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

Proposed Kokerboom 3 Wind Farm near Loeriesfontein, Namaqua District Municipality, Northern Cape

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EXECUTIVE SUMMARY

Business Venture Investments No. 1788 (Pty) Ltd is proposing to construct Kokerboom 3 Wind Farm in addition to the proposed Kokerboom 1 and 2 Wind Farms which are currently undergoing separate environmental impact assessment (EIA) processes. Kokerboom 3 Wind Farm and associated infrastructure will be situated some 60 km to the north of Loeriesfontein in the Namaqua District Municipality, Northern Cape. The present palaeontological heritage assessment is based on a desktop study combined with a short, field-based scoping study of the broader Kokerboom Wind Farm study area.

The Kokerboom 3 Wind Farm study area is underlain by several formations of potentially fossiliferous Late Palaeozoic sediments of the Ecca Group (Karoo Supergroup) that are extensively intruded by unfossiliferous igneous rocks of the Early Jurassic Karoo Dolerite Suite. The Ecca Group rocks (Prince Albert, Whitehill and Tierberg Formations) are very poorly-exposed and deeply-weathered near-surface. They have also been locally baked (thermally metamorphosed) by nearby dolerite intrusions and occasionally secondarily mineralised. The only fossils recorded within these rocks comprise low-diversity trace fossil assemblages that occur widely within the Loeriesfontein region and are therefore not of unique scientific interest. No fossil vertebrate or plant remains were recorded during the field assessment.

The Karoo dolerites that crop out over portions of the Kokerboom 3 Wind Farm study area are also poorly-exposed, deeply-weathered for the most part and, in addition, do not contain fossils. Several unmapped, small-scale occurrences of post-Karoo breccia pipes and igneous

intrusions were encountered during fieldwork. Some of the associated sandy sediments contain simple invertebrate trace fossils of uncertain age and stratigraphic position. Similar traces have previously been recorded from similar settings elsewhere within the Loeriesfontein region; they are not considered to be of great scientific significance.

None of the wide range of Late Caenozoic superficial deposits examined during fieldwork (*e.g.* alluvium, colluvium, surface gravels, calcretes, stream and pan sediments, sandy soils) appear to be highly fossiliferous. Important mammalian remains are known from pan and river sediments elsewhere in Bushmanland, but they are rare and their occurrence is unpredictable.

Highly sensitive no-go areas within the area have not been identified in this study. It is concluded that the bedrocks and superficial sediments underlying the Kokerboom 3 Wind Farm study area are of *low* palaeontological sensitivity.

Potential impacts to fossil heritage resources within the study area involve the disturbance, damage or destruction of fossil material within the development footprint during the construction phase of the Kokerboom 3 Wind Farm. Due to the rarity of well-preserved, unique fossils of potential scientific importance within the study area, potential impacts on palaeontological heritage during the construction phase are assessed as of *very low (negative) significance* (before and after mitigation). The No-go alternative (*i.e.* no Kokerboom 3 Wind Farm development) will have a neutral impact on palaeontological heritage. Cumulative impacts posed by the three separate Kokerboom Wind Farms are inferred to be low. This also applies to cumulative impacts from known alternative energy developments within a 30 km radius of the project area.

Pending the potential discovery of significant new fossil remains (*e.g.* vertebrate bones and teeth, horn cores, petrified wood) during the construction phase of the Kokerboom 3 Wind Farm, no further specialist palaeontological studies or mitigation are recommended for this project. The Environmental Control Officer (ECO) responsible for the Kokerboom 3 Wind Farm should be made aware of the potential occurrence of scientifically-important fossil remains within the development footprint. During the construction phase all major clearance operations (*e.g.* for new access roads, turbine placements) and deeper (> 1 m) excavations should be monitored for fossil remains on an on-going basis. Should substantial fossil remains - such as vertebrate bones and teeth, or petrified logs of fossil wood - be encountered at surface or exposed during construction, the finds must be safeguarded preferably *in situ*, and South African Heritage Resources Agency, SAHRA, must be alerted as soon as possible (Contact details: Dr Ragna Redelstorff. Heritage Officer Archaeology, Palaeontology & Meteorites Unit, SAHRA. 111 Harrington Street, Cape Town, 8001. Tel: +27 (0)21 202 8651. Fax: +27 (0)21

202 4509 E-mail:rredelstorff@sahra.org.za). This is to ensure that appropriate action (*i.e.* recording, sampling or collection of fossils, recording of relevant geological data) can be taken by a professional palaeontologist at the proponent's expense.

The palaeontologist concerned with any 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).

These monitoring and mitigation recommendations should be incorporated into the Environmental Management Programme (EMPr) for the Kokerboom 3 Wind Farm. The operational and decommissioning phases of this development is unlikely to have further significant impacts on palaeontological heritage and no recommendations are made in this regard.

1. INTRODUCTION

The proposed Kokerboom 3 Wind Farm, near Loeriesfontein, Northern Cape, overlies potentially fossiliferous bedrocks and superficial sediments of Permian to Recent age. Fossil remains preserved within these underlying rocks or exposed at surface are protected by law (National Heritage Resources Act, 1999) and may be disturbed, damaged or destroyed by the proposed wind farm development. The present combined desktop and field-based palaeontological heritage assessment has therefore been commissioned by Aurecon South Africa (Pty) Ltd as part of a comprehensive Heritage Impact Assessment for this alternative energy development, including all three proposed wind farms as well as the associated 132 kV transmission line connection to Helios Substation. This report relates to the Kokerboom 3 Wind Farm only. The Kokerboom 1 and 2 Wind Farms and grid connection infrastructure have been assessed *via* separate EIA processes, and a Basic Assessment process, respectively.

2. PROJECT OUTLINE & BRIEF

2.1. Project outline

The company Business Venture Investments No. 1788 (Pty) Ltd is proposing to construct Kokerboom 3 Wind Farm, in addition to two proposed wind farms that are currently undergoing EIA processes. The proposed Kokerboom 3 Wind Farm will be situated some 60 km to the north of Loeriesfontien in the Namakwa District Municipality and Hantam Local Municipality, Northern Cape (Figs. 1 & 2). The following land parcels are involved in Kokerboom 3 Wind Farm (See Figs. 1 & 2):

- Aan De Karree Doorn Pan Remainder of Farm 213
- Karree Doorn Pan Portion 1 of Farm 214
- Karree Doorn Pan Portion 2 of Farm 214

It is anticipated that the proposed Kokerboom 3 Wind Farm will generate up to 240 MW of electricity, with up to 60 wind turbines. The main infrastructural components associated with the Wind Farm will include:

- Gravel surface access roads (*c*. 8 m wide with 12m buffer/ reserve);
- Hard standing areas (*c*. 50 m x 25 m) alongside the turbines;
- A satellite substation (*c*. 120 x 120 m) to step up the current from medium voltage (e.g. 33kV) to 132kV;
- Workshop and administration buildings;
- Temporary lay-down areas;
- Medium voltage (MV) overhead and underground transmission lines; and
- High voltage (HV) overhead transmission lines.

Two switching stations (c 100 x 100 m) and a 132kV overhead transmission line required to connect the wind farm to the national electricity grid will be assessed separately in a basic assessment process.

Aurecon South Africa (Pty) Ltd (Aurecon) has been commissioned by the proponent to carry out three Environmental Impact Assessment (EIA) processes for the proposed Kokerboom Wind Energy Facilities (i.e. Kokerboom 1, 2 and 3) as well as one Basic Assessment (BA) process for the associated switching stations and transmission lines (Aurecon contact details: Ms Mieke Barry. Senior Environmental Consultant, Aurecon South Africa (Pty) Ltd. Address:

Aurecon Centre, 1 Century City Drive, Waterford Precinct, Century City, South Africa. Tel: +27 21 5266025. Fax: +27 86 5359856. E-mail: Mieke.Barry@aurecongroup.com).

2.2. Terms of Reference

The following Terms of Reference for the present palaeontological study have been defined by Aurecon South Africa (Pty) Ltd:

Palaeontological heritage impact assessment for three Environmental Impact Assessments and one Basic Environmental Assessment, to be undertaken by the Consultant. These are for three proposed Wind farms generating up to 240-256MW of electricity each, and one associated Transmission Line, near Loeriesfontein in the Northern Cape Province, South Africa. This report focuses on the Kokerboom 3 Wind Farm.

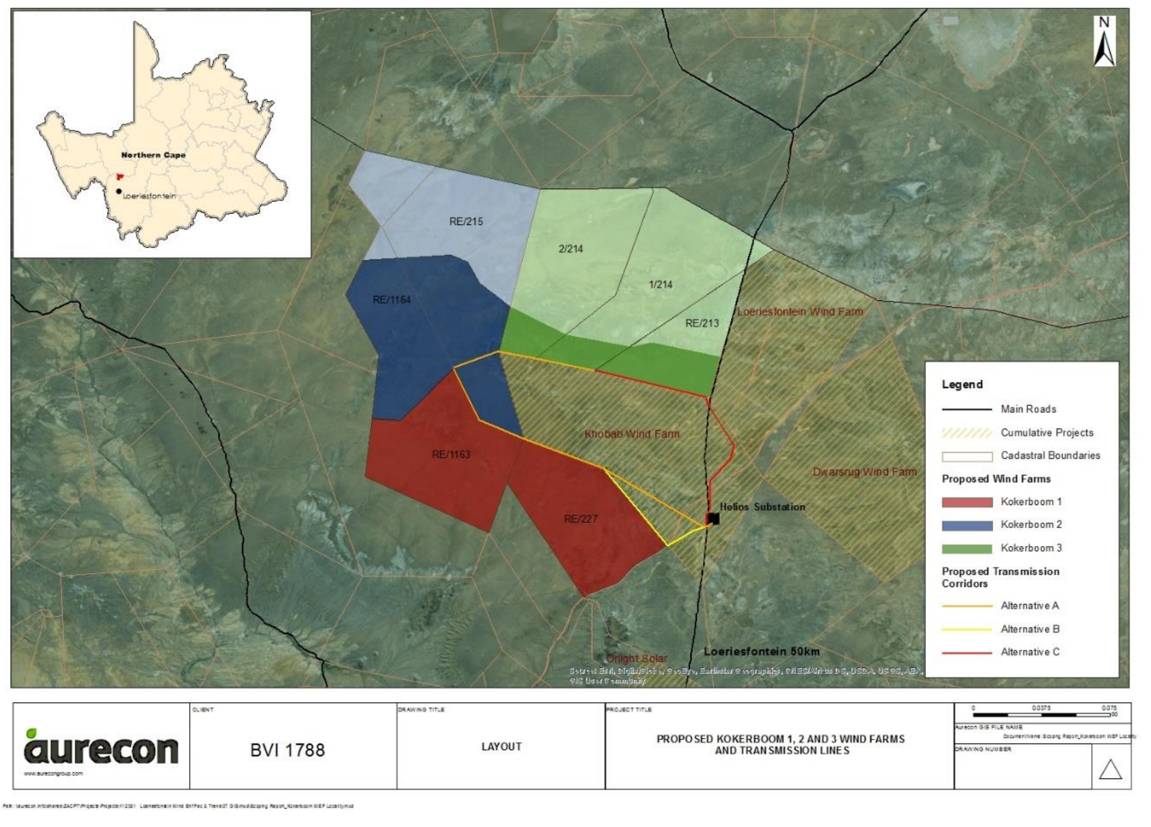

Figure 1: Map showing the location of the land parcels concerned in the proposed Kokerboom WEF situated some 60 km to the north of Loeriesfontein, Northern Cape. The development areas of the three constituent wind farms making up the WEF development are indicated by the darker colours. Kokerboom 3 Wind Farm is highlighted in dark green (Image provided by Aurecon South Africa (Pty) Ltd).

