PALAEONTOLOGICAL HERITAGE: COMBINED DESKTOP & FIELD-BASED BASIC ASSESSMENT

Grid connection for the proposed Impofu North, Impofu West & Impofu East Wind Farms near Humansdorp, Eastern Cape

John E. Almond PhD (Cantab.)
***Natura Viva* cc,**
PO Box 12410 Mill Street,
Cape Town 8010, RSA
naturaviva@universe.co.za

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EXECUTIVE SUMMARY

The present report provides a palaeontological heritage Basic Assessment of the proposed Impofu grid connection. This includes (a) the approximately 120 km-long, 2 km-wide 132 kV grid connection corridor between the proposed Impofu North, Impofu West and Impofu East Wind Farms and the national grid in the Nelson Mandela Bay Municipality (NMBM) near Port Elizabeth, Eastern Cape. Potential impacts of the proposed new Impofu collector switching station, wind farm switching stations and short 132 kV transmission lines linking them to the collector switching station as well as of substation extension areas are also considered. The report is based on a combined desktop and field-based study of the preferred grid connection corridor, incorporating a 2 km wide zone, with a special focus on areas underlain by potentially fossiliferous bedrocks.

The grid connection study area is underlain by several formations of potentially fossiliferous sediments of the Gamtoos Group, Cape Supergroup, Uitenhage Group and Algoa Group (Sections 6 & 7, Table 1). However, on the southern coastal platform most of the fossils originally preserved in these bedrocks appear to have been destroyed by tectonic deformation and deep chemical weathering. The overlying Late Caenozoic superficial sediments such as alluvium, soils and ferricretes, are likewise of low palaeontological sensitivity. Relict patches of Plio-Pleistocene aeolianites (wind-blown sands) of the Nanaga Formation (Algoa Group) present in the subsurface on the interior coastal platform contain Early Stone Age artefacts but any associated fossils such as mammalian remains, or terrestrial gastropods have probably been destroyed by weathering here. It is concluded that the great majority of the study area is in effect of LOW palaeontological sensitivity.

During the present study only two small areas of high palaeontological sensitivity have been identified within the grid connection study area: (1) steep cliff exposures of the Early Cretaceous Kirkwood Formation along the eastern banks of the Gamtoos River that are rich in fossil plant material, and (2) low fossiliferous scarp exposures of the Late Jurassic Bethelsdorp Member (lower Kirkwood Formation) along a pan margin some 1.8 km west of Sans Souci Substation (See polygons annotated on Figs. 35 & 36 herein). It is recommended that any excavations within the first area are carefully monitored for fossils by the Environmental Control Officer (ECO) (See Appendix 1: Chance Fossil Finds Procedure) while the latter should be treated as a No-Go area for development.

Due to the rarity of well-preserved, unique fossils of potential scientific importance within the grid connection corridor, potential impacts on palaeontological heritage during the construction phase are assessed as of *negligible (negative) significance* (both before and after mitigation). Significant impacts during the operational and decommissioning phases are not anticipated. The No-Go alternative (*i.e.* no grid connection) will have a neutral impact on palaeontological heritage.

Cumulative impacts posed by the grid connection and associated electrical infrastructure developments are inferred to be *minor*. This also applies to cumulative impacts from other approved or proposed transmission line developments in the region. Confidence levels for this assessment are *high* due to comparatively good field data available for the study region.

Pending the potential discovery of significant new fossil remains during the construction phase of the proposed Impofu grid connection, no further specialist palaeontological studies or mitigation are recommended for this project in the construction phase. There are no fatal flaws to the proposed electrical infrastructure project as far as fossil heritage is concerned. Providing that the Chance Fossil Finds Procedure outlined below and tabulated in Appendix 1 is followed through, there are no objections on palaeontological heritage grounds to authorisation of the Impofu grid connection and associated electrical infrastructure (including the Impofu collector switching station, three wind farm switching stations and short 132 kV transmission lines connecting these *plus* any substation extension areas).

The suitably qualified and experienced ECO responsible for the electrical infrastructure development construction phase should be made aware of the potential occurrence of scientifically-important fossil remains within the development footprint. During the construction phase all major clearance operations (*e.g.* for new access roads, pylon placements) and deeper (> 1 m) excavations should be monitored for fossil remains on an on-going basis by the ECO. Should substantial fossil remains be encountered at surface or exposed during construction, the ECO should safeguard these, preferably *in situ*. They should then alert the Eastern Cape Provincial Heritage Resources Agency, ECPHRA (Contact details: Mr Sello Mokhanya, 74 Alexander Road, King Williams Town 5600; smokhanya@ecphra.org.za) as soon as possible. This is to ensure that appropriate action (*i.e.* recording, sampling or collection of fossils, recording of relevant geological data) can be taken by a professional palaeontologist at the proponent's expense. These recommendations are summarized in the tabulated Chance Fossil Finds Procedure appended to this report (Appendix 1).

The palaeontologist concerned with any 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 developed by SAHRA (2013).

These monitoring and mitigation recommendations are to be incorporated into the Environmental Management Programme (EMPr) for the proposed Impofu grid connection. The operational and decommissioning phases of this development are unlikely to have further significant impacts on palaeontological heritage and no additional recommendations are made in this regard (The Chance Fossil Finds Procedure still applies).

1. INTRODUCTION

The company Red Cap Energy (Pty) Ltd is proposing to develop up to three adjoining wind farms with a total of up to 95 wind turbines on a consolidated site of approximately 15 500 hectares (ha) situated to the west of Humansdorp within the Sarah Baartman District Municipality (Kouga and Kou-Kamma Local Municipalities), Eastern Cape (Fig. 1). The present report provides a paleontological heritage Basic Assessment of (a) the approximately 120 km-long, 2 km -wide 132 kV grid connection corridor between the proposed Impofu North, Impofu West and Impofu East Wind Farms and the national grid in the Nelson Mandela Bay Municipality (NMBM) near Port Elizabeth, Eastern Cape,

(b) the new Impofu collector switching station, as well as of (c) the switching stations and 132 kV overhead transmission lines linking them to the collector switching station associated with the three wind farm projects and (d) extension areas of 150 m x 150 m for the San Souci Substation and 50 m extensions for the Melkhout and Chatty Substations. It is based on a combined desktop and field-based study of the preferred 132 kV grid corridor, incorporating a 2 km inclusion zone (Figs. 1 & 2), with a special focus on areas underlain by potentially fossiliferous bedrocks. The Impofu North, Impofu West and Impofu East Wind Farms are being assessed separately.

Aurecon South Africa (Pty) Ltd (Aurecon) has been commissioned by the proponent to carry out three Environmental Impact Assessment (EIA) processes for the proposed Impofu Wind Farms as well as one Basic Assessment (BA) process for the associated switching stations and transmission lines (Aurecon contact details: Mr Charles Norman, Aurecon South Africa (Pty) Ltd. Address: Aurecon Centre, 1 Century City Drive, Waterford Precinct, Century City, South Africa. Tel: +27 44 8055433. Fax: +27 21 5269500. E-mail: Charles.Norman@aurecongroup.com).

2. PROJECT OUTLINE & BRIEF

The grid connection corridor study area for the proposed 132 kV grid connection linking the proposed Impofu West, Impofu East and Impofu North Wind Farms to the national grid (orange polygon in Figs. 1 & 2) stretches for approximately 120 km in a WSW-ESE direction and is approximately 2 km wide on average over its length. It extends from the proposed new Impofu collector switching station in the SW, located some 18 km WSW of Humansdorp, *via* the existing Eskom Melkhout Substation and thence eastwards to the existing Sans Souci Substation or Chatty Substation located in the Nelson Mandela Bay Metropolitan Municipality (NMBM). A range of route options for the 132 kV grid connection is under consideration within the study corridor. Most of the currently preferred route would follow existing powerline servitudes and it is anticipated that existing access roads will be employed. A range of electrical pylon designs are under consideration (more than one of which may be employed) entailing footing excavation depths up to 3.7 m and excavation widths up to 9 m, depending on substrate conditions. Associated stays require foundations of up to 2 m x 2 m (depending on the suitability of the soils). The spacing of the pylons will depend on the alignment and topography and may vary from 260 to 800 m.

This study also includes an assessment of the Eskom switching stations (11,250 m^2) that will be associated with the new substations for each of the three Impofu Wind Farms as well as of the 132 kV transmission lines (± 5 km) between these switching stations and the new Impofu collector switching station (22,500 m^2) (See Figs. 1 & 3a). Possible extension areas of 150 m for the San Souci Substation and 50 m extensions for the Melkhout and Chatty Substations have also been assessed here. A palaeontological and geological heritage study of the consolidated Impofu Wind Farms project area including the footprints of these proposed electrical infrastructure developments has been carried out by Almond (2017).

2.1. Terms of Reference

The Terms of Reference for the desktop and field-based palaeontological heritage assessment of the Impofu Wind Farm projects have been defined by Aurecon South Africa (Pty) Ltd to comprise (1) three separate Scoping Impact Assessments, one for each wind farm, including the on-site substations, internal roads, underground and overhead cables and upgrading of public roads, as well as (2) one Basic Environmental Assessment for the associated 132 kV grid connection between the project area and Port Elizabeth, the Impofu collector switching station as well as the internal overhead132 kV transmission lines and switching stations within the wind farms project area.

Figure 1. Google Earth© satellite image of the western sector of the Impofu Wind Farm 132 kV grid connection corridor study area (orange polygon) extending from the proposed new Impofu collector switching station (red square) and the Gamtoos River, Eastern Cape. The three switching stations (black squares) connecting to the central collector switching station as well as the combined Impofu North, Impofu East and

Impofu West WEF project areas (white polygon) are also shown. See Fig. 35 for detail of palaeontologically-sensitive area F1 (red).

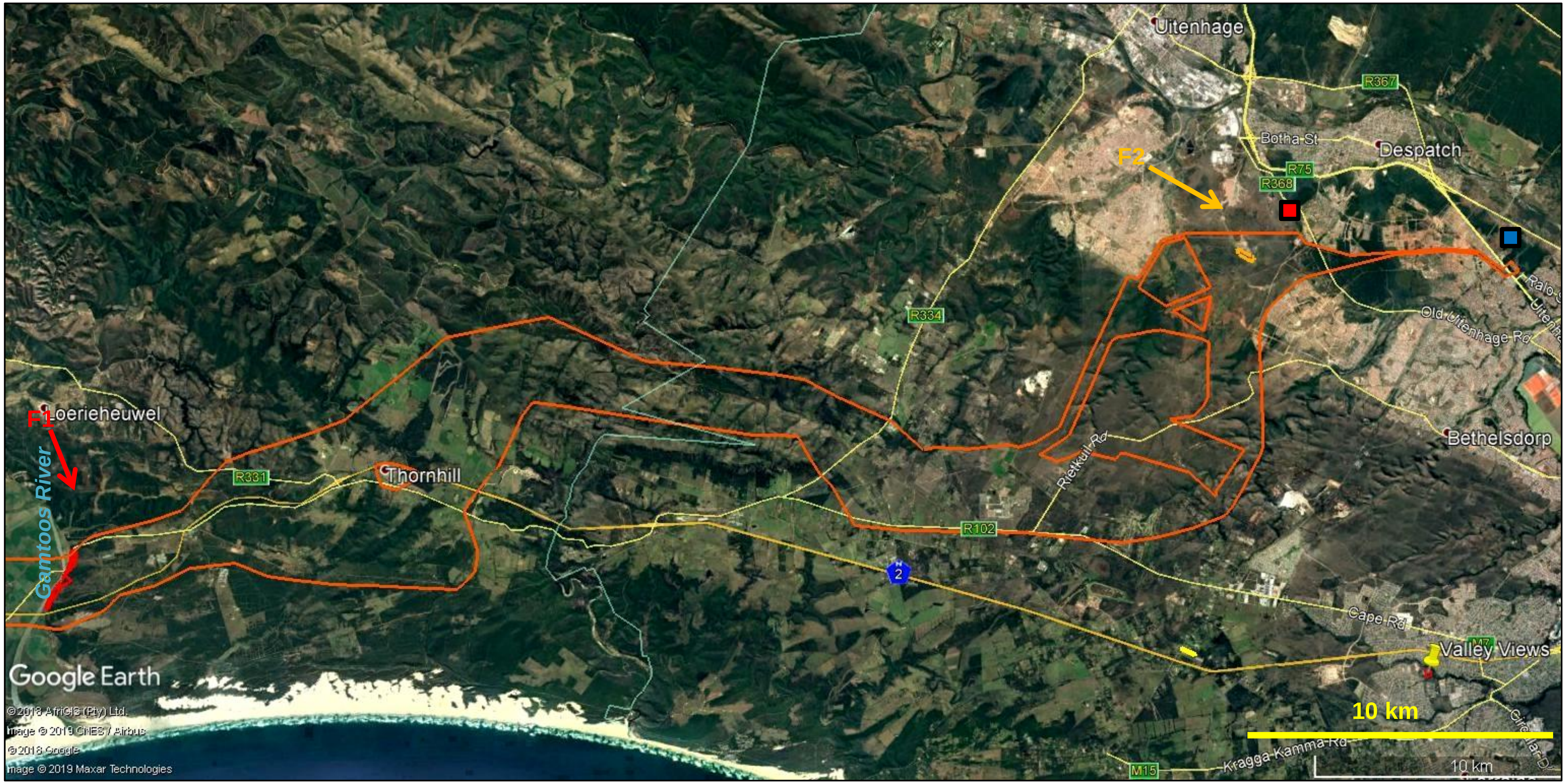


Figure 2. Google Earth© satellite image of the eastern sector of the Impofu grid connection corridor (orange polygon) extending from the Gamtoos River to the San Souci Substation (red square) and Chatty Substation (blue square) near Port Elizabeth, Eastern Cape. The revised corridor shown here shows route alternatives west of Chatty Substation, including along the existing powerline through Hopewell Estate. See Figs. 35 and 36 for details of palaeontologically-sensitive areas F1 (red) and F2 (orange).

