PALAEONTOLOGICAL DESKTOP STUDY

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

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EXECUTIVE SUMMARY

The Mainstream wind farm study area east of Noupoort is largely underlain by Mesozoic continental sediments of the Katberg Formation (Karoo Supergroup). These rocks are known to contain important fossil biotas of Early Triassic age, notably vertebrates (mammal-like reptiles, true reptiles, amphibians), trace fossils and rare plants of the *Lystrosaurus* Assemblage Zone. The Katberg 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 within or close to the study area and are represented in museum collections. Jurassic dolerite intrusions and Late Caenozoic superficial sediments (*e.g.* scree, alluvium) in the study area are generally of low palaeontological sensitivity.

Since the construction phase of the proposed wind farm will entail numerous excavations for wind turbine emplacements, underground cables, access roads *etc*, its impact significance as far as fossil heritage is concerned is potentially *high* (negative). Such impacts can only be adequately assessed, and any appropriate mitigation measures proposed, following a field-based study of the study area by a professional palaeontologist. The operational and decommissioning phases of wind farms do not involve significant negative impacts on fossil heritage. It is therefore recommended that:

- *Before* the development footprint of the wind farm is finalized, a professional palaeontologist should be contracted at the developer's expense to carry out a field study to assess the extent, sensitivity and distribution of fossil heritage actually present within the entire study area;

- The field study should identify any areas of high palaeontological sensitivity and propose appropriate mitigation measures to be incorporated into the EMP for this project (*e.g.* pre-construction collection and recording of near-surface fossils / monitoring of bedrock excavations by a professional palaeontologist and / or by the ECO / delineation of any no-go areas);

- In the case of any significant fossil finds (*e.g.* vertebrate teeth, bones, burrows, plant-rich beds or 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.

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 Louriesfontein. 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 Noupoort 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.

