Palaeontological specialist assessment: combined desktop and field-based study

PROPOSED DASSIESRIDGE WIND ENERGY FACILITY NEAR UITENHAGE, CACADU DISTRICT, EASTERN CAPE

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EXECUTIVE SUMMARY

Innowind (Pty) Ltd is proposing to construct a wind energy facility (Dassiesridge WEF) of up to 140 MW generation capacity, together with associated infrastructure, on a site in the Cacadu District of the Eastern Cape, to the north of Port Elizabeth. The study area of over 7300 hectares is situated in rolling hilly terrain on the eastern side of the R75 tar road, approximately 20 km from the small towns of Uitenhage, in the south, and Kirkwood, in the north.

The Dassiesridge WEF study area is underlain by approximately twelve sedimentary rocks units ranging in age from Early Devonian through Early Cretaceous and Neogene to Recent. On the basis of desktop analysis (including several previous palaeontological field assessments in the Uitenhage region) combined with field assessment of numerous representative rock exposures within and close to the WEF study area, only four of these units – namely the Voorstehoek Formation (Lower Bokkeveld Group), the Kirkwood and Sundays River Formations (Uitenhage Group), as well as the basal part of the Alexandria Formation in the southeast (Algoa Group) - are considered to be palaeontologically sensitive.

The great majority of infrastructure for the proposed WEF will be located in flatter-lying upland areas and ridges that are underlain by rock units of low palaeontological sensitivity – *viz*. limestones and aeolian sands of the Algoa Group on the plateaux and Bokkeveld sandstones forming the ridges in the northwest. Construction of the wind turbines, overhead power lines, access roads and associated infrastructure here is therefore unlikely to entail significant impacts on local fossil heritage resources. Direct impacts on fossiliferous beds of the Uitenhage Group in lower-lying areas will be very limited, especially because these sediments are generally overlain by thick unfossiliferous superficial deposits (soil, alluvium *etc*). Significant impacts on fossil heritage are not anticipated for any of the substation and transmission line route options, none of which is preferred on palaeontological grounds.

Significant impacts on fossil heritage for this project are only anticipated in two small portions of the Dassiesridge WEF study area (marked in green on Fig. 62 herein):

- a sector of the access road from the R75 that runs in a low-lying area underlain by the Voorstehoek Formation (Grassridge 187);
- wind turbine positions and associated access roads in the eastern portion of Farm 3/190 that may impact fossil oyster beds in the basal Alexandria Formation, as well as fossil wood and marine shells in the Kirkwood and Sundays River Formations respectively.

Due to (1) the general scarcity of fossil remains within most of the development footprint, (2) the high levels of bedrock weathering and tectonic deformation as well as (3) the extensive

superficial sediment cover overlying most portentially fossiliferous bedrocks within the Dassiesridge WEF study area, the overall impact significance of the construction phase of the proposed wind energy project is assessed as only MODERATE (negative). This applies to the wind turbines and associated infrastructure, access roads, substations as well as to the 132 kV transmission line connection to the Eskom grid. No significant further impacts on fossil heritage are anticipated during the operational and decommissioning phases of the WEF. There are no fatal flaws in the Dassiesridge WEF development proposal as far as fossil heritage is concerned. Cumulative impacts on fossil heritage of the adjacent Dassiesridge and Grassridge WEFs near Uitenhage are assessed as LOW, given the low palaeontological sensitivity and extensive outcrop area of the main rock units concerned.

Given the low palaeontological sensitivity of the majority of the Dassiesridge WEF study area, specialist palaeontological mitigation is only recommended within the two small areas shown on Fig. 62 herein, pending the discovery elsewhere of substantial new fossil remains during construction. Once excavations for infrastructure such as access roads and wind turbine footings within these two sensitive areas are opened, they should be inspected for fossil remains by a professional palaeontologist. Mitigation would normally involve the scientific recording and judicious sampling or collection of fossil material as well as associated geological data (*e.g.* stratigraphy, sedimentology, taphonomy).

During the construction phase all deeper (> 1m) bedrock excavations should be monitored for fossil remains by the responsible Environmental Control Officer (ECO). Should substantial fossil remains - such as vertebrate bones and teeth, fossil shell beds or petrified logs of fossil wood - be exposed during construction, the responsible Environmental Control Officer should safeguard these, preferably *in situ*, and alert ECPHRA (*i.e.* The Eastern Cape Provincial Heritage Resources Authority. Contact details: Mr Sello Mokhanya, 74 Alexander Road, King Williams Town 5600; smokhanya@ecphra.org.za) as soon as possible so that appropriate action can be taken by a professional palaeontologist at the developer's expense. These mitigation recommendations should be incorporated into the Environmental Management Plan (EMP) for the Dassiesridge WEF.

1. INTRODUCTION & BRIEF

1.1. Project outline

The company Innowind (Pty) Ltd is proposing to construct a wind energy facility (WEF), known as the Dassiesridge WEF, of up to 140 MW generation capacity, together with associated infrastructure, on a site in the Cacadu District of the Eastern Cape, to the north of Port Elizabeth (Fig. 1). The study area of over 7300 hectares is situated in rolling hilly terrain on the eastern side of the R75 tar road, approximately 20 km from the small towns of Uitenhage, in the south, and Kirkwood, in the north, and is transected by the railway line between Klipplaat and Port Elizabeth. It comprises the following land parcels, as shown in Fig. 2: portion of 11/185, 187, 188, 14/233, 15/233, 3/189, 3/190, 4/189, 4/233, 5/189, RE/189 and RE/2/189. The development footprint will be approximately 68 ha, depending on final layout design.

In addition to the approximately 42 to 47 wind turbines, the Dassiesridge WEF will comprise the following main infrastructural components:

- Concrete foundations to support the wind towers;
- Approximately 6 meter-wide internal access roads to each turbine;
- Underground cables connecting the turbines with each other and to the mini-substation;
- A building to house the control instrumentation and interconnection elements, as well as a storeroom for maintenance equipment;
- An onsite mini-substation to facilitate interconnection of the WEF with the Eskom grid.

Three substation options and five transmission line routes are under consideration (Fig. 62):

- Option 1: Loop-in loop-out on the 132 kV Skilpad line on the Western part of the site;
- Option 2: Loop-in loop-out on the 132 kV Skilpad line on the Eastern part of the site;
- Option 3: Connect at 132 kV at Olifantskop;
- Option 4: Loop-in loop-out on the 132 kV Nooitgedacht line (This option will probably require two substations);
- Option 5: Same as Option 4, but connecting onto one of the 400 kV Cookhouse lines.

The proposed new power lines use the existing power line servitudes for the majority of their length.

1.2. Brief for this palaeontological heritage study

The company EOH Coastal & Environmental Services (Pty) Ltd has been appointed to undertake the required environmental process for the Dassiesridge WEF in terms of the National Environmental Management Act (No. 107 of 1998), as amended, on behalf of InnoWind.

The present palaeontological heritage assessment has been commissioned by EOH Coastal & Environmental Services in accordance with Section 38 of the National Heritage Resources Act (1999) (Contact details: Ms Tarryn Martin. Coastal and Environmental Services (Pty) Ltd Tel: +27 46 622 2364. Fax: +27 46 622 6564. Street address: 67 African Street, Grahamstown, 6139. Postal address: PO Box 934, Grahamstown, 6140, South Africa).

The Dassiesridge WEF project area is underlain by potentially fossiliferous sediments of the Cape Supergroup of Palaeozoic age, the Uitenhage Group of Mesozoic age and the Algoa

Group of Late Caenozoic age of Palaeozoic age (Section 3). Fossil heritage preserved within these rocks is protected by law (National Heritage Resources Act of 1999). A combined desktop and field-based Phase 1 palaeontological heritage assessment for the Dassiesridge WEF as part of a comprehensive heritage assessment has accordingly been commissioned with the following brief, as defined by EOH Coastal & Environmental Services:

> A paleontological impact assessment will be conducted, the primary objective of which is to determine whether there are any indications that the proposed site is of paleontological significance. This will be a phase 1 assessment and will be largely desk-top, although a site visit will be required to provide the specialist with the opportunity to look for significant artefacts/fossils on the surface of the site. It is not expected that a more detailed Phase 2 assessment will be required, but this remains to be confirmed.
>
> The terms of reference for the Phase 1 paleontological study will be to:
> - Provide a summary of the relevant legislation;
> - Conduct a site inspection as required by national legislation;
> - Determine the likelihood of paleontological remains of significance in the proposed site;
> - Identify and map (where applicable) the location of any significant paleontological remains;
> - Assess the sensitivity and significance of paleontological remains on the site;
> - Assess the significance of direct and cumulative impacts of the proposed development and viable alternatives on paleontological resources; and
> - Identify mitigatory measures to protect and maintain any valuable paleontological sites and remains that may exist within the proposed site.
> - Prepare and submit any permit applications to the relevant authorities

The specialist study must also include the cumulative impacts of the Grassridge and Dassiesridge WEF.

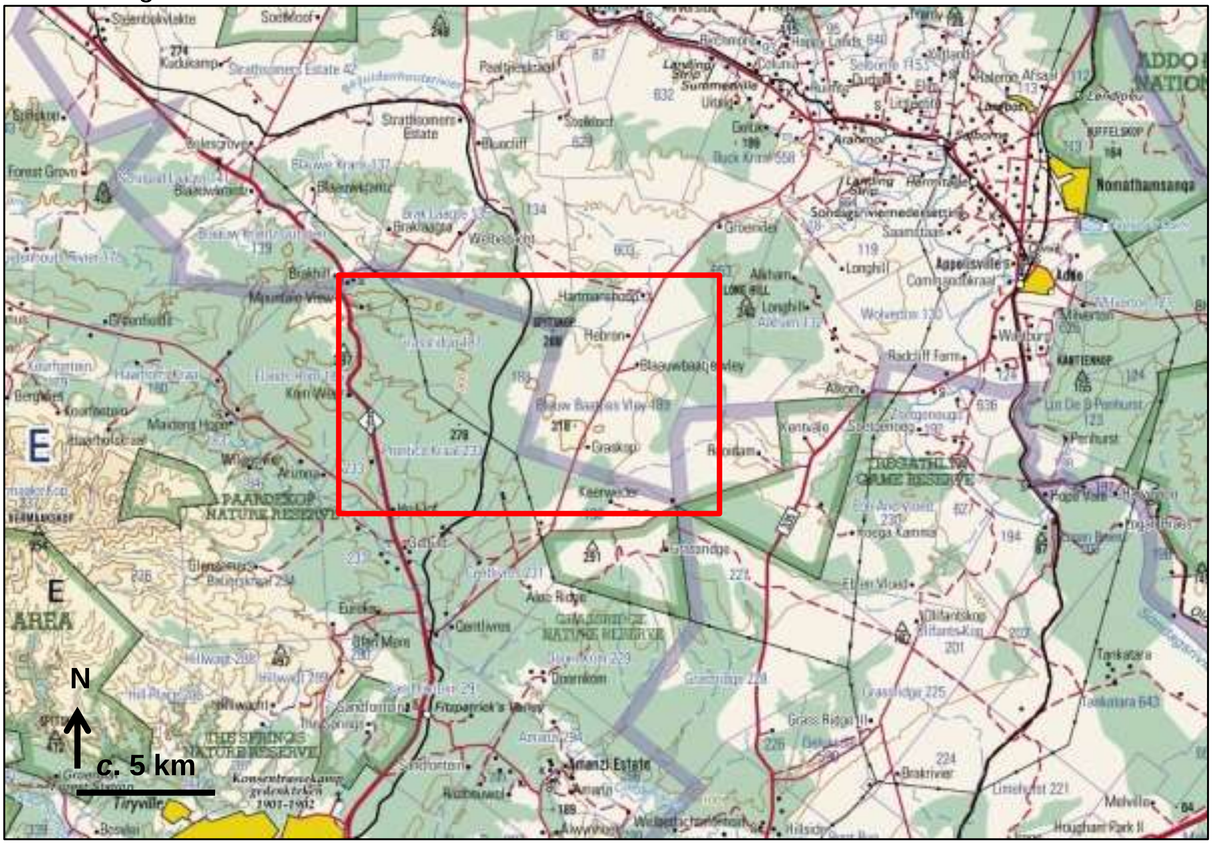


Fig. 1. Extract from 1: 250 000 topographical map 3324 Port Elizabeth (Courtesy of the Chief Directorate: National Geo-Spatial Information, Mowbray) showing the *approximate* location (red rectangle) of the proposed Dassiesridge WEF on the east of the R75 tar road to Jansenville and *c*. 20 km north of Uitenhage, Eastern Cape.

