

Natura Viva cc



**Environmental Impact Assessment for the
Establishment of the Langhoogte Wind Farm,
Western Cape Province**

Environmental Scoping Report

Palaeontology Specialist Study

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February 2012

DECLARATION OF INDEPENDENCE

I, Dr John E. Almond, as duly authorised representative of Natura Viva cc, hereby confirm my independence (as well as that of Natura Viva cc), as the palaeontology specialist for the Langhoogte wind farm project near Caledon, Western Cape, and declare that neither I nor Natura Viva cc have any interest, be it business, financial, personal or other, in any proposed activity, application or appeal in respect of which Arcus GIBB was appointed as environmental assessment practitioner in terms of the National Environmental Management Act, 1998 (Act No. 107 of 1998), other than fair remuneration for work performed in terms of the NEMA, the Environmental Impact Assessment Regulations, 2010 and the National Heritage Resources Act, 1999 for the Langhoogte wind farm project. I further declare that I am confident in the results of the studies undertaken and conclusions drawn as a result of it. I have disclosed, to the environmental assessment practitioner, in writing, any material information that has or may have the potential to influence the decision of the competent authority or the objectivity of any report, plan or document required in terms of the NEMA, the Environmental Impact Assessment Regulations, 2010 and The National Heritage Resources Act, 1999. I have further provided the environmental assessment practitioner with written access to all information at my disposal regarding the application, whether such information is favourable to the applicant or not. I am fully aware of and meet the responsibilities in terms of NEMA, the Environmental Impact Assessment Regulations, 2010 and any other specific and relevant legislation (national and provincial), policies, guidelines and best practice.



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EXECUTIVE SUMMARY

The Langhoogte wind farm study area between Botrivier and Caledon, Western Cape Province, is largely underlain by Early to Middle Devonian marine sediments of the Bokkeveld Group (Ceres and Bidouw Subgroups), with a small area of older Table Mountain Group rocks in the extreme west (Houhoekberge). The Table Mountain Group rocks typically only contain very sparse fossil remains. In contrast, the Bokkeveld Group rocks were probably once highly fossiliferous, containing rich assemblages of shelly invertebrates and trace fossils as well as drifted land plant remains, rare fish and microfossils. However, on the southern coastal plain their fossil content has been largely destroyed by intense tectonic deformation in the Permo-Triassic Cape Orogeny (mountain-building event) as well as by deep chemical weathering under humid tropical climates during the Late Cretaceous to Tertiary period beneath the so-called "African Surface". Exposure of these Palaeozoic rocks within the study area is very limited due to extensive cover by superficial sediments (mainly lag gravels, soils, alluvium, colluvium) that are themselves very poorly fossiliferous to unfossiliferous. A variety of Paleogene (Early Tertiary) to Quaternary duricrusts - tough, secondarily cemented superficial deposits including silcretes and ferricretes - are present in the broader study region but these are also largely unfossiliferous. Apart from local occurrences of poorly-preserved trace fossils of limited scientific interest, no fossil remains were noted within the study area during a two-day field assessment. Previous field-based studies in the southern Cape coastal region have also yielded very few fossil remains and there are very few records of fossils from this region in the literature. The effective paleontological sensitivity of the Table Mountain Group, Bokkeveld Group and younger sedimentary rocks in the study area is now very low.

The overall impact significance of the construction phase of the proposed Langhoogte wind farm project on fossil heritage resources is consequently assessed as low (*negative*). The impact significance of the alternative northern and southern routes for the proposed new 132 kV transmission line between the new on-site substation and the existing Botrivier substation is similar and low. There is consequently no preference for either route on palaeontological heritage grounds. The site of the proposed on-site substation on farm 361/1 is not palaeontologically sensitive.

The operational and decommissioning phases of the wind energy facility will not involve significant adverse or other impacts on palaeontological heritage. The proposed development has no fatal flaws in terms of impacts on fossil heritage and there are no recommendations for specialist palaeontological mitigation or further studies for this project. Confidence levels for this assessment are high.

At least three other alternative energy developments have been proposed for the Botrivier – Caledon region. Since the bedrocks in this region are generally of low to very low palaeontological sensitivity, the cumulative impact of the proposed developments on fossil heritage is considered to be of low significance.

The ECO responsible for the Langhoogte wind farm development should be alerted to the possibility of fossil remains being found on the surface or exposed by fresh excavations during construction. Should substantial fossil remains be discovered or exposed during development, the responsible ECO should alert Heritage Western Cape so that appropriate mitigation measures may be considered. These measures would normally involve the recording and judicious sampling of fossil material by a professional palaeontologist at the developer's expense. The specialist involved would require a collection permit from SAHRA, fossil material must be curated in an approved repository, and all work carried out should meet the minimum standards for palaeontological impacts developed by SAHRA. Mitigation in the form of fossil recording and collection should have a *positive* impact on our appreciation of local fossil heritage.

These recommendations should be incorporated into the Environmental Management Plan for the Langhoogte wind farm development.

**ENVIRONMENTAL IMPACT ASSESSMENT FOR THE
ESTABLISHMENT OF THE PROPOSED LANGHOOGTE WIND
FARM, WESTERN CAPE PROVINCE:
ENVIRONMENTAL SCOPING REPORT -
SPECIALIST PALAEOLOGY STUDY**

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1 INTRODUCTION

1.1 Background

The company SAGIT is proposing to construct a wind farm of between 40 and 65 MW generating capacity in an area of approximately 3940 hectares between the settlements of Botrivier and Caledon in the Western Cape Province (Figs. 1, 2). Land parcels involved in the Langhoogte wind farm project are shown in Figure 1 below.

The main components of the proposed Langhoogte wind energy facility are as follows:

- Between 20 and 30 wind turbines, each of 2.5 to 3 MW generating capacity. Construction of the wind turbine tower foundations (c. 17.3m wide) would involve excavating to a depth of approximately 3 meters, then using steel, gravel and concrete. Before each foundation is excavated, topsoil and subsoil will be salvaged and stored nearby.
- Internal access roads from the existing R43 / N2 to the operations area. Existing gravel farm roads will be upgraded where required and special haul roads may need to be constructed to and within the site to accommodate abnormally loaded vehicle access and circulation. Internal service roads will also be constructed between the turbines and infrastructure within the proposed site for use during construction and operation. As far as possible, existing roads will be utilized. The total length of these roads will vary depending on the arrangement of the turbines. The roads will be three to four meters wide, two track roads, covered with gravel. Where possible, gravel taken from areas of excavation (cut) will be used to provide material where more is required (fill) and to surface the road. If additional gravel is needed, it will be transported from a nearby quarry.
- A temporary track of approximately 13m in width will also be required for use by the crawler crane which will be used to erect towers and turbines during construction. This track will be located adjacent to the permanent road and use part of the permanent road. The track will be removed – rehabilitated with stockpiled soil and indigenous vegetation - once the crane is no longer required (after the assembly of the turbines).
- Underground transmission lines to carry the electricity from the turbines to a proposed on-site substation on Farm 362/1.
- A new 132 kV electricity transmission line (monopoles) from the on-site substation to the existing Eskom substation located immediately SW of Botrivier where the electricity will enter the grid. Two alternative powerline routes, referred to as the northern route (approximately 9.5 km long) and the southern route (approximately 8 km long), are currently under consideration. These routes are shown on Figure 2 below. The last 4.5 km of each route will run in parallel to an existing 66 kV transmission line.
- An off-site control center compound located potentially in Caledon or inland.
- Temporary works used during the construction period consisting of a temporary compound and staging area located within the site. As far as possible the construction compound will be located on already disturbed land. The main compound will include a parking area, a generator with fuel storage, and temporary buildings to provide secure storage, site offices, and welfare and first aid facilities.

1.2 Legislative and Policy Context

An Environmental Impact Assessment is being undertaken by Arcus Gibb Engineering and Science, Cape Town, for the proposed Langhoogte Wind Farm in accordance with the National Environmental Management Act 1998 (Act 107 of 1998).

The present report forms part of the Basic Assessment Process and EIA for the proposed Langhoogte Wind Farm, also falling under Section 38 (Heritage Resources Management) of the South African Heritage Resources Act (Act No. 25 of 1999), and it will also inform the Environmental Management Plan for this project.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

The proposed development area is underlain by potentially fossiliferous rocks of the Table Mountain and Bokkeveld Groups (Fig. 4). An integrated Heritage Impact Assessment (HIA) for this project has therefore been requested by Heritage Western Cape that is to include a palaeontological specialist study (HWC Interim Comment, 14 July 2011).

Minimum standards for the palaeontological component of heritage impact assessment reports (PIAs) are currently being developed by SAHRA. The latest version of the SAHRA draft guidelines was circulated for comment in November 2011.

1.3 Assessment Methodology

This specialist report provides an assessment of the observed or inferred palaeontological heritage within the study area in particular, with recommendations for specialist palaeontological mitigation where this is considered necessary. The report is based on (1) a review of the relevant scientific literature, (2) published geological maps and accompanying sheet explanations, (3) previous palaeontological assessments of developments in the region (e.g. Almond 2010a, 2010b, 2010c); (4) a two-day field assessment of the study region carried out over the period 1 to 3 November, 2011; (5) the author's extensive field experience with the formations concerned and their palaeontological heritage.

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

The focus of palaeontological scoping work is *not* simply to survey the development footprint or even the development area as a whole (e.g. farms or other parcels of land concerned in the development). Rather, the palaeontologist seeks to assess or predict the diversity, density and distribution of fossils within and beneath the study area, as well as their heritage or scientific interest. This is primarily achieved through a careful field examination of one or more representative exposures of all the sedimentary rock units present (*N.B.* Metamorphic and igneous rocks rarely contain fossils). The best rock exposures are generally those that are easily accessible, extensive, fresh (*i.e.* unweathered) and include a large fraction of the stratigraphic unit concerned (e.g. formation). These exposures may be natural or artificial and include, for example, rocky outcrops in stream or river banks, cliffs, quarries, dams, dongas, open building excavations or road and railway cuttings. Uncemented superficial deposits, such as alluvium, scree or wind-blown sands, may occasionally contain fossils and should also

be included in the scoping study where they are well-represented in the study area. It is normal practice for impact palaeontologists to collect representative, well-localized (e.g. GPS and stratigraphic data) samples of fossil material during scoping studies. All fossil material collected must be properly curated within an approved repository (usually a museum or university collection).

