**PALAEONTOLOGICAL HERITAGE ASSESSMENT: COMBINED DESKTOP & FIELD-BASED STUDY**

# AUTHORISED KARUSA WIND FARM NEAR SUTHERLAND, NAMAQUA DISTRICT MUNICIPALITY, NORTHERN CAPE PROVINCE

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## EXECUTIVE SUMMARY

Karusa Wind Farm (Pty) Ltd. is proposing to construct the authorised Karusa Wind Farm, in the Klein-Roggeveldberge region some 50 km south of Sutherland, Karoo Hoogland Local Municipality, Namaqua District Municipality, Northern Cape. The land parcels involved have a total area of ~*146* km$^2$ and include Farm De Hoop 202, Farm Standvastigheid 210, Portion 1, Portion 2 and Portion 3 of Farm Rheebokke Fontein 209 and the Remainder of Farm Rheebokke Fontein 209.

The fluvial Abrahamskraal Formation (Lower Beaufort Group, Karoo Supergroup) that underlies the Karusa Wind Farm study area is known for its diverse fauna of Permian fossil vertebrates - notably various small- to large-bodied therapsids and reptiles - as well as fossil plants of the *Glossopteris* Flora and low diversity trace fossil assemblages. However, desktop analysis of known fossil distribution within the Main Karoo Basin shows a marked paucity of fossil localities in the wider study region between Matjiesfontein and Sutherland where sediments belonging only to the lower part of the thick Abrahamskraal Formation succession, below the Moordenaars Member, are represented. Bedrock exposure levels in the broader study region are generally very poor due to the pervasive cover by superficial sediments (colluvium, alluvium, soils, calcrete) and vegetation. Nevertheless, a sufficiently large outcrop area of Abrahamskraal Formation sediments, exposed in stream and riverbanks, borrow pits as well as steep hillslopes and erosion gullies along the Klein-Roggeveld Escarpment and plateau, has been examined during the present field study to infer that macroscopic fossil remains of any sort are very rare here. Exceptions include common low-diversity trace fossil assemblages (small-scale invertebrate burrows, possible plant stem or root casts) and locally abundant but fragmentary plant remains. The latter include horsetail ferns (arthrophytes) as well as moulds of woody plant material weathering out from the base of channel sandstones high up within the local Abrahamskraal Formation succession (probably the Leeuvlei Member). No fossil vertebrate remains (bones, teeth, coprolites) were recorded within the Karusa Wind Farm study area, but a few equivocal vertebrate burrows-like structures were seen. Levels of bedrock tectonic deformation are generally low, although folding, faulting and cleavage development associated within the Cape Fold Belt are locally apparent. A narrow swarm of Early Jurassic dolerite dyke intrusions occurs within the wider study area but is of no palaeontological heritage significance. It is concluded that the Lower Beaufort Group bedrocks in the Karusa Wind Farm study area are **generally of low palaeontological sensitivity** and

this also applies to the overlying Late Caenozoic superficial sediments (colluvium, alluvium, calcrete, surface gravels, soils *etc*).

Construction of the proposed Karusa Wind Farm is unlikely to entail significant impacts on local fossil heritage resources. Due to the general great scarcity of fossil remains as well as the extensive superficial sediment cover observed within the study area, the **overall impact significance of the construction phase of the proposed alternative energy development is assessed as LOW.** The operational and decommissioning phases of the wind farm are very unlikely to involve further adverse impacts on local palaeontological heritage. This assessment applies to all wind farm infrastructural components including the proposed new access roads, both those within the Karusa Wind Farm study area and that linking Karusa with the adjoining proposed Soetwater Wind Farm to the north.

Given the low impact significance of the proposed Karusa Wind Farm near Sutherland as far as palaeontological heritage is concerned, no further specialist palaeontological heritage studies or mitigation are considered necessary for this project, pending the potential discovery or exposure of substantial new fossil remains during development. During the construction phase all deeper (> 1 m) bedrock excavations should be monitored for fossil remains by the responsible Environmental Control Officer (ECO) and/or Contractor's Environmental Officer (EO). Should substantial fossil remains such as vertebrate bones and teeth, plant-rich fossil lenses, fossil wood or dense fossil burrow assemblages be exposed during construction, the responsible ECO/EO should safeguard these, preferably *in situ*, and alert SAHRA, *i.e.* The South African Heritage Resources Authority, as soon as possible (Contact details: Mrs Colette Scheermeyer, P.O. Box 4637, Cape Town 8000. Tel: 021 462 4502. Email: cscheermeyer@sahra.org.za) so that appropriate action can be taken by a professional palaeontologist, at the Proponent's expense. Mitigation would normally involve the scientific recording and judicious sampling or collection of fossil material as well as associated geological data (*e.g.* stratigraphy, sedimentology, taphonomy) by a suitably qualified palaeontologist.

These mitigation recommendations should be incorporated into the Environmental Management Programme (EMPr) for the Karusa Wind Farm project.

Please note that:

- All South African fossil heritage is protected by law (South African Heritage Resources Act, 1999) and fossils cannot be collected, damaged or disturbed without a permit from SAHRA or the relevant Provincial Heritage Resources Agency;

- The palaeontologist concerned with potential mitigation work will need a valid fossil collection permit from SAHRA and any material collected would have to be curated in an approved depository (*e.g.* museum or university collection);

- All palaeontological specialist work should conform to international best practice for palaeontological fieldwork and the study (*e.g.* data recording fossil collection and curation, final report) should adhere as far as possible to the minimum standards for Phase 2 palaeontological studies recently developed by SAHRA (2013).

# 1. INTRODUCTION & BRIEF

## 1.1. Project outline

The company Karusa Wind Farm (Pty) Ltd. is proposing to construct the authorised Karusa Wind Farm, in the Klein-Roggeveldberge region some 50 km south of Sutherland, Karoo Hoogland Local Municipality, Namaqua District Municipality, Northern Cape (Fig. 1). The land parcels involved have a total area of *~146* km$^2$ and include Farm De Hoop 202, Farm Standvastigheid 210, Portion 1, Portion 2 and Portion 3 of Farm Rheebokke Fontein 209 and the Remainder of Farm Rheebokke Fontein 209 (Fig. 2).

The main infrastructural components of the proposed wind farm (the "Project") include the following:

- The construction of 43 wind turbines (3.3MW in capacity and with a 117 m rotor diameter and a hub height of 91.5 m);
- Medium voltage cabling between turbines to be laid underground were practical;
- Medium Voltage overhead power lines;
- Internal access roads to connect turbines, the substation complex and ancillary;
- Proposed 132kV substation complex;
- Proposed 132kV power line from the Karusa Facility substation complex to the Eskom Komsberg Main Transmission Substation;
- Operations and services workshop area / office building for control, maintenance and storage; and
- Temporary infrastructure including a site camp, laydown areas and a batching plant.

The Karusa Wind Farm study area is located in a region that is underlain by potentially fossiliferous sedimentary rocks of Late Palaeozoic and younger, Late Tertiary or Quaternary, age (described in more detail in Sections 2 & 3 of this report). The construction phase of the proposed wind farm will entail excavations into the superficial sediment cover and locally into the underlying bedrock as well. The development may adversely affect potential fossil heritage within the study area by destroying, disturbing or permanently sealing-in fossils preserved at or beneath the surface of the ground that are then no longer available for scientific research or other public good. The operational and decommissioning phases of the wind farm are unlikely to involve further adverse impacts on local palaeontological heritage.

The present palaeontological heritage assessment of the Karusa Wind Farm study area has been commissioned as part of the Basic Assessment for this development that is being co-ordinated by Savannah Environmental (Pty) Ltd, Woodmead (Contact details: Ms Tebogo Mapinga. Savannah Environmental (Pty) Ltd. 1st Floor, Block 2, 5 Woodlands Drive Office Park, Woodlands Drive, Woodmead, 2191. Tel: +27 11 656 3237. Fax: +27 86 684 0547. Cell: +27 72 738 3836. Email: tebogo@savannahsa.com. Postal address: P.O. Box 148, Sunninghill, 2157).

### 1.2. Legislative context for palaeontological assessment studies

The Karusa Wind Farm project is located in an area that is underlain by potentially fossiliferous sedimentary rocks of Late Palaeozoic and younger, Late Tertiary or Quaternary, age (described in more detail in Sections 2 & 3 of this report). The construction phase of the proposed wind farm development will entail substantial excavations into the superficial sediment cover and locally into the underlying bedrock as well. These include, for example, excavations for the wind turbine foundations, hardstanding areas, internal access roads, underground cables, transmission line pylon footings, electrical substations, operations and maintenance building, construction laydown areas and construction camp. All these developments may adversely affect potential fossil heritage within the study area by destroying, disturbing or permanently sealing-in fossils at or beneath the surface of the ground that are then no longer available for scientific research or other public good. The operational and decommissioning phases of the wind energy facility are unlikely to involve further adverse impacts on local palaeontological heritage, however.

The present combined desktop and field-based palaeontological heritage report contributes to the walk-through assessment for the authorised Karusa Wind Farm project and falls under the South African Heritage Resources Act (Act No. 25 of 1999). It will also inform the Environmental Management Programme for this Project.

The various categories of heritage resources recognised as part of the National Estate in Section 3 of the National Heritage Resources Act include, among others:

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

According to Section 35 of the National Heritage Resources Act, dealing with archaeology, palaeontology and meteorites:

(1) The protection of archaeological and palaeontological sites and material and meteorites is the responsibility of a provincial heritage resources authority.

(2) All archaeological objects, palaeontological material and meteorites are the property of the State.

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

(4) No person may, without a permit issued by the responsible heritage resources authority—

*(a)* destroy, damage, excavate, alter, deface or otherwise disturb any archaeological or palaeontological site or any meteorite;

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

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

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

(5) When the responsible heritage resources authority has reasonable cause to believe that any activity or development which will destroy, damage or alter any archaeological or palaeontological site is under way, and where no application for a permit has been submitted and no heritage resources management procedure in terms of section 38 has been followed, it may—

*(a)* serve on the owner or occupier of the site or on the person undertaking such development an order for the development to cease immediately for such period as is specified in the order;

*(b)* carry out an investigation for the purpose of obtaining information on whether or not an archaeological or palaeontological site exists and whether mitigation is necessary;

*(c)* if mitigation is deemed by the heritage resources authority to be necessary, assist the person on whom the order has been served under paragraph *(a)* to apply for a permit as required in subsection (4); and

*(d)* recover the costs of such investigation from the owner or occupier of the land on which it is believed an archaeological or palaeontological site is located or from the person proposing to undertake the development if no application for a permit is received within two weeks of the order being served.

Minimum standards for the palaeontological component of heritage impact assessment reports (PIAs) have recently been published by SAHRA (2013).

### 1.3. Approach to the palaeontological heritage study

The approach to a Phase 1 palaeontological heritage study is briefly as follows. Fossil bearing rock units occurring within the broader study area are determined from geological maps and satellite images. Known fossil heritage in each rock unit is inventoried from scientific literature, previous assessments of the broader study region, and the author's field experience and palaeontological database. Based on this data as well as field examination of representative exposures of all major sedimentary rock units present, the impact significance of the proposed development is assessed with recommendations for any further studies or mitigation.

In preparing a palaeontological desktop study the potentially fossiliferous rock units (groups, formations *etc.*) represented within the study area are determined from geological maps and satellite images. 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 field assessment 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 significantly the extent of fresh bedrock excavation envisaged. When rock units of moderate to high palaeontological sensitivity are present within the development footprint, a Phase 1 field assessment study by a professional palaeontologist is usually warranted to identify any palaeontological hotspots and make specific recommendations for any mitigation required before or during the construction phase of the development.

On the basis of the desktop and Phase 1 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. Phase 2 mitigation by a professional palaeontologist – normally involving the recording and sampling of fossil material and associated geological information (*e.g.* sedimentological data) may be required (a) in the pre-construction phase where important fossils are already exposed at or near the land surface and / or (b) during the construction phase when fresh fossiliferous bedrock has been exposed by excavations. To carry out mitigation, the palaeontologist involved will need to apply for a palaeontological collection permit from the relevant heritage management authorities, *i.e.* SAHRA for the Northern Cape (Contact details: Mrs Colette Scheermeyer, P.O. Box 4637, Cape Town 8000. Tel: 021 462 4502. Email: cscheermeyer@sahra.org.za) and Heritage Western Cape for the Western Cape (Contact details: Heritage Western Cape. Protea Assurance Building, Green Market Square, Cape Town 8000. Private Bag X9067, Cape Town 8001. Tel: 086-142 142. Fax: 021-483 9842. Email: hwc@pgwc.gov.za). 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.

### 1.4. Assumptions & 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.

In the case of palaeontological desktop studies without supporting Phase 1 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 the Karusa Wind Farm study area near Sutherland in the Northern Cape preservation of potentially fossiliferous bedrocks is favoured by the semi-arid climate and sparse vegetation but bedrock exposure is limited by extensive superficial deposits, especially in areas of low relief, as well as pervasive Karoo *bossieveld* vegetation (Central Mountain Shale Renosterveld and Tanqua Escarpment Shrubland). However, sufficient bedrock exposures were examined during the course of this study (See Appendix) to assess the palaeontological heritage sensitivity of the study area. Comparatively few academic palaeontological studies or field-based fossil heritage impact studies have been carried out in the region, so any new data from impact studies here are of scientific interest.

