PALAEONTOLOGICAL HERITAGE ASSESSMENT: COMBINED DESKTOP & FIELD-BASED STUDY

PROPOSED GUNSTFONTEIN WIND ENERGY FACILITY NEAR SUTHERLAND, KAROO HOOGLAND LOCAL MUNICIPALITY, NORTHERN CAPE PROVINCE

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EXECUTIVE SUMMARY

Gunstfontein Wind Farm (Pty) Ltd is proposing to develop a wind energy facility (WEF) with an installed capacity of up to 200 MW and all associated infrastructure on a site comprising the following farms located approximately 20 km south of Sutherland within the Karoo Hoogland Local Municipality, Namakwa District Municipality, Northern Cape: Portion 1 of the farm Gunstfontein 131; Remainder of the farm Gunstfontein 131; Farm Boschmans Hoek 177, and Remainder of the farm Wolven Hoek 182. The actual WEF development being assessed under this FEIR will be restricted to Remainder of the farm Gunstfontein 131.

The fluvial Abrahamskraal Formation (Lower Beaufort Group, Karoo Supergroup) that underlies the Gunstfontein WEF 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 region between Matjiesfontein and Sutherland where sediments belonging only to the lower part of the thick Abrahamskraal Formation succession (Moordenaars Member and underlying rock units) are represented. Bedrock exposure levels in the study area are generally poor, especially as far as potentially fossiliferous mudrocks are concerned, due to the pervasive cover by superficial sediments (colluvium, alluvium, soils) and vegetation. Nevertheless, a sufficiently large outcrop area of Abrahamskraal Formation sediments - exposed in rocky ridges, streambanks, borrow pits as well as steep hillslopes and erosion gullies along the Roggeveld Escarpment and on the Roggeveld Plateau - has been examined during the present field study to infer that macroscopic fossil remains of any sort are rarely found here. Exceptions include low-diversity trace fossil assemblages (small-scale invertebrate burrows, plant stem casts) and fragmentary plant fossil remains. The latter include horsetail ferns (arthrophytes), *Glossopteris* leaf impressions as well as concentrations of woody plant material preserved as moulds and blocks of silicified wood. The plant fossils are often associated with ferruginised channel sandstones and lag conglomerates (*koffieklip*). Cherty petrified wood clasts are extensively reworked into surface gravels. The only vertebrate fossil remains recorded within the study area comprise very sparse reworked bones and disarticulated fish scales preserved within ferruginised channel lag conglomerates. Early Jurassic dolerite intrusions and Late Cretaceous igneous rocks of the Sutherland Suite are not mapped within the study area but are known to occur a few kilometres to the north.

It is concluded on the basis of this combined desktop analysis and field-based palaeontological study that the Lower Beaufort Group bedrocks in the Gunstfontein WEF 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 Gunstfontein WEF is unlikely to entail significant impacts on local fossil heritage resources. Due to the general scarcity of well-preserved 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 Gunstfontein WEF 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 both to the core WEF infrastructure on the Roggeveld Plateau (wind turbines, access roads, underground cables, on-site substation *etc*) as well as the associated power line that will run down the Roggeveld Escarpment to the south (which will be the subject of a separate assessment report). There is no preference on palaeontological heritage grounds for any particular infrastructure layout or substation site among the options under consideration.

Five uranium ore occurrences have been previously mapped on Gunstfontein 131 (Cole & Vorster 1999). These may well be associated with fossil plant material which often played a key role in the precipitation of uranium minerals. It is proposed that these five uranium ore occurrences (detailed in this report) as well as an additional site on the western margins of Gunstfontein 131 (32°33'16.97"S, 20°38'0.73"E) that features concentrations of woody plant fossils and *koffieklip* (ferruginised channel sandstone) be safeguarded within 30 m-radius buffer zones.

Given the low impact significance of the proposed Gunstfontein WEF 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 logs 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 professional palaeontologist. These mitigation recommendations should be incorporated into the Environmental Management Programme (EMPr) for the Gunstfontein WEF 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).

Recent desktop and field-based assessments for several alternative energy projects in the Roggeveld Plateau – Klein Roggeveldberge region to the south of Sutherland – including the Jakhals Valley PV facility (Almond 2011), Kareebosch Wind Farm (Almond 2014), Karusa Wind Farm (Almond 2015b) and Soetwater Wind Farm (Almond 2015c) – indicate that scientifically significant palaeontological sites in the broader region (notably well-preserved fossil vertebrates) are very sparsely distributed. Cumulative impacts on palaeontological heritage resources of these projects in conjunction with the proposed Gunstfontein WEF are inferred to be low.

1. INTRODUCTION & BRIEF

1.1. Project outline

The company Gunstfontein Wind Farm (Pty) Ltd is proposing to develop a wind energy facility (WEF) with an installed capacity of up to 200 MW and all associated infrastructure on a site comprising the following farms located approximately 20 km south of Sutherland within the Karoo Hoogland Local Municipality, Namakwa District Municipality, Northern Cape (Fig1 & 2):

- Portion 1 of the farm Gunstfontein 131;
- Remainder of the farm Gunstfontein 131;
- Farm Boschmans Hoek 177, and
- Remainder of the farm Wolven Hoek 182.

A previous application by Networx Eolos Renewables (Pty) Ltd for the establishment of the Gunsfontein Wind Energy Facility with a total generating capacity of 280 MW was submitted in August 2013 (DEA Ref No.:14/12/16/3/3/2/395) and a Scoping Report was submitted and subsequently accepted by the DEA in October 2014. Due to a change in the Applicant as well as the project scope, the application was withdrawn on 17 August 2015. A new application was then lodged with the DEA under the NEMA EIA Regulations, 2014 for the proposed Gunstfontein Wind Energy facility with a contracted capacity of up to 200 MW, which represents an approximate 30% reduction from the previously proposed 280 MW project. This latest application was assigned DEA Ref No.: 14/12/16/3/3/2/826, and a Scoping Report was submitted and subsequently accepted by the DEA in November 2015. The wind energy facility will be developed in a single phase, with the number of wind turbines depending on the turbine model finally selected.

The main infrastructural components of the proposed wind energy facility include the following:

- Up to 100 wind turbines, each of up to 4 MW generation capacity, with WEF capacity limited to 200MW;
- Permanent concrete foundations to support the turbines, and crane pad/laydown areas;
- Cabling between the turbines, to be laid underground where practical and generally alongside the internal access roads, to connect to an on-site substation;
- An on-site substation to facilitate the connection between the wind energy facility and the electricity grid;

- Internal access roads to each turbine linking the wind turbines and other infrastructure on the site;
- Buildings and dedicated areas for workshops, control systems, maintenance and storage with parking areas where required; and
- Temporary construction compound and temporary site offices.

The wind energy facility is to be constructed within an area of approximately 12 000 ha, and together with the associated infrastructure listed above will constitute a development footprint of less than 1% of the total site. The optimal position for each turbine will be determined using specialist software and the turbines will be appropriately spaced to optimise the energy generating potential of the wind resource, taking into consideration any environmental sensitivity which might be identified through the EIA process. Two layout alternatives were considered, the one consisting of fewer larger turbines, and other of more smaller turbines. In addition two alternative substation positions were evaluated. No preference on palaeontological heritage grounds was found to exist amongst these alternatives.

The Gunstfontein WEF study area 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 WEF 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 WEF are unlikely to involve further adverse impacts on local palaeontological heritage.

The present combined desktop and field-based palaeontological heritage assessment of the Gunstfontein WEF study area has been commissioned as part of the Environmental Impact Assessment (EIA) 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 present combined desktop and field-based palaeontological heritage report contributes to the EIA for the proposed Gunstfontein Wind Energy Facility and falls under the South African Heritage Resources Act (Act No. 25 of 1999). It will also inform the Environmental Management Programme (EMPr) 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 ("mapable") 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 Gunstfontein WEF 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 (principally Roggeveld 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 at or to the south of Sutherland, including a golf course at Sutherland (Almond 2005), the Eskom Gamma – Omega 765 kV transmission line running across the Moordenaars Karoo (Almond 2010a) and several alternative energy facilities (Almond 2010b, 2010c, 2011, 2014, 2015a, 2015b, 2015c). These last notably include the proposed solar energy facility on Jakhals Valley (RE/99) just to the north of Gunstfontein 131 (Almond 2011) as well as the Kareebosch, Karusa and Soetwater WEFs on the southern border of the Gunstfontein study area (Almond 2015c).

4. A three-day palaeontological field assessment of the Gunstfontein WEF study area (November 2015) by the author and one assistant;

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 geological and palaeontological localities mentioned in the text are provided in the Appendix.

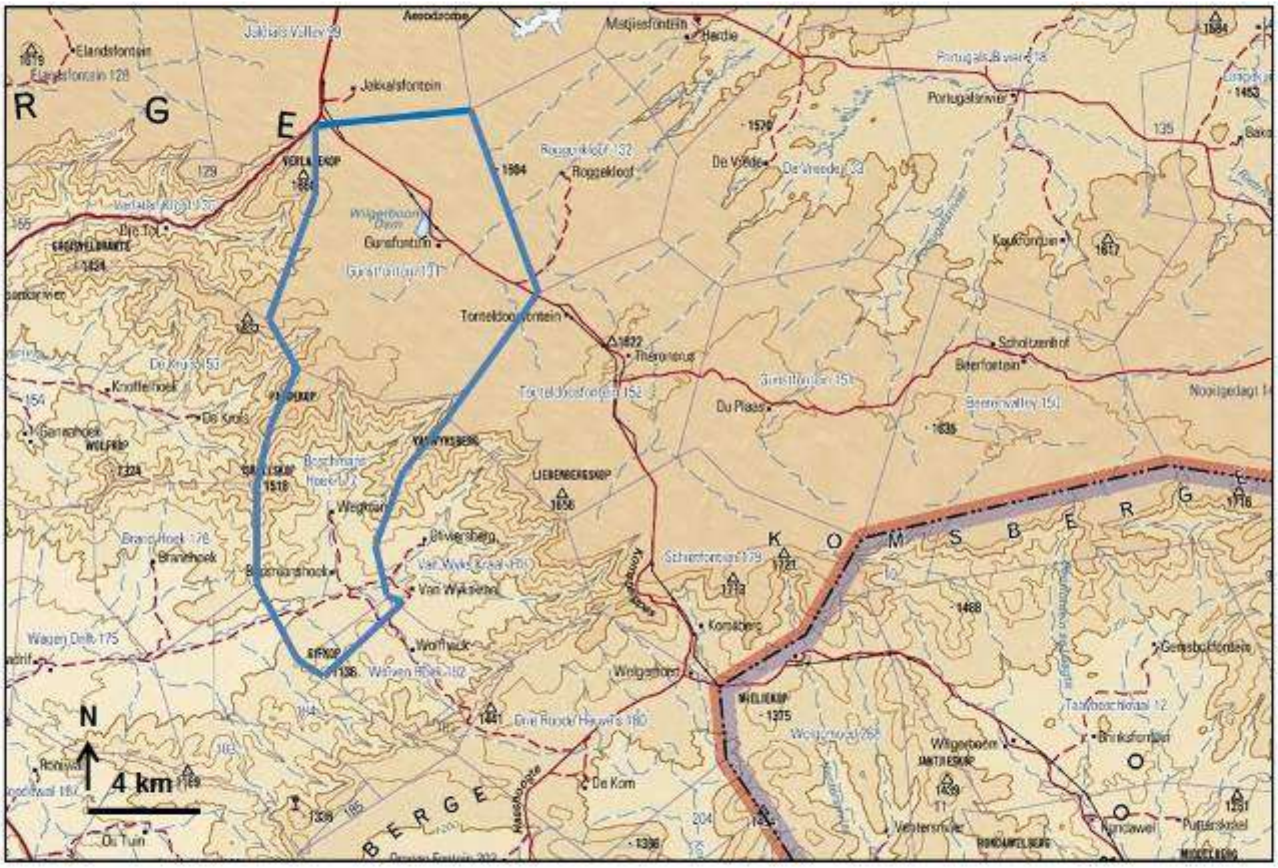

Figure 1. Extract from 1: 250 000 topographical sheet 3220 Sutherland showing the location of the proposed Gunstfontein WEF study area (blue polygon), located *c.* 20 km south of Sutherland, Northern Cape. The study area spans the Roggeveld Escarpment just to the east of the R354 Matjiesfontein to Sutherland tar road (Verlatekloof Pass) and is traversed in the north by the gravel road to the Komsberg Pass (Base map courtesy of the Chief Directorate of Surveys and Mapping, Mowbray).