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

Since natural bedrock exposure within the Langhoogte Wind Farm study area is very limited, most of the observations made during fieldwork focussed on extensive road cuttings along the N2, R43 and other minor roads crossing the area. Other informative sites included hillslope outcrops, erosion gullies, stream beds and farm dams. Railway cuttings were also available but were largely avoided for safety and access reasons. GPS locality information for all numbered localities mentioned in the text is given in Appendix 1.

On the basis of the desktop and field-based assessment studies, the likely impact of the proposed development on local fossil heritage and any need for specialist mitigation are then determined. Adverse palaeontological impacts normally occur during the construction rather than the operational or decommissioning phase. Mitigation by a professional palaeontologist – normally involving the recording and sampling of fossil material and associated geological information (e.g. sedimentological data) – is usually most effective during the construction phase when fresh fossiliferous bedrock has been exposed by excavations. To carry out mitigation, the palaeontologist involved will need to apply for a palaeontological collection permit from the relevant heritage management authority (e.g. Heritage Western Cape for the Western Cape). It should be emphasized that, *providing appropriate mitigation is carried out*, the majority of developments involving bedrock excavation can make a *positive* contribution to our understanding of local palaeontological heritage.

1.3.1 Assumptions & limitations

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

1. Inadequate database for fossil heritage for much of the RSA, given the large size of the country and the small number of professional palaeontologists carrying out fieldwork here. Most development study areas have never been surveyed by a palaeontologist.
2. Variable accuracy of geological maps which underpin these desktop studies. For large areas of terrain these maps are largely based on aerial photographs alone, without ground-truthing. The maps generally depict only significant (“mappable”) bedrock units as well as major areas of superficial “drift” deposits (alluvium, colluvium) but for most regions give little or no idea of the level of bedrock outcrop, depth of superficial cover (soil *etc*), degree of bedrock weathering or levels of small-scale tectonic deformation, such as cleavage. All of these factors may have a major influence on the impact significance of a given development on fossil heritage and can only be reliably assessed in the field.
3. Inadequate sheet explanations for geological maps, with little or no attention paid to palaeontological issues in many cases, including poor locality information.

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

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

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

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

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

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

For study areas on the southern coastal plain, including the Botrivier – Caledon region, the main factors usually limiting an accurate assessment of the potential impact of the proposed development on fossil heritage are uncertainties concerning the levels of weathering, tectonic deformation and superficial sediment cover within the outcrop areas of any palaeontologically sensitive rock units, and the degree to which these factors have compromised local fossil heritage. These uncertainties were adequately addressed during the two-day field assessment undertaken by the author. Levels of confidence concerning this palaeontological assessment are therefore high.

2 DESCRIPTION OF AFFECTED ENVIRONMENT

The Langhoogte Wind Farm study area is situated on hilly to mountainous terrain north of the N2 trunk road between the settlements of Botrivier and Caledon, Western Cape (Figs. 1 & 2; 1: 50 000 topographical maps 3419 AA, AB). The westernmost sector, west of the narrow Botrivier Valley, extends onto the steep, rocky eastern slopes of the Houhoekberge, up to about 800m amsl, which are clad with fynbos vegetation. The greater part of the study area, east of the Botrivier Valley, forms part of the gently hilly *rûens* region of the southern Cape coastal plain where low, rounded hills up to 330 m amsl are dissected by shallow streams. Most of the original vegetation here has been replaced by croplands, with the exception of deeper stream valleys and erosion gullies or *dongas*. Natural bedrock exposure in the *rûens* area is very poor indeed, and is mainly limited to intermittent exposures in stream beds and narrow *kranzes* along hillslopes. Artificial bedrock exposures are available, however, in numerous road cuttings (e.g. along the N10 and R43 as well as more minor farm and public roads traversing the study region), in railway cuttings, and around the margins of farm dams.

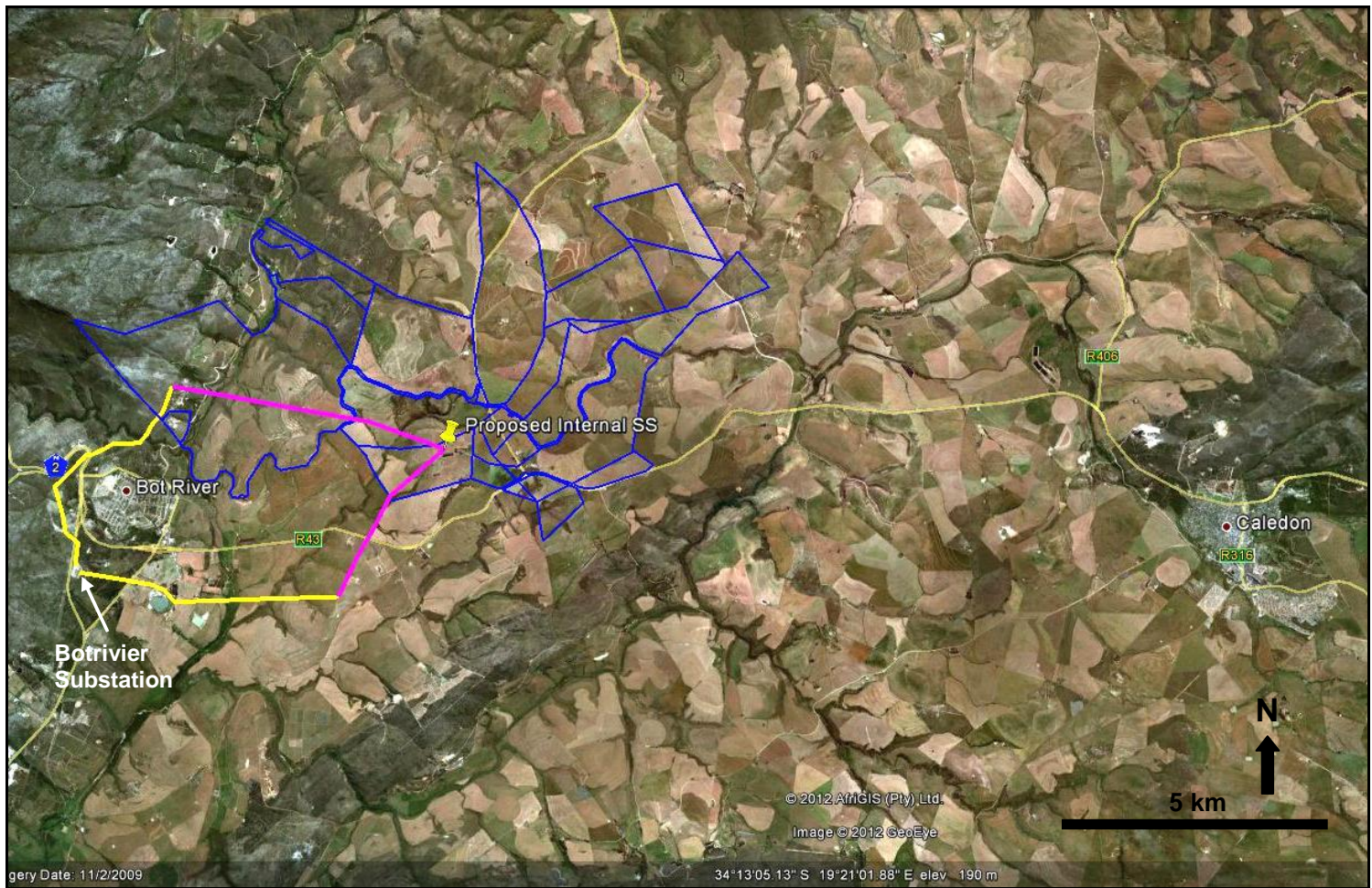


Figure 1. Google Earth® satellite image of the area between Botrivier and Caledon, showing the location of the Langhoogte Wind Farm study area (land parcels outlined in blue) extending from the eastern slopes of the Houhoekberge north of Botrivier into the extensively cultivated hilly *rûens* area north of the N2 highway. The pink and yellow lines show alternative routes for the proposed new 132 kV transmission line between the new on-site substation and the Botrivier Substation.