### 1.5. Information sources

The present combined desktop and field-based palaeontological study was largely based on the following sources of information:

1. A brief project outline kindly supplied by Savannah Environmental (Pty) Ltd;

2. Relevant geological maps and sheet explanations (*e.g.* Theron 1983, Cole & Vorster 1999) as well as Google earth© satellite imagery;

3. Several palaeontological heritage assessment reports by the present author for proposed developments in the Karoo region to the south of Sutherland, including the Eskom Gamma – Omega 765 kV transmission line that runs just across the southern portion of the study area (Almond 2010a) and several alternative energy facilities (Almond 2010b, 2010c, 2011, 2014, 2015);

4. A four-day palaeontological field assessment of the Karusa Wind Farm study area (August 2015) within the context of a broader-based review of fossil heritage resources for this and the adjacent Soetwater Wind Farm project area;

5. The author's previous field experience with the formations concerned and their palaeontological heritage (*cf* Almond & Pether 2008 and references listed above).

GPS data for all numbered localities mentioned in the text are provided in the Appendix. Further field data directly relevant to the Karusa Wind Farm study area is given in the previous palaeontological assessment of the Gamma-Omega transmission line by Almond (2010a).

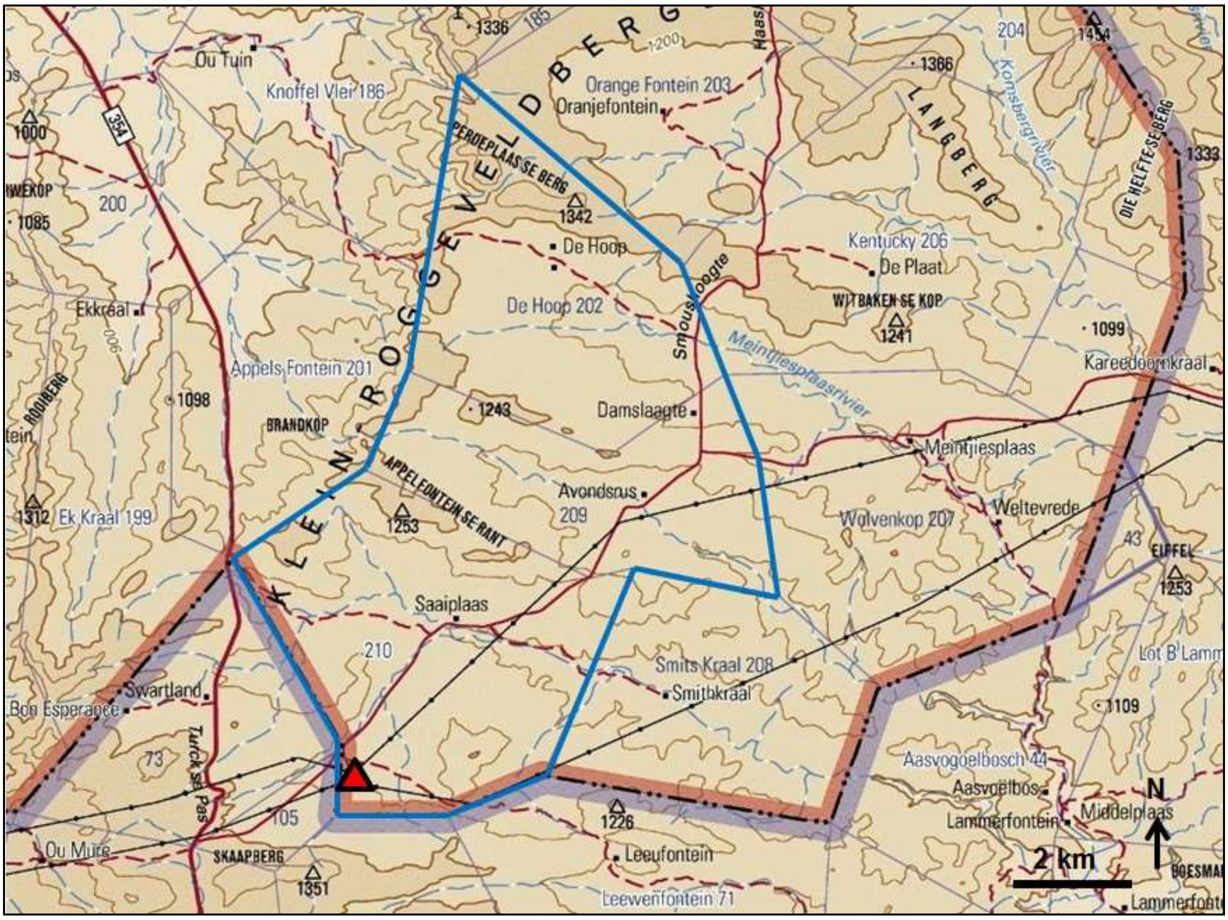


**Figure 1. Extract from 1: 250 000 topographical sheet 3220 Sutherland showing the location of the authorised Karusa Wind Farm study area (blue polygon), located *c*. 50 km south of Sutherland, Northern Cape. The study area spans the escarpment and plateau of the Klein-Roggeveldberge to the east of the R354 Matjiesfontein to Sutherland tar road and is traversed in the east by the gravel road from the R354 to the Komsberg Pass *via* Bakenshoogte (Base map courtesy of the Chief Directorate of Surveys and Mapping, Mowbray). The new Gamma-Omega 765 kV transmission line traverses the southern part of the study area from Komsberg Main Transmission Substation (red triangle).**

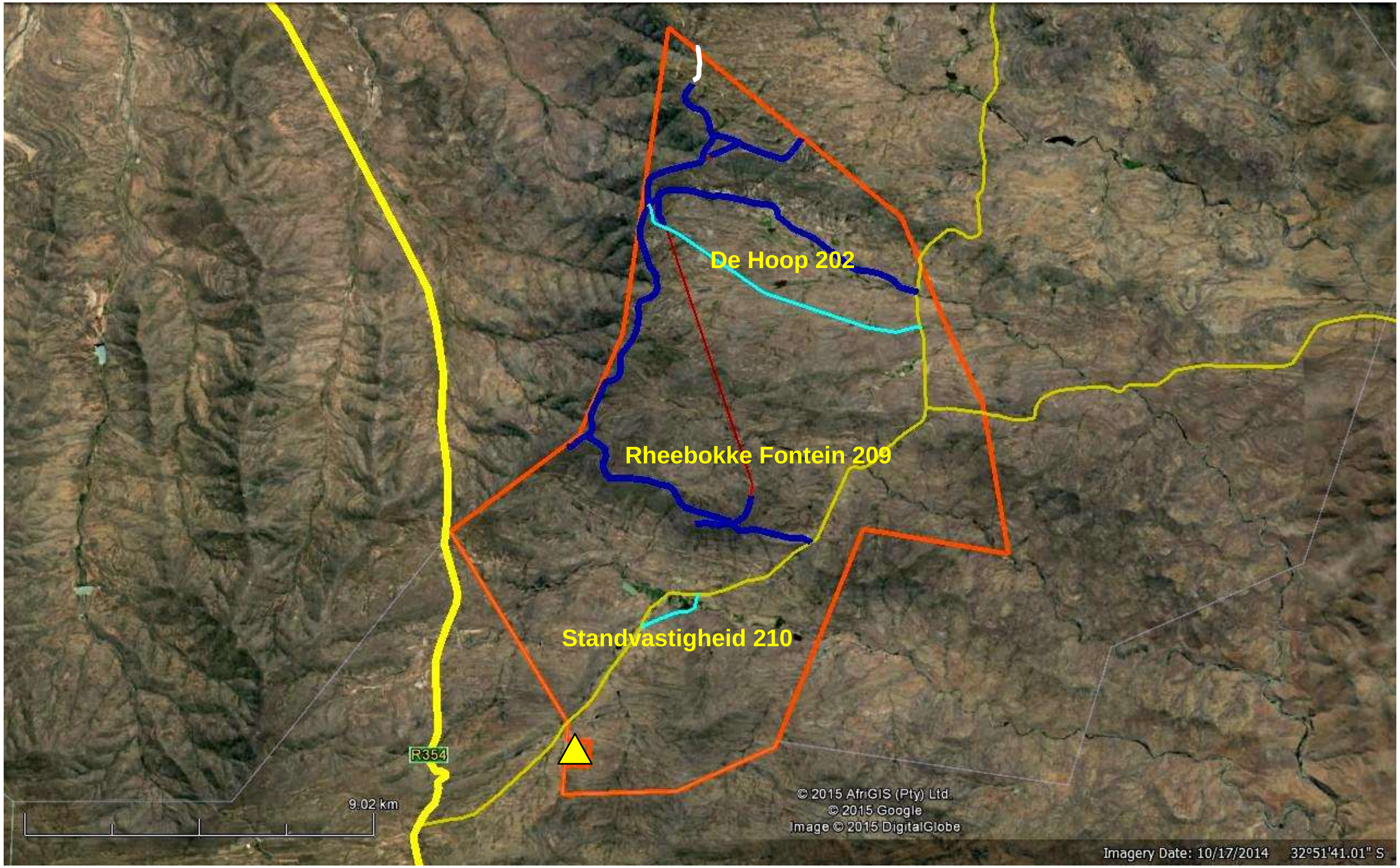


**Figure 2. Google earth© satellite image of the authorised Karusa Wind Farm study area (orange polygon) spanning the Klein-Roggeveldberge Escarpment and plateau showing the constituent farms. Also shown are existing roads (yellow, pale blue), proposed new access roads (dark blue, white), a proposed MV overhead line (dark red) and the existing Komsberg Main Transmission Substation (yellow triangle).**

## 2. GEOLOGICAL BACKGROUND

The Karusa Wind Farm study area is situated within hilly to mountainous terrain some 50 km to the south of Sutherland and south of the Great Escarpment, spanning the lower-lying plateau and steep, west-facing escarpment of the Klein-Roggeveldberge (Figs. 1 & 2), Great Karoo region, Northern Cape. The existing Eskom Komsberg Main Transmission Substation lies on the south-western edge of the study area and the R354 tar road between Matjiesfontein and Sutherland runs just to the west. The eastern portion of the area is transected by the gravel road between the R354 and the Komsberg Pass *via* the Bakenshoogte rise. Several WNW-ESE ridges extend across the Klein-Roggeveld Plateau here, including Appelfontein se Rant in the southwest (1253 m amsl), an unnamed ridge (1243 m amsl) in the centre and Perdeplaas se Berg (1342 m amsl) along the northern edge of the study area. The lower-lying plateau areas between the ridges (*c*. 1030-1100 m above mean sea level (amsl)) are in part cultivated (*e.g.* Saaiplaas – Smithskraal valley). They are drained by small non–perennial streams, with numerous side branches on hillslopes. These include the Meintjiesplaasrivier, but are mostly unnamed, and are tributaries of the ancient, south-flowing Buffelsrivier drainage system. The steep slopes of the west-facing Klein-Roggeveld Escarpment itself are incised by the gullies of numerous small, non-perennial streams and feature prominent-weathering sandstone ridges, giving a stepped profile. Away from the numerous drainage lines and sandstone ridges levels of bedrock exposure in the study area - notably that of the recessive-weathering mudrock facies - are generally very low, due to extensive cover by alluvial and colluvial deposits as well as karroid *bossieveld* vegetation (Central Mountain Shale Renosterveld and Tanqua Escarpment Shrubland) (Figs. 4 to 7).

The geology of the Sutherland region is outlined on the 1: 250 000 scale geology sheet 3220 Sutherland (Theron 1983) (Fig. 3) as well as the updated 1: 250 000 Sutherland metallogenic map that includes important new stratigraphic detail for the Lower Beaufort Group succession (Cole & Vorster 1999). The study area is entirely underlain by Middle Permian continental sediments of the **Lower Beaufort Group** (Adelaide Subgroup, Karoo Supergroup), and in particular the **Abrahamskraal Formation** (Pa) at the base of the Lower Beaufort Group succession (Johnson *et al.* 2006 and references cited below). The Beaufort Group sediments here are folded along numerous west-east trending fold axes, especially in the northern portion of the study area (Fig. 3), with some local cleavage development, minor faulting and quartz veining. However, levels of tectonic deformation are generally low, with bedding plane dips of 5º to 25º. In the Sutherland area to the north, situated just north of the Great Escarpment, the Lower Beaufort Group sediments have been extensively intruded and thermally metamorphosed (baked) by dolerite sills and dykes of the **Karoo Dolerite Suite** of Early Jurassic age (*c*. 182 Ma = million years ago; Duncan & Marsh 2006). These igneous rocks were intruded during an interval of crustal uplift and stretching that preceded the break-up of the supercontinent Gondwana. They show up on satellite images as rusty-brown areas. In the present study region well to the south of the Great Escarpment the only major dolerite intrusions are a set or swarm of laterally persistent, NW-SE trending dykes that transect the Karusa Wind Farm area, passing through Bakenshoogte; they can be well seen in road cuttings along the R354 (Jd, pink in Fig. 3). The Karoo dolerites are entirely unfossiliferous and will not be treated in any detail in this report. The Palaeozoic and Mesozoic bedrocks in the study area are very extensively overlain by Late Caenozoic **superficial deposits** such as scree and other slope deposits (colluvium and hillwash), stream alluvium, down-wasted surface gravels, calcretes and various soils. These geologically youthful sediments are generally of low palaeontological sensitivity and are also only briefly treated in this study.