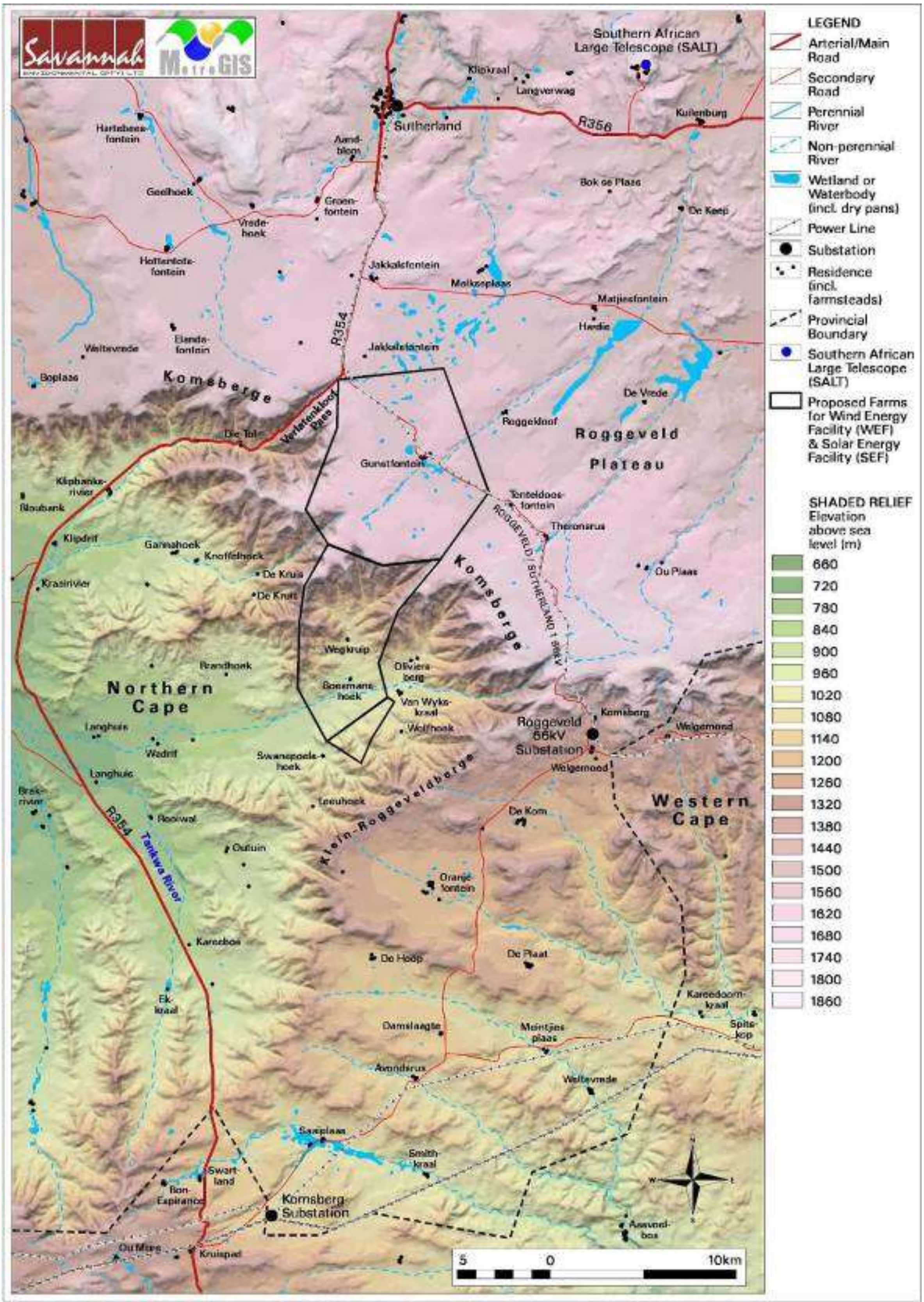

Figure 2. Map showing the topographical context of the study area (black polygon) for the proposed Gunstfontein WEF study area spanning the Roggeveld Escarpment to the south of Sutherland, Northern Cape (Image supplied by Savannah Environmental (Pty) Ltd).

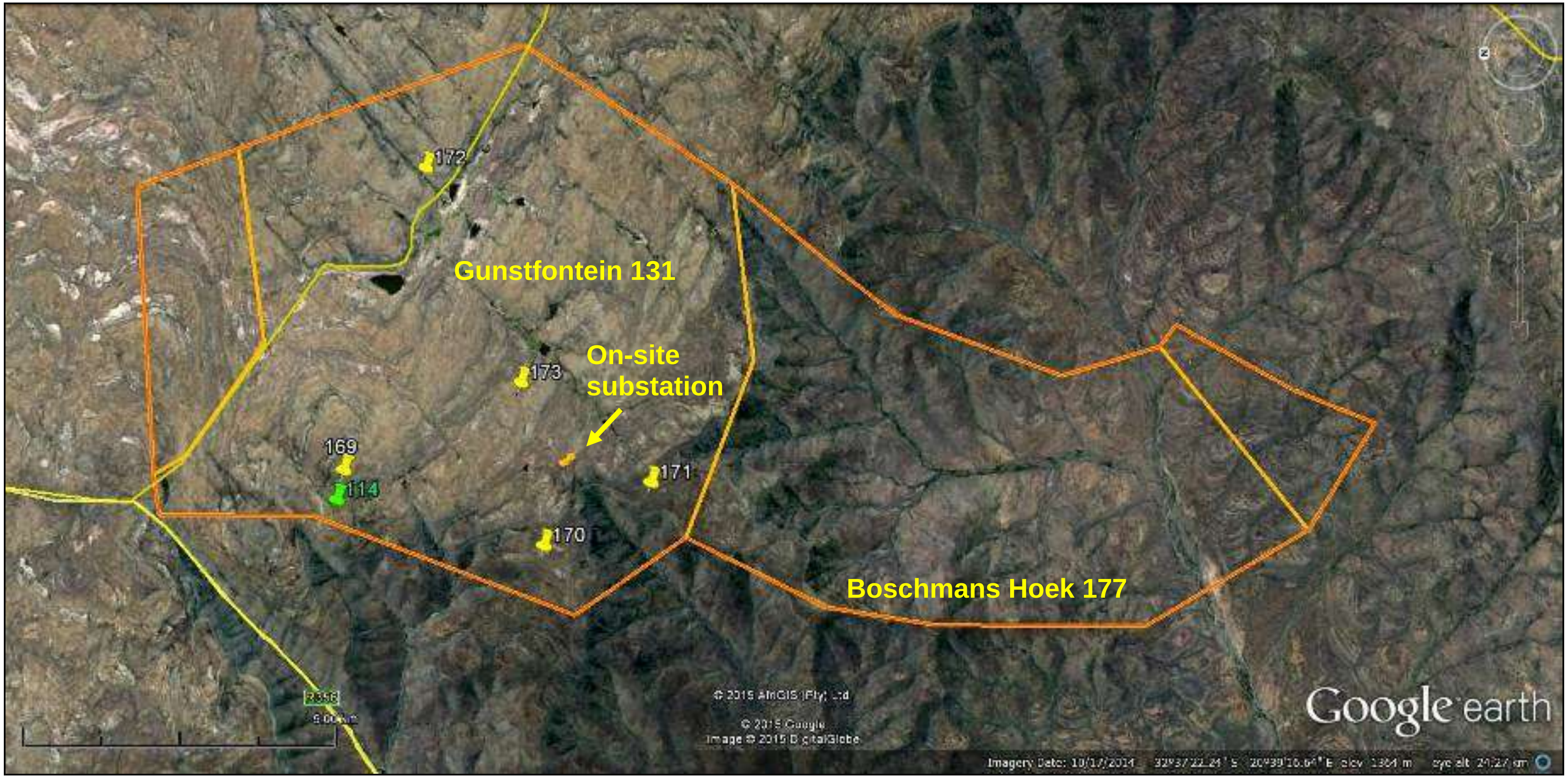

Figure 3. Google earth© satellite image of the proposed Gunstfontein WEF study area (orange polygon) spanning the Roggeveld Escarpment c. 20 km to the south of Sutherland, Northern Cape. The WEF itself is restricted to within Gunstfontein RE/131. Note North is towards the left hand side of the image. Yellow tacks indicate mapped uranium anomalies (169-173) while the green tack (114) indicates plant fossils associated with *koffieklip*.

2. GEOLOGICAL BACKGROUND

The main WEF project area on Farm Gunstfontein RE/131 comprises flat-lying to gently-hilly and rocky-ridged terrain on the Roggeveld Plateau that extends along the edge of the Roggeveld Escarpment some 20 km south of Sutherland, Northern Cape (Figs. 2 & 3 and 5 to 10). The R356 Verlatekloof Pass tar road between Matjiesfontein and Sutherland runs just to the west while the dust road to the Komsberg Pass traverses the northern portion of the study area. Elevations are highest close to the escarpment edge (*c*. 1640 - 1600 m amsl) and the ground slopes gradually down to around *c*. 1560 m amsl in the northeast. The prominent *koppie* Verlatekop (1660 m amsl) lies just outside the western border of the area. The Roggeveld sandstone plateau in this area shows low relief and is transected by several subparallel, SW-NE trending drainage lines related to a set of major bedrock fractures in the region (Fig. 3). These form part of the radial and tangential fracture network associated with crustal doming caused by late Cretaceous Salpeterkop igneous activity. The fractures may be intruded at depth by lamprophyre and breccia dykes of the Sutherland Suite (Cole & Vorster 1999, p. 9). The incised drainage lines are associated with intermittent-flowing streams and numerous pans or farm dams. A zone of pans / dams (*e.g.* the Wilgeboom Dam) also runs along the southwestern side of the Komsberg Pass road.

The adjacent steep, southwest-facing sector of the Roggeveldberg Escarpment on Boschmans Hoek 177 - part of the Great Escarpment of South Africa – spans an elevation of *c*. 900 m amsl at the base (near Boesmanshoek farmstead) up to 1630 m along the escarpment edge. It is dissected by several dendritic stream gullies, including Boesmanshoek and Brandkloof, which are tributaries of the extensive Tanqua River drainage system. Numerous subhorizontal *kranse* or step-like ridges reflect the successive, prominent-weathering channel sandstone horizons exposed here. Away from the numerous drainage lines and sandstone ridges, bedrock exposure within the study area - notably that of the recessive-weathering mudrock facies - is generally very low. This is due to extensive cover by sandy alluvial and gravelly colluvial deposits as well as karroid *bossieveld* vegetation (Roggeveld Shale Renosterveld and Tanqua Escarpment Shrubland). The WEF development footprint does not extend onto Boschmans Hoek 177.

The geology of the Sutherland region is outlined on the 1: 250 000 scale geology sheet 3220 Sutherland (Theron 1983) (Fig. 4) 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) (Fig. 13). 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 (Fig. 4). In the Sutherland area to the north of the Roggeveld 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. No dolerite or younger (Cretaceous) intrusions are mapped within the present study region along the edge of the Roggeveld Escarpment, however; major dolerite bodies intrude the Lower Beaufort Group over 5 km to the north. The Palaeozoic bedrocks in the study area are 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 sandy to gravelly soils. These geologically youthful sediments are generally of low palaeontological sensitivity.

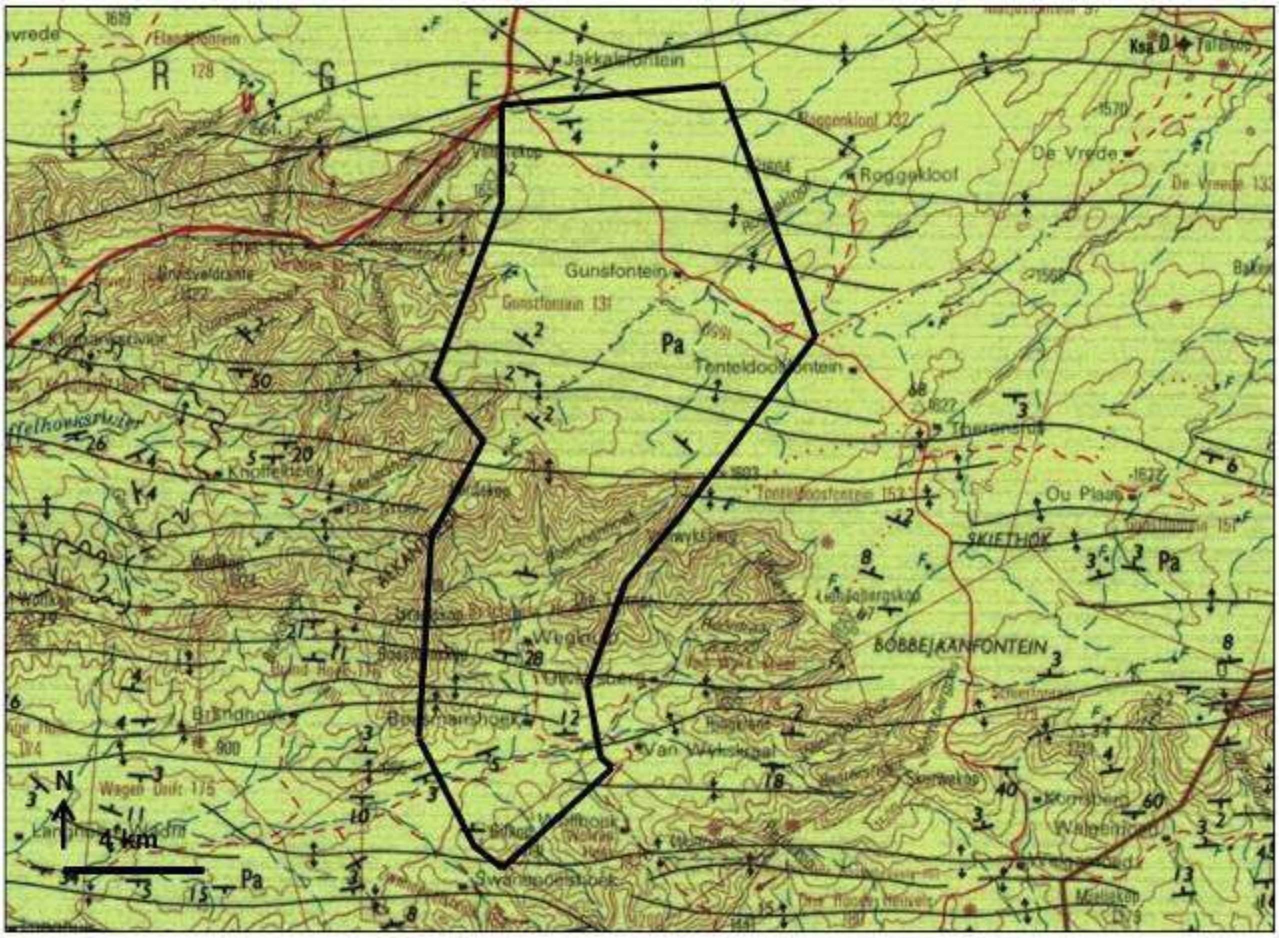

Figure 4. Extract from the 1: 250 000 scale geology sheet 3220 Sutherland (Council for Geoscience, Pretoria, 1983) showing the location of the proposed Gunstfontein WEF study area, *c*. 20 km south of Sutherland, Northern Cape Province (black polygon). The study area is entirely underlain by Middle Permian sediments of the Abrahamskraal Formation, Lower Beaufort Group (Pa, pale green). Note numerous west-east trending fold axes (black lines) within the northern and southern parts of the study area as well as the apparent absence of dolerite intrusions here.

