PALAEONTOLOGICAL SPECIALIST STUDY: COMBINED DESKTOP & FIELD ASSESSMENT REPORT

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

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EXECUTIVE SUMMARY

The Mainstream wind farm study area east of Noupoort, Northern Cape, is largely underlain by continental sediments of the Katberg Formation (Karoo Supergroup) that are known to contain important fossil biotas of Early Triassic age, notably vertebrates, trace fossils and rare plants of the *Lystrosaurus* Assemblage Zone. These fossils are of international palaeontological significance in that they document the recovery of terrestrial biotas following the catastrophic end-Permian mass extinction event of 251 million years ago. Several Early Triassic vertebrate fossil localities have already been recorded by previous workers close to the Noupoort study area and are represented in museum collections (*e.g.* the BPI at Wits University, Johannesburg). Part of the wind farm study area is underlain by intrusive rocks of the Early Jurassic Karoo Dolerite Suite that are not palaeontologically significant.

Over the great majority of the study area, including flatter-lying areas that are most likely to be directly affected by the proposed development, the Katberg Formation bedrocks are mantled with superficial deposits such as scree, soil and alluvium that are generally of low palaeontological sensitivity. The very few good exposures of potentially fossiliferous mudrocks within the region mainly occur on steeper hill slopes in the escarpment region that lie outside the wind farm development footprint. Even where bedrock exposure is good, fossil vertebrate remains are sparse, disarticulated and usually fragmentary (*e.g.* reworked bones and teeth in channel conglomerates). Rare plant fossils recorded are very poorly preserved and not identifiable to a specific plant group. Trace fossils (various invertebrate burrows) are locally abundant but assemblages are very low in diversity and represent common Katberg forms.

It is concluded that the construction phase of the proposed Mainstream Noupoort Wind Farm is likely to have only a LOW NEGATIVE impact on local palaeontological heritage resources (See table below). The operational and decommissioning phases of wind farms will not involve significant negative impacts. Fatal flaws or no-go areas with respect to fossil heritage conservation have not been identified for this project. There are no preferences on palaeontological heritage grounds for any particular alternative site for the on-site substation, operational and maintenance buildings or lay down area. Likewise, the various alternative transmission line routes from the wind farm to the Eskom grid near Noupoort are assessed as having a similar low negative impact with the exception of the Southern 2 Alternative. In this last case, negative impacts might be slightly higher (but still LOW overall) due to the comparatively good Katberg Formation bedrock exposure along Oorlogspoort.

It is considered that no further palaeontological heritage studies or specialist mitigation are warranted for this alternative energy project, pending the exposure of any substantial fossil remains (*e.g.* vertebrate bones and teeth, large blocks of petrified wood) during the construction phase.

The ECO responsible for the developments should be alerted to the possibility of fossil remains being found on the surface or exposed by fresh excavations during construction. Should substantial fossil remains be discovered during construction, these should be safeguarded (preferably *in situ*) and the ECO should alert SAHRA so that appropriate mitigation (*e.g.* recording, sampling or collection) can be taken by a professional palaeontologist.

The specialist involved would require a collection permit from SAHRA. Fossil material must be curated in an approved repository (*e.g.* museum or university collection) and all fieldwork and reports should meet the minimum standards for palaeontological impact studies developed by SAHRA.

These recommendations should be incorporated into the EMP for the Mainstream Noupoort Wind Farm.

Summarized impacts of proposed Mainstream Noupoort Wind Farm on palaeontological heritage resources

Environmental parameter	**Issues**	**Rating prior to mitigation**	**Average**	**Rating post mitigation**	**Average**
Fossil heritage resources	Disturbance, damage, destruction or sealing-in of fossil remains during the construction phase of the wind farm	-14		-14	
			- 14		- **14**
			Low Negative Impact		Low Negative Impact

1. INTRODUCTION & BRIEF

The company Mainstream Renewable Power is proposing to develop a wind energy facility of *c*. 190 MW generation capacity and *c*. 55 hectare footprint in mountainous terrain just to the east of the small town of Noupoort, Pixley ka Seme District Municipality, Northern Cape Province (Figs. 1 & 2). A scoping level desktop study of palaeontological heritage within the Noupoort Wind Farm study area (Almond 2011) was previously commissioned on behalf of the client by SIVEST Environmental Division, Johannesburg (Contact details: SIVEST Environmental Division, 51 Wessel Road, PO Box 292, Rivonia 2128, South Africa; Phone + 27 11 798 0600; e-mail info@sivest.co.za).

The present palaeontological field assessment was subsequently commissioned by SIVEST, following the recommendations of the earlier desktop study which were supported by SAHRA.

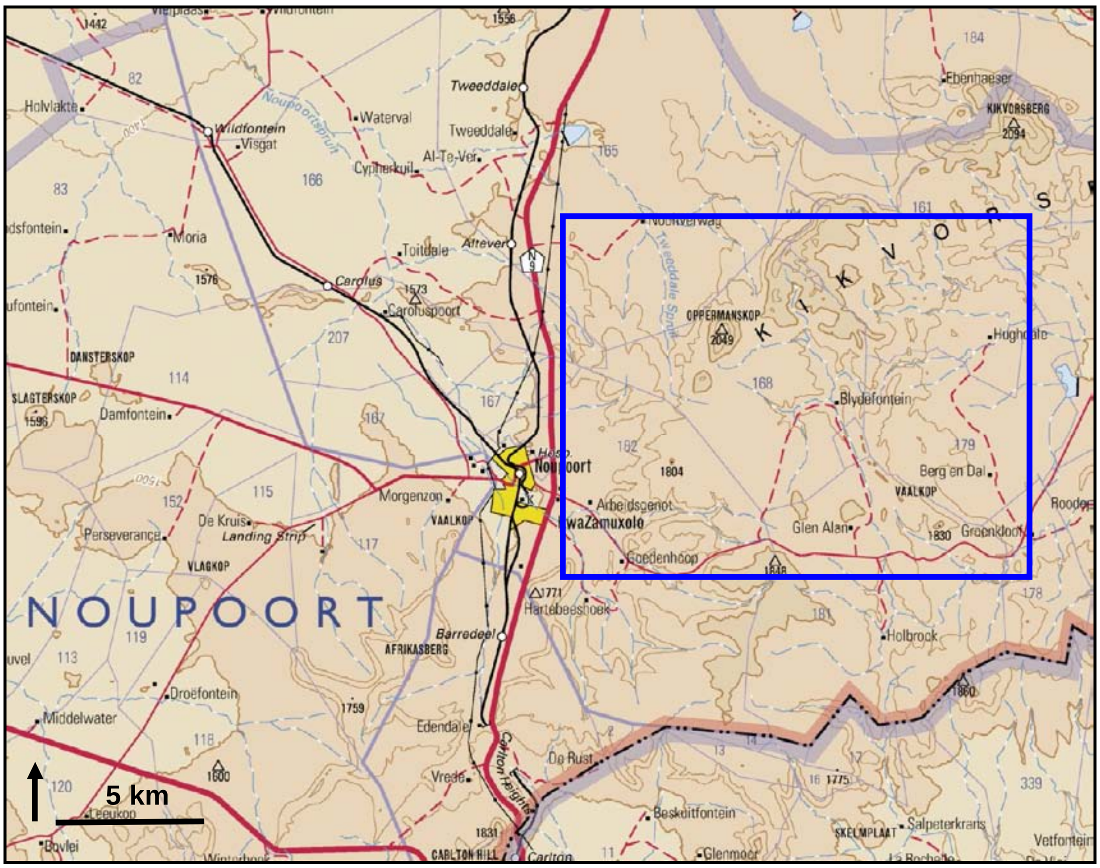

Figure 1: Extract from 1: 250 000 topographical map 3124 Middelburg (Courtesy of The Chief Directorate of Surveys & Mapping, Mowbray) showing the *approximate* location of the proposed Mainstream wind farm to the east of Noupoort, Northern Cape (blue rectangle).

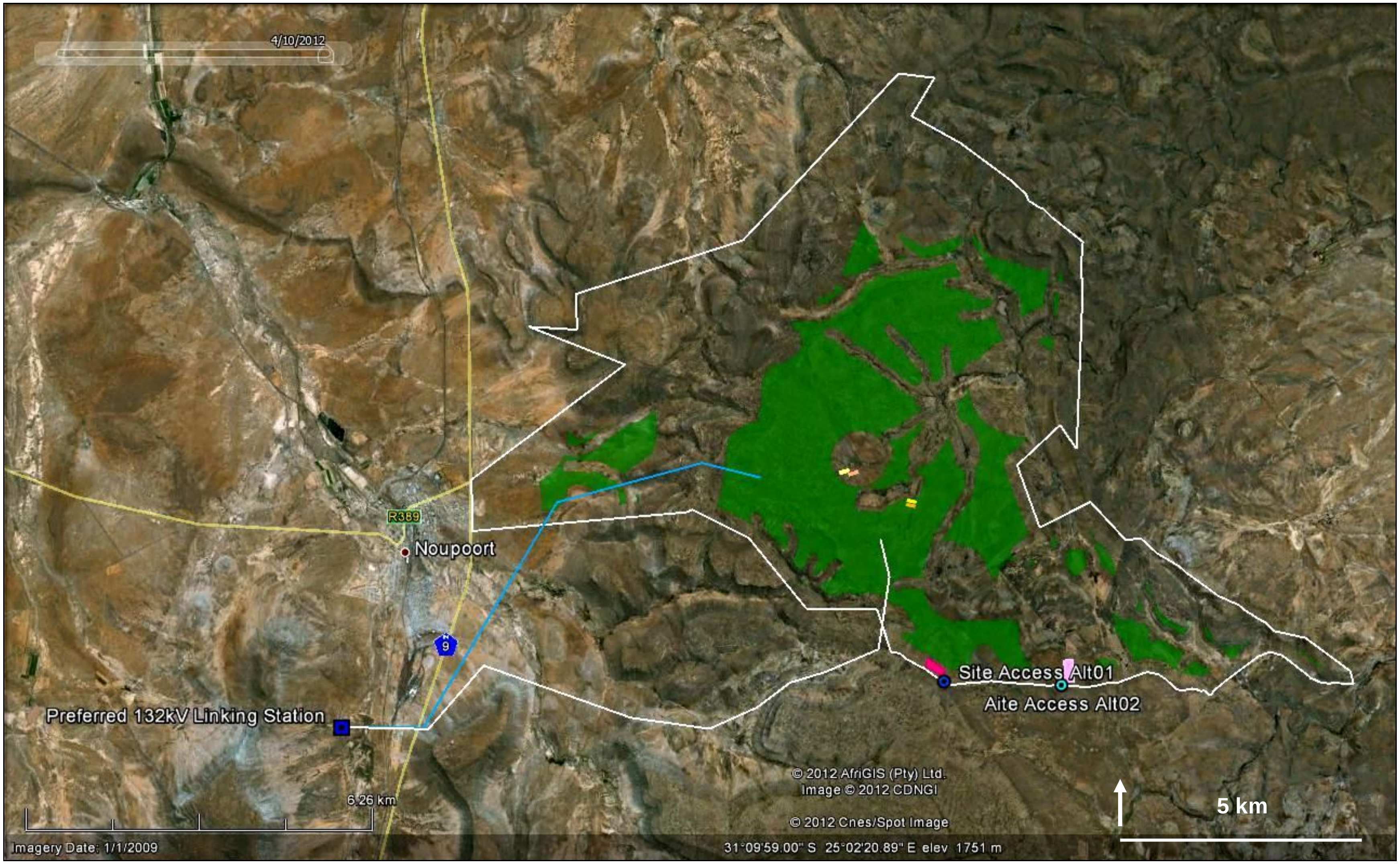

Figure 2: Google Earth© satellite image of the study area east of Noupoort showing the highly dissected, mountainous terrain of the Kikvorsberg. The green patches indicate the identified "buildable area".

1.1. Brief project description

The proposed Mainstream Noupoort Wind Farm is situated in mountainous terrain just to the east of the small town of Noupoort, Pixley ka Seme District Municipality, in the Northern Cape Province. Noupoort lies along the N9 tar road between Middelburg in the south and Colesberg to the north (Fig. 1). It lies approximately 53 km southeast of Colesberg and 55km southwest of Hanover. The wind farm study area here is around 7 490 hectares in extent and consists of three adjacent land portions, namely:

- Farm Blydefontein, Remainder of the Farm No.168, Colesberg (4 745.62 hectares);
- Farm Holbrook, Portion 1 of the Farm No. 181, Colesberg (1 469.99 hectares);
- Farm Harmonie, Portion 21 of the Farm No. 182 Hartebeest Hoek, Colesberg Road (1 276.80 hectares).

The wind farm will have a cumulative generation capacity of around 190 MW and a footprint of *c*. 55 hectares. The main components of the proposed wind farm that are relevant to the present palaeontological heritage study include:

- 82 wind turbines of 1-3 MW generation capacity with foundations of 20m x 20 m x 2.5 m deep;
- A hard standing area of 2 400 m^2 for each wind turbine;
- Underground cables connecting the wind turbines and on-site substation, with possible use of monopole overhead powerlines where necessary;
- An on-site substation with a footprint of 10 800 m^2;
- A new transmission line (overhead line and pole) connecting the on-site substation with the Eskom grid near Noupoort;
- Internal gravel access roads (6-10 m wide);
- A maximum 10 000 m^2 temporary lay down area including access route and site office up to 5000 m^2;
- Single storey administration and warehouse buildings, most likely be situated close to the substation;
- Borrow pits (if required).