**Figure 3. Extract from the 1: 250 000 scale geology sheet 3220 Sutherland (Council for Geoscience, Pretoria, 1999) showing the location of the proposed Karusa Wind Farm study area, *c*. 50 km south of Sutherland, Northern Cape Province (yellow polygon). The red triangle indicates the position of the existing Komsberg Main Transmission Substation. The study area is entirely underlain by Middle Permian sediments of the Abrahamskraal Formation, Lower Beaufort Group (Pa, pale green). The sediments are intruded by a NW-SE trending swarm of dolerite dykes of the Karoo Dolerite Suite (Jd, red) in the central part of the area, passing through Bakenshoogte. Note west-east trending fold axes (thin black lines) mapped in the north-eastern part of the study area.**

**Figure 4. Hilly terrain close to the Klein-Roggeveld Escarpment edge on the western portion of Standvastigheid 210, viewed from Appelfontein se Rant to the east.**

**Figure 5. View north-eastwards towards Appelfontein se Rant (Standvastigheid 210) showing low levels of bedrock exposure and blocky sandstone colluvium in the foreground.**

**Figure 6. View northwards along the west-facing Klein-Roggeveldberge Escarpment on the western edge of De Hoop 202. Tabular sandstone units weather out as prominent ridges but intervening mudrocks are largely covered by colluvium and soil.**

**Figure 7. View north-westwards along the ridge of Perdeplaas se Berg (De Hoop 202) with downwasted sandstone colluvial rubble in the foreground (Loc. 541).**

## 2.1. Lower Beaufort Group (Adelaide Subgroup)

A useful recent overview of the Beaufort Group continental succession has been given by Johnson *et al.* (2006). Geological and palaeoenvironmental analyses of the Lower Beaufort Group sediments in the western Great Karoo region have been conducted by a number of workers. Key references within an extensive scientific literature include various papers by Roger Smith (*e.g.* Smith 1979, 1980, 1986, 1987a, 1987b, 1988, 1989, 1990, 1993a, 1993b) and Stear (1978, 1980a, 1980b), as well as several informative field guides (*e.g.* Cole *et al.* 1990, Cole & Smith 2008) and two geological sheet explanations for the Sutherland area (Theron 1983, Cole & Vorster 1999). In brief, the thick Beaufort Group successions of clastic sediments were laid down by a series of large, meandering rivers within a subsiding basin over a period of some ten or more million years, largely within the Middle to Late Permian Period (*c*. 266-251 Ma). Sinuous sandstone bodies of lenticular cross-section represent ancient channel infills, while thin (<1.5 m), laterally-extensive sandstone beds were deposited by crevasse splays during occasional overbank floods. The bulk of the Beaufort sediments are greyish-green to reddish-brown or purplish mudrocks ("mudstones" = fine-grained claystones and slightly coarser siltstones) that were deposited over the floodplains during major floods. Thin-bedded, fine-grained playa lake deposits also accumulated locally where water ponded-up in floodplain depressions and are associated with distinctive fossil assemblages (*e.g.* fish, amphibians, coprolites or fossil droppings, arthropod, vertebrate and other trace fossils, plant fossils).

Frequent development of fine-grained pedogenic (soil) limestone or calcrete as nodules and more continuous banks indicates that semi-arid, highly seasonal climates prevailed in the Middle Permian Karoo. This is also indicated by the common occurrence of sand-infilled mudcracks and silicified gypsum "desert roses" (Smith 1980, 1990, 1993a, 1993b, Almond 2010a). Highly continental climates can be expected from the palaeogeographic setting of the Karoo Basin at the time – embedded deep within the interior of the Supercontinent Pangaea and in the rainshadow of the developing Gondwanide Mountain Belt. Fluctuating water tables and redox processes in the alluvial plain soil and subsoil are indicated by interbedded mudrock horizons of contrasting colours. Reddish-brown to purplish mudrocks probably developed during drier, more oxidising conditions associated with lowered water tables, while greenish-grey mudrocks reflect reducing conditions in waterlogged soils during periods of raised water tables. However, diagenetic (post-burial) processes also greatly influence predominant mudrock colour (Smith 1990).

### 2.1.2. Abrahamskraal Formation

The Abrahamskraal Formation is a very thick (*c*. 2.5 km) succession of fluvial deposits laid down in the Main Karoo Basin by meandering rivers on an extensive, low-relief floodplain during the Mid Permian Period, some 266-260 million years ago (Rossouw & De Villiers 1952, Johnson & Keyser 1979, Turner 1981, Theron 1983, Smith 1979, 1980, 1990, 1993a, 1993b, Smith & Keyser 1995a, Loock *et al*., 1994, Cole 7 Vorster 1999, McCarthy & Rubidge 2005, Johnson *et al*., 2006, Almond 2010a, Day 2013a). These sediments include (a) lenticular to sheet-like channel sandstones, often associated with thin, impersistent intraformational breccio-conglomerates (larger clasts mainly of reworked mudflakes, calcrete nodules, *plus* sparse rolled bones, teeth, petrified wood), (b) well-bedded to laminated, grey-green, blue-grey to purple-brown floodplain mudrocks with sparse to common pedocrete horizons (calcrete nodules formed in ancient soils), (c) thin, sheet-like crevasse-splay sandstones, as well as more (d) localized playa lake deposits (*e.g.* wave-rippled sandstones, laminated mudrocks, limestones, evaporites). A number of greenish to reddish weathering, silica-rich "chert" horizons are also found. Many of these appear to be secondarily silicified mudrocks or limestones but at least some contain subaerial or reworked volcanic ash (tuffs, tuffites). A wide range of sedimentological and palaeontological observations point to deposition of the Abrahamskraal sediments under seasonally arid climates. These include, for example, the abundance of pedogenic calcretes and evaporites (silicified gypsum pseudomorphs or "desert roses"), reddened mudrocks, sun-cracked muds, "flashy" river systems, sun-baked fossil bones, well-developed seasonal growth rings in fossil wood, rarity of fauna, and little evidence for substantial bioturbation or vegetation cover (*e.g.* root casts) on floodplains away from the river banks.

The 1: 250 000 Sutherland geological sheet 3220 (Theron 1983) shows a large area of undifferentiated Abrahamskraal Formation beds in the Sutherland area (Fig. 3). There have since been a number of attempts, only partially successful, to subdivide the very thick Abrahamskraal Formation succession in both lithostratigraphic (rock layering) and biostratigraphic (fossil) terms (*cf* Day & Rubidge 2010, Day 2013a). Among the most recent and relevant of these was the study by Loock *et al.* (1994) in the Moordenaarskaroo area north of Laingsburg. Detailed geological mapping here led to the identification of six lithologically-defined members within the Abrahamskraal Formation (Fig. 8). Several of these members have since been mapped in the Sutherland area by Cole and Vorster (1999). Very brief descriptions of these stratigraphic members are given by Loock *et al.* (1994) but the interested reader should refer to earlier works by Le Roux (1985) and Jordaan (1990) for detailed sedimentological data that is beyond the scope of the present palaeontological heritage study.

Based on the abundance of maroon mudrocks as well as the apparent absence or rarity of fossil vertebrate remains (Section 3), it is tentatively inferred that the Karusa Wind Farm study area is largely underlain by sediments assigned to the uppermost **Combrinkskraal Member** and lower part of the **Leeuvlei Member** of the Abrahamskral Formation (red dotted line in Fig. 8). These members are not differentiated on the Sutherland 1: 250 000 metallogenic map sheet (Cole & Vorster 1999). According to Loock *et al.* (1995) the *c*. 860 m-thick Leeuvlei Member is characterized by:

- Grey overbank mudrocks with calcrete concretions and thin pyritic horizons;
- Maroon mudrocks, locally with abundant equisetalean (arthrophyte) plant debris;
- Sheet-like channel sandstone bodies composed of very fine- to fine-grained sandstone showing horizontal lamination and ripple cross-lamination. Sandstone bases are erosional and in the upper part of the member they feature lag breccio-conglomerates composed of mudflake intraclasts, reworked calcrete nodules and fossil material (rolled tetrapod bone, arthrophyte stems);
- Well-developed palaeosurfaces on sharp upper sandstone surfaces showing ripple marks, ponds, rill marks *etc*;
- Heavy mineral laminations towards the tops of sandstone packages.
- Occasional thick channel packages with a multi-storey architecture and trough cross-bedding. These packages are locally associated with accumulations of plant debris and secondary uranium mineralization (*koffieklip*).

Stratigraphically lower-lying beds within the Karusa Wind Farm study area possibly belong to the upper part of the Combrinkskraal Member of the Abrahamskraal Formation, above the incoming of maroon mudrocks (indicated by the black dashed line in the south-western corner of the study area in Fig. 3). This rock unit is not clearly differentiated by Loock *et al.* (1994), however, apart from to say that it comprises grey and maroon overbank mudrocks, with thin siltstone and sandstone interbeds and occasional calcareous concretions, while the channel sandstones are sheet-like. This description would apply to much of the lower Abrahamskraal Formation succession of the Klein-Roggeveldberge region.

The Abrahamskraal Formation in the Klein-Roggeveld study region is a succession of continental fluvial rocks characterized by numerous lenticular to (especially) sheet-like sandstones with intervening, more recessive-weathering mudrocks (Stear 1980, Le Roux 1985, Loock *et al.* 1994, Cole & Vorster 1999) (Figs. 9 to 28). The channel sandstone units are up to several (5 m or more) meters thick and vary in geometry from extensive, subtabular sheets to single-storey lenticles or multi-storey channel bodies. The prominent-weathering, laterally-persistent sandstone ledges generate a distinctive stepped or terraced topography on hill slopes in the area (Figs. 6 & 15). The sheet sandstones are generally pale-weathering (enhanced by epilithic lichens), fine- to medium-grained, well-sorted and variously massive or structured by horizontal lamination (flaggy, with primary current lineation) or, more rarely, tabular to trough cross-bedding. Greyish hues of some freshly broken sandstone surfaces suggest an "impure" clay-rich mineralogy (*i.e.* wackes). Current ripple cross-lamination and horizontal lamination is common towards the tops of the sandstone beds. These may also feature well-preserved palaeosurfaces with swales or pools, wave ripples (locally variable wave crest azimuths), falling water marks, adhesion warts, trace fossils and rills (Fig. 13); according to Loock *et al.* (1994, p. 189) these features are commonly seen in the Leeuvlei Member. The lower contacts of the sandstones are often gradational or erosive on a small scale, especially lower down in the Abrahamskraal succession (Fig. 26). Channel sandstones higher in the succession may be associated with lenticular to sheet-like basal breccias that may infill small-scale erosive gullies (Figs. 23 to 25). The breccias may also occur within the body of the channel sandstone unit and are almost entirely composed of reworked mudflake intraclasts. Reworked small calcrete nodules (but not rolled vertebrate bones, teeth) have been observed locally in the Karusa Wind Farm study area. An interesting feature of some of the finer-grained, homogeneous channel sandstones and darker grey, impure wackes is their tendency to be very well-jointed and show exfoliation weathering, leading to the formation of sphaeroidal corestones in a rather dolerite-like manner. These well-rounded sandstone corestones of cobble to boulder size form an important component of local colluvial and downwasted surface gravels.

Although general mudrock exposure levels within the Karusa Wind Farm study area are low to very low, there are in fact numerous small exposures available along stream banks and steeper hillslopes, both along the Klein-Roggeveld Escarpment as well as on the plateau (Fig. 28). Much of the Abrahamskraal succession shows low dips (see geological map Fig. 3), but occasionally dips may be fairly steep, possibly associated with local faulting, as suggested by zones of quartz mineral lineation in zones of pervasive, steeply-inclined spaced cleavage that transects both mudrocks and fine-grained sandstones.

In the lower part of the Abrahamskraal succession the grain-size contract between the fine-grained sandstones / wackes and the silty overbank mudrocks is often slight, so upper and lower surfaces of channel and crevasse-splay sandstones, as well as channel margins, may be ill-defined and transitional (Figs. 20, 26). The fine- to very-fine-grained sandstones are typically tough, well-consolidated, well-sorted, greyish to slightly pinkish-purple (sometimes colour-mottled), dark grey-green when fresh, and well-jointed. They are usually structured by horizontal lamination or fine-scale ripple cross-lamination, or occasionally massive (Figs. 12, 21). Large-scale cross-bedding is rare (Figs. 14 & 18). Lower contacts are transitional, possibly loaded to only moderately erosional, with no marked gullying. They are usually not associated with well-defined, thick basal breccias, though thin mudclast breccias do occur within and at the base of some sandstone beds. A thick, multi-storey sandstone unit is exposed on the banks of a stream near a powerline just SE of Avondrus homestead (Rheebokke Fontein 209; co-ordinates 32 52 14 S, 20 40 43 E) and may serve as a useful marker bed.

Channel sandstones higher in the Abrahamskraal Formation succession – probably well within the Leeuvlei Member – are medium-grained, with a slightly crumbly, only moderately well-consolidated texture, frequently speckled or clotted in appearance (probably due to high feldspar content). Weathering hues vary from yellowish to brown (though often lichen-covered) (Fig. 22). Fabrics are variously massive, horizontally-laminated (*e.g.* flaggy, with primary current lineation), ripple cross-laminated to occasionally trough cross-bedded. The channel bases are moderately to markedly erosional and gullied. They are often associated with laterally-persistent, prominent-weathering, well-consolidated basal breccias up to 70-100 cm thick of reworked mudflakes and calcrete nodules, and occasionally also plant debris, including rare petrified wood (*e.g.* Loc. 548) (Figs. 23 & 25). Basal breccia lenses may be incorporated towards as well as at the base of the channel sandstone package and are often ferruginised. Flaggy sandstones higher up within these units may show well-developed, laterally-persistent, fine-scale heavy mineral banding.