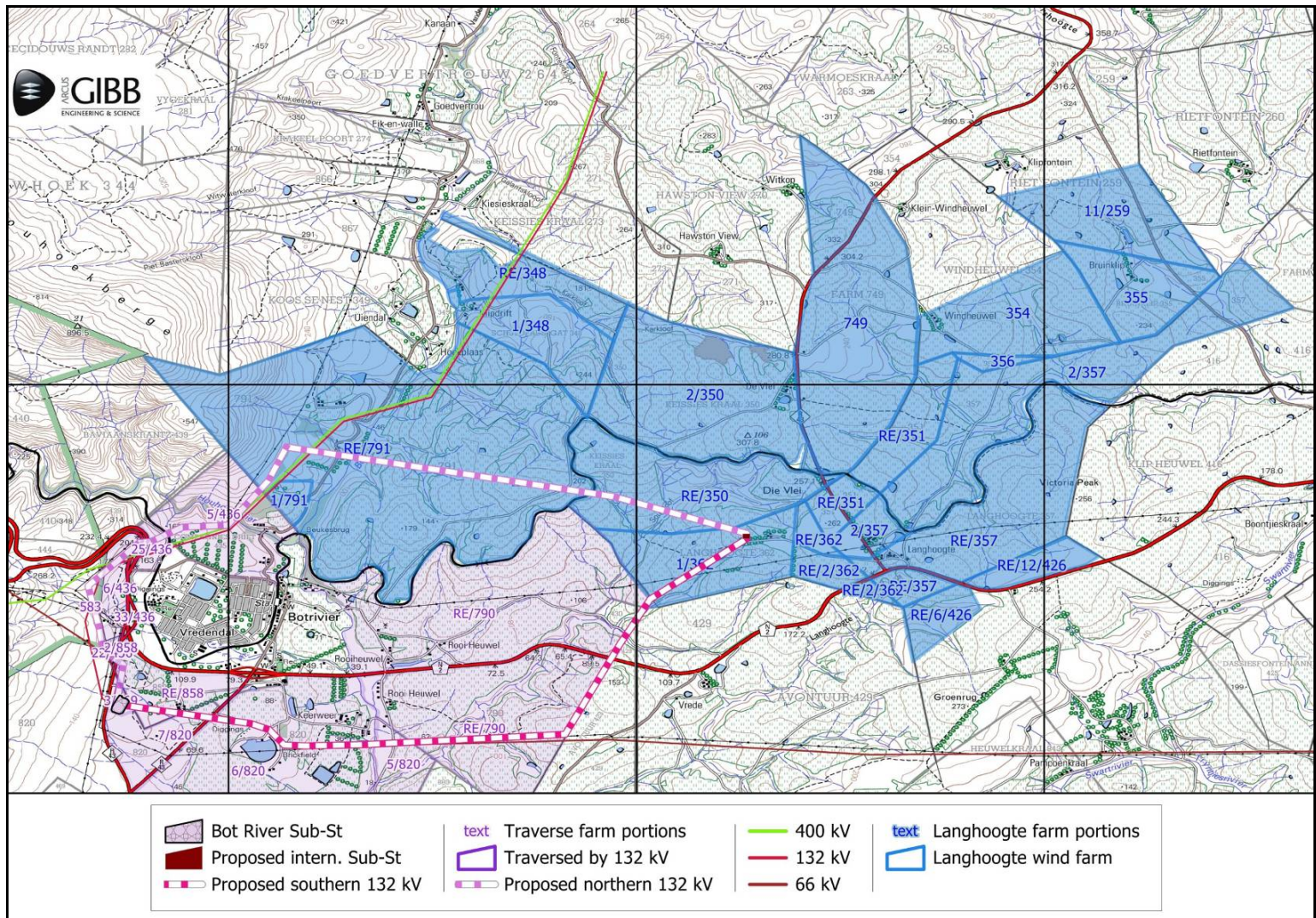


Figure 2. Land parcels involved in the proposed Langhoogte wind farm to the northeast of Botrivier and alternative routes of the proposed new 132 kV transmission lines (Image kindly provided by Arcus Gibb Engineering & Science).

2.1 Geological context

The geology of the study area is depicted on the 1: 250 000 scale geological sheet 3319 Worcester (Gresse & Theron 1992; see also the older 1: 125 000 Worcester- Hermanus map and sheet explanation by De Villiers *et al.* 1964) (Fig. 4). The study area is underlain by highly-deformed and deeply-weathered sedimentary rocks of the Early to Middle Palaeozoic **Cape Supergroup**. Resistent, quartzitic rocks of the **Table Mountain Group**, Silurian in age, build the Houhoekberge in the west. The hilly *rûens* area is underlain by marine to near-coastal mudrocks and sandstones of the Early to Middle Devonian **Bokkeveld Group**. In this region the two successions are juxtaposed along a major NE-SW trending fault running just to the west of Botrivier and on the western side of the Botrivier Valley. The Bokkeveld Group rocks form the outer limbs of a major NE-SW trending synclinal structure with more resistant-weathering rocks of the lower Witteberg Group rocks in its core, building the higher-lying ground to the NE of the wind farm study area (*e.g.* Bergfonteinkop). Most of the Bokkeveld Group rocks in the study area belong to the **Ceres Subgroup** (Lower Bokkeveld Group) but younger Bokkeveld sediments of the **Bidouw Subgroup** (Upper Bokkeveld Group) crop out in the north. The Palaeozoic bedrocks are extensively mantled by a range of **superficial deposits** of Late Tertiary to Recent age (*e.g.* soils, surface gravels, colluvium, alluvium). For the most part, these younger deposits are not indicated on geological maps at 1: 250 000 scale (Fig. 4).

Much of the general geological background information provided here has been abstracted from recent palaeontological assessment studies on similar rocks by the author elsewhere in the *rûens* region of the southern Cape coastal belt (*e.g.* Almond 2010a, 2010b, 2011). GPS locality information for all numbered localities mentioned in the text is given in Appendix 1.



Figure 3. View from N2 north-westwards across study area towards the Houhoekberge north of Botrivier. White dashed line indicates E-W trending fault causing tectonic repetition of the Table Mountain Group in the Houhoekberge (Oc = Cederberg Formation; Ss = Skurweberg Formation). Road cutting in the foreground shows deeply-weathered, thin-bedded mudrocks of the Tra Tra Formation (Bokkeveld Group) overlain by rubbly mudrock regolith, semi-consolidated soils and downwasted surface gravels (Loc. 153).

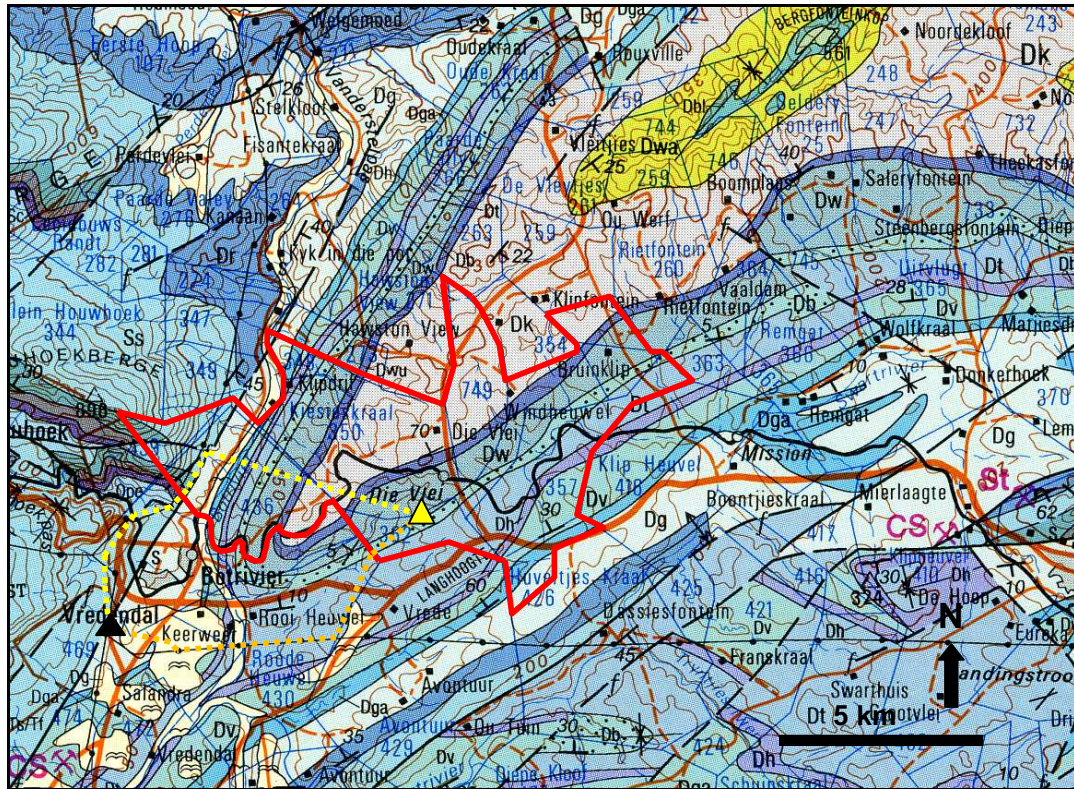


Figure 4. Extract from 1: 250 000 geology map 3319 Worcester (Council for Geoscience, Bellville) showing approximate outline of the Langhoogte wind farm study area (red polygon). The alternative northern route (yellow dotted line) and southern route (orange dotted line) for the proposed new 132 kV transmission line between the on-site substation (yellow dot) and Botrivier substation (black dot) are also shown.

The main bedrock units represented here include, in order of decreasing age:

TABLE MOUNTAIN GROUP (Silurian)

Skurweberg Formation (Ss, pale blue)

BOKKEVELD GROUP (Early to Middle Devonian)

Gydo Formation (Dg, pale blue) – mudrock dominated

Gamka Formation (Dga, middle blue) – sandstone dominated

Voostehoek Formation (Dv, greenish-blue) – mudrock dominated

Hexrivier Formation (Dh, lilac) – sandstone dominated

Tra Tra Formation (Dt, blue) – mudrock dominated

Boplaas Formation (Db, greenish-blue with dots) – sandstone dominated

Waboomberg Formation (Dw, blue) – mudrock dominated

Wuppertal Formation (Dwu, dark blue) – sandstone dominated

Karies *plus* Klipbökkop Formations (DK, pinkish) – mudrock and sandstone dominated respectively

SUPERFICIAL DEPOSITS

Pale yellow with “flying bird” symbol – alluvium, including High Level Gravels (some silcretised)

N.B. Most superficial deposits are not indicated on geological maps at this scale.

2.1.1. Table Mountain Group

Useful overviews of Table Mountain Group geology in general include Rust (1967, 1981), Hiller (1992), Malan & Theron (1989), Broquet (1992), Johnson *et al.*, (1999), De Beer (2002), Thamm & Johnson (2006), and Tankard *et al.*, (2009). For the Worcester sheet area specifically, these rocks are briefly described by Gresse and Theron (1992), as well as in the older sheet explanation by De Villiers *et al.* (1964). The Table Mountain Group rocks northwest of Botrivier are cut by a major E-W trending fault that has led to tectonic repetition of the succession, as clearly seen by the repeated recessive-weathering bands of the Cedarberg Formation (Figs. 3 & 5). Also seen here is the highly deformed Fold Zone within the uppermost Peninsula Formation and the reddish-brown coloration of the Goudini Formation. Only the overlying Skurweberg Formation may be directly affected by the proposed development.