3. STUDY APPROACH

This combined desktop and field-based PIA report provides an assessment of the observed or inferred palaeontological heritage within the Impofu grid connection corridor, with recommendations for specialist palaeontological mitigation where this is considered necessary. The report is based on (1) a review of the relevant scientific literature, including previous palaeontological impact assessments in the area (*e.g.* Almond 2010a, 2011a, 2011b, 2011c, 2011d, 2012a, 2013a, 2013b, 2013c, 2013d, 2016a, 2017 and De Klerk 2010a, 2010b, 2011), (2) published geological maps and accompanying sheet explanations, (3) a four-day field study of the consolidated Impofu Wind Farms study area (23-26 September 2017) and the resulting palaeontological heritage screening report (Almond 2017), (4) a two-day field study (20-21 March 2018) of potentially-sensitive areas within the grid connection study area, focusing on areas of natural or artificial bedrock exposure, as well as (5) the author's extensive field experience with the formations concerned and their palaeontological heritage (Almond *et al.* 2008).

4. ASSUMPTIONS AND LIMITATIONS

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

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

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

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

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

5. Absence of a comprehensive computerised database of fossil collections in major RSA institutions which can be consulted for impact studies.

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

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

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

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

In the case of the Impofu Wind Farms and the associated grid connection study area, bedrock exposure is highly constrained by extensive superficial deposits, especially in areas of low relief, as well as by grassy vegetation. The study area is very extensive and for the most part fairly flat, with some gentle hillslopes and few access roads (Figs. 4 to 6). However, sufficient bedrock exposures were examined during the course of the field studies to assess the palaeontological heritage sensitivity of the main rock units represented within the study area (See Appendix 2). Comparatively few academic palaeontological studies have been carried out hitherto in the region, so any new data from impact studies here are of scientific interest. Palaeontological and geological data from the recent field study is usefully supplemented by those from several other field-based fossil heritage impact studies carried out in the Kouga (Humansdorp - Jeffrey's Bay - Cape St Francis) region by the author and other palaeontologists in recent years (See reference list); the paucity of previous field-based palaeontological impact assessments within the central and eastern sectors of the grid connection corridor, as documented on the SAHRIS website, is noted, however. Confidence levels for this impact assessment are rated as high, despite the unavoidable constraints of limited exposure, time and access.

5. LEGISLATIVE CONTEXT

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

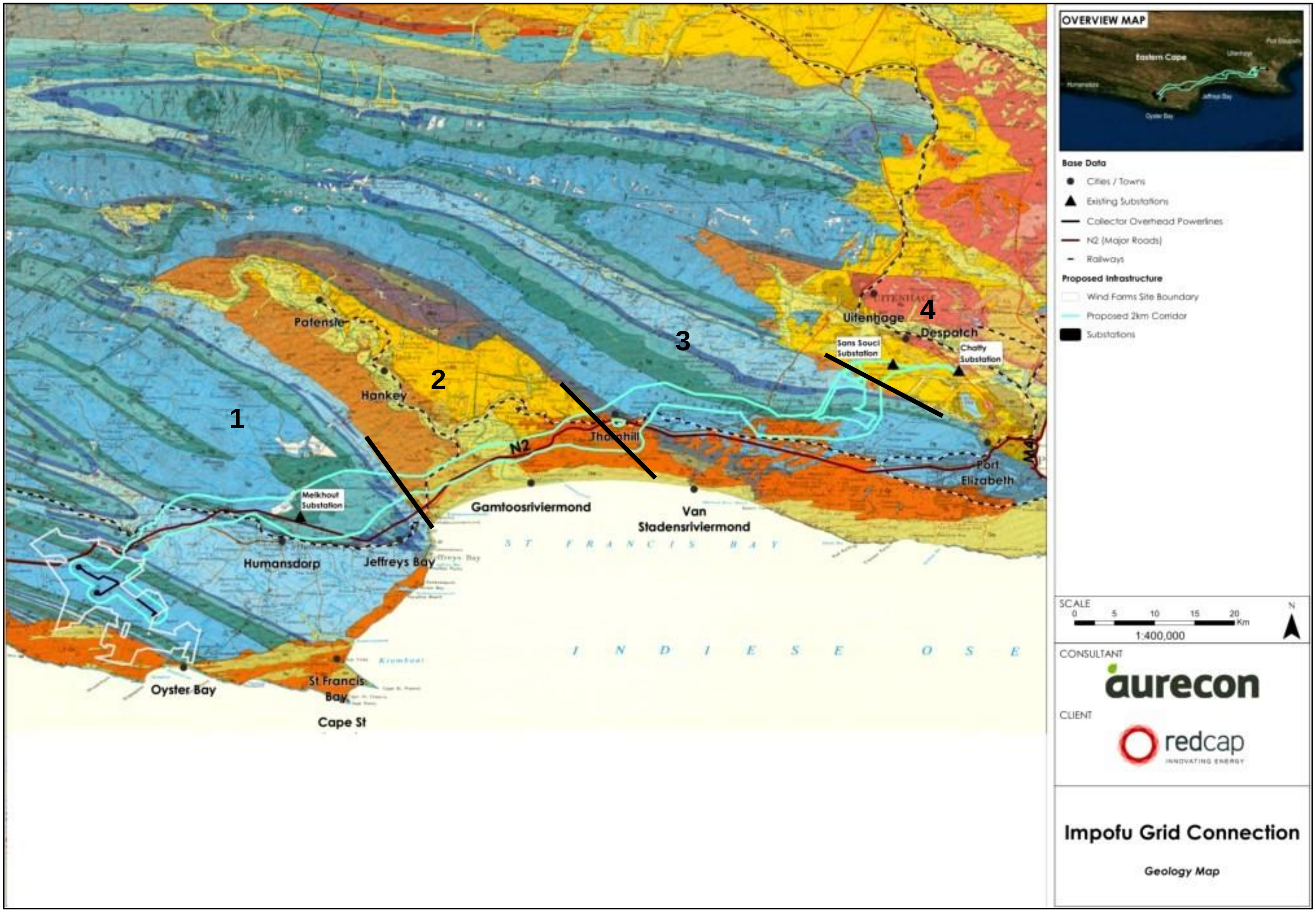
6. GEOLOGICAL CONTEXT

The proposed Impofu grid connection corridor traverses several geomorphic provinces on the southern coastal platform and Cape Fold Belt of southern Africa, as defined by Partridge *et al.* (2010), *viz*: the Southern Coastal Platform, Southern Coastal Lowlands as well as the Central and Eastern Cape Fold Mountains. This large region shows a considerable degree of topographic variety, due in large part to the varied underlying geology. This includes gently rolling hills and seawards-sloping plateaux along the wave-cut coastal platform inland from St. Francis Bay and Algoa Bay, rugged upland ridges of the NW-SE trending Cape Fold Mountains, as well as highly-dissected terrain along the margins of the Gamtoos River Valley. In addition to the ancient, deeply-incised Gamtoos River the study area is traversed by several smaller and younger drainage systems such as the Kromrivier, Swartrivier, Kabeljousrivier and Swartkopsrivier.

The geology of the grid connection corridor is shown on 1: 250 000 geology sheet 3324 Port Elizabeth (Toerien & Hill 1989) (Figs. 3, 3a, 3b), supplemented by sheet explanations for several larger-scale geological maps (*e.g.* Haughton 1928, Haughton *et al.* 1937, Engelbrecht *et al.* 1962, Le Roux 2000). It should be emphasised that mapping of the various geological formations outside the rugged uplands in this area is often *schematic* because of the generally poor levels of bedrock exposure; *i.e.* the outcrop areas shown in Fig. 3 may not be very accurate. Exposures in lowland areas where bedrocks are covered by superficial sediments (alluvium, colluvium, soils *etc*) are largely limited to river and stream banks, erosion gullies, borrow pits and quarries, road and railway cuttings and farm dams.

The geology and palaeontology of the sedimentary rocks represented here have already been outlined in several previous desktop and field-based studies by the author and others (notably Almond. 2010a, 2011f, 2012c, 2014), including field-based palaeontological assessments for 132 kV powerline corridors between Kareedouw and Patensie (Almond 2013a-c). A separate palaeontological and geological report for the consolidated Impofu Wind Farms project (Almond 2017) is relevant to the western sector of the proposed grid connection corridor as well as to the associated new Impofu collector switching station, switching stations and transmission lines connecting these. The main sedimentary rock units represented within the present grid connection study area are tabulated in Table 1 together with an outline of their potential fossil heritage and a provisional assessment of their palaeosensitivity (*N.B.* These sensitivity ratings have been updated from those shown on the SAHRIS palaeosensitivity maps based on recent field experience in the broader study region).

Figure 3 (following page). Extract from 1: 250 000 geology sheet 324 Port Elizabeth (Council for Geoscience, Pretoria) showing the outline of the Impofu grid connection corridor (elongate pale blue polygon) between the proposed Impofu West, East and North Wind Farms near Humansdorp (white polygon) and the existing Sans Souci or Chatty Substations in Nelson Mandela Bay Metropolitan Municipality, Eastern Cape (Image provided by Aurecon. See following figures for enlargements). The 2 km grid corridor (pale blue polygon) is subdivided into four numbered sectors on the basis of the bedrock geology. The numerous sedimentary rock units represented here are enumerated in Table 1. The palaeontologically-sensitive Kirkwood Formation outcrop area is coloured dark yellow.


OVERVIEW MAP
Eastern Cape
Base Data
Cities / Towns
Existing Substations
Collector Overhead Powerlines
N2 (Major Roads)
Railways
Proposed Infrastructure
Wind Farms Site Boundary
Proposed 2km Corridor
Substations
1
2
3
4
Patensie
Hankey
Uitenhage
Despatch
Sans Souci Substation
Chatty Substation
Port Elizabeth
M4
N2
Thornhill
Melkhout Substation
Humansdorp
Jeffreys Bay
Gamtoosriviermond
Van Stadensriviermond
S T F R A N C I S B A Y
I N D I E S E O S E
Oyster Bay
St Francis Bay
Cape St
SCALE
0 5 10 15 20 Km
1:400,000
N
CONSULTANT
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CLIENT
redcap
INNOVATING ENERGY
Impofu Grid Connection
Geology Map

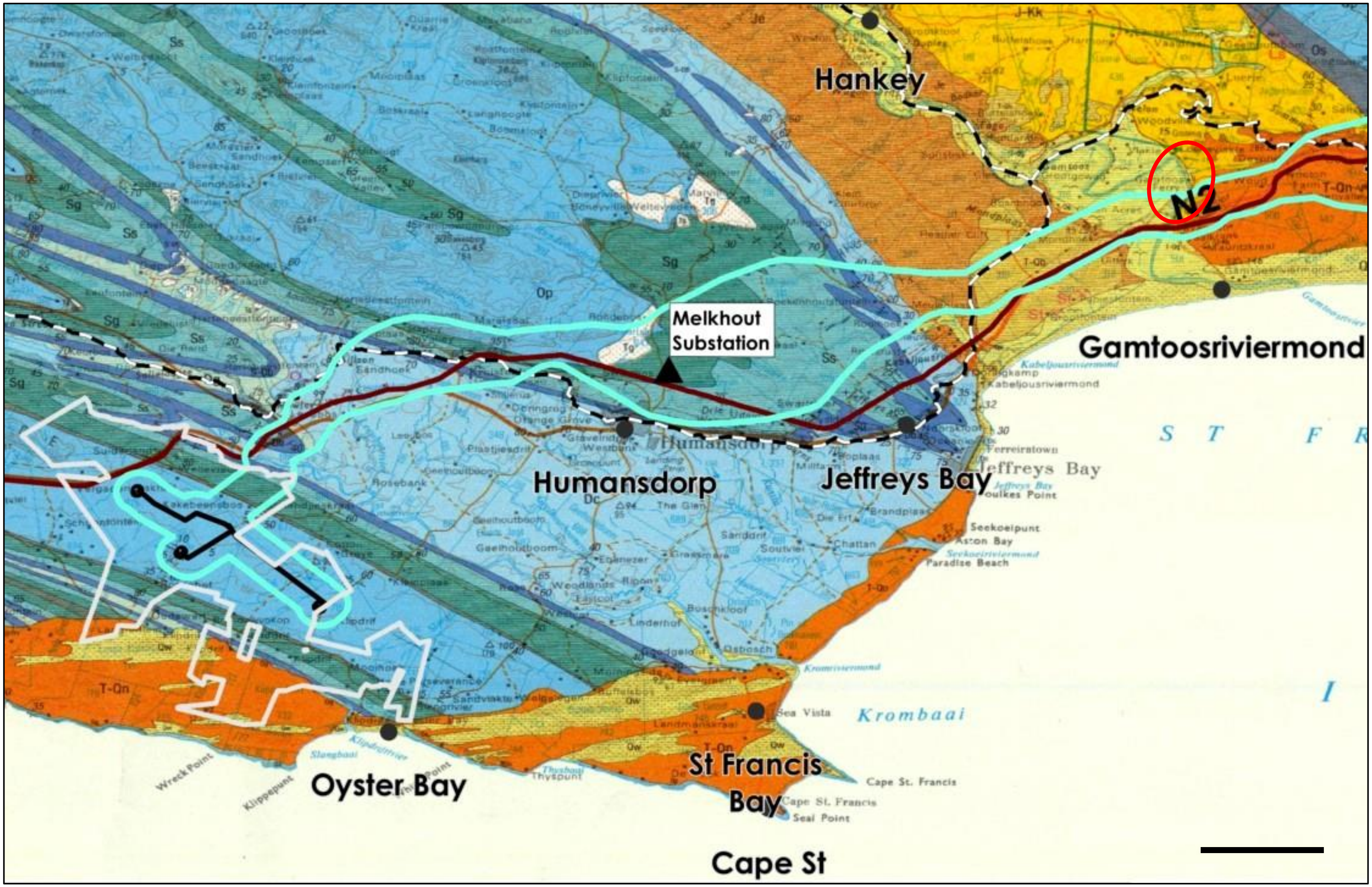

Figure 3a. Detail of the geological map show in the previous figure showing the rock units underlying the western portion of the Impofu grid connection corridor (pale blue polygon). New 132 kV transmission lines between the WEF switching stations and the new Impofu collector switching station are shown in black. The red ellipse indicates palaeontologically-sensitive cliff exposures of the Kirkwood Formation along the eastern banks of the Gamtoos River (*cf* satellite image in Fig. 35). Scale bar = 10 km.