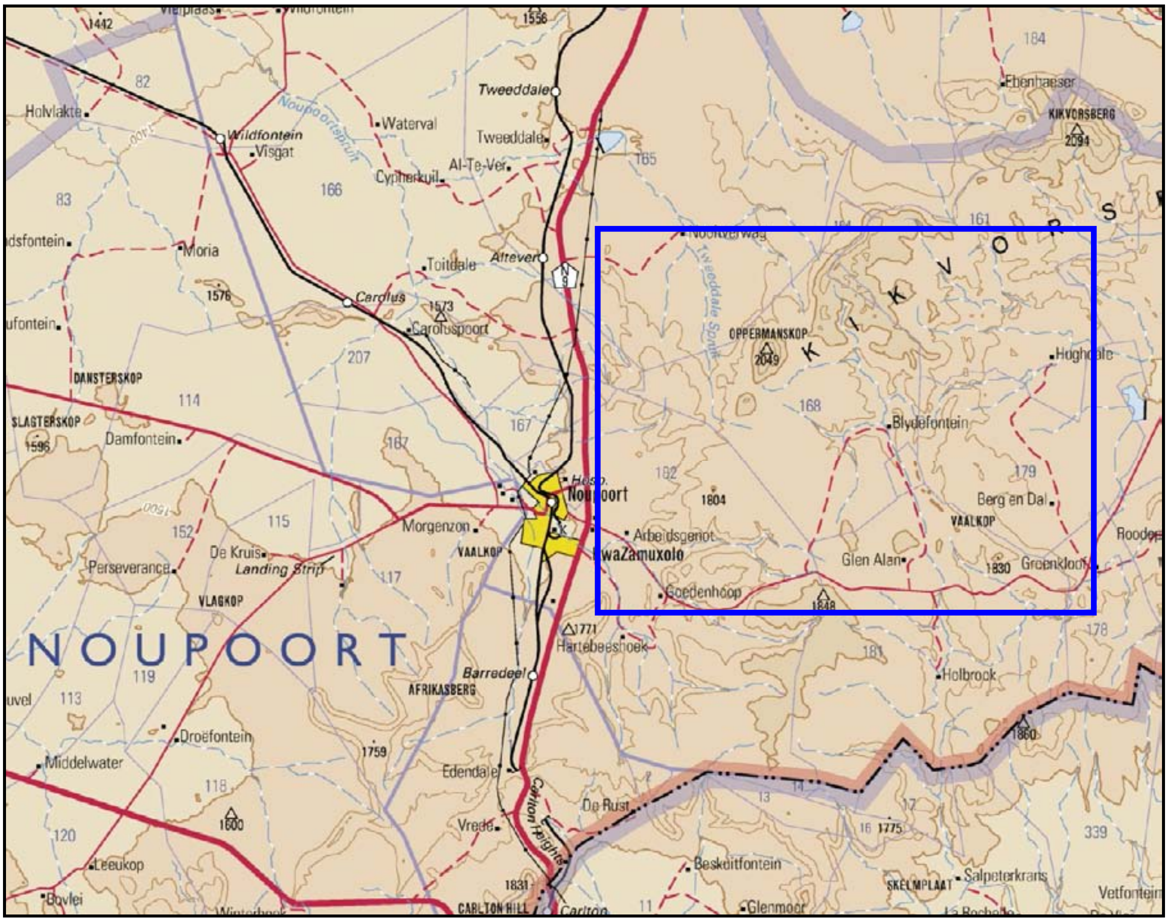


Figure 1: Extract from 1: 250 000 topographical map 3124 Middelburg (Courtesy of The Chief Directorate of Surveys & Mapping, Mowbray) showing the *approximate* location of the proposed Mainstream wind farm east of Noupoort, Northern Cape (blue rectangle).

Figure 2: Google Earth satellite image of the study area east of Noupoort showing the highly dissected, mountainous terrain of the Kikvorsberg.