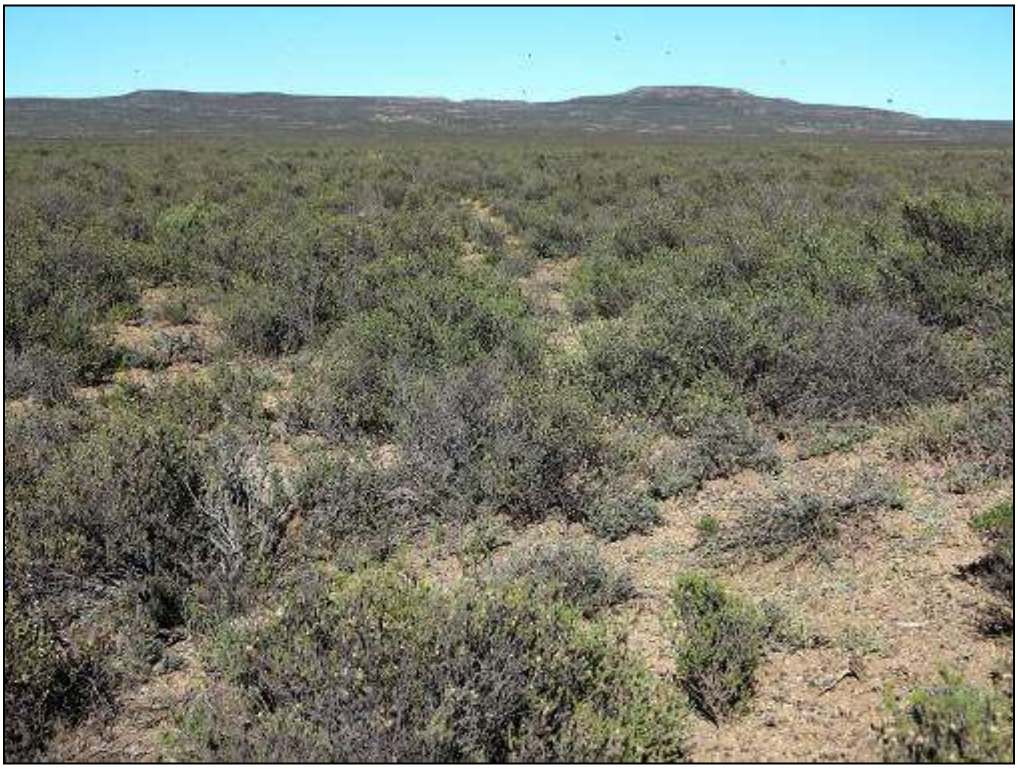

Figure 5. Low-relief terrain on the Roggeveld Plateau in the northern portion of Gunstfontein 131 looking SW towards Verlatekop (Taken from Loc. 104).

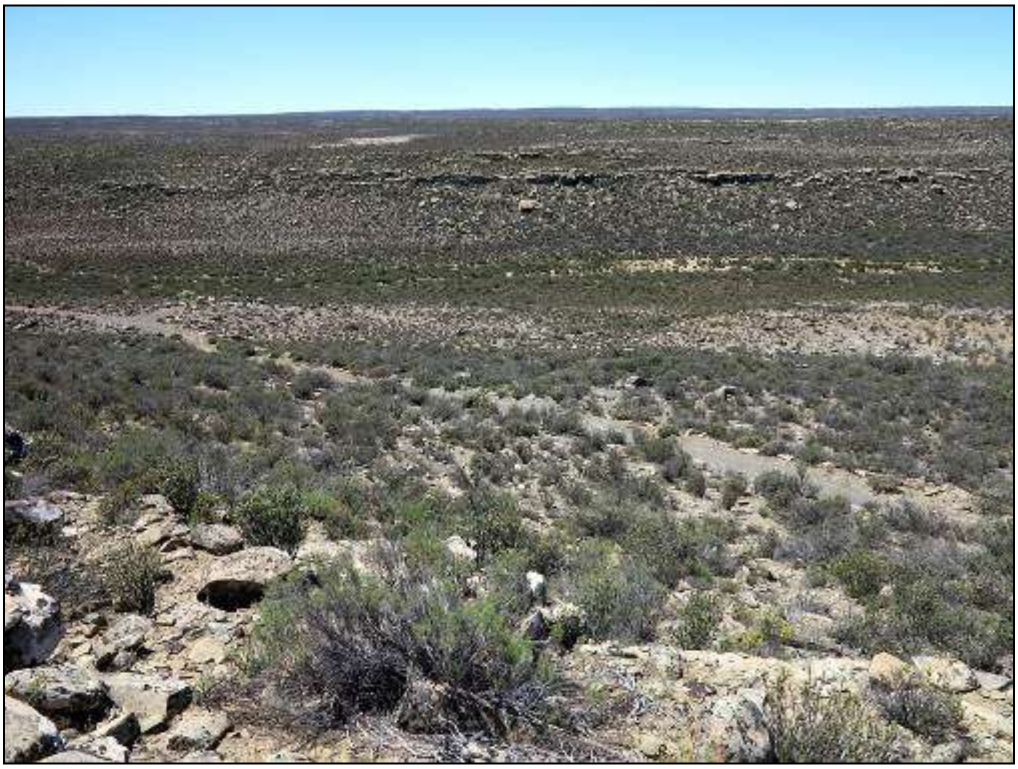

Figure 6. One of several SW-NE trending drainage lines on Gunstfontein that follow major fracture lines in the Lower Beaufort Group bedrocks (Loc. 091) (See also satellite image Fig. 3).

Figure 7. Rocky terrain towards the edge of the Roggeveld Plateau on Gunstfontein 131 showing downwasted sandstone rubble overlying flat-lying channel sandstones.

Figure 8. View towards the escarpment edge in the southwestern portion of Gunstfontein 131. Note the largely flat horizon towards the southeast.

Figure 9. View down the steep Roggeveld Escarpment on the western edge of Gunstfontein 131. The closely-spaced tabular sandstones towards the top of the escarpment belong to the Moordenaars Member of the Abrahamskraal Formation.

Figure 10. View north-westwards towards the Roggeveld Escarpment from the low-lying, southern portion of the study area (Boschmans Hoek 177). Note the scarcity of mudrock exposure between the prominent-weathering channel sandstones.

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 (<1.5m), 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 (*cf* Wilson *et al.* 2014). 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*. 2.5km) 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 & Vorster 1999, McCarthy & Rubidge 2005, Johnson *et al*., 2006, Almond 2010a, Day 2013a, Day & Rubidge 2014, Wilson *et al.* 2014). 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 reworked volcanic ash (tuffs, tuffites). A wide range of sedimentological and palaeontological observations point to deposition 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. 4). 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, Day & Rubidge 2014). 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. 12). Several of these members have since been mapped in the Sutherland area by Cole and Vorster (1999) (Fig. 13). A slightly modified scheme is presented by Day & Rubidge (2014) (Fig. 11).

According to the 1: 250 000 metallogenic map of Cole and Vorster (1999) the majority of the Gunstfontein WEF development area on the Roggeveld Plateau is underlain by the major channel sandstones of the **Moordenaars Member**. These rocks were previously included with the Verlatenkloof Member of Wadley and Hoffmann (1986), named after the Verlatenkloof gorge just to the west of the present study area. The package of closely-spaced, tabular channel sandstone bodies exposed on the slopes of the Roggeveld Escarpment in the southern portion of the study area probably belongs to the Koornplaats Member. The thin mudrock-dominated interval between these two sandstone packages - visible, for example, in the escarpment zone towards the top of the Komsberg Pass – belongs to the **Wilgerbos Member** (renamed the **Swaerskraal Member** by Day & Rubidge 2014) (Fig. 11). It is possible that the underlying **Leeuvlei Member** is represented along the valley floor to the south. These stratigraphic assignments remain tentative at present, however. Very brief descriptions of the various Abrahamskraal Formation subunits are given by Loock *et al.* (1994). The interested reader should refer to earlier works by Le Roux (1985) and Jordaan (1990) as well as informative recent papers by Day and Rubidge (2014; see their fig. 3, Section 6 for the Abrahamskraal Formation at Verlatenkloof) and Wilson *et al.* (2014) for detailed stratigraphic and sedimentological data on the Abrahamskraal Formation that is beyond the scope of the present palaeontological heritage study.

According to Loock *et al.* (1995) the **Koornplaats Member** of the Abrahamskraal Formation. is characterized by:

- Yellow-weathering sheet-like channel sandstone packages with heavy mineral laminations (up to 2 cm thick) towards the top and basal lag breccio-conglomerates. A prominent, laterally-persistent package of five yellowish fine-grained sandstone units marks the upper part of the member in the Roggeveld – Nuweveld Escarpment area. The sandstones are associated with fossil tetrapod material and reworked plant material, including silicified wood (rarely with exotic extra-basinal pebbles) and *Vertebraria* glossopterid roots. Uranium mineralization may be associated with transported plant material.

- Grey and maroon overbank mudrocks with calcrete horizons, tetrapod fossils.

The **Wilgerbos Member** comprises some 120 m of recessive-weathering, grey-green to purple-brown mudrocks with subordinate thin sandstones. Extensive playa lake deposits have been recognized within this unit (Loock *et al.* 1994). The revised stratigraphic scheme of Day and Rubidge (2014) refer to the mudrock interval between the Koornplaats and Moordenaars Members as the **Swaerskraal Member** (Fig. 11).

The **Moordenaars Member** is a 300-350 m – thick, sandstone-rich succession of continental fluvial rocks characterized by stacked sheet sandstones with intervening, more recessive-weathering mudrocks (Stear 1980, Le Roux 1985, Loock *et al.* 1994, Cole & Vorster 1999). The prominent, laterally-persistent sandstone ledges generate a distinctive terraced topography on hill slopes in the Sutherland area (Figs. 9 & 10). The sheet sandstones are generally pale-weathering (enhanced by epilithic lichens), fine-grained, and structured by horizontal lamination (flaggy, with primary current lineation) or tabular to trough cross-bedding (Figs. 14 & 22). The tabular-laminated units often contain numerous dark, very thin, laterally persistent laminae composed of heavy minerals that suggest density sorting during high energy sheet-flow conditions. The lower contacts of the channel sandstones are erosive, with lenticular basal breccias that may infill small-scale erosive gullies. The breccias, which may also occur within the body of the channel sandstone unit, are composed of reworked mudflake intraclasts, small rounded to irregular calcrete glaebules or nodules as well as occasional rolled vertebrate bones, teeth and local concentrations of plant debris. Some of the originally more organic-rich breccias are associated with secondary iron / manganese-rich (‘*koffieklip*”) and uranium ore mineralization (Cole & Vorster 1999). Five uranium anomalies have been mapped on the farm Gunstfontein 131 (numbered red symbols in map Fig. 13, yellow tack symbols in Fig. 3) and co-ordinates for these are given as follows in the sheet explanation by Cole and Vorster (1999):

Anomaly 169 (Gunstfontein 131):	32 33 20 S, 20 38 20 E
Anomaly 170 (Gunstfontein 131):	32 35 09 S, 20 37 29 E
Anomaly 171 (Gunstfontein 131):	32 36 07 S, 20 38 08 E
Anomaly 172 (Gunstfontein 131):	32 34 02 S, 20 41 40 E
Anomaly 173 (Gunstfontein 131):	32 34 56 S, 20 42 21 E

It is noted that, according to the Mineral and Petroleum Resources Development Act, 2002, the company proposing the wind farm development on Gunsfontein 131 is required to submit a report from the Council for Geoscience on the mineral potential of the development area to the Department of Mineral Resources (Dr Doug Cole, Council for Geoscience, Bellville, pers. comm. 2015).

