PALAEONTOLOGICAL HERITAGE ASSESSMENT: COMBINED DESKTOP & FIELD-BASED STUDY

AUTHORISED SOETWATER WIND FARM NEAR SUTHERLAND, NORTHERN CAPE PROVINCE

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EXECUTIVE SUMMARY

Soetwater Wind Farm (Pty) Ltd. is proposing to construct the authorised Soetwater Wind Farm, in the Klein-Roggeveldberge region some 40 km south of Sutherland, Northern Cape. The land parcels involved have a total area of *c*. 95 km^2 and include: Remainder of Orange Fontein 203, Orange Fontein 203 (Portion 1, 2 and Portion 4), Annex Orange Fontein 185, Zwanepoelshoek 184 and Leeuwe Hoek 183.

The fluvial Abrahamskraal Formation (Lower Beaufort Group, Karoo Supergroup) that underlies the Soetwater Wind Farm study area is known for its diverse fauna of Permian fossil vertebrates - notably various small- to large-bodied therapsids and reptiles - as well as fossil plants of the *Glossopteris* Flora and low diversity trace fossil assemblages. However, desktop analysis of known fossil distribution within the Main Karoo Basin shows a marked paucity of fossil localities in the wider study region between Matjiesfontein and Sutherland where sediments belonging only to the lower part of the thick Abrahamskraal Formation succession, below the Moordenaars Member, are represented. Bedrock exposure levels in the broader study region are generally very poor due to the pervasive cover by superficial sediments (colluvium, alluvium, soils, calcrete) and vegetation. Nevertheless, a sufficiently large outcrop area of Abrahamskraal Formation sediments, exposed in stream and riverbanks, borrow pits as well as steep hillslopes and erosion gullies along the Klein-Roggeveld Escarpment and plateau, has been examined during the present field study to infer that macroscopic fossil remains of any sort are very rare here. Exceptions include common low-diversity trace fossil assemblages (small-scale invertebrate burrows, possible plant root casts) and occasional fragmentary plant remains. The latter include horsetail ferns (arthrophytes), moulds of woody plant material and silicified wood fragments weathering out from the base of channel sandstones high up within the local Abrahamskraal Formation succession (Leeuvlei or Koornplaats Member). No fossil vertebrate remains (bones, teeth, coprolites) were recorded within the Soetwater Wind Farm study area, but several questionable vertebrate burrows-like structures were seen. Levels of bedrock tectonic deformation are generally low, although folding, faulting and cleavage development associated within the Cape Fold Belt are locally apparent. Early Jurassic dolerite intrusions are not mapped within the wider study area but are known to occur just to the south. It is concluded that the Lower Beaufort Group bedrocks in the Soetwater Wind Farm study area are generally of **low palaeontological sensitivity** and this also applies to the overlying Late Caenozoic superficial sediments (colluvium, alluvium, calcrete, surface gravels, soils *etc*).

Construction of the proposed Soetwater Wind Farm is unlikely to entail significant impacts on local fossil heritage resources. Due to the general great scarcity of fossil remains as well as the extensive superficial sediment cover observed within the study area, the **overall impact significance of the construction phase of the proposed Soetwater Wind Farm 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.

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

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

Please note that:

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

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

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

1. INTRODUCTION & BRIEF

1.1. Project outline

The company Soetwater Wind Farm (Pty) Ltd. is proposing to construct the authorised Soetwater Wind Farm, in the Klein-Roggeveldberge region some 40 km south of Sutherland, Northern Cape (Fig. 1). The land parcels involved have a total area of *c*. 95 km^2 and include: Remainder of Orange Fontein 203, Orange Fontein 203 (Portion 1, 2 and Portion 4), Annex Orange Fontein 185, Zwanepoelshoek 184 and Leeuw Hoek 183 (Fig. 2).

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

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

The Soetwater Wind Farm 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 wind farm will entail excavations into the superficial sediment cover and locally into the underlying bedrock as well. The development may adversely affect potential fossil heritage within the study area by destroying, disturbing or permanently sealing-in fossils preserved at or beneath the surface of the ground that are then no longer available for scientific research or other public good. The operational and decommissioning phases of the wind farm are unlikely to involve further adverse impacts on local palaeontological heritage.

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

1.2. Legislative context for palaeontological assessment studies

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

1.3. Approach to the palaeontological heritage study

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

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

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

086-142 142. Fax: 021-483 9842. Email: hwc@pgwc.gov.za). It should be emphasized that, *providing appropriate mitigation is carried out*, the majority of developments involving bedrock excavation can make a *positive* contribution to our understanding of local palaeontological heritage.

1.4. Assumptions & limitations

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

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

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

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

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

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

In the case of palaeontological desktop studies without supporting Phase 1 field assessments these limitations may variously lead to either:

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

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

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

In the case of the Soetwater Wind Farm study area near Sutherland in the Northern Cape preservation of potentially fossiliferous bedrocks is favoured by the semi-arid climate and sparse vegetation but bedrock exposure is limited by extensive superficial deposits, especially in areas of low relief, as well as pervasive Karoo *bossieveld* vegetation (Central Mountain Shale Renosterveld and Tanqua Escarpment Shrubland). However, sufficient bedrock exposures were examined during the course of this study (See Appendix) to assess the palaeontological heritage sensitivity of the study area. Comparatively few academic palaeontological studies or field-based fossil heritage impact studies have been carried out in the region, so any new data from impact studies here are of scientific interest.

1.5. Information sources

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

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

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

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

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

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

GPS data for all numbered localities mentioned in the text are provided in the Appendix.

Figure 1. Extract from 1: 250 000 topographical sheet 3220 Sutherland showing the location of the authorised Soetwater Wind Farm study area (blue polygon), located *c.* 40 km south of Sutherland, Northern Cape. The study area spans escarpment of the Klein-Roggeveldberge to the east of the R354 Matjiesfontein to Sutherland tar road and is traversed in the east by the gravel road to the Komsberg Pass between Smoushoogte and Haashoogte (Base map courtesy of the Chief Directorate of Surveys and Mapping, Mowbray).

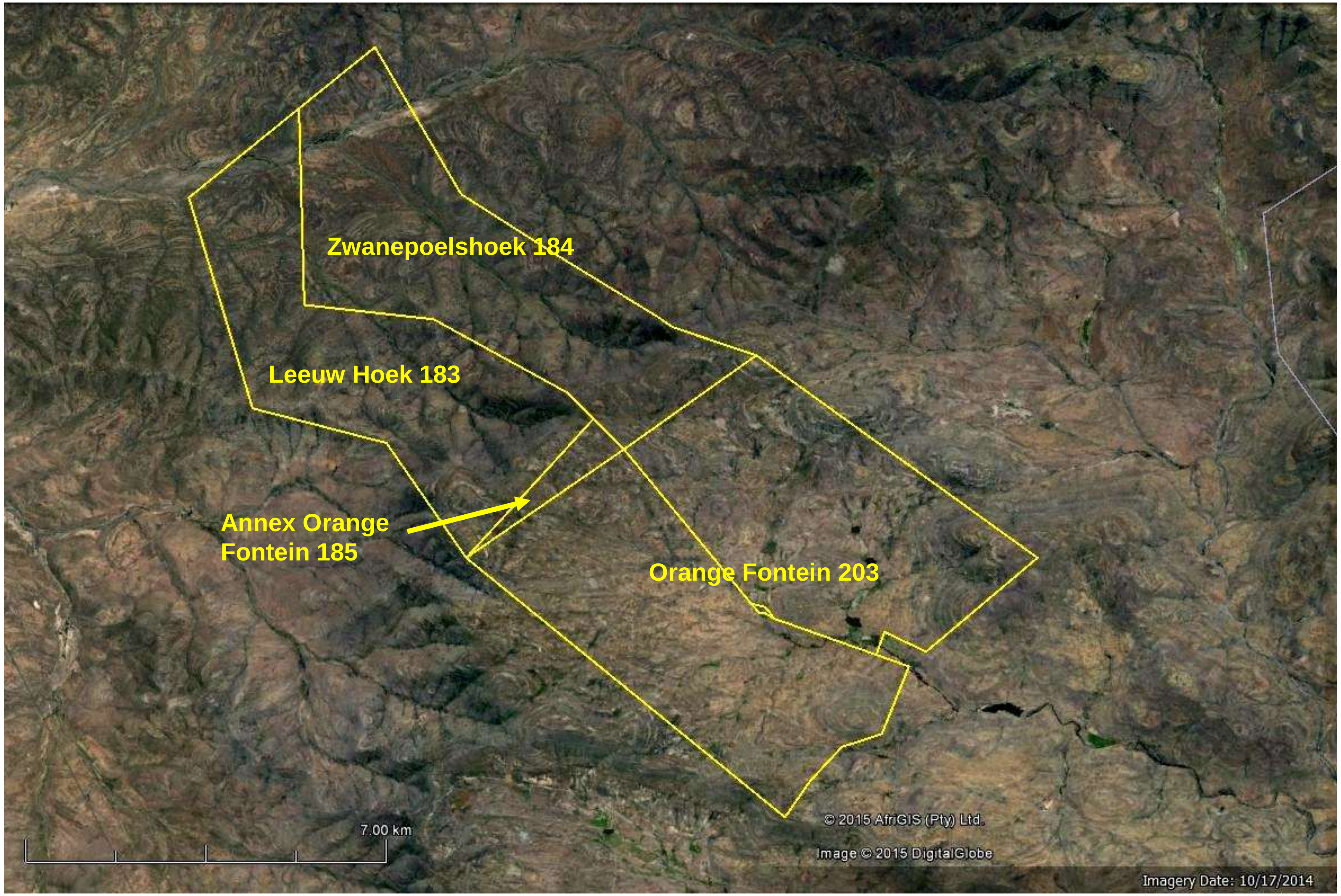

Figure 2. Google earth© satellite image of the authorised Soetwater Wind Farm study area (yellow polygon) spanning the Klein-Roggeveldberge Escarpment showing the constituent land parcels.