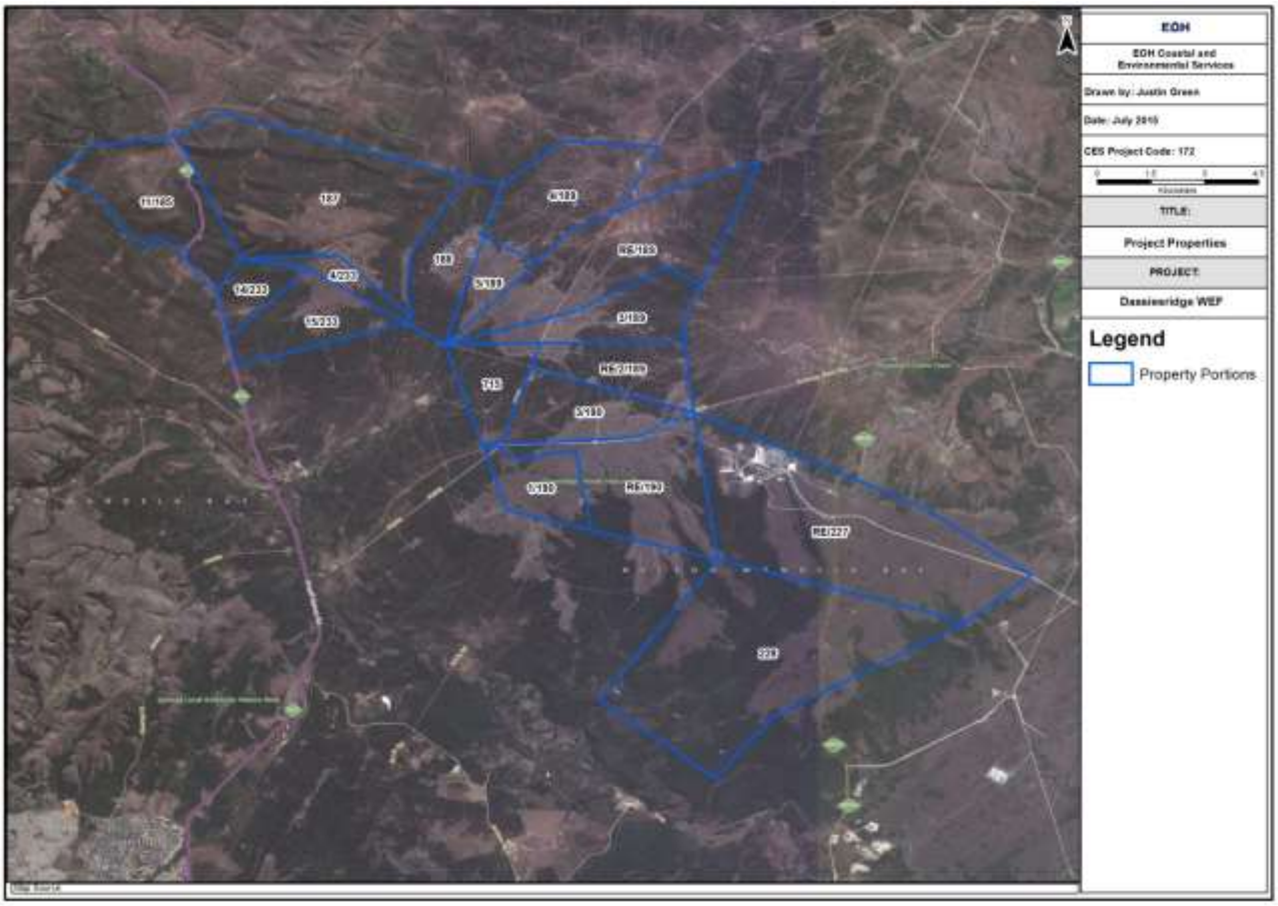


Fig. 2. Google earth© satellite image of the Dassiesridge WEF study area on the eastern side of the R75 tar road *c*. 20 km to the north of Uitenhage, Eastern Cape, showing the outlines (blue polygons) of the various land parcels concerned. Although the land parcel to the west of the R75 has been included in the application (this parcel spans the R75) the area to the west of the R75 does not form part of this study as no development will occur here. Should any development occur to the west, then further studies that cover this area will be required.

1.3. Legislative context for palaeontological assessment studies

The Dassiesridge WEF near Uitenhage is located in an area that is underlain by potentially fossil-rich sedimentary rocks of Middle Palaeozoic and younger, Mesozoic, Late Tertiary or Quaternary, age (Section 3). The construction phase of the proposed development will entail substantial excavations into the superficial sediment cover and locally into the underlying bedrock as well. These notably include excavations for turbine foundations, new internal access roads, underground cables, on-site substation and associated building infrastructure. In addition, substantial areas of bedrock may be sealed-in or sterilized by infrastructure such as hard standing areas for each wind turbine, lay down areas, as well as the new gravel road system. All these developments may adversely affect potential fossil heritage within the study area by destroying, disturbing or permanently sealing-in fossils at or beneath the surface of the ground that are then no longer available for scientific research or other public good. The operational and decommissioning phases of the wind farm development are unlikely to involve further adverse impacts on local palaeontological heritage, however.

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 Environmental Management Plan 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).

1.4. Approach to the palaeontological heritage study

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

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

On the basis of the desktop and Phase 1 field assessment studies, the likely impact of the proposed development on local fossil heritage and any need for specialist mitigation are then determined. Adverse palaeontological impacts normally occur during the construction rather than the operational or decommissioning phase. Phase 2 mitigation by a professional palaeontologist – normally involving the recording and sampling of fossil material and associated geological information (*e.g.* sedimentological data) may be required (a) in the pre-construction phase where important fossils are already exposed at or near the land surface and / or (b) during the construction phase when fresh fossiliferous bedrock has been exposed by excavations. To carry out mitigation, the palaeontologist involved will need to apply for a palaeontological collection permit from the relevant heritage management authority, *i.e.* ECPHRA (The Eastern Cape Provincial Heritage Resources Authority. Contact details: Mr Sello Mokhanya, 74 Alexander Road, King Williams Town 5600; smokhanya@ecphra.org.za). It should be emphasized that, *providing appropriate mitigation is carried out*, the majority of developments involving bedrock excavation can make a *positive* contribution to our understanding of local palaeontological heritage.

1.5. Assumptions & limitations

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

1. Inadequate database for fossil heritage for much of the RSA, given the large size of the country and the small number of professional palaeontologists carrying out fieldwork here. Most development study areas have never been surveyed by a palaeontologist.
2. Variable accuracy of geological maps which underpin these desktop studies. For large areas of terrain these maps are largely based on aerial photographs alone, without ground-truthing. The maps generally depict only significant ("mappable") bedrock units as well as major areas of superficial "drift" deposits (alluvium, colluvium) but for most regions give little or no idea of the level of bedrock outcrop, depth of superficial cover (soil *etc*), degree of bedrock weathering or levels of small-scale tectonic deformation, such as cleavage. All of these factors may have a major influence on the impact significance of a given development on fossil heritage and can only be reliably assessed in the field.
3. Inadequate sheet explanations for geological maps, with little or no attention paid to palaeontological issues in many cases, including poor locality information;
4. The extensive relevant palaeontological "grey literature" - in the form of unpublished university theses, impact studies and other reports (*e.g*. of commercial mining companies) - that is not readily available for desktop studies;
5. Absence of a comprehensive computerized database of fossil collections in major RSA institutions which can be consulted for impact studies. A Karoo fossil vertebrate database is now accessible for impact study work.

In the case of palaeontological desktop studies without supporting Phase 1 field assessments these limitations may variously lead to either:
(a) *underestimation* of the palaeontological significance of a given study area due to ignorance of significant recorded or unrecorded fossils preserved there, or
(b) *overestimation* of the palaeontological sensitivity of a study area, for example when originally rich fossil assemblages inferred from geological maps have in fact been destroyed by tectonism or weathering, or are buried beneath a thick mantle of unfossiliferous "drift" (soil, alluvium *etc*).

Since most areas of the RSA have not been studied palaeontologically, a palaeontological desktop study usually entails *inferring* the presence of buried fossil heritage within the study area from relevant fossil data collected from similar or the same rock units elsewhere, sometimes at localities far away. Where substantial exposures of bedrocks or potentially fossiliferous superficial sediments are present in the study area, the reliability of a palaeontological impact assessment may be significantly enhanced through field assessment by a professional palaeontologist. In the present case, site visits to the various loop and borrow pit study areas in some cases considerably modified our understanding of the rock units (and hence potential fossil heritage) represented there.

In the case of the present study area in the Uitenhage region of the Eastern Cape exposure of potentially fossiliferous bedrocks is mainly limited to river banks, erosion gullies and steep hill slopes, as well as artificial excavations such as railway and road cuttings and borrow pits, due to extensive cover by superficial sediments and grassy or bushy vegetation. Comparatively few academic palaeontological studies have been carried out in the region so any new data from impact studies here are of scientific interest.

1.6. Information sources

The information used in this desktop study was based on the following:

1. A brief project outline kindly supplied by EOH Coastal & Environmental Services (Pty) Ltd;

2. A review of the relevant scientific literature, including published geological maps and accompanying sheet explanations (*e.g.* Toerien & Hill 1989, Le Roux 2000) as well as several previous fossil heritage assessments in the Port Elizabeth sheet area (*e.g.* Gess 2008, Almond 2010, 2011, 2012, 2013);

3. The author's previous field experience with the formations concerned and their palaeontological heritage (*cf* Almond *et al.* 2008, Almond 2010);

5. A four and a half -day field assessment of the study area during the period 22-26 September, 2014. Fieldwork mainly focussed on the limited number of natural or artificial exposures of potentially fossiliferous bedrocks within or close to the study area as well as on thick deposits of Pleistocene and younger alluvium in stream valleys. Few of the informative rock exposures were situated in the upland plateau and hilltop sites where the wind turbines will be situated since the bedrocks here are usually mantled by soil and grassy vegetation.

2. GEOLOGICAL OUTLINE OF THE STUDY AREA

The geology of the Dassiesridge WEF study area between Uitenhage and Kirkwood is outlined on the 1:250 000 geology sheet 3324 Port Elizabeth (Toerien and Hill 1989) and in more detail on the 1: 50 000 sheets 3324CB Uitenhage (Noord) and 3325DA Addo (Le Roux 2000). The area overlies the west-east trending southern limb of the Permo-Triassic Cape Fold Belt and also lies along the western edge of the Mesozoic Algoa Basin. Some twelve or so discrete sedimentary rock units are mapped at 1: 50 000 scale within or on the margins of the Dassiesridge WEF study area (Fig. 3).

The oldest bedrocks are shallow marine to marginal marine siliciclastic sediments of the **Bokkeveld Group** (Ceres and Traka Subgroup) of Early to Middle Devonian age. Six successive formations of Bokkeveld Group rocks build a broadly west-east trending synclinal structure to the northeast of the Groot-Winterhoekberge mega-anticline. These Devonian sediments are generally highly deformed (*i.e.* folded with steep dips and cleaved) and are best represented in the north-western sector of the study area (*e.g.* Grassridge 187). Here the more resistant-weathering sandstone-dominated units (**Gamka**, **Hexrivier** and **Boplaas Formations**) build WNW-ESE trending rocky ridges while the mudrock-dominated units (**Voorstehoek**, **Tra Tra**, **Karies Formations**) underlie the intervening valleys and are generally very poorly exposed.