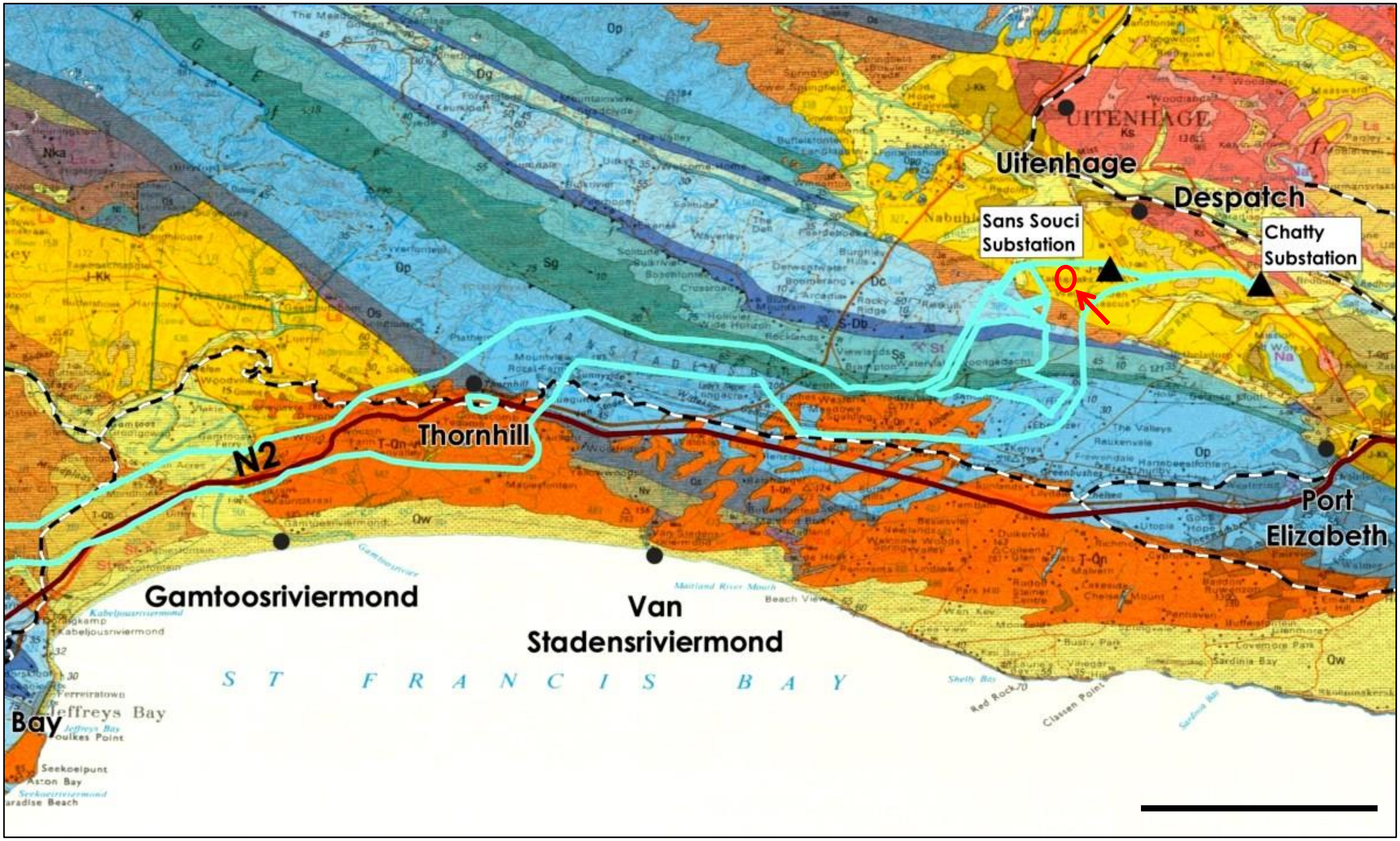

Figure 3b. Detail of the geological map shown in Figure 3 showing the rock units underlying the eastern portion of the Impofu grid connection corridor (pale blue polygon). The small red ellipse (arrowed) indicates palaeontologically-sensitive exposures of the Bethelsdorp Member (Kirkwood Formation) along pan margins just west of Sans Souci Substation (*cf* satellite image in Fig. 36). The revised corridor shown here shows route alternatives west of Chatty Substation, including along the existing powerline through Hopewell Estate. Scale bar = 10 km.

Figure 4. Flat sandy terrain with downwasted quartzitic surface gravels on the floor of the wide Gamtoos River Valley, looking towards the east (Loc. 005).

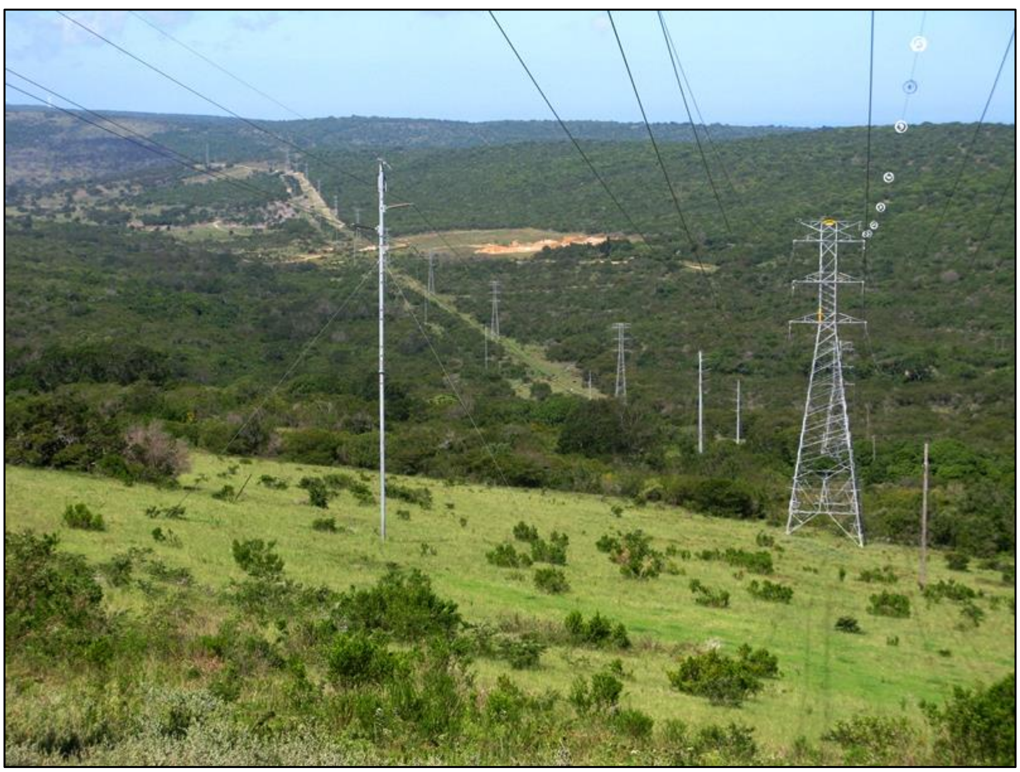

Figure 5. View south-westwards along existing powerline towards sand mine NE of Lemoenfontein showing hilly terrain east of the Gamtoos River Valley.

Figure 6. View northwards across slightly undulating, sandy terrain with thicket clumps in the region south of Uitenhage and west of Sans Souci Substation.

6.1. Geological overview of the proposed grid connection corridor

In this section of the report only a very brief overview of the main geological features of the grid connection study area are given (See previous palaeontological assessment reports listed in the References for more detail, notably those by Almond 2012b, 2013a-c, 2017). GPS locality data and brief descriptions of sites inspected during the two-day field visit are provided in Appendix 2, while selected good rock exposures are illustrated within the text below.

The proposed grid connection corridor (purple polygon in Figs. 3, 3a, 3b) can be broadly subdivided into four sectors (numbered 1 to 4 from west to east) in terms of the broad geological setting, *viz*:

1. A western-most **Sector 1** (including the Wind Farms) (*c*. 35 % of preferred grid alternative corridor length) underlain by folded Cape Supergroup bedrocks (Table Mountain (TMG) and Bokkeveld Groups) that build the southern coastal platform and low mountains along its inner margins. The latter include the Kareedouwberge as well as a low NW-SE upland ridge of braided fluvial to coastal marine quartzitic TMG rocks north of Humansdorp. The large outcrop areas of Bokkeveld Group marine bedrocks here, as well as narrow strips of Cederberg Formation mudrocks, are generally very poorly exposed and, where seen are normally highly-deformed (cleaved, folded) and chemically weathered (*e.g.* Almond 2012c, 2017). The tougher TMG bedrocks are also tightly folded along NW-SE axes, with extensive surface cover by downwasted and colluvial gravels as well as local development of ferruginous or siliceous pedocretes (Grahamstown Formation, seen, for example, north of Humansdorp).

2. A west-central **Sector 2** (*c*. 30 % of preferred grid alternative corridor length) centred on the Gamtoos River Valley which is underlain by Mesozoic continental sediments of the Uitenhage Group in the NW-SE trending Gamtoos Basin (Shone 2006, Muir *et al.* 2017a, 2017b, Muir 2018). Large outcrop areas and several good quarry and cliff exposures of the Enon and Kirkwood Formations are seen here (Figs. 7 & 8) but they have been palaeontologically neglected compared with the Algoa Basin outcrops to the east. Finer-grained, sandy to silty interbeds within the Enon succession are generally highly-weathered. The Late Jurassic to Early Cretaceous Uitenhage Group bedrocks are overlain by Late Caenozoic alluvium along the Gamtoos River (Fig. 9) as well as weathered Pleistocene aeolianites of the Nanaga Formation (Algoa Group) that extend well inland on the eastern side of the Gamtoos. Shelly Alexandria Formation beds are not encountered here.

Figure 7. Excellent quarry face sections through cobbly to pebbly fluvial conglomerates of the Enon Formation with occasional small-scale sandy channels and bars, Vlakteplaas Quarry (Loc. 003).

Figure 8. Riverine cliff sections through thick channel sandstones followed by overbank mudrocks and thin tabular sandstones of the Kirkwood Formation, eastern bank of the Gamtoos River (Loc. 010).

Figure 9. Trench exposure of sandy and pebbly alluvium underlying the Gamtoos River floodplain close to old road bridge (Loc. 009).

3. An east-central **Sector 3** (*c*. 20 % of preferred grid alternative corridor length) underlain by folded, WNW-ESE trending Cape Supergroup sediments that build a modestly elevated barrier of tougher-weathering Palaeozoic bedrocks separating the Gamtoos and Algoa Basins. Small outcrop areas of tectonically-deformed Late Precambrian (Ediacaran) metasediments of the Gamtoos Group crop out below the base of the TMG to the north of the Van Stadens and Maitland River Mouths but these ancient bedrocks are not mapped within the grid connection corridor. Otherwise, the geology of this sector closely resembles that of Sector 1 outlined above, including subordinate outcrop areas of deformed and weathered Lower Bokkeveld Group sediments in a mega-synclinal core, highly-weathered (and in part breccio-conglomeratic) Kirkwood Formation on the eastern edge of the Gamtoos Basin (Fig. 12), and an extensive mantle of leached Nanaga Formation (Algoa Group) Pleistocene aeolianites overlying these older bedrocks (Fig. 13). In the vicinity of the Van Stadens River Valley, outside the present study area, the basal part of the TMG, below the Peninsula Formation, is represented by deformed metasediments – conglomerates, sandstones and phyllites – of the Sardinia Bay Formation (Figs. 10 & 11) that were possibly deposited in a tidal shelf setting (Shone 1983, 1987, 1994, Toerien & Hill 1989, Johnson *et al.* 2006). The Sardinia Bay Formation outcrop area extends across the grid connection corridor to the NW of Thornhill but, on the basis of satellite images, is nowhere well-exposed here (highly wooded terrain). As in the Van Stadens River Valley exposures, the bedrocks here are likely to be highly-deformed.

Figure 10. R102 road cutting through folded quartzitic wackes and phyllitic pelites of the Sardinia Bay Formation, *c*. 1 km west of Van Stadensrivier (Loc. 025). Similar deformed siliciclastic sediments are likely to underlie the grid connection corridor to the NW of Thornhill but are not well exposed there.

Figure 11. Steeply-dipping, cross-bedded tabular wackes and thin-bedded pelites of the Sardinia Bay Formation, R102 road cutting *c.* 950 m west of Van Stadensrivier (Loc. 026).

Figure 12. Highly-weathered Kirkwood Formation sandstones and mudrocks and overlying ferricretes exposed in a R102 road cutting *c.* 4.5 WSW of Thornhill (Loc. 021).

Figure 13. Thin-bedded, orange-hued aeolian sands of the Pleistocene Nanaga Formation (Algoa Group) exposed in a sand mine NE of Lemoenfontein (Loc. 018) (Hammer = 30 cm).

4. An easternmost **Sector 4** (*c*. 15 % of preferred grid alternative corridor length) that is largely underlain by Late Jurassic – Early Cretaceous continental and marine sediments of the Uitenhage Group on the western margins of the Algoa Basin (Swartkops Subbasin). The bedrocks mainly belong to the Kirkwood Formation (Figs. 15 & 16) with narrow outcrop areas of Enon and Sundays River Formations in the SW and NE respectively. The geology and palaeontology of the study area near Bethelsdorp has been treated in part in a previous impact assessment by Almond (2012b). The TMG uplands in the southwest are highly folded, planed-off by pediment surfaces and mantled by ferruginised pediment gravels (Fig. 14). Of special note in the study area near Despatch are (a) geologically-important surface exposures of fossiliferous marine sediments of the latest Jurassic (Tithonian) Bethelsdorp Member towards the base of the predominantly continental Kirkwood Formation (*ibid*., Muir *et al.* 2017b) (Figs. 17 & 18) as well as (b) locally silcretised occurrences of alluvial fan deposits of the Eocene Damascus Formation (Hattingh 2001, his Fig. 3.1 and pp. 29-30) (Figs. 19 & 20), the only Tertiary (Neogene) sediments recorded from the Algoa Basin. The Damascus Formation outcrops south of Uitenhage have been erroneously mapped as Enon Formation on published geological maps. Relict patches of downwasted Alexandria Formation pebbly sediments (so-called “Bluewater Bay Formation”) and Pleistocene aeolianites (Nanaga Formation) cover parts of the Kirkwood Formation outcrop area, while Late Caenozoic alluvial and estuarine sediments are associated with the Swartkopsrivier (Fig. 21).