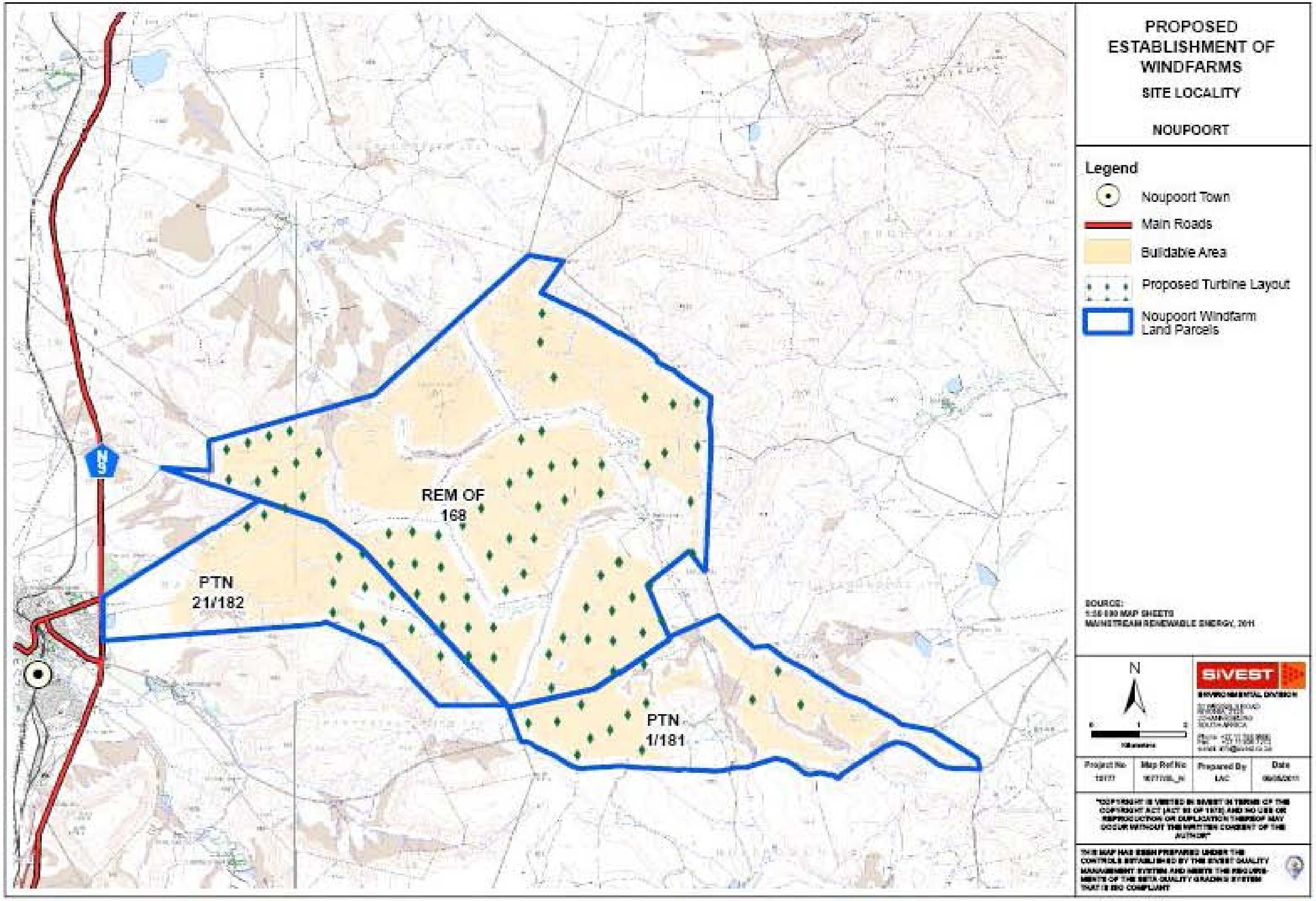
1.1. Location and extent of study area

The proposed 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 (Fig1). It lies approximately 53 km south east of Colesberg and 55km south west of Hanover. The wind farm study area here is around 7 490 hectares in extent and consists of three adjacent land portions, namely:

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

The boundaries 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 wind farm near Noupoort showing boundaries of the land parcels concerned and a provisional wind turbine layout (Image kindly provided by SIVEST Environmental Division).


PROPOSED
ESTABLISHMENT OF
WINDFARMS
SITE LOCALITY
NOUPOORT
Legend
Noupoort Town
Main Roads
Buildable Area
Proposed Turbine Layout
Noupoort Windfarm
Land Parcels
REM OF
168
PTN
21/182
PTN
1/181
N9
N
SIVEST

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 60-120m and a rotor diameter of 70-130m. They will be connected to each other and to the substation using underground 1m 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 on to 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 66kV (smaller wind farms) or 132kV (larger wind farms). In Noupoort the electrical connection to the grid will depend on the project size. For a smaller project size the connections will use a 66kV line while 132kV line will be used for the larger project size. A new substation (approx. 90 x 120m) and a transformer to the existing 132kV and 66kV 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 66kV and/or 132kV 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 2,250m^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 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 any hard standing areas for each wind turbine, 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. The analysis of 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 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 study area (*e.g.* museums).

The scoping level report must 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 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 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) 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.

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.

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 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 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 1600m 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 likely to be largely covered by colluvial debris. Furthermore, the map of the proposed wind turbine layout (Fig. 3) 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 I 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**) (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. In many areas the Mesozoic bedrocks are mantled with a variety of **superficial deposits** of presumed 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 scree and hill-wash are not mapped in Figure 3.