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. 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.

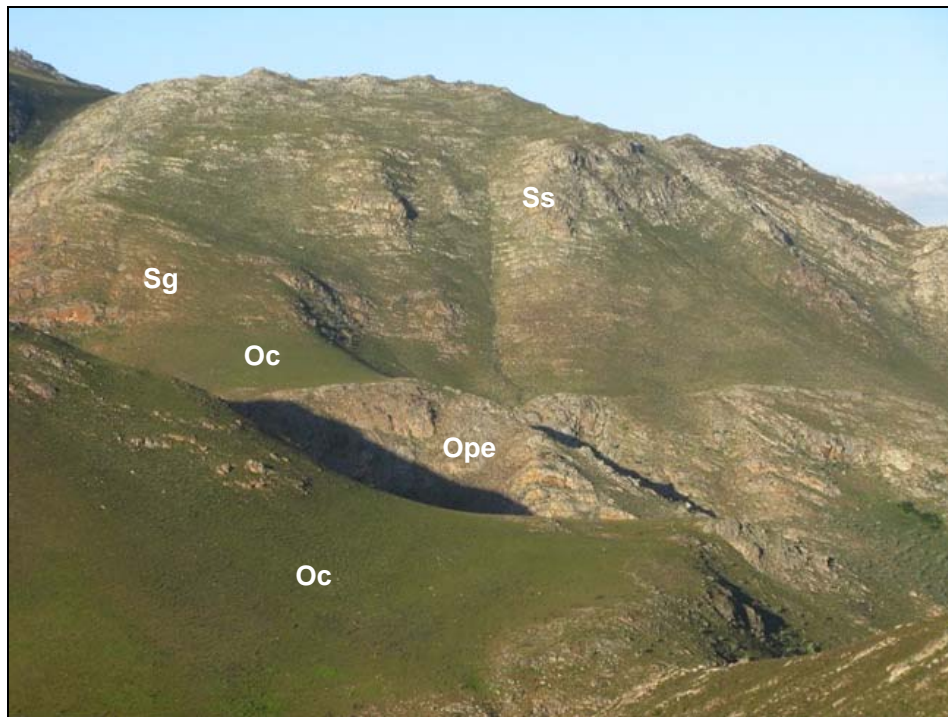


Figure 5. Table Mountain Group succession in the eastern Houhoekberge, viewed from the southwest. The wind farm study area lies just to the north east. A major E-W fault (white dashed line) runs along the valley in the background (Fig. 3). Formations seen here include: Peninsula Formation with well developed Fold Zone towards the top (Ope), Cedarberg Formation or “Shale Band” (Oc), reddish-brown weathering Goudini Formation (Sg) and grey-weathering Skurweberg Formation (Ss).

Good exposures of Skurweberg quartzites are seen in several roadcuttings along the N2 in the Houhoek Pass. Here medium- to thick-bedded, tabular to lenticular quartzites often display well-developed tabular cross-bedding (palaeocurrents to the SE), with occasional thin quartz pebble lenticles and heterolithic siltstone / sandstone intervals. The succession here is deeply weathered, as shown by the very pale, friable (leached) arenites and kaolinitisation of intervening mudrock units (Fig. 6). Quartz veins suggest bedding plane slippage during

folding. Skurweberg outcrops on the eastern face of the Houhoekberge are fairly subdued, with little bedrock exposure at lower elevations (Fig. 3). The surface is mantled in sandstone gravels, often secondarily ferruginised.



Figure 6. Highly weathered, pale quartzites of the Skurweberg Formation in Houhoek Pass showing well-developed tabular cross-bedding (palaeocurrents to the SE).

2.1.2. Bokkeveld Group

The Bokkeveld Group, the middle unit of the Cape Supergroup, is a thick (c. 1.5 to 3.5km) succession of fossiliferous sedimentary rocks which was deposited in shallow marine to coastal settings during the Early to Middle Devonian Period, about 400 to 375 million years ago. These sediments accumulated on an area of continental shelf – the Cape Basin – which then lay towards the southern edge of the supercontinent Gondwana at moderately high palaeolatitudes (c. 70°S). Key accounts of Bokkeveld Group geology and sedimentology are given by Theron (1972), Tankard and Barwis (1982), Theron and Loock (1988), Theron and Thamm (1990), Theron and Johnson (1991), Broquet (1992) as well as Thamm and Johnson (2006). An outline of the Bokkeveld Group rocks in the Worcester sheet area is given by Gresse and Theron (1992; see also De Villiers *et al.* 1964).

Due to extensive drift cover (alluvium, lag gravels, soils) as well as deep weathering and tectonic deformation, outcrops of fresh Bokkeveld bedrock are not available in the study area. For these reasons, as well as the southwards thinning of key sandstone marker horizons, it is difficult - though not impossible - to distinguish individual formations within the Ceres Subgroup for mapping purposes (Fig. 4). However, there are intermittent hillslope, stream and roadcutting exposures of the various marker sandstones. The Bokkeveld Group rocks in the study area are folded on both large and small scales and also transected by numerous faults.

The most extensive exposures of Bokkeveld Group rocks in the study area are found in several roadcuts along the N2, R43 and other, more minor roads in the study region as well as in a number of small dams, streams and rocky *kranzes*. Due to deep chemical weathering beneath the “African Surface” (See Section 2.1.3. below), which may extend to depths of 40-

100m beneath the land surface in the southern coastal belt (Marker *et al.* 2002), fresh Bokkeveld bedrock is almost nowhere to be seen in this region. The clay-rich Bokkeveld mudrocks have been extensively altered to kaolinite-rich saprolite showing variously white, cream, khaki, ochreous, maroon or lilac to pinkish hues (Figs. 7, 9). Recently exposed sections through these relatively incoherent rocks may develop honeycomb weathering. Lateritic weathering has also led to the segregation of iron-rich minerals as dark blackish to purple or rusty veins and patches within the generally pallid saprolite (Marker *et al.* 2002). Original medium- to small-scale sedimentary and tectonic features such as bedding, cleavage and lamination are often preserved, but occasionally the saprolite is (secondarily) massive. Greyish to buff sandstone-rich successions often show distinctive swaley to hummocky cross-lamination indicating deposition by major storms in an offshore / lower shoreface setting. Most sandstones are fine to medium-grained, micaceous “impure” wackes with a tabular to lenticular geometry. Thinner tempestite sandstones with wave-rippled tops are interbedded with wavy laminated siltstones to form heterolithic intervals which may contain small-scale coarsening-upwards (shoaling) parasequences. Fresher mudrocks are mainly grey to grey-green, wavy rippled to flat-laminated siltstones. Small-scale “rhythmites” consisting of stacked coarsening-upwards cycles a few cm thick represent distal turbidites or tempestites deposited on the offshore shelf.

Bokkeveld mudrock facies here generally display a pronounced tectonic cleavage, here axial planar to the NE-SW trending megasyncline between Botrivier and Caledon, and this is also developed as a well-developed spaced cleavage in clay-rich “dirty” sandstones or wackes (Figs. 11, 14). Cleavage facilitates penetration and movement of groundwater and hence chemical weathering. High levels of tectonic deformation (folding and faulting) of the original well-bedded Bokkeveld succession is also indicated by convolute to crumpled bedding, steep and variable dips, numerous small-scale faults (including low-angle thrusts), extensive quartz veining, boudinage of more competent sandstones, and brecciated zones.

2.1.2.1. Gydo Formation

Mudrocks of the Gydo Formation are well-exposed in N2 roadcuts west of Caledon where they are invariably altered to multi-hued, deeply weathered saprolite (Fig. 7). Superficially (but perhaps secondarily) massive as well as thin-bedded “rhythmite” facies are present. Secondary iron / manganese mineralisation is expressed as dense networks of veins as well as numerous irregular nodules, and has led to the replacement of tubular burrow systems that weather out as cylindrical hollow structures (Fig. 8). Large (1cm wide) cubical pseudomorphs after pyrite are also seen.

Extensive roadcuts along the Botrivier Valley also display weathered, highly-cleaved mudrocks. In this case the depth of weathering may have been enhanced by groundwater movement along the Table Mountain / Bokkeveld contact fault (Fig. 4).



Figure 7. Deeply-weathered saprolite developed from thin-bedded mudrocks of the Gydo Formation, N-facing roadcut on the N2 (Loc. 149).

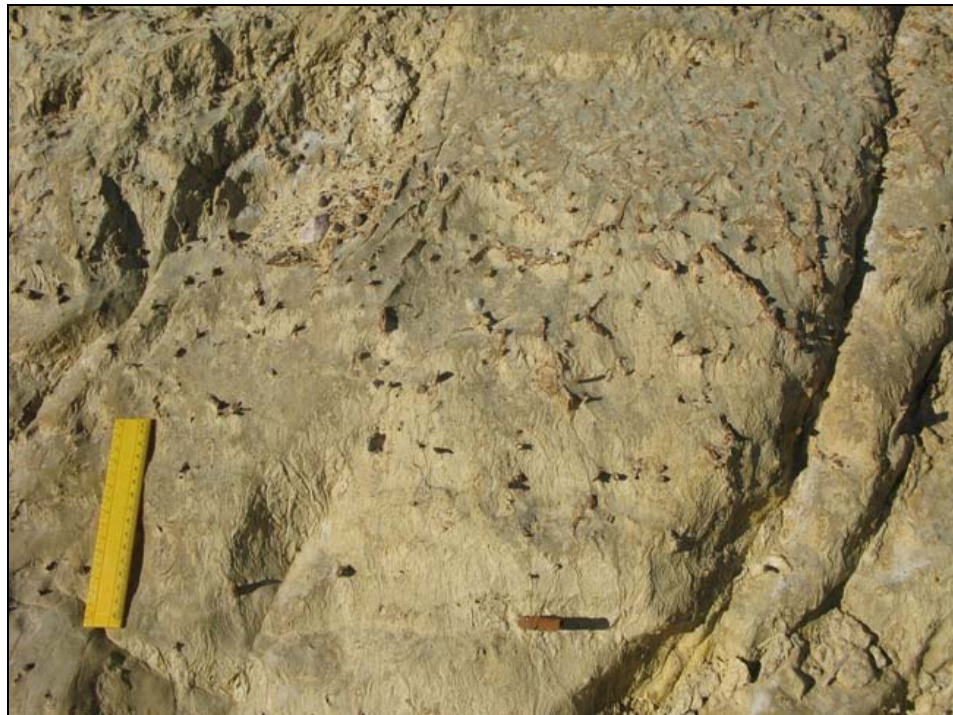


Figure 8. Detail of Gydo Formation saprolite in previous illustration showing secondary replacement of fossil burrows by ferruginous minerals (Ruler = 16 cm).