Figure 14. Gently-dipping quartzites of the Skurweberg Formation (Table Mountain Group) overlain by ferruginised gravels in an abandoned quarry, Bloemendal A/A (Loc. 216) (Hammer = 30 cm).

Figure 15. NW-facing cliff exposure of pale, weathered fluvial sediments, including small lenticular channel sandstone bodies, of the Kirkwood Formation in the Klipkuil valley, SE of Kwa-Nobuhle (Loc. 225).

Figure 16. Extensive gullied exposures of variegated overbank mudrocks with occasional thin sandstone horizons of the Kirkwood Formation, margins of abandoned brick pit near Despatch (Loc. 230).

Figure 17. Low scarp exposures of pale greyish mudrocks and yellowish tabular sandstones of the estuarine Bethelsdorp Member (Kirkwood Formation) with large ferruginous concretions in middle ground seen along a pan margin west of Sans Souci Substation (Loc. 236). Note capping of orange-brown sandy soils.

Figure 18. Possible series of several sandstone-capped shoaling cycles within the Bethelsdorp Member. The arrow indicates a horizon containing shelly marine fossils (See Figs. 31 to 34).

Figure 19. Quarry exposure on Bloemendal A/A of weathered, steeply-dipping, pale Bokkeveld Group mudrocks unconformably overlain by semi-consolidated alluvial fan gravels of the Eocene Damascus Formation (Hammer = 30 cm) (Loc. 218).

Figure 20. Silcretised coarse, proximal alluvial fan gravels of the Damascus Formation on hillslopes *c*. 100 m south of the R368 (Loc. 221).

Figure 21. Erosion gulley exposures of thick sandy to pebbly alluvial deposits overlying Kirkwood or Bokkeveld bedrocks in the Klipkuil Valley near Kwa-Nobuhle (Loc. 224).

7. PALAEONTOLOGICAL HERITAGE

The palaeontological record associated with the various sedimentary rock units within the proposed Impofu grid connection corridor has been described in several previous palaeontological assessment studies for the Humansdorp – Port Elizabeth (*e.g.* Almond 2012a, 2012 b, 2017) and is summarized below in Table 1. The following brief comments refer to the four informal geologically-defined sectors of the grid connection study area shown in Figure 3 with illustrations of palaeontological material recorded during recent fieldwork in the proposed grid connection corridor (See Appendix 2 for GPS data for all numbered fossil sites).

7.1. In **Sector 1** the Palaeozoic bedrocks of the Cape Supergroup are generally unfossiliferous due to high levels of tectonic deformation and chemical weathering, although isolated marine trace fossil assemblages have been recorded from quarry exposures into the Peninsula Formation near Rosenhof farmstead (Almond 2017). Unmapped relict patches of Pleistocene aeolianites (Nanaga Formation, Algoa Group) overlying the bedrocks are potentially fossiliferous (*e.g.* mammalian bones, teeth in fossil hyaena dens, land snails, calcretised rhizoliths) but in practice seem to be highly-leached chemically, with resulting dissolution of most original fossil remains. Based on desktop and field studies the palaeosensitivity of this sector of the grid connection corridor, as well as the associated wind farm switching stations, Impofu collector switching station and short 132 kV transmission lines between the two is generally LOW. No significant fossil sites are recorded within the electrical infrastructure footprint here (Almond 2017).

7.2. In **Sector 2** the Enon Formation (Uitenhage Group) conglomerates and minor sandstones are beautifully exposed in several active and inactive quarries but no fossil remains were recorded from these beds. The overlying Late Jurassic / Early Cretaceous fluvial sediments of the Kirkwood Formation in the Gamtoos Basin have previously yielded important plant fossil remains such as leaf compressions, woody material (lignites, impressions), amber (fossil resin) and organic-walled microfossils, but – so far – no dinosaur remains (*cf* McLachlan & McMillan 1976, Dingle *et al.* 1983, Gomez *et al.* 2002a, 2002b and refs. therein). Locally abundant impressions of woody axes and plant hash are recorded from fallen blocks of Kirkwood channel sandstones along the base of cliff exposures on the eastern bank of the Gamtoos River (Figs. Figs. 22 to 24). Most the cliff exposures here are too steep to be accessible, however. Important Pleistocene mammalian and other fossil remains might well occur within Late Caenozoic alluvial and aeolian deposits (*e.g.* Pleistocene Nanaga Formation), but are likely to be very sparse and localised; no fossils were reported from these younger units during the field study. It is concluded that the overall palaeosensitivity of this sector of the grid connection corridor is LOW with the exception of the Kirkwood Formation cliff exposures along the eastern banks of the Gamtoos River which are of HIGH sensitivity.

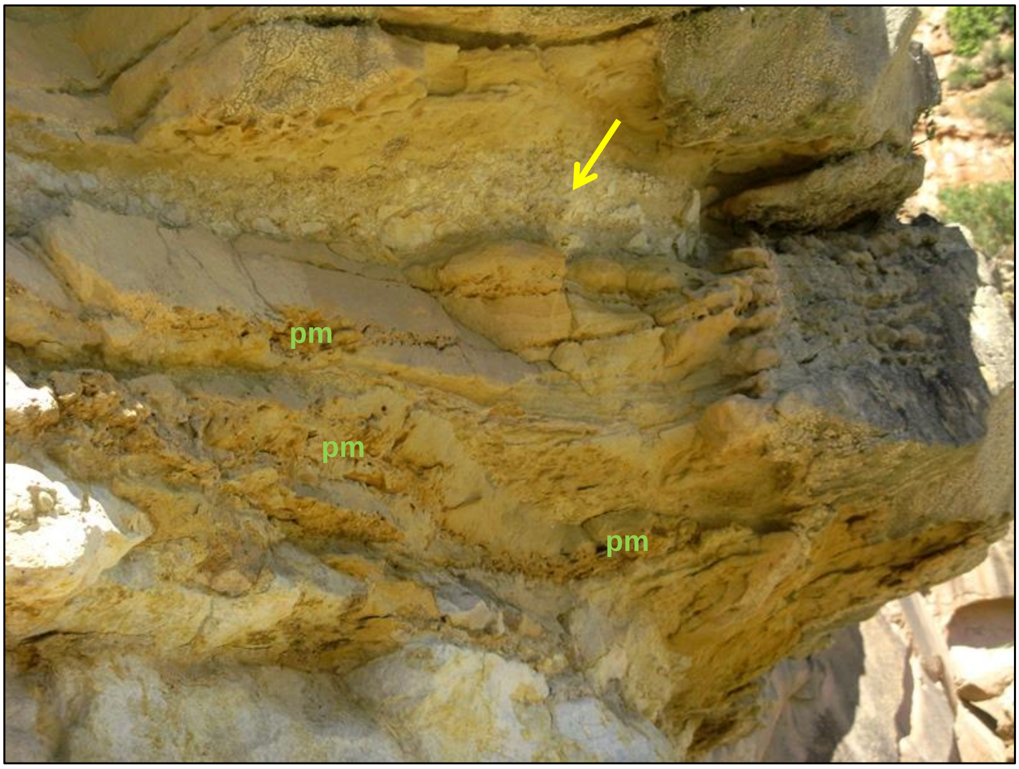

Figure 22. Lower portion of thick Kirkwood channel sandstone package showing multiple thin horizons of plant debris moulds (pm) as well as horizon of pale siltstone intraclasts (arrowed), Gamtoos River cliffs (Loc. 012).

Figure 23. Fallen block of Kirkwood channel sandstone showing concentration of aligned woody stem moulds as well as plant hash (Hammer = 30 cm), Gamtoos River cliffs (Loc. 011).

Figure 24. Ferruginous moulds of woody plant stems within Kirkwood Formation channel sandstone (Scale in cm), Gamtoos River cliffs (Loc. 013).

7.3. In **Sector 3** the Late Precambrian Gamtoos Group metasediments are not well-exposed and these beds are rated as of LOW palaeontological sensitivity since they are generally highly deformed and have so far only yielded microfossil assemblages. Good road cutting sections through the Sardinia Bay Formation (basal TMG) in the Van Stadens River Valley, outside the present study area, are also tectonically deformed, with no evidence of the trace fossils recorded from coastal outcrops (Shone 1991); this is likely to apply equally to the Sardinia Bay Formation outcrop area further inland, to the northwest of Thornhill. As elsewhere, the overlying Table Mountain Group formations are largely unfossiliferous while the overlying blanket of Nanaga Formation aeolian sands is highly leached, with no fossils recorded within sparse sand mine exposures. Kirkwood Formation sediments exposed in this sector appear to be highly weathered and ferruginised, so well-preserved fossil assemblages are not anticipated here. It is concluded that the palaeontological sensitivity of this sector of the grid connection is LOW and no significant fossil sites are recorded within the study area here.

7.4. In **Sector 4** the Table Mountain Group (TMG) bedrocks are steeply folded, truncated by pediment surfaces and overlying ferruginised pediment gravels. Potentially-fossiliferous mudrock interbeds are not exposed and are likely to be highly weathered. This applies equally to the Baviaanskloof Formation at the top of the TMG succession. Several excellent brick pit and stream gully exposures of fluvial facies of the Kirkwood Formation in low-lying region south of Uitenhage have not yielded significant continental biotas apart from low diversity invertebrate trace fossil assemblages (Fig. 25 and 26), although rare dinosaur remains (*Algoasaurus*) are reported from Despatch nearby (McLachlan & McMillan 1976). Most of the Kirkwood Formation outcrop area is mantled by unfossiliferous surface gravels, soils, alluvium and pan sediments but excellent exposures of continental facies on the margins of an inactive brick pit near Despatch include lenses of intensely-bioturbated sandstones (Figs. 25 and 26).

Palaeontologically- and geologically-important low scarp and gulley exposures of estuarine to marine mudrocks and sandstones of the Bethelsdorp Member (previously equated with the Colchester Member; Muir *et al.* 2017b) towards the base of the Kirkwood Formation occur along the southwestern margins of a large pan some 1.8 km west of Sans Souci Substation (Figs. 17 & 18). They are the best known surface exposures of these Latest Jurassic marine to estuarine rocks which are probably situated towards the base of the Kirkwood Formation succession (Muir *et al.* 2017b, Muir 2018). They have yielded a small range of invertebrate trace fossils associated with horizontally-laminated sandstones (Figs. 27 to 30) and also an impoverished shelly invertebrate fauna of flat-shelled bivalves, encrusting oysters and serpulid worms as well as cidaroid sea urchins within silty mudrock intervals (Figs. 31 to 34) (Almond 2012b; *cf* McLachlan & McMillan 1976, Dingle *et al.* 1983 who provide more extensive fossil lists for nearby localities at Bethelsdorp Salt Pan and North End Lake that are no longer accessible; McMillan 2010 reviews formainiferans from this rock unit). The Bethelsdorp Member outcrop area is of HIGH palaeontological sensitivity but only encroaches marginally into the grid connection study area (Figs. 3b & 36). The remainder of the sector is rated as of LOW palaeontological sensitivity and no significant fossil sites are recorded there.

Figure 25. Fallen block of intensely-bioturbated fluvial sandstone from the Kirkwood Formation showing dense network of intersecting hollow to sand-infilled invertebrate burrows (Scale in cm and mm) (Loc. 233).

Figure 26. ***In situ*** **lens of highly-bioturbated fluvial sandstone within the Kirkwood Formation, showing vertical as well as oblique to horizontal burrows (Scale in cm and mm) (Loc. 233).**

Figure 27. Horizontally-laminated tabular sandstone within the Bethelsdorp Member showing bioturbation by endichnial steeply-inclined burrows (Scale = c. 15 cm) (Loc. 037).

Figure 28. Bilobed horizontal to convex-downwards endichnial burrows within tabular sandstone of the Bethelsdorp Member, Kirkwood Formation (apparent branching of burrow system *may* be deceptive) (Scale in cm and mm) (Loc. 236).

Figure 29. Fallen block of tabular, brown-weathering Bethelsdorp Member sandstone showing dense network of intersecting cylindrical burrows (Scale = c. 15 cm) (Loc. 034).

Figure 30. Close-up of 4-6 mm wide horizontal cylindrical burrows seen in previous figure showing possible vague, finely-spaced meniscate backfill (Loc. 034).

Figure 31. Subrounded quartzite pebbles from the Bethelsdorp Member mudrocks showing partial covering by encrusting oysters (possibly *Amphidonta*) (Scale in cm and mm) (Loc. 237).

Figure 33. Washed-out, thin-shelled, flattened bivalves of the genus *Placunopsis* weathering out from greyish mudrocks of the Bethelsdorp Member (Loc. 237) (Shell fragments here are up to 4 cm across).

Fig. 34. Disarticulated, finely-tuberculate spines of the regular echinoid *Cidaris* washed out from the Bethelsdorp Member mudrocks (Loc. 237). Intact spines are *c*. 30 mm long and up to 4 mm wide towards the base.