Figure 3. View of the gravel-strewn *vlaktes* and foothills of the Klein-Roggeveld Escarpment, Leeuwe Hoek 183.

Figure 4. Typical stepped topography of the lower escarpment slopes, Leeuwe Hoek 183. Note overbank mudrock exposures along the stream gulley (Loc. 578).

Figure 5. Gently-dipping, prominent-weathering channel sandstones in the Klein-Roggeveld Escarpment zone, Zwanepoelshoek 184.

Figure 6. View towards the NW from the edge of the Klein-Roggeveld Escarpment, Leeuwe Hoek 183. Blocky sandstone colluvium in the foreground (Loc. 562).

Figure 7. View towards the SE from Bobbejaansfontein area (Orange Fontein 203, Loc. 559) along the south-western margin of the study area (Perdeplaas se Berg in the background).

Figure 8. Typical rugged sandstone scenery, uplands towards the escarpment edge, Bobbejaansfontein area (Orange Fontein 203, Loc. 559).

Figure 9. Typical scenery on the Klein-Roggeveld Plateau away from the escarpment edge (Orange Fontein 203) showing subdued relief and mantle of fine-grained alluvium.

Figure 10. Western slopes of Ruiter se Kop (Orange Fontein 203, Loc. 571) showing prominent-weathering lenticular channel sandstones on the lower slopes.

2. GEOLOGICAL BACKGROUND

The Soetwater Wind Farm study area is situated within hilly to mountainous terrain some 40 km to the south of Sutherland and south of the Great Escarpment, spanning the lower-lying plateau and steep, west-facing escarpment of the Klein-Roggeveldberge (Figs. 1 & 2), Great Karoo region, Northern Cape. The existing Eskom Komsberg Substation lies some 20 km to the south of the study area and the R354 tar road between Matjiesfontein and Sutherland runs to the west. The eastern portion of the area is transected by the gravel road between the R354 and the Komsberg Pass, between the Smoushoogte and Haashoogte rises. The low-lying, north-western portion of the area at *c*. 850 m above mean sea level (amsl) at the foot of the Klein-Roggeveld Escarpment lies along the valley of a west-flowing tributary stream of the Brawaterrivier that flows into the Tanqua River drainage network. The alluvial *vlaktes* here are spotted with dense *heuweltjies* or bush clumps on satellite images (Fig. 3). The steep slopes of the Klein-Roggeveld Escarpment itself are incised by the gullies of numerous small, non-perennial streams (*e.g.* Swanepoelshoek, Leeuhoek and Langkloof valleys) and feature prominent-weathering sandstone ridges, giving a stepped profile (Figs. 4 & 5). The south-eastern portion of the study area, where most of the wind farm infrastructure will be positioned, features rugged hilly terrain at the edge of the Klein-Roggeveld Escarpment at around 1200-1400 m amsl. (Figs. 6 to 8), with gentler terrain at 1100-1200 m amsl away from the edge to the southeast (The highest point is Graskop at 1430 m amsl) (Figs. 9 & 10). This flatter-lying area is drained by south-east flowing tributaries of the Komsbergrivier and features several farm dams. Away from the numerous drainage lines and sandstone ridges bedrock exposure in the study area - notably that of the recessive-weathering mudrock facies - is generally very low, due to extensive cover by alluvial and colluvial deposits as well as karroid *bossieveld* vegetation (Central Mountain Shale Renosterveld and Tanqua Escarpment Shrubland).

The geology of the Sutherland region is outlined on the 1: 250 000 scale geology sheet 3220 Sutherland (Theron 1983) (Fig. 11) as well as the updated 1: 250 000 Sutherland metallogenic map that includes important new stratigraphic detail for the Lower Beaufort Group succession (Cole & Vorster 1999). The study area is entirely underlain by Middle Permian continental sediments of the **Lower Beaufort Group** (Adelaide Subgroup, Karoo Supergroup), and in particular the **Abrahamskraal Formation** (Pa) at the base of the Lower Beaufort Group succession (Johnson *et al.* 2006 and references cited below). The Beaufort Group sediments here are folded along numerous west-east trending fold axes (Fig. 11), with local cleavage development, minor faulting and quartz veining. In the Sutherland area to the north, situated just north of the Great Escarpment, the Lower Beaufort Group sediments have been extensively intruded and thermally metamorphosed (baked) by dolerite sills and dykes of the **Karoo Dolerite Suite** of Early Jurassic age (*c*. 182 Ma = million years ago; Duncan & Marsh 2006). These igneous rocks were intruded during an interval of crustal uplift and stretching that preceded the break-up of the supercontinent Gondwana. They show up on satellite images as rusty-brown areas. In the present study region well to the south of the Great Escarpment the only major dolerite intrusions are a set of laterally persistent, NW-SE trending dykes that transect the adjoining Karusa Wind Farm area and that can be well seen in road cuttings along the R354 (Jd, pink in Fig. 11). The Karoo dolerites are entirely unfossiliferous and will not be treated further in this report. The Palaeozoic and Mesozoic bedrocks in the study area are very extensively overlain by Late Caenozoic **superficial deposits** such as scree and other slope deposits (colluvium and hillwash), stream alluvium, down-wasted surface gravels, calcretes and various soils. These geologically youthful sediments are generally of low palaeontological sensitivity.

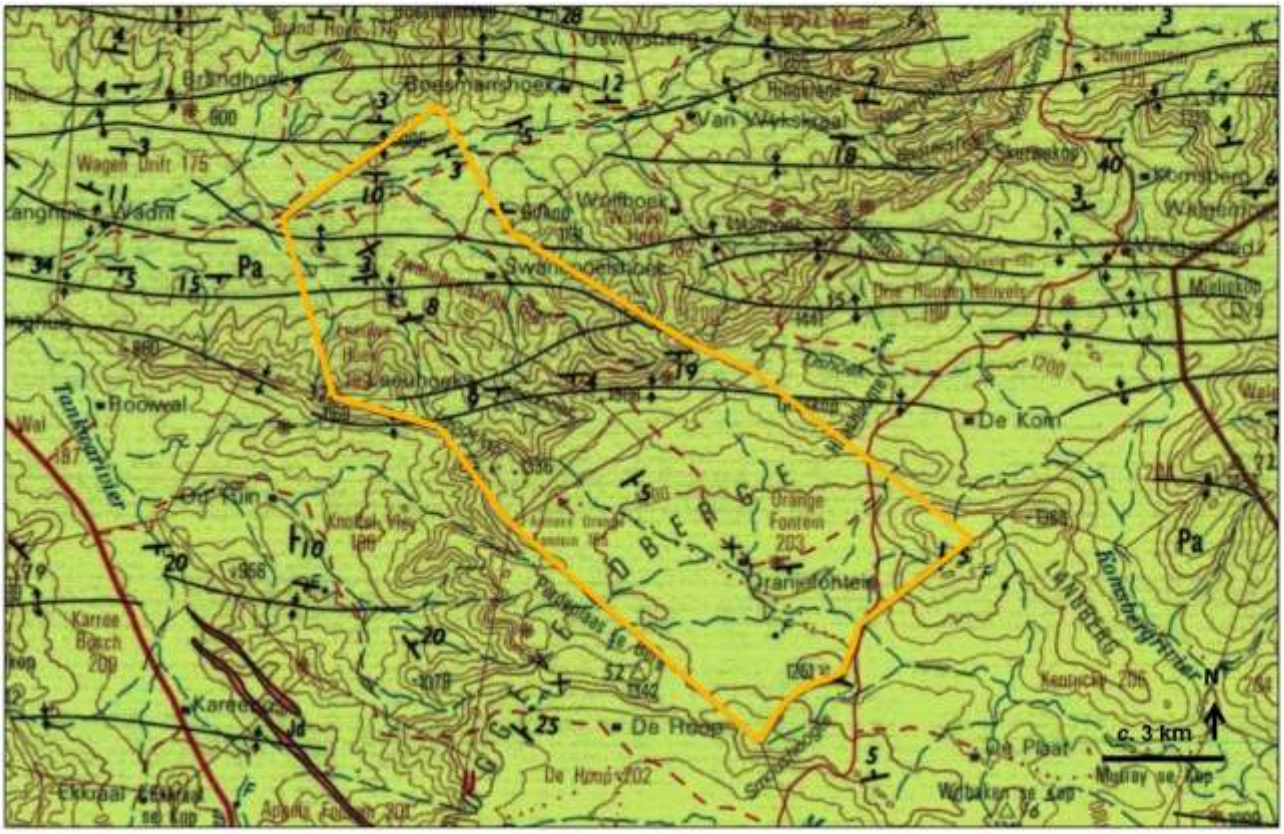

Figure 11. Extract from the 1: 250 000 scale geology sheet 3220 Sutherland (Council for Geoscience, Pretoria, 1999) showing the location of the proposed Soetwater Wind Farm study area, *c*. 40 km south of Sutherland, Northern Cape Province (yellow polygon). The study area is entirely underlain by Middle Permian sediments of the Abrahamskraal Formation, Lower Beaufort Group (Pa, pale green). Note numerous west-east trending fold axes (black lines) in the northern part of the study area.