2.1.2.2. Gamka Formation

Prominent-weathering ridges of Gamka sandstones are exposed along the eastern side of the Botrivier Valley, and cross the river at Klipdrift. Rare bedding plane exposures are seen at Loc. 170 where cleavage is locally very intense. Here buff to grey sandstones and wackes are thin- to medium-bedded, tabular to lenticular and folded. Bedding surfaces various display mudflake breccias, primary current lineation and straight-crested wave ripples. Small patches of bioturbated sandstone with poorly-preserved horizontal and oblique burrows are also seen.

2.1.2.3. Voorstehoek Formation

Useful exposures of Voorstehoek Formation mudrocks were not encountered during the present field study. It is confidently expected that they are deeply-weathered and unfossiliferous in this region.

2.1.2.4. Hexrivier Formation

Intermittent ridges of grey-weathering, medium-bedded wackes cropping out beneath transmission lines some 0.3km to the northeast of Klipdrift probably belong to this stratigraphic unit. The beds here show a well-developed spaced cleavage and good bedding plane exposures are not seen.

2.1.2.5. Tra Tra Formation

This formation is exposed in extensive road cuttings along the N2 along the southern edge of the study area (Figs. 11, 16-18, 20) as well as along minor roads to the north, for example near Die Vlei (Fig. 9). Facies vary from thin-bedded to massive mudrocks, with occasional subordinate thin to medium-bedded, trough cross-bedded sandstones. Small scale sedimentary structures such as channel features are sometimes preserved, but in general the rocks have been converted to deeply-weathered saprolite with cream, buff, ochre, pink and lilac hues (Fig. **). Folded, highly-weathered, kaolinitised sandstone beds are seen within the pallid zone beneath the silcrete capped-koppie on Avontuur 429 (Fig. 16). A pronounced, closely-spaced slaty cleavage is seen in several road cuts east of Botrivier (Fig. 11). The contrast between ochreous saprolitic mudrocks and pale, cleaved and jointed sandstones with local honeycomb weathering is well seen in a steamside donga exposure 0.3km SE of Klipdrift farmstead (Loc. 165, Fig. 10).



Figure 9. Multi-hued Tra Tra Formation saprolite in roadcutting near Die Vlei, showing extensive development of ferruginous veins cross-cutting pale kaolinitised mudrocks (Loc. 169). Hammer = 30cm.



Figure 10. Donga erosion into highly-weathered Tra Tra Formation saprolite showing contrast between ochrous mudrocks and more resistant-weathering, jointed grey sandstones, c. 0.3 km SE of Klipdrift homestead (Loc. 165).



Figure 11. Intensely-cleaved Tra Tra Formation in a road cutting along the N2 east of Botrivier (Loc. 157). The bedding here dips at about 30° to the NE, while the subvertical cleavage dips very steeply to the ESE.

2.1.2.6. Boplaas Formation

Tabular to lenticular, thin- to medium-bedded wackes of the Boplaas Formation are exposed on hillslopes some 0.6km east of Klipdrift homestead (Loc. 166, Fig. 12). Sedimentary structures include horizontal and swaley lamination as well as tabular cross-bedding. The beds are sliced up by spaced cleavage and good bedding plane exposures are not seen.

2.1.2.7. Waboomborg Formation

Useful exposures of Waboomborg Formation mudrocks were not encountered during the present field study. It is confidently expected that they are deeply-weathered and unfossiliferous in this region.



Figure 12. Exposures of tabular-bedded Boplaas Formation sandstones c. 0.6km east of Klipdrift homestead (Loc. 166). Hammer = 30 cm.

2.1.2.8. Wuppertal Formation

Extensive hillslope exposures of thin-bedded, greyish-brown Wuppertal Formation wackes are seen 1.3 km SE of Klipdrift homestead (Fig. 13). The rocks are medium-grained, tabular-bedded, with horizontal and ripple cross-lamination, and display abundant evidence for bioturbation (*i.e.* sediment churning by infaunal invertebrates). A well-developed spaced cleavage precludes development of good bedding plane surfaces.



Figure 13. Thinly-bedded, bioturbated wackes of the Wuppertal Formation exposed in a hillslope *krans* 1.3 km southeast of Klipdrift homestead (Loc. 167). Hammer = 30 cm.

2.1.2.8. Klipbökkop and Karies Formations

These two units are amalgamated under “Dk” on the 1: 250 000 Worcester sheet in the Botrivier – Caledon area (Fig. 4). Roadside exposures of highly cleaved greyish-brown mudrocks at Loc. 171 probably belong to the Karies Formation at the base of the Bidouw Subgroup (Upper Bokkeveld) succession. Typical brown-grey mottled impure sandstones of the Klipbökkop Formation are exposed in roadcutting at Locs. 172 and 173. Well-developed cleavage here cuts at a high angle across the bedding (Fig. 14). Ferruginous nodules and honeycomb weathering reflect high levels of weathering. Sparse, poorly preserved trace fossils (indeterminate horizontal and oblique burrows) are locally seen on bedding surfaces.



Figure 14. Roadside exposure of Klipbokkop Formation sandstones along the R43 near Klein-Windheuwel showing NW-dipping beds cut by a spaced, SE-dipping cleavage (Loc. 173).

2.1.3. Superficial sediments

According to classical, broad-scale studies of the geomorphic (landscape) evolution of southern Africa much of the southern coastal plain south of the Cape Fold Belt forms part of the so-called **African Surface** (King 1967, Partridge & Maud 1987, 2000, Partridge 1998, Marker & McFarlane 1997) (Fig. 15). This ancient, relict land surface is considered to have developed over a period of some 40 to 60 million years following the break-up of the supercontinent Gondwana, *i.e.* during the Cretaceous to Paleogene (Early Tertiary) Periods, and to have been affected by subsequent tectonic movements, crustal warping and erosional dissection. As a result of deep chemical weathering under humid, tropical climates and long periods of tectonic stability, the surface is characterized by deeply weathered *saprolite* (*in situ* weathered bedrock) and capped by *duricrusts* of silcrete and/or ferricrete reflecting the increased mobility of silica and iron under these circumstances (Marker & McFarlane 1997, Marker *et al.* 2002). Purported remnants of the African Surface are concentrated in the Caledon-Swellendam, Heidelberg-Riversdale, Albertinia-Mossel Bay and Grahamstown areas along the south and southeast coast. Detailed studies in the Albertinia area recognise elements of this composite surface lying between 120 and 400m+ above sea level and demonstrate that it is multiple in nature, with at least four subcomponents (here at 120-140m, 200m+, 330m +, and 380-400m+ asl), and that it is clearly polycyclic in origin (Marker & McFarlane 1997). The existence of an extensive, recognisable African Surface has been questioned by recent workers such as Roberts (2003). He argues that multiple episodes of landscape erosion and duricrust formation, influenced by a complex interplay of tectonic, eustatic and climatic factors, have occurred during the Late Mesozoic to Pleistocene interval, several of which are conflated within the classic concept of the African Surface. In his view "This term should be confined to the (very) few instances where a surface can be demonstrated to have undergone only one cycle of erosion and weathering since the dismemberment of Gondwana".

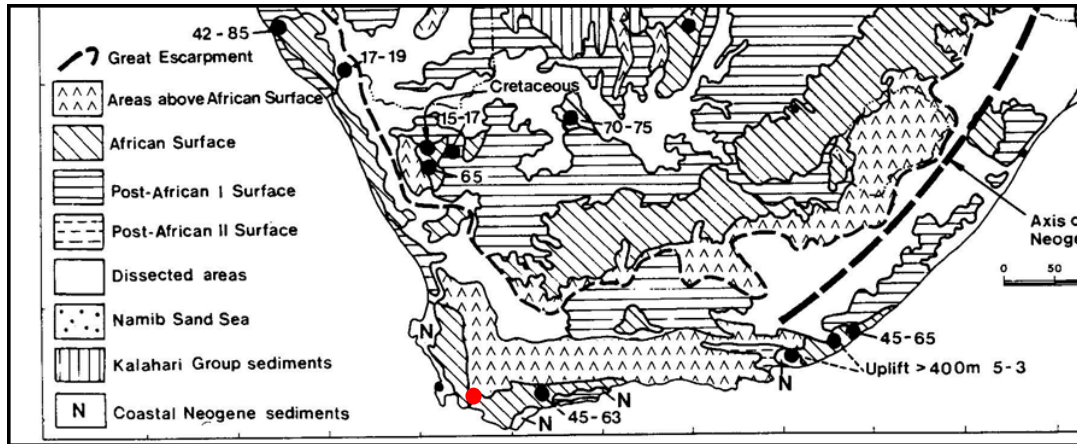


Figure 15. Major geomorphic regions in southern Africa (Modified from Partridge 1998). Note that the study region within the southern Cape coastal belt (red dot) is assigned here to the so-called African Surface.

Several small, relictual patches of *in situ* Tertiary-age silcretes, ferricretes and associated lag gravels capping deeply-weathered Bokkeveld saprolite on the southern Cape coastal plain are assigned to the **Grahamstown Formation** (Tg), often capping flat-topped *koppies*. Intact silcrete cappings are not seen within the present study region, but there is a good example at c. 130m amsl just south of the N2 on the farm Avontuur 429 (Fig. 16; mapped as alluvial deposits, though coarse gravels not seen here). The ubiquity of reworked silcrete clasts within superficial downwasted gravels in the study region suggests that silcrete cappings were once also present here but have subsequently been denuded by erosion.