Table 1: Main sedimentary rock units mapped within the proposed Impofu grid connection corridor, Eastern Cape, on 1: 250 000 geology sheet 3324 Port Elizabeth (Abstracted from Almond *et al.* 2008). Provisional palaeosensitivity ratings have been assigned here to each unit, based on desktop and field data (*N.B.* These ratings have been updated from those shown on the SAHRIS palaeosensitivity maps based on recent field experience in the broader study region):
Black = LOW / NEGLIGIBLE; Blue = LOW; green = MODERATE; purple = HIGH; red = VERY HIGH

GEOLOGICAL UNIT	ROCK TYPES & AGE	FOSSIL HERITAGE	COMMENTS
NEOGENE-PLEISTOCENE DRIFT - ALLUVIUM *ETC* Late Miocene and younger (correlated with Alexandria Fm *etc*, Algoa Group)	Alluvium, aeolian sands, pan, vlei and lake sediments, soils, surface gravels *etc* in the interior (*e.g.* alluvial terrace gravels of the Kudu's Kloof Formation in the Sunday's River Valley)	Pollens, freshwater molluscs, mammal bones and teeth *etc*	Alert for fossil human as well as other mammal remains (*cf* Hofmeyer Man skull in the Karoo, *c.* 36 000 BP)
GRAHAMSTOWN FORMATION **(Tg)**	Silcretes and ferricretes associated with deeply weathered saprolite (*in situ* weathered bedrock) Late Cretaceous (are also younger Tertiary silcretes, e.g. associated with Damascus Formation)	Rare fossil plants reworked Beaufort Group silicified wood (*e.g.* East London area)	Several patches of silcretised sediment mapped on S flanks of Winterhoekberge, NW of PE, as well as N of Humansdorp.
ALGOA GROUP **(Ta)** **Incl.** **Alexandria Formation (Ta)** **Nanaga Formation (T-Qn)**	Estuarine, coastal, shallow marine silicalstic sediments, limestones, coquinites, aeolian sands Early / Middle Eocene - Holocene	Rich marine / estuarine invertebrate fauna including diverse molluscs, plus corals, bryozoans, brachiopods, echinoids, crustaceans, microfossils, sharks' teeth,trace fossils. Local concentrations of mammalian bones and teeth, animal trackways, land snails, stone artefacts within Pleistocene aeolianites (*e.g.* related to fossil hyaena dens).	Main subunits represented in the coastal interior are the Alexandria Formation (Ta)(*e.g.* local dense fossil oyster beds) with its downwasted pebbly soils ("Bluewater Bay Formation", T-Qb, which is no longer recognised) as well as older Pleistocene aeolianites of the Nanaga Formation (mostly leached and unfossiliferous away from coast) (*cf* Almond 2010, 2017).
DAMASCUS FORMATION	Alluvial fan breccio-conglomerates and debris flow deposits (locally silcretised). Eocene	No fossils recorded.	Small outcrop areas south of Uitenhage (previously mapped as Enon Formation) (See Hattingh 2001).
UITENHAGE GROUP — **Buffelskloof Formation (Kb)**	terrestrial / fluvial breccio-conglomerates Early Cretaceous	No fossils recorded so far in E. Cape. Occasional records of petrified wood in Western Cape outcrop area.	

	Sundays River Formation **(Ks)** Early Cretaceous	Shallow marine / estuarine siliciclastics	Rich marine invertebrate fauna (molluscs, echinoderms *etc*), vertebrates (*e.g.* plesiosaurs), microfossils (foraminiferans, ostracods), trace fossils	Algoa Basin of E. Cape is the key area for terrestrial and shallow marine biotas of the Uitenhage Group in RSA
	Kirkwood Formation (J-Kk) Late Jurassic to Early Cretaceous	Terrestrial (fluvial / lacustrine) siliciclastics	Variety of small to large dinosaurs (theropods, sauropods, ornithopods), other reptiles, Mesozoic mammals, important floras of petrified wood ("Wood Beds"), charcoals, leaves (ferns, cycads, conifers), freshwater invertebrates (bivalves, crustaceans) Shelly marine to estuarine biotas (molluscs, echinoids *etc*), microfossils (Bethelsdorp Member)	Fossil logs may be locally abundant embedded within bedrock or reworked into surface gravels, alluvium. However, the woody tissue is often poorly-preserved, precluding detailed taxonomic studies. Important plant floras including woody plant impressions, lignite, microfossils in carbonaceous shales as well as amber (fossil resin) recorded from Gamtoos Basin (McLachlan & McMillan 1976). Shelly marine to estuarine invertebrates as well as low-diversity trace fossil assemblages reported from Bethelsdorp Member (previously part of Colchester Mb) near Uitenhage (*e.g. ibid,* Almond 2012b).
	Enon Formation (Je) Late Jurassic to Early Cretaceous	Coarse alluvial fanglomerates, breccias and braided stream fluvial gravels	Rare transported bone fragments, coalified and silicified wood (Muir *et al.* 2017a).	Extensive good exposures of Enon beds on western flanks of Gamtoos River Valley require palaeontological investigation (cf Almond 2013c).

BOKKEVELD GROUP		**CERES SUBGROUP (Dc)** Early – Mid Devonian (Emsian – Eifelian)	Shallow marine siliciclastics (alternating sandstone- and mudrock-dominated formations)	Diverse shelly invertebrate biotas dominated by brachiopods, echinoderms, trilobites and molluscs (with several other minor groups), diverse trace fossils, rare fish remains (acanthodians, placoderms, sharks, bony fish) & primitive vascular plants (psilophytes, lycopods); microfossils	Rich fossil invertebrate biotas commoner in mudrock-dominated units (esp. Gydo and Voorstehoek Fms), with low diversity shelly coquinas in sandstones (Dga, Dh), while trace fossils are best preserved in heterolithic units (thin bedded sandstones and mudrocks). Rich fossil record of these units in E. Cape poorly recorded compared with W. Cape. Tectonic deformation and weathering in E Cape limit fossil collection, especially within mudrock-rich horizons The undifferentiated Ceres Subgroup outcrop areas near Humansdorp – Jeffrey's Bay and NW of PE are largely of low palaeosensitivity due to high levels of weathering and tectonic deformation. However, important shelly invertebrate faunules are recorded locally within Ceres Subgroup near Uitenhage (See Le Roux 2000, Almond 2017)
TABLE MOUNTAIN GROUP	**NARDOUW SUBGROUP**	Baviaanskloof Fm (Sb, S-Db) Early Devonian	Shallow marine "dirty" sandstones and subordinate mudrocks	Low diversity, brachiopod-dominated shelly marine faunas (also bivalves, trilobites, tentaculitids, bryozoans, gastropods, crinoids, trace fossils). Possible primitive vascular plants.	Correlated with Rietvlei Fm in western Cape Basin Early Devonian age well-established on fossil evidence. Shelly fossils in Elands Valley noted by Haughton et al. (1937).
		Skurweberg Fm (Ss) Silurian	Braided fluvial pebbly sandstones with thin subordinate mudrocks, especially in shallow marine- /estuarine- influenced parts of succession, especially towards east	Sparse marine / estuarine /?fluvial trace fossil assemblages (trilobite burrows, *Skolithos* "pipe rock", horizontal burrows) within more mudrock-rich part of succession (W. Cape)	Previously also known as the Kouga Fm (Sk)
		Goudini Fm (Sg) Early Silurian			Previously also known as the Tchando Fm (St)

	Cederberg Fm (Oc) Late Ordovician	Post-glacial mudrocks (**Soom Member**) grading up into shallow marine sandstones (**Disa Member**)	**Soom Member** with moderately diverse marine biota of various microfossils, “algae”, soft-bodied and shelly invertebrates (eurypterids, trilobites, nautiloids, brachiopods *etc*), primitive jawless fish, some showing exceptional soft tissue preservation. **Disa Member** with low-diversity shelly invertebrate dominated by brachiopods, also rare molluscs, trilobites, shallow marine trace fossil assemblages	Cederberg Fm biota not recorded yet in E. Cape. Potentially fossiliferous mudrocks in E. Cape often affected by intense cleavage, shearing and chemical weathering, compromising both preservation and collection of fossil material (*cf* Almond 2017). This unit often obscured by Cape age deformation and poor exposure of mudrocks. Its development in the E. Cape is not well understood.
	Peninsula Fm (Op) Early – Late Ordovician	Fluvial sandstones, quartzites, subordinate mudrocks within thin marine / estuarine intercalations	Sparse shallow marine / coastal /estuarine to freshwater trace fossils, including eurypterid trackways, trilobite burrows	Traces mainly recorded from mudrock-rich, more marine-influenced parts of succession in W. Cape but also expected in E. Cape, at least where mudrock units have not been pinched out or sheared through Cape age tectonism.
	Sardinia Bay Formation (Os) Probably Early Ordovician or Cambrian	Deformed metasediments – conglomerates, sandstones, phyllites – of possible tidal shelf setting	Low diversity of acritarchs, questionable shallow marine trace fossils in coastal outcrop area (*Cruziana, Skolithos etc*) (Shone 1991, Gaucher & Germs 2006)	Stratigraphic boundaries of this unit uncertain. Correlated by different workers with Graafwater Fm or pre-Cape (Klipheuwel Group? Cango Group?) of W. Cape Reported trace fossils contested and well-preserved examples would be of considerable interest.
GAMTOOS GROUP **Van Staadens Fm (Nv)** **Kaan Fm (Nka)** **Kleinrivier Fm (Nk)** **Lime Bank Fm (Nl)** Probably Late Ediacaran **+ Undifferentiated Late Proterozoic (N)**		Highly deformed siliciclastic sediments, carbonates deposited in shallow marine, turbidite fan to alluvial settings	Acritarchs (organic-walled microfossils) in all formations Potential for stromatolites in carbonate rocks (Lime Bank, Kaan Fms) and vendobiontans in siliciclastic sediments (Kleinrivier, Van Staadens Fms)	Gamtoos Gp is correlated with Cango Caves Group of W. Cape. *NB* Vendobiontans recently (2008) discovered in Cango Caves Group (Groenefontein Fm.) of W. Cape

8. ASSESSMENT OF IMPACTS ON PALAEONTOLOGICAL RESOURCES

The proposed Impofu grid connection corridor is underlain by several formations of potentially fossiliferous sediments of the Gamtoos Group, Cape Supergroup, Uitenhage Group and Algoa Group (Sections 6 & 7). Combined desktop and field studies of the broader Impofu Wind Farm project area show that in practice the bedrocks and superficial sediments here are generally are of *low* palaeontological sensitivity due to high levels of bedrock deformation, fossil-poor sedimentary facies, as well as chemical weathering (Almond 2012, 2017, this study). The following palaeontological heritage assessment (based on the Aurecon standard impact assessment methodology and summarised in Table 2 below) applies to the *construction phase* of the grid connection including wind farm switching stations, Impofu collector switching station, short 132 kV overhead lines connecting the switching stations to the collector switching station, substation extension areas and any new access roads. Further significant impacts on fossil heritage during the operational and decommissioning phases of the grid connection are not anticipated so these phases are not separately assessed here.

The destruction, damage or disturbance out of context of legally-protected fossils preserved at the ground surface or below ground that may occur during construction of the grid connection entail direct *negative* impacts to palaeontological heritage resources that are confined to the development footprint and limited parts of the site (*very limited* extent). These impacts can often be effectively mitigated (*medium mitigatability*) but they are *permanent* and cannot be fully rectified (*low reversibility*). All of the sedimentary formations represented within the study area contain fossils of some sort (*e.g*. microfossils, trace fossils) but impacts on *scientifically important, well-preserved, unique or rare fossil material* that is worthy of special protection / conservation are likely to be *very rare / improbable*. Impacts of *some* sort on fossil heritage are definite but, given the general low palaeontological sensitivity of the study area, they are likely to be of *very low intensity* (Local impacts on highly-significant fossil remains – such as rare vertebrate fossils or rich plant assemblages – cannot be completely excluded). Most (but *not* all) of the fossils concerned are likely to be of widespread occurrence within the outcrop areas of the formations concerned; the probability of loss of *unique or rare* fossil heritage is therefore low (*low resource irreplaceability*). Given the extensive palaeontological field and desktop data now available for the study area between Humansdorp and NMBM, confidence levels for this assessment are rated as *high*.

As a consequence of (1) the paucity of irreplaceable, unique or rare fossil remains within the development footprint, (2) the high levels of chemical weathering in the study area, as well as (3) the extensive superficial sediment cover overlying most potentially-fossiliferous bedrocks within the grid connection study area, the overall impact significance of the construction phase of the proposed electrical infrastructure project *without mitigation* is assessed as *minor / negligible* (negative).

Should the recommended mitigation measures for the construction phase of the electrical infrastructure – as outlined in the Chance Fossil Finds Procedure (Appendix 1) - be fully implemented, the impact significance of the project is still likely to remain *minor / negligible* (negative). However, in this case any small residual impacts due to loss of fossil heritage would be partially offset by the *positive* impact represented by an improved palaeontological database for the Eastern Cape region as a direct result of appropriate mitigation. This is a *positive* outcome because any new, well-recorded and suitably curated fossil material from this palaeontologically under-recorded part of the Eastern Cape would constitute a useful addition to the scientific understanding of the fossil heritage here.

When considering the **No-Go Alternative** (*i.e.* no grid connection development), impacts on local fossil heritage would be essentially *neutral*. Without development natural weathering processes and erosion will continue to steadily destroy fossils preserved near or at the ground surface (*negative*), but at the same time new fossils will be continually exposed (*positive*). This No-Go alternative would forgo potential improvements in the palaeontological understanding of the study region through any mitigated new fossil finds made during construction (*negative*).

Table 2: Assessment of impacts on fossil heritage resources during the construction phase of the Impofu grid connection

Project phase	**Construction**			
Impact	**Fossil heritage**			
Description of impact	**Disturbance, damage or destruction of fossils preserved at surface or below ground as consequence of clearance or excavations (e.g. for access roads, pylon foundations)**			
Mitigatability	Medium	Mitigation exists and will notably reduce significance of impacts		
Potential mitigation	**Safeguarding and reporting of chance fossil finds by ECO to ECPHRA. Recording and sampling of significant fossils by professional palaeontologist.**			
Assessment	**Without mitigation**		**With mitigation**	
Nature	Negative		Negative	
Duration	Permanent	Impact may be permanent, or in excess of 20 years	Permanent	Impact may be permanent, or in excess of 20 years
Extent	Very limited	Limited to specific isolated parts of the site	Very limited	Limited to specific isolated parts of the site
Intensity	Very low	Natural and/ or social functions and/ or processes are slightly altered	Negligible	Natural and/ or social functions and/ or processes are negligibly altered
Probability	Rare / improbable	Conceivable, but only in extreme circumstances, and/or might occur for this project although this has rarely been known to result elsewhere	Rare / improbable	Conceivable, but only in extreme circumstances, and/or might occur for this project although this has rarely been known to result elsewhere
Confidence	High	Substantive supportive data exists to verify the assessment	High	Substantive supportive data exists to verify the assessment
Reversibility	Low	The affected environment will not be able to recover from the impact - permanently modified	Low	The affected environment will not be able to recover from the impact - permanently modified
Resource irreplaceability	Medium	The resource is damaged irreparably but is represented elsewhere	Medium	The resource is damaged irreparably but is represented elsewhere
Significance	**Negligible - negative**		**Negligible - negative**	
Comment on significance				
Cumulative impacts	Minor			

8.1. Cumulative impacts

Palaeontological heritage assessments for several other comparable transmission line projects in the broader Humansdorp – Nelson Mandela Bay Municipality region have been reviewed (*N.B.* Specialist palaeontological impact assessments (PIAs) for several other powerline projects in the region have not been undertaken, or are not available). These include grid connections for the Gibson Bay Wind Farm (Almond 2013d) and Tsitsikamma Community Wind Farm (Almond 2012a) as well as a 66 kV powerline from Eskom's Melkhout Substation near Humansdorp to the existing main intake substation in Jeffrey's Bay (Almond 2016) a 132 kV line between Kareedouw – Dieprivier – Melkhout and Patensie (Almond 2013a, 2013b, 2013c). Note that not all these projects are of equal relevance for cumulative impact assessments since they do not all cover the same spectrum of potentially fossiliferous rock units. Furthermore, cumulative palaeontological impacts are influenced by any substantial development in the region, and not just by transmission lines or wind farms.