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. 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 7 Vorster 1999, McCarthy & Rubidge 2005, Johnson *et al*., 2006, Almond 2010a, Day 2013a). These sediments include (a) lenticular to sheet-like channel sandstones, often associated with thin, impersistent intraformational breccio-conglomerates (larger clasts mainly of reworked mudflakes, calcrete nodules, *plus* sparse rolled bones, teeth, petrified wood), (b) well-bedded to laminated, grey-green, blue-grey to purple-brown floodplain mudrocks with sparse to common pedocrete horizons (calcrete nodules formed in ancient soils), (c) thin, sheet-like crevasse-splay sandstones, as well as more (d) localized playa lake deposits (*e.g.* wave-rippled sandstones, laminated mudrocks, limestones, evaporites). A number of greenish to reddish weathering, silica-rich "chert" horizons are also found. Many of these appear to be secondarily silicified mudrocks or limestones but at least some contain 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. 11). There have since been a number of attempts, only partially successful, to subdivide the very thick Abrahamskraal Formation succession in both lithostratigraphic (rock layering) and biostratigraphic (fossil) terms (*cf* Day & Rubidge 2010, Day 2013a). Among the most recent and relevant of these was the study by Loock *et al.* (1994) in the Moordenaarskaroo area north of Laingsburg. Detailed geological mapping here led to the identification of six lithologically-defined members within the Abrahamskraal Formation (Fig. 12). Several of these members have since been mapped in the Sutherland area by Cole and Vorster (1999). Very brief descriptions of these stratigraphic members are given by Loock *et al.* (1994) but the interested reader should refer to earlier works by Le Roux (1985) and Jordaan (1990) for detailed sedimentological data that is beyond the scope of the present palaeontological heritage study.

Based on the abundance of maroon mudrocks as well as the apparent absence or rarity of fossil vertebrate remains (Section 3), it is tentatively inferred that the Soetwater Wind Farm study area is largely underlain by the **Leeuvlei Member** (red dotted line in Fig. 12). According to Loock *et al.* (1995) this *c*. 860 m-thick member is characterized by:

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

Thicker sandstone packages that crop out along the Klein-Roggeveld Escarpment edge, and especially on the eastern and north-eastern margins of the project area (*e.g.* Ruiter se Kop, Graskop), may belong to the overlying *c*. 260 m-thick **Koornplaats Member** of the Abrahamskraal Formation. According to Loock *et al.* (1995) this 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 Abrahamskraal Formation in the Klein-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). 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. Obliquely side-steeping, successively higher channel bodies of laterally-migrating river systems are also seen within some intervals. The prominent, laterally-persistent sandstone ledges generate a distinctive stepped or terraced topography on hill slopes in the area (Figs. 5 & 10). The sheet sandstones are generally pale-weathering (enhanced by epilithic lichens), fine- to medium-grained, well-sorted and variously massive or structured by horizontal lamination (flaggy, with primary current lineation), or more rarely tabular to trough cross-bedding. Greyish hues of some freshly broken sandstone surfaces suggest an "impure" clay-rich mineralogy (*i.e.* wackes). Current ripple cross-lamination is common towards the tops of the sandstone beds which may also feature undulose bars and swales. The lower contacts of the channel sandstones are erosive on a small scale, and only occasionally associated with lenticular basal breccias that may infill small-scale erosive gullies. The breccias may also occur within the body of the channel sandstone unit and are almost entirely composed of reworked mudflake intraclasts. Reworked small calcrete nodules (but not rolled vertebrate bones, teeth) have been observed locally in the adjoining Karusa Wind Farm study area (Almond, in prep.). Heterolithic, thinly-interbedded sandstone and mudrock packages associated with some channel sandstones may represent delta-like levee deposits. An interesting feature of some of the finer-grained, homogeneous channel sandstones and darker grey, impure wackes is their tendency to be very well-jointed and show exfoliation weathering, leading to the formation of sphaeroidal corestones in a rather dolerite-like manner. These well-rounded sandstone corestones of cobble to boulder size form an important component of local colluvial and downwasted surface gravels.

Although general mudrock exposure levels within the Soetwater Wind Farm study area are low to very low, there are in fact numerous small exposures available along stream banks and steeper hillslopes, both along the Klein-Roggeveld Escarpment as well as on the plateau (Figs. 4, 16, 17, 18, 27, 29, 30, 31). Much of the Abrahamskraal succession shows low dips (see geological map Fig. 11), and occasionally dips may be fairly steep (*e.g*. Fig. 21, Loc. 559), possibly associated with local faulting, as suggested by zones of quartz mineral lineation in zones of pervasive, steeply-inclined spaced cleavage that transects both mudrocks and fine-grained sandstones (Fig. 22).

Within the greater part of the Abrahamskraal Formation succession building the foot and slopes of the Klein-Roggeveld Escarpment the channel sandstones – probably within the lower portion of the Leeuvlei Member - are fine-grained with tabular geometry, giving a stepped appearance to the landscape (Figs. 4, 5, 13 & 16). The grain-size contract between the fine-grained sandstones / wackes and the silty overbank mudrocks is often slight, so upper and lower surfaces of channel and crevasse-splay sandstones, as well as channel margins, may be ill-defined and transitional. The fine- to very-fine-grained sandstones are typically well-consolidated, well-sorted, greyish to slightly pinkish-purple (sometimes colour-mottled) and well-jointed. They are usually structured by horizontal lamination or fine-scale ripple cross-lamination, or occasionally massive. Lower contacts are only moderately erosional, with no marked gullying, and are usually not associated with well-defined basal breccias. A very thick channel sandstone cropping within Swanepoelshoek may act as a useful marker bed (32º 43′ 24.26″ S, 20º 38′ 40.0″ E)).

Channel sandstones higher in the Abrahamskraal Formation succession – possibly within the Koornplaats Member - tend to be thicker-bedded (up to several meters), massive, with a distinctive large-scale, rounded corestone and crusty weathering pattern (*e.g.* Locs. 559, 570) (Figs. 23, 25, 30, 32, 39). They are variously tabular to lenticular in geometry. Grain-size is medium to coarse, with a slightly crumbly, only moderately well-consolidated texture, frequently speckled or clotted in appearance. Weathering hues vary from yellowish to brown (though often lichen-covered). Fabrics are variously massive, horizontally-laminated (*e.g.* flaggy, with primary current lineation) (Fig. 20), ripple cross-laminated to occasionally trough cross-bedded. Cannonball-sized spheroidal concretions of ferruginous carbonate are of diagenetic origin (Fig. 26). The channel bases are moderately to markedly erosional and gullied. They are often associated with laterally-persistent, prominent-weathering, well-consolidated basal breccias up to 70-100 cm thick of reworked mudflakes and calcrete nodules, and occasionally also plant debris, including rare petrified wood (*e.g.* Loc. 559, 570) (Figs. 24, 47). Basal breccia lenses may be incorporated towards as well as at the base of the channel sandstone package and are often ferruginised. Flaggy sandstones within these successions may show well-developed, laterally-persistent, fine-scale heavy mineral banding. The approximation of the two main sandstone body types is well seen in the Bobbejaanfontein area in the western corner of Orange Fontein 203 (Loc. 559). Several closely-spaced to superimposed, thick-bedded channel sandstones of possible Koornplaats type are also well seen along the edge of the Klein-Roggeveld Escarpment. Lenticular sandstones of similar type are exposed on the west-facing hillslopes of Ruiter se Kop (easternmost Orange Fontein 203) (Figs. 30, 32).

