Palaeontological specialist assessment: combined field-based and desktop study

PROPOSED KAREEDOUW-DIEPRIVIER 132 kV TRANSMISSION LINE PROJECT, HUMANSDORP MAGISTERIAL DISTRICT, EASTERN CAPE.

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EXECUTIVE SUMMARY

Eskom are proposing to construct approximately 35 km of overhead 132 kV powerline from the Dieprivier Substation through to the Kou-Kamma Substation near Kareedouw in the Humansdorp District Municipality, Eastern Cape. The project also entails decommissioning of existing powerlines, the construction of a new substation at Dieprivier, the extension of the existing Kareedouw sub-station (Kou-Kamma) as well as the construction of new minor roads.

The proposed development footprint on the southern and northern sides of the Langkloof is underlain by Palaeozoic bedrocks of the Table Mountain Group and Bokkeveld Group (Cape Supergroup). Three of the formations involved – the Late Ordovician Cederberg Formation as well as the Early Devonian Baviaanskloof and Gydo Formations – are known elsewhere within the Cape Fold Belt for their important records of marine and terrestrial fossils. However in the Humansdorp region the bedrocks have generally suffered high levels of tectonic deformation and chemical weathering, seriously compromising their fossil heritage. No fossil remains were observed during a one-day palaeontological field assessment, neither within the Palaeozoic bedrocks nor in the overlying Late Caenozoic superficial sediments (colluvium, alluvium, pedocretes, soil *etc*).

On the basis of the current field assessment as well as the paucity of previous fossil records from the Humansdorp region it is concluded that the palaeontological sensitivity of the Palaeozoic bedrocks here is low due to high levels of tectonic deformation (*e.g.* folding, cleavage) and chemical weathering. This applies especially to the more mudrock-rich stratigraphic units (*e.g.* Cederberg and Gydo Formations) that may originally have been highly fossiliferous. The various Late Caenozoic superficial deposits mantling the bedrocks in the study region (*e.g.* alluvium, colluvium, soils, pedocretes) are also of low palaeontological sensitivity.

Given the resulting low to very low impact significance of the proposed transmission line – including the associated substation and road developments - as far as palaeontological heritage is concerned, no further specialist studies or mitigation are considered necessary for this project.

It is recommended that:

- The Environmental Control Officer (ECO) responsible for the transmission line development should be at least aware of the possibility – albeit low - of important fossils (*e.g.* shells, plant remains, trace fossils, mammalian bones and teeth) being present or unearthed on site and should regularly monitor all substantial excavations into superficial sediments as well as fresh (*i.e.* unweathered) sedimentary bedrock for fossil remains;

- In the case of any significant fossil finds (*e.g.* vertebrate teeth, bones) made during construction, these should be safeguarded - preferably *in situ* - and reported by the ECO as soon as possible to the relevant heritage management authority (ECPHRA. Contact details: Mr Sello Mokhanya, 74 Alexander Road, King Williams Town 5600; smokhanya@ecphra.org.za) so that appropriate mitigation (*i.e.* recording, sampling or collection) by a palaeontological specialist can be considered and implemented, at the developer's expense; and

- These recommendations should be incorporated into the Environmental Management Plan (EMP) for the 132 kV transmission line project.

The palaeontologist concerned with mitigation work will need a valid palaeontological collection permit from SAHRA (Contact details: Mrs Colette Scheermeyer, P.O. Box 4637, Cape Town 8000. Tel: 021 462 4502. Email: cscheermeyer@sahra.org.za). All 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 to the minimum standards for Phase 2 palaeontological studies developed by SAHRA (2013).

1. INTRODUCTION

Eskom are proposing the following infrastructure developments as part (Project 3) of their planned network strengthening and upgrade in the Patensie, Humansdorp and Kareedouw areas, Humansdorp and Hankey District Municipalities, Eastern Cape (Arcus GIBB (Pty) Ltd Background Information Document, April 2012):

- Construction of approximately 35 km of overhead 132 kV powerline from the Dieprivier Substation through to the Kou-Kamma Substation near Kareedouw (Fig. 1).

- Decommissioning of existing powerlines made redundant by new lines.

- Construction of a new substation at Dieprivier and decommissioning of the existing sub-station.

- Extension of the existing Kareedouw sub-station (Kou-Kamma).

- Construction of new, or maintenance of existing, minor roads.

Arcus Gibb Engineering and Science have been commissioned to conduct an Environmental Impact Assessment of the proposed 132 kV transmission line developments between Kareedouw and Patensie, Eastern Cape. A Phase 1 Heritage Impact Assessment Report for the entire Kareedouw – Patensie 132 kV transmission line study area by eThembeni Cultural Heritage area (Van Schalkwyk & Wahl, May 2012) included the following remarks and recommendations regarding palaeontological heritage resources, largely based on desktop input by present author:

The proposed electrical infrastructure between Kareedouw and Patensie is underlain by potentially fossiliferous bedrocks of Palaeozoic, Mesozoic and Caenozoic age, while the fossil potential of the Kareedouw – Dieprivier sector is likely low due to tectonism. Geological formations in the Dieprivier – Melkhout sector might contain well-preserved plant material. Early Cretaceous Kirkwood Formation beds near Patensie may contain important fossils of dinosaurs and other terrestrial vertebrates as well as petrified wood, while older alluvial sediments of the Gamtoos drainage system are also potentially fossil-bearing. The potential impact on palaeontological remains is low to medium.

A heritage practitioner should complete a 'walk-through' of the final selected power line route and all other activity areas (access roads, construction camps, materials' storage areas, etc.) prior to the start of any construction activities and assess direct impacts on discrete resources such as traditional burial places, and archaeological and palaeontological sites.

Since likely impacts on fossil heritage along the proposed new 132 kV transmission line are mainly associated with excavations for the pylon footings, as well as the construction of new substations, it is recommended that a Phase 1 palaeontological field assessment of the final transmission line route be undertaken once the pylon positions have been finalized and *before* construction commences. The resulting report should make recommendations regarding any necessary mitigation during the construction phase of the transmission line and associated infrastructure (*e.g.* recording, sampling of fossil assemblages, field monitoring of selected pylon positions).

The present palaeontological heritage assessment report dealing with Project 3 (Kareedouw to Dieprivier) of the 132 kV development has accordingly been commissioned on behalf of Eskom and Arcus GIBB (Pty) Ltd by eThembeni Cultural Heritage (Contact details: Box 20057 Ashburton 3213, Pietermaritzburg, South Africa. Tel: 033 – 326 1136. Fax: 086 – 672 8557. E-mail: thembeni@iafrica.com).

It contributes to the Environmental Impact Assessment for the proposed transmission line development and it will also inform the Environmental Management Plan for the project.

1.1. Legislative context for palaeontological assessment studies

The report has been commissioned on behalf of Eskom and Arcus GIBB Engineering and Science by eThembeni Cultural Heritage (Contact details: Box 20057 Ashburton 3213, Pietermaritzburg, South Africa. Tel: 033 – 326 1136. Fax: 086 – 672 8557. E-mail: thembeni@iafrica.com). It contributes to the Environmental Impact Assessment for the proposed transmission line development, governed by the National Environmental Management Act (NEMA, Act 107 of 1998, amended in 2008), and it will also inform the Environmental Management Plan for the project. The present palaeontological heritage report also falls under Section 38 (Heritage Resources Management) of the South African Heritage Resources Act (Act No. 25 of 1999).

The proposed transmission line developments are located in areas that are underlain by potentially fossiliferous sedimentary rocks of Palaeozoic and Late Tertiary or Quaternary age (Sections 2 and 3). The construction phase of the transmission line and associated infrastructure may entail substantial excavations into the superficial sediment cover as well as locally into the underlying bedrock. In addition, considerable areas of bedrock may be sealed-in or sterilized by lay-down areas as well as new gravel roads. All these developments may adversely affect fossil heritage resources at or beneath the surface of the ground within the development footprint by destroying, disturbing or permanently sealing-in fossils that are then no longer available for scientific research or other public good. Once constructed, the operational and decommissioning phases of the transmission line are unlikely to involve further adverse impacts on palaeontological heritage, however.

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 developed by SAHRA (2013).

1.2. Scope and brief for the desktop study

This palaeontological specialist report provides a combined desktop and field-based assessment of the observed or inferred palaeontological heritage along the proposed Kareedouw – Dieprivier 132 kV transmission line corridor (Fig. 1), with recommendations for further specialist palaeontological studies and / or mitigation where this is considered necessary.

The deliverables and scope of work for this study, as defined by eThembeni Cultural Heritage, are as follows:

- One PIA report for the Transmission Line Project.
- Assessment of heritage resource significance in term of standards and criteria acknowledged and accepted by the South African Heritage Resources Agency (SAHRA). These criteria should be clearly stipulated in an appendix to each report.
- Assessment of the potential development impact on heritage resources in terms of the criteria included in Appendix B.
- *Précis* of the qualifications and experience of the person preparing the reports, demonstrating her/his ability to undertake the principal services.
- Statement of independence of the person preparing the reports, demonstrating her/his ability to undertake the principal services in an objective, unbiased manner.

1.3. Approach to the palaeontological heritage Assessment study

A preliminary desktop study on fossil heritage within the broader study area was undertaken prior to field work. This study involvesd a review of relevant palaeontological and geological literature, including geological maps as well as previous palaeontological heritage assessments carried out in the region (*e.g.* Almond 2009, 2010a, 2010b, 2010c, 2011a, 2011b, 2012). Potentially informative rock exposures within the study region were identified before fieldwork commenced using aerial photographs and / or satellite images.

The field-based palaeontological heritage assessment of the proposed power line route focused on the identification of those sections of the route that are underlain by potentially fossiliferous rocks and that may therefore require mitigation before or during the construction phase of the development. GPS data for all numbered localities mentioned in the text are given in the Appendix.