All the relevant transmission line PIA studies listed concur in that, with few exceptions, the palaeontological sensitivity of the Humansdorp - NMBM region is generally low as far as the bedrocks are concerned, especially because of the high levels of chemical weathering and tectonic deformation observed here in conjunction with low levels of bedrock exposure. The most significant fossil sites recorded so far are (1) marine trace fossils in the Peninsula Formation near Rosenhof (Almond 2012, 2017) in the Impofu West Wind Farm project area, (2) the Late Pleistocene hyaena den bone, tooth and coprolite assemblages within Nanaga Formation aeolianites in the Gibson Bay WEF project area and near Oyster Bay (Carrion *et al.* 2000, Nilssen & Smith 2015, Brink 2015), (3) rich fossil plant assemblages and fossil resin on the eastern bank of the Gamtoos River (McLachlan & McMillan 1976, p. 207, Section 2.7 above) as well as (4) estuarine to marine shelly invertebrates and trace fossils within the Kirkwood Formation near Uitenhage (Section 7.4 above). Cumulative impacts on fossil heritage of the proposed Impofu grid connection in the context other powerline developments in the region as well as the three Impofu Wind Farm projects are inferred to be *minor* as far as the Palaeozoic bedrocks are concerned (Almond 2017). This would also apply to impacts on sparse but locally-rich fossil heritage preserved within the coastal aeolianites and Kirkwood Formation *provided that* adequate monitoring of major excavations here (*e.g.* pylon footings, access roads) is carried out during the construction phase.

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

Pending the potential discovery of significant new fossil remains (*e.g.* vertebrate bones and teeth, horn cores, shelly invertebrates, trace fossils, plant fossil lenses) during the construction phase of the proposed Impofu grid connection, no further specialist palaeontological studies or mitigation are recommended for this project.

Regarding two small areas of high palaeontological sensitivity recorded within the study area:

- Any bedrock excavations within the sector spanning the Kirkwood Formation cliffs on the eastern bank of the Gamtoos River (red polygon in Fig. 35) should be carefully monitored by the Environmental Control Officer for chance fossil finds such as wood and other plant material (See Appendix 1: Chance Fossil Finds Procedure);

- The outcrop area of the Bethelsdorp Member marine beds (yellow polygon in Fig. 36) to the west of Sans Souci Substation should be treated as a No-Go area.

The suitably qualified and experienced Environmental Control Officer (ECO) responsible for the transmission line development should be made aware of the potential occurrence of scientifically-important fossil remains within the development footprint. During the construction phase all major surface clearance and deeper (> 1 m) excavations operations (*e.g.* for new access roads, pylon placements, substations) should be monitored for fossil remains on an on-going basis by the ECO. Should substantial fossil remains be encountered at surface or exposed during construction, the ECO should safeguard these, preferably *in situ* (See Appendix 1: Chance Fossil Finds Procedure). They should then alert the Eastern Cape Provincial Heritage Resources Agency, ECPHRA (Contact details: Mr Sello Mokhanya, 74 Alexander Road, King Williams Town 5600; smokhanya@ecphra.org.za) as soon as possible. This is to ensure that appropriate action (*i.e.* recording, sampling or collection of fossils, recording of relevant geological data) can be taken by a professional palaeontologist at the proponent’s expense. These recommendations are summarized in the tabulated Chance Fossil Finds Procedure appended to this report (Appendix 1).

The palaeontologist concerned with any 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 developed by SAHRA (2013).

These monitoring and mitigation recommendations are to be incorporated into the Environmental Management Programme (EMPr) for the proposed Impofu grid connection project. The operational and decommissioning phases of the development are unlikely to have further significant impacts on palaeontological heritage and no additional recommendations are made in this regard (The Chance Fossil Finds Procedure still applies).

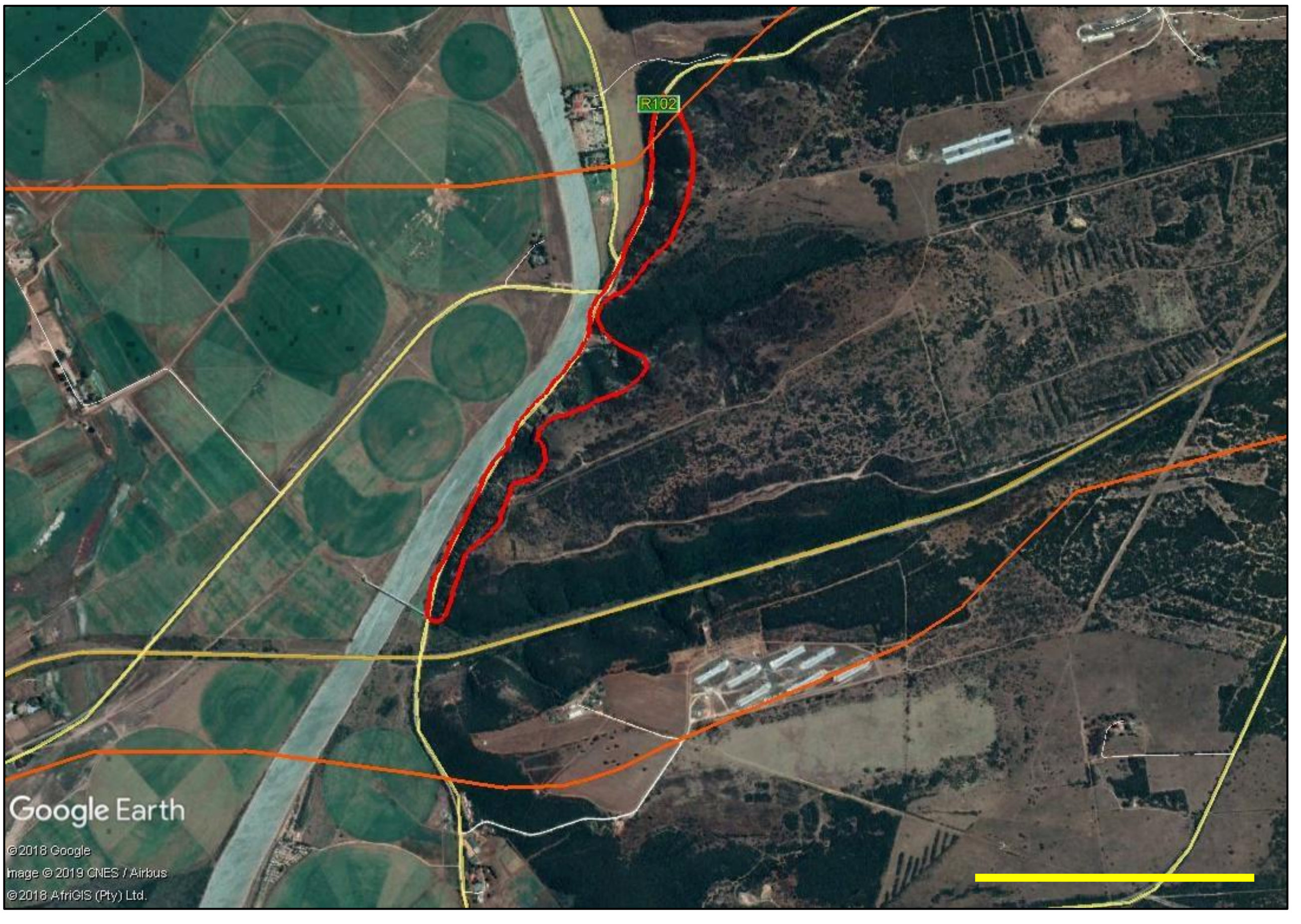

Figure 35. Google Earth© satellite image of the proposed grid connection corridor (orange polygon) showing an area of high palaeontological sensitivity (plant-rich Kirkwood Formation) exposed in steep cliffs on the eastern bank of Gamtoos River (red polygon). Any bedrock excavations in this sensitive area (*e.g.* pylon footings, access roads) should be carefully monitored for fossils by the ECO. Scale bar = 1 km.

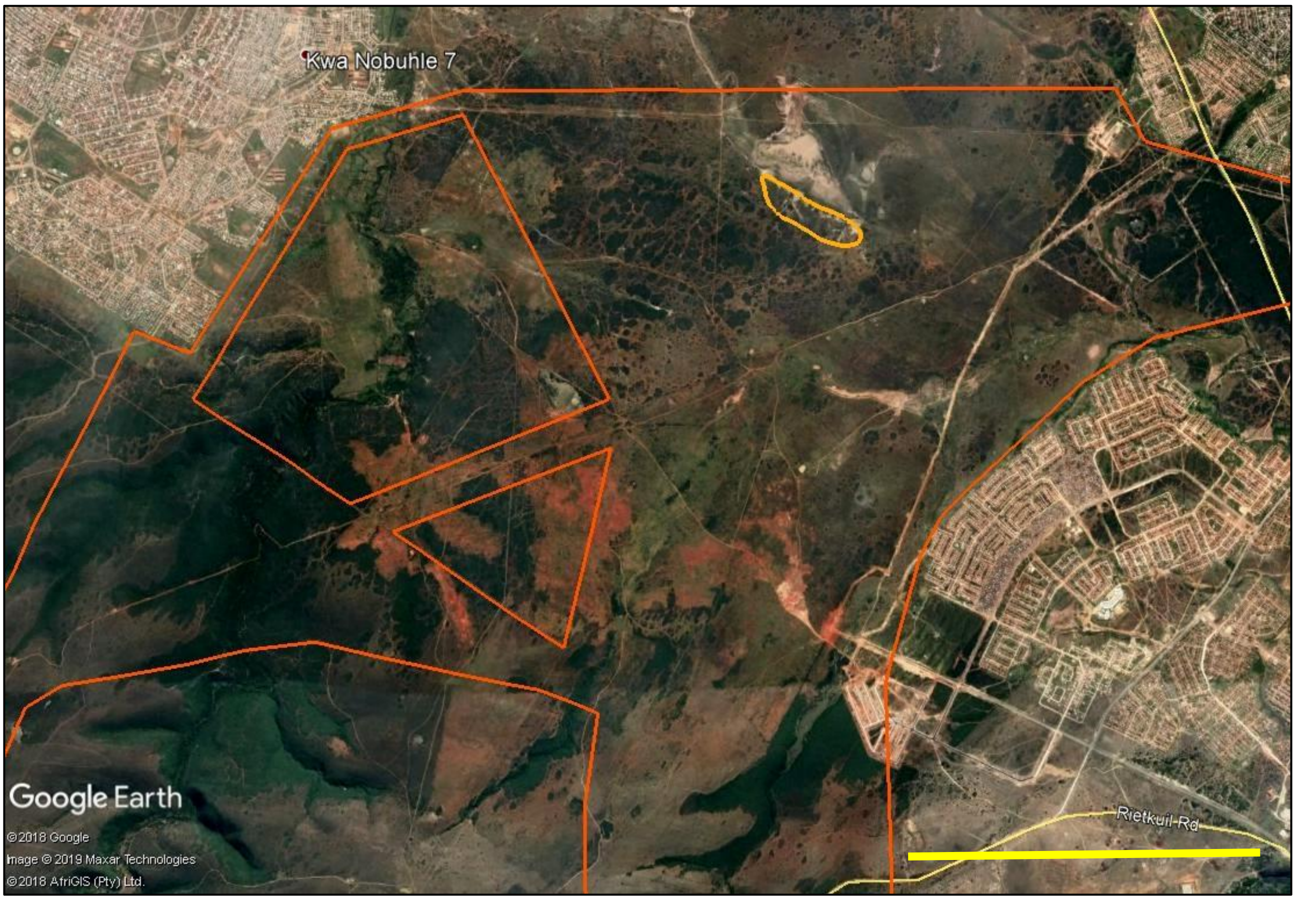

Figure 36. Google Earth© satellite image of the proposed grid connection corridor (orange polygon) showing an area of high palaeontological sensitivity (outcrop area of the fossiliferous Bethelsdorp Member) exposed along the south-western margins of a large pan *c*. 1.8 km west of Sans Souci Substation (yellow polygon). This should be treated as a No-Go area. Scale bar = 2 km.

10. CONCLUSIONS

The present palaeontological heritage basic assessment is based on several desktop and field-based studies in the Kouga region near Humansdorp and in the NMBM region as well as field studies of potentially-sensitive portions of the Impofu Wind Farms and associated 132 kV grid connection project areas (Almond 2017, this study). The proposed grid connection corridor is underlain by several formations of potentially fossiliferous sediments of the Gamtoos Group, Cape Supergroup, Uitenhage Group and Algoa Group (Sections 6 & 7, Table 1). However, on the southern coastal platform most of the fossils originally preserved in these bedrocks appear to have been destroyed by tectonic deformation and deep chemical weathering. The overlying Late Caenozoic superficial sediments such as alluvium, soils and ferricretes, are likewise of low palaeontological sensitivity. Relict patches of Plio-Pleistocene aeolianites (wind-blown sands) of the Nanaga Formation (Algoa Group) present in the subsurface on the interior coastal platform contain Early Stone Age artefacts but any associated fossils such as mammalian remains or terrestrial gastropods have probably been destroyed by weathering here. It is concluded that the great majority of the study area is in effect of LOW palaeontological sensitivity.

During the present study only two small areas of high palaeontological sensitivity have been identified within the grid connection study area: (1) steep cliff exposures of the Early Cretaceous Kirkwood Formation along the eastern banks of the Gamtoos River that are rich in fossil plant material, and (2) low fossiliferous scarp exposures of the Late Jurassic Bethelsdorp Member (lower Kirkwood Formation) along a pan margin some 1.8 km west of Sans Souci Substation (See polygons annotated on Figs. 35 & 36). It is recommended that any excavations within the first area are carefully monitored for fossils by the ECO (See Appendix 1: Chance Fossil Finds Procedure) while the latter should be treated as a No-Go area for development.