A high proportion of the Abrahamskraal overbank mudrocks within the study area are purple-brown to maroon, while non-reddish mudrocks may be more blue-green than greenish-grey, especially lower down in the succession. Horizons of small to large pedogenic calcrete are moderately common within the overbank mudrock packages at all stratigraphic levels. Larger-scale pedogenic calcretes are usually ferruginous, rusty brown, and often lenticular to irregular in form (Fig. 33), while smaller sphaeroidal calcrete nodules are usually pale grey. Oblique, cylindrical ferruginous calcrete bodies cutting across the mudrock bedding might represent calcretised vertebrate burrow infills (*e.g.* Locs. 557, 568) (Fig. 28), but this is considered unlikely. A small lenticular sandstone body embedded within overbank mudrocks at Loc. 568 is associated with a conglomerate of reworked calcrete nodules and may be an erosional palaeo-gulley infill. Pinkish, lenticular silica pseudomorphs after gypsum ("desert roses") are common at certain horizons within grey-green mudrocks low down within the Abrahamskraal Formation succession on Leeuwehoek 183, indicating highly arid climatic phases on the Middle Permian floodplain (Fig. 15).

Packages of several meters of thin-bedded, blue-grey siltstones with local development of wave-rippled bedding planes may be playa lake facies on the distal floodplain (*e.g.* Loc. 388) (Fig. 19) Thin- to medium-bedded heterolithic intervals (interbedded fine-grained sandstone and mudrock) are usually closely-associated with channel sandstones and are probably levee facies (*e.g.* Loc. 580, 584, 589) (Fig. 14). Lenticular channel sandstones may pass laterally into heterolithic facies, supporting this interpretation (*e.g.* Loc. 570). Thin, single-storey tabular sandstones of probable crevasse splay origin may occasionally be loaded at the base, suggesting soupy substrates on the floodplain.

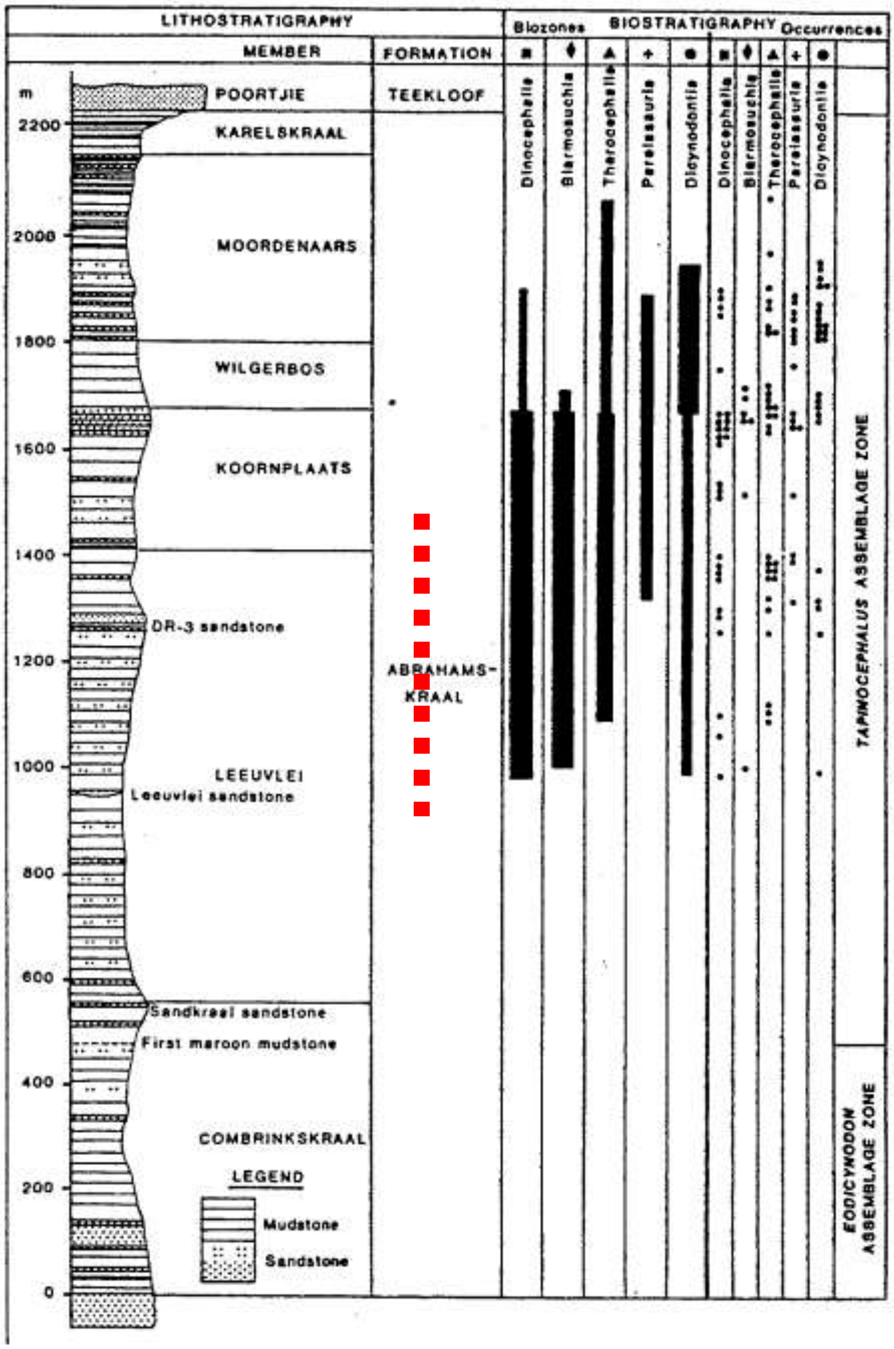

Figure 12. Chart showing the subdivision of the Abrahamskraal Formation in the western Karoo region with stratigraphic distribution of the major fossil vertebrate groups (Loock *et al*. 1994). The Soetwater Wind Farm study area is probably underlain by sediments within the the Leeuvlei Member (dotted red bar), above the first appearance of maroon mudstones, but the uppermost yellow-weathering sandstones may belong to the overlying Koornplaats Member.

Figure 13. Stream bank exposure of channel sandstones and overbank mudrocks of the Abrahamskraal Formation in the escarpment foothills, Leeuwe Hoek 183 (Loc. 575).

Figure 14. Channel sandstones overlain by thin-bedded heterolithic facies, river bank on Leewe Hoek 183 (Loc. 580) (Hammer = 30 cm).

Figure 15. Clumps of silica pseudomorphas after lenticular gypsum crystals ("desert roses") embedded within overbank mudrocks, Leeuwe Hoek 185 (Loc. 580) (Scale in cm).

Figure 16. Extensive river bank exposure of Abrahamskraal Formation bedrocks along the Swanepoelshoek valley, escarpment zone (Zwanepoelshoek 184, Loc. 584).

Figure 17. Laterally extensive bank and bed exposure of Abrahamskraal Formation bedrocks along a major stream valley in the Klein-Roggeveld plateau region, Orange Fontein 203 (Loc. 587).

Figure 18. Detail of exposure seen in previous figure showing thin, lenticular channel feature (Loc. 587)(Hammer = 30 cm).

Figure 19. Thick package of thin-bedded silty overbank mudrocks, Orange Fontein 203 (Loc. 588). Small scale wave ripples in the succession suggest playa lake facies on the distal floodplain (Hammer = 30 cm).

Figure 20. Flaggy-bedded channel sandstones with primary current lineation (N-S) exposed in a river bed near Oranje Fontein homestead (Orange Fontein 203, Loc. 569).

Figure 21. Excellent hillslope and gulley exposure of markedly dipping Abrahamskraal Formation bedrocks near Bobbejanfontein, Orange Fontein 203 (Loc. 559).

Figure 22. Detail of exposure seen in previous figure showing the pervasive steeply-dipping cleavage (Loc. 599)(Hammer = 30 cm).

Figure 23. Incoming of pale brown-weathering medium-grained channel sandstones with erosional bases, Bobbejaanfontein (Orange Fontein 203, Loc. 599).

Figure 24. Detail of base of channel sandstone package seen in the previous figure showing basal and intercalated intraclast breccio-conglomerates, mainly composed of reworked mudflakes and calcrete nodules (Loc. 599)(Hammer = 30 cm).

Figure 25. Typical thick-bedded, massive, medium- to coarse-grained channel sandstone cropping out towards the edge of the Klein-Roggeveld Escarpment, Bobbejaanfontein (Orange Fontein 230, Loc. 599).

Figure 26. Development of cannon ball-sized sphaeroidal concretions of ferruginous carbonate within thick-bedded channel sandstone facies, Bobbejaanfontein (Orange Fontein 203, Loc. 599) (Hammer = 30 cm).

Figure 27. Typical overbank mudrock succession of the Abrahamskraal Formation in the Klein-Roggeveld Plateau area, Orange Fontein 203 (Loc. 568).

Figure 28. Close-up of horizon of large, irregular, rusty-brown concretions of ferruginous carbonate in the upper part of the succession shown in the previous figure (Loc. 568) (Hammer = 30 cm). The inclined subcylindrical concretion *might* be related to a vertebrate burrow (considered unlikely).