During and following the break-up of Gondwana in Early Cretaceous times the Palaeozoic bedrocks in this region were deeply weathered and eroded to form a dissected palaeosurface across which meandering rivers deposited the pebbly channel sandstones and silty overbank mudrocks of the **Kirkwood Formation** (**Uitenhage Group**). The basal contact or unconformity between the Uitenhage and Bokkeveld Group rocks preserves the original high relief of the pre-Cretaceous landscape, with hills of Gamka Formation and younger Bokkeveld wackes projecting up through the lower Uitenhage Group fluvial succession. The Kirkwood continental sediments interfinger southwards, and are eventually overlain by, fine-grained estuarine to marine shelf sediments of the **Sundays River Formation** (Uitenhage Group) reflecting gradual flooding of the margins of southern Africa in Early Cretaceous times.

Following protracted erosion and intermittent uplift of the continental margin, the older Palaeozoic and Early Cretaceous bedrocks in the study area (now deeply weathered) were planed off by coastal erosion in Miocene – Pliocene times. A new, gently-sloping unconformity developed, overlain by a thin (10 m or less), limestone-dominated shallow marine to coastal succession, the **Alexandria Formation** (**Algoa Group**) in the Grassridge Plateau area. In many areas the Alexandria Formation is extensively blanketed in pebbly, reddish-brown residual soils. These were previously (1: 250 000 map) assigned to a separate **Blue Water Bay Formation** but are now incorporated into the Alexandria Formation (1: 50 000 map). Relict patches of Plio-Pleistocene aeolianites (dune sands) of the **Nanaga Formation** (Algoa Group) are scattered across the interior coastal plateau. These sands are often rubified (reddened) through weathering of metal-rich impurities. Geologically recent erosion by the southeast-flowing Coega River and its tributaries has led to dissection of the Algoa Group outcrop area and incised the soft, readily-weathered saprolite (*in situ* weathered bedrock) of the Uitenhage Group and Bokkeveld Group bedrocks. Isolated patches of Algoa Group limestones and aeolian sands are now restricted to hilly upland areas above 360 m amsl. Grassy vegetation tends to predominate overlying limestone and calcrete on the upland plateau areas where much of the proposed windfarm infrastructure will be sited. Valley slopes and floors underlain by Uitenhage Group mudrocks and minor sandstones are densely clothed in shrubby, thorny valley bushveld vegetation (Sundays Thicket) with very limited bedrock exposure indeed.

Throughout most of the Dassiesridge WEF and associated transmission line study area the Palaeozoic and Mesozoic bedrocks are mantled by a range of much younger superficial sediments of probable Late Tertiary / Quaternary to Recent age such as colluvium (slope deposits such as scree), alluvium, soils and downwasted surface gravels. These sediments are not mapped at 1: 50 000 scale for the most part (none are shown within the study area in Fig. 3) but they may be several meters thick and some (*e.g.* older alluvial deposits exposed by gulley or *donga* erosion) may contain important fossil heritage. Small areas of calcretised, cobbly High Level Gravels and associated finer-grained calcretised alluvium are mapped at around 220-220 m amsl overlying the Sundays River Formation just northeast of the study area.

Fig. 3 (following page). Extract from 1: 50 000 geological maps 3324CB Uitenhage (Noord) and 3325DA Addo (Council for Geoscience, Pretoria) showing the outline (black polygon) of the proposed Dassiesridge WEF study area to the north of Uitenhage. The main geological units represented within the WEF study region comprise the following (palaeontologically – sensitive units in blue):

1. BOKKEVELD GROUP

Gamka Formation (Dga, dark blue)
Voorstehoek Formation (Dv, pale yellow)
Hexrivier Formation (Dh, purple)
Tra Tra Formation (Dt, blue-green)
Boplaas Formation (Db, grey)
Karies Formation (Dk, pale blue)
Adolphspoort Formation (Da, grey) ***N.B. Outcrops within the study area mapped as Da are probably actually Gamka Formation (Dga).***

2. UITENHAGE GROUP

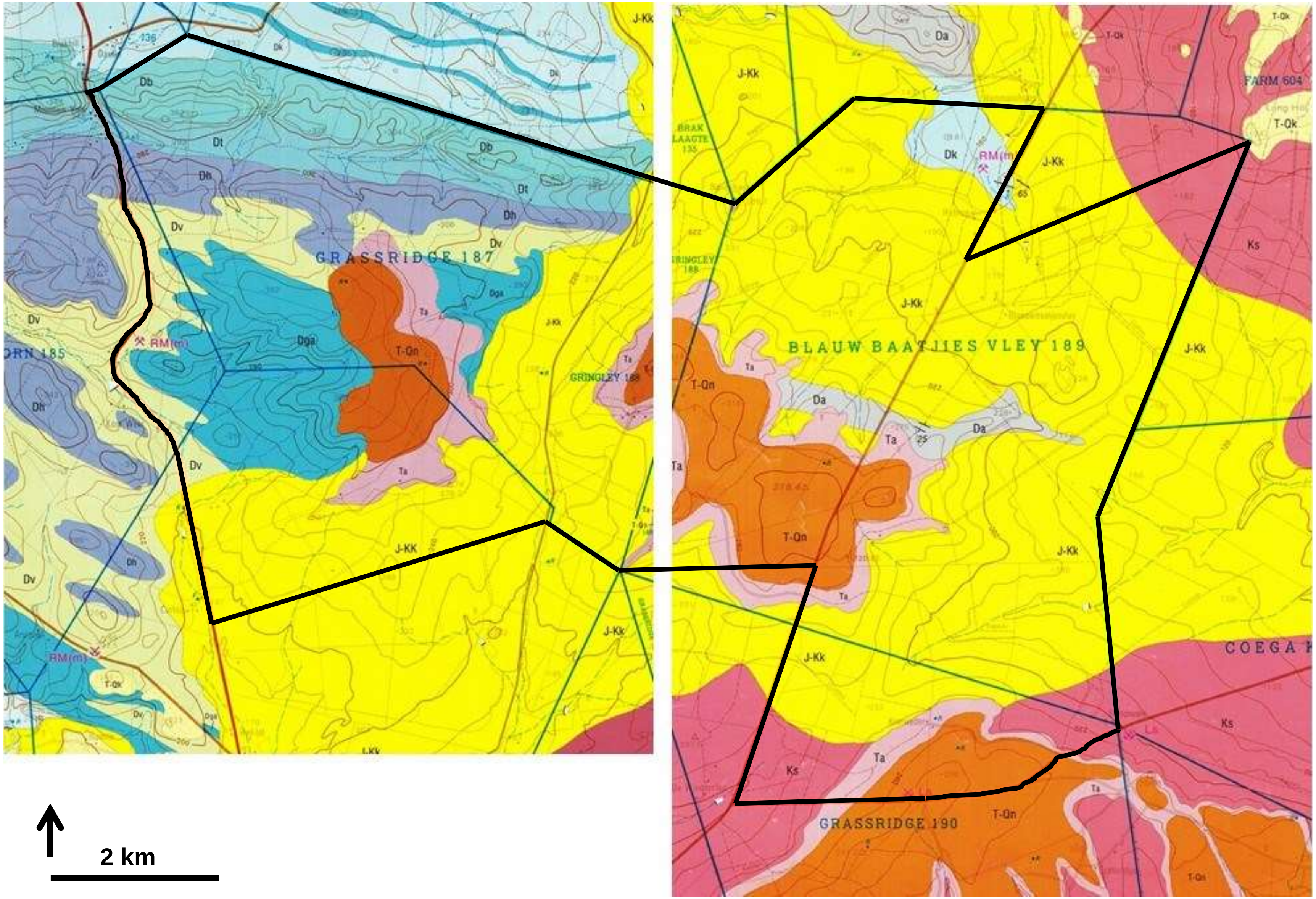
Kirkwood Formation (J-KK, yellow)
Sundays River Formation (Ks, red)

3. ALGOA GROUP

Alexandria Formation (Ta, pink)
Nanaga Formation (T-Qn, orange)

***N.B.* Large areas of Palaeozoic and Mesozoic bedrocks are mantled by a range of other Late Caenozoic superficial deposits, such as colluvium (slope deposits, *e.g.* scree),**

downwasted gravels and soils that may reach thicknesses of several meters but are generally not mapped at 1: 50 000 scale. Small areas of Late Caenozoic High Level Gravels (T-Qk, pale yellow) are mapped just to the NE of the study area.


GRASSRIDGE 187
BLAUW BAATJIES VLEY 189
GRASSRIDGE 190
GRINGLEY 188
COEGA K
FARM 604
J-Kk
T-Qn
T-Qk
Ta
Da
Dk
Ks
Dv
Dh
Db
Dt
Dga
RM(m)
2 km

3. GEOLOGICAL AND PALAEONTOLOGICAL FIELD OBSERVATIONS

The geology and palaeontology of the various rock units represented in the Dassiesridge WEF study area near Uitenhage have already been covered in the relevant sheet explanations by Toerien and Hill (1989) and Le Roux (2000) as well as in previous palaeontological assessment reports for the broader Port Elizabeth - Uitenhage – Coega region by the author (Almond 2010, 2011, 2012, 2013), to which the interested reader is referred. Also relevant is the palaeontological assessment for Amanzi Estates, located northeast of Uitenhage along the Coega River *c*. 8 km south of the present study area, by Gess (2008)

In the following section of the report, a brief, illustrated account of representative rock exposures of each rock unit examined for fossil heritage during the course of the present fieldwork study is provided, together with data on fossil material recorded there. GPS locality data for all numbered localities mentioned in the text is provided in the Appendix.

3.1. Bokkeveld Group

Within the western part of the Eastern Cape Province, only a handful of productive fossil localities within the Ceres Subgroup have been recorded so far. Most notably, these include the Cockscomb area between Willowmore and Steytlerville, Klein Kaba near Alexandria, and the Uitenhage North area (*e.g.* Theron 1972, Johnson 1976, Hiller 1980, Oosthuizen 1984, Toerien & Hill 1989, Le Roux 2000). As is the case to the west, shelly fossils are most abundant in the mudrock-dominated formations, including the Gydo, Voorstehoek and Tra Tra Formations. Indeed, the Voorstehoek Formation in the Eastern Cape may prove quite productive, although the assignation of some faunal records to this unit requires confirmation (*e.g.* Hiller 1980, Oosthuizen 1984, Hiller 1990). Useful faunal lists for the rich Gydo Formation biota at the Cockscomb Mountains and the unconfirmed Voorstehoek Formation biota at Klein Kaba are given by Oosthuizen (1984, Table III and p.138 respectively). The Cockcomb biota is preserved as moulds within early diagenetic nodules of phosphatic or other composition (*cf* Browning 2008). It includes a wide range of trilobites, brachiopods, bivalves, gastropods, crinoids, a possible echinoid, corals, abundant well-preserved conulariids, ostracods and various problematic groups (*e.g.* hyolithids, tentaculitids and other tubular fossils). The Klein Kaba faunule listed by Oosthuizen (1984) is dominated by a number of articulate brachiopods, but also comprises gastropods, bivalves, nautiloids, trilobites, crinoids, conulariids, various tubular fossils and traces.

3.1.1. Gamka Formation

Resistent-weathering, dirty-looking sandstone facies of the Gamka Formation build hilly slopes in a central band across the Dassiesridge WEF study area but are very rarely well-exposed. They are usually seen as rubbly angular colluvial gravels with occasional exposures of medium-bedded, greenish-brown to dark grey cleaved wackes and siltstone interbeds in farm tracks (Locs. 688, 700). Vertically-dipping, thick-bedded Gamka wackes are well seen in the banks of an incised stream on Prentice Kraal 233 (Fig. 4), just southwest of the WEF study area (Loc. 761a). The narrow NNW-SSE outcrop area of Adolphspoort rocks (Da) mapped on Blaauw Baatjies Vley 189 on the 1: 50 000 geological map (Fig. 3) is much more likely to belong to the Gamka Formation (Dga), and is mapped as such on the 1: 250 000 geology sheet 3324. The Gamka wackes and cleaved siltstones are well-exposed in road cuttings at Loc. 708 (Blaauw Baatjies Vley 189) (Fig. 5). Here they generally dip gently towards the south but are clearly tectonically disrupted with numerous small faults, joints and occasional bodies of fault breccia.