Palaeontological field assessment does not centre primarily on the examination of proposed pylon positions. Bedrock is often not well exposed at all these positions, while other components of the development footprint (including new access roads, construction camps, laydown areas) have not usually been finalised at the time of the field survey. Potential impacts of the power line development on fossil heritage must be *inferred* from a broader assessment of the palaeontological sensitivity of the rock units represented within and beneath the study area. This is primarily achieved through a careful field examination of representative exposures of all the rock units to determine the diversity, density and distribution of fossil remains within them. These exposures may be natural or artificial and include, for example, rocky outcrops in stream or river banks, cliffs, quarries, dams, dongas, open building excavations or road and railway cuttings. For the present project road cuttings along the R62

Kareedouw to Humansdorp tar road proved the most informative source of geological and palaeontological data. Unconsolidated or consolidated superficial deposits, such as alluvium, scree, calcrete or wind-blown sands, may occasionally contain fossils and were also included in the field assessment study where they are well-represented in the study area.

The present palaeontological field assessment report provides an illustrated, fully-referenced review of the (a) actual or known as well as (b) inferred palaeontological heritage within all rock units represented in the study area based on the initial desktop study as well as new data from fieldwork and any subsequent palaeontological analysis (*e.g.* lab identification of fossil material).

On the basis of the desktop and Phase 1 field assessment studies, the likely impact of the proposed development on local fossil heritage and any need for specialist mitigation were then determined. The impacts are assessed in Section 4 of this report. Adverse palaeontological impacts normally occur during the construction rather than the operational or decommissioning phase.

1.4. Assumptions & limitations

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

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

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

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

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

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

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

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

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

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

In the case of the Kareedouw – Dieprivier study area a major limitation for fossil heritage studies is the low level of exposure of potentially fossiliferous bedrocks, as well as the paucity of previous specialist palaeontological studies in this part of the Eastern Cape. However, representative exposures of all the relevant major bedrock and superficial rock units were examined along of close to the proposed transmission line corridor and confidence levels for this assessment are correspondingly high.

1.5. Information sources

This combined desktop and field-based study was based on the following information sources:

1. A short Background Information Document produced by Arcus Gibb Engineering and Science (April, 2012);

2. A Phase 1 Heritage Impact Assessment Report by for the Patensie to Kareedouw transmission line projects by Len van Schalkwyk and Elizabeth Wahl (May 2012);

3. A review of the relevant scientific literature, including published geological maps and accompanying sheet explanations, as well as several desktop and field-based palaeontological assessment studies in the broader Humansdorp study region by the author (*e.g.* Almond 2009, 2010a, 2010b, 2010c, 2011a, 2011b, 2012).

3. A one-day field survey of potentially fossiliferous rock exposures along the preferred transmission line corridor by the author (7 April 2013).

4. The author's previous field experience with the formations concerned and their palaeontological heritage (See also review of Eastern Cape fossil heritage by Almond *et al.* 2008).

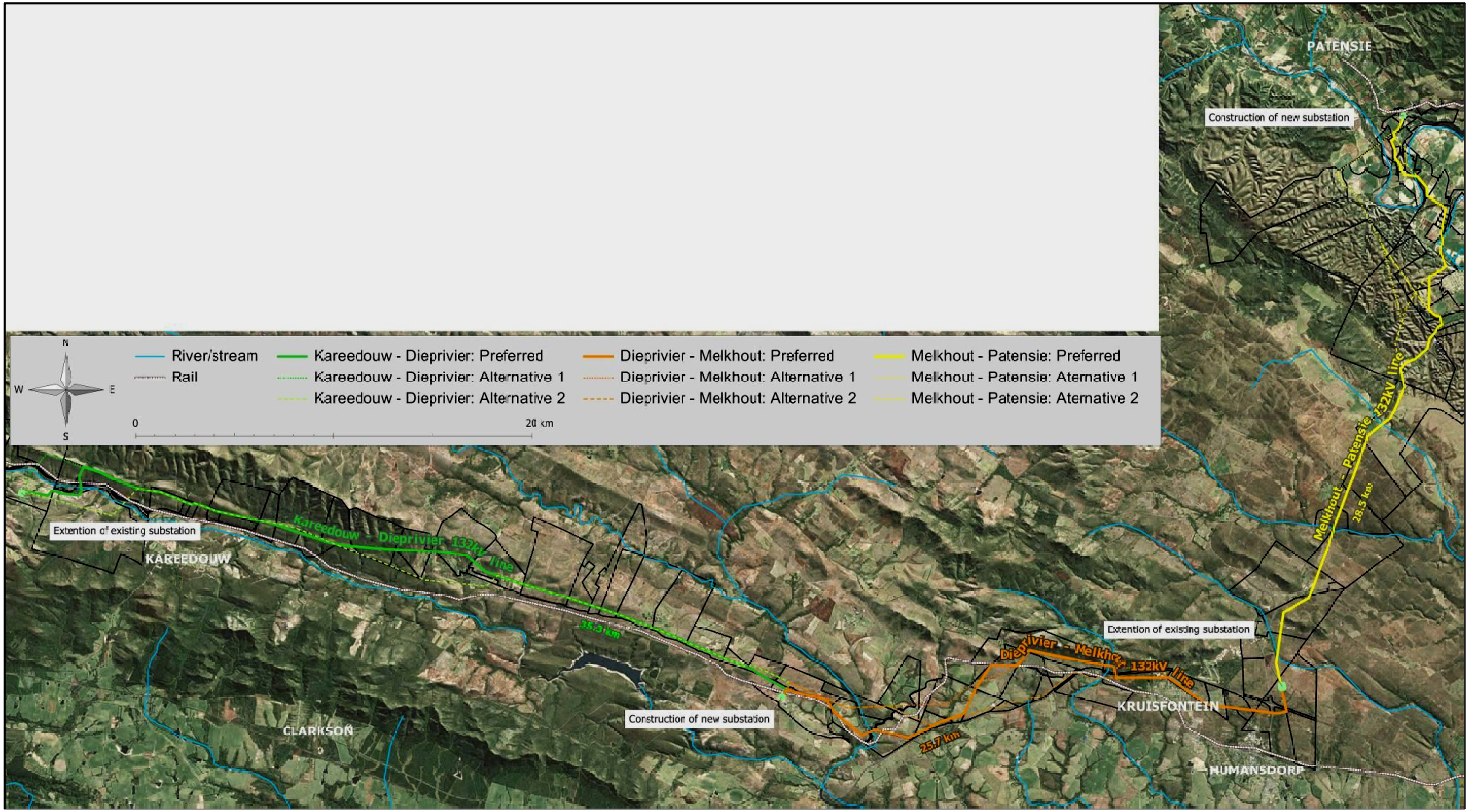

Fig. 1. Map showing proposed Eskom 132 kV transmission line developments between Kareedouw and Patensie, Eastern Cape (from the Background Information Document by Arcus Gibb Engineering and Science, April 2012). This report assesses palaeontological heritage resources along the western sector (*c.* 35.3 km) between Kareedouw and Dieprivier Substations to the west of Humansdorp (green line).

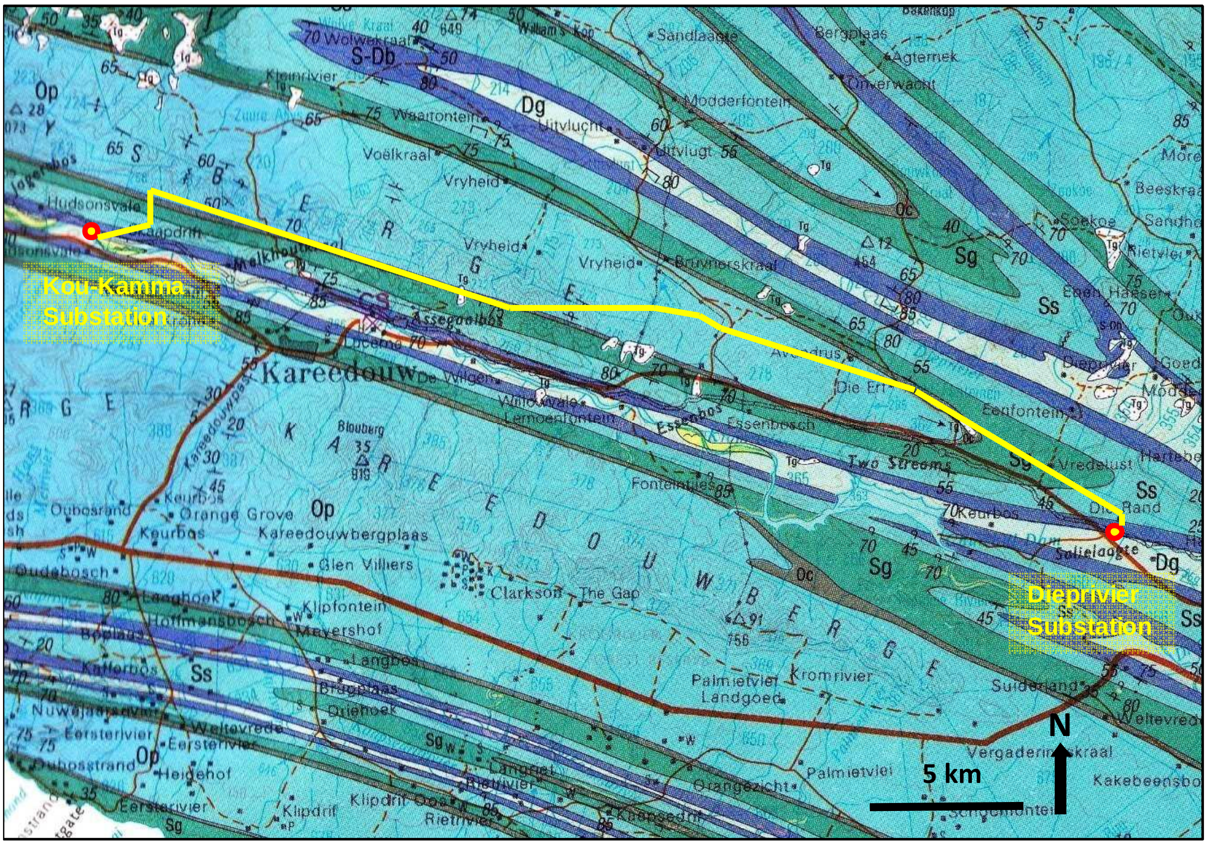

Fig. 2. Extract from 1: 250 000 geology sheet 3324 Port Elizabeth (Council for Geoscience, Pretoria) showing the *approximate* route of the proposed Kareedouw – Dieprivier 132 kV transmission line to the west of Humansdorp (yellow line). Please note that the outcrop areas of the various formations shown are also approximate at this scale and can only be accurately determined through fieldwork and where superficial sediment cover is low. The N2 trunk road is not indicated on this map.