A high proportion of the Abrahamskraal overbank mudrocks within the study area are purple-brown to maroon, while non-reddish mudrocks may be more blue-green than greenish-grey, especially lower down in the succession (Figs. 10, 12, 15 to 17, 19, 20, 22). Horizons of small to large pedogenic calcrete are moderately common within the overbank mudrock packages at all stratigraphic levels. Larger-scale pedogenic calcretes are usually ferruginous, rusty brown, and often sphaeroidal, lenticular to irregular in form (Fig. 28), while smaller sphaeroidal calcrete nodules are usually pale grey. Pinkish, lenticular silica pseudomorphs after gypsum ("desert roses") and sand-infilled mudcracks are common at certain horizons within reddish or grey-green mudrocks low down within the Abrahamskraal Formation succession, indicating highly arid climatic phases on the Middle Permian floodplain (Loc. 515, Fig. 45). Several angular float blocks of pale greenish, fine-grained cherty tuffs were recorded in Bakenshoogte area (e.g. Loc 540, Fig. 29), but tuff horizons were not seen *in situ*.

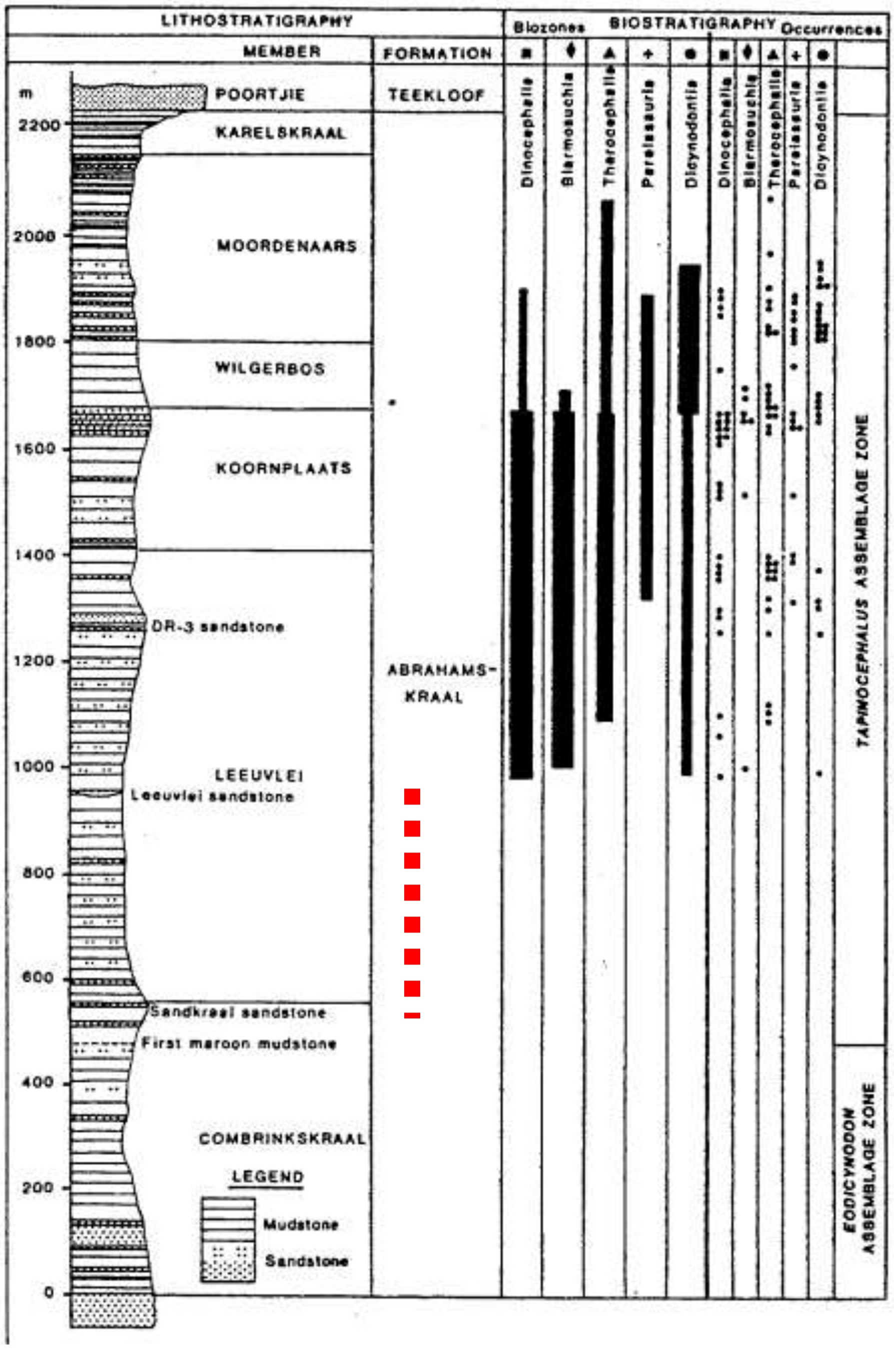


**Figure 8. Chart showing the subdivision of the Abrahamskraal Formation in the western Karoo region with stratigraphic distribution of the major fossil vertebrate groups (Loock *et al*. 1994). The Karusa Wind Farm study area is probably underlain by sediments within the the Leeuvlei Member (dotted red bar), above the first appearance of maroon mudstones, but the uppermost yellow-weathering sandstones may belong to the overlying Koornplaats Member.**

**Figure 9. Good stream gulley exposure of Abrahamskraal Formation bedrocks to the southeast of Saaiplaas, Standvastigheid 210 (Loc. 527).**

**Figure 10. Extensive exposure of thinly tabular-bedded overbank mudrocks and impure sandstones of the Abrahamskraal Formation, stream bank on Standvastigheid 210 (Loc. 526).**

**Figure 11. Tabular-bedded Abrahamskraal mudrocks and sandstones exposed along a stream bank, western part of Standvastigheid 210 (Loc. 516).**

**Figure 12. Good streambank exposure of Abrahamskraal Formation overbank mudrocks capped by a single-storey, fine-grained channel sandstone, Standvastigheid 210 (Loc. 501).**

**Figure 13. Stream bank exposure of a Middle Permian riverine palaeosurface with small-scale wave ripples as well as ponds or swales with falling water marks and rills, Standvastigheid 210 (Loc. 496)(Hammer = 30 cm).**

**Figure 14. Streambed exposure of Abrahamskraal Formation channel sandstones showing large-scale cross bedding (possibly epsilon crossbeds), Standvastigheid 210 (Loc. 509).**

**Figure 15. Stream gulley and hillslope exposure of Abrahamskraal purplish-brown mudrocks and thin, tabular sandstones on the southern flanks of Appelfontein se Rant, Standvastigheid 210 (Loc. 515).**

**Figure 16. Good hillslope exposure of Abrahamskraal overbank mudrocks and thin channel sandstones to the southeast of Bakenshoogte, Rheebokke Fontein 209 (Loc. 532).**

**Figure 17. Hillslope and stream gulley exposures of Abrahamskraal Formation overbank mudrocks at Bakenshoogte, Standvastigheid 210.**

**Figure 18. Tabular channel sandstone package, horizontally-laminated below and cross-bedded above, Appelfontein se Rant, Standvastigheid 210 (Loc. 513) (Hammer = 30 cm).**

**Figure 19. Stream gulley exposure of interbedded blue-green and purple-brown overbank mudrocks of the Abrahamskraal Formation, Appelfontein se Rant, Standvastigheid 210 (Loc. 512) (Hammer = 30 cm).**

**Figure 20. Possible thin, upward-coarsening packages within overbank mudrocks of the Abrahamskraal Formation, stream gulley section on Appelfontein se Rant, Standvastigheid 210 (Loc. 514).**

**Figure 21. Stream bed and waterfall exposure of a well-consolidated, well-jointed, fine-grained, tabular-bedded channel sandstone within the lower part of the local Abrahamskraal Formation succession, De Hoop 202 (Loc. 549).**

**Figure 22. Thick Abrahamskraal Formation overbank mudrock succession capped by yellowish-weathering, crumbly channel sandstones within the upper part of the local Abrahamskraal Formation succession, western portion of De Hoop 202 (Loc. 548).**

**Figure 23. Coarse, poorly-sorted, ferruginised channel breccio-conglomerate exposed at the base of the main channel sandstone seen in the previous figure, De Hoop 202 (Loc. 548) (Hammer = 30 cm).**

**Figure 24. Horizontally-laminated, grey-green channel sandstone overlying mudrocks with laterally-persistent ferruginous calcrete horizon, De Hoop 202 (Loc. 547).**

**Figure 25. Close-up of channel sandstone seen in the previous figure showing the well-developed, purplish-brown mudrock intraclast breccio-conglomerate at its base, De Hoop 202 (Loc. 547).**

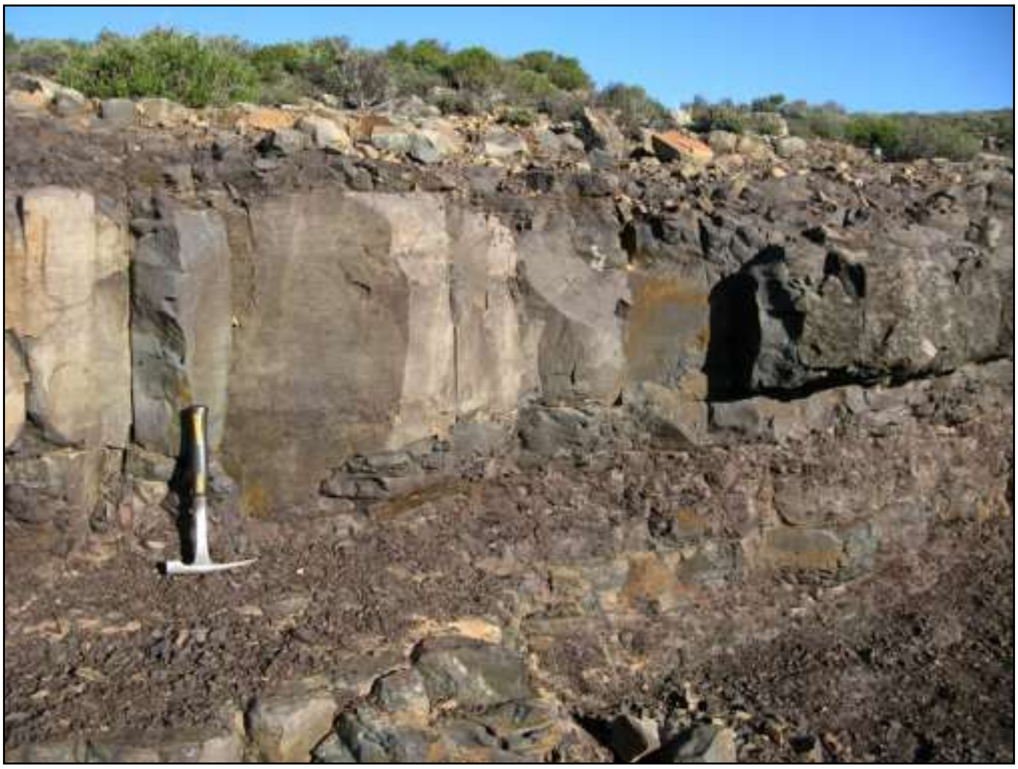

**Figure 26. Abrahamskraal Formation exposure near Bakenshoogte showing ill-defined, transitional base of the fine-grained impure sandstones, Standvastigheid 210 (Loc. 539) (Hammer = 30 cm).**

**Figure 27. Sharp, erosive-based channel sandstone (cross-bedded at bottom) of the Abrahamskraal Formation, Perdeplaas se Berg, De Hoop 202 (Loc. 541).**

**Figure 28. Large sphaeroidal concretions of ferruginous pedogenic calcrete within grey overbank mudrocks of the Abrahamskraal Formation, hillslope exposure on Standvastigheid 210 (Loc. 519) (Hammer = 30 cm).**

**Figure 29. Float blocks of fine-grained, pale greenish-yellow tuff (volcanic ash) from the Abrahamskraal Formation, Bakenshoogte area, Standvastigheid 210 (Loc. 540).**

**Figure 30. NW-SE striking dolerite dyke (*c*. 2.5 m thick) intruding, and slightly displacing, Abrahamskraal Formation country rocks, stream cutting on Rheebokke Fontein 209 (Loc. 530). The dyke weathers prominently as a blocky-jointed ridge.**

## 2.2. Karoo Dolerite Suite

A NW-SE trending swarm of Early Jurassic (*c*. 183 Ma) dolerite dykes of the Karoo Dolerite Suite traverse the wider Karusa Wind Farm study area and are well seen to the southeast of Balenshoogte (Locs. 530, 533; Fig. 30). The dykes vary from a few decimetre (dm) to several meters in width, are steeply inclined, rusty-brown and well-jointed, sometimes columnar-jointed. Cooled black basaltic margins as well as baked contact zones within the sedimentary country rocks can be observed. Small displacements of Abrahamskraal sandstone bodies either side of the intrusions suggests that they were probably intruded along a fault zone.

## 2.3. Late Caenozoic Superficial Deposits

On the Klein-Roggeveld plateau alluvial deposits, as exposed in stream-bank and erosion gulley sections, reach thicknesses of up to few meters and are dominated by well-bedded to massive pale buff sands and gravelly sands, with lenticles of fine to coarse, poorly-sorted gravel (*e.g.* Loc. 525, 538) (Figs. 31 & 32). There is often a basal lag of poorly-sorted, subangular to well-rounded gravels dominated by Beaufort Group sandstone and indurated mudrock with minor ferruginous palaeocalcrete nodules, reworked younger (Quaternary – Recent) calcrete and vein quartz.