According to the 1: 250 000 Sutherland sheet the Lower Beaufort Group rocks have been gently folded along east-west or WNW-ESE fold axes (Fig. 4). In the study area the beds are fairly flat-lying and levels of tectonic deformation are generally low. A series of southwards down-stepping monoclinal folds brings the Moordenaars Member beds down to lower elevations in the escarpment zone to the east of the Komberg Pass and a comparable fold zone appears to be exposed in the escarpment south of Gunsfontein 131 (*e.g.* slopes of Die Toring).

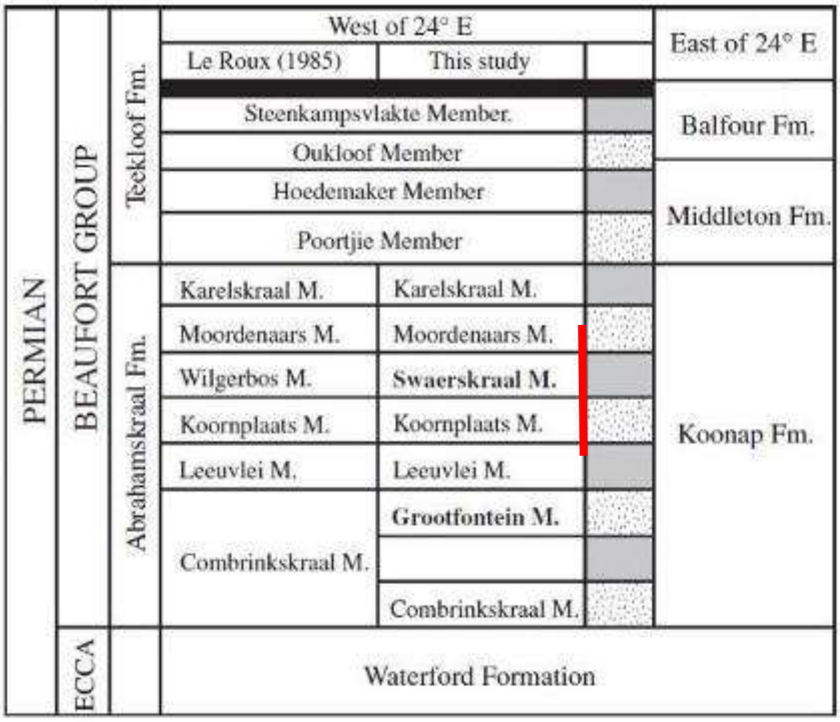

Figure 11. Revised subdivision of the Abrahamskraal Formation of Day and Rubidge (2014). The red bar indicated members that are probably represented within the Gunstfontein WEF study area.

The Abrahamskraal Formation in the Roggeveld study region is a succession of continental fluvial rocks characterized by numerous lenticular to sheet-like sandstones with intervening, more recessive-weathering mudrocks (Stear 1980, Le Roux 1985, Loock *et al.* 1994, Cole & Vorster 1999, Wilson *et al.* 2014). 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 with several partially superimposed, cross-cutting lenticular subunits, often demarcated at the base by thin mudrocks and / or basal breccio-conglomerates. The prominent, laterally-persistent sandstone ledges generate a distinctive stepped or terraced topography on hill slopes in the area (Fig. 14). 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) (Fig. 17), or more rarely tabular to trough cross-bedding. Extensive sandstone bed tops are exposed locally within the study area and occasionally show interesting weathering features such as tepee-shaped pop-ups generated by weathering-induced bedrock expansion (Fig. 19). Greyish hues of some freshly broken sandstone surfaces suggest an "impure" clay-rich mineralogy (*i.e.* wackes). Current ripple cross-lamination is common towards the tops of the sandstone beds which may also feature large-scale low-angle cross-lamination. The lower contacts of the channel sandstones are erosive on a small scale (Fig. 15), and often associated with lenticular basal breccias or breccio-conglomerates that may infill small-scale erosive gullies (Figs. 16, 20 & 21). The breccias may also occur within the body of the channel sandstone unit and are almost entirely composed of reworked mudflake intraclasts and / or calcrete glaebules (Fig. 22). They are generally impregnated by secondary ferruginous and / or manganese-rich cements, imparting a dark rusty-brow hue (*koffieklip*) and may contain reworked fossil bone and plant remains (Fig. 39). Large, oblate, meter-scale diagenetic concretions embedded within the channel sandstones are fairly common and also have a dark brown color (Fig. 18). Heterolithic, thinly-interbedded sandstone and mudrock packages associated with some channel sandstones may represent delta-like levee deposits.

Although general mudrock exposure levels within the Gunstfontein WEF study area are low to very low, there are in fact several small exposures of grey-green and purple-brown siltstone facies available along stream banks and steeper hillslopes, both along the Klein-Roggeveld Escarpment as well as on the Roggeveld Plateau itself (Figs. 23 to 27). The most extensive exposures of overbank mudrocks are seen in the low SW-facing scarp on the north-eastern side of the Komsberg Pass dust road, for example in the vicinity of the Gunstfontein homestead (Figs. 23). Lenses of ferruginous carbonate and pale grey pedogenic calcrete horizons are fairly common within the mudrock facies. Pinkish, lenticular to sphaeroidal silica pseudomorphs after gypsum ("desert roses") are common at certain horizons within grey-green mudrocks low down within the Abrahamskraal Formation succession on Boschmans Hoek 177, indicating highly arid climatic phases on the Middle Permian floodplain (Fig. 26).

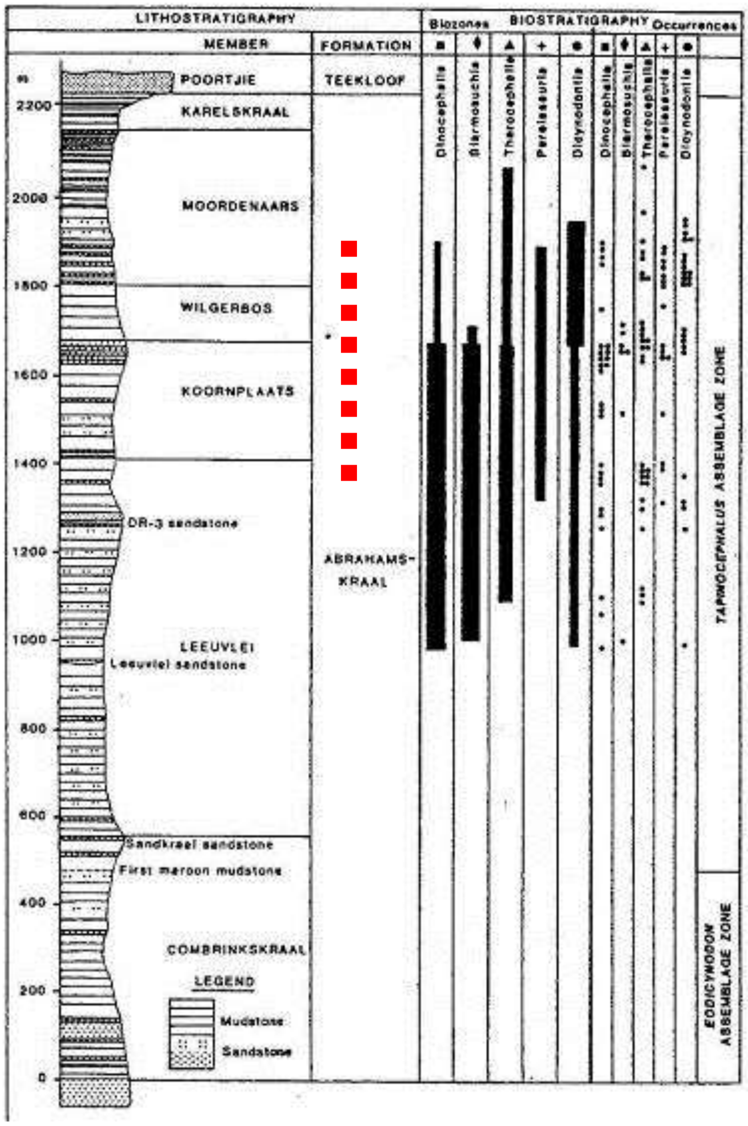

Figure 12. Chart showing the subdivision of the Abrahamskraal Formation in the western Karoo region with stratigraphic distribution of the major fossil vertebrate groups (Loock *et al*. 1994). The Gunsfontein WEF project area is largely underlain by sediments of the Mordenaars Member but lower stratigraphic intervals are represented within the Roggeveld Escarpment zone to the south (red dotted line).

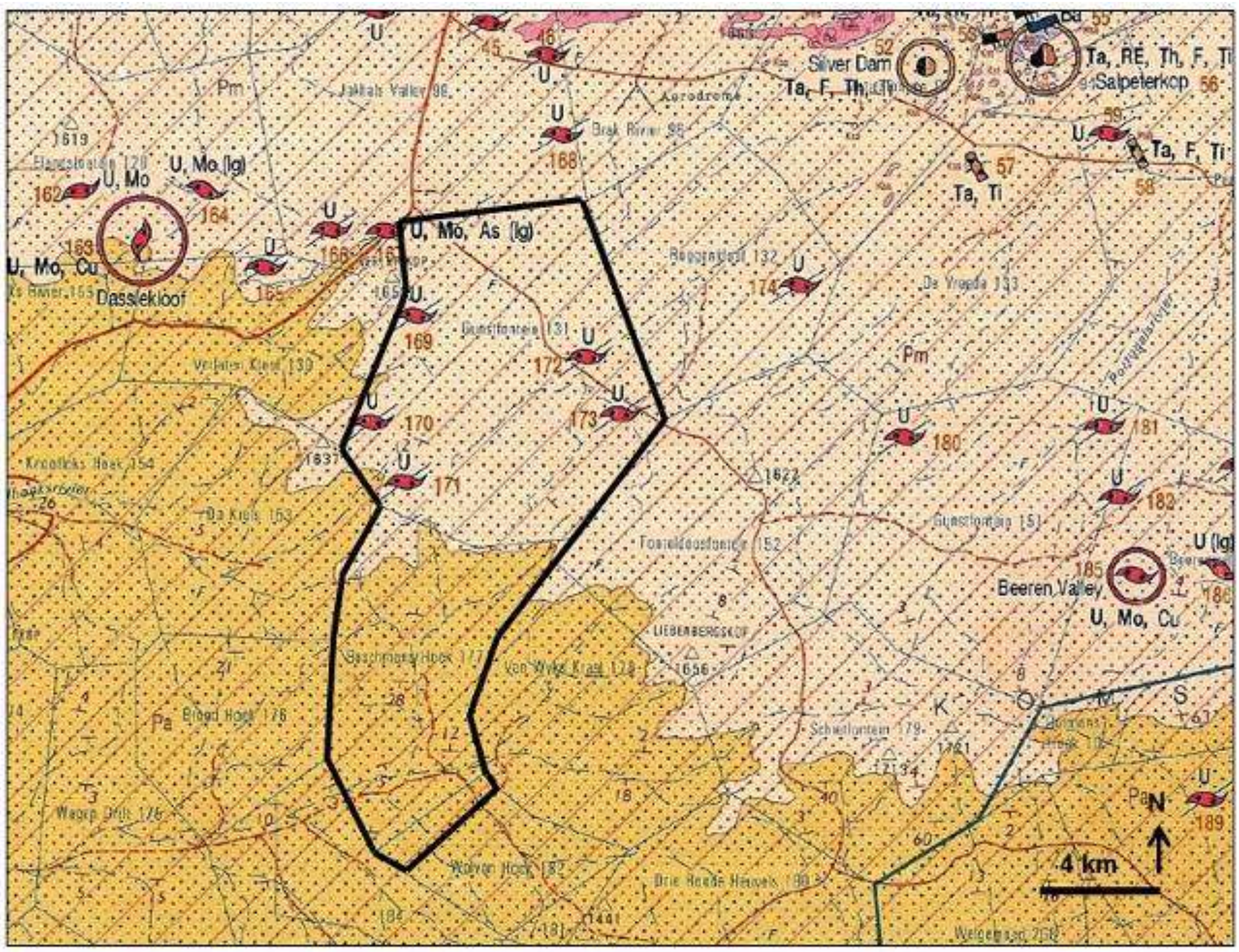

Figure 13. Extract from the 1: 250 000 scale metallogenic sheet 3220 Sutherland (Council for Geoscience, Pretoria, 1999) showing the location of the proposed Gunstfontein WEF study area, *c*. 20 km south of Sutherland, Northern Cape Province (black polygon). The core project area on the Roggeveld Plateau is underlain by the sandstone-rich package of the Moordenaars Member of the Abrahamskraal Formation (pale orange). The Roggeveld Escarpment zone to the south is built of underlying members of the Abrahamskraal Formation (dark orange). The numbered red symbols marked U refer to recorded uranium anomalies that may be associated with fossilised plant material (See Cole & Vorster 1999).