Figure 29. Alternating maroon and blue-green overbank mudrocks of the Abrahamskraal Formation (Loc. 555) (Hammer = 30 cm). Note indistinct lower contact of the fine-grained sandstone capping the sequence.

Figure 30. Hillslope exposures of lenticular channel sandstones and maroon overbank mudrocks on the western face of Ruiter se Kop, Orange Fontein 203 (Loc. 570).

Figure 31. Close-up of the overbank succession seen in the previous figure (Loc. 570) (Hammer = 30 cm). The thin-bedded, upward-coarsening heterolithic packages at the base are probably levee deposits.

Figure 32. Thick-bedded, coarse-grained channel sandstone with typical boulder corestone weathering, Ruiter se Kop, Orange Fontein 203 (Loc. 571).

Figure 33. Horizon of large, ferruginous calcrete concretions marking a palaeosol within overbank mudrocks, Orange Fontein 203 (Loc. 557) (Hammer = 30 cm).

2.2. Late Caenozoic Superficial Deposits

On the Klein-Roggeveld plateau alluvial deposits, as exposed in stream-bank and erosion gulley sections, reach thicknesses of up to few meters and are dominated by well-bedded to massive pale buff sands and gravelly sands, with lenticles of fine gravel (*e.g.* Loc. 556) (Figs. 35 & 36). There is often a basal lag of poorly-sorted subangular to well-rounded gravels dominated by Beaufort Group sandstone and indurated mudrock with minor ferruginous palaeocalcrete nodules, reworked younger (Quaternary – Recent) calcrete and vein quartz.

Thick (several meters, up to 5m or more) mixed alluvial, colluvial and sheetwash deposits on hillslopes are exposed by gulley erosion (*e.g.* Loc. 559) (Fig. 40) where they are seen to consist of poorly-sorted sandy matrix as well as angular, blocky sandstone clasts. Prominent-weathering sandstone *kranzes* along and above the escarpment are associated with aprons of angular to well-rounded blocks and corestones of Beaufort Group sandstone (*e.g.* Loc. 560) (Figs. 32 & 39). Downwasted sandstone rubble overlies sandstone channel bodies towards and away from the escarpment edge (Figs. 37 & 38).

Close to and along the main drainage lines in the low-lying *vlaktes* along the north-western margins of the study area very thick deposits of coarse, bouldery alluvial gravels are well exposed in stream sections (Fig. 34). 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. The upper, near-surface layers of the gravels are locally well-calcretised (*e.g.* Locs. 574, 581, 582). The coarser, older gravels are mantled with finer sandy to silty alluvium with downwasted surface gravels, mainly of sandstone. High Level Gravels elevated up to several meters above present stream beds are encountered overlying pediments of Beaufort Group bedrocks along major water courses.

Figure 34. Thick, coarse, poorly-sorted alluvial conglomerates in the escarpment foothills, Zwanepoelshoek 184 (Loc. 581) (Hammer = 30 cm).

Figure 35. Basal rubbly sandstone alluvium overlain by fine gravel and sandy alluvoial deposits, streambanks near Orange Fontein homestead (Loc. 564)(Hammer = 30 cm).

Figure 36. Well-bedded, fine sandy alluvium on the Klein-Roggeveld plateau (Loc. 556) (Hammer = 30 cm).

Figure 37. Downwasted sandstone rubble overlying channel sandstone bedrocks along the edge of the Klein-Roggeveld Escarpment, Leeuwe Hoek 183.

Figure 38. Rubbly sandstone colluvium mantling the upland areas of the Klein-Roggeveld Escarpment, Orange Fontein 203 (Loc. 585).

Figure 39. Apron of bouldery corestone colluvium mantling the slopes beneath a channel sandstone kranz, Bobbejaansfontein area (Orange Fontein 203).

Figure 40. Thick, poorly-sorted deposit of mixed colluvial and alluvial origin with angular sandstone megaclasts exposed in a stream gulley, Bobbejaansfontein (Orange Fontein 203, Loc. 559).

3. PALAEONTOLOGICAL HERITAGE

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

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

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

A chronological series of mappable fossil biozones or assemblage zones (AZ), defined mainly on their characteristic tetrapod faunas, has been established for the Main Karoo Basin of South Africa (Rubidge 1995, 2005, Van der Walt *et al.* 2010). Maps showing the distribution of the Beaufort Group assemblage zones within the Main Karoo Basin have been provided by Keyser and Smith (1979, Fig. 41 herein) and Rubidge (1995, 2005). A recently updated version is now available (Nicolas 2007, Van der Walt *et al.* 2010). The assemblage zone represented within the present study area is the Middle Permian ***Tapinocephalus* Assemblage Zone** (Theron 1983, Rubidge 1995) (See Figs. 12 & 41).

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. 43), small insectivorous millerettids), rare pelycosaurs, and diverse **therapsids** or "mammal-like reptiles" (*e.g.* numerous genera of large-bodied dinocephalians (Figs. 43 & 44), 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 (Fig. 11), Beaufort West sheet 3222, and on the map in Keyser and Smith (1977-78; Fig. 41). Vertebrate fossils found in the Sutherland sheet area are also listed by Kitching (1977) as well as Theron (1983). They include forms such as the pareiasaur *Bradysaurus*, tapinocephalid and titanosuchid dinocephalians *plus* rarer dicynodonts, gorgonopsians and therocephalians (*e.g.* pristerognathids, *Lycosuchus*) as well as land plant remains (*e.g.* arthrophyte stems and leaves). Numerous fossil sites were recorded along the eastern edge of the Moordenaarskaroo in the key biostratigraphic study of the Abrahamskraal Formation by Loock *et al.* (1994). A recent palaeontological heritage study was carried out by the author within the Abrahamskraal Formation of the Moordenaarskaroo to the east of the present study area (Almond 2010a). This fieldwork yielded locally abundant dinocephalian and other therapsid skeletal remains, large, cylindrical vertical burrows or plant stem casts, *Scoyenia* ichnofacies trace fossil assemblages and sphenophytes (horsetail ferns) associated with probable playa lake deposits, as well as locally abundant petrified wood.