In terms of access to the Eskom grid two transmission line routes are being considered, one route to the north linking to the Newgate Substation and one route to the south breaking the 132kV Newgate – Ludlow line. Whether the Northern or Southern connection route is used will be determined by Eskom and on-going land access negotiations. It is anticipated that all power line route alternatives will either link in with existing lines or link into a linking station to the southwest of the proposed site. It is expected that the capacity of the new transmission line will be 132 kV.

The boundaries of the study area together with a provisional layout of the wind turbines are shown in map Fig. 3A, kindly provided by SIVEST Environmental Division. Alternative locations of the on-site substation, lay down, operation and maintenance areas, as well as alternative routes for the transmission line connection to the Eskom grid near Noupoort are shown in Figs. 3A and 3B.

1.2. Potential implications of this project for fossil heritage

The proposed Mainstream wind farm to the east of Noupoort is located in an area of the eastern Karoo that is underlain by potentially fossil-rich sedimentary rocks of the Karoo Supergroup that are of Triassic 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*. 1m 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 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.

1.3. Scope of work

The Scope of Work for the present field-based study of palaeontological resources within the wind farm study area has been defined by SIVEST Environmental Division. The report is to include the following components:

a. Introduction;
b. Legislative Background as applicable to the Proposed Activity;
c. Environmental Baseline in terms of the Specialist Area;
d. Methodology;
e. The identification and mapping of palaeontological sites identified within the project area from general site visits and archival research;
f. An assessment of the significance of such sites in terms of palaeontological assessment criteria;
g. Findings;
h. Alternatives Assessment (including the "No-Go Alternative") in terms of Specialist Area;
i. Implications of Specialist Findings to the Proposed Activity (e.g. permits, licences etc.);
j. Potential Pre-construction, Construction, Operation, Decommissioning Phase and Cumulative Impacts Identification and Assessment;
k. Pre-construction, Construction, Operation and Decommissioning Phase Mitigation Measures Identification;
l. Recommendations of Preferred Placement or Routing (powerlines) of the Proposed Activity;
m. Conclusion

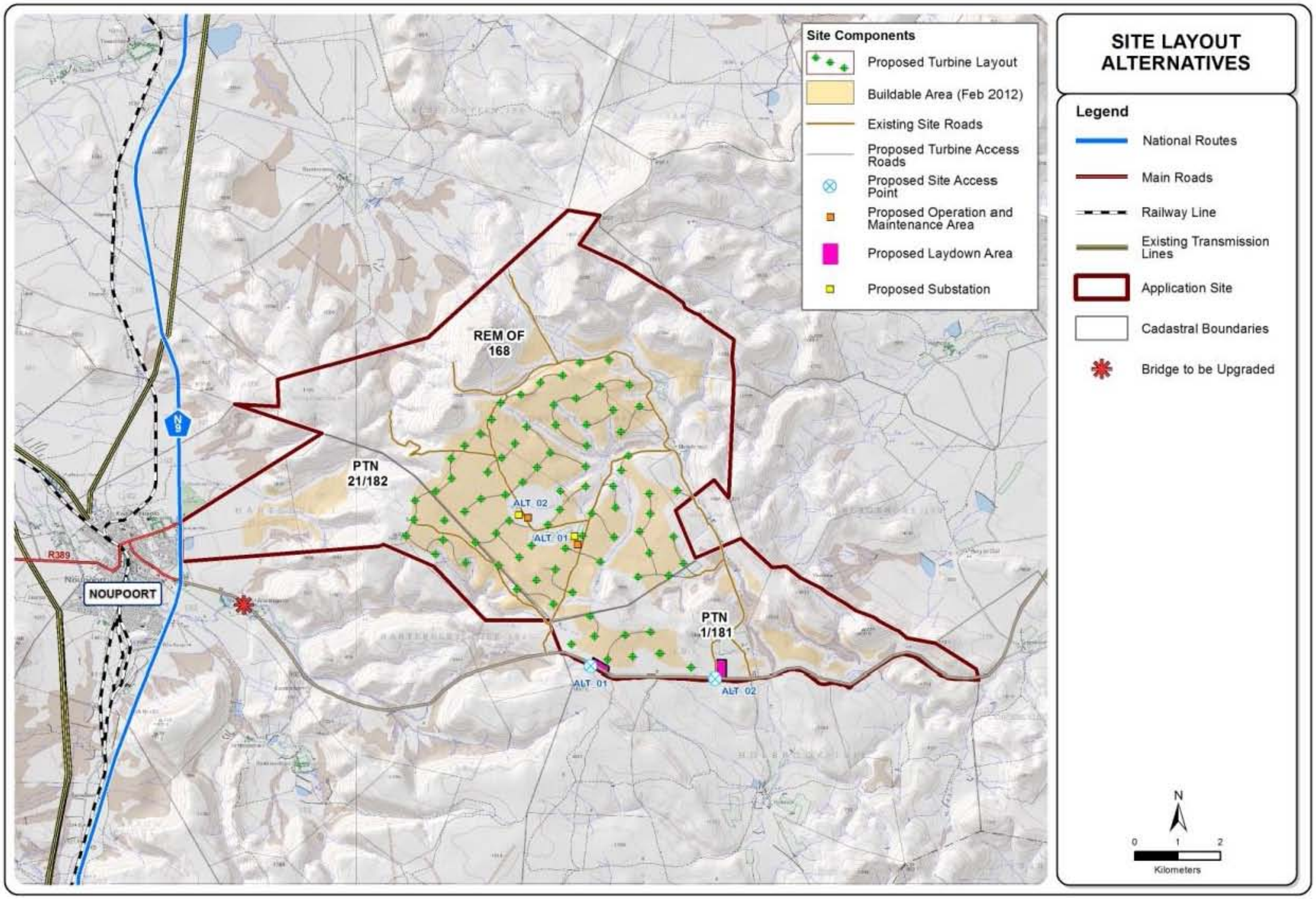

Figure 3A: Map of the proposed Mainstream wind farm near Noupoort showing boundaries of the land parcels concerned and a provisional wind turbine layout (Image kindly provided by SIVEST Environmental Division). Note alternative locations for on-site substation, lay down area and maintenance area.

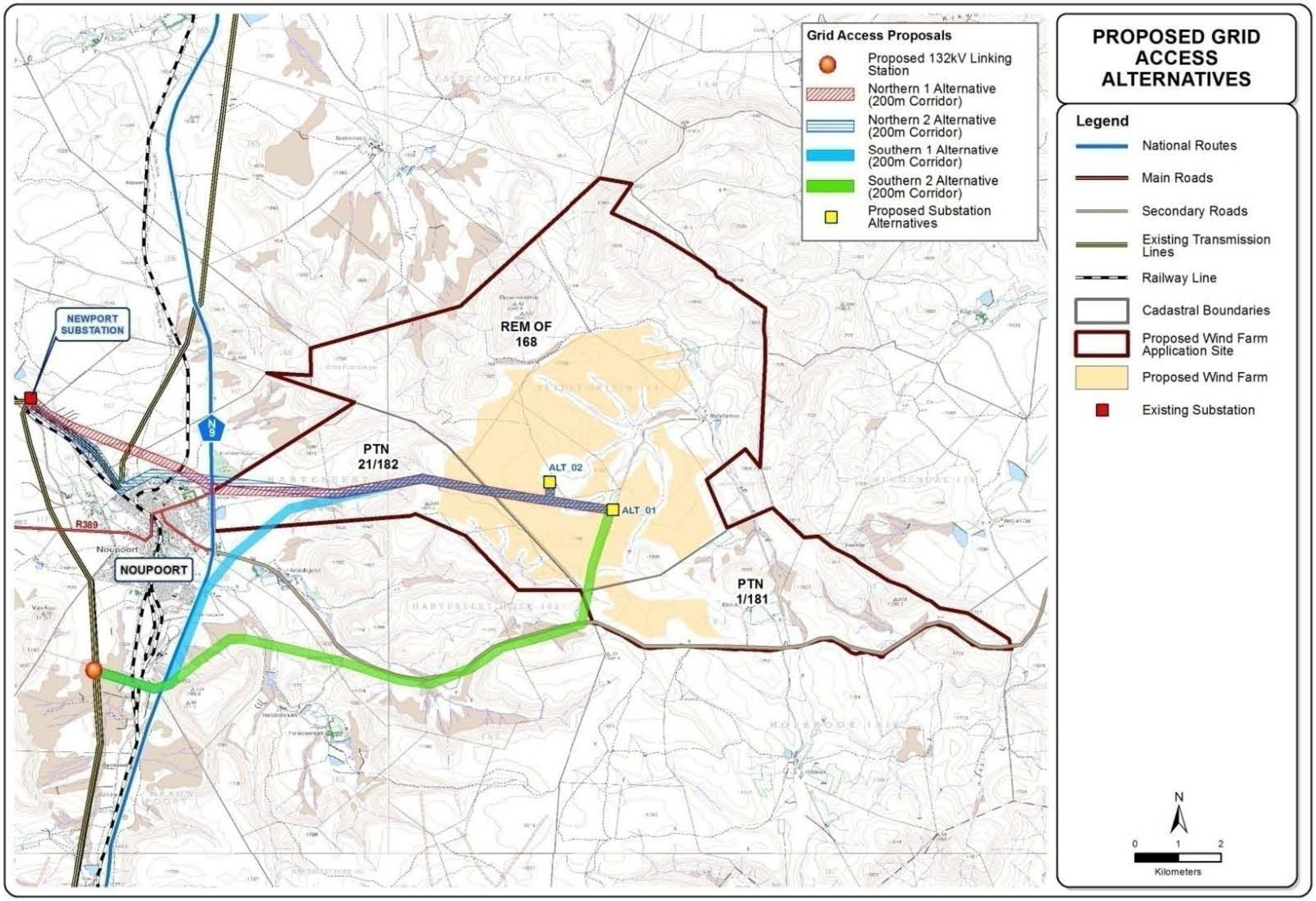

Figure 3B: Map of the proposed Mainstream wind farm showing alternative sites for the on-site substation as well as alternative routes for the new transmission line connections to the electricity grid near Noupoort (Image kindly provided by SIVEST Environmental Division).

1.4. Approach to this study

The present report represents a field-based assessment of palaeontological heritage resources within the Mainstream Noupoort 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 2011.

This palaeontological specialist report provides an assessment of the observed or inferred palaeontological heritage within the wind farm 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, summarised in the previous desktop study by Almond (2011), (2) published geological maps and accompanying sheet explanations, (3) data provided from the Karoo fossil database (kindly provided by Mike Day at the Bernard Price Institute for Palaeontological Research, Wits University, Johannesburg); (4) the author's extensive field experience with the formations concerned and their palaeontological heritage, and (5) a three-day field assessment over the period 4-7 April 2012 carried out by the author together with three experienced field assistants.

Because the level of natural rock exposure of the Beaufort Group sediments within the study area proved to be generally very poor, well-exposed sections through these rocks at Oorlogspoort, less than one kilometre south of the study area, as well as excellent new road cuttings at Carlton Heights along the N9 tar road some 11.6 km south of Noupoort, were also inspected for fossil remains.

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 scoping 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.

The focus of the field-based assessment work is *not* simply to survey the development footprint or even the development area as a whole (*e.g.* farms or other parcels of land concerned in the development). Rather, the palaeontologist seeks to assess or predict the diversity, density and distribution of fossils within and beneath the study area, as well as their heritage or scientific interest. This is primarily achieved through a careful field examination of one or more representative exposures of all the sedimentary rock units present (*N.B.* Metamorphic and igneous rocks rarely contain fossils). The best rock exposures are generally those that are easily accessible, extensive, and fresh (*i.e.* unweathered) and include a large fraction of the stratigraphic unit concerned (*e.g.* formation). These exposures may be natural or artificial and include, for example, rocky outcrops in stream or river banks, cliffs, quarries, dams, dongas, open building excavations or road and railway cuttings. Uncemented superficial deposits, such as alluvium, scree or wind-blown sands, may occasionally contain fossils and should also be included in the scoping study where they are well-represented in the study area. It is normal practice for impact palaeontologists to collect representative, well-localized (*e.g.* GPS and stratigraphic data) samples of fossil material during scoping studies. All fossil material collected must be properly curated within an approved repository (usually a museum or university collection).

Before fieldwork commenced, a preliminary screening of satellite images and 1: 50 000 maps of the Noupoort study area was conducted to identify sites of potentially good bedrock exposure to be examined in the field. Most of these sites, which were relatively few in number, were situated in mountainous terrain around the periphery of the main development footprint. The sites included both natural exposures (*e.g.* stream beds, steep escarpment slopes, gullies) as well as artificial exposures such as dams and cuttings along farm tracks.

Note that while fossil localities recorded during fieldwork within the study area itself are obviously highly relevant, most fossil heritage here is embedded within rocks beneath the land surface or obscured by surface deposits (soil, alluvium *etc*) and by vegetation cover. In many cases where levels of fresh (*i.e.* unweathered) bedrock exposure are low, the hidden fossil resources have to be *inferred* from palaeontological observations made from better exposures of the same formations elsewhere in the region but outside the immediate study area. Therefore a palaeontologist might reasonably spend far *more* time examining road cuts and borrow pits close to, but outside, the study area than within the study area itself. Field data from localities even further afield (*e.g.* an adjacent province) may also be adduced to build up a realistic picture of the likely fossil heritage within the study area.