Figure 14. Well-jointed, tabular channel sandstone with blocky scree fans at the edge of the Roggeveld Escarpment near Perdekop, Boschmans Hoek 177 (Loc. 111).

Figure 15. Erosive-based channel sandstone overlying purple-brown overbank mudrocks, central sector of Rooikrans Pass on Boschmans Hoek 177.

Figure 16. Heterolithic channel sandstone package showing possible loading and / or dewatering features and interbeds of purplish-brown mudflake breccia (Hammer = 30 cm) (Loc. 103).

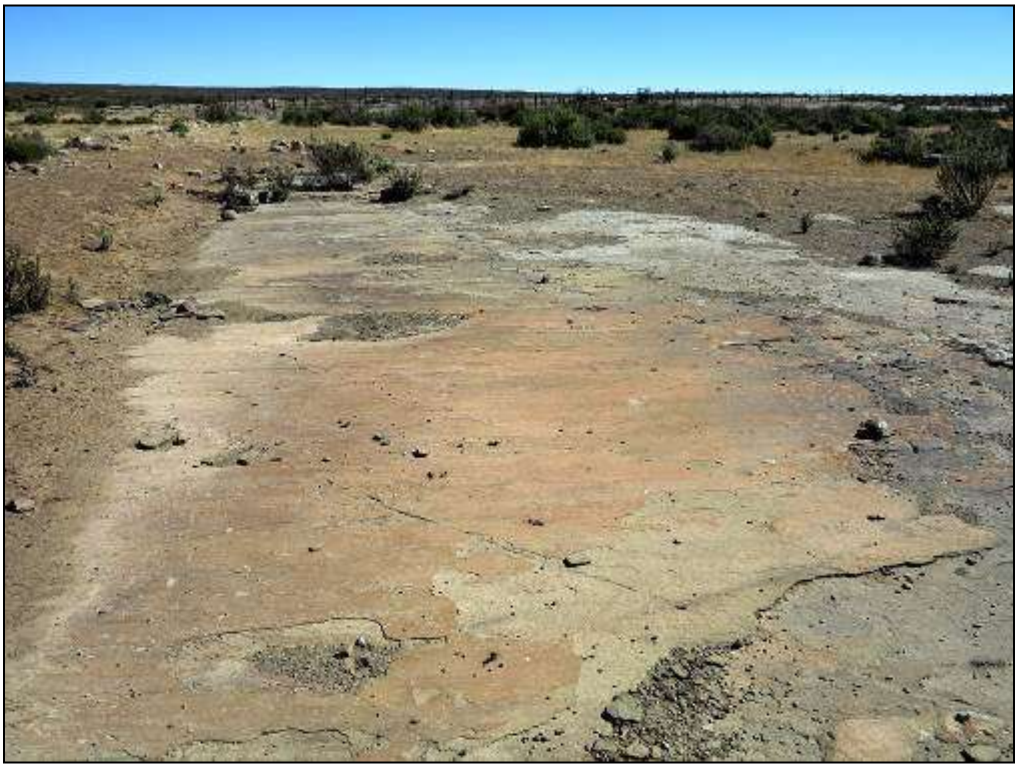

Figure 17. Primary current lineation within a sheet-like channel sandstone, close to farmstead on Gunstfontein 131 (Loc. 101).

Figure 18. Large, oblate, rusty-brown ferruginous carbonate concretions within the current-rippled top of a channel sandstone, Gunstfontein 131 (Loc. 101).

Figure 19. Tepee-shaped pop-up structure at the top of a channel sandstone body reflecting horizontal stresses generated by rock expansion due to chemical weathering, Gunstfontein 131 (Loc. 098).

Figure 20. Large lenticular body of ferruginous, carbonate-cemented sandstone and calcrete breccia (*koffieklip*) formed at the base of a channel sandstone in association with locally abundant plant material, Gunstfontein 131 (See Fig. 45) (Hammer = 30 cm) (Loc. 114).

Figure 21. Well-developed, ferruginised basal channel breccia, western portion of Gunstfontein 131 (Hammer = 30 cm) (Loc. 115).

Figure 22. Detail of channel breccia facies seen in the previous figure showing reworked, rounded to irregular calcrete nodules (pale grey) in a ferruginous carbonate-cemented sandstone matrix (Scale in cm) (Loc. 115).

Figure 23. Fresh exposures of overbank mudrocks and crevasse splay sandstones of the Moordenaars Member in a roadside quarry near the farmstead on Gunstfontein 131 (Loc. 102).

Figure 24. Gentle hillslope exposure of overbank mudrocks with calcrete pedocrete horizons near the escarpment edge, Gunstfontein 131 (Loc. 113).

Figure. 25. Interbedded thin sandstones and mudrocks exposed in the banks of a stream gulley towards the base of the Roggeveld Escarpment, Boschmans Hoek 177.

Figure 26. ***In situ*** **and weathered-out gypsum desert roses - now converted to pinkish siliceous pseudomorphs – within grey-green overbank mudrocks towards the base of the Roggeveld Escarpment, Boschmans Hoek 177 (Scale in cm) (Loc. 108).**

Figure 27. Rare hillslope exposure of grey-green and purple-brown overbank mudrock facies in the Roggeveld Escarpment adjacent to the Rooikrans Pass, Boschmans Hoek 177 (Loc. 106).

2.2. Late Caenozoic Superficial Deposits

On the Roggeveld Plateau alluvial deposits, as exposed in stream-bank and erosion gulley sections, locally 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 gravel or dispersed gravel clasts. The thickest alluvium is seen along the array of SW-NE fracture-related drainage lines which are now associated with numerous pans and farm dams (Figs. 3 & 31). Sometimes the alluvium is partially calcretised with dispersed calcrete glaebules (Fig. 32); calcrete hardpans were not seen, however. Sheet sandstones of the Moordenaaars Member are often covered by thin sandy deposits with a superficial veneer of dispersed surface gravels modified by sheet wash (Figs. 28 & 29). These gravels include a high proportion of resistant-weathering lithologies such as quartz, agates and silicified wood.

Prominent-weathering sandstone *kranzes* along and above the escarpment are associated with fans and aprons of angular to well-rounded blocks and woolsack-like corestones of Beaufort Group sandstone (Figs. 14 & 30). Downwasted sandstone rubble overlies sandstone channel bodies towards and away from the escarpment edge (Fig. 7). Most of the escarpment away from stream gullies is mantled by colluvial debris and soils, so bedrock exposure here is very limited (Figs. 9 & 10). Close to and along the main drainage lines towards the base of the Roggeveld Escarpment thick deposits of coarse, cobbly to bouldery alluvial gravels are well exposed in incised stream sections (Fig. 33). The gravels, largely composed of Beaufort Group sandstones and wackes, are subangular to well-rounded, poorly-sorted, semi-consolidated, clast-supported with a gritty to fine gravel matrix. The larger clasts are boulder-sized, well-rounded, and often show well-developed imbrication. Rubbly High Level Gravels elevated up to several meters above present stream beds are encountered overlying pediments of Beaufort Group bedrocks along major water courses (Fig. 37).

Figure 28. Surface exposures of channel sandstones mantled by thin sandy soils and downwasted sandstone rubble in the northern portion of Gunstfontein 131 (LOc. 088).

Figure 29. Bare patch of *veld* on the Roggeveld Plateau, Gunstfontein 131, showing sheet wash sands and sparse surface gravels of resistant-weathering rock types (including petrified wood) (Loc. 105).

Figure 30. Subrounded colluvial sandstone boulders mantling valley slopes along a major SW-NE drainage line, Gunstfontein 131 (Loc. 091).

Figure 31. Thick, pale, sandy alluvial deposits along the floor of major drainage line, Gunstfontein 131 (Loc. 093).

Figure 32. Development of dispersed calcrete nodules within thick alluvial deposits exposed around the margins of a small farm dam, Gunstfontein 131 (Loc. 104).

Figure 33. Crudely-bedded sandy and coarse, gravelly alluvium exposed in a deeply-incised stream bank, Boschmans Hoek 177 (Hammer = 30 cm) (Loc. 107).

Figure 34. Rubbly High Level Gravels of sandstone overlying an extensive pediment surface on Boschmans Hoek 177 (close to Loc. 107).

3. PALAEONTOLOGICAL HERITAGE

In this section of the report the fossil heritage recorded within the main rock units that are represented within the Gunstfontein WEF 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 mapable 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. 35 herein) and Rubidge (1995, 2005). A recently updated version is now available (Nicolas 2007, Van der Walt *et al.* 2010). The assemblage zone represented within the Gunstfontein project study area is the Middle Permian ***Tapinocephalus*** **Assemblage Zone** (Theron 1983, Rubidge 1995).

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. 12).

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, 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, beneath the escarpment and to the southeast 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 (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).

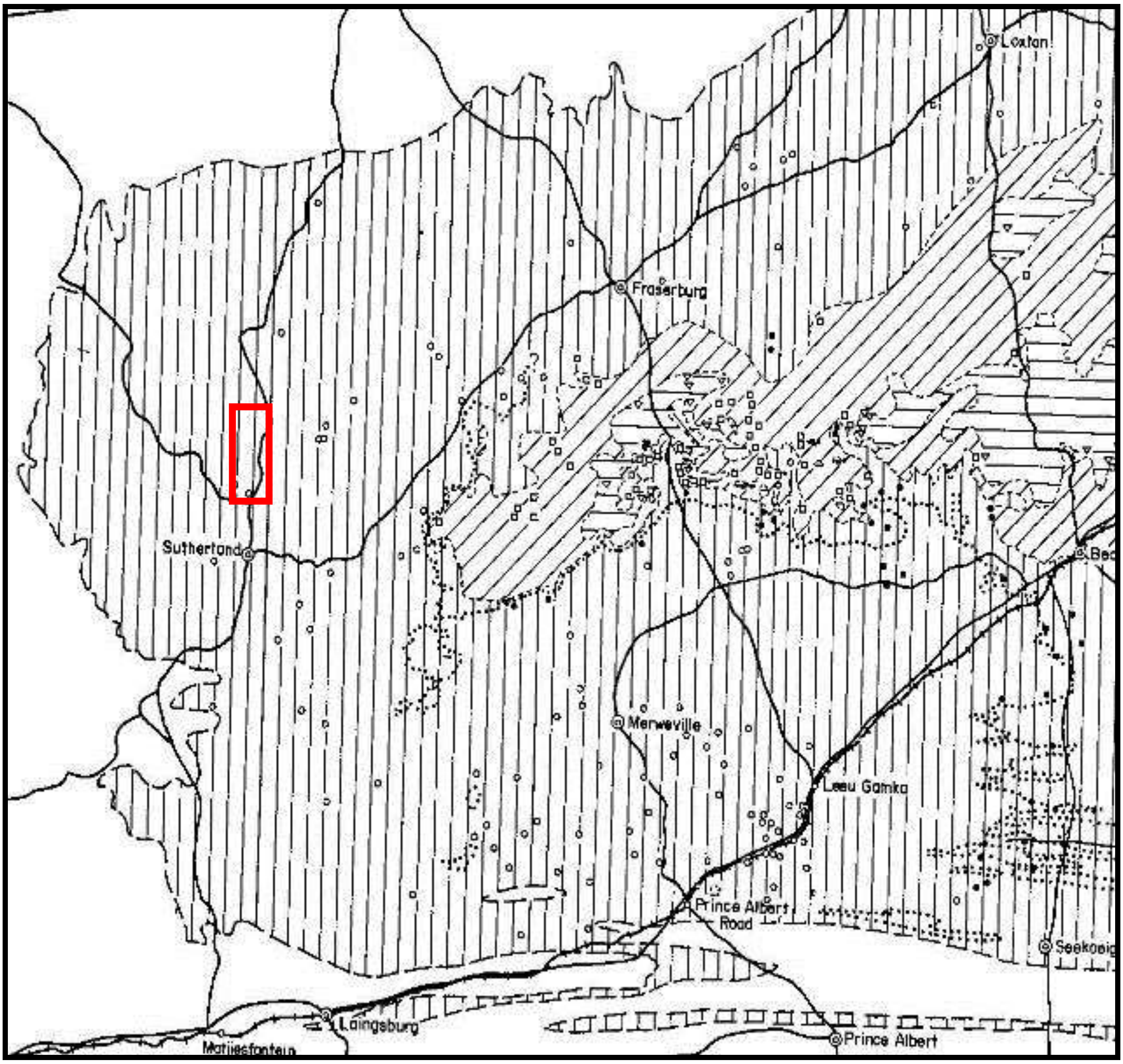

Figure 35. Vertebrate fossil localities within the Lower Beaufort Group in the south-western Karoo region (Map abstracted from Keyser & Smith 1977-78). Outcrop areas with a vertical lined ornament are assigned to the Middle Permian *Tapinocephalus* Assemblage Zone. Note the absence of fossil records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