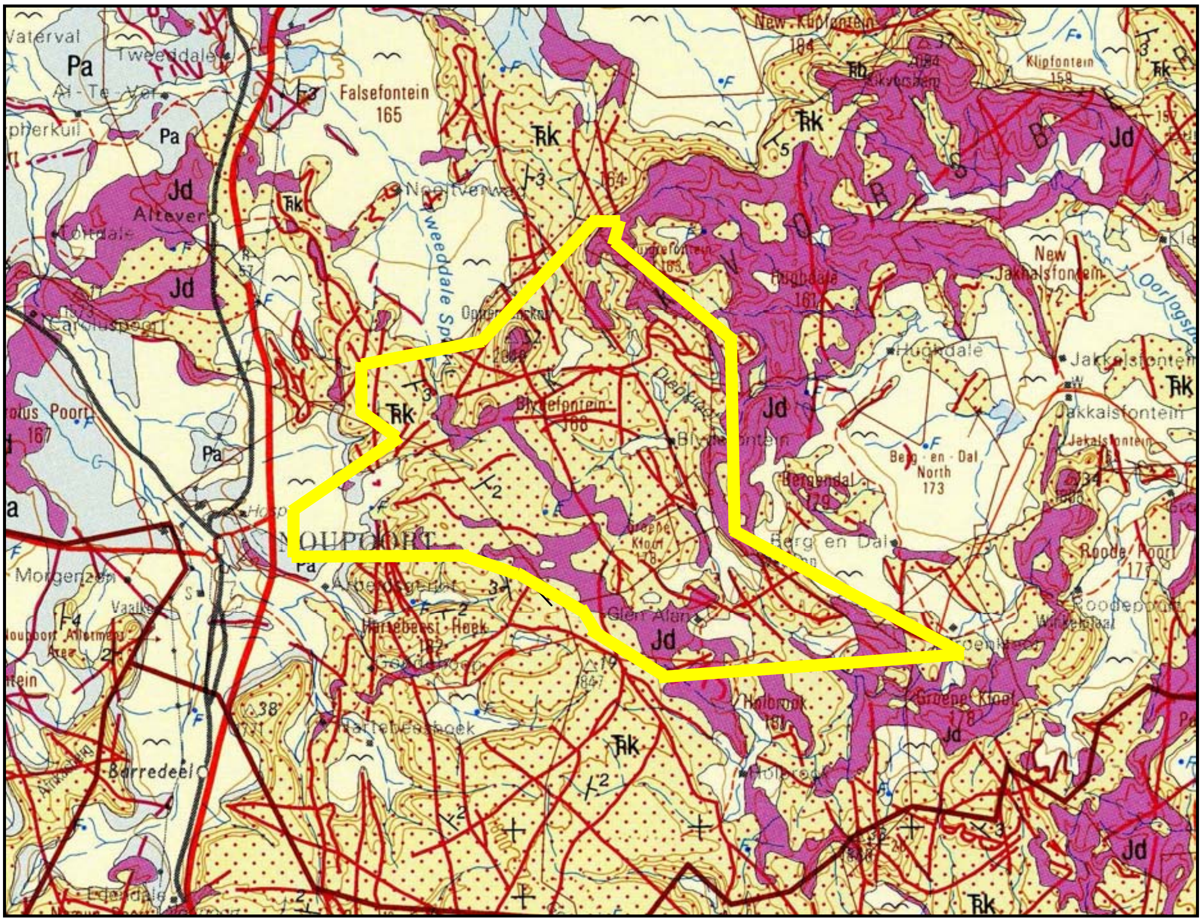


Figure 4: Extract from 1: 250 000 geology sheet 3124 Middelburg (Council for Geoscience, Pretoria) showing *approximate* outline of the study area to the east of Noupoort (yellow polygon). The main geological units represented here are:

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 = Quaterary to Recent alluvium
***N.B.* Other Caenozoic superficial deposits such as colluvium (scree *etc*) are not depicted here.**

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) also apply in part 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 formation. 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 are common. 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 limited by 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. 5). 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).

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. 3). Close to the margins of these intrusions the country rocks will have been thermally metamorphosed or baked to form tough, splintery quartzites and hornfels (derived from sandstones and mudrocks respectively). Because these igneous rocks 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).