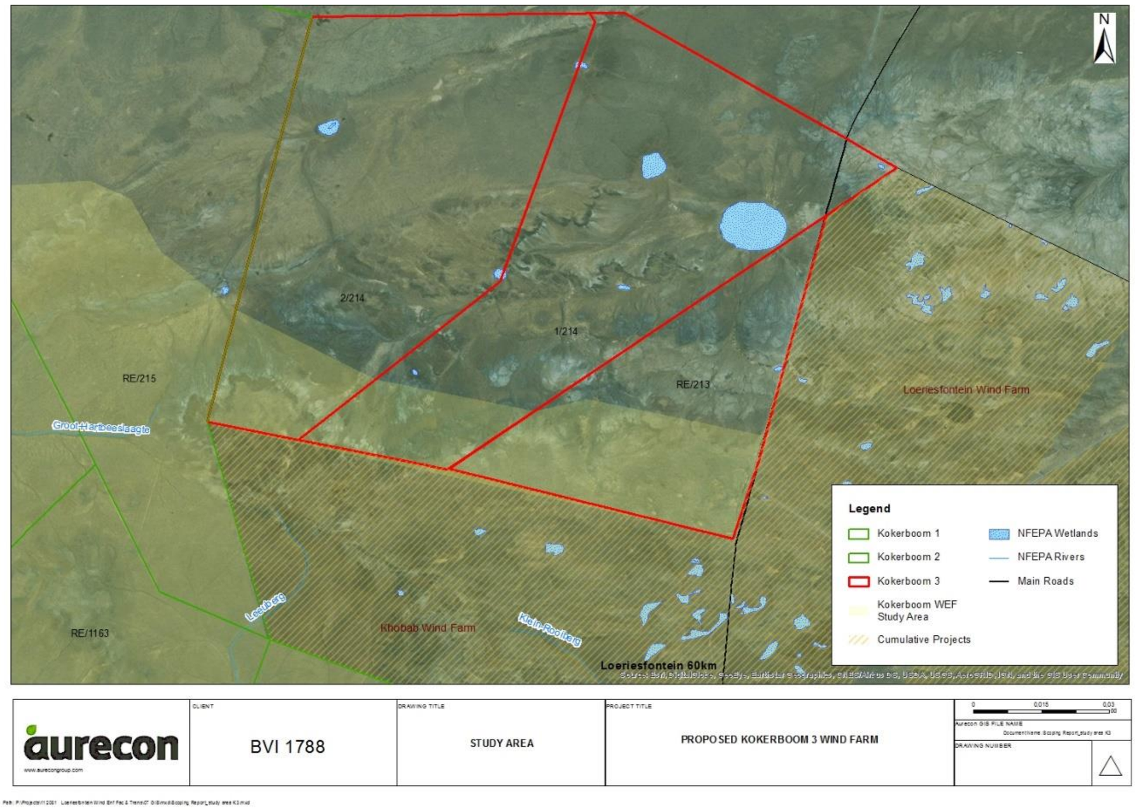

Figure 2. Satellite image of the semi-arid region of southern Bushmanland north of Loeriesfontein showing the study area considered by specialists (yellow polygon) and the land parcels concerned in the Kokerboom 3 Wind Farm (red polygons).

3. APPROACH TO STUDY

This PIA report provides an assessment of the observed or inferred palaeontological heritage within the Kokerboom 3 Wind Farm study area, with recommendations for specialist palaeontological mitigation where this is considered necessary. The report is based on (1) a review of the relevant scientific literature, including previous palaeontological impact assessments in the area (*e.g.* Almond 2008c, 2011a, 2011b, 2014b, 2014c), (2) published geological maps and accompanying sheet explanations, (3) a three-day field study in the broader Kokerboom WEF study area north of Loeriesfontein (23-25 June 2016) as well as (4) the author's extensive field experience with the formations concerned and their palaeontological heritage (*e.g.* Almond *in* Macey *et al.* 2011).

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 scoping during the compilation of the final report). This data is then used to assess the palaeontological sensitivity of each rock unit to development (Provisional tabulations of palaeontological sensitivity of all formations in the Western, Eastern and Northern Cape have already been compiled by J. Almond and colleagues; *e.g.* Almond & Pether 2008) and are shown on the palaeosensitivity map on the SAHRIS (South African Heritage Resources Information System) website. The likely impact of the proposed development on local fossil heritage is then determined on the basis of (1) the palaeontological sensitivity of the rock units concerned and (2) the nature and scale of the development itself, most notably the extent of fresh bedrock excavation and ground clearance envisaged. When rock units of moderate to high palaeontological sensitivity are present within the development footprint, a field assessment study by a professional palaeontologist is usually warranted.

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

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

On the basis of the desktop and field studies, the likely impact of the proposed development on local fossil heritage and any need for specialist mitigation are then determined. Adverse palaeontological impacts normally occur during the construction rather than the operational or decommissioning phase. Mitigation by a professional palaeontologist – normally involving the recording and sampling of fossil material and associated geological information (*e.g.* sedimentological and taphonomic data) – is usually most effective 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 authority, SAHRA (Contact details: Ms Ragna Redelstorff, Heritage Officer Archaeology, Palaeontology & Meteorites Unit South African Heritage Resources Agency. P.O. Box 4637, Cape Town 8000. Tel: 021 462 8651. Fax: 021 462 4509. Email: rredelstorff@sahra.org.za). It should be emphasised 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.

4. ASSUMPTIONS AND LIMITATIONS

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

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

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

major influence on the impact significance of a given development on fossil heritage and can only be reliably assessed in the field.

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

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

5. Absence of a comprehensive computerised 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, as in the case of the present study.

In the case of the Kokerboom 3 Wind Farm study area near Loeriesfontein in the Northern Cape preservation of potentially fossiliferous bedrocks is favoured by the semi-arid climate and sparse vegetation. However, bedrock exposure is highly constrained by extensive superficial deposits, especially in areas of low relief, as well as pervasive karooid *bossieveld* vegetation (Bushmanland Basin Shrubland). The study area is very extensive and for the most part fairly flat, with some gentle hillslopes and few access roads. However, sufficient bedrock exposures were examined during the course of the three-day field study to assess the palaeontological heritage sensitivity of the main rock units represented within the study area (See Appendix for locality data). Comparatively few academic palaeontological studies have been carried out hitherto in the region, so any new data from impact studies here are of scientific interest. Palaeontological and geological data from the recent field study is usefully supplemented by those from several other field-based fossil heritage impact studies carried out in the Loeriesfontein region by the author in recent years (See reference list). Confidence levels for this impact assessment are consequently rated as moderate, despite the unavoidable constraints of limited exposure, time and access.

5. LEGISLATIVE CONTEXT

The present combined desktop and field-based palaeontological heritage report falls under Sections 35 and 38 (Heritage Resources Management) of the South African Heritage Resources Act (Act No. 25 of 1999), and it will also inform the 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;
- 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).

6. GEOLOGICAL CONTEXT

The broader study area for the Kokerboom Wind Energy Facility (WEF) (consisting of Kokerboom 1, 2 and 3 Wind Farms), situated *c*. 60 km north of Loeriesfontein, lies within semi-arid, gently undulating terrain at elevations between *c*. 900 and 1000 m masl on the southern borders of the Bushmanland region (Figs. 1 & 2). The prominent, dolerite-capped hills of Groot Rooiberg, Klein Rooiberg and Leeuberg just to the south reach elevations of *c*. 880-1000 m amsl. (Fig. 5). The Sishen-Saldanha railway runs to the southeast and the Loeriesfontein – Granaatboskolk - Pofadder dust road traverses the eastern margins of the area. Several large pans are located some 10-20 km to the north and northeast. The southern portion of the Kokerboom WEF study area is drained by several southwesterly-flowing streams that eventually join the ancient Kromrivier drainage system flowing down into the Knersvlakte through a gap in the Great Escarpment. The northern portion of the area is drained by comparatively few ephemeral streams that flow into pans within or outside its margins (*e.g.* Kareedoringpan, Konnes se Pan) (Fig. 31).

The Kokerboom WEF study area is characterised by gently-undulating terrain with low hills, few rocky *kranzes* (ridges or scarps), shallow, usually dry water courses and extensive gravelly *vlaktes* (plains) (Figs. 3 & 4). The landscape is mantled in low karroid *bossieveld* with few, small trees along water courses and in rocky areas. In general levels of bedrock exposure are very low indeed due to the pervasive cover by superficial sediments (alluvium, colluvium, surface gravels, pedocretes *etc*); it is mainly limited to sporadic small dolerite *koppies*, stream beds, low scarps, erosion gullies as well as the margins of pans and dams. Several borrow pits, mainly situated along the Loeriesfontein – Pofadder dust road, provide important additional windows into the subsurface geology.

Figure 3: Typical low-relief terrain in the Kokerboom WEF study area, here on Karee Doorn Pan 214. Note surface gravels of reworked calcrete.

Figure 4: Sandy soils overlying nodular subsurface calcrete in the south-eastern portion of the broader Kokerboom WEF study area (Kleine Rooiberg 227; Kokerboom 1).

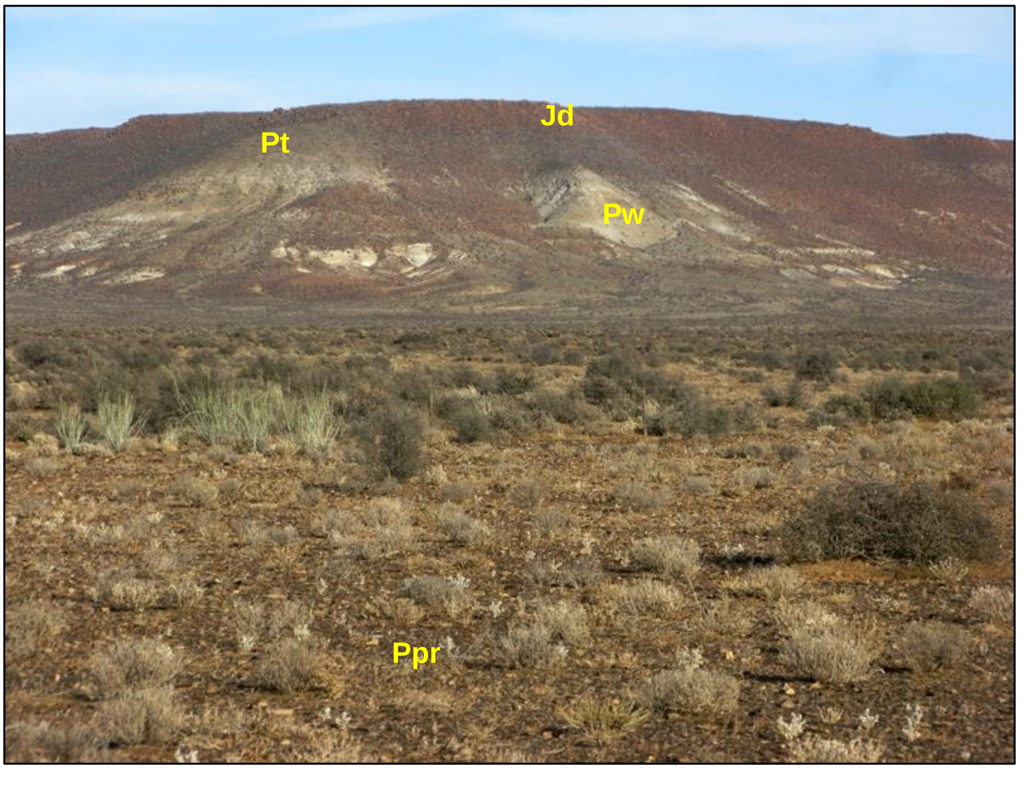

Figure 5: The main stratigraphic units represented in the Kokerboom WEF study area, as seen on the northern flanks of the Klein Rooiberg, just south of the area itself. Ppr = Prince Albert Fm; Pw = Whitehill Fm; Pt = Tierberg Fm; Jd = Karoo Dolerite Suite.