The resistant-weathering duricrusts represent secondarily cemented fluvial and other superficial drift deposits, as well as downwasted gravels derived from older or higher-lying weathering profiles (Summerfield 1983, Malan *et al.* 1994, Marker & McFarlane 1997, Botha 2000, Marker *et al.* 2002, Roberts 2003). The genesis of South African near-surface silcretes on alluvial plains and terraces has been discussed extensively by Roberts (2003) who relates them to episodes of poor-drainage and moist, humid climates following long periods of tectonic stability. The majority of silcretes on the coastal platform of the southeastern Cape are inferred to be Paleogene (Early Tertiary) in age, though some may well be Neogene. They reflect multiple periods of silica solution and precipitation. Their complex, polycyclic origin is indicated by the wide spectrum of contrasting facies seen within the silcrete cappings. They range from massive, grey to buff fine-grained silcretes showing a well-developed conchoidal fracture (extensively exploited for stone tools in the study area) that are formed from fine-grained sands and silicified saprolite, to vein quartz - rich gravelly silcretes and spectacular silcretized breccio-conglomerates containing cobble and boulder-sized megaclasts of reworked, older silcrete. The rounding of some silcrete intraclasts implies a measure of current transport (but may be enhanced by conchoidal fracture). Silcrete duricrusts may reach thicknesses of several meters (c. 2.5m on Avontuur 429), with sheet-like geometries, and may show a crude bedding. Vuggy silcretes are common, and cavernous weathering is seen locally. Typically the silcrete cappings overlie pallid to ferruginised saprolite, sometimes irregularly veined with silcrete, as well seen in Tra Tra Formation roadcuttings on the N2 (Fig. 16).

Within a given duricrust capping, buff silcretes may grade laterally or vertically into darker brown ferruginised silcrete and full-blown ferricrete facies. Well-developed, *in situ* ferricretes are relatively uncommon within the study area, though ferricretised silcretes are also observed, varying from massive, fine-grained forms with a dark brown to rusty hue and conchoidal fracture to coarse, ferruginised breccio-conglomerates. However, abundant nodular ferricrete blocks (*e.g.* within stone heaps at the edge of fields) and ferruginous gravels point to the abundance of ferricrete horizons within higher levels of pre-existing lateritic

weathering profiles here. Beneath ferricrete horizons the saprolite is often ochreous rather than white. According to Roberts (2003) and Roberts *et al.* (2008) the formation of silcretes and ferricretes was often contemporaneous and controlled by fluctuating hydrological and geochemical conditions, with low (acidic) pH favoring ferricrete and higher (alkaline) pH favouring silcrete genesis. The widespread occurrence of laterite weathering, with leaching of bases and silica and enrichment in iron, on the southern coastal plain is documented by Marker *et al.* (2002) and attributed to a protracted period of humid climates in the Tertiary. Silcretes may be preferentially preserved over ferricretes because the latter often occur higher in the weathering profile and are less indurated, so they are more prone to subsequent denudation.

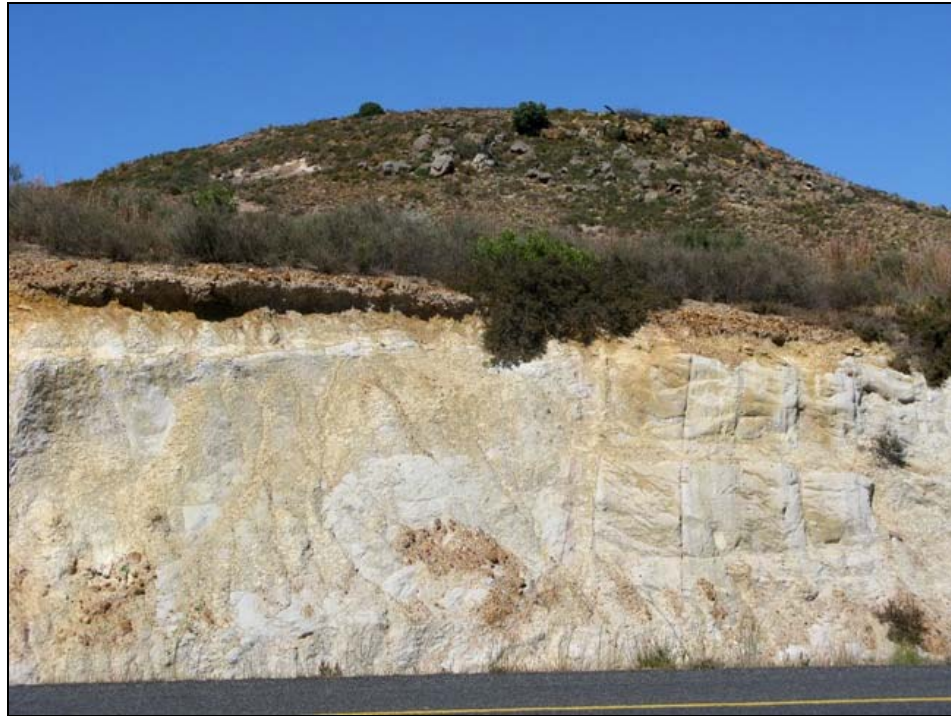


Figure 16. Highly-weathered, kaolinitised and steeply-dipping Tra Tra Formation saprolite within the pallid zone underlying a Tertiary silcrete capping, seen on the hilltop behind, N2 road cutting on Avontuur 429 (Loc. 155).

A wide spectrum of **superficial deposits** or “drift” mantles the weathered Bokkeveld bedrocks in the study area, as seen in road cuttings, stream banks, erosional gullies and around farm dams. These deposits reach thicknesses of several meters or more. Rounding of many outsized clasts as well as shallow channel incision of gravels into weathered bedrock point towards a degree of current transport, but downslope gravity-driven colluvial processes also play a role in their accumulation. Gravity-driven debris-flow processes were probably responsible for some of the matrix-supported diamictite facies with angular megaclasts embedded in a ferruginous sandy or muddy matrix. Sections through finer-grained soils and silty to gravelly alluvium are exposed around dams as well as in stream banks and excavations into stream beds.

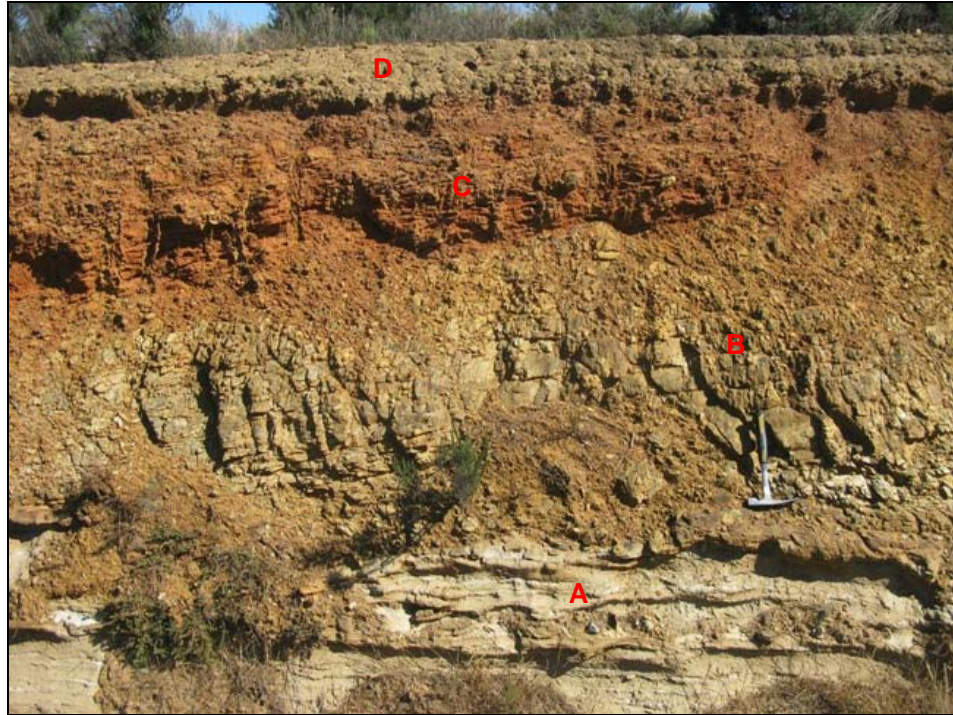


Figure 17. Weathering profile on top of the Tra Tra Formation showing (A) pale, thin-bedded Tra Tra mudrocks and thin sandstones overlain by (B) highly-fractured mudrock regolith, (C) ferruginous, semi-consolidated ancient colluvium with sparse gravel clasts, and (D) thin brown soil (Loc. 152). Hammer = 30 cm.