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 pedocretes (*e.g*..calcretes), colluvial slope deposits, river alluvium, as well as spring and pan sediments (*cf* Partridge *et al*. 2006). As a result, surface exposure of fresh Beaufort Group rocks within the development area – especially the recessive-weathering mudrocks - is generally poor, apart from stream beds, dongas and steeper hill slopes and artificial exposures in road and railway cuttings. 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). Thicker accumulations of sandy, gravelly and bouldery **alluvium** of Late Caenozoic age (< 5Ma) are found in stream and river beds. These colluvial and alluvial deposits may be extensively calcretised (*i.e.* cemented with soil limestone or **calcrete**), especially in the neighbourhood of dolerite intrusions where groundwaters are enriched in dissolved. Useful geological overviews of talus deposits, alluvium and calcrete occurrences in the Middelburg sheet area are given by Cole *et al.* (2004). 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). It is likely that Karoo Supergroup bedrocks are exposed here, at least at the base of the deeper *dongas*.

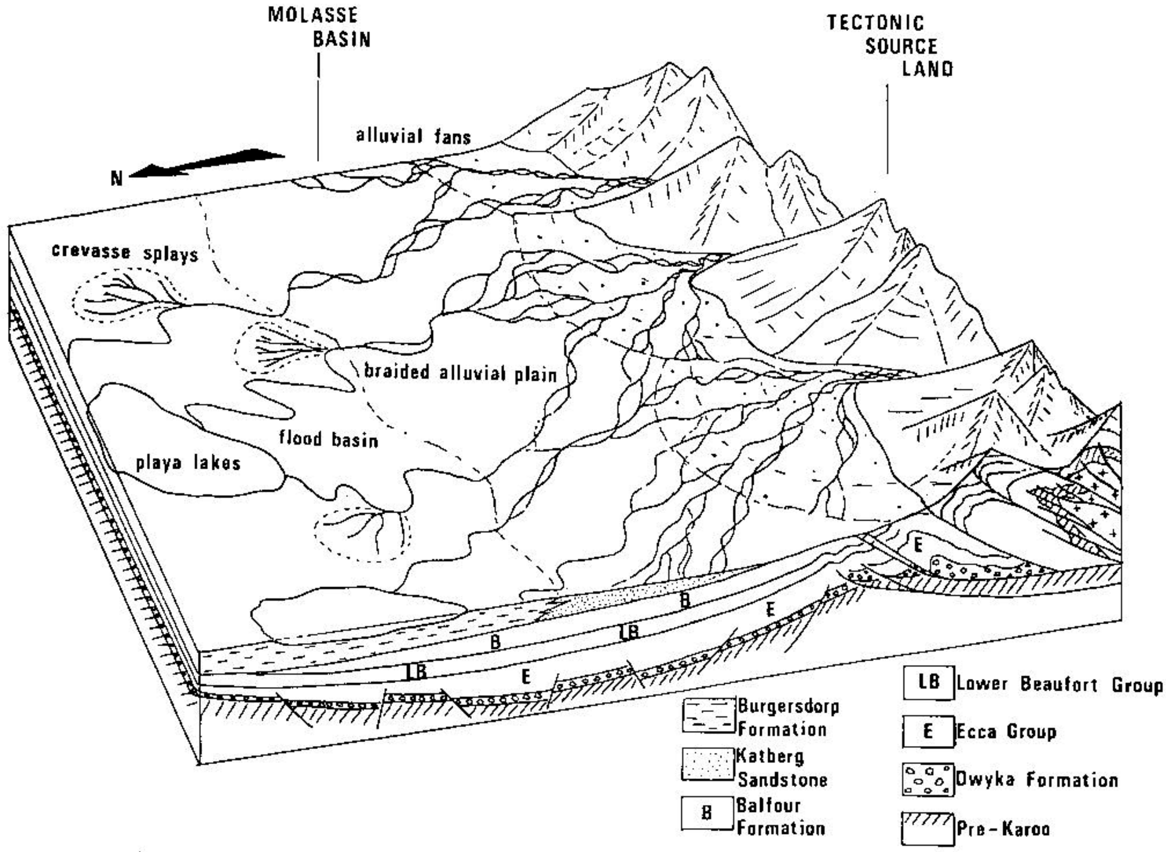


Figure 5: Reconstruction of the south-eastern part of the Main Karoo Basin in Early Triassic times showing the deposition of the sandy Katberg Formation near the mountainous source area in the south. The mudrock-dominated Burgersdorp Formation was deposited on the distal floodplain where numerous playa lakes are also found (From Hiller & Stavrakis 1984).