Thick (up to several meters) mixed alluvial, colluvial and sheetwash deposits on hillslopes are exposed by gulley erosion (Fig. 33) where they are seen to consist of poorly-sorted sandy matrix as well as angular, blocky sandstone clasts. The colluvium may form a semi-consolidated rubbly, clast-supported breccia bed locally (Fig. 34). Elsewhere diamictites consisting of angular, dispersed sandstone blocks within a poorly-sorted sandy to silty matrix may be debrites emplaced by gravity flow on steeper slopes (*e.g.* Loc. 515 on Appelfontein se Rant). The dating of these various colluvial deposits is uncertain but, by analogy with the better-studied Masotcheni Formation of Kwazulu-Natal and the Eastern Cape, they may well be Pleistocene to Holocene in age (*cf* Botha 1996). Prominent-weathering sandstone *kranzes* along and above the escarpment are associated with aprons of angular to well-rounded blocks and corestones of Beaufort Group sandstone. Downwasted sandstone rubble overlies sandstone channel bodies towards and away from the escarpment edge (Figs. 5 & 7).

**Figure 31. Good stream bank sections through thick sandy alluvium with gravel-filled channel deposits overlying Abrahamskraal Formation bedrocks, eastern portion of Standvastigheid 210 (Loc. 525).**

**Figure 32. Coarse modern alluvial stream bed gravels (largely sandstone) and stream bank exposure of sandy alluvium, Standvastigheid 210 (Loc. 516).**

**Figure 33. Erosion gulley exposures of sandy to gravelly colluvial deposits of ill-defined Pleistocene to Holocene age, western portion of De Hoop 202 near the Klein-Roggeveld Escarpment edge.**

**Figure 34. Bank of semi-consolidated, poorly-sorted, angular colluvial gravels overlying Abrahamskraal Formation bedrocks, stream bank on Standvastigheid 210 (Loc. 510) (Hammer = 30 cm).**

## 3. PALAEONTOLOGICAL HERITAGE

In this section of the report the fossil heritage recorded elsewhere within the main rock units that are represented within the Karusa Wind Farm study area, together with any fossils observed here during the present field assessment, are outlined.

### 3.1. Fossil biotas of the Lower Beaufort Group (Adelaide Subgroup)

The overall palaeontological sensitivity of the Beaufort Group sediments is high to very high (Almond & Pether 2008). These continental sediments have yielded one of the richest fossil records of land-dwelling plants and animals of Permo-Triassic age anywhere in the world (MacRae 1999, Rubidge 2005, McCarthy & Rubidge 2005, Smith *et al.* 2012). Bones and teeth of Late Permian tetrapods have been collected in the western Great Karoo region since at least the 1820s and this area remains a major focus of palaeontological research in South Africa.

A chronological series of mappable fossil biozones or assemblage zones (AZ), defined mainly on their characteristic tetrapod faunas, has been established for the Main Karoo Basin of South Africa (Rubidge 1995, 2005, Van der Walt *et al.* 2010). Maps showing the distribution of the Beaufort Group assemblage zones within the Main Karoo Basin have been provided by Keyser and Smith (1979, Fig. 41 herein) and Rubidge (1995, 2005). A recently updated version is now available (Nicolas 2007, Van der Walt *et al.* 2010). The principal assemblage zone represented within the present study area is the Middle Permian ***Tapinocephalus* Assemblage Zone** (Theron 1983, Rubidge 1995) (See Figs. 8 & 35).

The main categories of fossils recorded within the *Tapinocephalus* fossil biozone (Keyser & Smith 1977-78, Anderson & Anderson 1985, Smith & Keyser 1995a, MacRae 1999, Rubidge 2005, Nicolas 2007, Almond 2010a, Smith *et al.* 2012, Day 2013a, Day 2013b, Day *et al.* 2015b) include:

- isolated petrified bones as well as rare articulated skeletons of tetrapods (*i.e.* air-breathing terrestrial vertebrates) such as true **reptiles** (notably large herbivorous pareiasaurs like *Bradysaurus* (Fig. 37), small insectivorous millerettids), rare pelycosaurs, and diverse **therapsids** or "mammal-like reptiles" (*e.g.* numerous genera of large-bodied dinocephalians (Figs. 37 & 38), herbivorous dicynodonts, flesh-eating biarmosuchians, gorgonopsians and therocephalians);

- aquatic vertebrates such as large **temnospondyl amphibians** (*Rhinesuchus*, usually disarticulated), and **palaeoniscoid bony fish** (*Atherstonia*, *Namaichthys*, often represented by scattered scales rather than intact fish);

- freshwater **bivalves** (*Palaeomutela*);

- **trace fossils** such as worm, arthropod and tetrapod burrows and trackways, coprolites (fossil droppings) and plant root casts;

- **vascular plant remains** (usually sparse and fragmentary), including leaves, twigs, roots and petrified woods ("*Dadoxylon*") of the *Glossopteris* Flora, especially glossopterid trees and arthrophytes (horsetail ferns).

In general, tetrapod fossil assemblages in the *Tapinocephalus* Assemblage Zone are dominated by a wide range of dinocephalian genera and small therocephalians *plus* pareiasaurs while relatively few dicynodonts can be expected (Day & Rubidge 2010, Jirah & Rubidge 2010 and refs. therein). Vertebrate fossils in this zone are generally much rarer than seen in younger assemblage zones of the Lower Beaufort Group, with almost no fossils to be found in the lowermost beds (Loock *et al.* 1994) (Fig. 8).

Despite their comparative rarity, there has been a long history of productive fossil collection from the *Tapinocephalus* Assemblage Zone in the western and central Great Karoo area, as summarized by Rossouw and De Villiers (1952), Boonstra (1969) and Day (2013b). Numerous fossil sites recorded in the region are marked on the published 1: 250 000 Sutherland geology sheet 3220 (Fig. 3), Beaufort West sheet 3222, and on the map in Keyser and Smith (1977-78; Fig. 35). Vertebrate fossils found in the Sutherland sheet area are also listed by Kitching (1977) as well as Theron (1983). They include forms such as the pareiasaur *Bradysaurus*, tapinocephalid and titanosuchid dinocephalians *plus* rarer dicynodonts, gorgonopsians and therocephalians (*e.g.* pristerognathids, *Lycosuchus*) as well as land plant remains (*e.g.* arthrophyte stems and leaves). Numerous fossil sites were recorded along the eastern edge of the Moordenaarskaroo in the key biostratigraphic study of the Abrahamskraal Formation by Loock *et al.* (1994). A recent palaeontological heritage study was carried out by the author within the Abrahamskraal Formation of the Moordenaarskaroo to the east of the present study area (Almond 2010a). This fieldwork yielded locally abundant dinocephalian and other therapsid skeletal remains, large, cylindrical vertical burrows or plant stem casts, *Scoyenia* ichnofacies trace fossil assemblages and sphenophytes (horsetail ferns) associated with probable playa lake deposits, as well as locally abundant petrified wood.

Fossils in the *Tapinocephalus* Assemblage Zone occur in association with both mudrocks and sandstones, most notably in thin intraformational conglomerates (*beenbreksie*) at the base of channel sandstones (Rossouw & De Villiers 1952, Turner 1981, Smith & Keyser 1995a). Tetrapod bones actually occur in a wide range of taphonomic settings in the *Tapinocephalus* Assemblage Zone (Almond 2010a). For example they are recorded as:

1. Disarticulated bones within thin intraformational conglomerates at the base of shallow (unistorey) channel sandstones. The bones are often impregnated with secondary iron and manganese minerals (coffee brown and black respectively). They vary from highly-weathered and rounded fragments to intact and well-preserved specimens. Bones occur at the base of, within, or floating at the top of the conglomerates in association with calcrete nodules, mudflakes, petrified wood and gypsum pseudomorphs. Bones in these channel lags were variously eroded out of riverbanks or washed into drainage channels from upland areas, riverine areas and floodplains during floods or episodes of landscape denudation.

2. Disarticulated bones within or at the top of channel sandstones.

3. Bones coated with calcrete or embedded within calcrete nodules associated with arid climate palaeosols (ancient soils). These bones are often suncracked, showing that lay exposed on the land surface for a long time before burial.

4. Isolated bones or articulated skeletons (possible mummies) embedded within levee or floodplain mudrocks.

5. Well-articulated skeletons preserved within fossil burrows (Botha-Brink & Modesto, 2007).

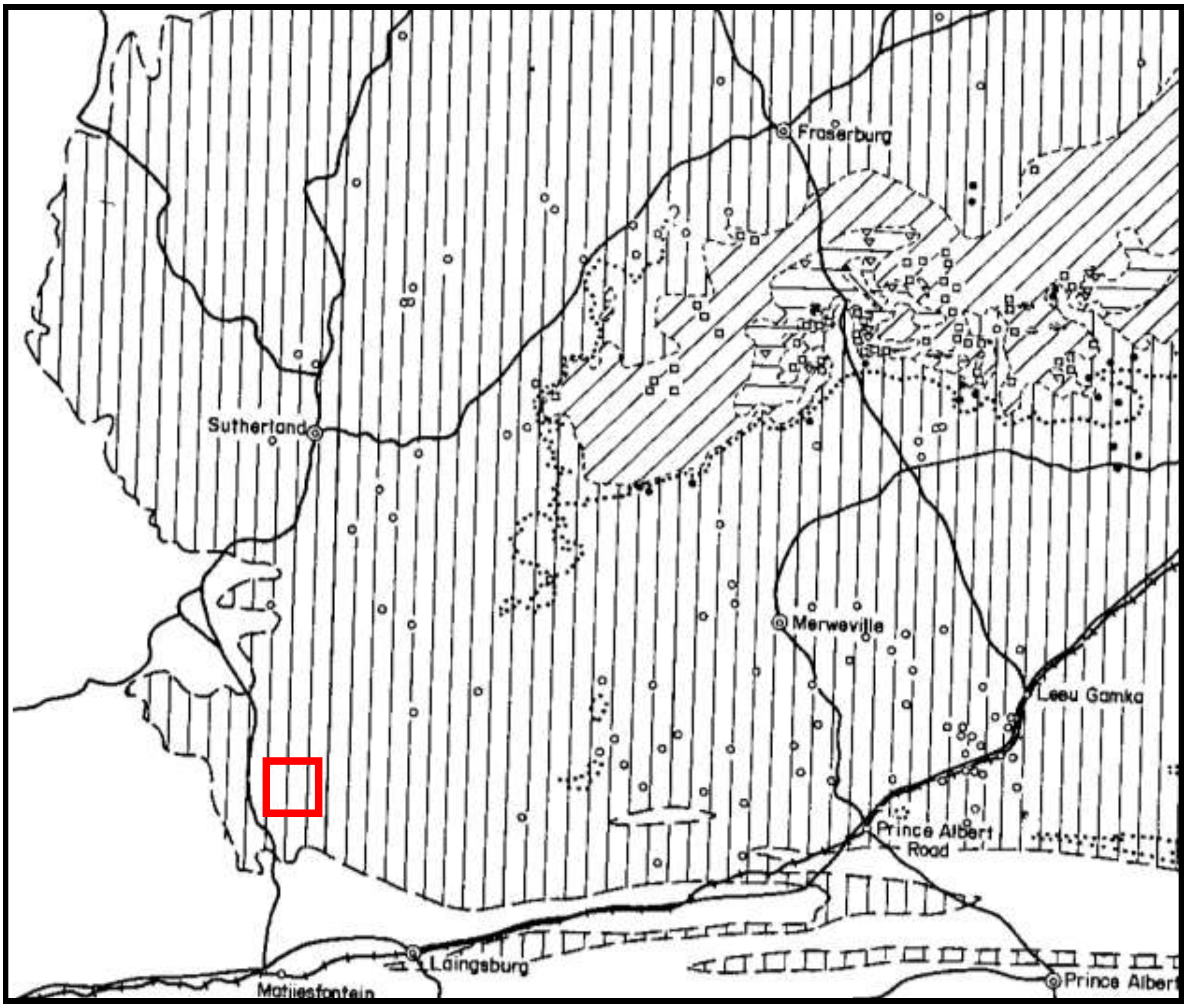


**Figure 35. Vertebrate fossil localities within the Lower Beaufort Group in the south-western Karoo region (Map abstracted from Keyser & Smith 1977-78). Outcrop areas with a vertical lined ornament are assigned to the Middle Permian *Tapinocephalus* Assemblage Zone. Note the absence of fossil records from the lower part of the Abrahamskraal Formation in the present Karusa Wind Farm study area to the south of Sutherland (red rectangle).**