On the basis of the desktop and field assessment studies, the likely impact of the proposed development on local fossil heritage and any need for specialist mitigation are then determined. Adverse palaeontological impacts normally occur during the construction rather than the operational or decommissioning phase. Mitigation by a professional palaeontologist – normally involving the recording and sampling of fossil material and associated geological information (*e.g.* sedimentological data) – is usually most effective during the construction phase when fresh fossiliferous bedrock has been exposed by excavations, although pre-construction recording of surface-exposed material may sometimes be more appropriate. To carry out mitigation, the palaeontologist involved will need to apply for a palaeontological collection permit from the relevant heritage management authority (*i.e.* SAHRA, Cape Town). It should be emphasized that, *providing appropriate mitigation is carried out*, the majority of developments involving bedrock excavation can make a *positive* contribution to our understanding of local palaeontological heritage.

1.5. 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.

In the case of palaeontological field studies in the Nouport region, the main limitations are:

- Extensive intrusion of the potentially fossiliferous Karoo Supergroup bedrocks by dolerite. Weathered dolerite colluvium (scree) and sheetwash blanket many of the hill slopes in the area, *i.e.* the very regions where fossiliferous bedrocks are usually exposed;

- High levels of bedrock cover by thick alluvial and colluvial soils and gravels.

These limitations were in part addressed through palaeontological surveying of areas beyond the boundaries of the Mainstream wind farm study area (Oorlogspoort, Carlton Heights), as outlined in Section 1.5 above. Despite very limited sedimentary bedrock exposure levels, confidence levels in the conclusions presented here are in consequence moderately high.

2. GEOLOGICAL BACKGROUND

As shown on satellite images (Fig. 2) as well as detailed topographical maps (3124BB Noupoort, 3125AA Kikvorsberg) the study area comprises highly dissected, mountainous terrain of the WSW-ESE trending Kikvorsberg range. This range reaches altitudes of 2050 to 2100m amsl at Oppermanskop and Kikvorsberg respectively, the latter lying outside the study area. The mountains are built of fairly flat-lying sediments of the Tarkastad Subgroup (= Upper Beaufort Group, Karoo Supergroup). These continental "red beds" are Early Triassic in age and contain numerous prominent-weathering, sheet-like sandstone packages. The Karoo succession is further reinforced by tough basic intrusions (horizontal sills and steeply-inclined dykes) of the Karoo Dolerite Suite. Weathering and erosion of these various resistant-weathering, subhorizontal rock layers has created a stepped mountainous landscape where flatter plateaux are incised by a complex, radial network of valleys with steep, rocky sides that are extensively mantled by rocky colluvium (*i.e.* scree, hill-wash and other slope deposits). These valleys reflect higher levels of erosional down-cutting under wetter climates of the Tertiary Era and are presently occupied by much smaller, intermittently flowing streams. Low-lying areas at elevations of 1500 to 1600 m amsl at the foot of the Kikvorsberg mountains are found towards the western and southern edges of the study area (on Portions 21/182 and 1/181 respectively). The gently-sloping terrain here is mantled with river alluvium as well as colluvial deposits (*e.g.* gravely alluvial fans and debris flows, finer-grained sheet wash) extending from the adjacent mountain slopes.

The geology of the study area to the east of Noupoort is shown on 1: 250 000 sheet 3124 Middelburg (Cole *et al.* 2004) (Fig. 4) and has been briefly described in the geotechnical report by Bok (2011). Most of the area is underlain by Early Triassic (*c*. 250 Ma = million years old) fluvial sediments of the **Katberg Formation** (**TRk**; Tarkastad Subgroup, Upper Beaufort Group). A very small area of Karoo sediments assigned to the underlying **Adelaide Subgroup** (**Pa**) is mapped in the western foothills of the Kikvorsberg close to the N9 (Portion 21/182). It is likely that these rocks belong to the uppermost portion of the Adelaide Subgroup, namely the **Palingkloof Member** of Latest Permian to Earliest Triassic age. According to Cole *et al.* (2004) this succession consists largely of reddish mudrocks and has a thickness of only some 20m or so in the Noupoort area (Carlton Siding). Given their location at the foot of the Katberg escarpment, the Adelaide Subgroup rocks here are largely covered by colluvial debris. Furthermore, the map of the proposed wind turbine layout (Fig. 3A) indicates that this part of the study area is unlikely to be directly impacted by the Noupoort wind farm development. For these reasons, the pre-Katberg rocks will not be treated in any detail in this report. It should be noted, however, that they are of considerable palaeontological significance elsewhere in the Main Karoo Basin since they record the catastrophic end-Permian mass extinction event and initial recovery among continental biotas (*e.g.* Smith & Ward 2001, Smith *et al.* 2002, Retallack *et al.* 2003 and 2006, Ward *et al.* 2005, Smith & Botha 2005, Botha & Smith 2007).

The Karoo Supergroup sedimentary rocks in the Nouport study area are extensively intruded by Early Jurassic (183 ± 2 Ma) igneous intrusions of the **Karoo Dolerite Suite** (**Jd**) (Cole *et al.* 2004, Duncan & Marsh 2006). The sills and dykes have thermally metamorphosed or baked the adjacent sediments. Levels of tectonic deformation in this region are low, as shown by recorded dips here of only two to three degrees within the Tarkastad Subgroup. Steeper northward dips were noted in Katberg sandstones along the western flank of the Langberg (Blydefontein 168) where possible low angle thrusting may have occurred. In most parts of the study area, including both the flatter-lying plateaux and *vlaktes* as well as steeper hillslopes, the Mesozoic bedrocks are mantled with a variety of **superficial deposits** of probable Late Caenozoic (Quaternary to Recent) age. However, apart from the more extensive areas of river alluvium in lower lying areas in the west and south, most of these geologically youthful deposits such as stream alluvium, scree and hill-wash are not mapped in Figure 4.

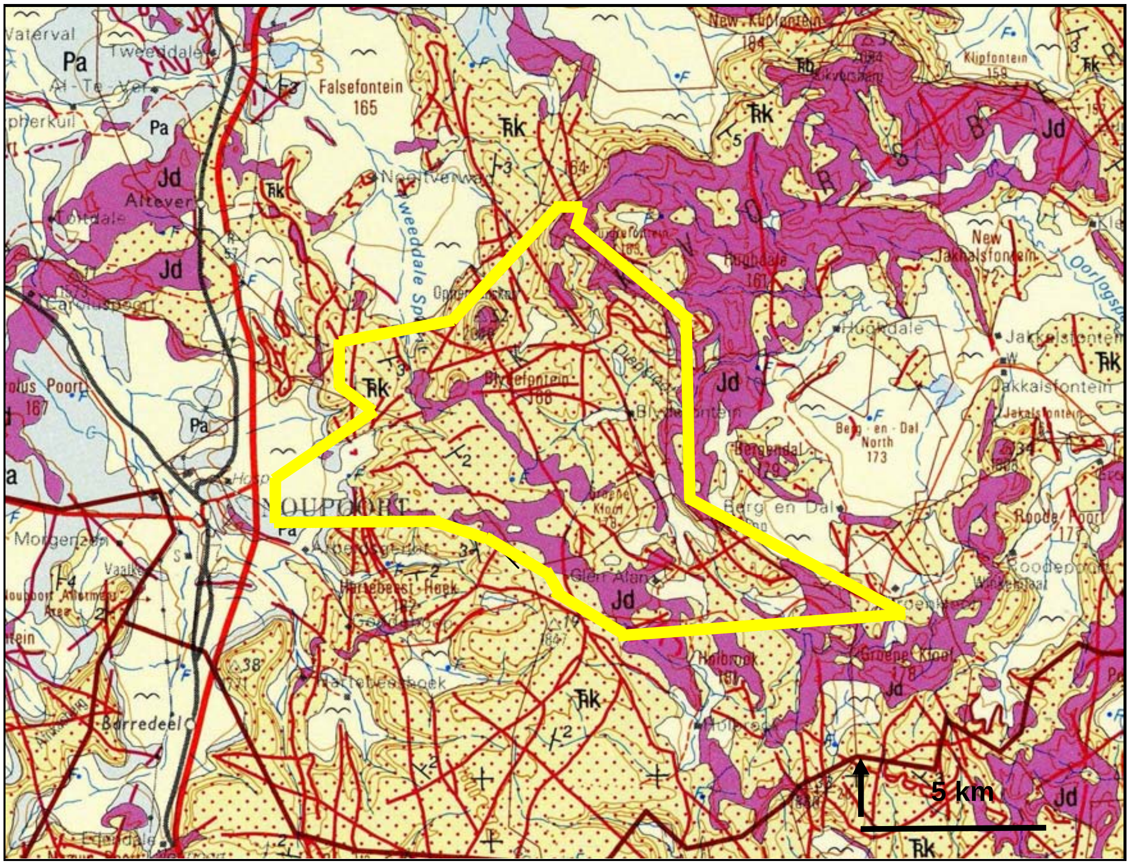

Figure 4: Extract from 1: 250 000 geology sheet 3124 Middelburg (Council for Geoscience, Pretoria) showing *approximate* outline of the study area to the east of Noupoort (yellow polygon). The main geological units represented here are:

Pa (pale blue) = Late Permian to Earliest Triassic Adelaide Subgroup (Lower Beaufort Group, Karoo Supergroup)
TRk (pale orange with red dots) = Early Triassic Katberg Formation of the Tarkastad Subgroup (Upper Beaufort Group, Karoo Supergroup)
Jd (purple) = Early Jurassic Karoo Dolerite Suite
White areas with "flying bird"symbol = Quaternary to Recent alluvium
***N.B.* Other Caenozoic superficial deposits such as colluvium (scree *etc*), soils and surface gravels are not depicted here.**

Figures 5 to 9 give an overview of the variety of terrain present within the Mainstream Noupoort Wind Farm study area. The general paucity of exposure of the Beaufort Group (Katberg Formation) bedrock – due to the pervasive blanket of soil, alluvium and colluvial deposits as well as dense grassy vegetation cover during the field season (early April) - is apparent here. The palaeontological sensitivity of the development footprint has necessarily to be gauged from the few scattered exposures of Katberg sedimentary rocks available. The best Katberg exposures within the study area were located in the steep escarpment zone on the western portion of Blydefontein 168 and the southern edge of Hartebeest Hoek 182 (Locs. 427, 428, 438-440), on the western slopes of Langberg (Loc. 429), and at over 1800m amsl on the northern margin of the study area (Loc. 436). Outside the study area good sections and hillslope exposures of Katberg rocks were examined for fossils in Oorlogskloof Poort (Loc. 431-434) and extensive new road cuttings at Carlton Heights (Loc. 437). GPS data for these localities is provided in the appendix.

Figure 5: View across wind farm study area on Blydefontein 168 looking NNW towards the prominent mountain Oppermanskop (2049m amsl). Note flat terrain here with little or no bedrock exposure.

Figure 6: Flat-lying, rocky terrain underlain by dolerite in the south-central portion of wind farm study area on Blydefontein 168, looking towards NNE.

Figure 7: South-eastern flank of Oppermanskop showing prominent-weathering sheet sandstones of the Katberg Formation. Note donga erosion into silty alluvial / colluvial surface deposits in foreground completely mantling Beaufort Group bedrocks.

Figure 8: Western face of Oppermanskop showing bouldery dolerite colluvium mantling lower slopes, Katberg sheet sandstones on steeper upper slopes and dolerite sill on the skyline.

Figure 9: Maroon mudrocks of the Katberg Formation exposed beneath superficial deposits in walls of dongas, area north-east of Glen-Alan homestead, Farm 181/1 (Loc. 435).

2.1. Katberg Formation

Useful geological descriptions of the **Katberg Formation** are given by Johnson (1976), Hancox (2000), Johnson *et al.* (2006), Smith *et al.* (2002) and for the Middelburg sheet area in particular by Cole *et al.* (2004). The more detailed sedimentological accounts by Stavrakis (1980), Hiller and Stavrakis (1980, 1984), Haycock *et al.* (1994), Groenewald (1996) and Neveling (1998) are also relevant to the Noupoort study area.

The Katberg Formation forms the regionally extensive, sandstone-rich lower portion of the Tarkastad Subgroup (Upper Beaufort Group) that can be traced throughout large areas of the Main Karoo Basin. In the Middelburg sheet area it reaches a maximum thickness of some 400m, but close to Noupoort thicknesses of 240-260m are more usual. The predominant sediments are (a) prominent-weathering, pale buff to greyish, tabular or ribbon-shaped sandstones up to 60m thick that are interbedded with (b) recessive-weathering, reddish or occasionally green-grey mudrocks. Up to four discrete sandstone packages can be identified within the succession. In the Noupoort area the overall sandstone:mudrock ratio is close to 1:1. Katberg channel sandstones are typically rich in feldspar and lithic grains (*i.e*. lithofeldspathic). They build laterally extensive, multistorey units with an erosional base that is often marked by intraformational conglomerates up to one meter thick consisting of mudrock pebbles, reworked calcrete nodules and occasional rolled fragments of bone. While the basal Katberg succession is often marked by a major cliff-forming sandstone unit, in the Noupoort area there is a transitional relationship with the underlying Adelaide Subgroup that is marked by an upward-thickening series of sandstone sheets. Internally the moderately well-sorted sandstones are variously massive, horizontally-laminated or cross-bedded and heavy mineral laminae occur frequently. Sphaeroidal carbonate concretions up to 10 cm across are common. The predominantly reddish Katberg mudrocks are typically massive with horizons of pedocrete nodules (calcretes), and mudcracks. Mudrock exposure within the study area is very limited due to extensive mantling of these recessive-weathering rocks by superficial sediments.