Potential impacts to fossil heritage resources within the proposed grid connection corridor involve the disturbance, damage or destruction of fossil material within the development footprint during the construction phase. Due to the rarity of well-preserved, unique fossils of potential scientific importance within the study area, potential impacts on palaeontological heritage during the construction phase are assessed as of *negligible (negative) significance* (both before and after mitigation). The No-Go alternative (*i.e.* no grid connection) will have a neutral impact on palaeontological heritage. Cumulative impacts posed by the grid connection and associated electrical infrastructure developments are inferred to be *minor*. This also applies to cumulative impacts from other approved or proposed transmission line developments in the region. Confidence levels for this assessment are high due to comparatively good field data available for the study region.

Pending the potential discovery of significant new fossil remains during the construction phase of the proposed Impofu grid connection, no further specialist palaeontological studies or mitigation are recommended for this project in the construction phase.

There are no fatal flaws to the proposed electrical infrastructure project as far as fossil heritage is concerned. Providing that the Chance Fossil Finds Procedure outlined below and tabulated in Appendix 1 is followed through, there are no objections on palaeontological heritage grounds to authorisation of the proposed Impofu grid connection (including the proposed 132 kV overhead powerline, substation extension areas, proposed Impofu collector switching station, three wind farm switching stations and short 132 kV overhead transmission lines connecting these).

The suitably qualified and experienced ECO responsible for the electrical infrastructure development construction phase, should be made aware of the potential occurrence of scientifically-important fossil remains within the development footprint. During the construction phase all major clearance operations (*e.g.* for new access roads, pylon placements) and deeper (> 1 m) excavations should be monitored for fossil remains on an on-going basis by the ECO. Should substantial fossil remains be encountered at surface or exposed during construction, the ECO should safeguard these, preferably *in situ*. They should then alert the Eastern Cape Provincial Heritage Resources Agency, ECPHRA (Contact details: Mr Sello Mokhanya, 74 Alexander Road, King Williams Town 5600; smokhanya@ecphra.org.za) as soon as possible. This is to ensure that appropriate action (*i.e.* recording, sampling or collection of fossils, recording of relevant geological data) can be taken by a professional palaeontologist at the proponent's expense. These recommendations are summarized in the tabulated Chance Fossil Finds Procedure appended to this report (Appendix 1).

The palaeontologist concerned with any 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 developed by SAHRA (2013).

These monitoring and mitigation recommendations are to be incorporated into the Environmental Management Programme (EMPr) for the proposed Impofu grid connection. The operational and decommissioning phases of this development are unlikely to have further significant impacts on palaeontological heritage and no additional recommendations are made in this regard (The Chance Fossil Finds Procedure still applies).

11. ACKNOWLEDGEMENTS

Mr Lance Blaine and Jadon Schmidt of Red Cap Energy (Pty) Ltd, Hout Bay as well as Ms Kim White of Aurecon South Africa (Pty) Ltd, Cape Town, are both thanked for commissioning this study, for discussing the project approach, for facilitating the fieldwork and reviewing the draft reports, as well as for providing the necessary background information. I am grateful to Dr. Peter Nilssen for helpful discussions on heritage aspects of the Impofu Wind Farms study area.

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13. QUALIFICATIONS & EXPERIENCE OF THE AUTHOR

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

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

Declaration of Independence

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

John E. Almond

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

<table>
<tr><td colspan="3">APPENDIX 1: CHANCE FOSSIL FINDS PROCEDURE: Impofu 132 kV Grid Connection between Impofu Wind Farms near Humansdorp & NMBM</td></tr>
<tr><td>Province & region:</td><td colspan="2">EASTERN CAPE, Humansdorp, Hankey & Uitenhage Districts</td></tr>
<tr><td>Responsible Heritage Resources Authority</td><td colspan="2">ECPHRA (Contact details: Mr Sello Mokhanya, 74 Alexander Road, King Williams Town 5600; smokhanya@ecphra.org.za)</td></tr>
<tr><td>Rock unit(s)</td><td colspan="2">Kirkwood Formation (including Bethelsdorp Member)</td></tr>
<tr><td>Potential fossils</td><td colspan="2">Shelly marine invertebrates, trace fossils, plant compressions, petrified wood, amber.</td></tr>
<tr><td rowspan="5">ECO protocol</td><td colspan="2">1. Once alerted to fossil occurrence(s): alert site foreman, stop work in area immediately (N.B. safety first!), safeguard site with security tape / fence / sand bags if necessary.</td></tr>
<tr><td colspan="2">2. Record key data while fossil remains are still in situ:
• Accurate geographic location – describe and mark on site map / 1: 50 000 map / satellite image / aerial photo
• Context – describe position of fossils within stratigraphy (rock layering), depth below surface
• Photograph fossil(s) in situ with scale, from different angles, including images showing context (e.g. rock layering)</td></tr>
<tr><td>3. If feasible to leave fossils in situ:
• Alert Heritage Resources Authority and project palaeontologist (if any) who will advise on any necessary mitigation
• Ensure fossil site remains safeguarded until clearance is given by the Heritage Resources Authority for work to resume</td><td>3. If not feasible to leave fossils in situ (emergency procedure only):
• Carefully remove fossils, as far as possible still enclosed within the original sedimentary matrix (e.g. entire block of fossiliferous rock)
• Photograph fossils against a plain, level background, with scale
• Carefully wrap fossils in several layers of newspaper / tissue paper / plastic bags
• Safeguard fossils together with locality and collection data (including collector and date) in a box in a safe place for examination by a palaeontologist
• Alert Heritage Resources Authority and project palaeontologist (if any) who will advise on any necessary mitigation</td></tr>
<tr><td colspan="2">4. If required by Heritage Resources Authority, ensure that a suitably-qualified specialist palaeontologist is appointed as soon as possible by the developer.</td></tr>
<tr><td colspan="2">5. Implement any further mitigation measures proposed by the palaeontologist and Heritage Resources Authority</td></tr>
<tr><td>Specialist palaeontologist</td><td colspan="2">Record, describe and judiciously sample fossil remains together with relevant contextual data (stratigraphy / sedimentology / taphonomy). Ensure that fossils are curated in an approved repository (e.g. museum / university / Council for Geoscience collection) together with full collection data. Submit Palaeontological Mitigation report to Heritage Resources Authority. Adhere to best international practice for palaeontological fieldwork and Heritage Resources Authority minimum standards.</td></tr>
</table>

APPENDIX 2

All GPS readings were taken in the field using a hand-held Garmin GPS map 62sc instrument. The datum used is WGS 84.

LOC.	GPS DATA	COMMENTS
001	33 59 27.2 S 24 55 59.4 E	Road cutting just E of Kabeljousrivier. Highly-weathered, pale mottled orange-hued siltstone, massive – possibly a silty interval within the Enon Formation Capped by well-rounded, quartzitic pebbles and cobbles (latter mapped as Blue Water Bay Fm)
002	33 58 44.8 S 24 54 07.4 E	Large roadside quarry west of Meuleplaas excavated into Enon Formation. Massive pale grey, pebbly to cobbly clast-supported quartzitic conglomerates with numerous weathered, pale orange to grey horizons and lenses of siltstone as well as cross-bedded sandstone. Occasional matrix-supported conglomerate horizons with polished quartzite pebbles. Minor clasts of siltstone and sandstone. Local development of pebble imbrication. Succession flat to gently southwards-dipping. Probably faulted. Bedrocks mantled by ferrruginised downwasted surface gravels (possibly related to "Bluewater Bay Formation").
003	33 57 06.3 S 24 56 22.4 E	Large working quarry N of Vlakteplaas homestead. Extensive exposure through thick succession of gently-dipping Enon Formation conglomerates. Thick (sev. m) packages of grey, clast-supported pebbly to cobbly conglomerates with pale grey weathered siltstone and sandstone interbeds, some clearly lenticular channel infills. Capped (variously gradational to sharp contact) by several meters of dark brown, ferruginised surface gravels, unconsolidated but locally well-calcretised with indurated sandy cement, occasional ferricretised gravels. Surface gravels possibly related to "Bluewater Bay Formation". No evidence for basal shelly gravels of Alexandria Formation.
004	33 57 04.5 S 24 56 22.7 E	Vlakteplaas Quarry – semi-consolidated upper brown-weathering gravels along N margin with matrix of grit, fine gravel and soil. Cobbles with rusty patina. Curious pelleted ferricrete (?) fabric between cobbles. No fossil oysters or other shells.
005	33 56 40.2 S 24 56 32.5 E	Views of flat terrain on floor of wide Gamtoos River Valley. Mantled with alluvial sands and quartzitic gravels.
006	33 55 59.0 S 24 57 46.7 E	Roadside quarry between Mondplaas and Green Acres excavated into Enon Fomation conglomerates. Weathered orange and pale grey-mottled siltstone interval on floor of quarry (Uitenhage Group or *possibly* underlying Ceres Subgroup). Vertical section through alluvial gravels and sands at western end of quarry.
007	33 56 01.7 S 24 58 32.9 E	Roadside borrow pit along powerline near Rustig farmstead exposing several meters of orange-hued, semi-consolidated, massive, well-sorted sands with occasional larger lonestones. Probably weathered Nanaga Formation aeolianites rather than alluvium.
009	33 55 20.6 S 25 01 30.2 E	Views of steep Kirkwood Formation cliffs along eastern banks of Gamtoos River, between old road bridge and newer N2 bridge to the south. Roadside trench cuts down into Gamtoos sandy alluvial deposits with pebbly lenses.
010	33 55 21,0 S 25 01 40.2 E	Steep riverine cliff exposures of the Kirkwood Formation along the eastern bank of the Gamtoos River close to old road bridge. Thick pale grey-green to orange-hued, erosive-based channel sandstones towards base of exposed succession not pebbly except for thin intraclast horizons towards base. Interbedded thinner sandstones and pale, weathered overbank mudrocks higher up within succession. Sandstones locally cross-bedded and honeycomb-weathered (*i.e.* possibly sl. calcareous).
011	33 55 16.8 S 25 01 42.8 E	Roadside fallen blocks of Kirkwood Fm channel sandstone with abundant ferruginised moulds of woody plant material, including highly-comminuted plant debris / hash. Overbank mudrocks beneath base of major channel sandstone are highly-weathered, kaolinitised, with lenticular sandstone interbeds.
012	33 55 18.8 S 25 01 42.0 E	Base of major Kirkwood channel sandstone package with multiple thin, lenticular horizons of plant debris moulds between or within lowermost sandstone units as well as several horizons – at channel base and higher up - of poorly-sorted, pale grey mudrock and sandstone intraclast breccio-conglomerates (reworked consolidated channel bank material) with sparse cobbly quartzite extrabasinal clasts (breccias *c*. 20 cm thick). Highly-weathered overbank mudrocks beneath channel sandstone package, with occasional fresher-looking purple-grey siltstone lenses.
013	33 55 20.1 S 25 01 41.7 E	Roadside fallen blocks of Kirkwood Fm channel sandstone with abundant ferruginised moulds of woody plant material.
014	33 55 30.5 S 25 01 34.8 E	Locally gullied base of cross-bedded major channel sandstones as well as well-developed intraformational breccio-conglomerates with occasional exotic quartzite clasts at base and margins of channel sandstone bodies. Chemical and solution weathering of sandstones expressed as Liesegang rings and honeycomb-weathered surfaces. Good channel cut-and-fill sections (axes E-W, presumably along basin axis). Possible soft-sediment deformation within overbank siltstones to the south.