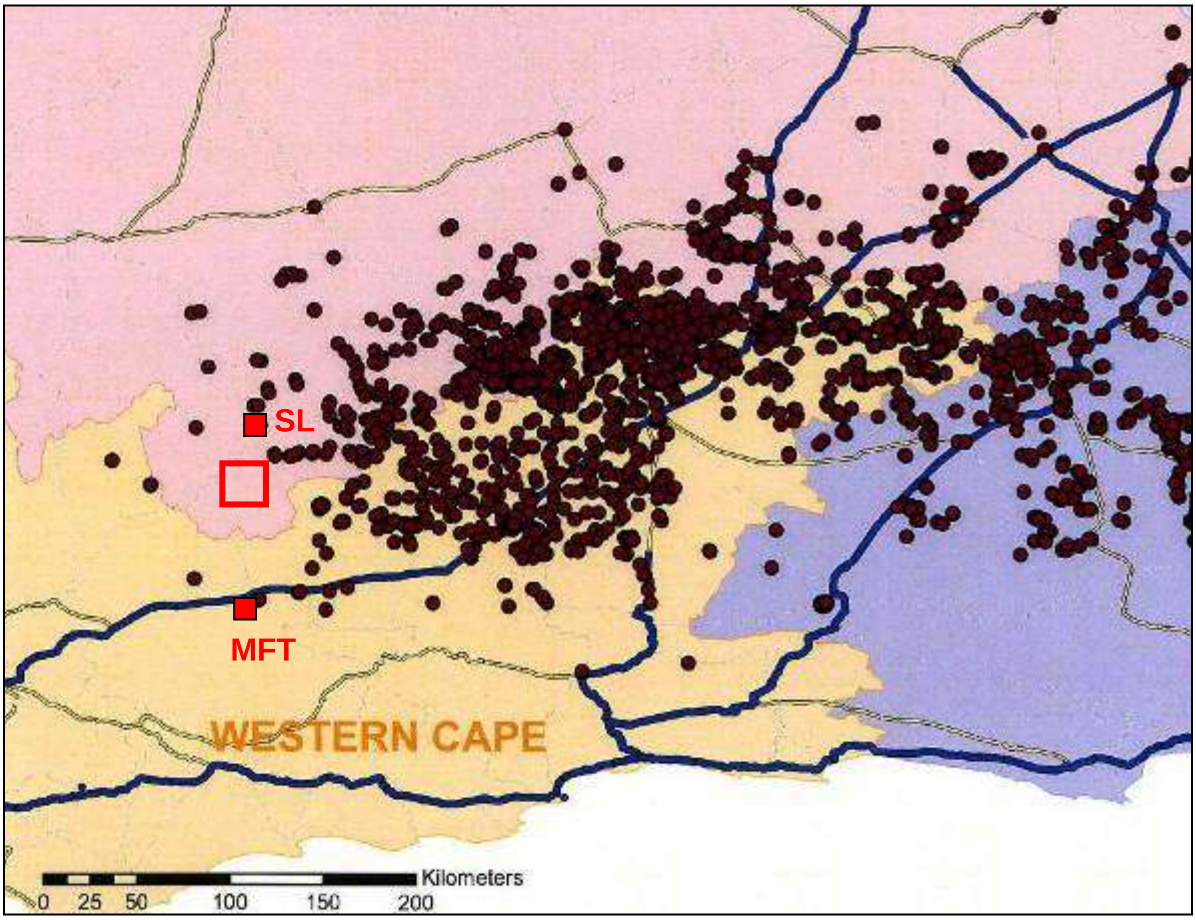

Figure 36. Distribution of recorded vertebrate fossil sites within the south-western portion of the Main Karoo Basin (modified from Nicolas 2007). The *approximate* location of the Gunstfontein WEF study area is indicated by the open red square. Note the lack of known fossil sites here. SL = Sutherland. 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. 12 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).

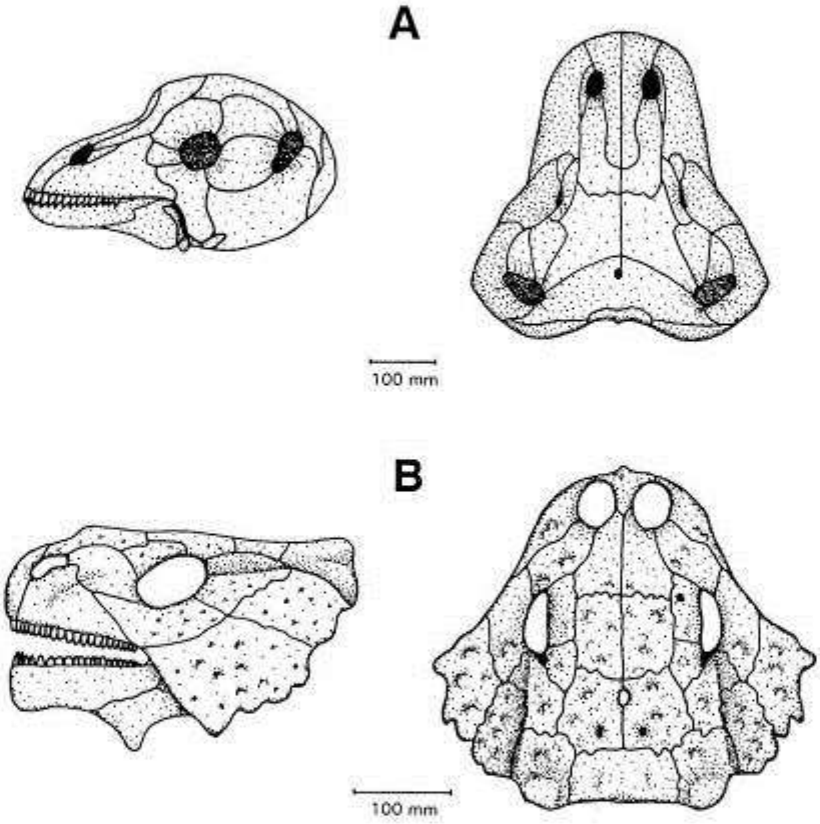

Figure 37. Skulls of two key large-bodied tetrapods of the *Tapinocephalus* Assemblage Zone: A – the dinocephalian therapsid *Tapinocephalus*; B – the pareiasaur *Bradysaurus* (From Smith & Keyser 1995b).

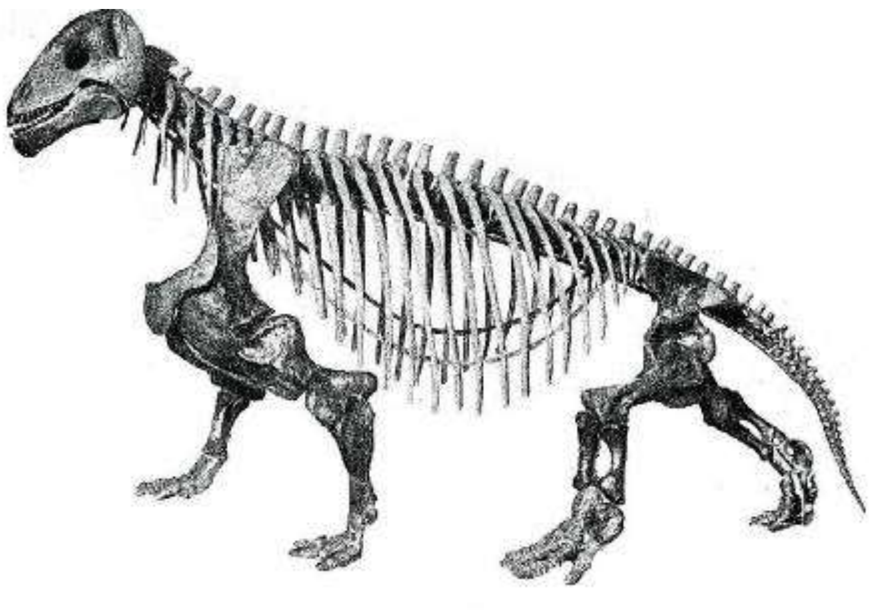

Figure 38. Skeleton of the tapinocephalid (thick-skulled) dinocephalian *Moschops*, a rhino-sized herbivorous therapsid that reached lengths of 2.5 to 3 m and may have lived in small herds.

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 (Fig. 4). 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. 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 by Almond (2011) from a Moordenaars Member study site *c*. 11 km south of Sutherland. This site lies on Farm Jakhals Valley 99 which borders Gunstfontein 131 on the northern side. A traverse through the Combrinkskraal and Leeuvlei Members along the Gamma – Omega 765 kV transmission line corridor well to the south of the present study area did not yield fossil vertebrate remains in this area, 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 southwest 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). Recent fieldwork within the Soetwater Wind Farm study area beneath the escarpment and just to the south of the Gunstfontein WEF study area has only yielded *Scoyenia* ichnofacies invertebrate burrows, *possible* vertebrate burrows, plant stem casts and rare fragments of silicified wood, but no vertebrate remains (Almond 2015c).

The present palaeontological field assessment of the Gunstfontein WEF study area yielded the following records of fossil material from the Abrahamskraal Formation bedrocks (all these records are from the Moordenaars Member on the Roggeveld Plateau):

- Rare transported fossil bone fragments and probable disarticulated bony fish scales preserved within ferruginised basal channel breccias (Locs. 086, 115) (Fig. 39);
- Low diversity trace fossil assemblages of the *Scoyenia* ichnofacies on sandstone sole surfaces as well as treptichnid-like serial probe burrows associated with high energy sheet-laminated sandstone facies (Loc. 101) (Figs. 40 & 41);
- Sandstone casts of reedy plants stems – probably sphenophytes ("horsetails") – within crevasse splay sandstones (Locs. 101, 102) (Fig. 42);
- Ferruginised or slightly dark-hued impressions of non-woody plant material, including occasional well-preserved, tongue-shaped glossopterid leaves showing midribs as well

as indeterminate leaf and stem fragments, preserved within dark brown, impure sandstone facies (Locs. 089, 112) (Fig. 47);

- Local concentrations of woody plant material preserved as ferruginised moulds in channel sandstones, often associated with basal breccio-conglomerates and / or *koffieklip* (Locs. 092, 114) (Figs. 44 & 45);
- Sparse to locally common, poorly- to well-preserved blocks of silicified wood, including portions of sizeable logs, occurring among surface sandstone rubble, downwasted surface gravels and sheetwash gravels (Locs. 089, 104, 105, 112, 113) (Figs. 43, 46 & 48). Much of this material has a pale yellowish to creamy, cherty, vuggy appearance with no obvious preservation of the original woody fabric and may represent wood that was silicified at a late stage of decomposition. However, some of the petrified wood fragments do show well-preserved xylem cells.

It is notable that occurrences of sandstone-hosted uranium ore bodies picked up by aerial surveys of the Sutherland sheet area are often associated with fossil plant material and *koffieklip*. Decomposition of rotting plant material embedded within channel sandstones often played a key role in the precipitation of uranium minerals (See detailed discussion in Cole & Vorster 1999, Cole & Wipplinger 2001). It is therefore very possible that the six uranium anomalies mapped within or just outside the Gunstfontein WEF study area may be associated with fossil plants, though this particular point was *not* addressed during recent fieldwork. One of the anomalies (No. 169 on map Fig. 13) lies some 500 m to the east of the fossil woody plant assemblage recorded at Loc. No. 114 (Fig. 45). On palaeontological, as well as economic geological and general geoscientific, grounds it is therefore recommended that a 30 m buffer zone be recognised as far as the proposed WEF layout is concerned around (1) the previously-identified uranium anomalies listed above in Section 5 and mapped in Fig. 13 as well as around (2) the substantial *koffieklip* – fossil plant assemblage recorded here at Loc. 114 (32°33'16.97"S, 20°38'0.73"E).

No fossil remains were recorded from the Abrahamskraal Formation bedrocks of the Roggeveld Escarpment on Boschmans Hoek 172. This may well reflect the very low levels of bedrock exposure here as well as the steep terrain which limits accessibility.

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 Gunstfontein WEF study area during the present field study.

Figure 39. Reworked fragment of well-preserved fossil limb bone (probably therapsid) embedded within a ferruginised channel basal breccio-conglomerate, Gunstfontein 131 (Bone is *c.*11 cm long as exposed here) (Loc. 089).

Figure 40. Low-diversity invertebrate trace fossil assemblages and possible plant stem casts on the sole of a displaced sandstone block near Gunstfontein farmstead (Scale in cm) (Loc. 101).

Figure 41. Treptichnid-like trace fossils associated with horizontally-laminated channel sandstones, Moordenaars Member on Gunstfontein 131 (Burrows are *c.* 3 mm wide) (Loc. 101).

Figure 42. Cross-sections through sand-infilled casts of reedy plant stems (probably sphenophytes) within a crevasse-splay sandstone capped with siltstone, Gunstfontein 131 (Scale in cm) (Loc. 102).

Figure 43. Downwasted surface gravels on Gunstfontein 131 composed of angular sandstone clasts and occasional blocks of brown silicified wood (arrowed), Gunstfontein 131 (Scale is c. 15 long) (Loc. 089).

Figure 44. Float blocks of ferruginised channel sandstone bearing striated moulds of woody plant material, Gunstfontein 131 (Scale in cm) (Loc. 092).

Figure 45. Concentrations of woody and other plant material preserved as ferruginised moulds in close association with *koffieklip* lenses Gunstfontein 131, (See Fig. 20) (Scale in cm) (Loc. 114).