The main geological units represented within the study include the following formations (Palaeontologically more sensitive marine units indicated in red):

TABLE MOUNTAIN GROUP (Ordovician to Early Devonian)
Peninsula Formation (Op, middle blue)
Cederberg Formation (Oc, grey)
Goudini Formation (Sg, green)
Skurweberg Formation (Ss, pale blue)
Baviaanskloof Formation (S-Db, dark blue)

BOKKEVELD GROUP (Early Devonian)
Gydo Formation (Dg, v. pale blue)

SUPERFICIAL DEPOSITS (Late Caenozoic)
Grahamstown Formation (Tg, white with red stipple) – ancient alluvial gravels, pedocretes (e.g. ferricrete)
Alluvium (yellow with "flying bird" symbol)

2. GEOLOGICAL OUTLINE OF THE STUDY AREA

The proposed 132 kV transmission line runs along the Langkloof Valley between the Kareedouw (Kou-Kamma) Substation on its southern flank, *c*. 7.5 km WNW of the village of Kareedouw, and the Dieprivier Substation *c*. 25.2 km ESE of Kareedouw and *c.* 20 km west of Humansdorp, Humansdorp Magisterial District, Eastern Cape (Fig. 1). The narrow Langkloof Valley, followed by the Kromrivier, lies between the WNW-ESE trending Tsitsikammaberge – Kareedouwberge Range in the south and the Suuranysberge in the north (Fig. 2). The slopes of these mountain ranges, built of resistant-weathering Table Mountain Group quartzites, are incised by numerous transverse streams. Bedrock exposure on the lower slopes and valley floor (*c*. 200 – 400 m amsl) where the transmission line is to be constructed is often poor due to pervasive cover by superficial sediments (colluvium, alluvium, soil) as well as by fynbos vegetation. The terrain is generally less rugged than seen in the more arid, western ranges of the Cape Fold Mountains because the resistance of the bedrocks here has been compromised by deep chemical weathering while the lower slopes have been planed off by erosion to form elevated, gently-sloping pediment surfaces of probable Late Tertiary (Neogene) age, reflecting ancient land surfaces (Partridge 1998, Partridge & Maud 1987, 2000) (Figs. 4 & 5)..

The geology of the Kareedouw – Dieprivier study area near Humansdorp is shown on the 1: 250 000 geology sheet 3324 Port Elizabeth published by the Council for Geoscience, Pretoria (Toerien & Hill 1989) (Fig. 2). Additional relevant data is provided by the more recent 1: 50 000 geological sheet explanation for the Port Elizabeth – Uitenhage area to the east (Le Roux 2000) as well as the older sheet explanation by Haughton *et al.* (1937) covering the coastal belt near the Gamtoos Valley.

The entire study area is underlain at depth by Early to Middle Palaeozoic sedimentary rocks of the **Cape Supergroup**. These comprise rocks of the sandstone-dominated **Table Mountain Group** of Ordovician to Early Devonian age and the immediately overlying, mudrock-dominated lowermost **Bokkeveld Group** of Early Devonian age. The stratigraphic relationships of the six Cape Supergroup sedimentary formations concerned are shown below in Fig. 3. They include:

- predominantly fluvial sandstones and quartzites of the **Peninsula** (Op), **Goudini** (Sg) and **Skurweberg (**Ss**) Formations**, of Ordovician to Silurian age;
- post-glacial mudrocks of the **Cederberg Formation** (Oc) of late Ordovician age (Note that the glacial diamictites of the underlying **Pakhuis Formation** are not mapped separately in this area.);
- earliest Devonian wackes (= impure sandstones) and mudrocks of the **Baviaanskloof Formation** (S-Db), interpreted to be inshore coastal marine to paralic (near-shore) fluvial deposits;
- shallow marine mudrocks and subordinate sandstones of the **Gydo Formation** (Dg) of Early Devonian age.

Most of these rocks have a poor fossil record but those three marine units emphasized with an asterisk in Fig. 3 are potentially highly fossiliferous, as outlined in Section 3. These three potentially sensitive rock units crop out on the lower flanks and floor of the Langkloof Valley (Fig. 2). The Cape Supergroup rocks in the study area lie within the south-eastern sector of the Cape Fold Belt of Permo-Triassic age (Newton *et al.* 2006). Levels of tectonic deformation here are high as a result of intense NNE-directed crustal compression, with steep bedding plane dips within tight folds along subparallel WNW-ESE trending axes (Some of these folds are overturned towards the north, as indicated by inverted bedding). Major anticlinal axes run along the line of the Tsitsikammaberge - Kareedouwberge Range and the Suuranysberge Range, with a broad zone of Peninsula Formation quartzites in their cores. In the Cape Fold Belt the northern limbs of such mega-anticlines are often complicated by smaller scale cascade or parasitic folds (*e.g.* Kareedouw Pass area). A narrow strip-like outcrop area of Gydo Formation sediments is mapped along the core of the tight syncline along the Langkloof. These comparatively soft-weathering rocks have been incised by the Kromrivier. The mudrock-dominated successions of the Cederberg and Gydo Formations in this part of the Cape Fold Belt are usually highly cleaved, and locally faulted- or squeezed-out, but levels of metamorphism within the Cape Fold Belt are generally low.

Due to protracted chemical weathering of bedrocks beneath the southern coastal plain and within the south-eastern margins of the Cape Fold Belt in Tertiary times, many of these older sedimentary rocks have been converted to poorly consolidated, easily eroded *saprolite* (*in situ* weathered bedrock), often pale or multi-hued due to the formation of kaolinitic clays and secondary ferruginous mineralisation respectively (See Figs. 7, 16 & 17 for example). Subdued relief and extensive chemical weathering ensures that bedrock exposures here often very limited, and mainly restricted to artificial excavations such as quarries, borrow pits, road and rail cuttings, dams and trenches. Under these circumstances, accurate geological mapping is impossible, and so the outcrop areas shown in Fig. 2 must be regarded as a provisional "best guess" pending further subsurface data.

A substantial portion of the Palaeozoic bedrocks within the study area are mantled by a veneer of **Late Caenozoic superficial sediments**; most of these are not mapped at 1: 250 000 scale, however. They include various clay-rich and gravelly soils overlying the Cederberg and Gydo Formations, colluvial and down-wasted sandstone or quartizte gravels overlying the arenitic Table Mountain Group units, as well as fine-grained, sandy to bouldery gravel alluvium along river and stream courses (*e.g.* Kromrivier). Small relict patches of ancient alluvial gravels (Late Caenozoic / Pleistocene "High Level Gravels") are mapped within the Langkloof study area where they generally overlie ancient elevated land surfaces or pediment surfaces incised into the upper Table Mountain Group rocks (Tg in map Fig. 2). Some of these older gravels, which are broadly subsumed into the **Grahamstown Formation** (**Tg**), have been secondarily cemented to form pedocretes, such as silica-rich **silcretes** and iron-rich **ferricretes** (*e.g.* Roberts 2003). Reworked and downwasted ferricrete gravels are well represented overlying the weathered Table Mountain and Bokkeveld Group outcrop areas along the Langkloof valley floor.