The Loeriesfontein region lies towards the north-western edge of the Main Karoo Basin of South Africa (Johnson *et al.* 2006). The geology of the Kokerboom WEF study area is shown on 1: 250 000 geology sheet 3018 Loeriesfontein (Macey *et al.* 2011) (Fig. 6). The sedimentary bedrock successions involved are predominantly basinal mudrocks assigned to the Early to Middle Permian **Ecca Group** (**Karoo Supergroup**) (See stratigraphic column in Fig. 10). They become broadly younger towards the east, although this pattern is largely obscured by much later, extensive dolerite intrusions. The three Ecca Group subunits represented in the study area include (1) dark mudrocks and fine-grained sandstones of the **Prince Albert Formation** (Ppr); (2) white-weathering carbonaceous mudrocks of the **Whitehill Formation** (Pw) followed by grey-green mudrocks and wackes (impure sandstones) of the **Tierberg Formation** (Pt). Early Jurassic sills of the **Karoo Dolerite Suite** (Jd) intrude the Ecca Group country rocks over large areas, especially in the west. In addition, several **breccia pipes** associated with Karoo dolerite intrusion occur in the area, but are unmapped. Swarms of such intrusive pipes are well known from the Karoo region north of Loeriesfontein where they are especially abundant in the Prince Albert Formation outcrop area but also pierce through the overlying Whitehill rocks (*cf.* Macey *et al.* 2011, Almond 2014c). Several small-scale intrusive bodies (possibly dykes) of pale greyish igneous rock encountered within the study area are tentatively assigned to the Late Cretaceous / early Tertiary **Gamoep Suite** (*cf* Macey *et al.* 2011, Chapter 6). A range of Late Caenozoic superficial sediments - mostly unconsolidated and probably of Quaternary to Recent age – represented within the study area include alluvial and pan deposits, pedocretes (*e.g.* calcrete), surface gravels (including doleritic rubble) and various sandy to gravelly soils.

In the remainder of this section of the report these various rock units are briefly described and illustrated with reference to the broader Kokerboom WEF study area (yellow polygon in Fig. 6), including the Kokerboom 3 Wind Farm study area (black polygon in Fig 6.) GPS data for all numbered localities mentioned in the text are given in the Appendix 1.

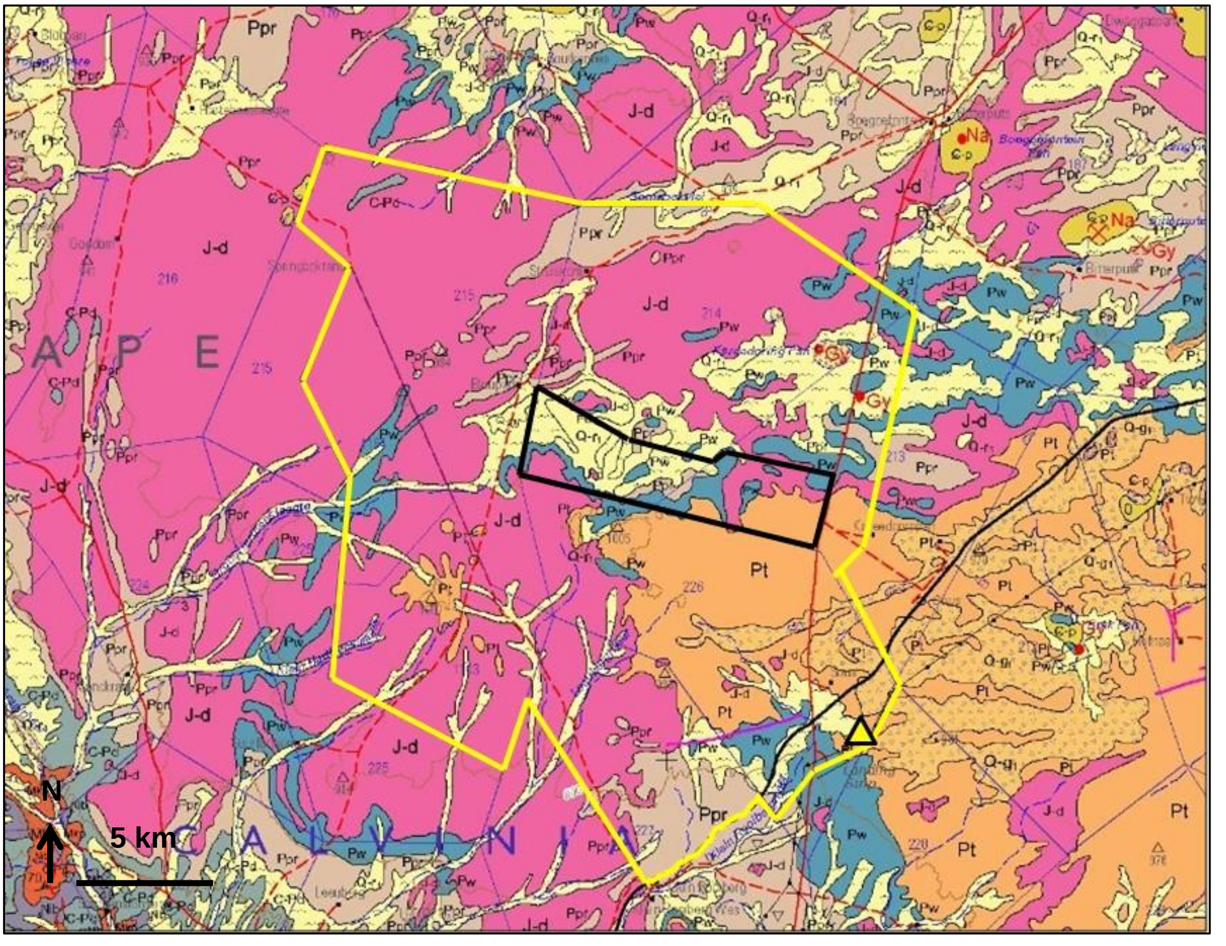

Figure 6: Extract from 1: 250 000 geology sheet 3018 Loeriesfontein showing the land parcels concerned with the larger Kokerboom WEF project (yellow polygon) situated *c*. 60 km north of Loeriesfontein, Northern Cape (Council for Geoscience, Pretoria). The black polygon shows the Kokerboom 3 Wind Farm study area, while the existing Eskom Helios Substation on farm Sous 226 is indicated by the yellow triangle.

The main rock units represented within the study area are:

1. KAROO SUPERGROUP

- **ECCA GROUP**

Prince Albert Formation (Ppr, buff)
Whitehill Formation (Pw, blue)
Tierberg Formation (Pt, orange)

2. KAROO DOLERITE SUITE

Dolerite sills and dykes (J-d, pink)

3. LATE CAENOZOIC SUPERFICIAL SEDIMENTS

Stream and river alluvium (pale yellow with flying bird symbol), sandy soils (Q-r1, pale yellow), dolerite rubble (Q-g1, pale orange with triangle symbols), unmapped scree deposits, various surface gravels, pan sediments (red dotted areas; Gy = gypsum deposits).

6.1. Ecca Group

Useful recent geological accounts of the Early to Middle Permian Ecca Group in the Loeriesfontein area are given by De Beer *et al.* (2002), Johnson *et al.* (2006), Johnson (2009) and Macey *et al.* (2011). Most of the Ecca Group bedrocks in the study area are mantled with shaly or doleritic surface gravels, or other superficial sediments, or obscured by shrubby vegetation (See, for example, Figs. 12 & 18). However, a few good exposures are seen in river beds and borrow pits. Better examples in the Loeriesfontein region have already been described and illustrated in previous palaeontological assessment reports by the author (*e.g.* Almond 2014b, 2014c).

- **Prince Albert Formation (Ppr)**

As shown on the new 1: 250 000 geological map (Fig. 6), basinal mudrocks of the **Prince Albert Formation** (Ppr) are poorly represented within the broader Kokerboom WEF study area except in the extreme south and north. These areas often appear dark on satellite images because the outcrop is mantled in gravels rich in ferromanganese minerals (Gravel clasts often have a shiny-black patina of "desert varnish"). Key geological accounts of the Prince Albert Formation are given by Visser (1992) and Cole (2005), while Macey *et al.* (2011) and Almond (2014c) describe occurrences in the Loeriesfontein area. The succession is Early Permian (Asselian / Artinskian) in age and was previously known as "Upper Dwyka Shales". The Prince Albert succession consists mainly of tabular., thin--bedded mudrocks of blue-grey, olive-grey to reddish-brown colour with occasional thin (dm) buff sandstones and even thinner (few cm), soft-weathering layers of yellowish water-lain tuff (*i.e.* volcanic ash layers). Deposition was largely by suspension settling of fine muds in a fairly deep, cool, post-glacial sea. Extensive diagenetic modification of these sediments has led to the formation of thin cherty beds, pearly- blue phosphatic nodules, rusty iron carbonate nodules, as well as beds and elongate ellipitical concretions impregnated with iron and manganese minerals. These last occur within prominent-weathering, metallic-looking beds, some of which display well-developed snuffbox weathering and concentric *Liesegang* rings. Partial cementation of fine-grained siliciclastics by secondary minerals may result in the formation of distinctive "spherulitic" horizons that are spotted with small spherical nodules of silica and / or iron minerals.

Figure 7: Flaggy, grey-green mudrocks of the Prince Albert Formation exposed in the bed of the Klein-Rooibergrivier to the east of Klein Rooiberg Wes (Loc. 249).

Figure 8: Close-up of laminated mudrocks of the Prince Albert Formation (Loc. 249) (Hammer = 30 cm).

Figure 9: Dark grey baked hornfels of the Prince Albert Formation on hillslopes north of Bloupan farmstead (Loc. 254) (Hammer = 30 cm).

Extensive bedding plane exposures of tabular-bedded, flaggy, greenish-grey laminated mudrocks of the Prince Albert Formation are exposed in the bed of the Klein-Rooibergrivier to the east of Klein Rooiberg Wes (Figs. 7 & 8). Elsewhere the outcrop area of this formation is largely mantled in angular, platy surface gravels of mudrock and dark grey hornfels, with common desert-vanished ferruginised mudrock clasts (Fig. 9).

- **Whitehill Formation (Pw)**

A broad band of country across the Kokerboom WEF study area is underlain by finely-laminated sediments of the Whitehill Formation (Pw) but this recessive-weathering unit is extensively intruded and baked by Karoo dolerite. It comprises a thin (*c*. 80 m) succession of well-laminated, carbon-rich mudrocks of Early / Mid Permian (Artinskian) age. These distinctive clay-rich and subordinate silty sediments were laid down about 278 Ma (million years ago) in an extensive shallow, brackish to freshwater basin – the Ecca Sea – that stretched across southwestern Gondwana, from southern Africa into South America. Thin volcanic tuffs and large, irregular to oblate dolomitic diagenetic nodules occur within the laminated mudrocks. Key fossiliferous exposures of the Whitehill Formation are present on the outskirts of Loeriesfontein and elsewhere on 1:250 000 geology sheet 3018 (McLachlan & Anderson 1973, Oelofsen 1981, 1987, Visser 1992, 1994, Cole & Basson 1991, Johnson *et al*. 2006, Almond 1996, Macey *et al.* 2011, Evans & Bender 1999, Evans 2005, Johnson *et al*.