Rounded boulders of Gamka wacke seen at *c*. 340 m amsl on Grassridge 187 (Loc. 665b) may have been reworked by coastal wave action in Alexandria Formation times (Fig. **).

Palaeontology

No fossil remains were recorded from the Gamka Formation during the present field study. Le Roux (200, p. 16) mentions that the Gamka Formation in the Port Elizabeth area is fossiliferous, but gives no further details.

3.1.2. Voorstehoek Formation

Cleaved, greyish, lilac and grey-green, mottled, medium-bedded, bioturbated siltstones and fine-grained, laminated wackes (often micaceous) dipping *c*. 30º towards the south are exposed in a sizeable roadside quarry on Elands Hoorn 185 (Loc. 656, marked on the geological map Fig. 3) (Fig. 6). The bedrocks are weathered and locally ferruginised but retain common, well-preserved shelly fossil moulds. Small, pebble-size sphaeroidal diagenetic concretions are common at some horizons and do not appear to be fossiliferous. The Voorstehoek bedrocks exposed in nearby road cuttings along the R75 (*e.g.* Loc. 658) are highly cleaved and mantled by shaly gravels as well as orange-brown silty soils.

Palaeontology

Moulds of shelly invertebrate fossils are moderately abundant within Voorstehoek mudrocks on Elands Hoorn 185 (Loc. 656) (See also Le Roux 2000, p. 16) (Figs. 7 to 11). The moulds occur either dispersed within the mudrocks or as thin coquinas of disarticulated shelly remains concentrated on siltstone or sandstone bedding planes. Several of the fossils have clearly been distorted by tectonic compression.

Fossil taxa recorded here include:

Trilobites: *Burmeisteria*, possible *Metacryphaeus*
Articulate brachiopods: *Australospirifer*, *Australoceolia*, various chonetids
Molluscs: nuculid bivalves (*Nuculites*, *Palaeoneilo*, *Phestia* / *Nuculana*), bellerophontid *Plectonotus*
Echinoderms: articulated and disarticulated crinoid columnals, calyx plates of the blastoid *Pachyblastus*, possible carpoids (*cf Placocystella*)
Other groups: tentaculitids, possible ostracods
Trace fossils: various simple horizontal burrows

This locality is of considerable palaeontological interest as one of the few fairly prolific Lower Bokkeveld Group fossil sites in the Port Elizabeth sheet area, and indeed the Eastern Cape as a whole.

Fig. 4. Subvertical arenitic beds of the Gamka Formation, stream bank cliffs on Prentice Kraal 233 (Loc. 671a).

Fig. 5. Cleaved, tectonised wackes of the Gamka Formation, road cutting along dust road to Kirkwood (Loc. 708) (Hammer = 30 cm).

Fig. 6. Steeply-dipping, tabular-bedded wackes of the Voorstehoek Formation, borrow pit adjacent to the R75, Elands Hoorn 185 (Loc. 656) (Hammer = 30 cm).

Fig. 7. Moulds of chonetid brachiopods and *Australoceolia*, Voorstehoek Formation (Loc. 656) (Scale in cm and mm).

Fig. 8. Thin shelly coquina dominated by tentaculitids and occasional disarticulated crinoid columnals, Voorstehoek Formation (Loc. 656) (Scale in cm and mm).

Fig. 9. Distorted internal mould of the cephalon of the trilobite *Burmeisteria*, Voorstehoek Formation (Loc. 656) (Scale in cm and mm).

Fig. 10. Thin carpet of shelly fossil moulds (nuculitid bivalves, chonetid brachiopods, *Australoceolia etc*) on a siltstone bedding plane, Voorstehoek Formation (Loc. 656) (Largest shell seen here is 18 mm long).

Fig. 11. Moulds of nuculoid bivalves (*Palaeoneilo, Nuculites*), Voorstehoek Formation (Loc. 656) (Scale in cm and mm).

3.1.3. Hexrivier Formation

Limited hillslope exposures of resistant-weathering, well-jointed greyish to brown wackes of the Hexrivier Formation are exposed along a low ridge in the northwestern sector of Grassridge 187 (Loc. 660) (Fig. 12). The SW-dipping wackes here are thin- to medium-bedded and show abundant evidence of small-scale faulting (quartz mineral lineation) as well as NE-dipping cleavage development in muddier facies.

Palaeontology

No fossil remains were recorded from the Hexrivier Formation during the present field study. Vertical mud-lined burrows are recorded from this rock unit on nearby farm Elands Hoorn 185 by Le Roux (2000, p. 17).

Fig. 12. Well-jointed brownish-weathering wackes of the Hexrivier Formation, Grassridge 187 (Loc. 659) (Hammer = 30 cm).

3.1.4. Tra Tra Formation

The mudrock-dominated Tra Tra Formation underlies a west-east trending valley between the Hexrivier and Boplaas ridges on Grassridge 187 but is almost nowhere exposed. Weathered, steeply-dipping, fractured, lilac-grey, laminated Tra Tra siltstones are visible in a farm track at Loc. 604 where they are extensively veined by calcrete (Fig. 13). Vein quartz is abundant among the surface gravels here, suggesting local faulting.

Palaeontology

No fossil remains were recorded from the Tra Tra Formation during the present field study. Le Roux (2000, p. 17 & his fig. 4.3) reports trilobites from Tra Tra rocks in a quarry on farm Haarhoffskraal 180.

Fig. 13. Farm track exposure of weathered Tra Tra Fm mudrocks traversed by calcrete veins, Grassridge 187 (Loc. 664) (Hammer = 30 cm).

3.1.5. Boplaas Formation

Two small hillslope exposures of Boplaas Formation rocks (Locs. 660, 661) are located along the Boplaas ridge in the north-western sector of farm Grassridge 187. At Loc. 661 the beds are subvertical, tabular, and young towards the north. A lower succession of thick- to medium-bedded greyish wackes, massive to finely-laminated shows occasional wave-rippled bedding planes. It is overlain by a purple-brownish-weathering, heterolithic, thin- to medium-bedded succession of micaceous siltstones and horizontally-laminated to ripple cross-laminated wackes. Low-angle cross-lamination may reflect hummocky cross-stratification. Some of the finer-grained beds and wackes are highly bioturbated and there are thin intraformational breccio-conglomerates. The Boplaas succession here is extensively quartz-veined. Cleavage and quartz mineral lineation is clearly developed within the brownish-weathering, SW-dipping wackes at Loc. 660.

Palaeontology

Apart from isolated horizontal burrows, no fossil remains were recorded from the Boplaas Formation during the present field study. Le Roux (2000, p. 18) reports highly bioturbated units within the Boplaas Formation in the Port Elizabeth area, with common trace fossils within the thin-bedded, heterolithic upper part of the succession on Elands Hoorn 185.

Fig. 14. Subvertical wackes and siltstones of the Boplaas Formation on Grassridge 187 (Loc. 661).

Fig. 15. Close-up view of heterolithic beds towards the top of the Boplaas Formation succession, younging towards the left (north). These beds contain trace fossils.

3.1.6. Karies Formation

Karies Formation mudrocks are well-exposed in the large quarry on Farm 4/189 near Hartmanshoop farmstead (Loc. 704) (Fig. 16) as well as in nearby road cuttings (Loc. 706) (Fig. 17). In the quarry a thick succession of weathered, grey-green to dark grey siltstones shows well-developed cleavage dipping at around 45º towards the south. The beds are locally crumpled, secondarily ferruginised and may show a phyllitic sheen. In the road cuttings, the bedding dips gently north and the cleavage dips more steeply to the south. Flaser and lenticular lamination is developed in some units. The cleaved Bokkeveld bedrocks are unconformably by subhorizontal overbank mudrocks of the Kirkwood Formation and younger alluvium in the southern portion of the quarry (Fig. 24).

No fossil remains were recorded from the Karies Formation during the present field study. Le Roux (2000, p. 18) reports plant stem impressions and trace fossils from unspecified horizons within the Upper Bokkeveld Group (Traka Subgroup) in the Port Elizabeth area.

Fig. 16. Weathered, ferruginised and cleaved mudrocks of the Karies Formation, quarry on Farm 4/189 (Loc. 704).

Fig. 17. Road cutting through Karies Formation mudrocks and wackes showing bedding dipping towards the north (left) cut by a pervasive, steeper cleavage dipping towards the south (Loc. 706).

3.2. Uitenhage Group

The palaeontology of the Uitenhage Group rocks in the Port Elizabeth – Uitenhage area has been summarized, with extensive references, by Almond (2010, 2011, 2012, 2013) as well as in the relevant sheet explanations by Toerien and Hill (1989) and Le Roux (2000).

3.2.1. Kirkwood Formation

Good exposures of the variegated overbank siltstones and grey-green sandstones of the Kirkwood Formation are seen on Farm 14/233 (Locs. 677-686), Gringley 188 (Locs. 689-692) and - especially - on the eastern portion of Blaauw Baatjies Vley (RE/189, Locs. 722-723) (Figs. 18, 23, 24, 25, 30, 31). The beds are generally flat lying to gently dipping. Massive, tabular or lenticular bedding, flat-lamination, current cross-bedding and thin pebbly or mudflake conglomeratic or gritty beds are seen among the poorly-consolidated channel sandstones, some of which are secondarily calcified and bioturbated. The overlying surface gravels contain occasional characteristic, highly-polished pebbles of reworked sandstone or other resistant lithology as well as downwasted petrified wood (Fig. 56). The overbank siltstones are typically multi-hued, with pinkish, buff, khaki and green-grey horizons, and occasionally contain palaecalcretes. A good cross-section through a lenticular channel sandstone body is seen in the road cutting at Loc. 707 (Farm 603 (Fig. 23).

The unconformity between strongly-dipping, folded, cleaved Bokkeveld Group bedrocks and fairly flat-lying, variegated Kirkwood beds is seen in the large quarry on Farm 4/189 (Loc. 705). Kirkwood sediments beneath the basal Algoa Group unconformity are typically deeply weathered with powdery, structureless silty mudrocks and friable, leached, ferruginised and often calcrete-veined sandstones (*e.g.* Locs. 689-690, Gringley 188, Loc. 723 on RE/189) (Figs. 30, 54).

Palaeontology

Sizeable logs of petrified wood are locally common within channel sandstones of the Kirkwood Formation ("Wood Beds") and weathered-out blocks of fossil wood are well-represented in the associated surface gravels (Figs. 21, 22, 26-29, 32, 33, 56). Good examples of *in situ* fossil logs within the WEF study area recorded from the Geluksdal Private Game Reserve (Farm 14/233) (Locs. 674-686), Gringley 188 (Loc. 691) and Blaauw Baatjies Vley 189 (RE/189) (Loc. 721). Preferential orientation of the logs was not observed except very locally (Loc. 684)(Fig. 27) and they do not seem to be confined to particular horizons within the channel sandstone bodies. They reach lengths of over three meters and diameters of 50 cm. Some fossil wood material appears to be preserved as structureless casts whereas in other cases the original wood microstructure, including seasonal growth rings, is well preserved in silica (Figs. 22, 32, 33). Previous studies of Kirkwood fossil woods suggest that the majority belong to gymnosperms of coniferan and podocarpacean affinities (Bamford 2004). Occasional blocks contain irregular winding channels that might represent insect borings (Fig. 29). Bedding planes covered with moulds of comminuted woody plant material (and *possibly* needle-like leaves) are also seen. Additional sites where petrified Kirkwood fossil wood fragments as well as sandstone float blocks with fossil wood moulds have been recorded in surface gravels but not *in situ* include Loc. 700 (Farm 4/189), Loc. 715 (in gravel road near entrance gate to Farm 3/189) and Loc. 719 (Farm 3/189) (Fig. 56). It is possible that resistant-weathering clasts of silicified wood have been preferentially concentrated in some areas along the contact of the Kirkwood and Alexandria Formations through weathering, denudation and coastal reworking of the underlying fossiliferous beds.