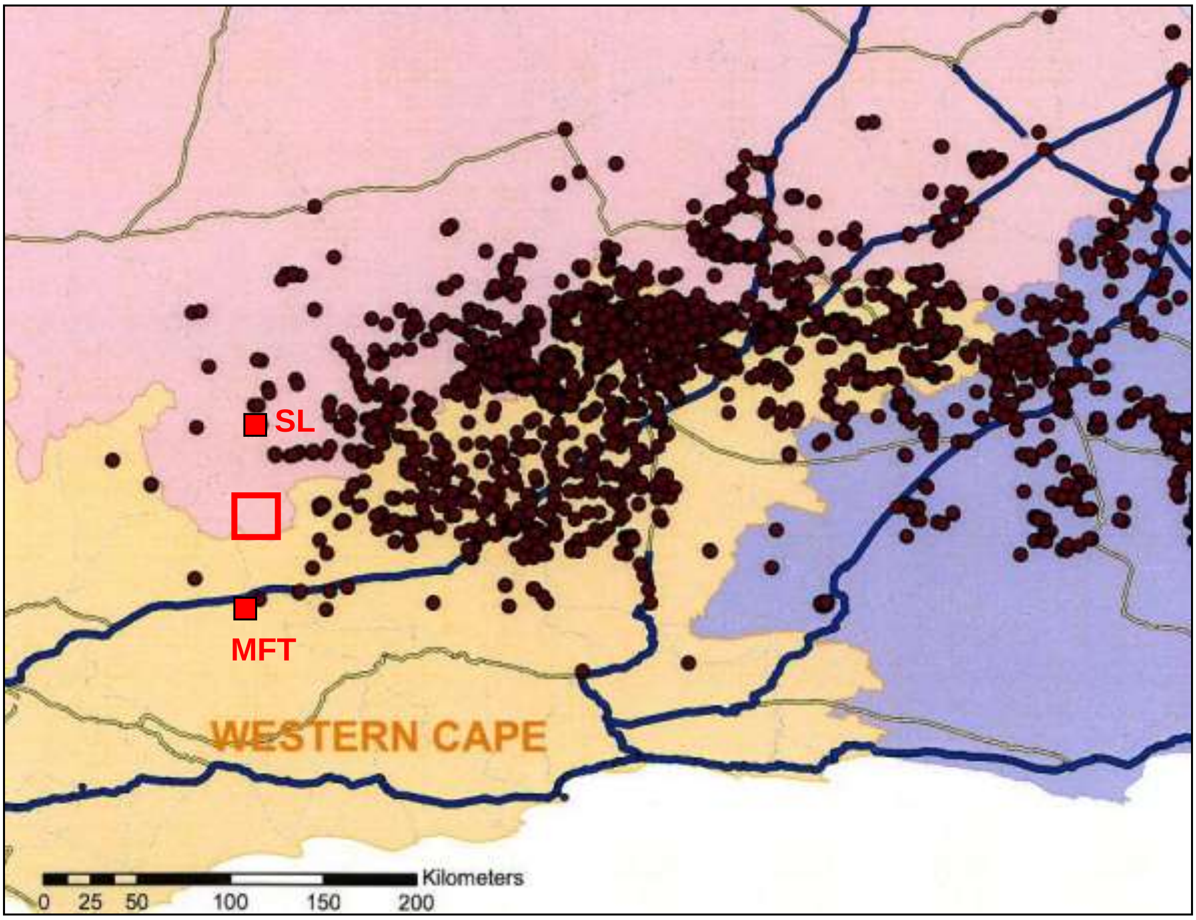


**Figure 36. Distribution of recorded vertebrate fossil sites within the south-western portion of the Main Karoo Basin (modified from Nicolas 2007). The approximate location of the Karusa Wind Farm study area is indicated by the open red square. Note the lack of known fossil sites here. SL = Sutherland. MFT = Matjiesfontein.**

Intensive fossil collection within the middle part of the Abrahamskraal Formation succession has suggested that a significant faunal turnover event may have occurred at or towards the top of the sandstone-rich Koornplaats Member, with the replacement of a more archaic, dinocephalian-dominated fauna (with primitive therapsids like the biarmosuchians) by a more advanced, dicynodont-dominated one at this level (Loock *et al.* 1994; Fig. 8 herein). This is the "faunal reversal" previously noted by Boonstra (1969) as well as Rossouw and De Villiers (1953). Other fossil groups such as therocephalians and pareiasaurs do not seem to have been equally affected. Problems have arisen in trying to correlate the lithologically-defined members recognized within the Abrahamskraal Formation by different authors across the whole outcrop area, with evidence for complex lateral interdigitation of the sandstone-dominated packages (D. Cole, pers. com., 2009). A research project is currently underway to subdivide the Abrahamskraal Formation on a biostratigraphic basis, emphasizing the range zones of various genera of small dicynodonts such as *Eodicynodon, Robertia* and *Diictodon* (Day & Rubidge 2010, Jirah & Rubidge 2010, 2014, Day 2013a, 2013b, Day *et al.* 2015a, 2015b).

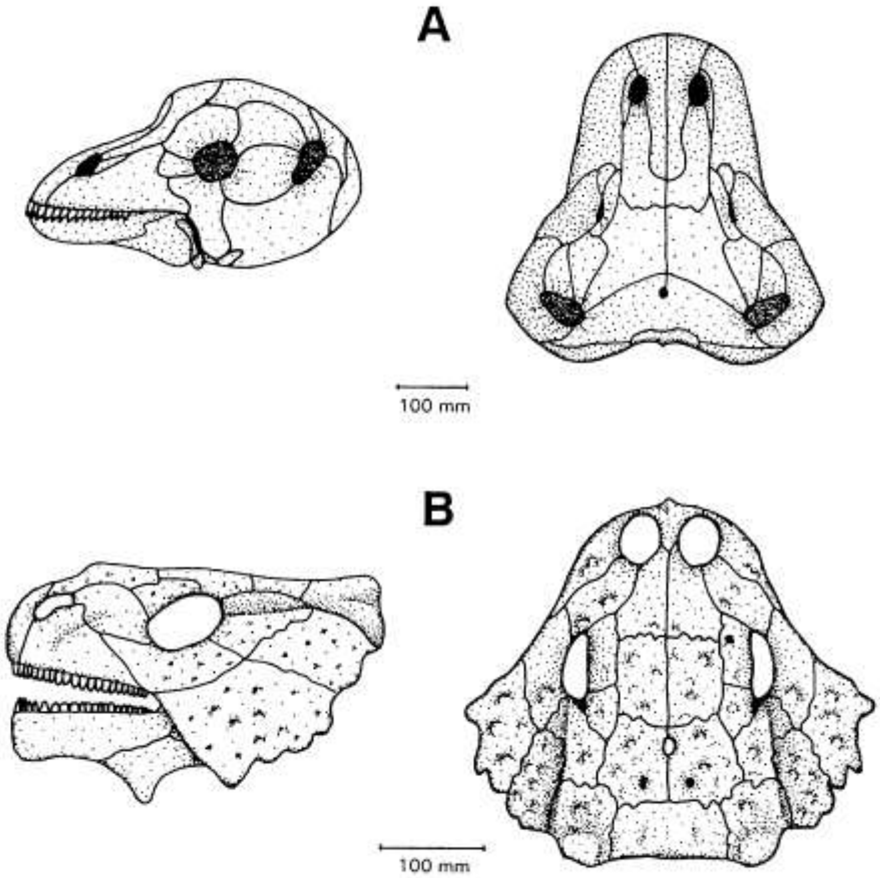


**Figure 37. Skulls of two key large-bodied tetrapods of the *Tapinocephalus* Assemblage Zone: A – the dinocephalian therapsid *Tapinocephalus*; B – the pareiasaur *Bradysaurus* (From Smith & Keyser 1995b).**

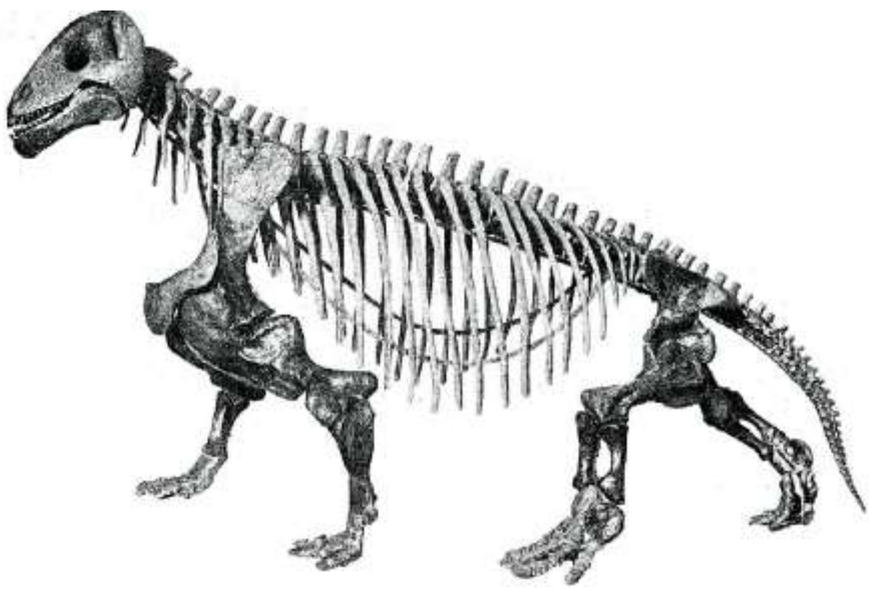

**Figure 38. Skeleton of the tapinocephalid (thick-skulled) dinocephalian *Moschops*, a rhino-sized herbivorous therapsid that reached lengths of 2.5 to 3 m and may have lived in small herds.**

According to Loock *et al.* (1994) much of the Combrinkskraal Member is assigned to the Middle Permian ***Eodicynodon* Assemblage Zone**, the oldest recognised biozone of the Abrahamskraal Formation (Fig. 8). This may apply in particular to the succession below the first appearance of reddish-hued overbank mudrocks. Since this largely excludes the present Karusa Wind Farm study area, the fossil record of this assemblage zone is not considered in any detail here. Fossil tetrapods are notoriously rare within *Eodicynodon* Assemblage Zone, mainly comprising a few taxa of primitive dicynodonts (*Eodicynodon*) and dinocephalians (*e.g. Tapinocaninus*) *plus* even rarer represenatives of other therapsid subgroups such as therocephalians (Rubidge 1995, Smith *et al.* 2012, Day 2013a). Other fossil groups include palaeonescoid fish, rhinesuchid amphibians, freshwater molluscs, low diversity trace fossil assemblages and a few vascular plant taxa of the *Glossopteris* Flora (*e.g. Schizoneura, Equisetum, Glossopteris*). The tetrapod fossils are usually associated with overbank mudrock facies, especially those reflecting lake margin settings with the development of subspherical calcareous concretions (Smith *et al.* 2012).

Selected fossil sites recorded within the *Tapinocephalus* Assemblage Zones in the Sutherland region are indicated on outline maps by Kitching (1977), Keyser and Smith (1977-78) (Fig. 35) and Nicolas (2007) (Fig. 36). Several fossil sites near Sutherland are also shown on the 1: 250 000 geological sheet 3220 Sutherland published by the Council for Geoscience, Pretoria. In addition Kitching (1977) provides palaeofaunal lists for specific localities within the Great Karoo region. It is notable that these works suggest a profound paucity of vertebrate fossil finds in the present study area to the south of Sutherland, although a few localities are indicated in stratigraphically lower-lying beds of the Lower Beaufort Group to the west and south of the study area. This palaeontological impoverishment seems to apply even to the excellent exposures of Abrahamskraal Formation sediments within the Verlatekloof Pass near Sutherland. The reasons for the lack of fossils even here - despite appropriate facies and good bedrock exposure - is currently unresolved and may have a palaeoenvironmental component. A previous palaeontological field assessment of Mordenaars Member rocks on the outskirts of Sutherland by Almond (2005) yielded only transported plant remains (arthrophytes including *Phyllotheca*, glossopterid and other, more strap-shaped leaves, possible wood tool marks), sparse trace fossil assemblages of the damp-ground *Scoyenia* ichnofacies, and rare fragments of rolled bone. Reworked silicified wood from surface gravels, scattered, fragmentary plant remains associated with channel sandstones and rare disarticulated bones were reported from a Moordenaars Member study site *c*. 1 km south of Sutherland by Almond (2011). A traverse through the Combrinkskraal and Leeuvlei Members along the Gamma – Omega 765 kV transmission line corridor through the southern portion of the present study area did not yield fossil vertebrate remains here, although locally abundant plant material (*e.g.* sphenophytes, possible floating log tool marks) and sizeable vertical burrows (possibly casts of plant stems / roots) were seen, mainly further to the east in the Moordenaarskaroo region (Almond 2010a).

The only fossil remains recorded from the Abrahamskraal Formation within the Karreebosch Wind Farm study area located to the west of the present study area (Almond 2014) include rare, fragmentary remains of vascular plants - notably disarticulated sphenophyte (horsetail fern) stems embedded within massive siltstones – as well as widely occurring, low-diversity trace fossil assemblages of the *Scoyenia* ichnofacies that have been attributed to earthworms and / or insect larvae (*cf* Seilacher 2007).

No vertebrate fossil material or petrified wood was recorded within any of the Lower Beaufort Group facies reported within the Karusa Wind Farm study area during the present field study, including the channel lag deposits. The apparent absence of fossil vertebrate bones and teeth within the Karusa Wind Farm study area is notable, since a substantial number of good Abrahamskraal Formation bedrock exposures were examined here during the course of the field study (See Appendix). This supports the proposition that the bedrocks here lie within the fossil-poor lower part of the Leeuvlei Member and perhaps also the uppermost Combrinkskraal Member (Fig.8).