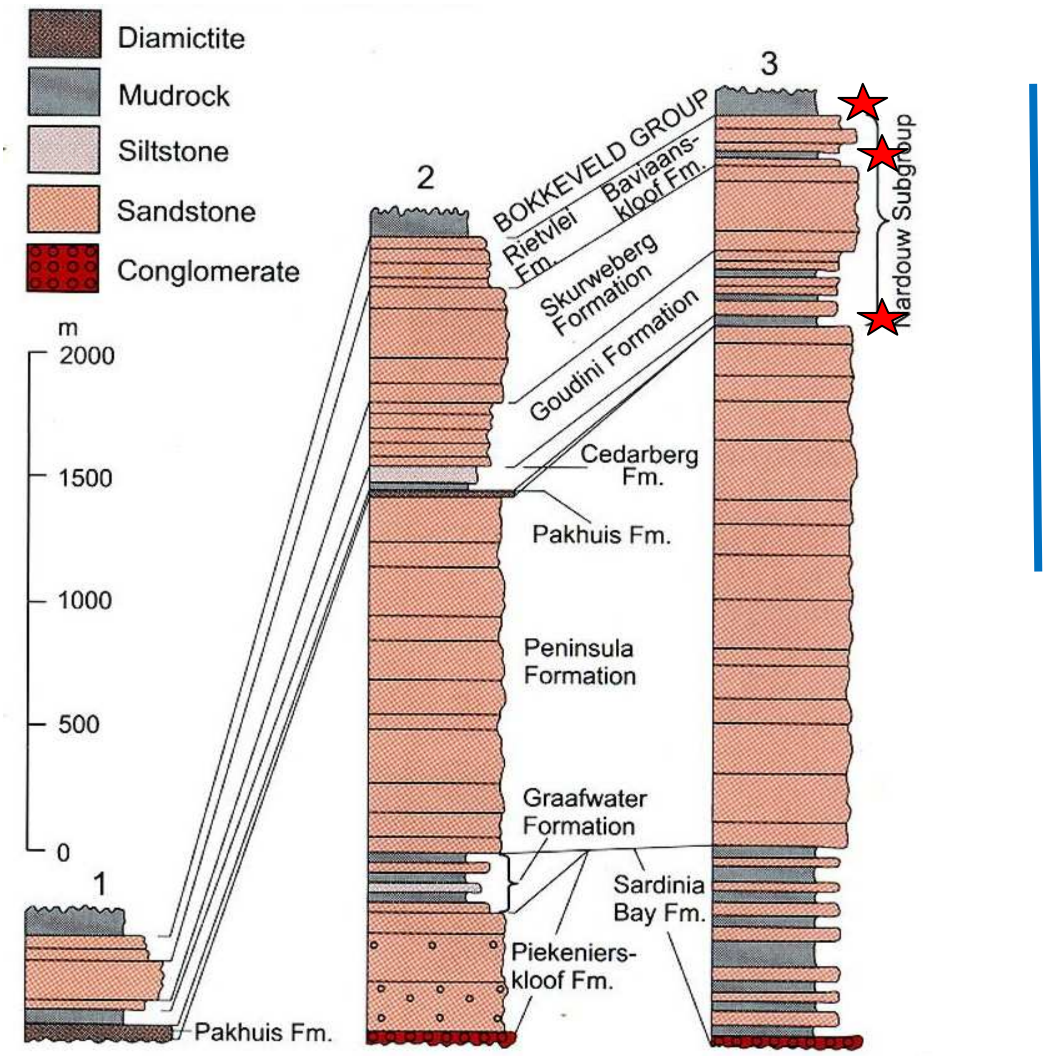

Fig. 3. Stratigraphy of the Table Mountain Group in the Western and Eastern Cape outcrop areas (From Thamm & Johnson 2006). Column 3 for the Eastern Cape is most relevant for the present study near Humansdorp. The vertical blue line indicated formations represented within the Kareedouw – Dieprivier study area. Table Mountain Group formations above the Cederberg Formation are grouped within the Nardouw Subgroup. Note the greater frequency of mudrock interbeds within the Goudini succession in the Eastern Cape, where the Cederberg Formation is often less well-defined. The fossiliferous mudrocks of the basal Bokkeveld Group belong to the Gydo Formation that is mapped within the study area along the Langkloof valley floor . The three marine rock units indicated with a red asterisk – *i.e.* Cederberg, Baviaanskloof and Gydo Formations - are potentially of high palaeontological sensitivity, but only where their fossil content is not compromised by chemical weathering and tectonism. The remaining units are predominantly non-marine and generally have a poor fossil record, dominated by low-diversity trace fossil assemblages.

In the following section of this report the main geological units represented within the broader Humansdorp – Kareedouw study area are briefly described, with short notes on representative exposures from the Kareedouw – Dieprivier study area, paying special attention to those formations that may be of palaeontological heritage significance. GPS data for all numbered localities mentioned in the text is provided in the Appendix.

Fig. 4. Bouldery alluvial gravels of the Kromrivier in Langkloof (Plattekloof area) viewed towards the NW. The proposed transmission line would run along the gently sloping pediment surface in the middle ground. The Suuranysberge range is seen in the background.

Fig. 5. View SW across the Langkloof towards the Kou-Kamma Substation site which overlies a well-developed, flat pediment surface along the southern side of Langkloof (middle ground). The Tsitsikammaberge is seen in the background.

2.1. Table Mountain Group

Useful overviews of Table Mountain Group geology in general include Rust (1967, 1981), Hiller (1982), Malan & Theron (1989), Broquet (1992), Johnson *et a*l., (1999), De Beer (2002), Thamm & Johnson (2006), and Tankard *et al*., (2009). For the Port Elizabeth sheet area specifically, these rocks are briefly described by Toerien and Hill (1989) and Le Roux (2000) as well as in older sheet explanations such as those by Engelbrecht *et al*. (1962) and Haughton *et al*., (1937). Also useful are various reports by the South African Committee for Stratigraphy (SACS), such as those by Malan *et al*. (1989), Malan and Theron (1989) and Hill (1991). Due to poor exposure and high levels of bedrock weathering in the study region it is not always possible to differentiate the arenitic subunits of the Table Mountain Group in the field with full confidence.

The Mid to Late Ordovician **Peninsula Formation** is a very thick succession of resistant-weathering, well-washed, braided fluvial sandstones and quartzites with subordinate pebbly lenses and thin (< 1m) heterolithic (mudrock / sandstone) intervals with sparse trace fossils that are attributed to intermittent marine transgressive events (Toerien & Hill 1989, Le Roux 2000). Common sedimentary structures include unidirectional cross-bedding and over-turned cross-bedding. The thickness of the formation is unclear due to the frequent occurrence of tectonic reduplication but is unlikely to be more than 3000m.

High levels of bedrock weathering are seen in good roadcutting exposures of the Peninsula Formation along the Kareedouw Pass that runs southwest from Kareedouw (Locs. 018-019) (Figs. 6 & 7). Here medium- to thick-bedded, tabular, sparsely pebbly arenites have been deeply leached and weathered to form pale buff, cream and greyish, friable saprolite. The steeply dipping to subvertical beds are variously obscurely defined, or secondarily massive, or preserve relict tabular cross-bedding. Reddish hues due to secondary ferruginsation and quartz veins are seen locally. No heterolithic sedimentary packages (commonly associated elsewhere with trace fossil assemblages) were observed. The Peninsula Formation bedrocks are overlain by semi-consolidated, ferruginised downwasted colluvial gravels.

Fig. 6. Steeply-dipping, cross-bedded quartzites of the Peninsula Formation mantled by ferruginised colluvial gravels, Kareedouw Pass. View towards the Kareedouwberge in the southeast (Loc. 019).

Fig. 7. Close-up of highly weathered, leached arenites of the Peninsula Formation with relict quartz veins, Kareedouw Pass (Loc. 018) (Hammer = 27 cm).

The **Cederberg Formation** of Latest Ordovician (Hirnantian) age is a thin, coarsening-upwards succession of mudrocks, siltstones and sandstones that was deposited within shallowing, frigid post-glacial seas following a short-lived, multiple Gondwana glacial event. The Cederberg rocks are generally recessive-weathering and poorly-exposed; pervasive cleavage formation may be expected in the Port Elizabeth sheet area. Dark, carbonaceous, finely-laminated shales with occasional dropstones typify the lower part of the succession. Glacial rocks (sandy, muddy and pebbly diamictites) of the **Pakhuis Formation** that occur directly below the Cederberg mudrocks in the Western Cape are not separately mapped in the study area. However, Toerien and Hill (1989) mention sporadically-developed glacial diamictites within the lower part of the “Cederberg Formation” (technically Winterhoek Subgroup) outcrop area in the Humansdorp District. They are exposed, for example, on the banks of the Kouga River. As shown in the stratigraphic column for the Table Mountain Group in the Eastern Cape (Fig. 3) the Cederberg / Goudini transition zone is characterised by heterolithic interbedding of arenitic and mudrock units or packages. Recognition of a discrete Cederberg Formation under these circumstances is difficult, and complicated by enhanced tectonism at this horizon in the eastern Cape Fold Belt.

The **Goudini Formation** (Sg) consists predominantly of quartzose sandstones, frequently cross-bedded, that characteristically display reddish to brownish tints due to higher levels of iron and / or manganese impurities compared with the purer underlying and overlying Peninsula and Skurweberg Formations. Sandstone beds are generally thinner, and heterolithic successions (*i.e.* interbedded sandstones and mudrocks) commoner, than in the overlying Skurweberg Formation. Consequently exposures of the Goudini rocks are more recessive weathering. The mudrocks, which are often reddish in colour, are rarely exposed. In the Western Cape at least, occasional trace fossil assemblages within the Goudini Formation suggest intermittent marine influence but the bulk of the succession is probably fluvial in origin.

A laterally extensive, recessive-weathering heterolthic zone running along the southern slopes of the Suuranysberg, as seen on satellite images (*e.g.* stream valleys along strike), is probably equivalent to the Cederberg and Goudini Formations. Deeply weathered, multi-hued (buff, grey, brick red) laminated mudrocks towards the base of this zone are exposed along the mountain pass running across the Suuranysberg to the north of Kareedouw (Loc. 030) (Fig. 8). The subvertical fissility here probably reflects slaty cleavage rather than just primary shaly lamination. Pale cream to buff, superficially massive claystones in a roadcutting along the R62 at Loc. 039 (just east of turnoff to Jumanji Nature Reserve) are also deeply weathered (Fig. 9). They are interbedded here with ripple cross-laminated sandstones. Tabular cross-bedded sandstones interbedded with grey horizontally laminated mudrocks are well seen along the Suuranysberg mountain pass at Locs. 031 and 032 (Fig. 10). Similar beds, striking NW-SE, are well exposed in the nearby borrow pit at Loc. 029 (Figs. 11 & 12). Here deeply-weathered, pale grey to cream, fine-grained to gritty sandstones, thin- to medium-bedded, variously horizontally laminated, ripple cross-laminated to tabular cross-bedded, are interbedded with darker grey, tabular massive to horizontally laminated claystones and siltstones. There are no good bedding plane exposures here, however.

Fig. 8. Deeply-weathered, ferruginised mudrock succession along the Suuranysberg Pass road north of Kareedouw (Loc. 030) (Hammer = 27 cm). These mudrocks probably belong to the lower part of the Cederberg Formation.

Fig. 9. Cream-coloured, deeply weathered claystones overlain by gravelly soil, R62 road cutting near the Jumanji Nature Reserve (Hammer = 27 cm) (Loc. 039).

Fig. 10. Cross-bedded, tabular sandstones interbedded with weathered grey mudrocks of the upper Cederberg Formation or Goudini Formation, Suuranysberg Pass (Loc. 032) (Hammer = 27 cm).

Fig. 11. Borrow pit exposure of highly weathered, interbedded sandstone / mudrock succession along the Suuranysberg Pass (Loc. 029) (Hammer = 27 cm). These rocks belong to either the upper Cederberg Formation (Disa Member) or the overlying Goudini Formation.

Fig. 12. Rapid alternation of thin-bedded, tabular, pale grey sandstone beds and darker grey mudrocks (siltstones and claystones) (Loc. 029) (Hammer = 27 cm).

The **Skurweberg Formation** (Ss) is dominated by very pale, resistant-weathering sandstones and quartzites that typically show well-developed unidirectional (current) cross-bedding and sometimes thin quartz pebble lenticles (These last far less common in the Eastern than Western Cape outcrops). Bedding is often thick (thicknesses of one or more meters are common) and although thin, lenticular, dark mudrock intervals also occur, these are rarely exposed at outcrop. Sedimentological features within this formation indicate deposition across an extensive sandy alluvial braidplain.