018	33 54 58.0 S 25 05 08.1 E	Sand mine NE of Lemoenfontein. Cut face exposures through foresets of orange-hued, semi-consolidated aeolian sand dunes of Nanaga Formation. No ferricretes or quartzite lonestones seen.
021	33 54 11.4 S 25 05 22.2 E	Long R102 road cuttings *c*. 4.5 km WSW of Thornhill. Intercalated, weathered channel sandstones and overbank mudrocks of the Kirkwood Fm, dipping towards the NE. Mudrocks with occasional polished pebble lonestones, orange-hued and pale mottled. Upper part of section secondarily ferruginised, with ferricrete development. Bedrocks overlain by pebbly horizon and brown soils.
022	33 54 13.3 S 25 05 41.9 E	R102 road cuttings through Kirkwood Formation *c*. 4 km WSW of Thornhill. Thick channel sandstone packages, locally thin-bedded, with minor, highly-weathered, kaolinitised overbank mudrocks. Succession dips to northwest. Eastern end of cuttings show coarse, rubbly breccio-conglomerate facies (oligomict, quartzite clasts) with sandstone interbeds (upward-fining units). Possibly developed proximal to basin-edge fault line and may interfinger north-westwards with, and/or underlie, channel sandstone and mudrock facies further into basin. Uitenhage Group succession overlain by diamictite-like matrix-supported pebbly sandstones, pebble lenses and dark orange-hued Nanaga Fm aeolianites; these younger deposits may infill a palaeo-gulley within the Uitenhage Group bedrocks.
023	33 54 15.8 S 25 06 19.9 E	*c.* 3.3. km WSW of Thornhill, R102 road cutting through rubbly grey breccio-conglomerates – possibly marginal facies of Uitenhage Group in Gamtoos Basin. Alternatively this is the basal conglomeratic unit of the Sardinia Bay Formation (and Table Mountain Group, younging to the NE in this area).
024	33 54 38.1 S 25 10 54.0 E	R102 road cuttings through Sardinia Bay Formation (basal Table Mountain Group) *c*. 1.3 km west of Van Stadensrivier. Pale grey, weathered, prominently cross-bedded quartzites, medium-bedded, tabular, medium- to thick-bedded. Thicker beds closely jointed (possibly spaced cleavage).
025	33 54 39.4 S 25 11 00.8 E	R102 long road cuttings through Sardinia Bay Formation *c*. 1.0 km west of Van Stadensrivier. Darker grey "phyllitic" mudrock interbeds between subordinate channel sandstone packages. Beds dip steeply to SW, tabular bedding planes flat to undulose, brittle, well-jointed, local development of boudinage in sandstones / quartzites. Vague ripple marks on some upper bedding plane surfaces.
026	33 54 37.7 S 25 11 06.2 E	R102 long road cuttings through Sardinia Bay Formation *c*. 950 m west of Van Stadensrivier. Steeply dipping packages of medium to thin-bedded tabular wackes intercalated with phyllitic pelitic packages. Well-developed tabular cross-bedding within wackes. Some highly tabular wackes and heterolithic packages reminiscent of turbidite fan facies (but not tabular cross-sets). Generally moderate to high levels of tectonic deformation, especially of politic units, with development of major quartz veins locally.
027	33 54 36.8 S 25 11 34.9 E	R102 road cutting through thick-bedded, cross-bedded quartzites of Peninsula Fm *c*. 240 m NW of Van Stadensrivier, close to lower contact with Sardinia Bay Formation.
029	33 54 47.9 S 25 12 12.9 E	R102 road cutting (*c*. 800 m east of Van Standensrivier) through thin- to medium-bedded quartzites of the Peninsula Formation showing generally high levels of deformation (folding, fracturing).
030	33 50 45.1 S 25 26 17.7 E	Trench near NW margin of Booysen Park new development showing section through dark orange-brown sandy soils overlying pale fine gravelly material – *possibly* reworked calcrete and Kirkwood Formation mudrock.
031	33 50 37.6 S 25 26 19.4 E	Trench close to SE edge of Kakkerlaksvlei exposing pale brownish sandy soils overlain by grey soil with dispersed quartzite cobbles (brown-patinated).
032	33 50 32.2 S 25 26 12.7 E	Kakkerlaksvlei – dried up *vlei* with sandy to silty, pale grey soils and sparse surface gravels (vein quartz, quartzite, calcrete). Low banks of poorly-sorted alluvial sands and gravels; clasts of weathered / etched TMG quartzite, sandstone, vein quartz, reworked calcrete - angular to subrounded, occasional rounded pebbles and cobbles. Patchy exposures of well-developed vuggy to solid cream- to slightly pinkish coloured calcrete hardpan along pan margins, locally with enclosed pebbles.
034	33 49 53.6 S 25 25 41.0 E	Bethelsdorp Member (Kirkwood Fm) low scarp exposures along SW edge of large pan. Prominent-weathering, tabular, laminated sandstone blocks with low diversity trace fossil assemblages dominated by 4-6 mm wide horizontal, unbranched cylindrical burrows preserved in positive or negative relief, on bedding planes or endichnially. Some infilled burrows retain faint meniscate backfill.
035	33 49 55.1 S 25 25 47.5 E	Several large collapsed or downwasted blocks of Bethelsdorp Member tabular sandstone with well-preserved cylindrical trace fossils on bedding planes (5-6 mm wide). Burrows visible from above within upper part of *in situ* sandstone bed. Branching of burrows is probably only apparent. Faint traces of relict meniscate backfill in positive relief burrows.
037	33 49 57.1 S 25 25 50.0 E	Two closely-spaced tabular sandstones (up to 50 cm thick) within Bethelsdorp Formation – possibly successive deepening cycles. Poorly-preserved vertical to oblique burrows at base of, and within, upper, orange-hued laminated sandstone.
038	33 49 59.9 S 25 25 57.6 E	Small (3-6 cm) oblate and prolate, blackish-brown sphaeroidal concretions, possibly of ferruginous carbonate, weathered out of Bethelsdorp Formation. Some preserve traces of burrows on surface.
039	33 50 02.2 S 25 26 01.2 E	Subtly colour-banded estuarine mudrocks of Bethelsdorp Member.

216	33 52 34.8 S 25 25 21.2 E	Bloemendal A/A, extensive inactive gravel road material quarrying area just N. of R368 Stanford Road. Excavated into weathered, locally ferruginised, well-jointed, highly fractured, cross-bedded Skurweberg Formation quartzites and sandstones (Table Mountain Group). Quartzites dip south and truncated by flat, gravelly pediment surface at *c*. 200 m amsl., with deeply incised valley just to N (Northern edge of coastal platform; see Hattingh (2001) Fig. 3.1). Bedrocks overlain by angular, rubbly quartzite regolith (0.5 m), subangular to well-rounded, purple-brown silcrete-patinated and ferricrete gravels and grey-brown soils with suspended gravels (up to 2 m).
217	33 52 13.3 S 25 25 54.9 E	Bloemendal A/A. Hillslope exposure of steeply S-dipping, pale-grey, mature, thick-bedded Skurweberg Fm quartzites showing conchoidal fracture, low angle tabular cross-bedding.
218	33 51 48.2 S 25 26 13.6 E	Bloemendal A/A. Extensive shallow borrow pit for mudrock road material N of R368 Stanford road. Excavated into pale grey to pinkish-hued, cleaved, deeply-weathered, locally ferruginised mudrocks mapped as Ceres Subgroup (Lower Bokkeveld Group). Bedrocks truncated by pediment surface and mantled by well-consolidated pediment gravels of subangular to well-rounded TMG quartzite clasts, schistose sandstone, cleaved Bokkeveld mudrock. These consolidated, clast- to matrix-supported gravels up to several m thick and now assigned to the Early Tertiary (probably Eocene) Damascus Formation (Hattingh 2001) but previously mapped as Enon Formation. Pale grey to pinkish diamictite of weathered Bokkeveld mudrock slurry with suspended blocks of weathered mudrock, reworked quartizitic pebbles probably represent debris flow deposits (debrits).
219	33 51 56.7 S 25 26 17.6 E	Road cutting along R368 Stanford Road transecting gravels of Damascus Formation covered by brown soils. Clasts of subangular to well-rounded quartzite, sandstone.
220	33 51 51.4 S 25 26 31.1 E	Erosion gulley exposure N of R358 near Chatty, Damascus. Damascus Fm colluvial gravels overlying deeply-weathered silty to sandy colluvial deposits with ferruginous mottling, 3D polygonal network of pale veins and ridges, sparse, dispersed, angular quartzitic grits and gravels. Overlain by grey-brown soils and surface graveks.
221	33 51 53.3 S 25 26 38.8 E	Hillslopes *c*. 100 m south of R368. Silcretised proximal debris flow gravels at top of Early Tertiary Damascus Formation alluvial fans in type area of formation (see Hattingh 2001 Fig. 3.1 and pp. 27-29). Silcretised gravel breccio-conglomerates several meters thick, poorly-sorted, rubbly, crudely-bedded, matrix- to clast-supported, locally ferruginous. Angular to subrounded lasts of TMG quartzite. Sandstone lenses cross-bedded.
222	33 51 27.2 S 25 26 14.1 E	Trench exposure of thick (> 1.5 m) orange-brown, sparsely pebbly soils overlying Kirkwood Fm
223	33 50 46.9 S 25 25 49.4 E	Small pan surrounded by orange-brown soils, sparse downwasted quartzitic surface gravels and pebbly to cobbly calcrete nodules. Calcrete hardpan developed beneath modern soils. Occasional patches of concentrated surface gravels in region as well as gravel lenses beneath soils exposed in erosion gullies – brown, grey and purplish quartzite, vein quartz and reworked Pleistocene calcrete clasts, some moderately to well-rounded.
223a	33 50 32.7 S 25 25 00.0 E	Kakkerlaks Vley 400. Large shallow pan or vlei (Kakkerlaksvlei). Marginal exposures of well-developed calcrete hardpan beneath surface orange-brown soils and gravels. Grey-brown silty soils with sparse gravels within pan itself (some flaked quartzite clasts).
224	33 50 33.6 S 25 24 23.0 E	Klipkuil valley, SE of Kwa-Nobuhle. Deep *donga* incision downstream of dam exposing several meter thickness of pebbly alluvial gravels and orange-brown, silty to sandy soils with sparse quartzite and calcrete clasts. Weathered Kirkwood or Bokkeveld greenish mudstone bedrock at base of erosion gulley.
225	33 50 31.8 S 25 24 23.3 E	Klipkuil valley, SE of Kwa-Nobuhle. Extensive, thick and well-exposed, NW-facing cliff section through gently dipping, pale grey-green, greenish and pinkish silty overbank mudrocks and lenticular channel sandstones of Kirkwood Formation. Channel sandstones yellowish-brown, up to few m thick, lenticular in geometry (contrast highly tabular sandstones of Bethelsdorp Member), sharp-based, not pebbly, deeply-weathered. Mudrocks contain dispersed polished sandstone pebbles typical of Kirkwood debrites. Ledge of younger, gently-dipping, sparsely-gravelly Caenozoic alluvium abuts against Kirkwood cliff locally.
226	33 50 24.1 S 25 24 27.0 E	Weathered, crumbly and cracked cliff exposure of grey-green Kirkwood Fm mudrocks near Klipkuil pond.
227	33 50 29.2 S 25 24 29.8 E	Stream gullies with boulder- and cobble-sized clasts of TMG quartzite and greenish Kirkwood sandstone (up to > 1m across), calcrete – downwasted High Level Gravels related to Damascus Formation (Hattingh 2001, Fig. 3.1). Some boulders well-rounded. Mantled by orange-brown soils.
228	33 48 56.0 S 25 26 34.4 E	R368 road cuttings between Campher Park & Khayamnandi. Pinkish-brown weathered Kirkwood overbank mudrocks with capping of alluvial gravels (well-rounded TMG pebbles, quartzite), brown soils Gravel-based channel cut-and-fill structures incising Kirkwood bedrocks.
230	33 48 43.5 S 25 25 28.2 E	Industrial Park area, large flooded quarry (previous brick pit). Extensive quarry margin low cliff exposures through grey-green, blue-grey, orange, cream and pink-hued, subordinate, subhorizontal to gently-dipping Kirkwood overbank mudrocks ("variegated marls") and thin grey-green channel sandstones. Near-surface calcretes with complex crystalline network fabric (possibly replacement after gypsum).

231	33 48 56.3 S 25 25 27.7 E	As above. High levels of invertebrate bioturbation of thin (10-30 cm) lenticular, grey-green channel sandstones. Ill-defined vertical burrows at channel sandstone base, *plus* networks of open or sand-infilled cylindrical endichnial burrows (*c*. 5 mm wide).
232	33 49 09.7 S 25 25 18.4 E	Low cliffs of Kirkwood Fm mudrocks to south of main abandoned brick quarry.
233	33 49 11.0 S 25 25 22.3 E	Cliff exposures of Kirkwood Fm colour-banded overbank mudrocks with intensely bioturbated thin, lenticular, vuggy channel sandstones. Dense network of intersecting, irregular subcylindrical burrows (open and cast in sand).
234	33 49 14.2 S 25 25 21.2 E	Sandy alluvium overlain by pale brown soils. Shallow streams with pebbly alluvial gravels.
235	33 49 52.2 S 25 25 42.1 E	Large pan or quarry area 1.8 km west of electrical substation, due N of Kakkerlaksvlei. Extensive low cliff exposures of flat-lying to gently-dipping marine-influenced (possibly estuarine) sediments of the Bethelsdorp Member (previously Colchester Member; Muir *et al.* 2017) of the Kirkwood Formation along SW margins of the pan. Pale grey to grey-green overbank mudrocks with occasional yellowish sandier zones and thin (few dm), prominent-weathering, highly-tabular, horizontally-laminated or occasionally wavy-rippled , non-pebbly, medium-grained, buff sandstones (may be dark brown-weathering or show calcareous honeycomb weathering), up to 40 cm thick. Large (sev. dm wide), cracked sphaeroidal, rusty-brown ferruginous carbonate concretions low down in exposed succession. Occasional highly-polished grey quartzite pebbles within overbank mudrocks. Mesozoic bedrocks overlain by orange-brown sandy soils.
236	33 49 56.6 S 25 25 48.9 E	Good steep scarp exposures of Bethelsdorp Member succession with numerous fallen blocks of tabular sandstone facies (up to *c*. 50 cm thick). Well-exposed cushion-shaped to sphaeroidal ferruginous carbonate concretions (30-40 cm diam.). Also pale flattened, irregular-shaped, greyish concretions within mudrock – probably calcareous (show possible solution weathering); form major component of locally-derived scree gravels. Capped by orange-brown sandy soils (*cf* Nanaga Fm). Apparently branching endichnial burrows with longitudinally bilobate bases (*c*. 1 cm wide). Bethelsdorp succession dips gently to N.
237	33 49 57.6 S 25 25 48.5 E	Narrow south-directed erosion gulley incising Bethelsdorp Member deposits with good exposures of stratigraphy (possibly 2-3 successive upward-shallowing and –coarsening cycles: basal yellowish sandy zone, thick package of grey to grey-green silty mudrocks with large sphaeroidal ferruginous carbonate concretions towards the top, upper yellowish unconsolidated sandy horizon, prominent-weathering tabular sandstone towards top of exposed succession. *N.B.* Absence of lenticular channel sandstones, palaeosols, lilac and orange variegated mudrocks of terrestrial Kirkwood facies, presence of large ferruginous concretions, tabular laminated sandstones, shelly horizons). Laterally-persistent horizon low down in grey-green silty succession (but above ferruginous concretion horizon) with loose small oyster shells as well as oysters encrusting subrounded grey quartzite pebbles - possibly a form of *Amphidonte* (*Ceratostreon*). Weathering-out lenses of thin-shelled bivalve *Placunopsis* - most specimens fragmentary but a few intact and articulated specimens also present – and occasional disarticulated spines of regular echinoid *Cidaris*, possible encrusting spirorbid tubes on pebbles (*cf* McLachlan & McMillan 1976). Shelly material possibly concentrated on seabed by winnowing.
238	33 49 59.5 S 25 25 49.8 E	Cracking silty mudrocks of Bethelsdorp member with thin, brittle ferruginous mineral plates. Abundant small lenticles of pale creamy concretionary material – possibly carbonate – weathering out as scree gravels.
239	33 49 56.9 S 25 25 46.6 E	Western occurrence of shelly and pebbly horizon within Bethelsdorp Member. Possible encrusting spirorbid tubes on pebbles
240	33 50 02.7 S 25 26 02.5 E	Low scarp exposures of grey silty beds of Bethelsdorp Member at SE end of vlei. Occasional isolated fossil oyster shells, oyster-encrusted quartzite pebbles and cobbles.
241	33 49 34.7 S 25 25 45.6 E	Gulley and low cliff exposures of continental Kirkwood facies with variegated mudrocks, including pinkish and lilac hues, highly polished grey quartzite lone stone pebbles. Occasional washed-out elongate-subcylindrical calcrete structures (c. 2 cm wide) – possibly infilled burrows or rhizoliths (age unclear – possibly Late Caenozoic – occur *in situ* close to modern land surface).