Sandstone deposition was mainly due to intermittently flooding, low-sinuosity braided river systems flowing northwards from the rising Cape Fold Belt mountains in the south into the subsiding Main Karoo Basin (Fig. 10). Mudrocks were largely laid down by suspension settling within overbank areas following episodic inundation events, while other fine-grained sediments are associated with lakes and temporary playas in lower-lying areas on the arid floodplain, especially in the northern Katberg outcrop area and its lateral correlatives in the Burgersdorp Formation. Palaeoclimates inferred for the Early Triassic Period in the Main Karoo Basin were arid with highly seasonal rainfall and extensive periods of drought. This is suggested by the abundant oxidised ("rusty red") mudrocks, desiccation cracks, and palaeosols associated with well-developed calcretes. Arid settings are also supported by taphonomic and behavioural evidence such as pervasive carbonate encrustation of fossil bones, mummification of postcrania, bone-bed death assemblages associated with water holes and the frequency of burrowing habits among tetrapods, including large dicynodonts like *Lystrosaurus* (Groenewald 1991, Smith & Botha 2005, Viglietti 2010).

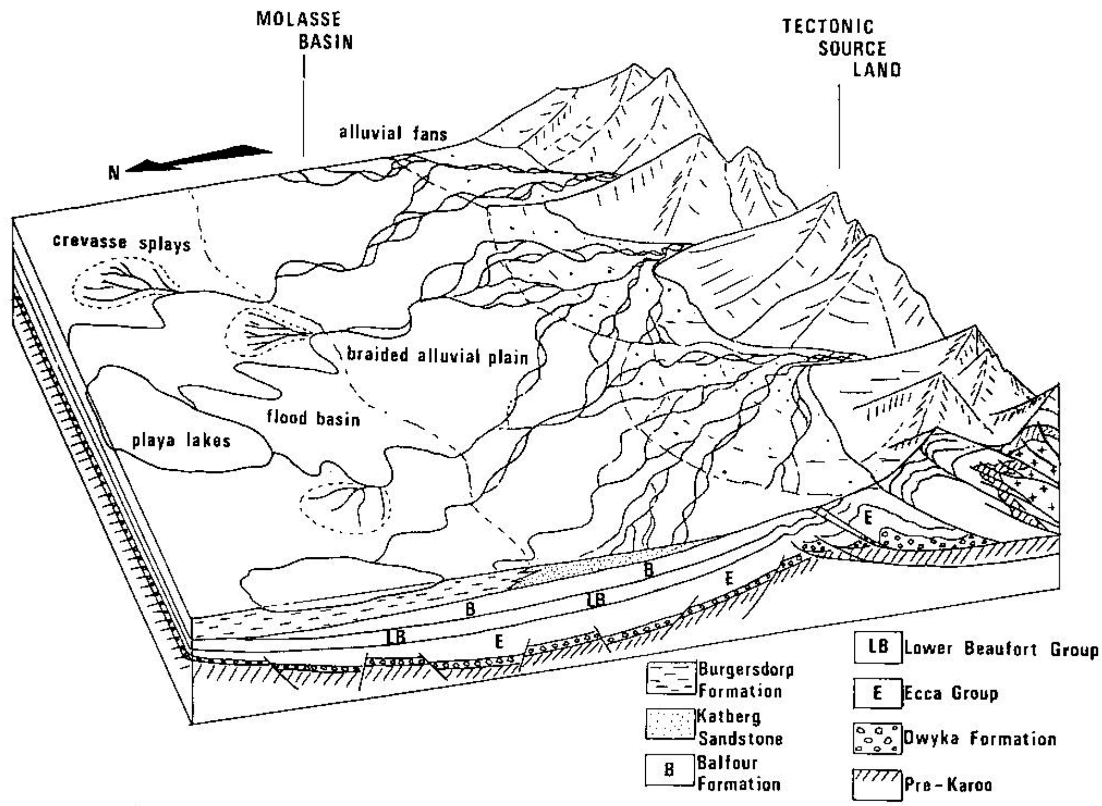

Figure 10: Reconstruction of the south-eastern part of the Main Karoo Basin in Early Triassic times showing the deposition of the sandy Katberg Formation near the mountainous source area in the south. The mudrock-dominated Burgersdorp Formation was deposited on the distal floodplain where numerous playa lakes are also found (From Hiller & Stavrakis 1984).

Informative exposures, including vertical sections, of Katberg Formation sandstones and mudrocks were studied in Oorlogspoort and Carlton Heights as well as a few localities on Blydefontein 168 and Hartebeest Hoek 182. A selection of some of the sedimentary features observed here are illustrated in Figures 11 to 20 below and briefly described in the accompanying figure legends.

Figure 11: Typical hillside exposure of buff to grey-green, flat-lying Katberg Formation sheet sandstones on the southern side of Oorlogspoort road (Hartebeest Hoek 182). Note very limited exposure of intervening Katberg mudrocks here.

Figure 12: Various sedimentary facies within buff-weathering Katberg sandstones just south of Bushman rock shelters, Blydefontein 168. Note tabular cross-bedded unit (below hammer, 32 cm), thin-bedded sandstones and massive sandstones forming top of ridge.

Figure 13: Comparatively good, but limited, exposure of Katberg Formation mudrocks beneath prominent sandstone ridge, southwestern slopes of Langberg, Blydefontein 168 (Locs. 429-430).

Figure 14: Detail of Katberg Formation outcrop seen in previous figure showing maroon mudrocks with thin tabular sandstone interbeds. This locality (Loc. 430) yields poorly preserved fossil plants (Figure 34) and low diversity trace fossil assemblages.

Figure 15: Thick silty and gravelly alluvium mantling Katberg bedrocks in the escarpment zone, western portion of Blydefontein 168 (Loc. 427). Reworked fossil bone clasts occur among the surface gravels here, while the Katberg sandstone, conglomerate and mudrock exposure in the background yielded numerous, mainly fragmentary fossil vertebrate remains.

Figure 16: Detail of Katberg Formation exposure seen in previous figure, showing grey-green mudrocks at base overlain by ferruginised calcrete conglomerates (beneath hammer, = 32 cm) and medium- to thick-bedded buff sandstones (Loc. 427).

Figure 17: Sandstone / mudrock contact in the same exposure showing deeply gullied sandstone sole surface and numerous ferruginous pedogenic calcrete nodules within the underlying grey-green siltstones (Loc. 427). The latter may occasionally be associated with vertebrate fossils.

Figure 18: Prominently gullied sandstone overlain by coarse conglomerate of reworked mudflakes and well-rounded calcrete nodules, Hartebeest Hoek 182 (Hammer = 32 cm) (Loc. 438).

Figure 19: Cross-bedded breccio-conglomerate of reworked grey-green to maroon platy mudflake rip-up clasts within base of braided channel sandstone, southern side of Oorlogspoort on Hartebeest Hoek 182 (Hammer = 32 cm) (Loc. 434).

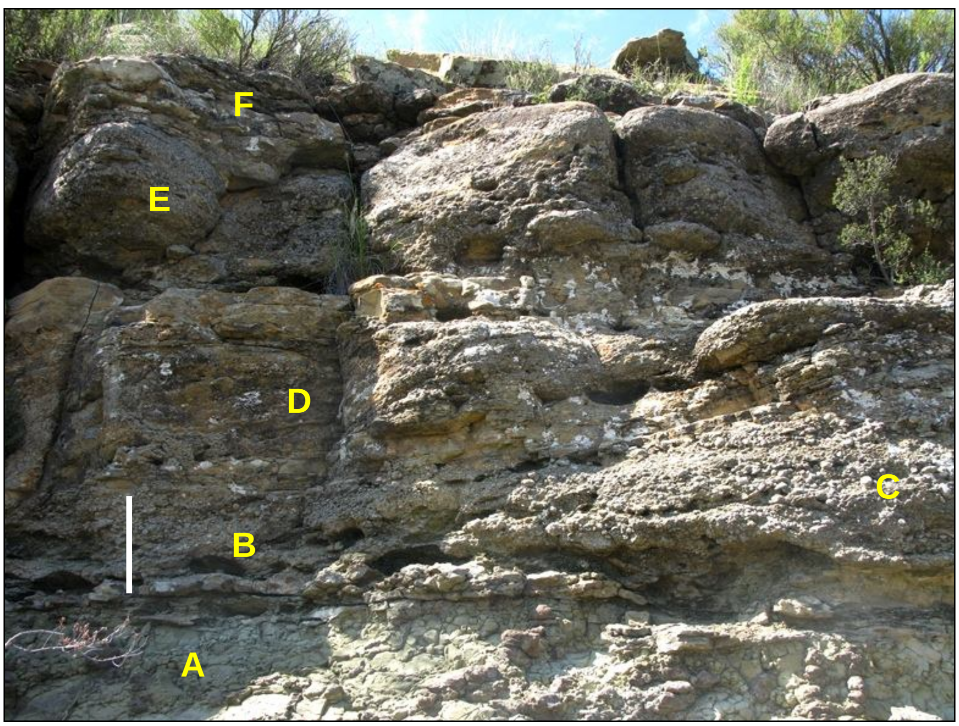

Figure 20: Basal Katberg channel succession in escarpment zone, western Blydefontein 168, showing grey-green overbank siltstones (A) overlain by basal breccio-conglomerate of large mudrock rip-up clasts (B), lenticular grey conglomerate of well-rounded calcrete nodules (C), lenticular, thin-bedded sandstone (D), second, finer-grained and ferruginised calcrete glaebule conglomerate (E) and thin-bedded buff sandstone. Units A and E contain sparse fossil vertebrate remains. Vertical scale bar = *c*. 30 cm. Loc. 427.

2.2. Karoo Dolerite Suite

Basic igneous intrusions intruding the Beaufort Group north of the Great Escarpment are referred to the Karoo Dolerite Suite of Early Jurassic age (*c*. 182 Ma) and are associated with crustal stretching that preceded the final break-up of Gondwana (Duncan & Marsh 2006). Major subhorizontal, broadly conformable sills occur within the Katberg succession within the study area which is also traversed by numerous narrow, inclined dykes (thin red lines in map Fig. 4). Close to the margins of these intrusions the country rocks have been thermally metamorphosed or baked to form tough, splintery quartzites and hornfels (derived from sandstones and mudrocks respectively). Thermal metamorphosis and accompanying metasomatism (chemical alteration by hot migrating fluids) has led to the extensive secondary ferruginisation of Katberg carbonates (pedocrete nodules, calcrete conglomerates) and the formation of locally abundant ferruginous carbonate and siliceous nodules within sandstone facies. In some areas (*e.g.* Loc. 436) the reworked calcrete clasts within channel conglomerates have been dissolved to leave empty vugs (cavities), and this was probably the fate of any accompanying fossil bones or teeth.

Because the Karoo dolerites are igneous rocks that are not of direct palaeontological significance, they will not be treated in detail here. An excellent overview of the Karoo dolerites in the Middelburg sheet area is given by Cole *et al.* (2004). Prominent mountains such as Oppermanskop are capped by relicts of a once-extensive dolerite sill (Fig. 8). Figure 6 shows gravel-strewn dolerite outcrop within the wind farm study area on Blydefontein 168. The full extent of the dolerite intrusion here is obscured by soil cover.

2.3. Late Caenozoic superficial deposits

Various types of superficial deposits (“drift”) of Late Caenozoic (Miocene / Pliocene to Recent) age occur widely throughout the Karoo study region. They include minor pedocretes (*e.g*. calcretes), colluvial slope deposits, stream and alluvium, as well as spring and pan sediments (*cf* Partridge *et al*. 2006). Useful geological overviews of talus deposits, alluvium and calcrete occurrences in the Middelburg sheet area are given by Cole *et al.* (2004). As a result of superficial sediment cover, surface exposure of fresh Beaufort Group rocks within the Noupoort development area – especially the recessive-weathering mudrocks - is generally very poor indeed, apart from stream beds, dongas and steeper hill slopes and artificial exposures in road and railway cuttings (Figs. 7-9, 15, 21). The hill slopes are typically mantled with a thin layer of **colluvium** or slope deposits (*e.g.* sandstone and dolerite scree or talus deposits, sheetwash, surface gravels) (Fig. 8). Thicker accumulations of sandy, gravelly and bouldery **alluvium** of Late Caenozoic age (< 5Ma) are found in stream and river beds (Fig. 21). In the Karoo these colluvial and alluvial deposits are often extensively calcretised (*i.e.* cemented with soil limestone or **calcrete**), especially in the neighbourhood of dolerite intrusions where groundwaters are enriched in dissolved carbonate, although this phenomenon was not observed during the present field study.

According to the Geotechnical Report for the Noupoort Wind Farm project prepared by Mainstream Renewable Power, Engineering and Construction (2012, 24 pp), test pits within the “buildable areas” within the land parcels (green areas in Fig. 2) concerned encountered superficial sands and silts up to one metre or more thick overlying sandstone and bouldery gravels.

Rusty-brown areas seen on satellite images (Fig. 2) probably represent dolerite-rich colluvial gravels. Alluvial areas in the western and southern portions of the study area are extensively affected by gulley erosion, as indicated by dark patches on 1: 50 000 topographic maps (See also Bok 2011). Karoo Supergroup bedrocks are also exposed in these areas, at the base of the deeper *dongas* (Fig. 15).

Figure 21: Thick, well-bedded succession of greyish to brown alluvial siltstones and sparse gravels exposed in stream valley south of Bushman rock shelters, Blydefontein 168. Laterally persistent gravel horizons within thick alluvial successions are not widely developed in this area, although coarse, blocky basal gravels are common.