Good exposures of tabular-bedded Skurweberg arenites, here showing steep subvertical dips, are seen along the Suuranysberg mountain pass to the west of Assegaaibos Station (Locs. 033, 034). Many of the beds show well-developed tabular cross-sets (Fig. 13). Heterolithic, mudrock-rich packages were not seen.

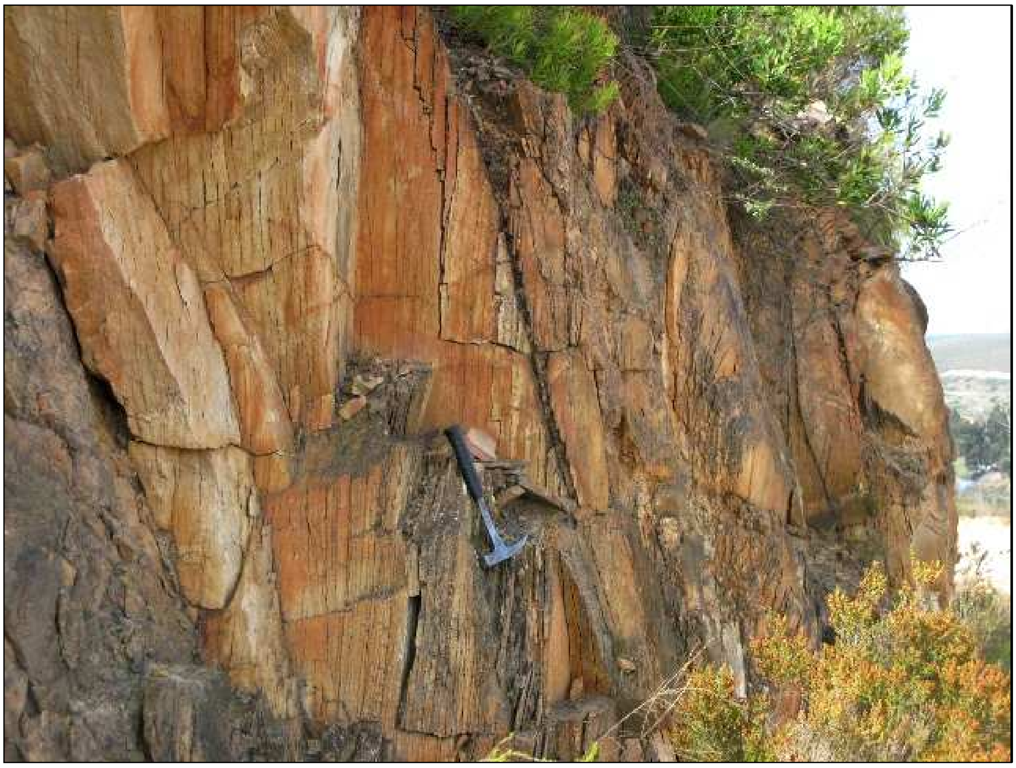

Fig. 13. Steeply south-dipping, tabular, prominently tabular cross-bedded quartzites of the Skurweberg Formation, Suuranysberg Pass road (Loc. 034) (Hammer = 27 cm).

The **Baviaanskloof Formation** (S-Db) is typically less clean-washed than the older subunits of the Nardouw Subgroup, with a higher proportion of lithic grains and clay minerals giving darker hues and more recessive weathering patterns. Sandstones are often (but not invariably) greyish, impure wackes and may be massive or ripple cross-laminated. Dark grey to black carbonaceous and micaceous mudrock intervals are quite common but rarely well exposed (A *c.* 15m-thick band of micaceous shale within the upper Baviaanskloof Formation in the Gamtoos area is mentioned by Haughton *et al*., 1937, for example). The heterolithic "passage beds" of the Baviaanskloof Formation incorporate the sedimentary transition between the fluvial-dominated lower units of the Nardouw Subgroup and the marine shelf sediments of the Lower Bokkeveld Group (Fig. 3). Locally abundant shelly fossils such as articulate brachiopods, trace fossils as well as wave ripple lamination demonstrate the shallow marine origins of at least some of the upper sandstones, while the dark mudrocks with dense mats of vascular plant remains may be lagoonal in origin (See Section 3).

Road cuttings along the R62 at Loc. 021 expose fairly fresh (*i.e.* unweathered), thin- to medium-bedded, greyish to grey-green wackes of the Baviaanskloof Formation towards road level, but grade into highly weathered bedrocks higher up (Fig. 14). The fresher rocks are well-jointed and show *en echelon* quartz veins, reflecting tectonic deformation. Deeply-weathered, friable arenites at Locs. 036 and 037 that probably belong to the Baviaanskloof Formation show honeycomb weathering, quartz veining and secondary ferruginisation. The upper contact with overlying ferruginous pebbly gravels and soils is a highly irregular erosion surface (Fig. 15). Exposures of mudrock interbeds within this formation were not observed in the study area.

Fig. 14. Comparatively unweathered, quartz-veined, grey-green wackes of the Baviaanskloof Formation along the R62 (Loc. 021)

Fig. 15. Deeply weathered arenites of the Baviaanskloof Formation along the R62 (Loc. 037). Note irregular erosional contact with the overlying gravelly soils.

2.2. Lower Bokkeveld Group

The lower **Bokkeveld Group** (= **Ceres Subgroup**) – represented in the present study area only by the **Gydo Formation** (Dg) - is a thick succession of fine- to medium-grained sedimentary rocks that were laid down in a range of shallow to moderately deep continental shelf environments during the Early to Middle Devonian Period (*c*. 140 to 390 Ma, *i.e*. Emsian to Eifelian; Ma = million years ago). Throughout this period of deposition the Cape Basin was situated at high palaeolatitudes (over 70º S) and was gradually approaching the southern palaeopole. In the eastern outcrop area of the Bokkeveld Group, near Port Elizabeth, it reaches a total thickness of *c*. 3.5km. Precise figures are difficult to obtain due to tectonic thickening and reduplication (folding, thrust faulting *etc*) as well as generally poor exposure. Key geological references for the Bokkeveld Group succession include Tankard and Barwis (1982), Theron and Loock (1988), Hiller and Theron (1988), as well as Theron and Johnson (1991), Broquet (1992), Thamm & Johnson (2006). Brief accounts of the Bokkeveld Group in the Port Elizabeth region have been given by Toerien and Hill (1989), and Le Roux (2000).

The rocks forming the Bokkeveld Group are predominantly fine-grained mudrocks – *claystones* formed from soft muds (mainly clay minerals) and *siltstones* formed from slightly larger, silt-sized particles including small quartz grains and micas. Extensive fresh outcrops are rare due to post-Gondwana weathering as well as drift (scree, soil *etc*) and vegetation cover. Sandstone-dominated successions with total thicknesses in the range of 50-100m also occur and are sometimes mapped as separate formations. The Ceres Subgroup has accordingly been subdivided into a series of six laterally persistent formations, alternately dominated by mudrocks and sandstones. However, with the exception of the basal **Gydo Formation** (Dg) with an estimated thickness of some 500m, these formations are generally grouped together as a single stratigraphic unit (Dc) on the published 1: 250 000 geology map of the Port Elizabeth region, due to poor exposure and locally intense folding towards the eastern end of the Cape Fold Belt (Toerien and Hill 1989). The clay-rich sediments of the lower Bokkeveld Group have often suffered extensive cleavage formation in the Humansdorp area (Haughton *et al.* 1937) and deep Tertiary-age chemical weathering is evident here.

The Bokkeveld sandstones are typically thin-bedded (dm scale to 50 cm or more), poorly-sorted by grain-size, and compositionally “impure”; *i.e.* they contain a small proportion of clay or mica minerals, tiny rock fragments (*lithic* grains), and feldspar in addition to the dominant mineral quartz. The technical term for quartz sandstones that contain over 15% of other (non-quartz) grain types is *wackes*, in contrast to purer quartz sandstones (> 85% quartz) such as those of the Table Mountain Group which are called *arenites*. The readily decomposed impurities give the Bokkeveld sandstones / wackes slightly darker, buff to brownish colours and a more friable or crumbly texture than pure sandstones or quartzites. Due to their higher clay and mica content the former are also more likely to develop a pronounced cleavage as a result of tectonic deformation than are purer sandstones, and are therefore more prone to weathering. Quartz cements are less well developed in the impure Bokkeveld sandstones than in the Table Mountain Group arenites.

Lower Bokkeveld Group sediments are well-exposed in several extensive road cuttings along the R62 within the Kou-Kamma to Dieprivier study area (*e.g.* Locs. 022, 022a, 025, 035). The Bokkeveld succession here is typically highly dominated by mudrocks and is invariably deeply weathered so that the original bedding is often obscure. Where preserved, the bedding is tabular and usually steeply dipping. The mudrocks (claystones, siltstones) are multi-hued (ochreous, buff, rusty red, pinkish *etc*), often secondarily mineralised, with prominent-weathering veins or lenticles of secondary ferromanganese minerals, and display a pervasive, steeply-dipping to subvertical tectonic cleavage (Figs. 16 to 19). Sandstone interbeds are sparse, also highly weathered, and bedding plane exposures are very rarely available. The Bokkeveld bedrocks are typically mantled in brick red terra rossa-type soils, locally gravelly, beneath less ferruginous, brownish modern soils. Highly weathered Gydo Formation bedrocks are exploited for brick clay within an extensive quarry adjacent to the Assegaaibosch Lodge in Kareedouw.

Fig. 16. Gently dipping, tabular-bedded siltstones and minor sandstones of the Gydo Formation, R62 road cutting. Pale ochreous hues here indicate deep chemical weathering (Loc. 020).

Fig. 17. Multi-hued, deeply weathered Gydo Formation saprolite exposed in a R62 road cutting (Loc. 022). Note subvertical bedding and brick-coloured ferruginous terra rossa – like soils overlying the weathered bedrock.

Fig. 18. Close-up of weathered, ferruginised Gydo Formation in R62 road cutting at Loc. 025 (Hammer = 27 cm). Note prominent-weathering lenticles or blobs of secondary minerals.