2006). Near-surface weathering of these highly-carbonaceous sediments to release gypsum produces pale grey to cream colours that are readily seen in satellite images and hillslopes where the bedrock is exposed (Fig. 2). Good sections through the Whitehill Formation are seen on the northern and western flanks of the Klein Rooiberg, just south of the present study area (Figs. 7 & 8).

Most of the Whitehill Formation outcrop within the Kokerboom WEF study area is topographically subdued and mantled with pale grey platy mudrock clasts as well as fragments of downwasted dolomite concretions and gypsum (Fig. 12). Locally, upward-coarsening packages of dark, paper-laminated to thin-bedded mudrocks are exposed along low scarps, capped by thin-bedded greyish siltstones (Fig. 13) that are recorded in the middle and top of the Whitehill Formation succession in the Loeriesfontein area (See stratigraphic log, Fig. 10). Both laminated and silty facies are well-exposed in several roadside borrow pits as well as erosion gullies along pan margins in the eastern part of the broader Kokerboom WEF study area (Karee Doorn Pan 214). The bedrocks here are deeply-weathered and covered with a thick mantle of saprolite (*in situ* weathered material) and silty soils (Figs. 14, 32). Lenses and thin horizons of transluscent gypsum are common. Whitehill beds exposed in an old gypsum borrow pit at Loc. 263 show small-scale folding that is probably a consequence of extensive secondary ferro-manganese mineralisation as well as surface gossans and irregular gypsum lenses (Figs. 15 & 16).

Thin tabular beds and lenses of a hard, creamy-whitish mineral, variously showing a vuggy (*i.e.* containing open cavities), fibrous or pustular texture, are locally associated with the Whitehill Formation outcrop on Karee Doorn Pan 214 (*e.g.* Loc. 237) (Figs. 16a & 16b). The identity and origin of these mineral bodies are unclear; they may represent secondary modification (*e.g.* silicification) of gypsum or calcrete, perhaps associated with Mesozoic or younger hydrothermal activity, though this is highly speculative.

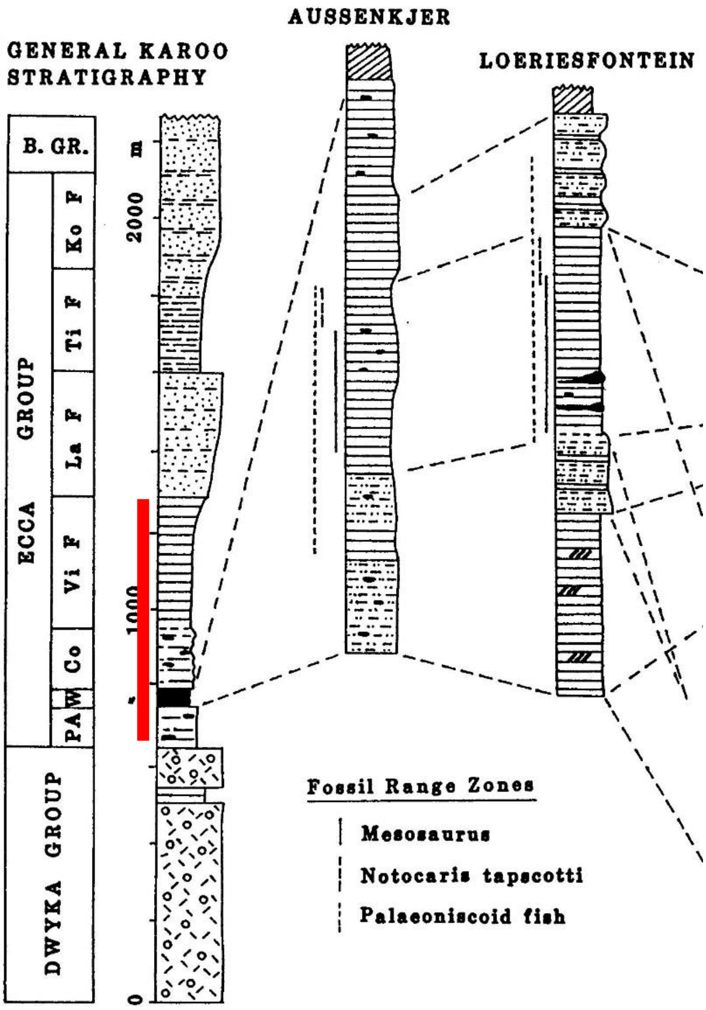

Figure 10: Stratigraphy of the Ecca Group in the Main Karoo Basin (Modified from Visser 1992). The position of the Prince Albert (PA) and Whitehill (W) Formations as well as the overlying basal mudrocks of the Tierberg Formation (equivalent to Co and Vi F on this figure) represented in the present study area is emphasized here by the red bar. On the right hand side is presented a detailed section through the Whitehill Formation at Loeriesfontein, showing the range zones of major fossil groups.

Figure 11: Good hillslope exposures of the pale-weathering Whitehill Formation on the northern side of Klein Rooiberg, just south of the Kokerboom WEF study area. Prominent-weathering silty beds are seen in the middle and towards the top of the Whitehill succession (*cf* Fig. 10).

Figure 12: Typical low-relief outcrop of the Whitehill Formation within the study area, the bedrocks mantled by pale grey, platy mudrock clasts (Loc. 244).

Fig. 13. Low *kranz* of dark- to pale grey-weathering, papery carbonaceous Whitehill mudrocks overlain by thin-bedded grey siltstones (Loc. 244) (Hammer = 30 cm).

Figure 14: Borrow pit cut face section through gently-dipping, tabular-bedded mudrocks of the Whitehill Formation overlain by saprolite and thick, silty, gypsiferous soils (Loc. 261) (Hammer = 30 cm).

Figure 15: Thick lenticular body of layered, greyish, transluscent gypsum exposed in an old gypsum quarry excavated into the Whitehill Formation (Loc. 263) (Hammer = 30 cm).

Figure 16: Folding and contortion of thin beds in the Whitehill Formation associated with extensive secondary ferro-manganese mineralisation (Loc. 263) (Hammer = 30 cm).

Figure 16a. Rubbly surface exposure of unidentified dense, opaque white rock of uncertain identity – possibly a hydrothermal alteration product – associated with the Whitehill Formation outcrop area on Karee Doorn Pan 214 (Loc. 237).

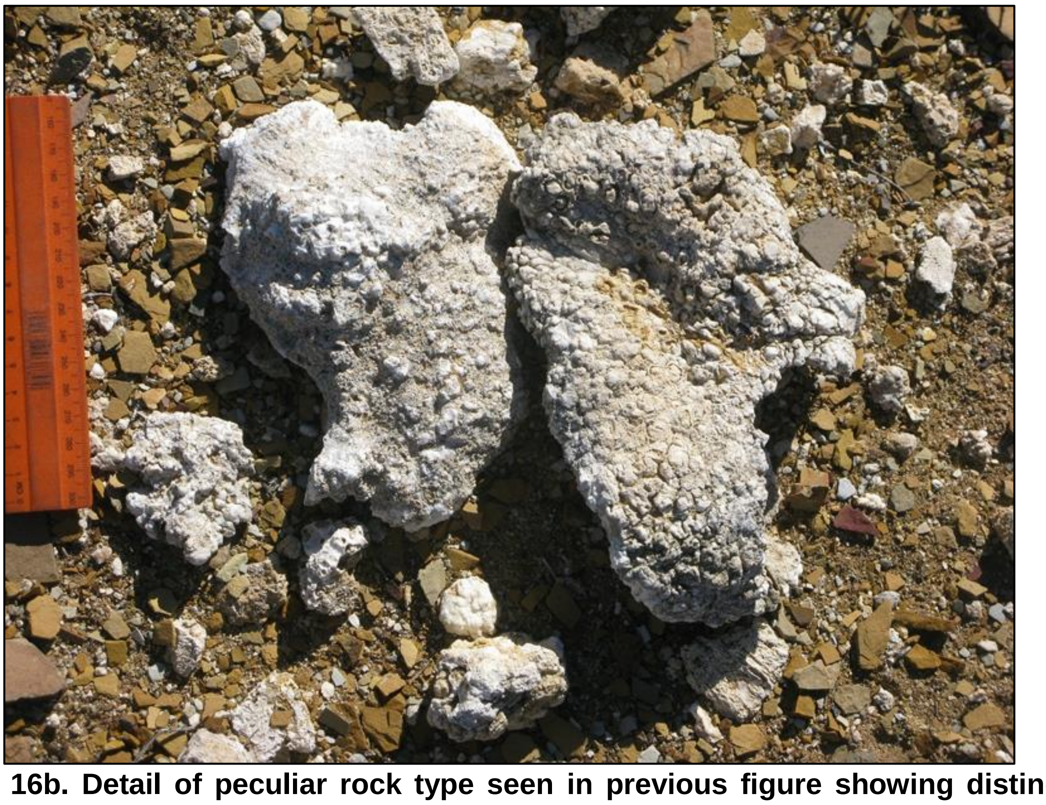

Figure 16b. Detail of peculiar rock type seen in previous figure showing distinctive pustulose surface texture that is considered to be of non-biological origin (Scale in cm and mm).

- **Tierberg Formation (Pt)**

The Tierberg Formation is a thick, recessive-weathering, mudrock-dominated succession consisting predominantly of dark, often brown to grey, well-laminated, carbonaceous shales with subordinate thin, fine-grained sandstones or wackes (Prinsloo 1989, Le Roux 1993, Viljoen 2005, Johnson *et al*., 2006). The Tierberg shales are Early to Middle Permian in age and were deposited in a range of offshore, quiet water environments below wave base. These include basin plain, distal turbidite fan and distal prodelta in ascending order (Viljoen 2005, Almond *in* Macey *et al.* 2011). Thin coarsening-upwards cycles occur towards the top of the formation with local evidence of soft-sediment deformation, ripples and common calcareous concretions. Thin water-lain tuffs (volcanic ash layers) are also known. A restricted, brackish water environment is reconstructed for the Ecca Basin at this time. Close to the contact with Karoo dolerite intrusions the Tierberg mudrocks are often baked to a dark grey hornfels with a reddish-brown crust (Prinsloo 1989).

The Tierberg Formation outcrop area is mainly confined to the easternmost portion of the Kokerboom WEF study area that is associated with the proposed new transmission lines but also crops out in the SE portion of the Kokerboom 3 study area. On satellite images the Tierberg Formation outcrop area has a distinctive, finely-banded appearance reflecting cyclical deposition patterns (*e.g.* thin upward-coarsening cycles) (*cf* Almond 2015c). Good bedrock exposure in this rolling hilly terrain is very limited indeed, with small bedding plane exposures along stream gullies and thin, prominent-weathering tabular beds observed on some steeper hillslopes (Fig. 17). As mapped, much of the outcrop area is mantled by blocky surface rubble of doleritic or quartzitic / hornfels composition (Fig. 28), while the bedrocks have frequently been baked by adjacent dolerite intrusions. Elsewhere the outcrop is usually mantled by platy, orange-brown patinated surface gravels of baked mudrock, wacke and quartzite, or by alluvial soils in low-lying areas. Occasional thin, tabular, greyish, rusty-brown weathering cherty beds (Fig. 18) may represent northern correlatives of the volcanic tuff-related Matjiesfontein Member (Collingham Formation) that is recognised further to the south within the Main Karoo Basin.