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 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.

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 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 (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. 6 and 7). 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 burrowing 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 (Hiller & Stavrakis 1980). Between typical fossil assemblages of the *Lystrosaurus* and *Cynognathus* Assemblage Zones lies a possible *Procolophon* Acme Zone characterized by abundant material of procolophonids and 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 is found in the intraformational conglomerates at the base of some the channel sandstones

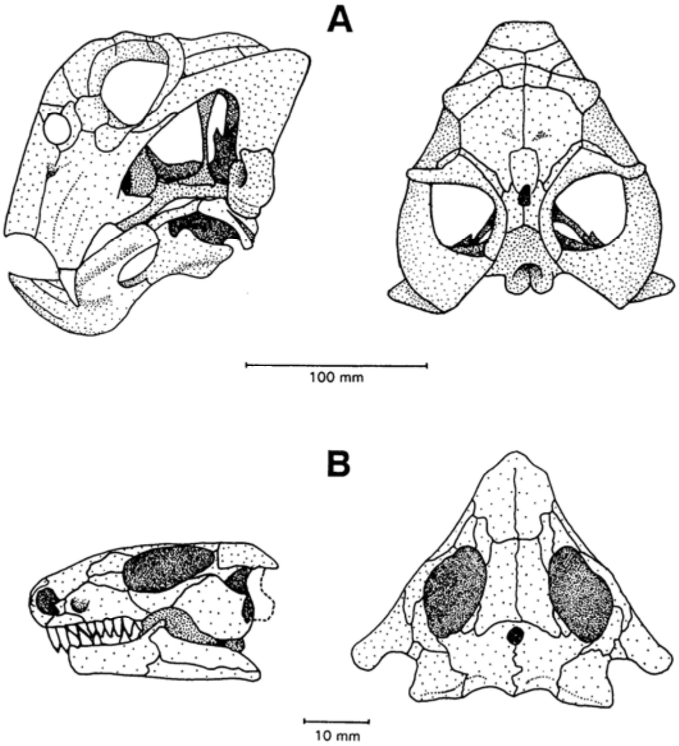


Figure 6: Skulls of two key tetrapod genera from the Early Triassic *Lystrosaurus* Assemblage Zone of the Main Karoo Basin: the pig-sized dicynodont *Lystrosaurus* (A) and the small primitive reptile *Procolophon* (B) (From Groenewald and Kitching, 1995).

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. 8 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 7: 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.