Fig. 19. Deeply-weathered Gydo Formation mudrocks displaying pervasive subvertical tectonic cleavage, R62 road cutting (Loc. 020) (Hammer = 27 cm).

2.3. Superficial sediments

Gentler valley slopes along the Langkloof are extensively mantled by coarse, rubbly **colluvial deposits** that may reach thicknesses of several meters, as seen for example along the Suuranysberg mountain pass and road cuttings along the R62 (*e.g.* Locs. 019, 027, 028, 040). The colluvial gravels are usually highly angular and poorly sorted, usually massive but occasionally crude bedding defined by contrasting grain-size spectra and sorting can be defined (Figs. 20 & 21). Older gravels are semi-consolidated and partially cemented by ferruginous minerals, occasionally by silica to form **silcretes** (Loc. 040), giving reddish-brown to tan hues respectively (Fig. 22).

The Kromrivier is associated with modern coarse gravelly **alluvium** with pebbles, cobbles and boulders dominated by Table Mountain Group quartzites and sandstones overlain by finer-grained sandy to silty alluvium and soils (Fig. 4). At slightly higher elevations thick deposits of sparsely pebbly, sandy alluvium locally display ferruginous mottling (Loc. 038) (Fig. 26).

Relict patches of **High Level Gravels** ("Grahamstown Formation") are preserved overlying the gently sloping pediment surfaces along the Langkloof, as seen for example at the Kou-Kamma Substation site at *c*. 350 m amsl (Loc. 023) (Fig. 5). Here well-rounded fluvial pebbles and cobbles of Table Mountain Group quartzite, *plus* subordinate ferricrete, ferruginous sandstone and chert, overlie planed-off, steeply-dipping beds of the Skurweberg Formation (Fig. 25). The ancient alluvial gravels here lie some 100 m above the present level of the Kromrivier and are probably Late Tertiary (Neogene) in age. Another good example of a pediment surface, here at c. 340 m amsl, is seen on the farm Plattekloof to the northwest of Kareedouw (Fig. 4). Such pediment surfaces incised into the Nardouw Subgroup bedrocks and gradually falling in elevation towards the ESE are extensively exploited by the proposed transmission line route down the northern side of the Langkloof. Road cuttings along the R62 just east of Kareedouw (Loc. 026) show good vertical sections through coarse, cobbly to bouldery ancient alluvial gravels at *c*. 270 m amsl (some 50-60 m above the bed of the Kromrivier to the north), here sharply overlying steeply-dipping, weathered bedrocks of the Gydo Formation (Fig. 24). The gravels here are moderately well-consolidated and the quartzitic clasts are well-rounded, the larger boulders showing superficial impact crescents.

Silcretised alluvial (as opposed to colluvial) gravels were not observed in the study area. Well-developed **ferricretes** are seen in the vicinity of the Dieprivier Substation where they overlie weathered Bokkeveld Group mudrocks (Locs. 041, 042) (Fig. 23). Excavated float blocks of ferricrete show pebbly gravels and nodules in a deeply ferricretised, purplish-brown gritty matrix. Thick banks of *in situ* ferricrete are exposed along the margins of trenches and small dam here.

Fig. 20. Coarse rubbly quartzitic colluvium overlying Skurweberg bedrocks on the southern slopes of the Suuranysberg (Loc. 027).

Fig. 21. Thick, semi-consolidated, angular colluvial gravels showing crude bedding defined by differences in grain size and sorting, R62 road cutting (Loc. 027) (Hammer = 27 cm).

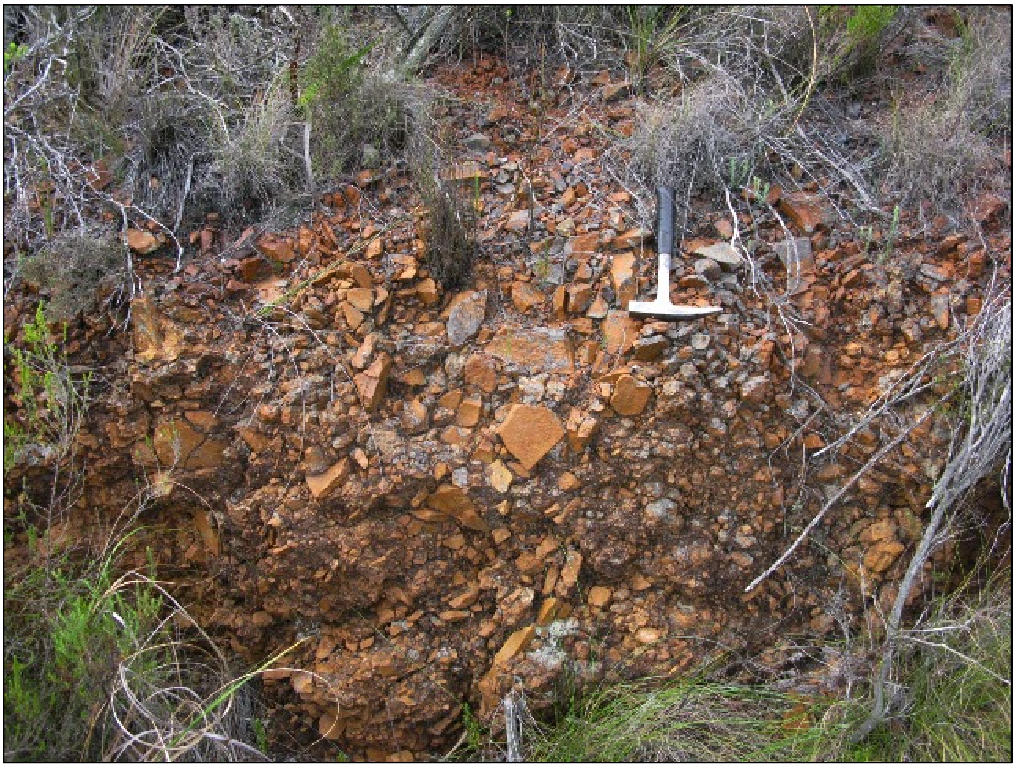

Fig. 22. Well-consolidated, poorly-sorted and partially silcretised angular colluvial gravels along the R62 (Loc. 040) (Hammer = 27 cm).

Fig. 23. Subsurface bank of ferricretised gravels overlying weathered Gydo Formation and mantled by silty grey-brown soils in the vicinity of Dieprivier Substation (Loc. 042) (Hammer = 27 cm).

Fig. 24. Coarse, bouldery High Level Gravels of alluvial origin and probable Late Tertiary age overlying deeply-weathered Gydo Formation, R62 road cutting just east of Kareedouw (Loc. 026).

Fig. 25. Downwasted quartzitic High Level Gravels of alluvial origin overlying a pediment surface in the neighbourhood of the Kou-Kamma Substation (Loc. 023) (Hammer = 27 cm).

Fig. 26. Thick, sparsely gravelly, semi-consolidated sandstones of possible alluvial origin showing prominent mottling by reddish-brown ferruginous minerals, R62 roads cutting (Loc. 038).

3. PALAEONTOLOGICAL HERITAGE WITHIN THE STUDY REGION

A brief review of the fossil assemblages recorded from the various major rock units represented within the broader Kareedouw – Humansdorp study area is given here. Most of these rock units are only sparsely fossiliferous to unfossiliferous. However, rich and scientifically important fossil assemblages have been recorded from the Cedarberg and Baviaanskloof Formations of the Table Mountain Group as well as the Gydo Formation at the base of the Bokkeveld Group elsewhere in the Cape Fold Belt. The palaeontological sensitivity of these three rock units has generally been seriously compromised in the study region near Humansdorp as a result of high levels of tectonic deformation (*e.g.* cleavage formation) as well as deep chemical weathering since the fragmentation of Gondwana some 120 million years ago. Furthermore, the outcrop areas of the mudrock-rich sedimentary successions that are most likely to yield fossil remains are narrow and ill-defined, and are largely mantled in a veneer of superficial deposits such as soil, alluvium and gravels that may shield any fresher (less weathered), potentially fossiliferous bedrocks from significant disturbance during development.

3.1. Fossils in the Table Mountain Group

Body fossils (shells, teeth, bones *etc*) are so far unknown from the **Peninsula Formation** but a modest range of shallow marine to nearshore fluvial and / or estuarine trace fossils have been recognised, mainly from the Western Cape outcrop area (*e.g.* Rust 1967, Potgieter & Oelofsen 1983, Broquet 1990, 1992, Almond 1998a,b, Braddy & Almond 1999, Thamm & Johnson 2006). These traces include trilobite resting and feeding burrows (*Cruziana*, *Rusophycus*), arthropod trackways (*e.g.* *Diplichnites, Palmichnium*) that are variously attributed to eurypterids, crustaceans or trilobites, palmate, annulated feeding burrows (*Arthrophycus*), dense assemblages ("pipe rock") of vertical dwelling burrows of unknown suspension feeders (*Skolithos, Trichichnus*), vertical columns or cones of densely reworked sediment (*Metaichna* / possible *Heimdallia*), and several types of horizontal burrows (*Palaeophycus,* possible *Aulichnites*).

An important, albeit low diversity, assemblage of Peninsula Formation trace fossils was recently recorded from heterlithic beds exposed in the Rosenhof Quarry site within the broader Tsitsikamma Community Wind Energy Facility study region to the southwest of Humansdorp by Almond (2012). Traces here include vertical *Skolithos* burrows, *Rusophycus* and *Cruziana* arthropod scratch burrows that were probably generated by trilobites, possible bivalve burrows (*Lockeia*) and teichichnoid spreiten burrows, as well as abundant flower-shaped "gyrophyllitid" burrows that had previously been reported from beach boulders at Cape Saint Francis.

Recessive weathering of trace-rich heterolithic intervals is undoubtedly responsible for under-recording of fossils within the Peninsula Formation. It is also likely that relatively unweathered samples of fine-grained muddy sediments within these heterolithic intervals may eventually yield microfossil assemblages (*e.g.* organic-walled acritarchs) of biostratigraphic and palaeonvironmental significance.