Sparse to concentrated assemblages of horizontal, oblique and vertical invertebrate burrows are recorded from occasional thin, lenticular, greyish-buff sandstones within the Kirkwood overbank mudrocks (Loc. 719 on Farm 3/189 and Loc. 723 on RE/189) (Figs. 19, 20).

Fig. 18. Excellent erosion gulley exposure of multi-hued overbank mudrocks and channel sandstones of the Kirkwood Formation, Prospect Vale (RE/189) (Loc. 723).

Fig. 19. Impersistent greyish sandstone beds showing high levels of bioturbation, Kirkwood Formation, Prospect Vale (RE/189) (Loc. 723) (Hammer = 30 cm).

Fig. 20. Pale sandstone lens containing dense vertical invertebrate burrows, Kirkwood Formation, Prospect Vale (RE/189) (Loc. 723) (Scale in cm).

Fig. 21. Large (*c*. 2.5 m long) fossil log weathering out of channel sandstones of the Kirkwood Formation, Prospect Vale (RE/189) (Loc. 721) (Hammer = 30 cm).

Fig. 22. Blocks of silicified wood showing preservation of internal wood microstructure, including seasonal growth rings, Kirkwood Formation, Prospect Vale (RE/189) (Loc. 721) (Scale in cm).

Fig. 23. Road cutting exposure of lenticular channel sandstone body within weathered Kirkwood Formation saprolite, Farm 603 (Loc. 707).

Fig. 24. Subhorizontal, multi-hued overbank mudrocks of the Kirkwood Formation overlain by partially calcretised orange alluvium and gravels, quarry on Farm 4/189 (Loc. 705).

Fig. 25. Hillslope exposure of olive-green cross-bedded channel sandstones and pebbly grits of the Kirkwood Formation, Portion 14/233 (Hammer = 30 cm) (Loc. 685).

Fig. 26. Large petrified log weathering out of Kirkwood Formation channel sandstones, Portion 14/233 (Hammer = 30 cm).

Fig. 27. Parallel logs of petrified wood (possibly current-orientated), Kirkwood Formation channel sandstones, Portion 14/233 (Hammer = 30 cm).

Fig. 28. Oblique end-on view of fossil log projecting from Kirkwood Formation sandstones, Portion 14/233 (Hammer = 30 cm). Note external mould seen here.

Fig. 29. Block of Kirkwood petrified wood showing probable insect boring (arrow), surface gravels on Portion 14/233 (Block is *c*. 11 cm across).

Fig. 30. Highly weathered, leached and calcrete-veined, cross-bedded sandstones of the Kirkwood Formation, gulley exposure on Gringley 188 (Loc. 690).

Fig. 31. Deeply weathered overbank mudrocks and ferruginised channel sandstones of the Kirkwood Formation, gulley exposure on Gringley 188 (Loc. 692).

Fig. 32. Well-preserved fossil wood fragments from a partially embedded log that is breaking-up *in situ*, Kirkwood Formation, Gringley 188 (Hammer = 30 cm) (Loc. 691).

Fig. 33. Close-up of one of the Kirkwood wood fragments seen in the previous figure showing preservation of the original woody fabric (Scale in cm).

3.2.2. Sundays River Formation

Road cuttings through thick, apparently massive, grey-green siltstones with occasional thin, impersistent, grey-green sandstone lenses at Loc. 671b, near Centlivres, are mapped as Kirkwood Formation but accord more closely with the Sundays River Formation that is mapped a few kilometres to the east. Thin, pinkish-brown, laminated sandstone lenticles are also seen here. Slightly further north (Loc. 672) thin- to medium-bedded, tabular, olive-brown to buff sandstones with a poorly-consolidated, crumbly texture show numerous, closely-spaced partings carpeted with abundant mudflake intraclasts, wood fragments, sparse bivalve moulds and other plant debris.

Friable, brownish-weathering sandstones in road cuttings along the R75 (Loc. 672) contain sparse disarticulated valve moulds of marine bivalve molluscs – principally nuculids, but also rare, more highly ornamented taxa – in association with abundant fragmentary plant material and reworked mudflakes (Figs. 35, 36). These beds may represent nearshore, estuarine to marine facies close to the interface of the Kirkwood and Sundays River Formation. They are mapped as Kirkwood but are assigned here rather to the Sundays River Formation because of the marine mollusc fauna.

Good exposures of fossiliferous Sundays River Formation are seen in an abandoned brick pit near Centlivres Siding on Prentice Kraal 233 (Loc. 695, mapped as Kirkwood Formation). Olive-green siltstones are intebedded with prominent-weathering, thin (few dm) benches of flat-bedded, well-cemented, brownish-weathering coquina limestone of possible tempestite origin (Fig. 39). These limestone beds are packed with comminuted shell fragments as well as occasional intact valves (*e.g.* trigoniids, small oysters such as *Amphidonte*, pectinoids) and fairly common small gastropod shells (Figs. 40 to 44). Some bedding surfaces are covered with carpets of closely-packed small bivalves (mainly nuculids, including tiny juveniles) similar to those previously reported from Bontrug area (Coega IDZ) by Almond (2010). Moulds of wood fragments co-occur with the fossil shells, suggesting nearshore depositional setting that is also supported by the abundance of oyster material. Common greyish to buff, oblate sphaeroidal "claystone nodules" within the silty facies are apparently unfossiliferous at this locality. Nearby road cuttings through similar Sundays River sandstones and siltstones on Farm Centlivres 231 (Loc. 698) show abundant claystone nodules and horizons rich is disarticulated, reworked thin-shelled oysters. These are sometimes concentrated into lenticular limestone lenses of shelly coquina (Figs. 37 to 38).

Fig. 34. Tabular, friable sandstones exposed in an R75 road cutting (Loc. 672), mapped as Kirkwood Formation but more probably Sundays River Formation (Hammer = 30 cm) or close to the interface between the two Early Cretaceous units.

Fig. 35. Scattered moulds of marine bivalves (e.g. nuculids) associated with grey reworked mudflakes, Sundays River Formation, R75 road cutting (Loc. 672) (Scale in cm and mm).

Fig. 36. Dense hash of reworked fragmentary fossil wood material associated with mudflakes, Sundays River Formation, R75 road cutting (Loc. 672) (Scale in cm and mm).

Fig. 37. Road cutting through grey-green Sundays River mudrocks, Centlivres 231 (Loc. 698), containing dispersed oyster shells, calystone nodules as well as dense oyster shell coquina lenses (arrow) (Hammer = 30 cm).

Fig. 38. Close-up of disarticulated, thin-shelled oysters (possibly *Amphidonte*) weathering out from the Sundays River beds at the locality illustrated in the preceding figure (Scale in cm).

Fig. 39. Good exposures of Sundays River mudrocks and prominent-weathering tabular sandstones associated with shelly coquina limestones, abandoned brick pit near Centlivres Siding (Loc. 695).

Fig. 40. Dark brown shelly limestone from the locality illustrated above showing finely comminuted shelly debris associated with moulds of fossil wood, Sundays River Formation (Scale in cm) (Loc. 695).

Fig. 41. Close-up of shelly coquina from the Sundays River Formation dominated by oyster shell fragments as well as occasional intact small gastropods (arrows). The largest shell fragments seen here are about 1 cm across (Loc. 695).

Fig. 42. Distinctive ribbed, tuberculate shell of a small trigoniid bivalve (*c*. 4 cm long) within shelly coquinas of the Sundays River Formation (Loc. 695). Note also small gastropods (arrowed).

Fig. 43. Small cemented cluster of medium-sized, thick-shelled fossil oysters from the Sundays River Formation (Loc. 695). The largest shell is *c*. 4 cm across (interior view).

Fig. 44. Carpet of small-sized fossil bivalves (mainly nuculids, including probable juveniles) preserved in similar convex-up orientation on a bedding plane of Sundays River fine-grained sandstone (Loc. 695) (Scale in cm).

3.3. Algoa Group

The palaeontology of the Algoa Group rocks in the Port Elizabeth – Uitenhage area has been summarized, with extensive references, by Almond (2010, 2011) as well as in the relevant sheet explanations by Toerien and Hill (1989) and Le Roux (2000).

3.3.1. Alexandria Formation

Limited exposures of this unit commonly consist of calcretised, massive to cross-bedded, pale greyish to cream-hued calcarenites, locally gritty or pebbly, and mantled with calcrete rubble (Loc. 665a, 669). There is generally little bedrock exposure in the low-relief limestone plateau areas, parts of which show clear evidence of karstification (Locs. 669, 694, 696) (Figs. 45 to 46). The Alexandria Formation limestones are locally mantled by orange-brown sandy soils, pebbly surface gravels (reminiscent of the Bluewater Bay facies of some authors) and rubbly surface calcrete. Good sections through the Alexandria Formation are only seen in occasional low scarps or *kranzes* along the plateau edge, for example at Loc. 696 on Farm 15/233 where several meters of gritty, sparsely pebbly, massive to low angle cross-laminated calcarenites are exposed (Fig. 45). Pebbles, mainly of Table Mountain quartzite, are commoner towards the erosive base and well-rounded.

Good exposures of the paraconformable, erosive basal contact between thin (< 1 m) conglomeratic calcarenites of the Alexandria Formation and deeply-weathered Kirkwood saprolite are seen along plateau margins (*e.g.* Loc. 689 at 280 m amsl on Gringley 188, Loc. 716 at 270 m amsl on Farm 3/189) and road cuttings (*e.g.* Loc. 709, at 270 m amsl) (Fig. 47). The well-consolidated, ruditic basal Alexandria beds contain brown, well-rounded pebbles and cobbles of Table Mountain quartzite as well as rarer blocks of local bedrock lithologies (*e.g.* dark, greenish-brown Bokkeveld wackes or Kirkwood / Sundays River sandstones) and occasional fragmentary mollusc shells, especially oysters (Fig. 48). They are overlain by coarse-grained calcarenites and surface calcretes showing karstic weathering and multiple generations of calcretisation. Linear concentrations of well-rounded surface boulders of Gamka wacke and calcarenite, as seen for example on Grassridge 187 (Locs. 665b at 340 m amsl, Loc. 667 at 352 m amsl) may represent relict Miocene-Pliocene boulder beaches preserved along the basal Algoa Group unconformity (Fig. 57). Pitting in the less resistant clasts may be due to boring organisms.

Palaeontology

Comminuted shelly material (especially oysters, but also the thick-shelled bivalve *Glycimeris*) is commonly seen within among the pebbly and cobbly clasts within the basal Alexandria Formation conglomerate facies (*e.g.* Loc. 689) (Fig. 48). Spectacular, laterally extensive oyster coquinas or shell beds capped by calcrete mark the base of the Alexandria Formation in road cuttings along the northern edge of the Grassridge Nature Reserve (Loc. 711) (Figs. 49 to 51). These fossil oyster beds are about one meter thick and consist almost entirely of large (*c*. 15 cm long) shells of the extant taxon *Crassostrea margaritacea* which lives today along the Southern African coast from False Bay to Mozambique (Kilburn & Rippey 1982; Le Roux 1987a, 1990 2000). The thick, irregularly-shaped shells are mostly disarticulated and not in life position, but some articulated specimens are also seen. Some of the shells have bored surfaces. The best-preserved specimens tend to occur within the base of the bed, while the upper part of the coquina mainly comprises shell fragments. Well-consolidated calcarenites with dispersed, reworked and fragmentary oyster remains also occur in the vicinity, along strike from the oyster coquina beds (*e.g.* roadside quarry on Grassridge 190 opposite Loc. 711).