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

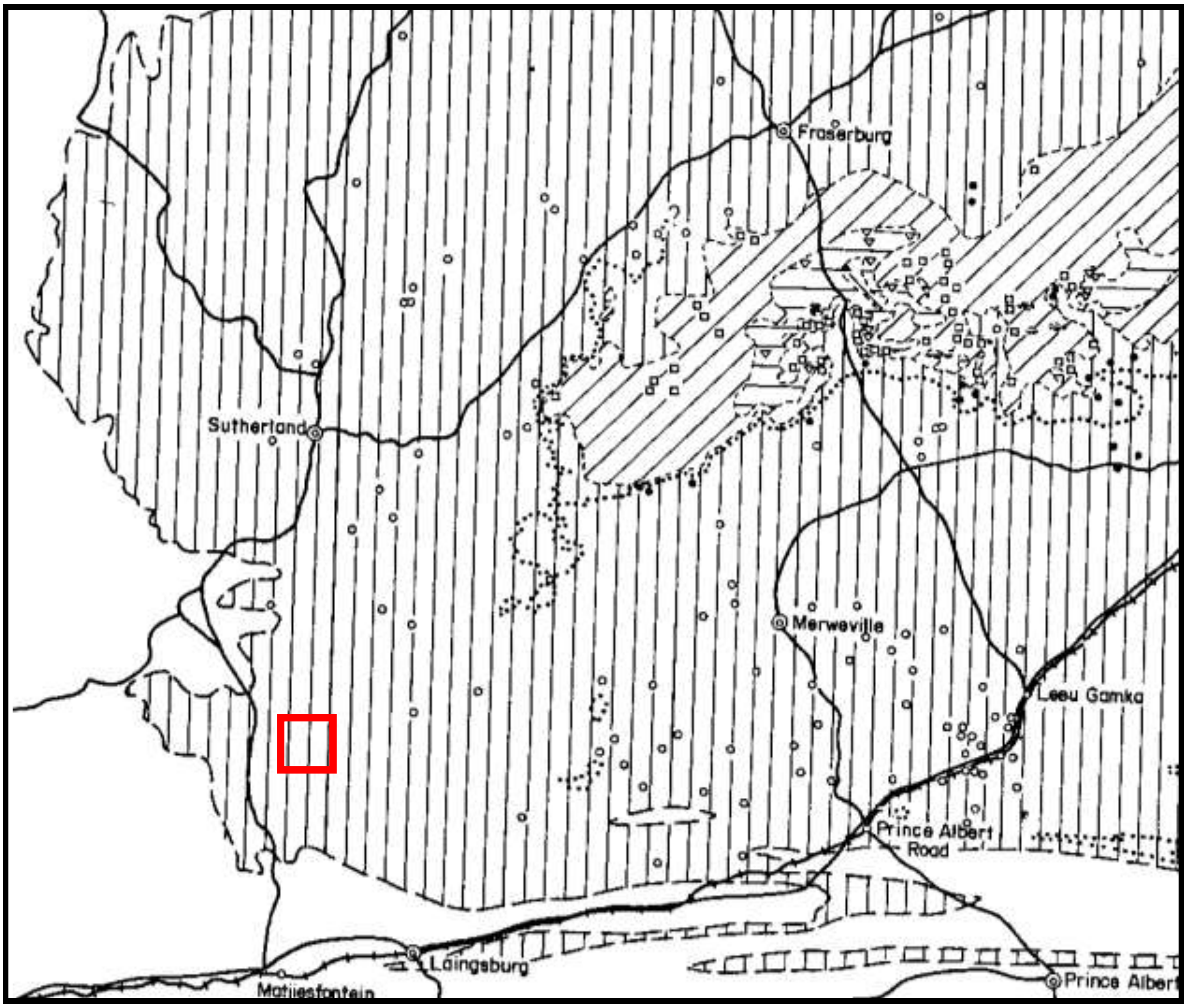

Figure 41. Vertebrate fossil localities within the Lower Beaufort Group in the south-western Karoo region (Map abstracted from Keyser & Smith 1977-78). Outcrop areas with a vertical lined ornament are assigned to the Middle Permian *Tapinocephalus* Assemblage Zone. Note the absence of fossil records from the lower part of the Abrahamskraal Formation in the present Soetwater Wind Farm study area to the south of Sutherland (red rectangle).

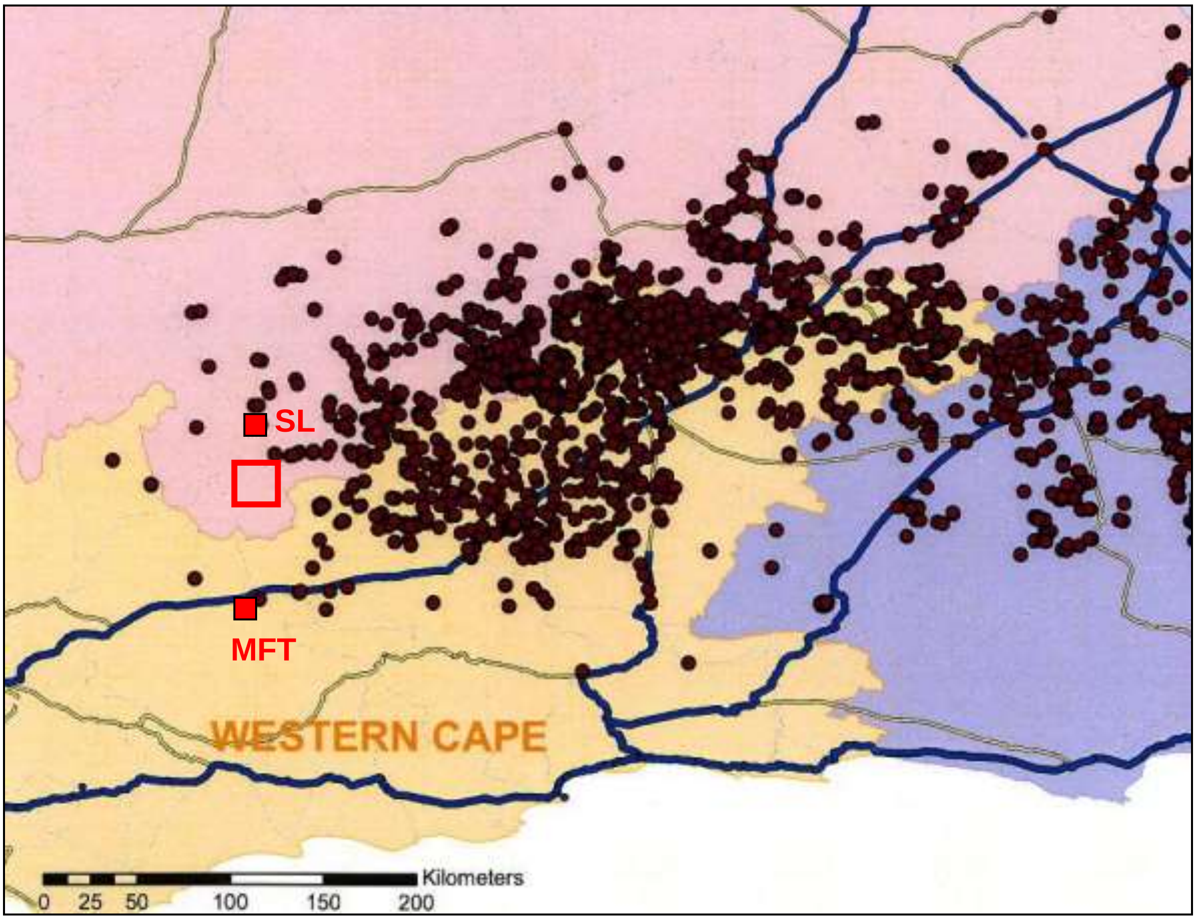

Figure 42. Distribution of recorded vertebrate fossil sites within the south-western portion of the Main Karoo Basin (modified from Nicolas 2007). The approximate location of the Soetwater Wind Farm study area is indicated by the open red square. Note the lack of known fossil sites here. SL = Sutherland. MFT = Matjiesfontein.

Intensive fossil collection within the middle part of the Abrahamskraal Formation succession has suggested that a significant faunal turnover event may have occurred at or towards the top of the sandstone-rich Koornplaats Member, with the replacement of a more archaic, dinocephalian-dominated fauna (with primitive therapsids like the biarmosuchians) by a more advanced, dicynodont-dominated one at this level (Loock *et al.* 1994; Fig. 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).

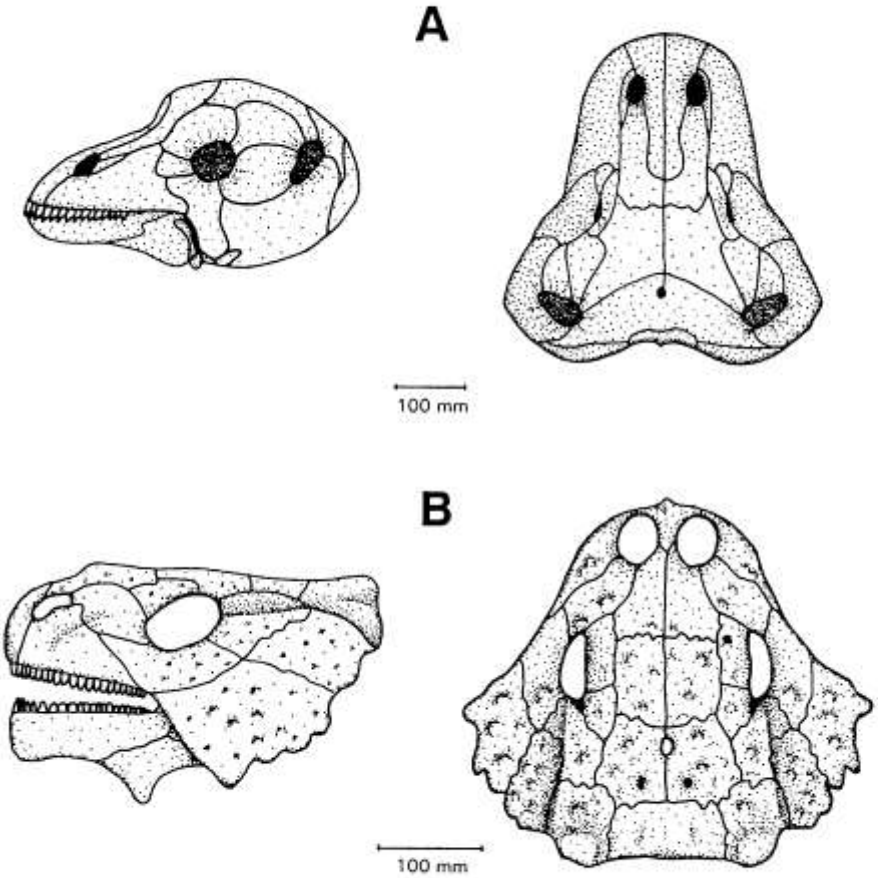

Figure 43. Skulls of two key large-bodied tetrapods of the *Tapinocephalus* Assemblage Zone: A – the dinocephalian therapsid *Tapinocephalus*; B – the pareiasaur *Bradysaurus* (From Smith & Keyser 1995b).