3. PALAEONTOLOGICAL HERITAGE

The fossil heritage within each of the major rock units that are represented within the Noupoort wind farm study area is outlined here, together with a brief account of Upper Beaufort Group fossil records from the Noupoort region itself. Note that a separate account of fossils from the uppermost Adelaide Subgroup (Pa) is not given because the upper part of the Palingkloof Member belongs to the same assemblage zone (*i.e.* the *Lystrosaurus* AZ) as the overlying Katberg Formation, and no exposures of Palingkloof Member rocks were identified in the field.

GPS data for fossil localities mentioned in the text are provided separately in an appendix to this report.

3.1. Fossil heritage in the Katberg Formation and uppermost Adelaide Subgroup

The Katberg Formation is known to host a low-diversity but palaeontologically important terrestrial fossil biota of Early Triassic (Scythian / Induan - Early Olenekian) age, *i.e.* around 250 million years old (Groenewald & Kitching 1995, Rubidge 2005). The biota is dominated by a small range of therapsids ("mammal-like reptiles"), amphibians and other tetrapods, with rare vascular plants and trace fossils, and has been assigned to the ***Lystrosaurus* Assemblage Zone** (**LAZ**). This impoverished fossil assemblage characterizes Early Triassic successions of the upper part of the Palingkloof Member (Adelaide Subgroup) as well as the Katberg Formation and - according to some earlier authors – the lowermost Burgersdorp Formations of the Tarkstad Subgroup. Recent research has emphasized the rapidity of faunal turnover during the transition between the sand-dominated Katberg Formation (*Lystrosaurus* Assemblage Zone) and the overlying mudrock-dominated Burgersdorp Formation (*Cynognathus* Assemblage Zone) (Neveling *et al.* 2005). In the proximal (southern) part of the basin the abrupt faunal turnover occurs within the uppermost sandstones of the Katberg Formation and the lowermost sandstones of the Burgersdorp Formation (*ibid*., p.83 and Neveling 2004). This work shows that the *Cynognathus* Assemblage Zone correlates with the entire Burgersdorp Formation; previous authors had proposed that the lowermost Burgersdorp beds belonged to the *Lystrosaurus* Assemblage Zone (*e.g.* Keyser & Smith 1977-78, Johnson & Hiller 1990, Kitching 1995). It should also be noted that the dicynodont *Lystrosaurus* has now been recorded from the uppermost beds of the Latest Permian *Dicynodon* Assemblage Zone but only becomes super-abundant in Early Triassic times (*e.g.* Smith & Botha 2005, Botha & Smith 2007 and refs. therein).

Useful illustrated accounts of LAZ fossils are given by Kitching (1977), Keyser and Smith (1977-1978), Groenewald and Kitching (1995), MacRae (1999), Hancox (2000), Smith *et al.* (2002), Cole *et al*. (2004), Rubidge (2005 *plus* refs therein) and Damiani *et al.* (2003a), among others. These fossil biotas are of special palaeontological significance in that they document the recovery phase of terrestrial ecosystems following the catastrophic end-Permian Mass Extinction of 251.4 million years ago (*e.g.* Smith & Botha 2005, Botha & Smith 2007 and refs. therein). They also provide interesting insights into the adaptations and taphonomy of terrestrial animals and plants during a particularly stressful, arid phase of Earth history in the Early Triassic.

Key tetrapods in the *Lystrosaurus* Assemblage Zone biota are various species of the medium-sized, shovel-snouted dicynodont *Lystrosaurus* (by far the commonest fossil form in this biozone. contributing up to 95% of fossils found), the small captorhinid parareptile *Procolophon*, the crocodile-like early archosaur *Proterosuchus*, and a wide range of small to large armour-plated "labyrinthodont" amphibians such as *Lydekkerina* (Figs. 22 and 23). Botha and Smith (2007) have charted the ranges of several discrete *Lystrosaurus* species either side of the Permo-Triassic boundary. Also present in the LAZ are several genera of small-bodied true reptiles (*e.g.* owenettids), therocephalians, and early cynodonts (*e.g. Galesaurus, Thrinaxodon*). Animal burrows are attributable to various aquatic and land-living invertebrates, including arthropods (*e.g. Scoyenia* scratch burrows), as well as several subgroups of fossorial tetrapods such as cynodonts, procolophonids and even *Lystrosaurus* itself (*e.g.* Groenewald 1991, Damiani *et al.* 2003b, Abdala *et al.* 2006, Modesto & Brink 2010, Bordy *et al.* 2009, 2011). Vascular plant fossils are generally rare and include petrified wood ("*Dadoxylon*") as well as leaves of glossopterid progymnosperms and arthrophyte ferns (*Schizoneura*, *Phyllotheca*). An important, albeit poorly-preserved, basal Katberg palaeoflora has recently been documented from the Noupoort area (Carlton Heights) by Gastaldo *et al.* (2005). Plant taxa here include sphenopsid axes, dispersed fern pinnules and possible peltasperm (seed fern) reproductive structures. Pebbles of reworked silicified wood of possible post-Devonian age occur within the Katberg sandstones in the proximal outcrop area near East London (Hiller & Stavrakis 1980, Almond unpublished obs.). Between typical fossil assemblages of the *Lystrosaurus* and *Cynognathus* Assemblage Zones lies a possible *Procolophon* Acme Zone characterized by abundant material of procolophonids and of the amphibian *Kestrosaurus* but lacking both *Lystrosaurus* and *Cynognathus* (Hancox 2000 and refs. therein).

Most vertebrate fossils are found in the mudrock facies rather than channel sandstones. Articulated skeletons enclosed by calcareous pedogenic nodules are locally common, while intact procolophonids, dicynodonts and cynodonts have been recorded from burrow infills (Groenewald and Kitching, 1995). Fragmentary rolled bone and teeth (*e.g.* dicynodont tusks) are found in the intraformational conglomerates at the base of some the channel sandstones

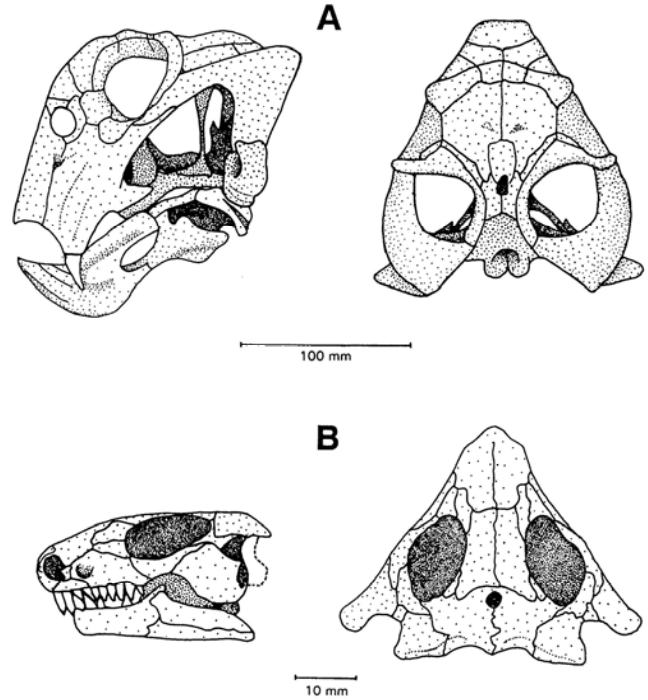

Figure 22: Skulls of two key tetrapod genera from the Early Triassic *Lystrosaurus* Assemblage Zone of the Main Karoo Basin: the pig-sized dicynodont *Lystrosaurus* (A) and the small primitive reptile *Procolophon* (B) (From Groenewald and Kitching, 1995).

Several Karoo vertebrate fossil sites are reported from the Katberg Formation and underlying rocks in the Middelburg – Noupoort region by Kitching (1977; see Karoo biozonation map in Fig. 24 herein). For example, he recorded as many as five different species of *Lystrosaurus* from good mountain slope exposures as well as road and railway cuttings in the Carlton Heights area near Noupoort. Abundant lystrosaurids, including three species of the genus, were found at Edenvale and on Noupoort Commonage (*ibid*., pp. 89-100). It is interesting that the spectrum of *Lystrosaurus* species recorded by Kitching (1977) in the Noupoort region – if correctly identified - suggests that Latest Permian beds referable to the *Dicynodon* Assemblage Zone may in fact be present here (*cf.* Botha & Smith 2007). This is supported by a recent search for fossil records from the Noupoort area in the Karoo fossil database at the BPI (Wits University) kindly undertaken by Mr Mike Day. Sites on the farms Naauwport 1, Bergendal 179, New Jakkalsfontein 172 and Carolus Poort 167 have yielded abundant material of *Lystrosaurus* together with *Procolophon*, *Tetracynodon* and a few specimens of *Dicynodon*.

An unusually diverse LAZ assemblage has recently been recorded from Barendskraal near Middelburg by Damiani *et al.* (2003a). The spectrum of nine or more tetrapod species found here includes *Lystrosaurus* (albeit with low abundance), therocephalians, archosaurs and several procolophonid reptiles. The poorly-preserved fossil flora recorded by Gastaldo *et al.* (2005) from the basal Katberg at Carlton Heights near Noupoort is of special interest because plant fossils are so rare in this stratigraphic interval.

Figure 23: Reconstruction of Early Triassic biotas of the *Lystrosaurus* Assemblage Zone (From Benton 2003 *When life nearly died*). Animals illustrated here include the crocodile-like archosaur reptile *Proterosuchus* (top) and below this the dominant, pig-sized dicyndont *Lystrosaurus*, a small predatory therocephalian therapsid (middle left), several small lizard-like reptiles such as procolophonids (middle right), and two large amphibians (bottom). Plants shown here include several ferns and reedy horsetails.

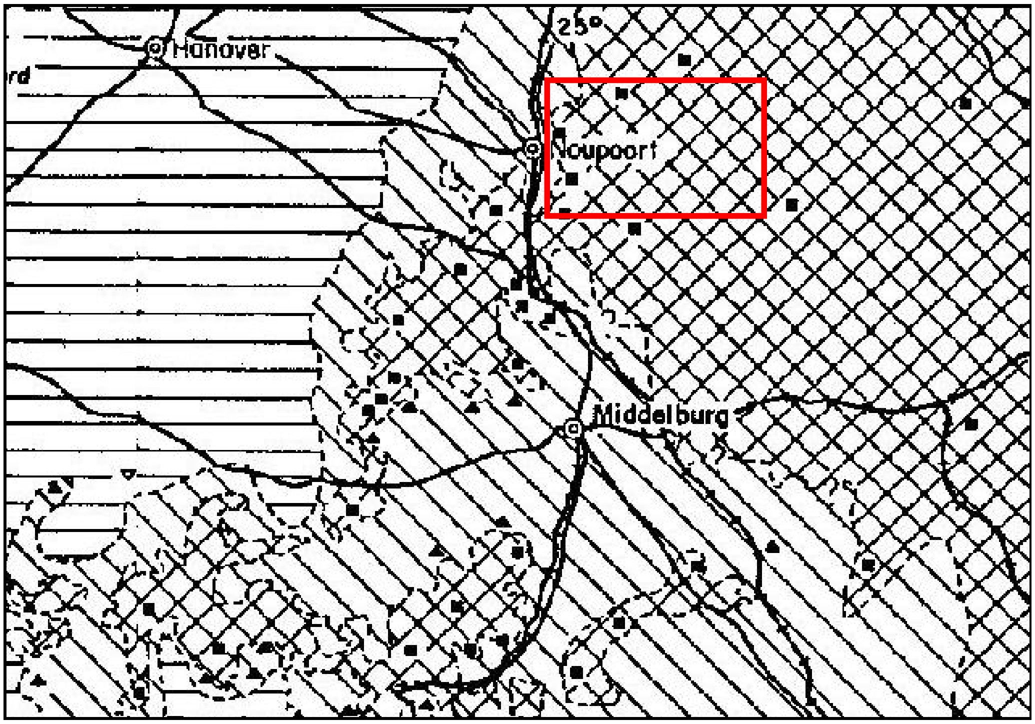

Figure 24: Fossil zonation map of the Middelburg – Noupoort region showing the occurrence of several fossil localities in the area to the east of Noupoort (red rectangle). Black squares here refer to fossils of the Early Triassic *Lystrosaurus* Assemblage Zone (mainly within the Katberg Formation). Triangles to the south are *Dicynodon* AZ fossils within Late Permian rocks of the Adelaide Subgroup. Figure modified from Karoo biozonation map of Kitching (1977).

Of the several potentially fossiliferous exposures of Katberg Formation sediments identified within the Noupoort wind farm study area during fieldwork, only three areas yielded significant palaeontological material (See appendix for GPS data).

The densest fossil remains were recorded within and below low cliffs of Katberg sandstone at Loc. 427 in the western escarpment zone on Blydefontein 168 (Fig. 15). The base of the thin Lower Katberg succession exposed here comprises maroon mudrocks containing small, irregular-shaped calcrete nodules that are overlain by grey-green siltstones with irregular sandstone blobs (possibly load balls). The base of the overlying channel sandstone sheet is formed by coarse, sandstone-hosted breccio-conglomerates of platy mudclasts as well as distinctive pale greyish-weathering calcrete glaebule conglomerates, locally cross-bedded, up to a meter or more in thickness and lenticular in geometry (Figs. 16, 17, 20). Fragmentary reworked skeletal remains, including disarticulated skulls, postcrania and teeth (especially dicynodont tusks) are fairly common within the greyish calcrete conglomerates (Figures 29-30). Some of the fossils were clearly encased in ferruginous pedogenic calcrete *before* they were exhumed and reworked. Lenticular bodies of thin bedded, low angle cross-bedded sandstone also occur within the conglomerate zone. This is overlain by massive grey-green siltstones with rare "bone-bed" concentrations (*e.g. Lystrosaurus* skull and postcrania) and horizons of large ferruginous calcrete nodules representing palaeosols (Figs. 25-27). The following prominent-weathering channel unit largely consists of well-sorted, thick-bedded buff sandstone showing well-developed horizontal lamination, primary current lineation and occasional tabular cross-bedding. The basal breccio-conglomerates contain large mudrock intraclasts associated with small flute clasts. This composite channel infill comprises several beds of buff sandstone separated by intraclast and calcrete-rich conglomerates. Thinner sandstone beds often show a distinctive deep erosional gullying into underlying overbank mudrocks implying high rates of denudation of the Katberg floodplain (Figs. 17 & 18).