Fig. 45. Vertical section through karstified calcarenites of the Alexandria Formation along the edge of the limestone plateau on Portion 15/233 (Loc. 696).

Fig. 46. Extensively karstified calcarenites of the Alexandria Formation, Portion 5/189 (Hammer = 30 cm).

Fig. 47. Conglomeratic basal beds of the Alexandria Formation capped by calcretised calcarenites, Gringley 188 (Loc. 689) (Hammer = 30 cm).

Fig. 48. Close-up of the basal Alexandria Formation conglomerates on Gringley 188 (Loc. 689) showing fragments of oyster shell as well as a fairly intact specimen of the large bivalve *Glycimeris* (arrow) (Scale in cm and mm).

Fig. 49. Meter-thick coquina of, in part intact but disarticulated, shells of the large oyster *Crassostrea margaritacea* that characterises the base of the Alexandria Formation near the Grassridge Nature Reserve (Loc. 711) (Hammer = 30 cm)

Fig. 50. Close-up of well-preserved valves of the large oyster *Crassostrea margaritacea* towards the base of the shelly coquina at the locality illustrated above (Loc. 711). The shells are around 15 cm long.

Fig. 51. Isolated upper and lower valves of the large oyster *Crassostrea margaritacea* that have weathered out of the coquina bed at Loc. 711 (Scale in cm).

3.3.2. Nanaga Formation

Thick (up to several meters) orange-brown sandy soils overlying the often karstified upper surface of the Alexandria calcarenites are assigned to the Nanaga Formation (*e.g.* Locs. 665, 668) (Fig. 52). Subdued linear NW-SE trending ridges in the surface topography may reflect relict palaeodunes (*e.g.* Loc. 666) but are usually difficult to recognize at ground level (Fig. 53).

The Nanaga aeolianites are often mantled by calcretes and overlying younger soils. The abandoned limestone quarry on Farm Grassridge 190 (Loc. 714) is excavated into calcretes that are mapped within the Nanaga Formation outcrop area.

Palaeontology

No fossil remains were recorded from the Nanaga Formation during the present field study.

Fig. 52. Deep orange-brown, rubified aeolian sands of the Nanaga Formation overlying cross-bedded calcarenites of the Alexandria Formation, road cutting on Grassridge 187 (Loc. 665a) (Hammer = 30 cm).

Fig. 53. Ridge-like, undulating terrain within the Nanaga Formation outcrop area on Grassridge 187 (Loc. 666). The ridges may be subdued aeolian dunes, or perhaps simply erosion gullies.

3.4. Late Caenozoic Superficial sediments

Thick silty to sandy alluvium and hillwash overlying the Uitenhage Group mudrocks is often difficult to distinguish from deeply-weathered Kirkwood or Sundays River saprolite, except for the presence of occasional pebbly stream gravels and Quaternary calcrete nodules (e.g. Loc. 705) (Fig. 24). Brown sandy alluvium spotted with calcrete nodules is well exposed above weathered Kirkwood bedrocks in a gulley on Gringley 188 (Loc. 692) (Fig. 59).

Poorly-sorted conglomerates and overlying calcretised finer-grained sediments exposed in road cuttings at Loc. 707 (Farm 603) are mapped as relict Tertiary / Quaternary High Level Gravels (T-Qk). They are situated at *c*. 170 m amsl, *i.e.* at a significantly lower elevation that the regional base of the Alexandria Formation, and here erosionally incise weathered variegated siltstones and channel sandstones of the Kirkwood Formation (Fig. 54) (mapped as Sundays River Formation). The calcretised fluvial conglomerates consist mainly of well-rounded, pebbly to bouldery clasts of quartzite or sandstone, many of which have probably been reworked from the Alexandria Formation. Shelly material such as oysters is apparently absent and the overlying calcretised sands and silts do not include shell hash and calcarenites, as seen in the superficially similar basal Alexandria beds. The latter also tend to be better consolidated than the Late Caenozoic alluvium and do not show the high level of erosional incision into underlying bedrock seen here.

Surface gravels dominated by platy siltstone cleavage blocks or smaller flakes as well as more resistant vein quartz and wackes occur within the Bokkeveld Group outcrop area, associated with reddish-brown sandy and clay-rich soils (e.g. Loc. 662). Rubbly surface gravels are especially common on hillslopes built of the Gamka Formation. Orange-brown pebbly to cobbly soils overlying the Sundays River Formation are well seen in road cuttings along the R75 at Loc. 671 near Centlivres.

Gravels on slopes beneath scarps of Alexandria Formation limestones typically are dominated by well-rounded quartzitic and sandstone pebbles and cobbles weathering out from the base of the formation. Downwasted pebbly, reddish soils of the “Bluewater Bay” facies overlie large portions of the Alexandria Formation outcrop area (Fig. 58) (see discussion and references in Almond 2010). Anthropogenically flaked Stone Age stone artefacts are often common at surface in these areas.

Thick sequences of orange-brown sands in low-lying areas (below the basal Algoa Group unconformity) probably represent aeolian material from the Nanaga Formation that has been reworked downslope as hillwash and alluvium. The dune-like sands occasionally contain lenses of alluvial gravels dominated by rounded pebbles and cobbles from the Alexandria Formation upslope (sometimes anthropogenically flaked) (Locs. 701-702, Farm 4/189) (Fig. 60).

Shallow pan-like areas are floored by thick, fine-grained silty soil (Locs. 663, 670).

Poorly-sorted stream gravels near Loc. 700 on Farm 4/189 consist of a mixture of well-rounded pebbles and cobbles eroded out of the Alexandria Formation outcrop upstream as well as sandstones and occasional petrified wood clasts from the underlying Kirkwood Formation (Fig. 55).

Thick surface or subsurface calcretes with sparse pebbles but no marine shell remains occur in association with the Alexandria Formation especially, but also overlie other formations such as the Kirkwood Formation (*e.g.* quarries at Loc. 710, Farm 3/190 and Loc. 717, Farm 3/189) (Fig. 61), Nanaga Formation and Late Caenozoic alluvial deposits (Loc. 707). They may be up to several meters thick and are usually capped by a dense hardpan that may show several generations of calcretisation.

Palaeontology

Apart from sparse calcretised fossil invertebrate burrows and possible rhizoliths (root casts) from surface calcretes and soils, as well as locally abundant petrified wood blocks eroded out into surface gravels from the Kirkwood Formation (*qv*) (Fig. 56), no fossil remains were recorded from the various Pleistocene to Holocene superficial sediments within the Dassiesridge WEF study area.

Fig. 54. Poorly-sorted, coarse, calcretised High Level Gravels cutting down into weathered Kirkwood Formation saprolite, road cutting near Farm 603 (Loc. 707).

Fig. 55. Poorly-sorted modern stream gravels overlying the Kirkwood Formation outcrop area on Farm RE/189 (Loc. 700). The gravels have mainly been reworked from the Alexandria Formation upstream, but also contain Kirkwood sandstone and fossil wood.

Fig. 56. Reworked blocks of petrified fossil wood among surface gravels overlying the Kirkwood Formation, Farm RE/189 (Loc. 700) (Hammer = 30 cm). Reworked fossil wood material may be concentrated at the base of the Alexandria Formation where this overlies the Kirkwood succession.

Fig. 57. Boulder bed towards the base of the Alexandria Formation, Grassridge 187 (Loc. 667) (Hammer = 30 cm). The rounded boulders of calcarenite and sandstone or wacke may have once been part of a storm beach deposit.

Fig. 58. Karstified surface of Alexandria Formation calcarenites and pebbly calcarenites overlain by orange-brown soils and pebbly gravels of the "Bluewater Bay" facies, Grassridge 187 (Loc. 669).

Fig. 59. Thick silty to sandy alluvium, secondarily rubified and incipiently calcretised above, overlying weathered Kirkwood Formation saprolite, gulley exposure on Gringley 188 (Loc. 693) (Hammer = 30 cm).

Fig. 60. Thick, orange-brown sands at low elevations on Farm RE/189. These deposits have probably been reworked downslope from the Nanaga Formation.

Fig. 61. Thick surface calcretes exposed in a borrow pit on Farm 3/189 (possibly calcretised Nanaga aeolianites) (Loc. 717) (Hammer = 30 cm).

4. CONCLUSIONS & ASSESSMENT OF IMPACTS ON FOSSIL HERITAGE

The Dassiesridge WEF study area is underlain by approximately twelve main sedimentary rocks units ranging in age from Early Devonian through Early Cretaceous and Neogene to Recent, as shown on the 1: 50 000 scale geological map (Fig. 3). On the basis of (1) desktop analysis of the fossil records of the various rock units underlying the Dassiesridge WEF study area (including several previous palaeontological field assessments by the author and others in the Uitenhage region), combined with (2) field assessment of numerous representative rock exposures within and close to the WEF study area, only four of these units – namely the Voorstehoek Formation (Lower Bokkeveld Group), the Kirkwood and Sundays River Formations (Uitenhage Group), as well as the basal part of the Alexandria Formation in the southeast (Algoa Group) - are considered to be palaeontologically sensitive.

Devonian marine to marginal marine formations of the **Bokkeveld Group** that underlie the north-western and central portions of the study area (*e.g.* Grassridge 187) are generally only sparsely fossiliferous. The potentially fossiliferous mudrock subunits (*e.g.* Tra Tra and Karies Formations) are usually too cleaved and weathered to contain useful fossil material near-surface. The sandstone-dominated units (Gamka, Hexrivier, Booplaas Formations) usually contain only low-diversity trace fossil assemblages and are also extensively folded, faulted and cleaved. However, moderately diverse shelly invertebrate biotas are recorded from siltstones and sandstones of the Early Devonian **Voorstehoek Formation** here (*e.g.* on Elands Hoorn 185), including a range of trilobites, brachiopods, molluscs, echinoderms and tentaculitids. This includes one of the few informative fossil sites within the Lower Bokkeveld Group of the Eastern Cape.

Early Cretaceous fluvial sediments of the **Kirkwood Formation** ("Wood Beds", Uitenhage Group) that underlie valleys and lower hill slopes in large parts of the south-western, central and eastern portions of the study area are generally very poorly exposed. However, where seen at surface they are often characterised by an abundance of petrified wood, including logs up to several meters long and half a meter across. Some of the fossil logs are only preserved as moulds but others retain fine details of the original woody tissue microstructure and are therefore of considerable palaeontological interest.

Marine shelf and estuarine sediments of the Early Cretaceous **Sundays River Formation** (Uitenhage Group) are only mapped on the south-eastern and north-eastern edges of the WEF study area but their outcrop may in fact be more extensive than shown in Fig. 3. They are generally very poorly-exposed. Where accessible in road cuttings and abandoned brick pits in the region they yield rich fossil faunas of shelly invertebrates, especially various groups of molluscs.

Coastal to shallow marine limestones and conglomerates of the Neogene **Alexandria Formation** (Algoa Group) that cap grassy plateau areas within the Dassiesridge WEF have mainly yielded fragmentary remains of robust molluscs here. Most of the limestones are recrystallized and fossil-poor. However, impressive oyster beds up to a meter thick are associated with the base of the formation in the south-eastern portion of the study area (Grassridge 190) and these are of palaeontological significance. Construction of proposed access roads in this part of the study area (Fig. 62, red lines) may disturb or destroy parts of these fossil shell beds.

A wide range of Late Caenozoic superficial deposits, mostly unconsolidated, mantle the Palaeozoic and Mesozoic bedrocks in the study area. They include Neogene High Level Gravels, Holocene stream gravels, downwasted surface gravels and colluvium, gravelly, sandy and silty soils, pan sediments and calcretes that are generally of low palaeontological sensitivity. The Pleistocene sands of the **Nanaga Formation** (Algoa Group) overlying the

Alexandria limestones in upland plateau areas are weathered and unfossiliferous. The only fossils recorded from the unconsolidated superficial deposits are locally abundant blocks of Cretaceous fossil wood reworked from the Kirkwood Formation into surface gravels and gravelly alluvium.