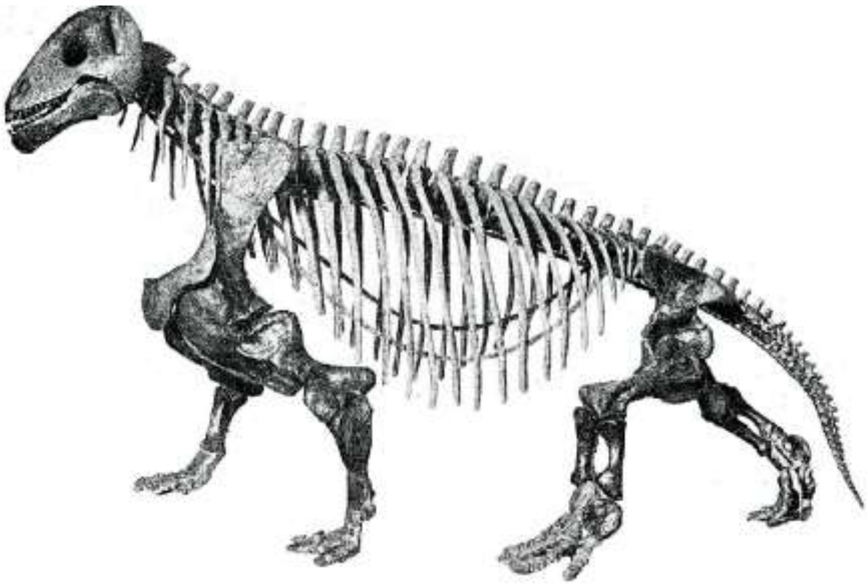

Figure 44. Skeleton of the tapinocephalid (thick-skulled) dinocephalian *Moschops*, a rhino-sized herbivorous therapsid that reached lengths of 2.5 to 3 m and may have lived in small herds.

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. 41) and Nicolas (2007) (Fig. 42). 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. 11). In addition Kitching (1977) provides palaeofaunal lists for specific localities within the Great Karoo region. It is notable that these works suggest a profound paucity of vertebrate fossil finds in the present study area to the south of Sutherland, although a few localities are indicated in stratigraphically lower-lying beds of the Lower Beaufort Group to the west and south of the study area. This palaeontological impoverishment seems to apply even to the excellent exposures of Abrahamskraal Formation sediments within the Verlatekloof Pass near Sutherland. The reasons for the lack of fossils even here - despite appropriate facies and good bedrock exposure - is currently unresolved and may have a palaeoenvironmental component. A previous palaeontological field assessment of Mordenaars Member rocks on the outskirts of Sutherland by Almond (2005) yielded only transported plant remains (arthrophytes including *Phyllotheca*, glossopterid and other, more strap-shaped leaves, possible wood tool marks), sparse trace fossil assemblages of the damp-ground *Scoyenia* ichnofacies, and rare fragments of rolled bone. Reworked silicified wood from surface gravels, scattered, fragmentary plant remains associated with channel sandstones and rare disarticulated bones were reported from a Moordenaars Member study site *c*. 1 km south of Sutherland by Almond (2011). A traverse through the Combrinkskraal and Leeuvlei Members along the Gamma – Omega 765 kV transmission line corridor 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 west of the present study area (Almond 2014) include rare, fragmentary remains of vascular plants - notably disarticulated sphenophyte (horsetail fern) stems embedded within massive siltstones – as well as widely occurring, low-diversity trace fossil assemblages of the *Scoyenia* ichnofacies that have been attributed to earthworms and / or insect larvae (*cf* Seilacher 2007). Current fieldwork within the Karusa Wind Farm study area to the north of Komsberg Substation has only yielded sparse sphenophyte plant stems, *Scoyenia* ichnofacies burrows and unidentified large cylindrical vertical burrows, but no vertebrate remains (Almond, in prep.). No vertebrate fossil material was recorded within any of the Lower Beaufort Group facies reported within the Soetwater Wind Farm study area during the present field study, including the channel lag deposits. The only fossil remains recorded from the Abrahamskraal Formation here include:

- sparse, low-diversity trace fossil assemblages, including arthropod or earthwork scratch burrows of the ichnogenus *Scoyenia* as well as indeterminate sand-infilled cylindrical structures (*c*. 1 cm diameter) that might be vertical invertebrate burrows or perhaps casts of plant stems / roots (Locs. 567, 576) (Figs. 48 & 49).
- *Possible* vertebrate burrows – subcylindrical, oblique to horizontal fine sandstone or calcretised siltstone structures within overbank mudrocks (Locs. 557, 568, 590) (Figs. 28 & 50). No scratch marks were seen are the trace fossil status of these structures is considered questionable.
- Rare pieces of silicified wood showing well-developed seasonal growth lines and ferruginised moulds of woody plant stems (Loc. 571, Orangiefontein 203) (Figs. 45 & 46). The material appears to have weathered out from the base of major channel sandstones (Fig. 47).

The apparent absence of fossil vertebrate bones and teeth within the study area is notable, since a substantial number of Abrahamskral Formation bedrock exposures were examined here during the course of the field study (See Appendix). This may suggest that the bedrocks lie within the fossil-poor lower part of the Leeuvlei Member (Fig. 12) but, as discussed in Section 3.1.2, some of the upper sandstones resemble those of the higher-lying Koornplaats Member.

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 Soetwater Wind Farm study area during the present field study.

Figure 45. Float block of silicified wood among surface gravels, Orange Fontein 203 (Loc. 571) (Scale in cm and mm).

Figure 46. Block of ferruginous basal breccia showing impressions of woody plant stems, Orange Fontein 203 (Loc. 571) (Scale in cm and mm).

Figure 47. Close-up of basal portion of thick channel sandstone package showing reworked grey-green mudrock intraclasts, Ruiter se Kop, Orange Fontein 203 (Loc. 571) (Hammer = 30 cm). This basal zone is probably the source of the transported fossil wood material seen in the previous two figures.

Figure 48. Vertical section through a ripple cross-laminated sandstone bed showing the subvertical cast of a plant stem / root or fossil burrow (Loc. 567) (Scale in cm and mm).

Figure 49. Thin sandstone bed top with silty mudrock veneer showing sections through cylindrical, sand-infilled burrows or plant stem / root casts (Loc. 576) (Scale in mm).

Figure 50. Dorso-ventrally flattened, horizontal body of fine sandstone embedded within maroon overbank mudrocks – questionably a vertebrate burrow cast (Loc. 590) (Hammer = 30 cm).

4. CONCLUSIONS & RECOMMENDATIONS

The fluvial Abrahamskraal Formation (Lower Beaufort Group, Karoo Supergroup) that underlies the Soetwater Wind Farm study area is known for its diverse fauna of Permian fossil vertebrates - notably various small- to large-bodied therapsids and reptiles - as well as fossil plants of the *Glossopteris* Flora and low diversity trace fossil assemblages. However, desktop analysis of known fossil distribution within the Main Karoo Basin shows a marked paucity of fossil localities in the wider study region between Matjiesfontein and Sutherland where sediments belonging only to the lower part of the thick Abrahamskraal Formation succession, below the Moordenaars Member, are represented. Bedrock exposure levels in the broader study region are generally very poor due to the pervasive cover by superficial sediments (colluvium, alluvium, soils, calcrete) and vegetation. Nevertheless, a sufficiently large outcrop area of Abrahamskraal Formation sediments, exposed in stream and riverbanks, borrow pits as well as steep hillslopes and erosion gullies along the Klein-Roggeveld Escarpment and plateau, has been examined during the present field study to infer that macroscopic fossil remains of any sort are very rare here. Exceptions include common low-diversity trace fossil assemblages (small-scale invertebrate burrows, possible plant root casts) and occasional fragmentary plant remains. The latter include horsetail ferns (arthrophytes), moulds of woody plant material and silicified wood fragments weathering out from the base of channel sandstones high up within the local Abrahamskraal Formation succession (Leeuvlei or Koornplaats Member). No fossil vertebrate remains (bones, teeth, coprolites) were recorded within the Soetwater Wind Farm study area, but several questionable vertebrate burrows-like structures were seen. Levels of bedrock tectonic deformation are generally low, although folding, faulting and cleavage development associated within the Cape Fold Belt are locally apparent. Early Jurassic dolerite intrusions are not mapped within the wider study area but are known to occur just to the south. It is concluded that the Lower Beaufort Group bedrocks in the Soetwater Wind Farm study area are generally **of low palaeontological sensitivity** and this also applies to the overlying Late Caenozoic superficial sediments (colluvium, alluvium, calcrete, surface gravels, soils *etc*).

Construction of the proposed Soetwater Wind Farm is unlikely to entail significant impacts on local fossil heritage resources. Due to the general great scarcity of fossil remains as well as the extensive superficial sediment cover observed within the study area, **the overall impact significance of the construction phase of the proposed Soetwater Wind Farm 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.

Given the low impact significance of the proposed Soetwater Wind Farm near Sutherland as far as palaeontological heritage is concerned, no further specialist palaeontological heritage studies or mitigation are considered necessary for this project, pending the potential discovery or exposure of substantial new fossil remains during development. During the construction phase all deeper (> 1 m) bedrock excavations should be monitored for fossil remains by the responsible ECO and/or Contractor's EO. Should substantial fossil remains such as vertebrate bones and teeth, plant-rich fossil lenses, fossil wood or dense fossil burrow assemblages be exposed during construction, the responsible 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 Soetwater Wind Farm project.