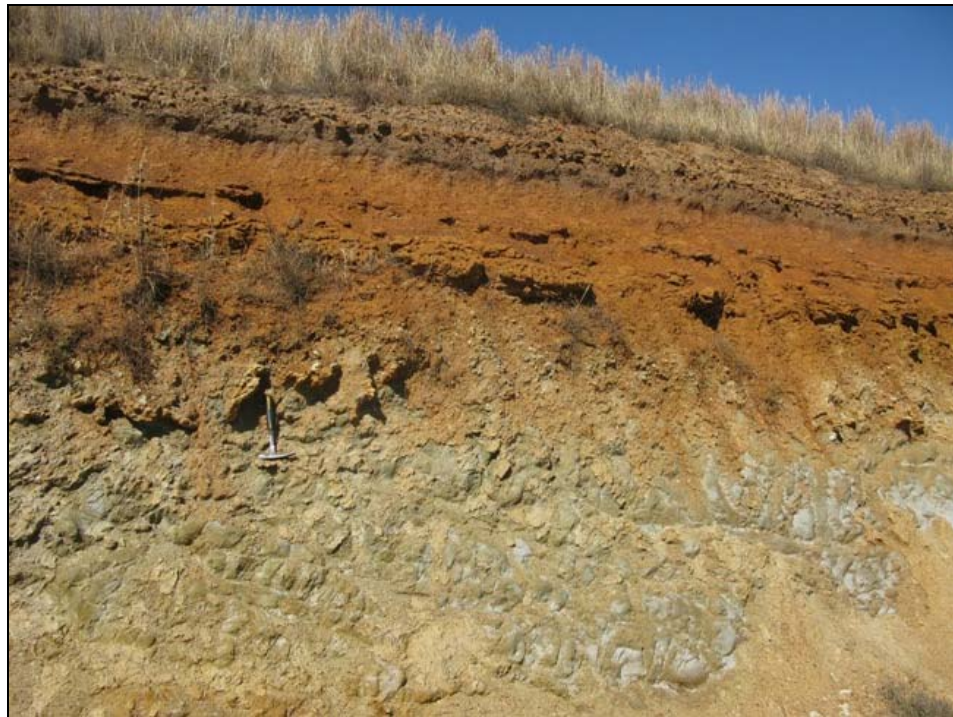


Figure 18. Orange-brown lateritic weathering profile overlying Tra Tra Formation mudrocks in N2 roadcut (Loc. 154). Irregular, resistant-weathering pale buff structures near hammer are probably veins of silcrete. Hammer = 30 cm.

Good weathering profiles through Bokkeveld rocks are seen in N2 road cuttings such as at Loc. 152 (Fig. 17). Here intact thin-bedded Tra Tra saprolite is overlain by highly fractured, cleaved and jointed regolith. Above this lies a reddish-brown, semi-consolidated ferruginous layer with sparse gravel clasts and then a pale brown soil. The soil surface is locally mantled by coarse gravels with clasts up to boulder grade of well-rounded Table Mountain quartzite, ferruginised sandstone, vein quartz, ferricrete and silcrete. Channel-like features cutting down into Bokkeveld saprolite are commonly seen in roadcuttings (Fig. 20). They are variously infilled with platy Bokkeveld clasts, or matrix-supported gravels (reworked silcrete / ferricrete nodules, milky quartz etc) of probable colluvial (debris flow) rather than alluvial origin.

Coarse bouldery alluvium is seen along some stream gullies, with larger clasts, up to boulder-sized, largely comprising moderately-rounded Bokkeveld sandstones (Loc. 162). In colluvial deposits on stream banks and hillslopes the clasts tend to be much less well-rounded, and are usually Bokkeveld sandstone cleavage flakes. At Loc. 164 dark, manganese-stained clast- and matrix-supported breccias of Bokkeveld sandstone blocks directly overlie cleaved Bokkeveld bedrocks in a stream bed. Several meters of crudely-bedded orange-brown silty alluvium or colluvium with horizons of angular sandstone clasts are seen overlying deeply-weathered Bokkeveld beds in stream bank sections at Loc. 163 and Loc. 168 (Fig. 19).

Surface gravels occur widely over the study area and are usually dominated by milky (vein) quartz, well-rounded pebbles and cobbles of Table Mountain quartzites, slaty Bokkeveld mudrocks, platy to irregular Bokkeveld sandstone clasts, milky vein quartz, yellowish-brown silcreted, and spotted black, dark red to ochreous nodular ferricretes (mainly goethite with subordinate haematite). These gravels often have a reddish ferruginous, fine-grained matrix and may be fairly well-consolidated. Many of the pedocrete clasts (e.g. most ferricretes) are downwasted lags from duricrust horizons that once lay higher up within the, now deeply denuded, "African Surface" weathering profiles. Downwasted *remanié* surface gravels of resistant lithologies cover many hillslopes and field margins in the study area. Outsized float clasts have sometimes been collected by farmers and dumped in heaps away from the cultivated fields (Loc. 168).



Figure 19. Several meters of crudely bedded, gravelly colluvial deposits overlying deeply weathered Bokkeveld Group saprolite (probably Tra Tra Formation), stream cutting in Karkloof, c. 0.75 km NE of Klipdrift homestead (Loc. 163).



Figure 20. Channel-like incision into Tra Tra Formation saprolite that is infilled with slightly ferruginous mudrock breccias and overlain by pebbly to cobbly down-wasted surface gravels (Loc. 150). Hammer = 30 cm.

2.2 Palaeontological heritage

In this section of the PIA report the recorded fossil record of each geological unit that is mapped within the study area, as listed in Section 2.1 above, is outlined, together with an indication of its overall sensitivity to development (See also summary in Table 1 herein). Much of this data has been derived from previous impact studies on similar rocks in the Overberg region by the author (e.g. Almond 2010a, 2010b, 2010c).

2.2.1. Skurweberg Formation (Overall palaeontological sensitivity = LOW)

The fossil record of the upper Table Mountain Group (Nardouw Subgroup), dominated by braided fluvial sandstones, is very sparse indeed. This largely non-marine unit 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 (1967, 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 *Arthropycus*, poorly preserved “bilobites” (bilobed arthropod scratch burrows, some of which are probably attributable to trilobites), gently curved epichnial furrows and possible arthropod tracks (Almond 2008). It is possible that more diverse ichnoassemblages - and even microfossils (e.g. organic-walled acritarchs) 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. However, exposure of these recessive-weathering finer-grained sediments is generally very poor.

No fossils were observed within the Skurweberg rocks in the study region. It is likely that they have mostly been destroyed by the high levels of weathering seen here, but poor exposure of bedding planes may also compromise recording of fossil material.

2.2.2. Lower Bokkeveld Group / Ceres Subgroup (Palaeontological sensitivity generally HIGH, but VERY LOW in study area due to deformation and weathering)

The lower part of the Bokkeveld Group in the Western Cape (Ceres Subgroup *plus* lowermost Bidouw Subgroup) is known for its rich fossil assemblages of shallow marine invertebrates of the Malvinokaffric Faunal Province of Gondwana (Cooper 1982, Oosthuizen 1984, Hiller & Theron 1988, Theron & Johnson 1991, MacRae 1999, Almond *in De Beer et al.* 2002, Thamm & Johnson 2006, Almond 2008). Key fossil groups here include trilobites, brachiopods, various subgroups of molluscs (bivalves, gastropods, nautiloids *etc*), and echinoderms (starfish, brittle stars, crinoids, carpoids *etc*), with several minor taxa including corals, conulariids, tentaculitids and rare fish remains, among others (Fig. 21). These shelly fossil assemblages – generally preserved as impressions or moulds, but occasionally in the Gydo Formation also embedded within phosphatic or siliceous nodules – are especially abundant within the mudrock-dominated units such as the Gydo, Voorstehoek and Waboomberg Formations in their more distal (offshore) outcrop areas. Remarkably diverse and well-preserved assemblages of marine trace fossils (burrows, trackways *etc*) occur in heterolithic (*i.e.* interbedded sandstone and mudrock) facies of the northern, more proximal outcrop area of the Ceres Subgroup (Swart 1950, Theron 1972, Oosthuizen 1984, Almond 1998a, 1998b, De Beer *et al.* 2002, Almond 2008). However, these have not been extensively recorded from the more distal, southern outcrop area.

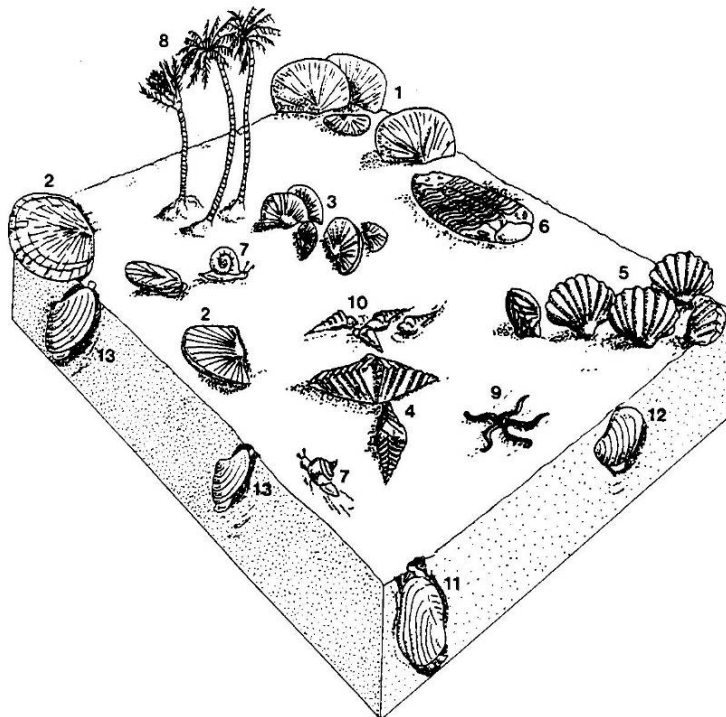


Figure 21. Reconstruction of a typical shelly invertebrate community from the Lower Bokkeveld Group (Early - Mid Devonian). Taxa include the articulate brachiopods *Australostrophia* (1), *Schuchertella* (2), *Pleurochonetes* (3), *Australospirifer* (4), *Australocoelia* (5), the trilobite *Metacryphaeus* (6), the gastropod *Pleurotomaria* (7),

crinoids (8), ophiuroids or brittle stars (9), hyoliths (10), and the bivalves *Sanguinolites* (11), *Palaeoneilo* (12) and *Nuculites* (13). From Hiller & Theron (1988).

No shelly fossils at all, and only a few ill-defined trace fossils (poorly preserved horizontal and oblique burrows) were observed during the field studies of Lower Bokkeveld Group sandstones and mudrocks in the Botrivier – Caledon study area. Malan *et al.* (1994) only record lycopod (clubmoss) impressions, indeterminate trace fossils and occasional crinoid moulds within sandstones of the Ceres Subgroup in the adjacent Riversdale sheet area. The rarity of Bokkeveld fossil records here may be attributed to several factors, notably:

- deep chemical weathering of sediments beneath the “African Surface” which has obliterated fossil moulds;
- intensive tectonic deformation of the Bokkeveld succession, with pervasive cleavage formation within the normally fossiliferous mudrocks (*N.B.* Most fossils are preserved and seen on bedding planes, which are rarely exposed here, rather than secondary cleavage planes which cut across fossil-rich layers);
- the extensive mantle of drift deposits (including lag gravels, soil and pedocretes) covering the Bokkeveld Group bedrock.