Loc. 429 on the southwestern flanks of Langberg (Blydefontein 168) did not yield any vertebrate fossil remains, despite locally good exposures of maroon mudrocks and occasional thin sandstone interbeds (Figs. 13, 14). Low diversity trace fossil assemblages, primarily cylindrical vertical burrows attributed provisionally to the ichnogenus *Skolithos*, are common here and may form dense populations within thin calcretised siltstone horizons (*cf* Fig. 32). Float blocks of coarse, greenish sandstone contain concentrations of rusty-hued impressions of fragmentary plant remains, none of which are identifiable (Fig. 35). Plant fossils are notoriously rare in the Katberg Formation but have been previously recorded from Carlton Heights south of Noupoort (Gastaldo *et al.* 2005).

Closely-spaced localities 438-440 on Hartebeest Hoek 182 are situated in small stream gullies in the western escarpment zone. They lie within the lowermost part of the Katberg succession, which in this region has a gradational rather than abrupt contact with the underlying Adelaide Subgroup (Section 2.1). The spectrum of sedimentary facies seen here mirrors that described earlier at Loc. 427 which lies only 2.4 km to the northeast. Likewise, semi-articulated skeletal remains (*e.g.* of a small-bodied tetrapod, possibly a procolophonid reptile, Fig. 28) occur within grey-green overbank mudrocks while scattered reworked bones and teeth are found in grey-weathering calcrete-dominated channel conglomerates. Vertical burrows ("*Skolithos*") up to several centimetres deep are locally abundant within calcretised siltstones (Fig. 32). Centimetre-wide meniscate back-filled invertebrate burrows ("*Taenidium*") occur within similar settings here (Fig. 33).

It is notable that excellent Katberg mudrock exposures examined in Oorlogspoort, just south of the study area, did not yield body fossils after a search of several hours, although trace fossils such as "*Skolithos*" are common here (*N.B.* only a very small portion of the available mudrock exposures in Oorlogspoort were examined; Locs. 431-434). Calcrete intraclasts within channel conglomerates are often irregularly elongate to vermiform in shale, and occasionally cylindrical (Fig. 31). These delicate objects must have been of fairly local origin, though probably protected by debris-flow (slurry) processes during emplacement by flood events. They may well represent reworked calcretised plant rootlets and / or invertebrate burrows.

The new and very extensive road cuttings at Carlton Heights, 11.6 km south of Noupoort along the N9, provide outstanding vertical and horizontal sections through the Katberg Formation that are of considerable sedimentological interest (*e.g.* fossil mudcracks, channel geometries). Of palaeontological relevance here is the apparent rarity of vertebrate skeletal remains within the Katberg mudrock intervals here (*cf* Kitching 1977); only a few postcranial remains and a calcrete-encrusted tusk were identified during a search of two hours. Numerous examples of the cm-wide subcylindrical invertebrate burrow *Katbergia* occur here, penetrating down through grey-green mudrocks at an oblique angle (Fig. 34). These burrows show surface scratch markings and have been tentatively attributed to decapod crustaceans (Gastaldo & Rolerson 2008, Bordy *et al.* 2010). Poorly preserved plant fossil assemblages were recorded from this area by Gastaldo *et al.* (2005).

Figure 25: Grey-green overbank mudrocks containing semi-articulated skeleton of a medium-sized therapsid (probably *Lystrosaurus*), Blydefontein 168 (Loc. 427) (Scale in cm).

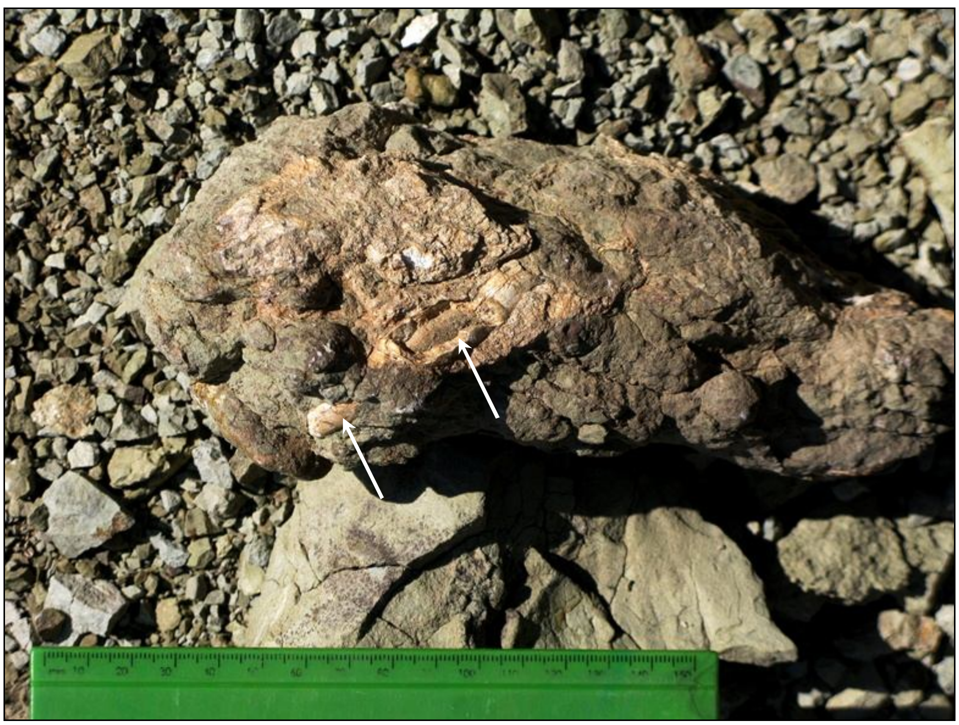

Figure 26: Crushed skull of medium-sized therapsid (probably *Lystrosaurus*) embedded within mudrock (Loc. 427) (Scale in cm, mm). Tusk of animal is arrowed.

Figure 27: Postcranial remains of same animal shown in Figures 25-26 above, showing pinkish – lilac bone coloration. The arrowed bone is a vertebra (Loc. 427).

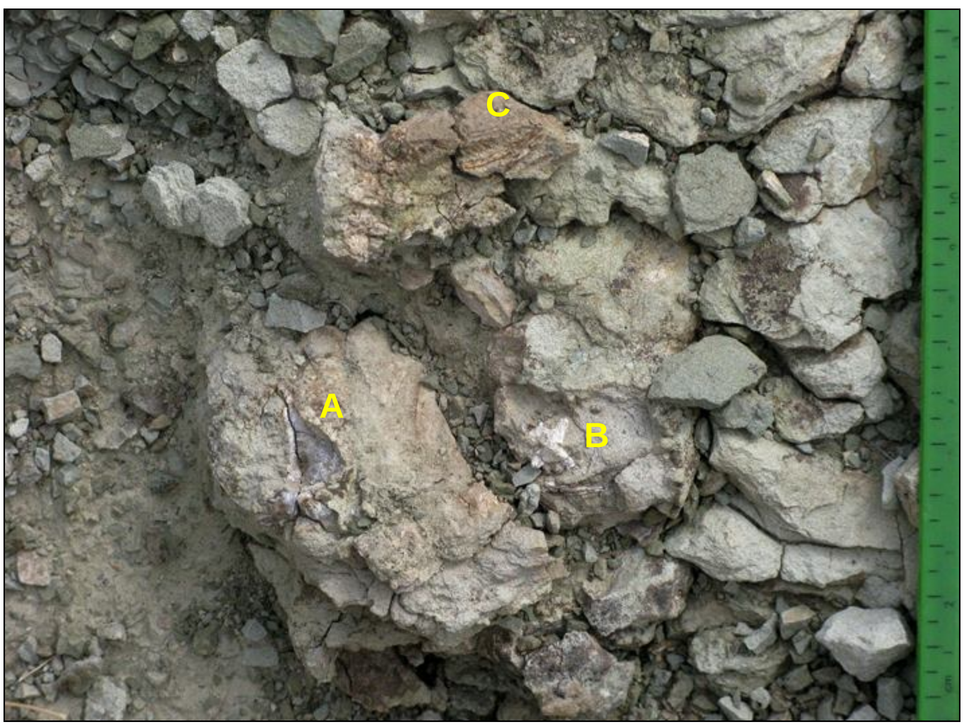

Figure 28: Postcranial skeletal remains of a very small vertebrate (perhaps a procolophonid) embedded in overbank mudrocks in the lowermost part of the Katberg Formation, Hartebeest Hoek 182 (Scale in cm) (Loc. 440). Skeletal elements include parts of a limb girdle (A), vertebra (B) and ribs (C).

Figure 29: Vertical section through the skull of a medium-sized dicynodont (probably *Lystrosaurus*) showing prominent canine tusk (arrow). The fossil is embedded in a basal channel conglomerate composed largely of reworked calcrete nodules (grey) (Loc. 427). Specimen is *c*. 6 cm across.

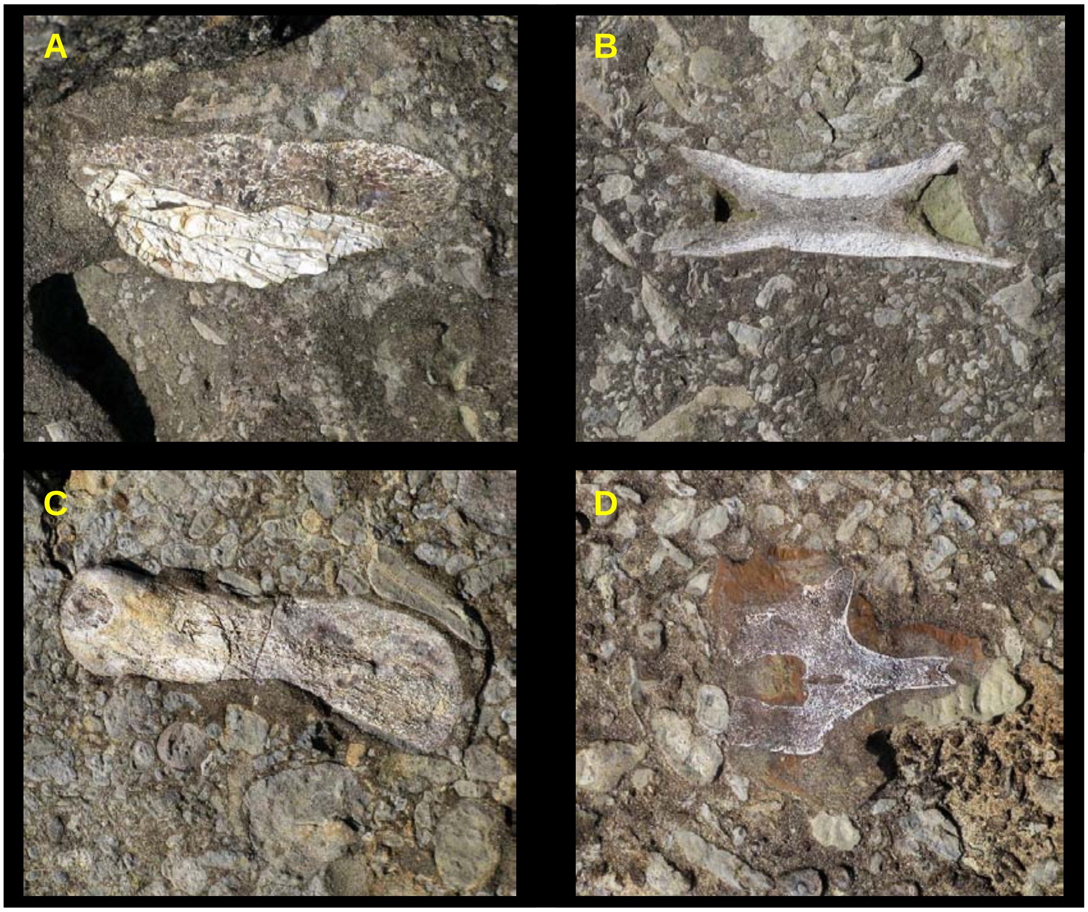

Figure 30: Reworked, disarticulated fossil bones embedded within grey basal channel conglomerates dominated by well-rounded calcrete nodules, Blydefontein 168 (Loc. 427). The bones are often fragmentary, secondarily rounded (*e.g.* A) and may have been already embedded in pedogenic calcrete before they were exhumed and reworked into the base of the channel (*e.g.* D). Dimensions of specimens as shown here (left – right) are approximately: A (5.5 cm), B (7 cm), C (6.5 cm), D (3.5 cm).

Figure 31: Basal channel conglomerate of calcrete material, Oorlogspoort (Loc. 434), showing local abundance of elongate and vermiform structures – possibly locally reworked calcretised rootlets and burrows formed within pre-existing overbank mudrocks (Scale in cm, half cm).