Figure 17: Very limited surface exposure of baked, thin-bedded, flaggy wackes of the Tierberg Formation on Karee Doorn Pan 214 (Loc. 239) (Hammer = 30 cm).

Figure 18: Tabular, pale greyish cherty bed within the lowermost Tierberg Formation, with pale grey outcrop of the underlying Whitehill Formation in the background (Loc. 248) (Hammer = 30 cm).

6.2. Karoo Dolerite Suite and younger igneous rocks

The Karoo Dolerite Suite is an extensive network of basic igneous bodies (dykes, sills) that were intruded into sediments of the Main Karoo Basin in the Early Jurassic Period, about 183 million years ago (Duncan & Marsh 2006, Cole *et al.* 2004). These dolerites form part of the Karoo Igneous Province of Southern Africa that developed in response to crustal doming and stretching preceding the break-up of Gondwana. Hard cappings of blocky, reddish-brown to rusty-weathering dolerite are a very typical feature of the flat-topped koppies in the Great Karoo region (*e.g.* Klein Rooiberg Fig. 11). In the Loeriesfontein area the dolerite sills variously intrude the Prince Albert, Whitehill Formation and Tierberg Formations of the Ecca Group as well as the underlying Dwyka Group. As seen on the geological map (Fig. 6), dolerite intrusions are mapped as underlying a very large portion of the Kokerboom WEF study area, especially in the west. Close to the margins of these intrusions the country mudrocks have been thermally metamorphosed or baked to form tough, splintery hornfels.

The Karoo dolerites are unfossiliferous igneous rocks and so will only be briefly treated here. Despite the large mapped area of dolerite within the study area, fresh exposures are in fact very rare since the outcrop area is largely mantled in superficial deposits. Highly-weathered, crumbly dolerite ("*sabunga*") showing extensive veining by Late Caenoziic calcrete as well as well-developed overlying nodular calcretes is well seen in erosion gullies incised through the superficial sediment cover (Fig. 20). Small bouldery *koppies* of moderately- to well-rounded dolerite corestones, often showing desert varnish, are seen in the northern part of the broader study area (Fig. 19); they have formed by *in situ* weathering of major intrusive bodies. Doleritic surface rubble that is mapped in the eastern portion of the study area (*e.g.* in the vicinity of Helios Substation) reflects downwasting of buried dolerite intrusions. Highly weathered dolerite *sabunga*, locally with a platy fracture or enclosing onionskin-weathered corestones, is well seen in several large borrow pits in this region (*e.g.* Loc. 258).

Numerous breccia pipes related to dolerite intrusion in the Early Jurassic punctuate the Prince Albert and Whitehill outcrop areas to the north of Loeriesfontein, including several unmapped examples within the study area itself (*cf* Macey *et al.* 2011, Almond 2014c). They are of palaeontological interest as possible conduits for the degassing of potent greenhouse gases (*e.g.* methane) that may have played an important role in climate-driven extinction events in the Early Jurassic (Toarcian) (Svensen *et al.* 2007). Several low rounded hills of brownish-weathering, ferruginous, igneous or hybrid igneous-sedimentary rocks were encountered within the broader Kokerboom WEF study area (e.g. Loc. 247 on the border of Karee Doorn Pan 214 and Sous 226); these are interpreted as probable breccia pipes.

Several intrusive bodies of brownish-weathering, pale grey, massive, medium-grained, quartz-poor igneous rock with whitish phenocrysts are locally seen cross-cutting the Ecca Group country rocks (Figs. 21 & 22). They show blocky or onionskin weathering as well as enclosed sedimentary clasts and might represent younger (Cretaceous – Early Tertiary) intrusive dykes or pipes related to the post-Karoo Gamoep Suite (*cf* Macey *et al.* 2011, Chapter 6). The thin-bedded, steeply–dipping beds of greyish arenite and associated greyish igneous rocks that are seen at Loc. 255 (northern edge of Karee Doorn Pan 214) may be related to a sediment-infilled diatreme of the Gamoep Suite (Fig. 23).

Figure 19: Typical bouldery dolerite *koppie* on the margins of a small pan, Karee Doorn Pan 214 (Loc. 256).

Figure 20: Highly-weathered, olive-grey dolerite bedrock (*sabunga*) exposed in an erosion gulley on Springbok Tand 215. Note the well-developed nodular calcrete horizon within the overlying sandy soils.

Figure 21: Trackway exposure of pale grey, blocky weathering igneous sheet or dyke intruding Ecca country rocks, Karee Doorn Pan 214 (Loc. 246) (Hammer = 30 cm).

Figure 22: Dark-hued, baked Ecca country rocks (LHS) cross-cut by pale grey intrusive igneous body (RHS), Karee Doorn Pan 214 (Loc. 255) (Hammer = 30 cm).

Figure 23: Steeply-dipping, thin beds of greyish arenite associated with the igneous intrusive rocks illustrated above, both probably related to a sediment-infilled diatreme or pipe (possible Gamoep Suite).

6.3. Late Caenozoic superficial sediments

Various types of superficial deposits of Late Caenozoic (Miocene / Pliocene to Recent) age occur widely throughout the Karoo study region (*e.g.* Holmes & Marker 1995, Cole *et al.* 2004, Partridge *et al.* 2006). They include pedocretes (*e.g*. calcretes), colluvial slope deposits, down-wasted surface gravels, river alluvium, wind-blown sands as well as spring and pan sediments. This mantle of superficial deposits obscures the Palaeozoic and Mesozoic bedrock geology in many parts of the Kokerboom WEF study area. Furthermore, deep chemical weathering in the Late Cretaceous to Tertiary interval has probably converted some of the near-surface Ecca rocks to *in situ* weathered saprolite (*cf* Bok 2011).

Useful geological overviews of talus deposits, alluvium and calcrete occurrences in a semi-arid Karoo region are given by Cole *et al.* (2004). Short accounts of the superficial deposits in the Loeriesfontein sheet area are given in the geological sheet explanation by Macey *et al.* (2011) and the recent palaeontological heritage report by Almond (2014c). The Karoo Supergroup hillslopes around Loeriesfontein are typically mantled with a thin to thick layer of colluvium or slope deposits (*e.g.* sandstone and dolerite scree or talus deposits, sheetwash). Thicker accumulations of sandy, gravelly and bouldery alluvium of Late Caenozoic age (< 5 Ma) are found in stream and river beds. Alluvial gravels in the study area are composed largely of angular, platy clasts of Ecca mudrocks and hornfels as well as reworked, rounded dolerite corestones (Figs. 24 & 25). These colluvial and alluvial deposits may be extensively calcretised (*i.e*. cemented with soil limestone or calcrete), especially in the neighbourhood of dolerite intrusions where groundwaters are enriched in dissolved carbonate. Rusty-brown areas seen on satellite images often represent dolerite-rich colluvial or down-wasted surface gravels.

A wide range of eluvial surface gravels are developed over the various Ecca Group formations within the Kokerboom WEF study area, variously dominated by platy siltstone or sandstone, grey dolomite, shiny dark brown (desert-varnished) ferruginous mudrock, brown ferruginous carbonate, hornfels, quartzite, wacke, reworked calcrete or dolerite *etc* (*e.g.* Figs. 27 & 28). Tough-weathering, often ferruginous gravel clasts are common over Prince Albert mudrocks and dolerite gravels over Whitehill mudrocks. The Tierberg Formation outcrop area has fewer resistant gravels and more platy shale / hornfels / wacke clasts, although ferruginous carbonate concretion fragments and sandstones may be locally very abundant. Closely-spaced platy clasts at surface may form a coherent *reg* or desert pavement. Extensive areas of doleritic rubble are separately mapped in the easternmost portion of the study area (Q-g1 in Fig. 6). The rounded to angular fragments of dolerite rock, including downwasted and reworked corestones, locally overlie orange-brown, ferruginous lateritic soils.

Angular to subrounded float clasts of semi-transluscent chert with an orange-brown cortex and superficial shrinkage cracks are widely dispersed within surface gravels across the study area (Concentrations were observed at Locs. 237, 243 on Karee Doorn Pan 214, for example) (Figs. 29 & 29a). They frequently show anthropogenic flaking. The fresh cherts are often greenish-yellow, but flaked examples show a wide spectrum of hues, including an opaque porcellanous cream colour (Almond 2014c). Their provenance is unclear, but may involve older carbonate deposits around the margins of local pans, as is the case with Plio-Pleistocene cherts at Etosha Pan, Namibia (Pickford *et al.* 2009). Comparable, so-called Magadi-type cherts have been widely recorded from Pleistocene and older alkaline lake deposits in East Africa and elsewhere. The original source of the opaline silica may have been hydrothermal (hotsprings or vents), volcanogenic (*e.g.* tuff material) or biogenic (diatoms / bacteria). Rubbery precursor nodules of hydrated sodium silicate (the mineral magadiite) with a mammilated surface were converted to chert bodies with distinctive shrinkage cracks and surface reticulation patterns (Schubel & Simonson 1990, Behr 2012). The chert-forming lakes concerned near Loeriesfontein might be Quaternary or older pans in southern Bushmanland, or perhaps related to the much older, Late Cretaceous – Tertiary volcanic pipes of the Gamoep Suite that occur abundantly in the region.

Subsurface calcretes are locally well developed in the study area, especially in the vicinity of extensive subsurface dolerite intrusions where they cement older alluvial gravels, siltstones and soils and form veins penetrating into the underlying bedrocks. Beautiful examples of large, pebble-sized, well-rounded subsurface calcrete nodules are exhumed along the sides of farm tracks (Figs. 20 and 26). They show a marked concentric lamination internally. Extensive calcretisation of thick (> 2 m) silty soils overlying the Whitehill Formation outcrop area is seen in roadside borrow pits and erosion gullies along the margins of pans (Fig. 32). The overlying gravels comprise mudrock flakes, dolomite, calcrete and some ferruginous chert or ironstone.

Stream gravels are poorly represented in the study region where they reflect local resistant-weathering lithologies (*e.g.* platy clasts of Ecca mudrocks or fine-grained sandstones, wackes, hornfels, dolerite rubble, reworked calcrete or ferruginous carbonate nodules, minor chert) (Figs. 24 & 25). The alluvium is often calcretised subsurface, as well seen in streambank exposures. Finer-grained alluvial deposits may reach thicknesses of several metres and coarse, gravelly basal or internal horizons are often well- to semi-consolidated by carbonate cement. The underlying bedrocks are often permeated by calcrete veins. The basal, poorly-sorted, gravel-rich alluvium is overlain by finer-grained younger silty alluvium and downwasted surface gravels. Polymict older stream gravels (dolerite, hornfels, sandstone *etc*) may occur up to a couple of metres above the present stream beds.

Thick, orange-brown sandy soils are frequently developed overlying subsurface dolerite and calcrete (Fig. 30). Deflated areas show concentrations of fine, resistant-weathering gravels (*e.g.* dark ferruginous mudrock, hornfels, quartzite). Pan areas (*e.g.* northern portion of Karee Doorn Pan 214) feature thick, silty to sandy deposits that are usually calcretised at depth and show efflorescence of various evaporite minerals at the surface (Figs. 31 & 32).