The great majority of infrastructure for the proposed WEF (Fig. 62) will be located in flatter-lying upland areas and ridges that are underlain by rock units of low palaeontological sensitivity – *viz*. limestones and aeolian sands of the Algoa Group on the plateaux and Bokkeveld sandstones forming the ridges in the northwest. Construction of the wind turbines, overhead power lines, access roads and associated infrastructure here is therefore unlikely to entail significant impacts on local fossil heritage resources. Direct impacts on fossiliferous beds of the Uitenhage Group in lower-lying areas will be very limited, especially because these sediments are generally overlain by thick unfossiliferous superficial deposits (soil, alluvium *etc*).

Substation location options in the western part (Farm 4/233) and the eastern part (Farm 188) of the Dassiesridge WEF overlie potentially fossiliferous Kirkwood Formation beds. However, the footprint involved is relatively small and the potentially fossil-rich bedrocks are probably buried by thick superficial deposits, so significant impacts on fossil heritage are not anticipated here. Substations on the Grassridge Plateau to the southeast of the Dassiesridge project area (within the Grassridge WEF; Fig. 62) overlie Alexandria Formation limestones that contain only sparse fossil remains (Almond 2011). These two sites are also of low palaeontological sensitivity. Proposed 132 kV transmission line connections for the Dassiesridge WEF to the Eskom grid are all short and largely follow existing servitudes. Furthermore, the pylon footing footprints involved are small. All five transmission line options (as outlined in Section 1.1) are therefore considered to be of low impact significance as far as fossil heritage is concerned and there is no preferred option on palaeontological heritage grounds.

Significant impacts on fossil heritage are only anticipated in two small portions of the Dassiesridge WEF study area (marked in green on Fig. 62):

- a sector of the access road from the R75 that runs in a low-lying area underlain by the Voorstehoek Formation (Grassridge 187);
- wind turbine positions and associated access roads in the eastern portion of Farm 3/190 that may impact fossil oyster beds in the basal Alexandria Formation as well as fossil wood and marine shells in the Kirkwood and Sundays River Formations respectively.

The inferred impact of the proposed Dassiesridge WEF development on local fossil heritage is analysed in Table 1 below. This assessment applies only to the construction phase of the WEF development since further impacts on fossil heritage during the operational and decommissioning phases of the WEF are not anticipated. The assessment applies both to the main WEF (wind turbines, access roads, substations and associated infrastructure) as well as the 132 kV overhead transmission lines connecting to the Eskom grid.

The destruction, damage or disturbance out of context of fossils preserved at the ground surface or below ground that may occur during construction represents a *negative* impact that is confined to the development footprint (*localised*). Such impacts are limited to the *construction phase*, can usually be mitigated but cannot be fully rectified (*i.e. irreversible*). Most of the sedimentary formations represented within the study area contain fossils of some sort, so impact on fossil heritage are *probable*. However, because of the generally sparse occurrence of well-preserved fossils within the majority of the bedrock formations concerned here (notably those underlying the proposed wind turbine sites and access roads) as well as within the overlying superficial sediments (soil, alluvium, colluvium *etc*), the severity of these impacts is conservatively rated as *slight*. Because of the generally low levels of bedrock exposure within the study area, confidence levels for this palaeontological heritage assessment are only *moderate* following the field assessment of numerous representative rock exposures.

Due to (1) the general scarcity of fossil remains within most of the development footprint, (2) the high levels of bedrock weathering and tectonic deformation as well as (3) the extensive superficial sediment cover overlying most potentially fossiliferous bedrocks within the Dassiesridge WEF study area, the overall impact significance of the construction phase of the proposed wind energy project is assessed as only MODERATE (negative). This applies to the wind turbines and associated infrastructure, access roads, substations as well as to the 132 kV transmission line connection to the Eskom grid. No significant further impacts on fossil heritage are anticipated during the operational and decommissioning phases of the WEF. There are no fatal flaws in the Dassiesridge WEF development proposal as far as fossil heritage is concerned.

4.1. Cumulative impacts

The fossil heritage impact significance of the existing Grassridge WEF (yellow polygon in Fig. 62), immediately to the southeast of the proposed Dassiesridge WEF, was assessed as low in a previous study by Almond (2011). Impacts in Grassridge WEF area mainly concern poorly-fossiliferous, recrystallized marine limestones of the Alexandria Formation similar to those underlying the main development footprint for the Dassiesridge WEF. The limestones and sparse associated fossils are of widespread occurrence within the broader Port Elizabeth – Uitenhage region (*cf* Almond 2010). It is concluded that the cumulative impacts of the two adjacent wind energy facilities is LOW.

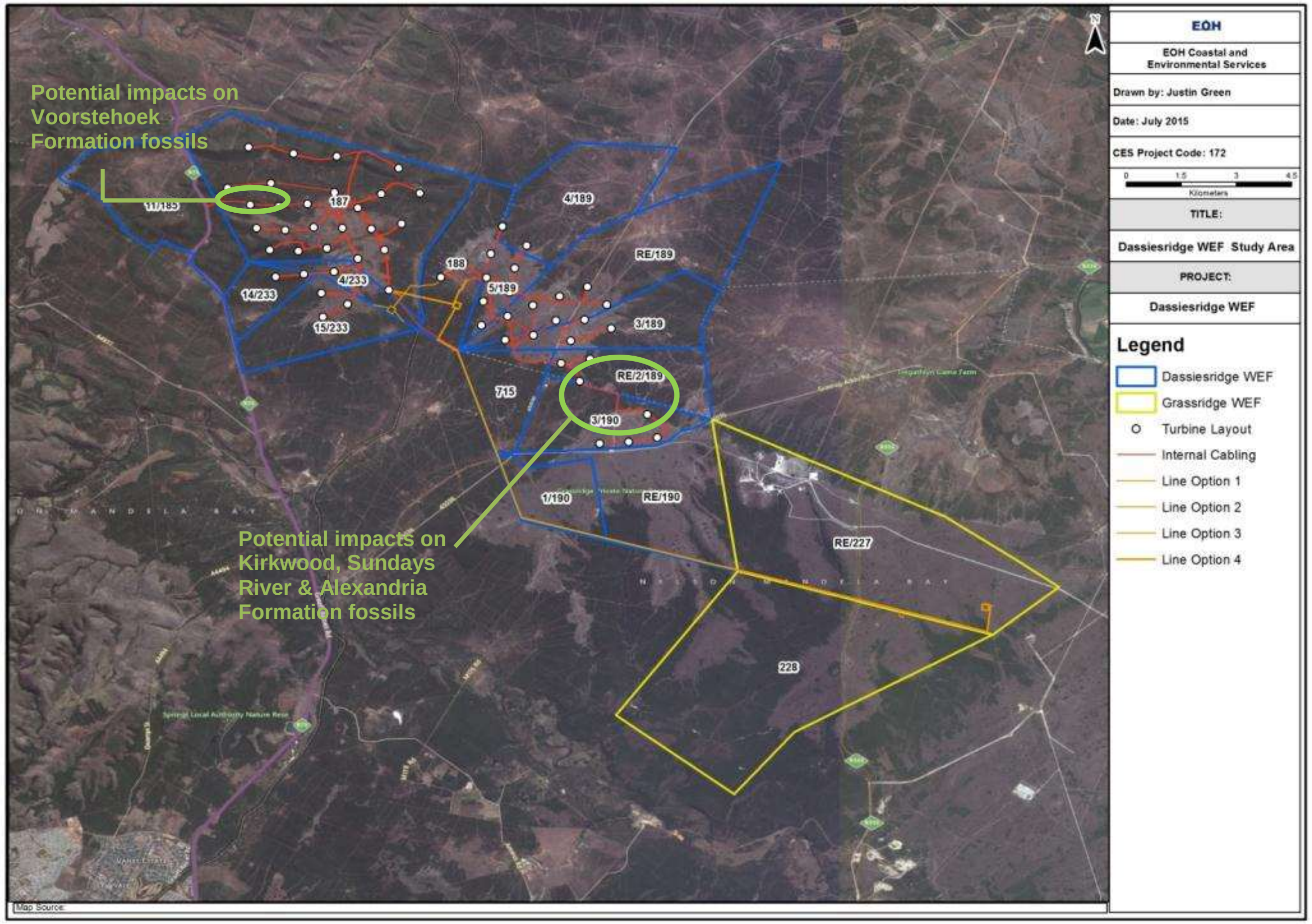


Fig. 62. Google earth© satellite image of the Dassiesridge WEF study area showing outline of land parcels (blue), main access roads (red), turbine positions (white dots) and alternative transmission line connections (orange). Substation options are indicated by orange squares. The yellow polygon shows the location of the existing Grassridge WEF. Green ellipses outline two areas within the Dassiesridge WEF study area where significant impacts on fossil heritage may be anticipated. Although the land parcel to the west of the R75 has been included in the application (this parcel spans the R75) the portion to the west of the R75 does not form part of this study as no development is planned for this area. Should any development occur here then further studies for this area will be required.

5. MITIGATION & RECOMMENDATIONS FOR THE ENVIRONMENTAL MANAGEMENT PLAN

Given the low palaeontological sensitivity of the majority of the Dassiesridge WEF study area, specialist palaeontological mitigation is only recommended within the two small areas shown on Fig. 62, pending the discovery elsewhere of substantial new fossil remains during construction. Once excavations for infrastructure such as access roads and wind turbine footings within these two sensitive areas are opened, they should be inspected for fossil remains by a professional palaeontologist. Mitigation would normally involve the scientific recording and judicious sampling or collection of fossil material as well as associated geological data (*e.g.* stratigraphy, sedimentology, taphonomy).

During the construction phase all deeper (> 1 m) bedrock excavations should be monitored for fossil remains by the responsible Environmental Control Officer (ECO). Should substantial fossil remains - such as vertebrate bones and teeth, fossil shell beds or petrified logs of fossil wood - be exposed during construction, the responsible Environmental Control Officer should safeguard these, preferably *in situ*, and alert ECPHRA (*i.e.* The Eastern Cape Provincial Heritage Resources Authority. Contact details: Mr Sello Mokhanya, 74 Alexander Road, King Williams Town 5600; smokhanya@ecphra.org.za) as soon as possible so that appropriate action can be taken by a professional palaeontologist at the developer's expense.

The palaeontologist concerned with mitigation work will need a valid fossil collection permit from ECPHRA 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 recently developed by SAHRA (2013).

These mitigation recommendations should be incorporated into the Environmental Management Plan (EMP) for the Dassiesridge WEF. The operational and decommissioning phases of the development are unlikely to have significant impacts on palaeontological heritage and no further 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 (ECPHRA) for professional recording and collection, as recommended here, the overall impact significance of the project would remain moderate (negative). However, residual negative impacts from 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 would constitute a useful addition to our scientific understanding of the fossil heritage here.

7. SUMMARY STATEMENT ON FOSSIL HERITAGE IMPACTS AND PROPOSED MITIGATION

IMPACT: Disturbance, damage or destruction of fossil heritage during the construction phase of the WEF

Cause and comment:

Four of the twelve sedimentary bedrock formations represented within the Dassiesridge WEF study area are moderately to highly fossiliferous, notably the Voorstehoek, Kirkwood and Sundays River Formations as well as the base of the Alexandria Formation in some areas. Most of the development footprint is located on higher-lying plateaux and rocky ridges underlain by rocks of low palaeontological sensitivity, however.

The construction phase of the proposed Dassiesridge Wind Energy Facility will entail substantial excavations into the superficial sediment cover (soils, surface gravels *etc*) and in most cases also into the underlying bedrock. These notably include excavations for the wind turbine foundations and transmission line pylon footings, underground cables, new internal access roads and foundations for associated infrastructure such as on-site substations and the control / storeroom building. In addition, sizeable areas of potentially fossiliferous bedrock may be sealed-in or sterilized by infrastructure such as hard standing areas for each wind turbine, lay down areas and access roads. All these developments may adversely affect potential fossil heritage exposed at the surface or preserved below the surface within the study area by damaging, destroying, disturbing or permanently sealing-in fossils that are then no longer available for scientific research or other public good.