Figure 32: Ferruginous calcretised overbank mudrock showing locally abundant cylindrical vertical burrows of *c*. 0.5 cm diameter, Oorlogspoort (Scale in cm, half cm) (Loc. 434).

Figure 33: Ferruginous pedogenic calcrete showing cm-wide horizontal burrows with a vague meniscate back-filled structure, Hartebeest Hoek 182 (Scale in cm) (Loc. 438).

Figure 34: Characteristic oblique cylindrical burrow of the ichnogenus *Katbergia* penetrating grey-green overbank siltstones, new road cutting at Carlton Heights (Scale in cm) (Loc. 437).

Figure 35: Rusty moulds of fragmentary, transported plant material embedded within coarse greenish-brown channel sandstone, south-western slopes of Langberg (Loc. 430). Scale bar = *c*. 3 cm.

3.2. Fossil heritage within the Karoo Dolerite Suite

The dolerite outcrops within the Noupoort study area are in themselves of no palaeontological significance since these are high temperature igneous rocks emplaced at depth within the Earth's crust. However, as a consequence of their proximity to large dolerite intrusions in the Great Escarpment zone, the Beaufort Group sediments nearby have probably been thermally metamorphosed or "baked" (*i.e*. recrystallised, impregnated with secondary minerals). Embedded fossil material of phosphatic composition, such as bones and teeth, is frequently altered by baking – bones may become blackened, for example - and can be very difficult to extract from the hard matrix by mechanical preparation (Smith & Keyser, p. 23 *in* Rubidge (Ed.) 1995). Thermal metamorphism by dolerite intrusions therefore tends to *reduce* the palaeontological heritage potential of adjacent Beaufort Group sediments. This is possibly apparent in the present study area at Loc. 436 on the northern margins of Blydefontein 168 where reworked calcrete nodules and any associated vertebrate fossil material (bones, teeth) within Katberg basal channel conglomerates has been dissolved away in the neighbourhood of dolerite intrusions.

3.3. Fossil heritage within the Late Caenozoic superficial deposits ('drift')

The relatively young - largely Quaternary to Recent - superficial deposits (colluvium, gravels, silty alluvium *etc*) in the Karoo region as a whole have been comparatively neglected in palaeontological terms for the most part. However, they may occasionally contain important fossil biotas, notably the bones, teeth and horn cores of mammals (*e.g.* Skead 1980, Klein 1984, MacRae 1999, Partridge & Scott 2000, Partridge *et al.,* 2006). Other late Caenozoic fossil biotas from these superficial deposits include non-marine molluscs (bivalves, gastropods, rhizoliths), ostrich egg shells, trace fossils (*e.g.* calcretised termitaria, coprolites, trackways), and plant remains such as peats or palynomorphs (pollens) in organic-rich alluvial horizons. Stone artefacts of Pleistocene and younger age may prove useful in constraining the age of superficial deposits such as gravelly alluvium within which they are occasionally embedded.

Thick successions of incised stream alluvium and colluvial deposits within the Noupoort study area (*e.g.* Figs. 7, 15, 21) were examined for fossil remains, generally without success. Surface gravels downslope from fossiliferous Katberg Formation exposures contain sparse reworked fossil bone fragments (Loc. 21, Figs. 15, 36). Some of the darker grey, fine-grained alluvium (Fig. 21) appears to be carbonaceous and may contain palaeontologically useful plant material (including palynomorphs).

Figure 36: Fossil remains of vertebrates (probably *Lystrosaurus*) from Loc. 427, Blydefontein 168 (See also Figure 26). The rolled bone fragments on the bottom left were collected from surface gravels downslope from the main fossil locality.

4. SIGNIFICANCE OF IMPACTS ON PALAEONTOLOGICAL HERITAGE

The proposed Mainstream Wind Farm near Noupoort is located in an area of the Karoo that is underlain by potentially fossiliferous sedimentary rocks of Triassic and younger, probably Quaternary age (Sections 3 & 4). The construction phase of this alternative energy development will entail numerous excavations into the superficial sediment cover and in some areas into the underlying bedrock as well. These include, for example, excavations for the wind turbine foundations, underground cables, new electricity transmission lines and substations, as well as new gravel access roads and any control / administrative buildings. In addition, substantial areas of bedrock will be sealed-in or sterilized by infrastructure such as lay-down and standing areas for the wind turbines as well as new access roads. All these developments may adversely affect fossil heritage preserved at or below the ground surface within the development footprint by destroying, disturbing or permanently sealing-in fossils that are then no longer available for scientific research or other public good.

The significance of anticipated impacts on palaeontological heritage resources within the Noupoort Wind Farm study area is assessed for the construction phase in Table 1 below, according to the scheme developed by Sivest Environmental Division. The proposed development is assessed as having an overall NEGATIVE LOW impact and no project-specific mitigation measures or further studies are considered necessary for this project.

Please note that:

- the operational and decommissioning phases of the wind energy facility will not involve further significant adverse or other impacts on palaeontological heritage;

- impacts from the construction of associated new road infrastructure and transmission lines are treated as part of the overall impact of the wind farm development, and have not been considered separately in Table 1.

Alternative locations for the on-site substation, lay down, operation and maintenance areas, as well as alternative routes for the transmission line connection to the Eskom grid near Noupoort are shown in Figs. 3A and 3B.

The anticipated impacts on palaeontological heritage of alternative sites for the on-site substation, operational and maintenance area and lay down area are considered to be similar and LOW. There are no preferences for any of the alternatives on palaeontological heritage grounds.

Likewise, the anticipated impacts of the various proposed transmission line routes between the Noupoort Wind Farm and the Eskom grid near Noupoort and considered to be LOW. However, the Southern 2 Alternative (green in Fig. 3B) that runs along the Oorlogspoort valley to the south of the study area traverses one of the few areas in the mountainous region to the east of Noupoort where fairly extensive, laterally persistent hillslope exposures of potentially fossiliferous Katberg Formation mudrocks are present (Fig. 37). The other routes are therefore preferred on palaentological heritage grounds. However, good mudrock exposures in Oorlogspoort are limited to particular horizons along the hillslopes as well as the incised stream bed. Most of the flatter-lying valley floor is mantled with thick alluvial deposits. If the proposed Southern 2 transmission line route follows the valley floor, as seen with the telephone line in Figure 37, then anticipated impacts on fossil heritage here are also very low.

Fig. 37. View of steep, north-facing hillslopes along Oorlogspoort showing laterally extensive mudrock exposure (pale grey zone, arrowed) higher up but mantling of bedrocks by alluvial deposits lower down.

Table 1: Assessment of impacts of proposed Mainstream Noupoort Wind Farm on palaeontological heritage resources (Construction Phase)

Environmental Parameter	*Fossil material (notable remains of vertebrates, plants, trace fossils within the Katberg Formation) preserved at or beneath the ground surface within the development footprint.*	
Issue/Impact/Environmental Effect/Nature	*Disturbance, damage, destruction or sealing-in of fossil remains during the construction phase of the wind farm (mainly as result of excavations for wind turbines, cables, access roads and associated infrastructure such as laydown areas, transmission line pylons) (Negative impact).*	
Extent	*Limited to development footprint (site).*	
Probability	*Possible.*	
Reversibility	*Destruction of fossil remains and their sedimentary context is generally irreversible. Mitigation during construction may reduce negative impact.*	
Irreplaceable loss of resources	*Marginal, since comparable fossil remains are present within the extensive outcrop area of same rock unit (Katberg Formation) elsewhere in the region.*	
Duration	*Permanent.*	
Cumulative effect	*Cumulative impacts cannot be realistically assessed in the absence of data on other development projects in the broader study region, but are likely to be negligible to low given the large outcrop area of the Katberg Formation.*	
Intensity/magnitude	*Low, given the apparent scarcity of vertebrate and plant fossil remains in the Katberg Formation in the Noupoort region.*	
Significance Rating	*Negative Low impact, so no project-specific mitigation measures recommended for palaeontological heritage*	
	Pre-mitigation impact rating	Post mitigation impact rating
Extent	1	1
Probability	2	2
Reversibility	4	4
Irreplaceable loss	2	2
Duration	4	4
Cumulative effect	1	1
Intensity/magnitude	1	1
Significance rating	-14 (Negative Low impact)	-14 (Negative Low impact)
Mitigation measures	*Should substantial fossil remains (*e.g.* vertebrate bones, teeth, petrified wood) be discovered during construction, these should be safeguarded (preferably* in situ*) and the ECO should alert SAHRA so that appropriate mitigation (*e.g.* recording, sampling or collection) can be taken by a professional palaeontologist.*	

Table 2: Comparative Assessment of Noupoort Wind Farm Alternatives in terms of palaeontological heritage issues

Key:

Preferred	The alternative will result in a low impact / reduce the impact
Not Preferred	The alternative will result in a high impact / increase the impact
Favourable	The impact will be relatively insignificant

Alternative	**Preference**	**Reasons**
WIND FARM		
Substation Alt 1	No preference	Insignificant impact
Substation Alt 2	No preference	Insignificant impact
Operation and Maintenance Buildings Alt 1	No preference	Insignificant impact
Operation and Maintenance Buildings Alt 2	No preference	Insignificant impact
Laydown Area Alt 1	No preference	Insignificant impact
Laydown Area Alt 2	No preference	Insignificant impact

5. CONCLUSIONS & RECOMMENDATIONS

The Mainstream wind farm study area east of Noupoort, Northern Cape, is largely underlain by continental sediments of the Katberg Formation (Karoo Supergroup) that are known to contain important fossil biotas of Early Triassic age, notably vertebrates, trace fossils and rare plants of the *Lystrosaurus* Assemblage Zone. These fossils are of international palaeontological significance in that they document the recovery of terrestrial biotas following the catastrophic end-Permian mass extinction event of 251 million years ago. Several Early Triassic vertebrate fossil localities have already been recorded by previous workers close to the Noupoort study area and are represented in museum collections (*e.g.* the BPI at Wits University, Johannesburg). Part of the wind farm study area is underlain by intrusive rocks of the Early Jurassic Karoo Dolerite Suite that are not palaeontologically significant.

Over the great majority of the study area, including flatter-lying areas that are most likely to be affected by the proposed development, the Katberg Formation bedrocks are mantled with superficial deposits such as scree, soil and alluvium that are generally of low palaeontological sensitivity. The very few good exposures of potentially fossiliferous mudrocks within the region mainly occur on steeper hill slopes in the escarpment region that lie outside the wind farm development footprint. Even where bedrock exposure is good, fossil vertebrate remains are sparse, disarticulated and usually fragmentary (*e.g.* reworked bones and teeth in channel conglomerates). Rare plant fossils recorded are very poorly preserved and not identifiable to a specific plant group. Trace fossils (various invertebrate burrows) are locally abundant but assemblages are very low in diversity and represent common Katberg forms.

It is concluded that the construction phase of the proposed Mainstream Noupoort Wind Farm is likely to have only a LOW NEGATIVE impact on local palaeontological heritage resources (Table 3). The operational and decommissioning phases of wind farms will not involve significant negative impacts. Fatal flaws or no-go areas with respect to fossil heritage conservation have not been identified for this project. There are no preferences on palaeontological heritage grounds for any particular alternative site for the on-site substation, operational and maintenance buildings or lay down area. Likewise, the various alternative transmission line routes from the wind farm to the

Eskom grid near Noupoort are assessed as having a similar low negative impact with the exception of the Southern 2 Alternative. In this last case, negative impacts might be slightly higher (but still LOW overall) due to the comparatively good Katberg Formation bedrock exposure along Oorlogspoort.

Table 3: Summarized impacts of proposed Mainstream Noupoort Wind Farm on palaeontological heritage resources

Environmental parameter	Issues	Rating prior to mitigation	Average	Rating post mitigation	Average
Fossil heritage resources	Disturbance, damage, destruction or sealing-in of fossil remains during the construction phase of the wind farm	-14		-14	
			- 14		- **14**
			Low Negative Impact		Low Negative Impact

It is considered that no further palaeontological heritage studies or specialist mitigation are warranted for this alternative energy project, pending the exposure of any substantial fossil remains (*e.g.* vertebrate bones and teeth, large blocks of petrified wood) during the construction phase.

The ECO responsible for the developments should be alerted to the possibility of fossil remains being found on the surface or exposed by fresh excavations during construction. Should substantial fossil remains be discovered during construction, these should be safeguarded (preferably *in situ*) and the ECO should alert SAHRA so that appropriate mitigation (*e.g.* recording, sampling or collection) can be taken by a professional palaeontologist.

The specialist involved would require a collection permit from SAHRA. Fossil material must be curated in an approved repository (*e.g.* museum or university collection) and all fieldwork and reports should meet the minimum standards for palaeontological impact studies developed by SAHRA.

These recommendations should be incorporated into the EMP for the Mainstream Noupoort Wind Farm.

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6. REFERENCES

ABDALA, F., CISNEROS, J.C. & SMITH, R.M.H. 2006. Faunal aggregation in the Early Triassic Karoo Basin: earliest evidence of shelter-sharing behaviour among tetrapods. Palaios 21, 507-512.

ALMOND, J.E. 2011. Proposed Mainstream wind farm near Noupoort, Pixley ka Seme District Municipality, Northern Cape Province. Palaeontological desktop study, 20 pp. Natura Viva cc, Cape Town.

ALMOND, J.E., DE KLERK, W.J. & GESS, R. 2008. Palaeontological heritage of the Eastern Cape. Draft report for SAHRA, 30 pp. Natura Viva cc, Cape Town.