Low-diversity invertebrate trace fossil assemblages of the *Scoyenia* ichnofacies, as well as narrow, vertical, sand-infilled cyclindrical burrows or plant stem or root casts up to 8 mm in diameter are recorded on fine- to medium-grained sandstone bedding planes (Locs. 495, 504, 528, 532; Figs. 42 & 43). Simple horizontal invertebrate burrows (*c*. 0.5 cm wide) are preserved as positive epichnia or sand-infilled endichnia on sandstone bedding planes at Loc. 498 (Fig. 48). Apparently segmented horizontal invertebrate burrows (*c*. 5 mm wide) are associated with an adhesion-warted sandstone palaesurface at Loc. 509 (Fig. 47). Washed-out simple traces are associated with flaggy, horizontally-laminated and current-lineated sandstones at Loc. 513. Water-worn channel sandstones extensively exposed in the riverbed between Saaiplaas and Smithkraal (Standvastigheid 210) show concentrations of horizontal cylindrical to oblique burrows *c*. 1 cm in diameter (Loc. 523; Fig. 46). Bioturbation levels at some horizons here are high.

A large, sand-infilled structure (*c*. 30 cm wide) emplaced within a thin-bedded, heterolithic, mud-cracked sedimentary package that underlies a cross-bedded sandstone at Loc. 515 (Appelfontein se Rant) *might* be a vertebrate burrow cast, though this is equivocal (Fig. 45). Several sizeable, vertical, subclindrical to tapering sandstone casts of plant axes (or possibly burrows) occur within a mudrock horizon underlying a thin sandstone on Standvastigheid 210 (Loc. 522; Fig. 44) (See also Almond 2010a).

Transported plant debris, consisting largely of impressions of finely-ridged, fragmentary plant stems of equisetaleans (arthrophyte ferns) or other vascular plants up to 5 cm across, is common within the lower part of the Abrahamskraal succession (Locs. 499, 501, 502, 506, 509, 518, 524, 526 *etc*; Figs. 39 & 40). The plant fossils are variously dispersed or concentrated as laterally-persistent fossiliferous layers on bedding planes of fine-grained sandstone (crevasse splays) or silty overbank mudrocks. They generally show no sign of preferential orientation. Basal channel sandstones containing locally abundant, feruginised moulds of reworked woody plant material are seen on De Hoop 202 (Loc. 547, Fig. 41).

**Figure 39. Compression fossil of a longitudinally-ridged plant stem, possibly a large equisetalean fern, preserved within dark grey overbank mudrocks, Standvastigheid 210 (Scale in cm) (Loc. 501).**

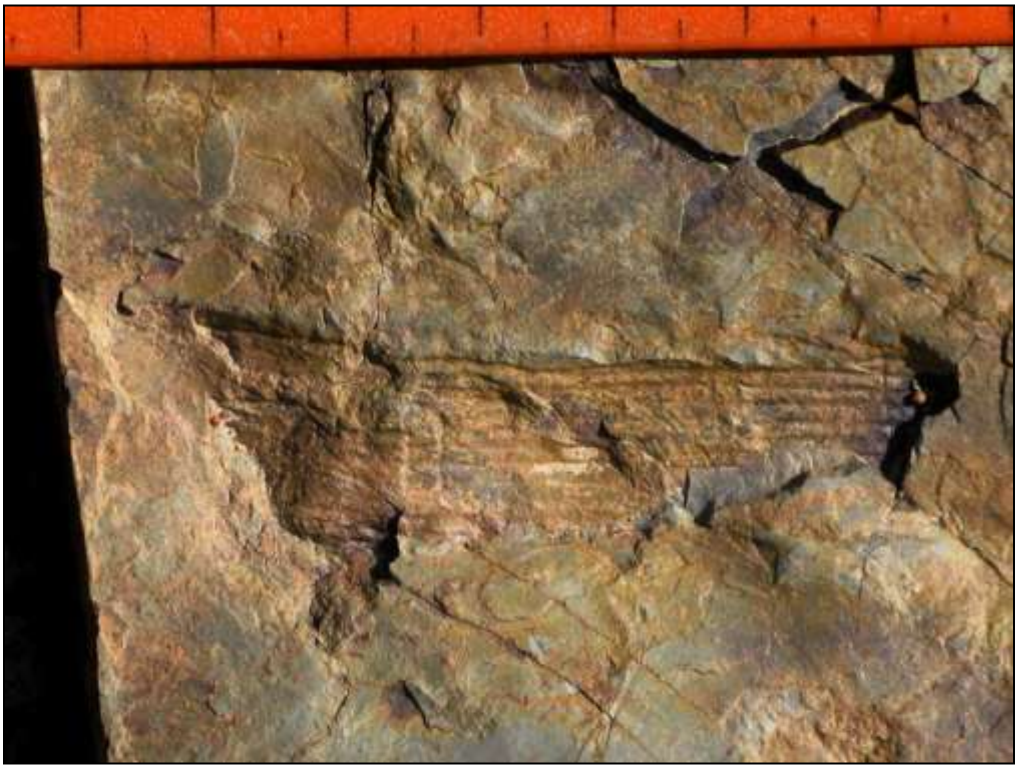

**Figure 40. External mould of a longitudinally-ridged equisetalean fern stem preserved within fine-grained sandstone, Standvastigheid 201 (Scale in cm and half-cm) (Loc. 499).**

**Figure 41. Sandstone float block derived from a coarse-grained channel sandstone base containing concentrations of reworked woody plant material preserved as ferruginised moulds, De Hoop 202 (Scale in cm) (Loc. 547).**

**Figure 42. Vertical, cylindrical sand-infilled structures (*c*. 8 mm wide) – possibly plant stem casts - within a finer-grained channel sandstone, Standvastigheid 210 (Loc. 504) (Scale in cm & mm)**

**Figure 43. Thin-bedded, fine-grained sandstone with dark mudstone veneer showing scattered rounded structures – possibly sections through reedy plant stem casts, Standvastigheid 210 (Loc. 495) (Scale in cm).**

**Figure 44. One of several 4-5 cm wide, subcylindrical to downward-tapering sandstone casts (arrowed) penetrating from the base of a sandstone bed into underlying mudrock, Standvastigheid 210 (Loc. 522)(Hammer = 30 cm).**

**Figure 45. Thin-bedded, purple-brown overbank mudrocks beneath a cross-bedded channel sandstone showing sand-infilled casts of downward-tapering mudcracks (yellow arrow) as well as of a wider structure that *might* be a vertebrate burrow (adjacent to hammer), Standvastigheid 210 (Loc. 515) (Hammer = 30 cm).**

**Figure 46. Water-worn channel sandstones showing darker, sand-infilled horizontal and oblique invertebrate burrows, river bed on Standvastigheid 210 (Loc. 523) (Scale in cm).**

**Figure 47. Sandstone upper bedding plane showing possible adhesion warts as well as horizontal epichnial burrows with a segmented structure, Standvastigheid 210 (Loc. 509) (Scale in cm and mm).**

**Figure 48. Upper sandstone bedding plane showing horizontal sand-infilled burrows up to 0.5 mm across , Standvastigheid 210 (Loc. 498) (Scale in cm).**

**Figure 49. Dense assemblage of vertical and oblique, meniscate back-filled invertebrate burrows, probably of the ichnogenus *Scoyenia*, Standvastigheid 210 (Loc. 528) (Scale in mm).**

### 3.2. Fossils within the superficial deposits

The diverse superficial deposits within the South African interior have been comparatively neglected in palaeontological terms. However, sediments associated with ancient drainage systems, springs and pans in particular may occasionally contain important fossil biotas, notably the bones, teeth and horn cores of mammals as well as remains of reptiles like tortoises (*e.g.* Skead 1980, Klein 1984b, Brink, J.S. 1987, Bousman *et al.* 1988, Bender & Brink 1992, Brink *et al*. 1995, MacRae 1999, Meadows & Watkeys 1999, Churchill *et al*. 2000, Partridge & Scott 2000, Brink & Rossouw 2000, Rossouw 2006). Other late Caenozoic fossil biotas that may occur within these superficial deposits include non-marine molluscs (bivalves, gastropods), ostrich egg shells, trace fossils (*e.g.* calcretised termitaria, coprolites, invertebrate burrows, rhizocretions), and plant material such as peats or palynomorphs (pollens) in organic-rich alluvial horizons (Scott 2000) and diatoms in pan sediments. In Quaternary deposits, fossil remains may be associated with human artefacts such as stone tools and are also of archaeological interest (*e.g.* Smith 1999 and refs. therein). Ancient solution hollows within extensive calcrete hardpans may have acted as animal traps in the past. As with coastal and interior limestones, they might occasionally contain mammalian bones and teeth (perhaps associated with hyaena dens) or invertebrate remains such as snail shells.

No fossils were observed within the various Late Caenozoic superficial deposits represented within the Karusa Wind Farm study area during the present field study.

## 4. CONCLUSIONS & RECOMMENDATIONS

The fluvial Abrahamskraal Formation (Lower Beaufort Group, Karoo Supergroup) that underlies the Karusa Wind Farm study area is known for its diverse fauna of Permian fossil vertebrates - notably various small- to large-bodied therapsids and reptiles - as well as fossil plants of the *Glossopteris* Flora and low diversity trace fossil assemblages. However, desktop analysis of known fossil distribution within the Main Karoo Basin shows a marked paucity of fossil localities in the wider study region between Matjiesfontein and Sutherland where sediments belonging only to the lower part of the thick Abrahamskraal Formation succession, below the Moordenaars Member, are represented. Bedrock exposure levels in the broader study region are generally very poor due to the pervasive cover by superficial sediments (colluvium, alluvium, soils, calcrete) and vegetation. Nevertheless, a sufficiently large outcrop area of Abrahamskraal Formation sediments, exposed in stream and riverbanks, borrow pits as well as steep hillslopes and erosion gullies along the Klein-Roggeveld Escarpment and plateau, has been examined during the present field study to infer that macroscopic fossil remains of any sort are very rare here. Exceptions include common low-diversity trace fossil assemblages (small-scale invertebrate burrows, possible plant stem or root casts) and locally abundant but fragmentary plant remains. The latter include horsetail ferns (arthrophytes) as well as moulds of woody plant material weathering out from the base of channel sandstones high up within the local Abrahamskraal Formation succession (probably the Leeuvlei Member). No fossil vertebrate remains (bones, teeth, coprolites) were recorded within the Karusa Wind Farm study area, but a few equivocal vertebrate burrows-like structures were seen. Levels of bedrock tectonic deformation are generally low, although folding, faulting and cleavage development associated within the Cape Fold Belt are locally apparent. A narrow swarm of Early Jurassic dolerite dyke intrusions occurs within the wider study area but is of no palaeontological heritage significance. It is concluded that the Lower Beaufort Group bedrocks in the Karusa Wind Farm study area are **generally of low palaeontological sensitivity** and this also applies to the overlying Late Caenozoic superficial sediments (colluvium, alluvium, calcrete, surface gravels, soils *etc*).

Construction of the proposed Karusa Wind Farm is unlikely to entail significant impacts on local fossil heritage resources. Due to the general great scarcity of fossil remains as well as the extensive superficial sediment cover observed within the study area, the **overall impact significance of the construction phase of the proposed alternative energy development is assessed as LOW.** The operational and decommissioning phases of the wind farm are very unlikely to involve further adverse impacts on local palaeontological heritage. This assessment applies to all wind farm infrastructural components including the proposed new access roads, both those within the Karusa Wind Farm study area and that linking Karusa with the adjoining proposed Soetwater Wind Farm to the north.

Given the low impact significance of the proposed Karusa Wind Farm near Sutherland as far as palaeontological heritage is concerned, no further specialist palaeontological heritage studies or mitigation are considered necessary for this project, pending the potential discovery or exposure of substantial new fossil remains during development. During the construction phase all deeper (> 1 m) bedrock excavations should be monitored for fossil remains by the responsible ECO and/or Contractor's EO. Should substantial fossil remains such as vertebrate bones and teeth, plant-rich fossil lenses, fossil wood or dense fossil burrow assemblages be exposed during construction, the responsible Environmental Control Officer should safeguard these, preferably *in situ*, and alert SAHRA, *i.e.* The South African Heritage Resources Authority, as soon as possible (Contact details: Mrs Colette Scheermeyer, P.O. Box 4637, Cape Town 8000. Tel: 021 462 4502. Email: cscheermeyer@sahra.org.za) so that appropriate action can be taken by a professional palaeontologist, at the Proponent's expense. Mitigation would normally involve the scientific recording and judicious sampling or collection of fossil material as well as associated geological data (*e.g.* stratigraphy, sedimentology, taphonomy) by a suitably qualified palaeontologist.

These mitigation recommendations should be incorporated into the Environmental Management Programme (EMPr) for the Karusa Wind Farm project.

Please note that:

- All South African fossil heritage is protected by law (South African Heritage Resources Act, 1999) and fossils cannot be collected, damaged or disturbed without a permit from SAHRA or the relevant Provincial Heritage Resources Agency;

- The palaeontologist concerned with potential mitigation work will need a valid fossil collection permit from SAHRA and any material collected would have to be curated in an approved depository (*e.g.* museum or university collection);

- All palaeontological specialist work should conform to international best practice for palaeontological fieldwork and the study (*e.g.* data recording fossil collection and curation, final report) should adhere as far as possible to the minimum standards for Phase 2 palaeontological studies recently developed by SAHRA (2013).

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## 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, Limpopo, Northwest and the Free State under the aegis of his Cape Town-based company *Natura Viva* cc. He has served as 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 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 development 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.