Once constructed, the operational and decommissioning phases of the wind energy facility will not involve further adverse impacts on palaeontological heritage, however.

Significance Statement

Impacts associated with the disturbance, damage or destruction of fossil heritage during the construction phase of the WEF are probable and permanent in effect but significant impacts are likely to be limited to small portions of the development footprint. The overall significance of the impact without mitigation would be MODERATE NEGATIVE. Impact significance can be meaningfully reduced through mitigation but will still remain moderate negative. Improved understanding of local fossil heritage through professional palaeontological mitigation can be viewed as a positive impact, however.

Table 1: Assessment of impacts of the proposed Dassiesridge WEF on local fossil heritage resources

Impact	Effect			**Risk or Likelihood**	**Overall Significance**
	Temporal Scale	Spatial Scale	Severity of Impact		
***Impact* : Disturbance, damage or destruction of fossil heritage during the construction phase of the WEF**					
Without Mitigation	Permanent	Localised	Slight	Probable	MODERATE-
With Mitigation	Permanent	Localised	Slight	Probable	MODERATE-

Impact Mitigation

- Monitoring of all deeper (> 1m) excavations for newly exposed fossil material (bones, teeth, shells, petrified wood *etc*) by the ECO during the construction phase. Significant finds to be reported to ECPHRA for possible recording and sampling by a professional palaeontogist
- Inspection of two small, potentially sensitive areas (shown in Fig. 62) for fossil remains by a professional palaeontologist, once bedrock excavations for infrastructure are opened, with recording and sampling of any significant fossil remains

8. ACKNOWLEDGEMENTS

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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.

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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 wind farm development project, application or appeal in respect of which I was appointed other than fair remuneration for work performed in connection with the activity, application or appeal. There are no circumstances that compromise the objectivity of my performing such work.

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APPENDIX: GPS LOCALITY DATA FOR NUMBERED SITES MENTIONED IN TEXT

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

N.B. Given the sensitivity and conservation importance of fossil sites in the RSA, this data is *not* for public release.

LOCALITY NO.	GPS DATA	COMMENTS
656	S33 35 04.6 E25 25 53.8	Quarry into Voorstehoek Fm, adjacent to R75, Elands Hoorn 185 / Grassridge 187. Abundant shelly invertebrate fossils.
657	S33 34 31.5 E25 25 53.9	R75 road cutting into Voorstehoek Fm wackes, Elands Hoorn 185.
659	S33 34 12.6 E25 26 33.4	Hill slope exposure of Hexrivier Fm wackes, Grassridge 187.
660	S33 33 42.8 E25 26 51.6	Small hill slope exposure of cleaved wackes of Boplaas Fm, Grassridge 187.
661	S33 33 38.9 E25 26 55.7	Extensive exposure of subvertical Boplaas Fm wackes and siltstones, Grassridge 187.
662	S33 33 12.8 E25 26 17.0	Mixed quartzitic alluvial and colluvial surface gravels, Grassridge 187.
663	S33 33 27.0 E25 26 51.9	Soil-covered pan, Grassridge 187.
664	S33 33 52.9 E25 26 54.3	Farm track exposure of weathered Tra Tra Fm mudrocks, calcrete veins, Grassridge 187.
665a	S33 34 26.3 E25 27 15.0	Cross-bedded calcarenite of Alexandria Fm overlain by thick orange-brown Nanaga sands, Grassridge 187.
665b	S33 34 33.1 E25 27 28.9	Bouldery outcrop of Gamka Fm wackes with orange-brown gravelly soils, calcrete mantling bedrock, Grassridge 187.
666	S33 34 39.4 E25 27 44.4	Nanaga Fm terrain with subdued ridge-like dunes, Grassridge 187.
667	S33 35 17.3 E25 27 39.0	Alexandria Fm boulder bed (calcarenite, Gamka wacke, calcrete), Grassridge 187.
668	S33 35 19.3 E25 28 17.2	Alexandria Fm calcarenites overlain by orange-brown Nanaga aeolian sands, Grassridge 187.
669	S33 35 23.1 E25 28 25.4	Alexandria Fm karstified pebbly calcarenites and calcareous grits overlain by Bluewater Bay facies pebbly downwasted gravels Grassridge 187.
670	S33 35 22.2 E25 29 01.9	Pan area with sandy soils, Grassridge 187.

671a	S33 37 50.5 E25 25 55.33	Subvertical Gamka Fm wackes in streamside cliffs, opposite Valley Bushveld Guest Lodge, Prentice Kraal 233.
671b	S33 39 44.6 E25 27 24.1	R75 road cuttings into Sundays River Fm mudrocks, just N of Centlivres turnoff, capped by pebbly gravels.
672	S33 39 26.1 E25 27 18.7	Pale brown, medium-bedded sandstones with sparse moulds of marine shells, reworked wood fragments. R75 road cuttings just N of Centlivres turnoff, mapped as Kirkwood Fm, but probably Sundays River Fm.
674	S33 36 11.5 E25 26 32.7	Surface gravels overlying Kirkwood Fm with rare Bokkeveld shelly fossils, Portion 14/233 (Geluksdal Private Game & Nature Reserve).
675	S33 36 12.0 E25 26 31.9	Abundant weathered out blocks of petrified wood from the Kirkwood Fm, Portion 14/233.
676	S33 36 12.3 E25 26 31.2	Abundant weathered out blocks of petrified wood from the Kirkwood Fm, Portion 14/233.
677	S33 36 13.3 E25 26 31.0	*In situ* fossil logs, Kirkwood Fm sandstones, Portion 14/233.
678	S33 36 13.3 E25 26 31.0	*In situ* fossil logs, Kirkwood Fm sandstones, Portion 14/233.
679	S33 36 13.1 E25 26 32.6	*In situ* fossil logs, Kirkwood Fm sandstones, Portion 14/233.
680	S33 36 13.9 E25 26 35.9	*In situ* fossil logs, Kirkwood Fm sandstones, Portion 14/233.
681	S33 36 13.7 E25 26 36.9	*In situ* fossil logs, Kirkwood Fm sandstones, Portion 14/233.
682	S33 36 13.0 E25 26 37.2	Good exposures of Kirkwood Fm channel sandstones, Portion 14/233.
683	S33 36 13.1 E25 26 37.9	Downwasted fossil wood blocks and in situ fossil logs on top of Kirkwood Fm escarpment, Portion 14/233.
684	S33 36 12.3 E25 26 37.9	*In situ* fossil logs, Kirkwood Fm sandstones, Portion 14/233.
685	S33 36 12.0 E25 26 39.2	Thin-bedded, gritty and pebbly Kirkwood channel sandstone facies, Portion 14/233.
686	S33 36 11.5 E25 26 39.3	*In situ* fossil logs, Kirkwood Fm sandstones, Portion 14/233.
688	S33 35 45.0 E25 27 19.2	Small exposure of Gamka Fm wackes in farm track, Ortion 14/233.
689	S33 35 33.3 E25 29 27.1	Alexandria Fm pebbly calcarenites and calcretes overlying deeply-weathered and calcrete-veined Kirkwood Fm, gulley exposure, Gringley 188.
690	S33 35 25.6 E25 29 23.2	Ferruginised Kirkwood channel sandstones, gulley exposure, Gringley 188.

691	S33 35 25.9 E25 29 23.2	Petrified log breaking up in situ, gulley exposure of Kirkwood Fm, Gringley 188.
692	S33 35 22.7 E25 29 31.6	Gulley exposure of deeply-weathered Kirkwood Fm capped by calcrete, Gringley 188.
693	S33 35 19.2 E25 29 25.8	Thick sandy soils with calcrete nodules overlying weathered Kirkwood Fm, gulley exposure, Gringley 188.
694	S33 35 24.0 E25 30 05.9	Capping of Alexandria Fm calcarenites showing karst weathering, Portion 5/189.
695	S33 38 39.1 E25 27 27.7	Large abandoned brick-making quarry into mudrocks and sandstones of the Sundays River Fm nr Centlivres Siding.
696	S33 36 12.3 E25 27 22.0	Karstified escarpment and plateau of Alexandria Fm calcarenites and pebbly conglomerates, Portion 15/233.
698	S33 39 51.6 E25 28 16.5	Road cuttings through Sundays River Fm, Centlivres 231. Fossil oysters.
700	S33 35 36.1 E25 31 20.5	Abundant petrified wood weathered out into surface gravels and stream gravels overlying Kirkwood Fm bedrock, adjacent to farm track on RE/189. Gamka Fm crops out in track just downslope to N (erroneously mapped as Da).
701	S33 35 13.9 E25 31 44.7	Thick orange-brown sandy soils – probably reworked Nanaga Fm material, RE/189.
702	S33 35 10.8 E25 31 48.5	Thick orange-brown sandy soils – probably reworked Nanaga Fm material – with pebbly stream gravels, RE/189.
704	S33 33 55.4 E25 32 29.3	Large existing quarry into cleaved Karies Fm mudrocks near Hartmanshoop farmstead, Farm 4/189.
705	S33 34 01.1 E25 32 32.9	Pinkish Kirkwood overbank mudrocks overlain by gravelly and calcretised alluvial deposits, large existing quarry near Hartmanshoop farmstead, Farm 4/189.
706	S33 34 09.9 E25 32 32.6	Road cutting through cleaved Karies Fm, dust road to Kirkwood, Blaauw Baatjies Vlei 189.
707	S33 33 13.4 E25 33 07.8	Calcretised High Level Gravels (or perhaps Alexandria Fm) erosionally overlying weathered Kirkwood Fm saprolite (mapped as Sundays River Fm), road cutting along dust road to Kirkwood, Farm 603.
708	S33 35 38.4 E25 31 38.6	Cleaved and faulted Gamka Fm wackes (erroneously mapped as Da), road cutting along dust road to Kirkwood, Blauw Baatjies Vley 189.
709	S33 35 46.7 E25 31 33.5	Conglomerates and calcarenites of Alexandria Fm (Or High Level Gravels) overlying Kirkwood Fm saprolite, road cutting along dust road to Kirkwood, Blauw Baatjies Vley 189.
710	S33 37 13.1 E25 30 55.1	Existing borrow pit into surface calcrete, Farm 3/19 0.

711	S33 38 11.8 E25 31 11.1	Road cuttings exposing fossil oyster coquinas in Alexandria Fm, northern edge of Grassridge Nature Reserve.
714	S33 38 11.1 E25 31 52.1	Abandoned calcrete quarry adjacent to road, Farm 3/190.
715	S33 36 35.4 E25 31 05.7	Fossil wood in gravels on dust road to Kirkwood, adjacent to entrance to Farm 3/189.
716	S33 36 27.3 E25 31 27.9	Gulley exposure of weathered Kirkwood Fm capped by Alexandria Fm pebbly calcarenites, Farm 3/189.
717	S33 36 25.6 E25 31 23.4	Small borrow pit into calcarenites, Farm 3/189.
718	S33 36 26.4 E25 31 39.8	Small borrow pit into weathered Kirkwood Fm. overbank mudrocks capped by conglomeratic basal Alexandria Fm, Farm 3/189.
719	S33 36 27.4 E25 32 31.2	Dam exposure of Kirkwood Fm sandstones and mudrocks, petrified wood blocks, sparse invertebrate burrows, Farm 3/189.
721	S33 35 23.5 E25 32 53.5	Petrified logs *in situ* within Kirkwood Fm. channel sandstone, Prospect Vale (RE/189).
722	S33 35 22.8 E25 32 55.0	Extensive borrow pit exposure of Kirkwood overbank mudrocks, channel sandstones, Prospect Vale (RE/189).
723	S33 35 19.7 E25 32 57.8	Excellent gulley exposure of Kirkwood Fm. overbank mudrocks, channel sandstones, Prospect Vale (RE/189) overlain by pebbly gravels .