BENTON, M.J. 2003. When life nearly died. The greatest mass extinction of them all, 336 pp. Thames & Hudson, London.

BOK, S.N. 2011. Four potential wind farm sites near Lady Grey, Noupoort, Prieska and Louriesfontein. Geotechnical desktop study, 18 pp. Jeffares & Green (Pty) Ltd.

BORDY, E. M., SZTANÓ, O., RUBIDGE, B.S. AND BUMBY, A. 2009. Tetrapod burrows in the southwestern main Karoo Basin (Lower Katberg Formation, Beaufort Group), South Africa. Extended Abstracts of the 15th Biennial Conference of the Palaeontological Society of Southern Africa. September 11-14, Matjiesfontein, South Africa. Palaeontologia Africana 44, 95-99.

BORDY, E.M., SZTANÓ, O, RUBDIGE, B. & BUMBY, A. 2011. Early Triassic vertebrate burrows from the Katberg Formation of the south-western Karoo Basin, South Africa. Lethaia 44, 33-45.

BOTHA, J. & SMITH, R.M.H. 2007. *Lystrosaurus* species composition across the Permo-Triassic boundary in the Karoo Basin of South Africa. Lethaia 40, 125-137.

CLUVER, M.A. 1978. Fossil reptiles of the South African Karoo. 54pp. South African Museum, Cape Town.

COLE, D.I., NEVELING, J., HATTINGH, J., CHEVALLIER, L.P., REDDERING, J.S.V. & BENDER, P.A. 2004. The geology of the Middelburg area. Explanation to 1: 250 000 geology Sheet 3124 Middelburg, 44 pp. Council for Geoscience, Pretoria.

DAMIANI, R., NEVELING, J., MODESTO, S. & YATES, A. 2003a. Barendskraal, a diverse amniote locality from the Lystrosaurus Assemblage Zone, Early Triassic of South Africa. Palaeontologia Africana 39, 53-62.

DAMIANI, R., MODESTO, S., YATES, A. & NEVELING, J. 2003b. Earliest evidence for cynodont burrowing. Proceedings of the Royal Society of London B. 270, 1747-1751.

DINGLE, R.V., SIESSER, W.G. & NEWTON, A.R. 1983. Mesozoic and Tertiary geology of southern Africa. viii + 375 pp. Balkema, Rotterdam.

DUNCAN, A.R. & MARSH, J.S. 2006. The Karoo Igneous Province. In: Johnson, M.R., Anhaeusser, C.R. & Thomas, R.J. (Eds.) The geology of South Africa, pp. 501-520. Geological Society of South Africa, Marshalltown.

GASTALDO, R.A., ADENDORFF, R., BAMFORD, M., LABANDEIRA, C.C., NEVELING, J. & SIMS, H. 2005. Taphonomic trends of macrofloral assemblages across the Permian – Triassic boundary, Karoo Basin, South Africa. Palaios 20, 479-497.

GASTALDO, R.A. & ROLERSON, M.W. 2008. *Katbergia* Gen. Nov., a new trace fossil from the Upper Permian and Lower Triassic rocks of the Karoo Basin: implications for palaeoenvironmental conditions at the P/TR extinction event. Palaeontology 51, 215-229.

GROENEWALD, G.H. 1991. Burrow casts from the *Lystrosaurus-Procolophon* Assemblage-zone, Karoo Sequence, South Africa. Koedoe 34, 13-22.

GROENEWALD, G.H. & KITCHING, J.W. 1995. Biostratigraphy of the *Lystrosaurus* Assemblage Zone. Pp. 35-39 in RUBIDGE, B.S. (ed.) Biostratigraphy of the Beaufort Group (Karoo Supergroup). South African Committee for Stratigraphy, Biostratigraphic Series No. 1, 46 pp. Council for Geoscience, Pretoria.

HANCOX, P.J. 2000. The continental Triassic of South Africa. Zentralblatt für Geologie und Paläontologie, Teil 1, 1998, 1285-1324.

HAYCOCK, C.A., MASON, T.R. & WATKEYS, M.K. 1994. Early Triassic palaeoenvironments in the eastern Karoo foreland basin, South Africa. Journal of African Earth Sciences 24, 79-94.

HILLER, N. & STAVRAKIS, N. 1980. Distal alluvial fan deposits in the Beaufort Group of the Eastern Cape Province. Transactions of the Geological Society of South Africa 83, 353-360.

HILLER, N. & STAVRAKIS, N. 1984. Permo-Triassic fluvial systems in the southeastern Karoo Basin, South Africa. Palaeogeography, Palaeoclimatology, Palaeoecology 34, 1-21.

JOHNSON, M.R. 1966. The stratigraphy of the Cape and Karoo Systems in the Eastern Cape Province. Unpublished MSc Thesis, Rhodes University, Grahamstown.

JOHNSON, M.R. 1976. Stratigraphy and sedimentology of the Cape and Karoo sequences in the Eastern Cape Province. Unpublished PhD thesis, Rhodes University, Grahamstown, xiv + 335 pp, 1pl.

JOHNSON, M.R., VAN VUUREN, C.J., VISSER, J.N.J., COLE, D.I., DE V. WICKENS, H., CHRISTIE, A.D.M., ROBERTS, D.L. & BRANDL, G. 2006. Sedimentary rocks of the Karoo Supergroup. In: Johnson, M.R., Anhaeusser, C.R. & Thomas, R.J. (Eds.) The geology of South Africa, pp. 461-499. Geological Society of South Africa, Marshalltown.

KEYSER, A.W. & SMITH, R.M.H. 1977-78. Vertebrate biozonation of the Beaufort Group with special reference to the Western Karoo Basin. Annals of the Geological Survey of South Africa 12: 1-36.

KITCHING, J.W. 1977. The distribution of the Karroo vertebrate fauna, with special reference to certain genera and the bearing of this distribution on the zoning of the Beaufort beds. Memoirs of the Bernard Price Institute for Palaeontological Research, University of the Witwatersrand, No. 1, 133 pp (incl. 15 pls).

KLEIN, R.G. 1984. The large mammals of southern Africa: Late Pliocene to Recent. In: Klein, R.G. (Ed.) Southern African prehistory and paleoenvironments, pp 107-146. Balkema, Rotterdam.

MACRAE, C. 1999. Life etched in stone. Fossils of South Africa. 305pp. The Geological Society of South Africa, Johannesburg.

MCCARTHY, T. & RUBIDGE, B. 2005. The story of Earth and life: a southern African perspective on a 4.6-billion-year journey. 334pp. Struik, Cape Town.

MODESTO, S.P. & BOTHA-BRINK, J. 2010. A burrow cast with *Lystrosaurus* skeletal remains from the Lower Triassic of South Africa. Palaios 25, 274-281.

NEVELING, J., RUBIDGE, B.S. & HANCOX, P.J. 1999. A lower *Cynognathus* Assemblage Zone fossil from the Katberg Formation (Beaufort Group, South Africa). South African Journal of Science 95, 555-556.

NEVELING, J. 2004. Stratigraphic and sedimentological investigation of the contact between the *Lystrosaurus* and the *Cynognathus* Assemblage Zones (Beaufort Group: Karoo Supergroup). Council for Geoscience, Pretoria, Bulletin, 137, 164pp.

NEVELING, J., HANCOX, P.J. & RUBIDGE, B.S. 2005. Biostratigraphy of the lower Burgersdorp Formation (Beaufort Group; Karoo Supergroup) of South Africa – implications for the stratigraphic ranges of early Triassic tetrapods. Palaeontologia Africana 41, 81-87.

PARTRIDGE, T.C. & SCOTT, L. 2000. Lakes and pans. In: Partridge, T.C. & Maud, R.R. (Eds.) The Cenozoic of southern Africa, pp.145-161. Oxford University Press, Oxford.

PARTRIDGE, T.C., BOTHA, G.A. & HADDON, I.G. 2006. Cenozoic deposits of the interior. In: Johnson, M.R., Anhaeusser, C.R. & Thomas, R.J. (Eds.) The geology of South Africa, pp. 585-604. Geological Society of South Africa, Marshalltown.

RETALLACK, G.J., SMITH, R.M.H. & WARD, P.D. 2003. Vertebrate extinction across the Permian-Triassic boundary in the Karoo Basin, South Africa. Geological Society of America Bulletin 115, 1133-1152.

RETALLACK, G.J., METZGER, C.A., GREAVER, T., HOPE JAHREN, A., SMITH, R.M.H. & SHELDON, N.D. 2006. Middle – Late Permian mass extinction on land. GSA Bulletin 118, 1398-1411.

RUBIDGE, B.S. (Ed.) 1995. Biostratigraphy of the Beaufort Group (Karoo Supergroup). South African Committee for Biostratigraphy, Biostratigraphic Series No. 1., 46 pp. Council for Geoscience, Pretoria.

RUBIDGE, B.S. 2005. Re-uniting lost continents – fossil reptiles from the ancient Karoo and their wanderlust. South African Journal of Geology 108: 135-172.

SKEAD, C.J. 1980. Historical mammal incidence in the Cape Province. Volume 1: The Western and Northern Cape, 903pp. Department of Nature and Environmental Conservation, Cape Town.

SMITH, R.H.M. & WARD, P.D. 2001. Pattern of vertebrate extinction across an event bed at the Permian-Triassic boundary in the Karoo Basin of South Africa. Geology 29, 1147-1150.

SMITH, R.M.H., HANCOX, P.J., RUBIDGE, B.S., TURNER, B.R. & CATUNEANU, O. 2002. Mesozoic ecosystems of the Main Karoo Basin: from humid braid plains to arid sand sea. Guidebook 8th International Symposium on Mesozoic Terrestrial Ecosystems, Cape Town, South Africa, 116 pp.

SMITH, R. & BOTHA, J. 2005. The recovery of terrestrial vertebrate diversity in the South African Karoo Basin after the end-Permian extinction. Comptes Rendus Palevol 4, 555-568.

STAVRAKIS, N. 1980. Sedimentation of the Katberg Sandstone and adjacent formations in the south-eastern Karoo Basin. Transactions of the Geological Society of South Africa 83, 361-374.

VIGLIETTI, P. 2010. Origin, sedimentology and taphonomy of an Early Triassic Lystrosaurus bonebed, Katberg Formation, Karoo Basin, South Africa. Proceedings of the 16th Conference of the Palaeontological Society of Southern Africa, Howick, August 5-8, 111a-111c.

VISSER, J.N.J. & DUKAS, B.A. 1979. Upward-fining fluviatile megacycles within the Beaufort Group, north of Graaff-Reinet, Cape Province. Transactions of the Geological Society of South Africa 82, 149-154.

WARD, P.D., BOTHA, J., BUICK, R., DE KOCK, M.O., ERWIN, D.H., GARRISON, G.H., KIRSCHVINK, J.L. & SMITH, R.M.H. 2005. Abrupt and gradual extinction among Late Permian land vertebrates in the Karoo Basin, South Africa. Science 307, 709-714.

APPENDIX: GPS LOCALITY DATA FOR SITES LISTED IN TEXT

All GPS readings were taken in the field using a hand-held Garmin GPSmap 60CSx instrument. The datum used is WGS 84.

GPS LOCALITY NUMBER	SOUTH	EAST	COMMENTS
425	31° 09' 36.9"	25° 00' 40.8"	Baked Katberg sediments, Blydefontein 168
426	31° 09' 28.2"	25° 00' 43.9"	Ferruginised channel conglomerates, Blydefontein 168
427	31° 09' 34.2"	25° 00' 35.2"	Reworked bones & teeth in Katberg channel conglomerates. Semi-articulated *Lystrosaurus* skull & postcrania. Rolled bone clasts in surface gravels, Blydefontein 168
428	31° 08' 54.6"	25° 01' 09.9"	Katberg maroon mudrocks with rare bone within calcrete nodules, Blydefontein 168
429	31° 07' 51.4"	25° 02' 24.7"	Good exposure of Katberg mudrocks with abundant trace fossils, Langberg, Blydefontein 168
430	31° 07' 48.5"	25° 02' 27.9"	Fragmentary plant remains in coarse sandstone float blocks, Langberg, Blydefontein 168
431	31° 12' 37.5"	25° 01' 02.4"	Oorlogspoort good road cutting exposures of Katberg succession
432	31° 12' 30.2"	25° 01' 10.8"	Oorlogspoort good road cutting exposures of Katberg succession
433	31° 12' 27.5"	25° 01' 14.7"	Oorlogspoort good road cutting exposures of Katberg succession
434	31° 12' 18.2"	25° 01' 37.3"	Good Katberg exposures at top of Oorlogspoort. Trace fossils locally common.
435	31° 11' 38.0"	25° 04' 52.3"	Donga exposures of maroon mudrocks, Farm 181
436	31° 07' 52.5"	25° 04' 19.9"	Highly baked Katberg sediments, Blydefontein 168
437	31° 17' 27.3"	24° 57' 05.9"	New N9 roadcutings through Katberg Formation, Carlton Heights
438	31° 10' 33.8"	24° 59' 54.0"	Stream gully exposure of Katberg, Hartebeest Hoek, trace fossil assemblages
439	31° 10' 37.0"	24° 59' 50.9"	Katberg channel conglomerates with reworked bone and teeth, Hartebeest Hoek
440	31° 10' 35.4"	24° 59' 49.7"	Postcranial remains of small tetrapod (possible procolophonid) in Katberg overbank mudrocks, Hartebeest Hoek

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, Limpopo, Free State and Gauteng for SAHRA and HWC. Dr Almond is an accredited member of PSSA and APHP (Association of Professional Heritage 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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