Figure 24: Basal gravelly and overlying sandy alluvial deposits overlying Ecca Group bedrocks along the banks of the Klein-Rooibergrivier (Loc. 249) (Hammer = 30 cm).

Figure 25: Stringer of resistant-weathering stream gravels - including dark, desert-varnished ferruginous mudrock or ironstone and white reworked calcrete - exposed along a shallow drainage line on Karee Doorn Pan 214 (Loc. 245).

Figure 26: Well-developed nodular calcrete horizon overlain by silty alluvial soils, farm track on Kleine Rooiberg 227 (Hammer = 30 cm).

Figure 27: Carpet of angular gravel clasts of ferruginised mudrock overlying the Tierberg Formation (Loc. 239, Karee Doorn Pan 214) (Hammer = 30 cm).

Figure 28: Angular surface gravels of baked hornfels and wacke of the Tierberg Formation overlying subsurface dolerite, Sous 226 (Loc. 257) (Hammer = 30 cm). These deposits are sometimes mapped as doleritic rubble.

Figure 29: Gravel clasts of greenish chert with a pale cream-coloured cortex showing local shrinkage cracks – possibly Magadi-type cherts downwasted from ancient alkalkine lake deposits (Loc. 237, Karee Doorn Pan 214) (Scale in cm and mm).

Figure 29a. Pale cherty concretions (RHS) within surface gravels associated with multi-hued stone artefacts (Loc. 237, Karee Doorn Pan 214) (Scale in cm and mm).

Figure 30: Sandy soils on the northern edge of Karee Doorn Pan, seen in the distance (Loc. 240).

Figure 31: Typical sandy to silty pan deposits with pale salty efflorescence, small pan on the northern margin of Karee Doorn Pan 214 (Loc. 256).

Figure 32: Pale grey, laminated Whitehill Formation bedrocks overlain by poorly-consolidated saprolite and then several meters of calcretised pan sediments, northern margins of Karee Doorn Pan (Loc. 243).

7. PALAEONTOLOGICAL HERITAGE

In this section of the report fossil assemblages that have been previously recorded from the main sedimentary rock units represented within the Kokerboom WEF study area, including the Kokerboom 3 Wind Farm study area, are outlined, while fossil material recorded during the present field assessment is listed and illustrated. Much of the background data has been abstracted from the unpublished report on the fossil heritage of the Loeriesfontein 1: 250 000 sheet area by Almond *in* Macey *et al.* (2011) as well as several palaeontological heritage assessments in the Loeriesfontein area by the author (especially Almond 2014c). GPS locality details and brief descriptions for numbered palaeontological sites are provided in the Appendix.

7.1. Fossils in the Prince Albert Formation

The fossil biota of the postglacial mudrocks of the Prince Albert Formation is summarised by Cole (2005), Almond (2008b) and Almond *in* Macey *et al.* (2011). Epichnial (bedding plane) trace fossil assemblages of the non-marine *Mermia* Ichnofacies, dominated by the ichnogenera *Umfolozia* (arthropod trackways) and *Undichna* (fish swimming trails), are commonly found in basinal mudrock facies of the Prince Albert Formation throughout the Ecca

Basin. These assemblages have been described by Anderson (1974, 1975, 1976, 1981) and briefly reviewed by Almond (2008a, b; Almond *in* Macey 2011). The only fossils recorded from the Prince Albert Formation in the Loeriesfontein sheet area are various types of trace fossils, some of which have apparently been misinterpreted as plant remains by earlier authors (Almond 2008a). Almond (1996) describes seaweed-like "fucoids" on the farm Bloukranz 1173, along the R355 just to the south of the present study area, that take the form of distinctively bifurcating, flat, smooth burrow systems up to several centimetres across. Similar bifurcating burrow systems characterise the khaki sandstone facies within the Prince Albert Formation to the north of Loeriesfontein (Almond 2014c).

Diagenetic nodules containing the remains of palaeoniscoids (primitive bony fish), sharks, spiral bromalites (coprolites, spiral gut infills *etc* attributable to sharks or temnospondyl amphibians) and petrified wood have been found in the Ceres Karoo (Almond 2008b and refs. therein). Rare shark remains (*Dwykaselachus*) are recorded near Prince Albert on the southern margin of the Great Karoo (Oelofsen 1986). Microfossil remains in this formation include sponge spicules, foraminiferal and radiolarian protozoans, acritarchs and miospores. The most diverse, as well as biostratigraphically, palaeobiogeographically and palaeoecologically interesting, fossil biota from the Prince Albert Formation is that described from calcareous concretions exposed along the Vaal River in the Douglas area of the Northern Cape (McLachlan and Anderson 1973, Visser *et al.,* 1977-78). The important Douglas biota contains petrified wood (including large tree trunks), palynomorphs (miospores), orthocone nautiloids, nuculid bivalves, articulate brachiopods, spiral and other "coprolites" (probably of fish, possibly including sharks) and fairly abundant, well-articulated remains of palaeoniscoid fish. Most of the fish have been assigned to the palaeoniscoid genus *Namaichthys* but additional taxa, including a possible acrolepid, may also be present here (Evans 2005). The invertebrates are mainly preserved as moulds.

Trace fossil material recorded from dark mudrocks of the Prince Albert Formation during the present field assessment includes straight to curved, highly-flattened, unbranched horizontal burrows (*c*. 1 cm width) from shaly mudrocks and fine-grained sandstones (Fig. 33). The burrows have a distinctive shiny sheen and may contain a subordinate meandering substructure within them (possibly a siphon or snorkel trace). Dark- to pearly-hued, broad, strap-shaped, smooth burrow systems showing dichotomous or right-angle branching patterns ("fucoids") are well exposed on flaggy siltstones in the bed of the Klein-Rooibergrivier (Figs. 34 & 35). They have been described previously from the Prince Albert beds in the Loeriesfontein area (*e.g.* Almond 1996, 2014c).

Figure 33: Horizontal intrastratal burrows with a narrow central strand from the Prince Albert Formation, bed of the Klein-Rooibergrivier (Loc. 249) (Scale in cm and mm).

Figure 34: Dichotomously branching, flattened "fucoid" burrows within bioturbated siltstones of the Prince Albert Formation (Loc. 249) (Scale in cm).

Figure 35: Dichotomous to right-angled branching, flattened "fucoid" burrows within bioturbated siltstones of the Prince Albert Formation (Loc. 249) (Scale in cm).

7.2. Fossil heritage within the Whitehill Formation

In palaeontological terms the Whitehill Formation is one of the richest and most interesting stratigraphic units within the Ecca Group. The overall palaeontological sensitivity of this formation has accordingly been rated as very high (Almond & Pether 2008). The rich fossil record of the Whitehill formation in the Loeriesfontein sheet area has been reviewed by Almond *in* Macey *et al.* (2011). The biostratigraphic distribution of the most prominent fossil groups – mesosaurid reptiles, palaeoniscoid fishes and notocarid crustaceans – within the Whitehill Formation has been documented by several authors, including Oelofsen (1987), Visser (1992) and Evans (2005), and is shown here in Figure 10. A non-technical illustrated account of the fossil biota of the Ecca Sea is given by MacRae (1999). Note that in the earlier geological literature the Whitehill Formation or "Witband" was included within the Upper Dwyka Shales.

In brief, the main groups of Early Permian fossils found within the Whitehill Formation include:

- aquatic **mesosaurid reptiles** (the earliest known sea-going reptiles)
- rare **cephalochordates** (ancient relatives of the living lancets)
- a variety of **palaeoniscoid fish** (primitive bony fish)

- highly abundant small **eocarid crustaceans** (bottom-living shrimp-like forms)
- **insects** (mainly preserved as isolated wings, but some intact specimens also found)
- a low diversity of **trace fossils** (*e.g.* king crab trackways, possible shark coprolites / faeces)
- **palynomorphs** (organic-walled spores and pollens)
- **petrified wood** (mainly of primitive gymnosperms, silicified or calcified)
- other sparse **vascular plant remains** (*Glossopteris* leaves, lycopods *etc*).

Important material of the fossil groups listed above has mainly been collected in the Western Cape Province during the twentieth century by a series of palaeontologists (See, for example, McLachlan & Anderson 1973, Oelofsen 1981, 1987, Almond 1996, 2008a, 2008b, Almond & Pether 2008, Evans & Bender 1999, Evans 2005, and refs. therein). Where the Whitehill Formation has been thermally metamorphosed or baked by nearby dolerite intrusions, as is often the case in the Loeriesfontein study area, the preservation of moulds of mesosaurid reptiles and fish may be locally enhanced.

No new body fossil localities within Whitehill Formation were recorded during the present field study, including from the well-developed dolomitic lenses that occasionally contain well-preserved crustaceans in the southern Karoo. The recessive-weathering Whitehill sediments within the study area are usually highly weathered, thermally-metamorphosed by nearby dolerite intrusions, and mantled with thick shaly surface gravels and soil.

7.3. Fossil heritage within the Tierberg Formation

The fossil record of the Tierberg Formation in the Loeriesfontein sheet area and elsewhere within the Main Karoo Basin has been reviewed in detail by Almond *in* Macey *et al.* (2011). Rare body fossil records include disarticulated microvertebrates (*e.g.* fish teeth and scales) from calcareous concretions in the Koffiefontein sheet area (Zawada 1992) and allochthonous plant remains (leaves, petrified wood). The latter become more abundant in the upper, more proximal (prodeltaic) facies of the Tierberg succession (*e.g.* Wickens 1984). Prinsloo (1989) records numerous plant impressions and unspecified “fragmentary vertebrate fossils” within fine-grained sandstones in the Britstown sheet area. Dark carbonaceous Ecca mudrocks are likely to contain palynomorphs (*e.g.* pollens, spores, acritarchs).

The commonest fossils by far in the Tierberg Formation are sparse to locally concentrated assemblages of trace fossils that are often found in association with thin event beds (*e.g.*distal turbidites, prodeltaic sandstones) within more heterolithic successions. A modest range of ten or so different ichnogenera have been recorded from the Tierberg Formation (*e.g.* Abel 1935, Anderson 1974, 1976, Wickens 1980, 1984, 1994, 1996, Prinsloo 1989, De Beer *et al*., 2002, Viljoen 2005, Almond *in* Macey *et al.* (2011)). These are mainly bedding parallel, epichnial and hypichnial traces, some preserved as undertracks.

Low-diversity trace fossil assemblages are recorded from Tierberg finely, rhythmically-laminated wackes at several localities in the Loeriesfontein area. Dense monospecific bedding plane-parallel populations of simple, hollow, flattened horizontal intrastratal burrows with a pale yellowish or brownish coloration are well seen, for example, at Loeriesfontein reservoir (Almond 2014b). Dense, moderately diverse ichnoassemblages are well seen on a bedding plane of baked Tierberg Formation laminated mudrocks in the Loeriesfontein townlands (*ibid.*). The epichnial trace assemblages are dominated by two or more types of arthropod trackway – a large (4 cm wide) form of *Umfolozia* (possibly crustacean) as well as a trackway with a median drag mark and strongly oblique rows of tracks within each set (possibly chelicerate, *cf Palaeohelcura, Palmichnium, Kouphichnium*) – but there are also sinuous fish swimming trails (*Undichna*) and wiggly, "segmented" horizontal burrows, bilobed epichnial ridges ("*Gyrochorte*"), and vaguely-preserved horizontal furrows (perhaps "*Scolicia*" of Anderson 1974). Flattened, band-shaped endichnial horizontal burrows up to 6 cm wide with a smooth or possibly pelleted surface and reflective sheen, as widely recorded from the Prince Albert Formation in the Loeriesfontein-Calvinia area (*e.g.* Almond 1996), are also seen in the younger Tierberg Formation near Loeriesfontein. Strap-shaped burrows (possible "*Plagiogmus*"), hollow "segmented" horizontal burrows, *Umfolozia* arthropod trackways, microbial mat textures and small-scale under mat burrows (3 mm wide positive epichnia) are seen on baked bedding planes of Tierberg mudrocks on the Loeriesfontein townlands (Almond 2014b).