Figure 46. Angular fragments of sizeable fossil logs replaced by pale cherty material that have weathered out from channel sandstones, Gunstfontein 131 (Scale in cm) (Loc. 112).

Figure 47. Mould of a tongue-shaped glossopterid leaf preserved within brown impure channel sandstone, Gunstfontein 131 (Scale in mm) (Loc. 114).

Figure 48. Subrounded clasts of silicified fossil wood reworked by sheetwash processes and concentrated among surface gravels, Gunstfontein 131 (Scale in cm) (Loc. 105) (See also Fig. 29).

4. EVALUATION OF IMPACTS ON PALAEONTOLOGICAL HERITAGE

The Gunsfontein WEF project is located in an area that is underlain by potentially fossiliferous sedimentary rocks of Late Palaeozoic and younger, Late Tertiary or Quaternary, age as described in Sections 2 & 3 of this report. The construction phase of the proposed wind farm development will entail substantial ground clearance as well as excavations into the superficial sediment cover and locally into the underlying bedrock. These include, for example, excavations for the wind turbine foundations, crane pad / laydown areas, internal access roads, underground cables, power line tower footings, on-site substation, various buildings and construction compound. 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 inferred impact of the proposed wind energy development on local fossil heritage resources is evaluated in Table 1 below, based on the system employed by Savannah Environmental (Pty) Ltd. This assessment applies only to the construction phase of the development since further impacts on fossil heritage during the operational and decommissioning phases of the facilities are not anticipated.

In general, the destruction, damage or disturbance out of context of fossils preserved at the ground surface or below ground that may occur during construction represents a *negative* impact that is limited to the development footprint (*local*). Such impacts can usually be mitigated but cannot be fully rectified or reversed (*i.e. permanent, irreversible*). Most of the sedimentary formations represented within the study area contain fossils of some sort, so impact on fossil heritage are *probable*. However, because of (a) the generally sparse occurrence of well-preserved fossils within the bedrocks concerned here, as well as within the overlying superficial sediments (soil, alluvium, colluvium *etc*), (b) the widespread occurrence of the fossils concerned (primarily petrified wood and other plant remains) outside the study area, and (c) the mantling of the bedrocks with largely unfossiliferous superficial sediments in many areas, the magnitude of these impacts is conservatively rated as *low*. This assessment applies both to the core infrastructure of the wind energy facility itself (wind turbines, access roads, underground cables, on-site substation *etc*) that will be located on the Roggeveld Plateau as well as the associated power line that will run down the Roggeveld Escarpment to the south (even though it is noted that this will be assessed separately).

No areas or sites of exceptional fossil heritage sensitivity or geoscientific significance have been identified within the study area, with the exception of:

(1) Loc. 114 (32°33'16.97"S, 20°38'0.73"E) on the western margins of Gunstfontein 131 where concentrations of fossil plants (moulds of woody material) are associated with ferruginous *koffieklip* (Figs. 20 & 45); and
(2) the five uranium anomalies on Gunstfontein 131 that are documented on the 1: 250 000 metallogenic map for the Sutherland area (locality data provided in Section 5 as well as map Figs. 3 & 13).

The fossil remains identified in this study are mostly of widespread occurrence within the study area itself as well as within the outcrop area of the formations concerned (*i.e.* not unique to the study area). Irreplaceable loss of fossil heritage is therefore unlikely. Should fossil remains be impacted by the proposed development, these impacts can be partially mitigated by a chance-find procedure, as outlined in the following section of the report.

There are no fatal flaws in the Gunstfontein WEF development proposal as far as fossil heritage is concerned. Due to the general scarcity of fossil remains as well as the extensive superficial sediment cover observed within the entire study area, the overall impact significance of the construction phase of the proposed alternative energy project is assessed as LOW. The no-go option (*i.e.* no development of the WEF) is of neutral impact significance for fossil heritage.

It should be noted that, should new fossil remains be discovered before or during construction and reported by the responsible ECO to the responsible heritage management authority (SAHRA) for professional recording and collection as recommended below, the overall impact significance of the project would remain LOW. Residual negative impacts from inevitable loss of fossil heritage would be partially offset by an improved palaeontological database for the study region as a direct result of appropriate mitigation. This is a *positive* outcome because any new, well-recorded and suitably curated fossil material from this palaeontologically under-recorded region would constitute a useful addition to our scientific understanding of the fossil heritage here.

Palaeontological assessments for other proposed alternative energy developments in the region to the south of Sutherland include a solar energy project on Jakhals Valley (RE/99) to the north of Gunstfontein 131 as well as the Roggeveld, Karusa and Soetwater WEFs on the southern border of the present study area (Almond 2011, 2015c). In both cases, scientifically valuable fossil sites were not identified and vertebrate fossils appear to be very rare. It is concluded that the cumulative impact on fossil heritage resources posed by the Gunstfontein WEF is *low*.

Because of the generally low levels of bedrock exposure within the study area, confidence levels for this palaeontological heritage assessment are only MODERATE.

5. RECOMMENDATIONS FOR MONITORING AND MITIGATION

Given the low impact significance of the proposed Gunstfontein WEF 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.

Due to their potential economic as well as geoscientific interest (including possible association with fossil plants), the five uranium anomalies mapped on Gunstfontein 131 (See maps Figs. 3 & 13) should be protected by buffer zones of 30 m radius. The GPS locations of these five anomalies are as follows:

Anomaly 169 (Gunstfontein 131): 32 33 20 S, 20 38 20 E
Anomaly 170 (Gunstfontein 131): 32 35 09 S, 20 37 29 E
Anomaly 171 (Gunstfontein 131): 32 36 07 S, 20 38 08 E
Anomaly 172 (Gunstfontein 131): 32 34 02 S, 20 41 40 E
Anomaly 173 (Gunstfontein 131): 32 34 56 S, 20 42 21 E

It is also recommended that a similar 30 m-radius buffer zone be established to safeguard the association of abundant fossilised plant material with a sizeable body of *koffieklip* (rusty-brown ferruginised sandstone) recorded at Loc. 114 ((32°33'16.97"S, 20°38'0.73"E) on the western margins of Gunstfontein 131 (Figs. 20 & 45).

During the construction phase all deeper (> 1 m) bedrock excavations should be monitored for fossil remains by the responsible ECO. Should substantial fossil remains such as vertebrate bones and teeth, plant-rich fossil lenses or dense fossil burrow assemblages be exposed during construction, the responsible Environmental Control Officer and / or Contractors EO should safeguard these, preferably *in situ*, and alert SAHRA so that appropriate action can be taken by a professional palaeontologist, at the Proponent's expense (Contact details: SAHRA, 111 Harrington Street, Cape Town. PO Box 4637, Cape Town 8000, South Africa. Phone: +27 (0)21 462 4502. Fax: +27 (0)21 462 4509. Web: www.sahra.org.za). 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 professional palaeontologist. These mitigation recommendations – as summarized below in Table 2 - should be incorporated into the Environmental Management Plan (EMPr) for the Gunstfontein WEF.

Provided that the recommended mitigation measures are carried through, it is likely that any potentially negative impacts of the proposed alternative development on local fossil resources will be substantially reduced. Furthermore, they will be partially offset by the *positive* impact represented by increased understanding of the palaeontological heritage of the Great Karoo region.

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 (SAHRA in this case);

- The palaeontologist concerned with 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 would have to 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 developed by SAHRA (2013).

Given the internationally recognised value of Karoo fossil heritage (*e.g.* MacRae 1999, McCarthy & Rubidge 2005), the known occurrence of scientifically valuable fossil material elsewhere in the Sutherland / Moordenaarskaroo region, as well as the legal protection of all fossil remains under the National Heritage Resources Act (1999), these mitigation measures are considered to be essential.

Table 1: Assessment of impacts and cumulative impacts of the proposed Gunstfontein WEF on fossil heritage resources during the construction phase of the development (*N.B.* Significant impacts are not anticipated during the operational and decommissioning phases).

Nature of impact: Disturbance, damage, destruction or sealing-in of fossil remains preserved at or beneath the ground surface within the development area, most notably by ground clearance and bedrock excavations during the construction phase of the wind energy facility.		
	Without mitigation	**With mitigation**
Extent	Local (1)	Local (1)
Duration	Permanent (5)	Permanent (5)
Magnitude	Low (1)	Low (1)
Probability	Probable (3)	Probable (3)
Significance	**Low (21)**	**Low (21)**
Status	Negative	Negative (loss of fossils) & positive (improved fossil database following mitigation)
Reversibility	Irreversible	Irreversible
Irreplaceable loss of resources?	No, since the limited fossil resources concerned are also represented outside the development area (*i.e.* not unique)	No, since the limited fossil resources concerned are also represented outside the development area (*i.e.* not unique)
Can impacts be mitigated?	Yes	Yes.
Mitigation: Monitoring of all substantial bedrock excavations for fossil remains by ECO, with reporting of substantial new palaeontological finds (notably fossil vertebrate bones & teeth, concentrations of petrified wood) to SAHRA for possible specialist mitigation.		
Cumulative impacts: Low, since several palaeontological assessments in the region to the south of Sutherland indicate that well-preserved vertebrate fossil remains are rare here.		
Residual impacts: Negative impacts due to loss of local fossil heritage will be partially offset by *positive* impacts resulting from mitigation (*i.e.* improved palaeontological database).		

Nature*:* Cumulative impacts on of fossil remains preserved at or beneath the ground surface		
	Without mitigation	**With mitigation**
Extent	Local (2)	Local (2)
Duration	Permanent (5)	Permanent (5)
Magnitude	Low (4)	Low (3)
Probability	Probable (2)	Probable (2)
Significance	**Low (22)**	**Low (22)**
Status (positive or negative)	Negative	Negative (loss of fossils) & positive (improved fossil database following mitigation)
Reversibility	No	
Irreplaceable loss of resources	No, since the limited fossil resources concerned are also represented outside the development area (*i.e.* not unique)	
Can impacts be mitigated	Yes	
Mitigation: » Monitoring of all substantial bedrock excavations for fossil remains by ECO's for each facility, with reporting of substantial new palaeontological finds (notably fossil vertebrate		

bones & teeth, concentrations of petrified wood) to SAHRA for possible specialist mitigation.

Nature*:* Cumulative impacts on of fossil remains preserved at or beneath the ground surface		
	Without mitigation	**With mitigation**
Extent	Local (2)	Local (2)
Duration	Permanent (5)	Permanent (5)
Magnitude	Low (4)	Low (3)
Probability	Probable (2)	Probable (2)
Significance	**Low (22)**	**Low (22)**
Status (positive or negative)	Negative	Negative (loss of fossils) & positive (improved fossil database following mitigation)
Reversibility	No	
Irreplaceable loss of resources	No, since the limited fossil resources concerned are also represented outside the development area (*i.e.* not unique)	
Can impacts be mitigated	Yes	
Mitigation: » Monitoring of all substantial bedrock excavations for fossil remains by ECO's for each facility, with reporting of substantial new palaeontological finds (notably fossil vertebrate bones & teeth, concentrations of petrified wood) to SAHRA for possible specialist mitigation.		

Table 2: Recommendations concerning fossil heritage management during the construction phase for inclusion into the draft EMPr for the proposed Gunstfontein WEF (*N.B.* Significant impacts are not anticipated during the operational and decommissioning phases).

OBJECTIVE: Safeguarding, recording and sampling of any important fossil material exposed

Project Component/s	» Construction of wind energy facility and associated infrastructure.
Potential Impact	» Disturbance, damage, destruction or sealing-in of scientifically valuable fossil material embedded within bedrock or weathered-out at ground surface.
Activities/Risk Sources	» Extensive bedrock excavations and surface disturbance (*e.g.* wind turbine foundations, laydown areas, new access roads, power line tower footings, on-site substation, foundations for the office / workshop, underground cables).
Mitigation: Target/Objective	» Recording, judicious sampling and curation of any important fossil heritage exposed during construction within the WEF development area. » Safeguarding of known plant fossil site and mapped uranium anomalies.

Mitigation: Action/Control	**Responsibility**	**Timeframe**
Monitoring of all bedrock excavations for fossil remains during construction phase. Fossil finds to be	ECO	Construction phase

Mitigation: Action/Control	Responsibility	Timeframe
safeguarded and reported to SAHRA for possible mitigation.		
Recording and judicious sampling of exceptional new fossil material from the development footprint.	Professional palaeontologist assisted by ECO	Construction phase
Curation of fossil specimens at an approved repository (*e.g.* museum).	Professional palaeontologist	Following mitigation
Final technical report on palaeontological heritage within study area	Professional palaeontologist	Following mitigation and preliminary analysis of fossil finds

Performance Indicator	» Identification of any new palaeontological hotspots within broader development footprint by ECO. » Cumulative acquisition of geographically and stratigraphically well-localised fossil records, samples and relevant geological data from successive subsections of the development area. » Submission of interim and final technical reports to SAHRA by palaeontologist involved with any mitigation work. » Safeguarding known uranium anomalies and identified plant fossil site from damage or destruction by new infrastructure.
Monitoring	» Monitoring during construction phase of fresh bedrock exposures within development footprint by ECO and, if necessary, by professional palaeontologist.