**Dr John E. Almond**
**Palaeontologist**
***Natura Viva* cc**

## APPENDIX: GPS LOCALITY DATA

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

| Locality number | GPS data | Comments |
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| **495** | S32° 53' 25.3"<br>E20° 37' 14.0" | Standvastigheid 210, streambed exposure of grey-green mudrocks, thin sandstones with narrow vertical cylindrical burrows / plant stem casts, traces of the *Scoyenia* ichnofacies. Rubbly sandstone colluvium. MSA flake of medium-grained sandstone. |
| **496** | S32° 53' 01.2"<br>E20° 36' 34.7" | Standvastigheid 210, streambed exposure of grey-green and purple-brown mudrocks, well-jointed fine channel sandstones. Wave-rippled sandstone palaeosurface. Stream bank section through coarse and fine-grained alluvial deposits. Sandstone colluvium. |
| **497** | S32° 53' 06.5"<br>E20° 36' 32.9" | Standvastigheid 210, streambed and bank exposure of grey-green and purple-brown mudrocks. |
| **498** | S32° 53' 02.3"<br>E20° 36' 36.3" | Standvastigheid 210, streambed exposure of sandstone bedding planes with simple horizontal burrows. |
| **499** | S32° 53' 02.0"<br>E20° 36' 38.1" | Standvastigheid 210, shallow erosion gulley and hillslope exposures of overbank mudrocks, small palaoecalcrete nodules, thin sandstones and siltstones with transported plant debris (equisetalean fern stems). |
| **500** | S32° 53' 00.1"<br>E20° 36' 35.2" | Standvastigheid 210, streambank exposure of purple-brown & grey-green, hackly-weathering mudrocks with large ferruginous calcrete concretions, lenses. Thin crevasse-splay sandstones. |
| **501** | S32° 52' 45.5"<br>E20° 35' 56.8" | Standvastigheid 210, excellent streambank exposure of overbank mudrocks and thin, well-jointed channel sandstones. Dispersed plant impressions (equisetaleans), small, pale grey calcrete concretions, ferruginous brown calcrete lenses, sand-infilled mudcracks and silicified gypsum pseudomorphs within thin-bedded mudrocks. |
| **502** | S32° 52' 37.5"<br>E20° 35' 51.0" | Standvastigheid 210, extensive streambed and bank exposure of well-jointed overbank mudrocks, sandstones. Possible loading of sandstones into mudrock. Abundant equisetalean plant debris in laterally-persistent layers on on crevasse-splay sandstone upper bedding surfaces. |
| **503** | S32° 52' 37.5"<br>E20° 35' 35.7" | Standvastigheid 210, stream-gulley exposure of thick package of grey-brown overbank mudrocks with thin crevasse-splay sandstones. |
| **504** | S32° 52' 37.0"<br>E20° 35' 34.2" | Standvastigheid 210, streamside exposure of medium-grained channel sandstones with sand-infilled vertical cylindrical burrows or plant stem casts. |
| **505** | S32° 52' 36.1"<br>E20° 35' 33.9" | Standvastigheid 210, hillslope exposure of interbedded tabular sandstones and hackly-weathering mudrocks with palaeosols marked by large ferruginous calcrete nodules. |
| **506** | S32° 52' 34.7"<br>E20° 35' 30.8" | Standvastigheid 210, hillslope exposure of packages of tabular sandstones and thin-bedded, hackly-weathering grey-green and purple-brown mudrocks. Sparse plant stem impressions. |
| **507** | S32° 52' 37.7"<br>E20° 35' 28.3" | Standvastigheid 210, stream bed / waterfall exposure of tabular sandstones and thin-bedded, hackly-weathering grey-green and purple-brown mudrocks |
| **508** | S32° 52' 48.0"<br>E20° 35' 33.5" | Standvastigheid 210, viewpoint NE towards Appelfontein se Rant. |
| **509** | S32° 52' 54.4"<br>E20° 35' 40.6" | Standvastigheid 210, extensive stream bed / waterfall exposure of tabular sandstones and thin-bedded, hackly-weathering grey-green and purple-brown mudrocks, calcrete nodules, thick, cross-bedded channel sandstone (possibly epsilon cross-stratification). Sandstone palaesurface with adhesion warts, segmented horizontal burrows. |
| **510** | S32° 52' 45.6"<br>E20° 36' 06.4" | Standvastigheid 210, stream bank exposure of semi-consolidated sandstone alluvial / colluvial gravels overlying Beaufort Group bedrocks. |
| **511** | S32° 52' 38.7"<br>E20° 37' 25.8" | Standvastigheid 210, Appelfontein se Rant stream exposure of Beaufort Group siltstones and fine sandstones. |
| **512** | S32° 52' 46.0"<br>E20° 37' 29.1" | Standvastigheid 210, Appelfontein se Rant stream exposure of Beaufort Group purple-brown and grey-green siltstones and fine sandstones. |
| **513** | S32° 52' 53.7" | Standvastigheid 210, Appelfontein se Rant hillslope and stream |

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| | E20° 37' 32.2" | gulley exposure of Beaufort Group purple-brown and grey-green siltstones and fine sandstones (locally cross-bedded). Quartz veining, slickensides, brecciation. Wash-out trace fossils and / or plant stem casts in sandstone. Sandstone surfaces with adhesion warts. |
| **514** | S32° 52' 53.2"<br>E20° 37' 30.6" | Standvastigheid 210, Appelfontein se Rant hillslope and stream gulley exposure of Beaufort Group purple-brown and grey-green siltstones and fine sandstones (locally cross-bedded). Possible upward-coarsening sequences, capped by channel sandstone. |
| **515** | S32° 52' 53.8"<br>E20° 37' 29.6" | Standvastigheid 210, Appelfontein se Rant hillslope colluvial deposits, possible matrix-supported debrites. Lower Beaufort streambed exposure with thin-bedded heterolithic package, sand-infilled mudcracks, *possible* vertebrate burrow cast. |
| **516** | S32° 53' 49.6"<br>E20° 34' 49.8" | Standvastigheid 210, extensive riverbank exposure of tabular-bedded Lower Beaufort Group sediments. Coarse alluvial gravels, sandy modern alluvium. |
| **517** | S32° 53' 44.2"<br>E20° 34' 55.5" | Standvastigheid 210, coarse modern alluvial gravels. |
| **518** | S32° 53' 42.2"<br>E20° 34' 46.8" | Standvastigheid 210, riverine exposure of Lower Beaufort gp. Impressions of equisetalean debris on fine-grained sandstone surfaces. |
| **519** | S32° 53' 23.2"<br>E20° 34' 22.2" | Standvastigheid 210, gullied hillslope exposure of Lower Beaufort Group. Gypsum pseudomorphs, well-developed pedogenic calcrete concretions & lenses. |
| **520** | S32° 53' 19.7"<br>E20° 34' 12.5" | Standvastigheid 210, gullied hillslope exposure of Lower Beaufort Group mudrocks with laterally-persistent calcrete nodule horizons, gypsum pseudomorphs. |
| **521** | S32° 54' 14.8"<br>E20° 39' 13.2" | Standvastigheid 210, hillslope exposure of Lower Beaufort Group, mudrocks showing subvertical cleavage. |
| **522** | S32° 54' 33.9"<br>E20° 39' 41.6" | Standvastigheid 210, large, vertical, subclindrical sandstone casts of plant axes or burrows within mudrocks underlying thin sandstone. |
| **523** | S32° 54' 29.7"<br>E20° 39' 35.3" | Standvastigheid 210, very extensive riverbed exposures of well-jointed Lower Beaufort Group sandstones between Saaiplaas and Smithkraal showing locally abundant cylindrical burrows. Overlying gravelly and sandy modern alluvium. |
| **524** | S32° 54' 09.2"<br>E20° 39' 17.9" | Standvastigheid 210, hillslope exposure of Lower Beaufort Group. Local tectonism indicated by quartz veining and slickensides, mineral lineation. Dispersed plant stem moulds in mudrocks. |
| **525** | S32° 54' 14.2"<br>E20° 38' 16.7" | Standvastigheid 210, good vertical sections through fine and coarse Late Caenozoic alluvium. |
| **526** | S32° 54' 24.3"<br>E20° 37' 58.9" | Standvastigheid 210, excellent stream bank and hillslope exposures of thin-bedded grey-green overbank mudrocks and channel sandstones of the Lower Beaufort Group. Rare plant fossil impressions. Isolated float block of greenish chert. |
| **527** | S32° 54' 34.8"<br>E20° 38' 00.3" | Standvastigheid 210, extensive Lower Beaufort bedrock exposure in deep stream gulley. |
| **528** | S32° 54' 39.1"<br>E20° 37' 59.7" | Standvastigheid 210, trace fossils of the *Scoyenia* ichnofacies within sandstone beds near dam outflow. |
| **529** | S32° 55' 13.3"<br>E20° 38' 55.0" | Standvastigheid 210, stream bed exposure of Lower Beaufort Group. |
| **530** | S32° 53' 02.4"<br>E20° 40' 14.6" | Rheebokke Fontein 209, Bakenshoogte area, extensive stream bed and bank exposures of Lower Beaufort Group jointed channel sandstones, overbank mudrocks intruded by a steeply-dipping dolerite dyke (*c*. 2.5 m thick). |
| **531** | S32° 53' 08.4"<br>E20° 40' 20.7" | Rheebokke Fontein 209, Bakenshoogte area, stream bed exposure of current-lineated flaggy sandstone. Bedding surfaces with washed-out ripple crests |
| **532** | S32° 53' 11.4"<br>E20° 40' 21.8" | Rheebokke Fontein 209, Bakenshoogte area, good stream gulley and bank exposure of Lower Beaufort Group sediments. Locally abundant vertical cylindrical burrows or plant stem casts. Faulted base of channel sandstone. Weathered, well-jointed NW-SE dolerite dyke with corestones in the vicinity. |
| **533** | S32° 53' 04.1"<br>E20° 40' 11.1" | Rheebokke Fontein 209, Bakenshoogte area, wide steeply-dipping NW-SE dolerite dyke. |
| **534** | S32° 52' 58.3"<br>E20° 40' 03.8" | Rheebokke Fontein 209, Bakenshoogte area, narrow basaltic dyke intruding mudrocks in stream bed exposure. |
| **535** | S32° 52' 05.1"<br>E20° 39' 22.4" | Rheebokke Fontein 209, stream bed exposure of Lower Beaufort Group. |
| **536** | S32° 51' 27.7"<br>E20° 37' 31.4" | Rheebokke Fontein 209, stream bank exposure of Lower Beaufort Group. |
| **537** | S32° 52' 40.2"<br>E20° 41' 23.0" | Rheebokke Fontein 209, extensive stream bank exposure of Lower Beaufort Group, including well-jointed fine-grained |

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| | | sandstones. |
| **538** | S32° 52' 46.7"<br>E20° 41' 36.5" | Rheebokke Fontein 209, streambank sections through thick Late Caenozoic fine- and coarse-grained alluvial deposits. |
| **539** | S32° 53' 13.5"<br>E20° 39' 47.3" | Standvastigheid 210, Bakenshoogte area, extensive hillslope and gulley exposures of Lower Beaufort Group. Ferruginised calcrete nodule horizons (probably related to dolerite intrusion in the vicinity). |
| **540** | S32° 53' 12.3"<br>E20° 39' 49.2" | Standvastigheid 210, Bakenshoogte area, several isolated float blocks of fine-grained greenish tuff. |
| **541** | S32° 48' 13.4"<br>E20° 40' 10.3" | De Hoop 202, Perdeplaas se Berg, roadside hillslope exposure of grey-green mudrocks, thin crevasse splay sandstones and horizontally-laminated to cross-bedded channel sandstones of Lower Beaufort Group. |
| **542** | S32° 48' 13.1"<br>E20° 40' 20.8" | De Hoop 202, Perdeplaas se Berg, hillslope exposure of dark grey mudrocks, ferruginised calcrete concretions. Evidence for local deformation. |
| **543** | S32° 48' 28.4"<br>E20° 37' 02.0" | De Hoop 202, west-facing escarpment, gulley exposure of Lower Beaufort Group with laterally-persistent pedocrete nodules. |
| **544** | S32° 48' 26.5"<br>E20° 37' 16.2" | De Hoop 202, east-facing hillslope exposure of Lower Beaufort mudrocks, sand-infilled mudcracks, close to escarpment edge. |
| **545** | S32° 48' 34.2"<br>E20° 37' 14.3" | De Hoop 202, extensive gullied hillslope exposures of Lower Beaufort Group mudrocks. Ripple cross-laminated siltstones. Sandstone float blocks with "bar code" heavy mineral laminations. |
| **546** | S32° 48' 45.1"<br>E20° 37' 09.6" | De Hoop 202, good steep exposure of Lower Beaufort Group. Mudclast basal breccia beneath channel sandstones. |
| **547** | S32° 48' 46.9"<br>E20° 37' 22.5" | De Hoop 202, channel sandstone float block containing moulds of reworked woody material. Blocks of ferruginised basal channel conglomerate with reworked palaeocalcrete clasts. Extensive exposures of Lower Beaufort Group. |
| **548** | S32° 48' 47.8"<br>E20° 37' 23.7" | De Hoop 202, thick hillslope exposure of Lower Beaufort Group mudrocks capped by yellowish-weathering, crumbly channel sandstone with erosive base, ferruginous coarse basal breccias, heavy mineral lamination towards the top. Laterally extensive pedogenic calcrete horizons within mudrocks. |
| **549** | S32° 48' 38.8"<br>E20° 37' 19.0" | De Hoop 202, stream bed and waterfall exposure of fine-grained, well-cemented and -jointed greyish channel sandstone. Horizontally-laminated, flaggy sandstones towards top, with current rippled upper surface. |
| **550** | S32° 51' 28.3"<br>E20° 42' 39.6" | Rheebokke Fontein 209, gentle hilly exposures of Lower Beaufort Group purple-brown and blue-green mudrocks. Extensive pedocrete nodules. |