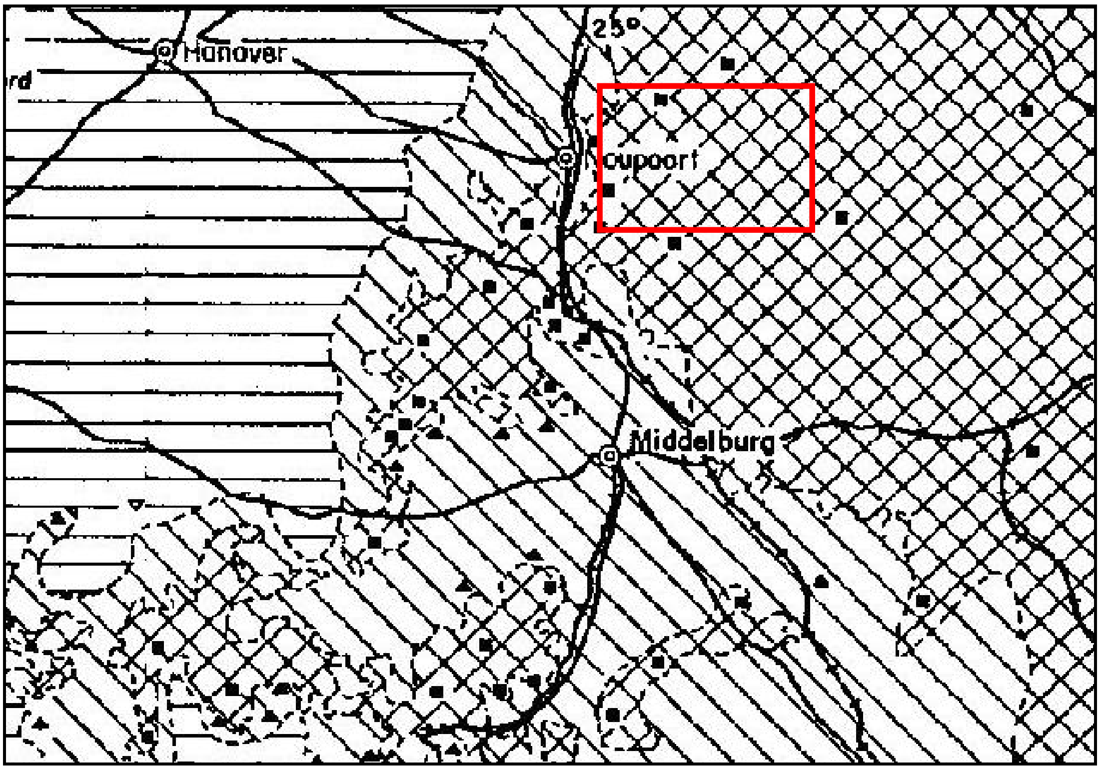


Figure 8: Fossil zonation map of the Middelburg – Noupoort region showing the occurrence of several fossil localities in the area to the east of Noupoort (red rectangle). Black squares here refer to fossils of the Early Triassic *Lystrosaurus* Assemblage Zone (mainly within the Katberg Formation). Triangles to the south are *Dicynodon* AZ fossils within Late Permian rocks of the Adelaide Subgroup. Figure modified from Karoo biozonation map of Kitching (1977).

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 1995). Thermal metamorphism by dolerite intrusions therefore tends to *reduce* the palaeontological heritage potential of adjacent Beaufort Group sediments.

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.

4. CONCLUSIONS & RECOMMENDATIONS

The Mainstream wind farm study area east of Noupoort 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 within or close to the study area and are represented in museum collections (*e.g.* the BPI at Wits University, Johannesburg). Despite the occurrence in many areas of superficial deposits such as scree and alluvium that are generally of low palaeontological sensitivity, good exposures of potentially fossiliferous mudrocks are found in the study region on steep hill slopes as well as in road and railway cuttings and probably also in erosional gullies. Since the construction phase of the proposed wind farm will entail numerous excavations for wind turbine emplacements, underground cables, access roads *etc*, its impact significance as far as fossil heritage is concerned is potentially *high* (negative). Such impacts can only be adequately assessed, and any appropriate mitigation measures proposed, following a field-based study of the study area by a professional palaeontologist. The operational and decommissioning phases of wind farms do not involve significant negative impacts on fossil heritage.

It is therefore recommended that:

- *Before* the development footprint of the wind farm is finalized, a professional palaeontologist should be contracted at the developer's expense to carry out a field study to assess the extent, sensitivity and distribution of fossil heritage actually present within the entire study area;

- The field study should identify any areas of high palaeontological sensitivity and propose appropriate mitigation measures to be incorporated into the EMP for this project (*e.g.* pre-construction collection and recording of near-surface fossils / monitoring of bedrock excavations by a professional palaeontologist and / or by the ECO / delineation of any no-go areas);

- In the case of any significant fossil finds (*e.g.* vertebrate teeth, bones, burrows, plant-rich beds or 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;

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 a as possible should adhere to the minimum standards for palaeontological studies currently being developed by SAHRA.

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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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