Please note that:

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

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

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

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QUALIFICATIONS & EXPERIENCE OF THE AUTHOR

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

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

Declaration of Independence

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

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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
555	S32° 44' 47.6" E20° 42' 50.0"	Haashoogte / Graskop. Good gulley & hillslope exposure of Abrahamskraal Fm mudrocks and sandstones. Possible debris flow slurry of angular mudflakes in calcretised matrix (or *in situ* calcretisation breccia).
556	S32° 45' 54.6" E20° 42' 36.6"	Orangiefontein 203. Stream bank sections through fine-grained alluvium.
557	S32° 46' 04.7" E20° 42' 23.0"	Orangiefontein 203. Gentle hillslope and stream bank exposures of Abrahamskraal Fm mudrocks, large ferruginous calcrete nodules, some possibly developed within large vertebrate burrows (considered unlikely, however).
558	S32° 46' 21.3" E20° 41' 33.4"	Orangiefontein 203. Prominent-weathering thick-bedded channel sandstone near Orangiefontein homestead.
559	S32° 45' 39.5" E20° 37' 53.4"	Orangiefontein 203, Bobbejaanfontein area. Excellent hillslope and gulley exposure of Abrahamskraal Fm mudrocks (dipping, cleaved) and several superimposed yellow-weathering crumbly sandstones with persistent basal breccio-conglomerates, corestone weathering.
560	S32° 45' 44.3" E20° 37' 59.0"	Orangiefontein 203, Bobbejaanfontein area. Well-jointed, well-sorted fine-grained sandstones with sparse mudflake breccia layers.
561	S32° 45' 20.2" E20° 37' 54.5"	Leeuhoek 183. Stream bed and bank exposure of Abrahamskraal Fm mudrocks close to escarpment edge.
562	S32° 45' 01.5" E20° 37' 30.7"	Leeuhoek 183. View point down Klein-Roggeveld Escarpment.
563	S32° 46' 41.0" E20° 41' 09.7"	Orangiefontein 203. Streambed exposure of Abrahamskraal Fm mudrocks overlain by thick alluvial deposits in stream banks.
564	S32° 46' 44.2" E20° 41' 11.4"	Orangiefontein 203. Good vertical sections through coarse, poorly-sorted,semi-consolidated and fine unconsolidated Late Caenozoic alluvium, stream banks.
565	S32° 46' 45.2" E20° 41' 12.6"	Orangiefontein 203. Good vertical sections through coarse, poorly-sorted,semi-consolidated and well-bedded, fine unconsolidated Late Caenozoic alluvium, stream banks
566	S32° 47' 25.0" E20° 42' 26.2"	Orangiefontein 203. Hillslope and gulley exposure of Abrahamskraal Fm mudrocks, large ferruginous palaeocalcrete nodule horizon.
567	S32° 47' 26.1" E20° 42' 27.5"	Orangiefontein 203. Hillslope and gulley exposure of Abrahamskraal Fm mudrocks. Possible plant root traces or fossil burrows within fine-grained, ripple cross-laminated sandstone.
568	S32° 47' 26.8" E20° 42' 31.4"	Orangiefontein 203. Hillslope and gulley exposure of Abrahamskraal Fm mudrocks. Oblique body of ferruginous calcrete – possible tetrapod burrow (considered unlikely). Small-scale sandstone lens associated with reworked calcrete breccia – possible microchannel or palaeogully infill.
569	S32° 46' 27.4" E20° 41' 07.1"	Orangiefontein 203. Extensive streambed exposure of well-jointed flaggy sandstones with primary current lineation, small-scale cut and fill structures, possible trough cross-bedded megaripples. South to north palaeocurrents.
570	S32° 45' 49.0"	Orangiefontein 203. Good hillslope exposures of lenticular,

	E20° 43' 05.6"	thick channel sandstones and overbank mudrocks of Abrahamskraal Fm. Palaeocalcrete horizons, basal mudflake breccias.
571	S32° 45' 52.3" E20° 43' 03.6"	Orangiefontein 203. Float block of petrified wood as well as ferruginised mould of woody stem, probably weathered out from breccias within the base of thick channel sandstone body upslope. Concentration of flaked artefacts here (chert, fine sandstone, vein quartz).
572	S32° 45' 10.4" E20° 43' 17.0"	Drie Roode Heuwels 180. Stream section through Abrahamskraal Fm showing thick heterolithic package and thin-bedded, trough cross-bedded sandstones.
573	S32° 45' 09.7" E20° 43' 18.0"	Drie Roode Heuwels 180. Prominent overhang within thick, sharp-based, grey-green, fine-grained channel sandstone package showing well-devoped current ripple cross-lamination.
574	S32° 41' 54.2" E20° 35' 04.0"	Leeuwehoek 183. Calcretised High Level gravels.
575	S32° 42' 39.5" E20° 35' 34.6"	Leeuwehoek 183. Stream bank section of Abrahamskraal lenticular to tabular fine-grained sandstones and overbank mudrocks.
576	S32° 43' 03.5" E20° 35' 56.6"	Leeuwehoek 183. Stream bank section of Abrahamskraal lenticular to tabular fine-grained sandstones and overbank mudrocks overlain by High Level Gravels. Sand-infilled vertical burrows or plant stem / root casts. *Scoyenia* Ichnofacies trace fossil assemblages.
577	S32° 42' 59.2" E20° 35' 56.9"	Leeuwehoek 183. Stream bank section of Abrahamskraal lenticular to tabular fine-grained sandstones and overbank mudrocks overlain by High Level Gravels. Clusters of pinkish lenticular gypsum pseudomorphs within overbank mudrocks.
578	S32° 43' 10.7" E20° 36' 10.7"	Leeuwehoek 183. Stream bank and long stream gulley section of Abrahamskraal lenticular to tabular fine-grained sandstones and overbank mudrocks. Clusters of pinkish lenticular gypsum pseudomorphs within overbank mudrocks.
579	S32° 43' 10.6" E20° 36' 16.6"	Leeuwehoek 183. Stream bank section of Abrahamskraal lenticular to tabular fine-grained sandstones and overbank mudrocks. Clusters of pinkish lenticular gypsum pseudomorphs within overbank mudrocks.
580	S32° 43' 29.0" E20° 36' 29.5"	Leeuwehoek 183. Stream bank section of Abrahamskraal lenticular to tabular fine-grained sandstones and overbank mudrocks. Thin-bedded heterolithic packages associated with channel sandstones. Clusters of pinkish lenticular gypsum pseudomorphs within overbank mudrocks. Local folding / faulting of Lower Beaufort Group.
581	S32° 42' 06.5" E20° 36' 50.6"	Zwanepoelshoek 184. Stream bank exposure of thick, bouldery alluvial deposits, calcretised towards the top.
582	S32° 43' 11.8" E20° 38' 05.9"	Zwanepoelshoek 184. Thick coarse stream gravels. Hillslope exposure of Abrahamskraal Fm mudrocks and channel sandstones, including lenticular channel edge facies.
583	S32° 43' 15.4" E20° 38' 13.9"	Zwanepoelshoek 184. Good stream bank and bed exposures of Abrahamskraal Fm.
584	S32° 43' 13.7" E20° 38' 28.2"	Zwanepoelshoek 184. Extensive stream bank and steep hillslope exposures of Abrahamskraal Fm.
585	S32° 44' 50.0" E20° 39' 43.6"	Orangiefontein 203. Extensive exposure of Abrahamskraal Fm mudrocks along stream banks and bed. Thin mudflake intraclast breccias within sandstones.
586	S32° 44' 51.2" E20° 39' 40.2"	Orangiefontein 203. Extensive exposure of Abrahamskraal Fm mudrocks along stream banks and bed. Small-scale wave ripples on thin-bedded, fine-grained sandstone

		bedding planes. Erosive base of lenticular channel sandstone.
587	S32° 44' 54.0" E20° 39' 39.6"	Orangiefontein 203. Very extensive, continuous exposure of Abrahamskraal Fm mudrocks and sandstones along stream banks and bed. Thin lenticular minor channel sandstones.
588	S32° 44' 57.2" E20° 39' 42.7"	Orangiefontein 203. Very extensive, continuous exposure of Abrahamskraal Fm mudrocks and sandstones along stream banks and bed. Thick package of thin-bedded siltstone facies, wave-rippled bedding planes. Thin, low-angle trough cross-bedded sandstone lenticles.
589	S32° 45' 01.7" E20° 39' 46.0"	Orangiefontein 203. Very extensive, continuous exposure of Abrahamskraal Fm mudrocks and sandstones along stream banks and bed. Heterolithic thin-bedded facies.
590	S32° 44' 53.7" E20° 39' 39.9"	Orangiefontein 203. Elongate resistant-weathering structure embedded within purple-brown mudrocks. Possible vertebrate burrow (uncertain).