Apart from vague meniscate backfilled burrows from late glacial or postglacial dropstone argillites in the Hex River Valley, no fossil remains have been described from the **Pakhuis Formation** (Almond 2008).

An exceptionally important and interesting biota of soft-bodied (*i.e.* unmineralised) and shelly invertebrates, primitive jawless vertebrates and microfossils has been recorded since the middle 1970s from finely laminated, black mudrocks of the **Soom Member**, forming the lower, mudrock-dominated portion of the **Cedarberg Formation**. This is one of only two so-called soft-body *Lagerstaette* of Late Ordovician age recorded worldwide (the other example was recently discovered in Canada; Young *et al.,* 2007). The "Soom Shale" is between 10-15m thick, and fossils occur sporadically throughout the succession, from 1m above the base upwards. This biota has been extensively reviewed by Aldridge *et al*. (1994, 2001) and Selden and Nudds (2004) while much new information remains to be published (See review in Almond 2008 and refs. therein). The macrofossils include a range of macroalgae, shelly invertebrates (*e.g.* inarticulate brachiopods, conical-shelled nautiloids and other molluscs, crustaceans, unmineralised trilobites and eurypterids or "water scorpions") and several groups of primitive jawless fish (*e.g.* anaspids, conodonts). Important microfossil groups include chitinozoans, spore tetrads of land plants and marine acritarchs. A further interesting category of fossils recorded from the Soom Member of Kromrivier are bromalites. These are the various fossilised products of ancient animal guts such as droppings (coprolites), regurgitates and stomach contents that sometimes contain the comminuted remains of recognisable prey animals such as conodonts or brachiopods (Aldridge *et al*., 2006). The majority of Soom fossils have been collected from a handful of localities, most of which lie on the Clanwilliam sheet within the central to northern Cedarberg (Gray *et al*. 1986, Cocks & Fortey 1986, Theron *et al*. 1990, Aldridge *et al*. 1995). New fossiliferous localities have recently been identified in the Clanwilliam area, while well preserved trilobite trace fossils (*Rusophycus*) have been collected from thin tempestite sandstones towards the base of the Soom Member in the Hex River Mountains by Almond (unpublished obs., 2011).

A low diversity shelly faunule, dominated by articulate and inarticulate brachiopods together with a small range of trace fossils is recorded from the heterolithic **Disa Member** that forms the upper portion of the Cedarberg Formation. Marine invertebrate fossils have been recorded from the Disa Member in the Groot Winterkoek mountains near Porterville, some 30km southeast of Piketberg, while important post-glacial trace fossil assemblages are known from the Clanwilliam region (Rust 1967b, Cocks *et al.* 1970, Cocks & Fortey 1986, Almond 2008).

The fossil record of the **Goudini** and **Skurweberg Formations**, dominated by braided fluvial sandstones, is very sparse indeed. This reflects major global regression (low sea levels) during the Silurian Period, peaking during the latter part of the period (Cooper 1986). Sporadic, low diversity ichnoassemblages from thin, marine-influenced stratigraphic intervals have been recorded from all three Nardouw formations in the Western Cape by Rust (1967a, 1981) and Marchant (1974). There are also scattered, often vague reports of trace fossils in geological sheet explanations and SACS reports (*e.g.* Malan *et al.* 1989, De Beer *et al.* 2002). Most involve "pipe rock" (*Skolithos* ichnofacies) or various forms of horizontal epichnial burrows, including possible members of the *Scolicia* group which may be attributable to gastropods. Also recorded are typical Early Silurian palmate forms of the annulated burrow *Arthrophycus*, poorly preserved "bilobites" (bilobed arthropod scratch burrows), gently curved epichnial furrows and possible arthropod tracks (Almond 2008). It is possible that more diverse ichnoassemblages (and even microfossils from subordinate mudrock facies where these have not been deeply weathered or tectonised) may eventually be recorded from the more marine-influenced outcrops of the Eastern Cape Fold Belt.

A distinctive marine shelly invertebrate faunule of Early Devonian, Malvinokaffric aspect characterises the upper portion of the **Baviaanskloof Formation** from the Little Karoo eastwards along the Cape Fold Belt. It is dominated by the globose, finely-ribbed articulate brachiopod *Pleurothyrella africana*. Rare homalonotid trilobites, a small range of articulate and inarticulate brachiopods, nuculid and other bivalves, plectonotid "gasteropods" and bryozoans also occur within impure brownish-weathering wackes (Boucot *et al*. 1963, Rossouw *et al*. 1964, Johnson 1976, Toerien & Hill 1989, Hill 1991, Theron *et al.* 1991, Almond *in* Rubidge *et al*. 2008). In many cases fossil shells are scattered and disarticulated, but *in situ* clumps of pleurothyrellid brachiopods also occur. This shelly assemblage establishes an Early Devonian (Pragian / Emsian) age for the uppermost Nardouw Subgroup, based on the mutationellid brachiopod *Pleurothyrella* (Boucot *et al*. 1963, Theron 1972, Hiller & Theron 1988). Trace fossils include locally abundant, mud-lined burrows (*Palaeophycus*, *Rosselia*) and rare giant rusophycid burrows of Devonian aspect (*R. rhenanus*) that are attributed to homalonotid trilobites. Recently, dense assemblages of primitive vascular plants with forked axes and conical terminal "sporangia" that are provisionally ascribed to the genus *Dutoitia* have been collected from Baviaanskloof Formation mudrocks near Cape St Francis, Eastern Cape, some 20 k south of Humansdorp (Dr Mark Goedhart, Council for Geoscience, Port Elizabeth, pers. comm., 2008; Robert Gess pers. comm., 2011; *cf* Hoeg 1930, Anderson & Anderson 1985).

During the present one-day field study almost all the Table Mountain Group exposures showed high levels of tectonic deformation (*e.g.* steep bedding, quartz veins, pervasive cleavage within mudrock intervals) as well as deep chemical weathering. These two factors, which are both more extremely developed within the potentially more fossiliferous mudrock-rich intervals of the Table Mountain Group (*e.g.* Cederberg, Goudini and Baviaanskloof Formation), have seriously compromised fossil preservation here. No fossil remains were observed within the Table Mountain Group sediments in the study area and the various formations concerned are considered to have a low palaeontological sensitivity in this region.

3.2. Fossils in the Lower Bokkeveld Group (Ceres Subgroup)

The most important fossil groups recorded from the lower Bokkeveld Group (Ceres Subgroup) include shelly marine invertebrates and traces (burrows *etc*), together with rare fish remains, primitive vascular plants, trace fossils (burrows, borings *etc*) and microfossils (*e.g.* foraminiferans, ostracods, palynomorphs). The overall palaeontological sensitivity of this stratigraphic unit is generally considered to be high to very high (Almond *et al*. 2008), but may be compromised locally by cleavage and weathering (*cf* Haughton *et al.* 1937, p. 23).

The Lower Bokkeveld Group is especially well known for its rich fossil assemblages of **marine invertebrates** of Early to Mid-Devonian age. The main invertebrate taxa concerned are trilobites, brachiopods, molluscs and echinoderms. Numerous more minor groups are also recorded - corals, conulariids, hyolithids, tentaculitids *etc* - making the Bokkeveld Group one of the palaeontologically most important Devonian units in the southern hemisphere. Fossil invertebrates are especially diverse and abundant within the mudrock-dominated formations, although low-diversity sandstone-hosted fossils assemblages also occur. Shells are generally preserved as external and internal moulds and casts (*e.g.* Schwarz 1906, Reed 1925, Du Toit 1954, Cooper 1982, Oosthuizen 1984, Hiller 1995, Hiller & Theron 1988, Theron & Johnson 1991, Jell & Theron 1999, Thamm & Johnson 2006, Almond 2008). Remarkably rich marine trace fossil assemblages are also known from the lower Bokkeveld Group, especially in nearshore facies (Almond 1998a, 1998b).

The only **vascular plants** recorded from the Ceres Subgroup are a small range of dichotomously branching, leafless forms known as psilophytes (*e.g. Dutoitia*) and primitive lycopods or “club mosses” such as *Palaeostigma*. The material is generally transported (washed offshore from the land), poorly preserved, and has mainly been recorded from the eastern outcrop area of the Bokkeveld Group (Plumstead 1967, 1969, Theron 1972, Anderson and Anderson 1985).

Very sparse **fossil fish** remains have been recorded from the Ceres Subgroup (Gydo and Tra Tra Formations), several retaining their original phosphatic bony material. They comprise acanthodians (“spiny sharks”), primitive sharks, placoderms, and bony fish or osteichthyans, but so far no agnathans (Almond 1997, Anderson *et al*. 1999a, 1999b). The material is fragmentary but of considerable palaeontological significance since so little is known about Early Devonian ichthyofaunas of the ancient supercontinent Gondwana.

So far, the great majority of published records of fossils from the Ceres Group refer to the much better known western outcrop areas in the Western Cape. In the Eastern Cape Province, where the potentially fossiliferous mudrocks are frequently highly deformed, cleaved, and often deeply weathered or covered by dense vegetation, the fossil known record is still rather sparse and understudied. Most of the early geological mapping surveys revealed very few useful fossil records – essentially a scattering of poorly preserved, often deformed marine shells and locally abundant trace fossils (*e.g.* Haughton 1928, 1935, Haughton *et al*., 1937, Engelbrecht *et al*., 1962). Apart from probable records of the primitive vascular plant *Dutoitea*, most early records of plant material and arthropods from the Bokkeveld Group in the Eastern Cape (such as those from near Port Alfred) are probably more correctly assigned to the younger lower Witteberg Group (*e.g.* Anderson & Anderson 1985).

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

The Gydo Formation succession in the Kareedouw – Humansdorp study area is dominated by offshore mudrocks and has clearly suffered high levels of tectonic deformation (steep bedding, pervasive cleavage *etc*) as well as deep chemical weathering. Since no fossil remains (apart from possible ferruginised low diversity invertebrate burrow assemblages) were observed during the present field study, these two factors have apparently obliterated most of all the fossil remains originally preserved in the near-surface bedrocks whose palaeontological sensitivity here is therefore assessed as low.