The only fossils recorded from the very poorly-exposed Tierberg Formation within the Kokerboom WEF study area were a small range of epichnial and endichnial horizontal burrows seen within siltstone or wacke float blocks (Fig. 36).

Figure 36: Simple horizontal burrows preserved within grey-green siltstone float blocks of the Tierberg Formation (Loc. 238) (Scale in cm and mm).

7.4. Fossil heritage within the Karoo Dolerite suite and Gamoep Suite

The extensive dolerite intrusions in the Loeriesfontein study area are in themselves of no palaeontological significance. These are high temperature igneous rocks emplaced at depth within the Earth's crust so they do not contain fossils. However, as a consequence of their proximity to large dolerite intrusions, some of the Ecca Group sediments will have been thermally metamorphosed or "baked" (*i.e*. recrystallised, impregnated with secondary minerals). Embedded fossil material of phosphatic composition, such as bones and teeth, is frequently altered by baking – bones may become blackened, for example - and can be very difficult to extract from the hard matrix by mechanical preparation. In some cases – such as fossil moulds of mesosaurid reptiles and palaeoniscoid fish - baking may enhance the quality of preservation of Ecca fossils while other fossil groups (*e.g*. carbonaceous remains of plants, organic-walled palynomorphs) are more likely to be compromised.

Steeply-dipping, pale grey, flaggy sandstones associated with greyish volcanic rocks on Karee Dorn Pan 214 (Fig. 23) contain simple intrastratal burrows preserved in positive and negative relief (Fig. 37). These sediments have been tentatively correlated with diatreme infills of the Late Cretaceous – Early Tertiary Gamoep Suite, which elsewhere is associated with a range of fossil vertebrates, plants and microfossils (See Almond *in* Macey *et al.* 2011). However, the trace-bearing beds might alternatively represent deformed country rocks of the Ecca Group, so their age and relations are currently highly ambiguous (*cf* also Almond 2014c for other occurrences of trace fossils associated with breccia pipe margins close to the Kokerboom WEF study area).

Figure 37: Flaggy grey sandstones with simple horizontal burrows preserved on parting surfaces (Loc. 255) (Scale in cm and mm). The age of these fossiliferous beds, which are associated with a probable breccia pipe, is not established.

7.5. Fossil heritage within the Late Caenozoic superficial deposits

The central Karoo "drift deposits" have been comparatively neglected in palaeontological terms. However, they may occasionally contain important fossil biotas, notably the bones, teeth and horn cores of mammals as well as remains of reptiles like tortoises. Good examples are the Pleistocene mammal faunas at Florisbad, Cornelia and Erfkroon in the Free State and elsewhere (Wells & Cooke 1942, Cooke 1974, Skead 1980, Klein 1984, 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). Other late Caenozoic fossil biotas from these superficial deposits include non-marine molluscs (bivalves, gastropods), ostrich egg shells, trace fossils (*e.g.* calcretised termitaria, coprolites), and plant remains such as peats or palynomorphs (pollens, spores) in organic-rich alluvial horizons (Scott 2000) and siliceous 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). Stone artefacts of Pleistocene and younger age may additionally prove useful in constraining the age of superficial deposits such as gravelly alluvium within which they are occasionally embedded.

No fossil remains were recorded from the Late Caenozoic superficial deposits within the Kokerboom WEF study area.

8. ASSESSMENT OF IMPACTS ON PALAEONTOLOGICAL RESOURCES

The Kokerboom 3 Wind Farm study area is underlain by several formations of potentially fossiliferous sediments of the Ecca Group (Karoo Supergroup) that are extensively intruded by unfossiliferous igneous rocks of the Karoo Dolerite Suite (Fig. 6). Combined desktop and field studies dealing with the entire Kokerboom WEF study area show that:

- The Ecca Group rocks (Prince Albert, Whitehill and Tierberg Formations) are very poorly-exposed and deeply-weathered near-surface. They have also been locally baked (thermally metamorphosed) by nearby dolerite intrusions and occasionally secondarily mineralised. The only fossils recorded here within these rocks comprise low-diversity trace fossil assemblages that occur widely within the Loeriesfontein region and therefore not of unique scientific importance. No scientifically important vertebrate or plant remains were recorded during the field assessment.
- The Karoo dolerites that crop out over the majority of the Kokerboom Wind Farm study area are also poorly-exposed, deeply-weathered for the most part and, in addition, do not contain fossils.
- Several unmapped, small-scale occurrences of post-Karoo breccia pipes and igneous intrusions were encountered during fieldwork. Some of the associated sandy sediments contain simple invertebrate trace fossils of uncertain age and stratigraphic position. Similar traces have previously been recorded from similar settings elsewhere within the Loeriesfontein region; they are not considered to be of great scientific significance.
- None of the wide range of Late Caenozoic superficial deposits examined during fieldwork (*e.g.* alluvium, colluvium, surface gravels, calcretes, stream and pan sediments, sandy soils) appears to be highly fossiliferous. Important mammalian remains are known from pan and river sediments elsewhere in Bushmanland, but they are rare and their occurrence is unpredictable.

It is concluded that the bedrocks and superficial sediments underlying the Kokerboom 3 Wind Farm study area generally are of *low* palaeontological sensitivity. The assessment applies to all the key infrastructural components outlined in Section 5.1, which includes *inter alia* wind turbines, hard standing areas, access roads, and substations.

The destruction, damage or disturbance out of context of legally-protected fossils preserved at the ground surface or below ground that may occur during construction of the Kokerboom 3 Wind Farm entail direct *negative* impacts to palaeontological heritage resources that are confined to the development footprint (*site specific*). These impacts can often be mitigated but they are permanent and cannot be fully rectified (*i.e.* they are *long term* and *irreversible*). All of the sedimentary formations represented within the Kokerboom 3 Wind Farm study area contain fossils of some sort (*e.g*. microfossils) but scientifically important, well-preserved, unique or rare fossil material is likely to be very rare. Impacts of some sort on fossil heritage are definite but, given the general low palaeontological sensitivity of the study area, they are likely to be of *very low magnitude* (Local impacts on highly-significant fossil remains – such as rare vertebrate fossils – cannot be completely excluded). Most (but *not* all) of the fossils concerned are likely to be of widespread occurrence within the outcrop areas of the formations concerned; the probability of loss of *unique or rare* fossil heritage is therefore low (*unlikely*). Given the very low levels of sedimentary bedrock exposure within the Kokerboom 3 study area, confidence levels for this assessment - based on desktop as well as fieldwork data for the Kokerboom WEF study area as well as for several nearby regions in southern Bushmanland - are rated as moderate (*sure*).

As a consequence of (1) the paucity of irreplaceable, unique or rare fossil remains within the development footprint, (2) the high levels of bedrock weathering and thermal metamorphism in the study area, as well as (3) the extensive superficial sediment cover overlying most potentially-fossiliferous bedrocks within the Kokerboom 3 study area, the overall impact significance of the construction phase of the proposed wind energy project is assessed as *VERY LOW* (negative). There are therefore no preferences on palaeontological heritage grounds for any particular layout (*e.g.* transmission line route) among the various options under consideration. A palaeontological heritage assessment has only been conducted here for the *construction phase* of the Kokerboom 3 Wind Farm since further impacts on fossil heritage during the design, operational and decommissioning phases of Kokerboom 3 are not anticipated.

Given the low palaeontological sensitivity of the entire Kokerboom WEF study area, and the very low impact significance determined for each of the three wind farms of the development (as well as for the associated transmission lines), the cumulative impact significance of the total WEF itself is rated as *low*. Taking into account several alternative energy developments proposed or authorised in the vicinity, these have likewise been assessed to be of low palaeontological impact significance (*e.g.* Almond 2011b, 2014c, Pether 2012). The cumulative impact of all these developments is inferred to be *low*.

The No-go Alternative (*i.e.* no Kokerboom 3 Wind Farm development) will have a neutral impact on palaeontological heritage. Without development natural weathering processes and erosion will continue to steadily destroy fossils preserved near or at the ground surface, but at the same time new fossils will be continually exposed. There are no fatal flaws to the proposed Kokerboom 3 Wind Farm as far as fossil heritage is concerned. Providing that the proposed recommendations outlined below for palaeontological monitoring and mitigation are followed through, there are no objections on palaeontological heritage grounds to authorisation of the Kokerboom 3 Wind Farm project.

9. RECOMMENDED MONITORING AND MITIGATION (FOR INCLUSION IN ENVIRONMENTAL MANAGEMENT PROGRAMMES)

Pending the potential discovery of significant new fossil remains (*e.g.* vertebrate bones and teeth, horn cores, petrified wood) during the construction phase of the Kokerboom 3 Wind Farm development, no further specialist palaeontological studies or mitigation are recommended for this project.

The Environmental Control Officer (ECO) responsible for the WEF developments should be made aware of the potential occurrence of scientifically-important fossil remains within the development footprint. During the construction phase all major clearance operations (*e.g.* for new access roads, turbine placements) and deeper (> 1 m) excavations should be monitored for fossil remains on an on-going basis. Should substantial fossil remains - such as vertebrate bones and teeth, or petrified logs of fossil wood - be encountered at surface or exposed during construction, the finds should be safeguarded, preferably *in situ* and the South African Heritage Resources Agency, SAHRA, should be notified as soon as possible (Contact details: Dr Ragna Redelstorff. Heritage Officer Archaeology, Palaeontology & Meteorites Unit, SAHRA. 111 Harrington Street, Cape Town, 8001. Tel: +27 (0)21 202 8651. Fax: +27 (0)21 202 4509 E-mail:rredelstorff@sahra.org.za). This is to ensure that appropriate action (*i.e.* recording, sampling or collection of fossils, recording of relevant geological data) can be taken by a professional palaeontologist at the proponent’s expense.

The palaeontologist concerned with any 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).

These monitoring and mitigation recommendations should be incorporated into the Environmental Management Programme (EMPr) for the Kokerboom 3 Wind Farm. The operational and decommissioning phases of the development is unlikely to have further significant impacts on palaeontological heritage and no recommendations are made in this regard.

It should be noted that, should fossils 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 here, the overall impact significance of the project would remain very low (negative). However, residual negative impacts from inevitable loss of fossil heritage would be partially offset by an improved palaeontological database 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 of Bushmanland would constitute a useful addition to our scientific understanding of the fossil heritage here.

10. CONCLUSIONS

The present palaeontological heritage assessment is based on a desktop study combined with a short, field-based scoping study of the Kokerboom WEF study area, including the Kokerboom 3 Wind Farm. While levels of bedrock exposure within the study area are very low indeed due to pervasive superficial sediment cover (*e.g.* alluvium, surface gravels, calcrete), relevant supplementary geological and palaeontological data is available from several recent field studies carried out in the vicinity of Loeriesfontein.