6. CONCLUSIONS & RECOMMENDATIONS

The fluvial Abrahamskraal Formation (Lower Beaufort Group, Karoo Supergroup) that underlies the Gunstfontein WEF 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 region between Matjiesfontein and Sutherland where sediments belonging only to the lower part of the thick Abrahamskraal Formation succession (Moordenaars Member and underlying rock units) are represented. Bedrock exposure levels in the study area are generally poor, especially as far as potentially fossiliferous mudrocks are concerned, due to the pervasive cover by superficial sediments (colluvium, alluvium, soils) and vegetation. Nevertheless, a sufficiently large outcrop area of Abrahamskraal Formation sediments - exposed in rocky ridges, streambanks, borrow pits as well as steep hillslopes and erosion gullies along the Roggeveld Escarpment and on the Roggeveld Plateau - has been examined during the present field study to infer that macroscopic fossil remains of any sort are rarely found here. Exceptions include low-diversity trace fossil assemblages (small-scale invertebrate burrows, plant stem casts) and fragmentary plant fossil remains. The latter include horsetail ferns (arthrophytes), *Glossopteris* leaf impressions as well as concentrations of woody plant material preserved as moulds and blocks of silicified wood. The plant fossils are often associated with ferruginised channel sandstones and lag conglomerates (*koffieklip*). Cherty petrified wood clasts are extensively reworked into surface gravels. The only vertebrate fossil remains recorded within the study area comprise very sparse reworked bones and disarticulated fish scales preserved within ferruginised channel lag conglomerates. Early Jurassic dolerite intrusions and Late Cretaceous igneous rocks of the Sutherland Suite are not mapped within the study area but are known to occur a few kilometres to the north.

It is concluded on the basis of this combined desktop analysis and field-based palaeontological study that the Lower Beaufort Group bedrocks in the Gunstfontein WEF 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 Gunstfontein WEF is unlikely to entail significant impacts on local fossil heritage resources. Due to the general scarcity of well-preserved 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 Gunstfontein WEF 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 both to the core WEF infrastructure on the Roggeveld Plateau (wind turbines, access roads, underground cables, on-site substation *etc*) as well as the associated power line that will run down the Roggeveld Escarpment to the south. There is no preference on palaeontological heritage grounds for any particular infrastructure layout or substation site among the options under consideration.

Five uranium ore occurrences have been previously mapped on Gunstfontein 131 (Cole & Vorster 1999). These may well be associated with fossil plant material which often played a key role in the precipitation of uranium minerals. It is proposed that these five uranium ore occurrences (detailed in this report) as well as an additional site on the western margins of Gunstfontein 131 (32°33'16.97"S, 20°38'0.73"E) that features concentrations of woody plant fossils and *koffieklip* (ferruginised channel sandstone) be safeguarded within 30 m-radius buffer zones.

Given the low impact significance of the proposed Gunstfontein WEF 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 logs 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 professional palaeontologist. These mitigation recommendations should be incorporated into the Environmental Management Programme (EMPr) for the Gunstfontein WEF 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).

Recent desktop and field-based assessments for several alternative energy projects in the Roggeveld Plateau – Klein Roggeveldberge region to the south of Sutherland – including the Jakhals Valley PV facility (Almond 2011), Kareebosch Wind Farm (Almond 2014), Karusa Wind Farm (Almond 2015b) and Soetwater Wind Farm (Almond 2015c) – indicate that scientifically significant palaeontological sites in the broader region (notably well-preserved fossil vertebrates) are very sparsely distributed. Cumulative impacts on palaeontological heritage resources of these projects in conjunction with the proposed Gunstfontein WEF are inferred to be low.

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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
085	32 31 41.2 S 20 38 25.4 E	Gunstfontein 131. Gullied hillslope exposure of grey-green mudrocks of Moordenaars Member on N side of dust road to Komsberg Pass.
086	32 31 46.6 S 20 38 20.9 E	Gunstfontein 131. Extensive exposure of grey-green and purple-brown mudrocks, dark grey to buff crevasse splay sandstones of the Moordenaars Member around edge of farm dam. Possible plant stem casts within ripple-topped crevasse-splay sandstone. Rusty-brown to pinkish palaeocalcrete concretions and lenses within mudrocks. Downwasted channel sandstone blocks on flanks of sandstone ridge. Sandy alluvium and sandstone gravels along drainage line.
087	32 31 44.8 S 20 38 04.0 E	Verlaten Kloof 130. Gentle hillslope exposures of grey-green mudrocks near ruined buildings. Views of Moordenaars Member succession within top of Verlatekloof gorge. Pale grey, lichen-covered, well-jointed flaggy channel sandstones on nearby hillslopes.
088	32 32 39.6 S 20 40 15.5 E	Gunstfontein 131, north-eastern area. Low-relief bossieveld, sparse bare patches with downwasted sandstone and ferricrete surface gravels, low exposures of sandstone bedrock, sandy soils.
089	32 32 32.7 S 20 40 52.9 E	Gunstfontein 131, north-eastern area. *In situ* dark brown, ferruginised basal channel breccias as well as weathered blocks of breccia containing sparse, fragmentary & transported fossil bone, reworked calcrete glaebules. Occasional downwasted blocks of brown silicified wood. Channel sandstones with dispersed fragmentary plant material (indeterminate stem / leaf fragments).
090	32 32 42.2 S 20 42 12.7 E	Gunstfontein 131, north-eastern area. Low sandstone *kranzes* formed by tabular channel sandstone bodies, lichen-covered. Horizontal lamination.
091	32 33 29.7 S 20 42 18.4 E	Gunstfontein 131, north-eastern area. SW-NE trending valley eroded along major fracture line. Sandstone colluvium along valley slopes. Gravelly to sandy alluvium on valley floor, including large rounded sandstone boulders.
092	32 33 38.7 S 20 42 09.6 E	Gunstfontein 131, north-eastern area. Small valley slope and stream gulley exposures of grey-green & purple-brown mudrocks, sparse palaeocalcrete concretions, subrounded downwasted sandstone boulders. Longitudinally-striated moulds / casts / tool marks in brown ferruginised sandstone – possibly of fossil wood.
093	32 33 48.7 S 20 41 58.6 E	Gunstfontein 131, north-eastern area. Thick (> 2 m), pale buff, sandy alluvial deposits with dispersed small gravel clasts and angular sandstone basal gravels exposed by gulley erosion on floor of stream valley.
094	32 34 20.6 S 20 41 40.7 E	Gunstfontein 131, road cutting southeast of farmstead. Gullied base of ripple cross-laminated channel sandstone overlying thick package of purple-brown to grey-green, thin-bedded mudrocks. Line of pans / dams to southwest

		of Komsberg Pass dust road. Greyish sandy to silty alluvium and downwasted sandstone / *koffieklip* gravels along margins of pan.
095	32 34 32.5 S 20 42 14.4 E	Gunstfontein 131. SW-facing mudrock slopes to the NE of the Komsberg Pass dust road. Lenses of *koffieklip* and ferruginous palaeocalcrete concretions. Downwasted rounded boulders of sandstone overlying mudrock bedrocks. Fine gravelly to sandy colluvial soils in *vlaktes*.
095a	32 36 53.6 S 20 41 18.9 E	Gunstfontein 131, escarpment edge east of Karoofontein. Gently undulating, tabular channel sandstones of Moordenaars Member towards top of escarpment with occasional large (meter-scale) ferruginous carbonate concretions. Colluvial blanketing of escarpment slopes.
096	32 35 45.4 S 20 40 40.0 E	Gunstfontein 131, eastern plateau. Shallow borrow pit excavated into grey-green mudrocks and ferruginous carbonate concretions. Channel sandstones and *koffieklip* blocks downwasting onto underlying mudrock slopes. "Woolsack" weathering of channel sandstones into rounded corestones in the vicinity.
097	32 35 23.5 S 20 40 06.3 E	Gunstfontein 131, central plateau. Extensive exposure of scabby, exfoliating upper surface of large channel sandstone with occasional major fractures, horizontal to large-scale, low-angle cross-lamination, wave rippled bed tops, primary current lineation, heavy mineral lamination, local mudflake breccio-conglomerates.
098	32 35 19.7 S 20 40 10.8 E	Gunstfontein 131, central plateau. Local development of tepee-shaped sandstone pop-ups on upper surface of jointed channel body, probably generated by weathering-induced expansion of impure feldspathic sandstone.
099	32 35 12.0 S 20 39 47.3 E	Gunstfontein 131, central plateau. Wave-washed margin of farm dam / former pan along SW-NE drainage line showing sandy to silty alluvial muds capped by angular downwasted sandstone clasts.
100	32 34 24.8 S 20 40 28.0 E	Gunstfontein 131, central plateau to SW of farmstead. Extensive exposure of channel sandstone body with large (meter-scale) oblate ferruginous carbonate concretions.
101	32 34 05.2 S 20 40 56.1 E	Gunstfontein 131, just SW of farmstead (area near corbelled house). Displaced blocks of yellow-brown sandstone showing low diversity trace fossil assemblages on sole surfaces (possibly *Scoyenia* ichnofacies and / or plant stem moulds). Blocks of prominently mottled sandstone facies. Extensive development of large lenticular ferruginous carbonate lenses within channel sandstone. *In situ* dark brown-weathering flaggy sandstones showing primary current lineation and treptichnid-like trace fossil assemblages.
102	32 33 55.3 S 20 40 52.1 E	Gunstfontein 131, roadside borrow pit just north of farmstead. Good fresh exposures of Moordenaars Member thin-bedded, grey-green and purple-brown mudrock package, tabular crevasse-splay sandstones in borrow pit walls and surrounding hillslopes. Sandy casts of reedy plant stems (*c*. 1 cm diameter) within crevasse-splay sandstone.
103	32°33'52.69"S 20°41'2.90"E	Gunstfontein 131, extensive hillslope exposures of Moordenaars Member mudrocks on NE side of Komsberg Pass road to east of farmstead. Concentrations of weathered-out palaeocalcrete concretions in gullies as well as within *in situ* palaeosols. Loaded bases of sandstone beds associated with purple-brown mudflake and calcrete

		glaebule breccias (locally cross-bedded), sandstone-infilled desiccation cracks, Internally disrupted sandstone beds perhaps resulting from dewatering (possibly flame structures).
104	32°32'46.64"S 20°40'0.06"E	Gunstfontein 131. Pale brown, partially calcretised sandy alluvium around margins of farm dam. Isolated small fragments of petrified wood downwasted at surface.
105	32°33'17.09"S 20°40'7.08"E	Gunstfontein 131, western plateau. Bare patches of sandy alluvial soils among karroid bossieveld. Downwasted surface gravels modified by sheetwash and comprising various resistant-weathering lithologies, including agates and fragments of cherty, pinkish, yellowish and cream fine-grained silicified wood.
106	32°37'13.29"S 20°39'12.72"E	Boschmans Hoek 177, Rooikrans Pass. Hillslope exposure of package of grey-green and purple-brown mudrocks beneath channel sandstone. Thin crevasse-splay sandstones with wave-rippled tops.
107	32°40'12.29"S 20°38'34.60"E	Boschmans Hoek 177, south of Wegkruip farmstead. Vertical sections through semi-consolidated, coarse gravelly alluvium in steep stream banks.
108	32°38'40.97"S 20°38'20.45"E	Boschmans Hoek 177. Stream gulley and hillslope exposure of interbedded mudrocks and thin, tabular sandstones near windmill to N of Wegkruip farmstead. Palaeocalcrete concretion horizons, silicified gypsum pseudomorphs within mudrocks.
109	32°36'34.78"S 20°38'4.64"E	Boschmans Hoek 177, plateau NE of Perdekop. Gentle slope exposures of purple-brown mudrock with ferruginous calcrete concretions.
110	32°36'47.16"S 20°37'37.98"E	Boschmans Hoek 177, plateau NE of Perdekop. *Vlei* area with brown-stained downwasted sandstone blocks overlying a sandy substrate.
111	32°36'54.08"S 20°37'31.10"E	Boschmans Hoek 177, viewpoint along escarpment edge near Perdekop. Sandstone package of Moordenaars Member.
112	32°34'0.03"S 20°37'56.74"E	Gunstfontein 131. Viewpoint along incised escarpment edge on western edge of study area. Locally common cherty silicified wood (fragments of small logs) among surface float. Sparse moulds of fossil plant debris, including *Glossopteris* leaves, sphenophyte ferns, within dirty-brownish impure sandstones.
113	32°34'0.17"S 20°37'43.43"E	Gunstfontein 131. Gentle hillslope exposures of grey-green mudrocks with abundant ferruginised carbonate concretions, sparse silicified wood fragments.
114	32°33'16.97"S 20°38'0.73"E	Gunstfontein 131, western edge of study area SSE of Verlatekop. Sizeable trackside exposure of dark brown sandy to conglomeratic *koffieklip* (calcrete glaebules, mudflakes) associated with locally abundant, ferruginised moulds of woody plant material in medium-grained channel sandstone.
115	32°33'55.73"S 20°38'10.78"E	Gunstfontein 131, western edge of study area near stone buildings. Good exposure of ferruginised basal channel breccia containing reworked calcrete glaebules, small, finely-ridged bone fragments (probably disarticulated fish scales).