3.4. Fossils within Caenozoic superficial deposits

Sparse fossil remains have been recorded from Tertiary or younger silcretes (*i.e.* silica-cemented pedocretes) of the Grahamstown and equivalent formations by Roberts (2003) and earlier authors. These include a small range of trace fossils (*e.g.* rhizoliths or plant root casts and invertebrate burrows such as *Skolithos*), charophyte algae (calcareous stoneworts), reed-like wetland plants resembling the extant *Phragmites* (*fluitjiesriet*), and reworked Late Permian silicified wood from the Beaufort Group (See also Adamson 1934, Du Toit 1954, and Roberts *et al.,* 1997). Silicified termitaria might also be expected here, although termite activity is inhibited by waterlogged soils that probably prevailed in areas where silcrete formation occured.

Neogene to Recent alluvial deposits may also contain fossil remains of various types. In coarser sediments (*e.g.* conglomerates) these tend to be robust, highly disarticulated and abraded (*e.g*. rolled bones, teeth of vertebrates) but well-preserved skeletal remains of plants (*e.g.* wood, roots) and invertebrate animals (*e.g.* freshwater molluscs and crustaceans) as well various trace fossils may be found within fine-grained alluvium. Human artefacts such as stone tools that can be assigned to a specific interval of the archaeological time scale (*e.g.* Middle Stone Age) can be of value for constraining the age of Pleistocene to Recent drift deposits like alluvial terraces. Ancient alluvial “High Level Gravels” tend to be coarse and to have suffered extensive reworking (*e.g.* winnowing and erosional downwasting), so they are generally unlikely to contain useful fossils.

No fossil remains were observed within the various superficial deposits recorded within the Kareedouw – Humansdorp study area during the present field study.

4. ASSESSMENT OF TRANSMISSION LINE DEVELOPMENT IMPACTS ON PALAEONTOLOGICAL HERITAGE RESOURCES

The proposed 132 kV transmission line and associated substation developments are situated in areas that are underlain by potentially fossiliferous sedimentary rocks of Palaeozoic and Late Tertiary or Quaternary age (Sections 2 and 3). The construction phase of the transmission line and associated infrastructure may entail substantial excavations into the superficial sediment cover as well as locally into the underlying bedrock. In addition, considerable areas of bedrock may be sealed-in or sterilized by lay-down areas as well as new gravel roads. All these developments may adversely affect fossil heritage resources at or beneath the surface of the ground within the development footprint by destroying, disturbing or permanently sealing-in fossils that are then no longer available for scientific research or other public good. Once constructed, the operational and decommissioning phases of the transmission line are unlikely to involve further adverse impacts on palaeontological heritage, however.

The inferred impact of the proposed transmission line development on local fossil heritage is analysed in Table 1 below. This assessment applies to the transmission line itself as well as associated substation and road infrastructure developments.

In general, the destruction, damage or disturbance out of context of fossils preserved at the ground surface or below ground that may occur during construction represents a *negative* impact that is limited to the development footprint. Such impacts can usually be mitigated but cannot be fully rectified (*i.e. permanent*). Because of the generally sparse occurrence of fossils within most of the formations concerned as well as within the overlying superficial sediments (soil *etc*), as inferred from better exposed localities elsewhere, the intensity and probability of impacts are conservatively rated as *low*.

Due to the high to very high levels of bedrock weathering and tectonic deformation observed within and close to the Humansdorp study area, the impact significance of the construction phase of the proposed transmission line project with respect to fossil heritage resources is assessed as LOW. There are no fatal flaws in the development proposal as far as fossil heritage is concerned.

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

Despite the low levels of bedrock exposure within the study area, confidence levels for this assessment are HIGH following the one-day field assessment of representative geological sites, supplemented by other palaeontological heritage assessment studies in the Humansdorp region.

Table 1: Assessment of impacts on palaeontological heritage resources resulting from the proposed 132 kV Kareedouw – Dieprivier transmission line project

CRITERIA	RATING	COMMENTS
Nature	Negative	Disturbance, damage, destruction or sealing-in of fossil remains preserved on or beneath the ground surface within the development area, notably by bedrock excavations during the construction phase of the transmission line, substations.
Extent	Low	Site specific
Duration	High	Permanent
Intensity	Low	
Potential for impact on irreplaceable resources	Low	Sedimentary formations affected have large outcrop area outside development footprint
Consequence	Low	
Probability	Low	Almost all original fossil heritage has been destroyed near-surface by tectonic deformation and deep chemical weathering
Significance	LOW	No recommendation for further specialist palaeontological studies or mitigation for this project

5. CONCLUSIONS AND RECOMMENDATIONS

On the basis of the current field assessment as well as the paucity of previous fossil records from the Humansdorp region it is concluded that the palaeontological sensitivity of the Palaeozoic bedrocks here is low due to high levels of tectonic deformation (*e.g.* folding, cleavage) and chemical weathering. This applies especially to the more mudrock-rich stratigraphic units (*e.g.* Cederberg and Gydo Formations) that may originally have been highly fossiliferous. The various Late Caenozoic superficial deposits mantling the bedrocks in the study region (*e.g.* alluvium, colluvium, soils, pedocretes) are also of low palaeontological sensitivity.

Given the resulting low impact significance of the proposed transmission line – including the associated substation and road developments - as far as palaeontological heritage is concerned, no further specialist studies or mitigation are considered necessary for this project.

It is recommended that:

- The Environmental Control Officer (ECO) responsible for the transmission line development should be at least aware of the possibility – albeit low - of important fossils (*e.g.* shells, plant remains, trace fossils, mammalian bones and teeth) being present or unearthed on site and should regularly monitor all substantial excavations into superficial sediments as well as fresh (*i.e.* unweathered) sedimentary bedrock for fossil remains;

- In the case of any significant fossil finds (*e.g.* vertebrate teeth, bones) made during construction, these should be safeguarded - preferably *in situ* - and reported by the ECO as soon as possible to the relevant heritage management authority (ECPHRA. Contact details: Mr Sello Mokhanya, 74 Alexander Road, King Williams Town 5600; smokhanya@ecphra.org.za) so that appropriate mitigation (*i.e.* recording, sampling or collection) by a palaeontological specialist can be considered and implemented, at the developer's expense; and

- These recommendations should be incorporated into the Environmental Management Plan (EMP) for the 132 kV transmission line project.

The palaeontologist concerned with mitigation work will need a valid palaeontological collection permit from SAHRA (Contact details: Mrs Colette Scheermeyer, P.O. Box 4637, Cape Town 8000. Tel: 021 462 4502. Email: cscheermeyer@sahra.org.za). All 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 to the minimum standards for Phase 2 palaeontological studies developed by SAHRA (2013).

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8. 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 under the aegis of his Cape Town-based company *Natura Viva* cc. He is 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 transmission line project, application or appeal in respect of which I was appointed other than fair remuneration for work performed in connection with the activity, application or appeal. There are no circumstances that compromise the objectivity of my performing such work.

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

APPENDIX: GPS LOCALITY DATA FOR NUMBERED SITES LISTED IN TEXT

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

Location number	South	East	Comments
018	S33 57 41.4	E24 16 07.1	Weathered Peninsula Fm, Kareedouw Pass
019	S33 57 33.5	E24 16 14.2	Weathered Peninsula Fm overlain by ferruginised colluvial gravels, Kareedouw Pass
020	S33 55 58.7	E24 15 42.4	Weathered Gydo Fm, R62 road cutting
021	S33 55 39.3	E24 15 10.9	Baviaanskloof Fm wackes
022	S33 55 34.7	E24 14 43.5	Weathered Gydo Fm, R62 road cutting
022a			Weathered Gydo Fm, R62 road cutting
023	S33 55 40.5	E24 12 53.6	Kou-Kamma Substation site, pediment gravels on Table Mountain Group
024	S33 55 40.5	E24 12 53.6	Weathered Gydo Fm, R62 road cutting
025	S33 55 16.7	E24 12 53.1	Weathered Gydo Fm, R62 road cutting
026	S33 56 42.2	E24 18 17.9	Weathered Gydo Fm incised by ancient alluvial gravels, R62 road cutting
027	S33 56 25.9	E24 18 41.8	Colluvial gravel deposits overlying Nardouw succession
028	S33 56 03.9	E24 17 50.1	Colluvial gravel deposits overlying Nardouw succession
029	S33 55 33.4	E24 17 08.0	Heterolithic sandstones and mudrocks, possibly Disa Member of Cederberg Fm, borrow pit
030	S33 55 16.8	E24 16 55.4	Cederberg Formation mudrocks, road cutting
031	S33 55 33.2	E24 17 14.2	Heterolithic sandstones and mudrocks, possibly Disa Member of Cederberg Formation or Goudini Formation
032	S33 55 31.6	E24 17 15.5	Heterolithic sandstones and mudrocks, possibly Disa Member of Cederberg Formation or Goudini Formation
033	S33 55 46.0	E24 17 21.5	Cross-bedded Skurweberg Fm, colluvium in road cutting
034	S33 56 18.3	E24 18 20.7	Cross-bedded Skurweberg Fm, colluvium in road cutting
035	S33 56 57.0	E24 20 05.2	Ocheous deeply weathered Gydo Fm, R62 road cutting
036	S33 57 16.0	E24 21 23.8	Deeply-weathered Table Mountain Group, possibly Baviaanskloof Formation
037	S33 57 20.0	E24 21 35.1	Deeply-weathered Table Mountain Group, possibly Baviaanskloof Formation, plus surface gravels
038	S33 57 43.5	E24 23 03.2	Mottled ferruginised sandy alluvium
039	S33 58 52.1	E24 30 21.3	Possible weathered Cederberg Fm or Goudini Fm in R62 roadcutting
040	S33 59 43.4	E24 32 15.5	Rubbly ferruginised and sl. silcretised colluvial gravels overlying Table Mountain Group bedrock, R62 road cutting
041	S34 00 21.2	E24 33 25.4	Ferricrete float blocks and excavated blocks at Dieprivier Substation
042	S34 00 24.8	E24 33 21.8	In situ ferricrete near Dieprivier Substation