS

I am grateful to Mr Shaun Taylor and Ms Kelly Tucker of SIVEST Environmental Division for commissioning this study and for providing the necessary background information. Useful supplementary information was obtained from the geotechnical report for the three Mainstream wind farm projects in the Northern Cape that was prepared by Jeffares and Green (Pty) Ltd, Sunninghill (Bok 2011)

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7. QUALIFICATIONS & EXPERIENCE OF THE AUTHOR

Dr John Almond has an Honours Degree in Natural Sciences (Zoology) as well as a PhD in Palaeontology from the University of Cambridge, UK. He has been awarded post-doctoral research fellowships at Cambridge University and in Germany, and has carried out palaeontological research in Europe, North America, the Middle East as well as North and South Africa. For eight years he was a scientific officer (palaeontologist) for the Geological Survey / Council for Geoscience in the RSA. His current palaeontological research focuses on fossil record of the Precambrian - Cambrian boundary and the Cape Supergroup of South Africa. He has recently written palaeontological reviews for several 1: 250 000 geological maps published by the Council for Geoscience and has contributed educational material on fossils and evolution for new school textbooks in the RSA.

Since 2002 Dr Almond has also carried out palaeontological impact assessments for developments and conservation areas in the Western, Eastern and Northern Cape under the aegis of his Cape Town-based company *Natura Viva* cc. He is a long-standing member of the Archaeology, Palaeontology and Meteorites Committee for Heritage Western Cape (HWC) and an advisor on palaeontological conservation and management issues for the Palaeontological Society of South Africa (PSSA), HWC and SAHRA. He is currently compiling technical reports on the provincial palaeontological heritage of Western, Northern and Eastern Cape for SAHRA and HWC. Dr Almond is an accredited member of PSSA and APHAP (Association of Professional Heritage Assessment Practitioners – Western Cape).

Declaration of Independence

I, John E. Almond, declare that I am an independent consultant and have no business, financial, personal or other interest in the proposed alternative energy project, application or appeal in respect of which I was appointed other than fair remuneration for work performed in connection with the activity, application or appeal. There are no circumstances that compromise the objectivity of my performing such work.

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