The Kokerboom 3 Wind Farm study area is underlain by several formations of potentially fossiliferous sediments of the Ecca Group (Karoo Supergroup) that are extensively intruded by unfossiliferous igneous rocks of the Karoo Dolerite Suite. The Ecca Group rocks (Prince Albert, Whitehill and Tierberg Formations) are very poorly-exposed and deeply-weathered near-surface. They have also been locally baked (thermally metamorphosed) by nearby dolerite intrusions and occasionally secondarily mineralised. The only fossils recorded here within these rocks comprise low-diversity trace fossil assemblages that occur widely within the Loeriesfontein region and are therefore not of unique scientific interest. No vertebrate or plant remains were recorded during the field assessment.

The Karoo dolerites that crop out over the majority of the broader Kokerboom Wind Farm study area are also poorly-exposed, deeply-weathered for the most part and, in addition, do not contain fossils. Several unmapped, small-scale occurrences of post-Karoo breccia pipes and igneous intrusions were encountered during fieldwork. Some of the associated sandy sediments contain simple invertebrate trace fossils of uncertain age and stratigraphic position. Similar traces have previously been recorded from similar settings elsewhere within the Loeriesfontein region; they are not considered to be of great scientific significance.

None of the wide range of Late Caenozoic superficial deposits examined during fieldwork (*e.g.* alluvium, colluvium, surface gravels, calcretes, stream and pan sediments, sandy soils) appear to be highly fossiliferous. Important mammalian remains are known from pan and river sediments elsewhere in Bushmanland, but they are rare and their occurrence is unpredictable.

Highly sensitive no-go areas within the area have not been identified in this study. It is concluded that the bedrocks and superficial sediments underlying the Kokerboom 3 study area are of *low* palaeontological sensitivity.

Potential impacts to fossil heritage resources within the Kokerboom 3 study area involve the disturbance, damage or destruction of fossil material within the development footprint during the construction phase of the Kokerboom 3 Wind Farm. Due to the rarity of well-preserved, unique fossils of potential scientific importance within the Kokerboom 3 study area, potential impacts on palaeontological heritage during the construction phase are assessed as of *very low (negative) significance* (before and after mitigation). The No-go alternative (*i.e.* no Kokerboom 3 Wind Farm) will have a neutral impact on palaeontological heritage. Cumulative impacts posed by the three separate wind farms and transmission lines are inferred to be low. This also applies to cumulative impacts from known alternative energy developments in the region.

Pending the potential discovery of significant new fossil remains (*e.g.* vertebrate bones and teeth, horn cores, petrified wood) during the construction phase of the Kokerboom 3 development, no further specialist palaeontological studies or mitigation are recommended for this project.

The Environmental Control Officer (ECO) responsible for the Kokerboom 3 Wind Farm development should be made aware of the potential occurrence of scientifically-important fossil remains within the development footprint. During the construction phase all major clearance operations (*e.g.* for new access roads, turbine placements) and deeper (> 1 m) excavations should be monitored for fossil remains on an on-going basis. Should substantial fossil remains - such as vertebrate bones and teeth, or petrified logs of fossil wood - be encountered at surface or exposed during construction, the finds should be safeguarded, preferably *in situ* and the South African Heritage Resources Agency, SAHRA, should be notified as soon as possible (Contact details: Dr Ragna Redelstorff. Heritage Officer Archaeology, Palaeontology & Meteorites Unit, SAHRA. 111 Harrington Street, Cape Town, 8001. Tel: +27 (0)21 202 8651. Fax: +27 (0)21 202 4509 E-mail:rredelstorff@sahra.org.za). This is to ensure that appropriate action (*i.e.* recording, sampling or collection of fossils, recording of relevant geological data) can be taken by a professional palaeontologist at the proponent's expense.

The palaeontologist concerned with any 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).

These monitoring and mitigation recommendations should be incorporated into the Environmental Management Programme (EMPr) for the Kokerboom 3 Wind Farm. The operational and decommissioning phases of these developments are unlikely to have further significant impacts on palaeontological heritage and no recommendations are made in this regard.

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13. 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

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APPENDIX 1: GPS LOCALITY DATA

All GPS readings were taken in the field using a hand-held Garmin GPS map 60CSx instrument. The datum used is WGS 84. *N.B.* Fossil locality data is not for general release to the public for conservation reasons.

Locality number	GPS data	Comments
235	30 25 00.1 S 19 32 03.0 E	Karee Doorn Pan 214. *Vlaktes* with surface gravels (calcrete, Tierberg shale, silicified mudrock)
237	30 24 41.1 S 19 30 30.8 E	Karee Doorn Pan 214. Whitehill Fm outcrop area with weathered pale grey mudrocks, intrusive dark brown veins of igneous rock, lenses of creamy, vuggy, fibrous mineral (silicified or calcified gypsum / calcrete?), common float black of semi-translucent chert in surface gravels (often flaked).
238	30 24 43.7 S 19 30 35.6 E	Karee Doorn Pan 214. Locally abundant small float blocks of orange- to cream-patinated chert (often flaked) overlying weathered Tierberg Fm. Mudrocks. Occasional Tierberg siltstone float blocks with simple horizontal burrows.
239	30 24 31.6 S 19 31 26.1 E	Karee Doorn Pan 214. Low exposure of prominent-weathering, thin, reddish-brown weathering wacke within Tierberg Fm. Platy, orange-brown patinated surface gravels. Occasional flakes of pale grey, speckled Matjiesfontein Chert. Locally abundant desert-varnished surface gravels, some well-rounded.
240	30 21 29.1 S 19 33 18.4 E	Karee Doorn Pan 214, N of main pan. Pale brown sandy soils with patches of surface gravels (hornfels, dolerite, calcrete)
241	30 21 28.6 S 19 34 01.6 E	Karee Doorn Pan 214, N of main pan. Surface gravels dominated by downwasted hornfels, quarztite. Occasonal small blocks of semi-transluscent chert.
242	30 21 29.3 S 19 34 17.1 E	Karee Doorn Pan 214, N of main pan. Surface gravels dominated by downwasted dolerite rubble, corestones. Occasonal small blocks of semi-transluscent chert.
243	30 21 33.9 S 19 34 33.7 E	Karee Doorn Pan 214, margins of Kareedoorn Pan itself. Pale grey, highly-weathered Whitehill Fm shales with veins and lenses of gypsum overlain by thick (sev. m.) of pale brownish silty pan sediments, heavily calcretised, including remobilised slurry of Whitehill saprolite overlying bedrock. Ground surface around pan with gravels of downwasted calcrete, desert-varnished pebbles, occasional pale greenish-yellow cherty clasts.
244	30 23 50.0 S 19 30 11.9 E	Karee Doorn Pan 214, low kranz and hillslope exposure of weathered pale grey to blackish Whitehill Fm laminated mudrocks (paper-shale dark claystones coarsening-up to paler, laminated to thin-bedded, flaggy siltstones), veins of gypsum. Common float clasts of greenish-yellow chert in float around koppie margins, sometimes flaked.
245	30 24 10.1 S 19 30 10.0 E	Karee Doorn Pan 214, exposure of resistant stream gravels (subrounded desert-varnished, quartzite, hornfels, ferruginised mudrock and sandstone, calcrete, minor chert) along shallow drainage line.
246	30 24 20.2 S 19 30 01.0 E	Karee Doorn Pan 214, track exposure of pale greyish, blocky-weathering, medium-grained igneous rock with creamy phenocrysts – probably Late Cretaceous / Early Tertiary alkaline igneous intrusion (Gamoep Suite).
247	30 24 45.9 S 19 28 10.4 E	Border of Karee Doorn Pan 214 and Sous 226. Low koppie with brownish-weathering sandy ferruginous rock, massive, pale grey medium-grained igneous rock showing onionskin weathering -

		probably pipe-like Late Cretaceous / Early Tertiary alkaline igneous intrusion (Gamoep Suite).
248	30 23 12.9 S 19 29 44.4 E	Karee Doorn Pan 214. Thin capping of rusty-brown weathering, grey cherty beds overlying Whitehill Fm – possibly northern equivalent of Matjiesfontein Member chert bed within lowermost Tierberg Fm.
249	30 32 10.2 S 19 31 01.2 E	Klein Rooiberg 227. Extensive riverbed exposure of well-jointed greenish laminated mudrocks of the Prince Albert Fm in the Klein-Rooibergrivier to the east of Klein Rooiberg Wes. Bedding plane exposures of branching "fucoid" and simple horizontal burrow trace fossils. Good vertical sections through overlying Late Caenozoic sandy and gravelly alluvium.
250	30 29 14.9 S 19 27 48.3 E	Leeubergrivier 1163. Several meters of orange-brown sandy soils overlying calcrete hardpan and weathered dolerite at depth. Upper sandy soils pale above with small calcrete glaebules. Gravels of calcrete, Ecca shale and minor dolerite along shallow drainage lines. Exposures of large sphaeroidal calcrete nodules in shallow roadside cuttings.
251	30 26 07.5 S 19 25 33.3 E	Leeubergrivier 1163, Uitspankop. Platy surface gravels overlying baked Tierberg Fm outcrop area. Sparse flaked hornfels artefacts.
252	30 27 09.3 S 19 25 16.3 E	Leeubergrivier 1163, Harderant. Flaggy, baked Tierberg Fm mudrocks and fine wackes / quartzites.
253	30 20 58.2 S 19 22 53.8 E	Springbok Tand 215, gullies track exposure SE of Spirngboktand homestead showing deeply-weathered, calcrete-veined dolerite bedrocks overlain by well-developed nodular calcrete hardpan.
254	30 21 53.1 S 19 26 19.1 E	Springbok Tand 215, hillslopes N of Bloupan. Extensive angular surface gravels of dark grey hornfels overlying thin-bedded to laminated Prince Albert Fm mudrocks.
255	30 19 13.7 S 19 31 35.7 E	Karee Doorn Pan 214, northern edge. Cluster of boulder dolerite corestones. Thin-bedded, Ecca wackes nearby (probably Prince Albert Fm) baked, intruded by probable hybrid rock with small sediment inclusions within pale grey igneous matrix. Pale grey, thin-bedded, gently-dipping sandstones with horizontal burrows associated with breccia pipe.
256	30 19 37.5 S 19 31 13.5 E	Karee Doorn Pan 214, northern margin. Small pan surrounded by grassy terrain on deep, orange-brown sandy soils, boulder dolerite koppies.
257	30 27 24.6 S 19 34 20.7 E	Sous 226, north of Sous Farmstead. Surface gravels of angular, brown-weathering,baked Tierberg wackes, dolerite corestones near active quarry. Possibly mapped as doleritic rubble.
258	30 25 25.3 S 19 33 53.3 E	Aan Die Karee Doorn Pan 213, small quarry near Loeriesfontein dust road. Highly weathered dolerite with platy jointing, onionskin weathering.
260	30 27 02.5 S 19 35 41.6 E	Aan Die Karee Doorn Pan 213, large shallow quarry adjacent to railway line excavated into calcretised alluvial sediments overlying weathered dolerite, baked Tierberg Fm (latter exposed along northern pit margin).
261	30 23 12.2 S 19 34 03.7 E	Karee Doorn Pan 214, deep borrow pit just west of Loereisfontein road exposing deeply-weathered, gently-dipping Whitehill Fm overlain by calcretised saprolite and silty soils. Thin-bedded, tabular facies of Whitehill exposed in pit walls.
262	30 23 38.9 S 19 34 07.4 E	Karee Doorn Pan 214, deep borrow pit just west of Loereisfontein road exposing deeply-weathered, gently-dipping Whitehill Fm.
263	30 22 30.9 S 19 34 23.2 E	Karee Doorn Pan 214, extensive shallow gypsum quarry into heavily mineralised (iron / manganese), folded and tectonised Whitehill Formation.