It is also possible that the more distal, offshore, muddy settings within Agulhas Sea where these Bokkeveld Group sediments were deposited were somehow less favourable for the development of a thriving shelly benthos, perhaps due to frequent bottom anoxia, but this is largely speculative. Even where small scale sedimentary features such as ripple cross-lamination are preserved, no clear evidence for bioturbation or discrete trace fossils was observed (including on float slabs collected in stone heaps).

2.2.3. Upper Bokkeveld Group / Bidouw Subgroup (Palaeontological sensitivity generally HIGH, but VERY LOW in study area due to deformation and weathering)

The lowermost part of the Bidouw Subgroup in the Western Cape – notably the mudrock dominated Waboomberg Formation - is known for its rich fossil assemblages of shallow marine invertebrates of the Malvinokaffric Faunal Province of Gondwana (Cooper 1982, Oosthuizen 1984, Hiller & Theron 1988, Theron & Johnson 1991, MacRae 1999, Almond *in De Beer et al.* 2002, Thamm & Johnson 2006, Almond 2008).

An important, albeit low-diversity, fossil biota has been recorded from the Bidouw Subgroup (Klipbokkop and upper Kanies Formations) in the western Bokkeveld outcrop area as well as from laterally equivalent Middle Devonian sediments to the east (the Adolphspoord Formation of the Traka Subgroup) (Plumstead 1977, Chaloner *et al.* 1980, Anderson & Anderson 1985, Almond 1997, Anderson *et al.* 1999a, 1999b, Anderson *in* MacRae 1999, Almond 2008, 2009). The Klipbokkop / Adolphspoord fossil assemblages are mainly preserved as moulds and comprise:

- Fragmentary vascular plants, including several species of lycopods (the club mosses *Archaeosigillaria*, *Haplostigma*) plus possible psilopsids.
- Non-marine, thin-shelled bivalves (possibly unionids), often preserved in dense clumps.
- Rare marine invertebrates (*e.g.* the articulate brachiopod *Australospirifer*).
- A limited variety of trace fossils including rare trilobite burrows (*Cruziana*), and unusually small versions of the complex helical burrow *Spirophyton*.
- A low-diversity assemblage of bony and cartilaginous fish, including acanthodians (“spiny sharks”), several primitive sharks, bony-plated jawed fish known as placoderms (Fig. 22), and rare crossopterygians (lobe-finned bony fish). These

important Middle Devonian fossil fish have been described and illustrated in detail by Chaloner *et al.* (1980), Almond (1997), Anderson *et al.* (1999a, 1999b) and Long *et al.* (in prep). General accounts of Devonian fish groups from Gondawana are given by Anderson *in* MacRae (1999) and Long (1995).

Klipbokkop fish fossils mainly consist of disarticulated placoderm plates as well as isolated teeth and fin spines of antartilamnid sharks and acanthodians. The fossils are found scattered throughout the succession within silty mudrocks and occasionally within ferruginous carbonate-rich concretions. Thin conglomeratic layers of transported mudflakes mixed with fish teeth, spines and other skeletal elements are recorded from the mid to upper Klipbokkop Formation in the Cederberg region. Those parts of the succession with unionid-like bivalves, low-diversity trace assemblages dominated by small *Spirophyton*, vascular plants and fish fossils are considered to be non-marine in origin, perhaps accumulated on an extensive delta platform or prograding (advancing) shoreline zone. A mixture of fish originally from brackish to freshwater bodies near to the coastline (estuaries, lagoons, rivers, lakes) as well as salinity-tolerant marine forms may be represented in the fossil assemblages.

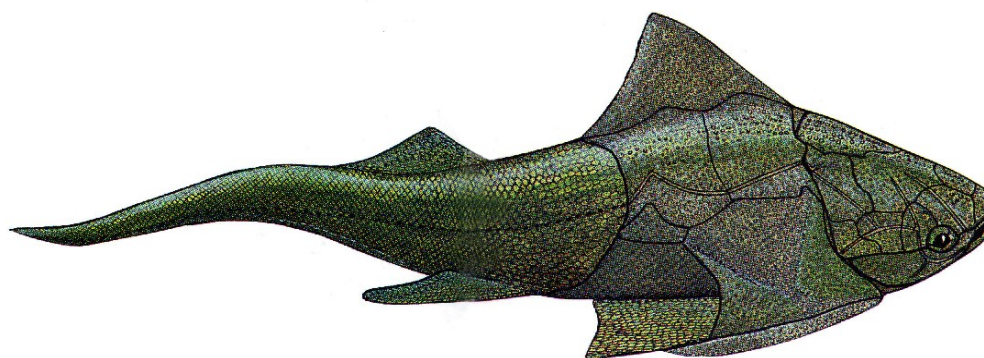


Figure 22. Reconstruction of the armour-plated placoderm fish *Groenlandaspis*, which is recorded from Middle to Late Devonian sediments worldwide, including the Bidouw Subgroup of South Africa (From Long 1995).

No shelly invertebrate, vascular plant or fish fossils were observed during the present scoping study of Upper Bokkeveld Group sandstones and mudrocks in the Botrivier – Caledon study area, and there are no fossil records from these rocks mentioned from this region in the Worcester sheet explanation by Gresse and Theron (1992). Where small scale sedimentary features such as ripple cross-lamination are preserved, however, evidence for *bioturbation* (sediment churning by infaunal animals) and occasionally discrete trace fossils are present in the study area (e.g. poorly-preserved horizontal burrows within the Klipbokkop Formation at Loc. 172).

The most prominent trace fossils in the southern Bidouw Subgroup succession that are recorded in the southern coastal plain region are the small to large (5-15cm diameter) deep tier burrow systems of the ichnogenus *Spirophyton*. They are locally abundant on *in situ* Bidouw micaceous sandstones and sandstone float blocks in the Heidelberg area, for example (Almond 2010c). *Spirophyton* burrows characterise much of the marine-influenced upper part of the Cape Supergroup. These complex, helical burrow systems are interpreted as *agrichnia* (“gardening burrows”) that were generated by an unknown group of invertebrate “worms” and during the Palaeozoic Era and are frequently associated with episodes of low oxygen supply on the sea bed. The size of the burrow system may be related to the level of environmental stress, with smaller “whorls” associated with more challenging inshore settings such as brackish estuaries and deltas whereas more predictable offshore habitats supported larger-diameter burrow systems (Miller 1991, Seilacher 2007).

2.2.4. Caenozoic duricrusts (Overall palaeontological sensitivity = LOW)

Sparse fossil remains have been recorded from Tertiary or younger silcretes 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 occurred. Narrow, regularly-spaced vertical tubes seen within many silcretes, including examples in the wider study region (Loc. 156), are apparently abiogenic and not relictual root structures (Roberts 2003, p. 3 and his fig. 2.6).

No fossils were observed within the Caenozoic duricrusts of the study region.

2.2.5. Caenozoic drift deposits (Overall palaeontological sensitivity = LOW)

Neogene to Recent alluvial deposits may also contain sparse fossil remains of various types (Table 1). 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 as 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 to modern alluvial and colluvial "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 fossils were observed within the Caenozoic drift deposits in the study region.

GROUP	FORMATION & AGE	ROCK TYPES	FOSSIL BIOTA	COMMENTS
LATE CAENOZOIC SUPERFICIAL MESEDINTS	Alluvial & colluvial gravels, soils, silty alluvium, calcretes Neogene - Recent	Bouldery to pebbly or gravelly alluvial gravels, sands, silts, near-surface calcretes	disarticulated to well-articulated skeletal remains (bones, teeth) or mammals, reptiles (e.g. tortoises), ostrich egg shells, freshwater molluscs, crabs, plant remains, trace fossils (e.g. rhizoliths, termitaria and other invertebrate burrows, vertebrate tracks), microfossils (e.g. pollens, spores, ostracods)	"High Level Gravels" are coarse, often semi-consolidated, ancient fluvial deposits at high elevations above the modern drainage systems. These are often mapped as part of the Grahamstown Formation.
	Grahamstown Formation (Tg) Paleogene (majority) to Neogene	Silcretes & ferricretes - cemented superficial deposits (gravels, sands, muds etc) overlying deeply-weathered and silicified bedrock (<i>saprolite</i>)	rare fossil plants (e.g. reedy <i>Phragmites</i>), charophyte algae (stoneworts), invertebrate burrows (e.g. <i>Skolithos</i>) occasional derived fossils (e.g. silicified wood from the Permian Beaufort Group)	Composite unit incorporating pedocretes of varying ages and origins, often polycyclic in origin (i.e. several phases of silica cementation, solution and erosion)
BOKKEVELD GROUP	BIDOUW SUBGROUP	Several poorly differentiated formations (Waboomberg, Wuppertal, Kanies, Klipbokkop Fms) Middle Devonian	Shallow marine to coastal (deltaic / estuarine) wackes and micaceous mudrocks as well as clean-washed tempestite sandstones Rich, diverse shelly biotas in lowermost part of succession (Waboomberg Formation), dominated by trilobites, brachiopods, molluscs and echinoderms plus various minor groups. Microfossils within mudrocks (e.g. organic-walled acritarchs). Upper Bidouw succession (Kanies & Klipbokkop Fm) with important non-marine fish (sharks, placoderms, acanthodians etc), primitive vascular plants (e.g. lycopods), non-marine bivalves, trace fossils (especially <i>Spirophyton</i>).	In study area fossil remains have been largely obliterated by intense tectonic deformation and chemical weathering. Bedrock exposure here very poor due to extensive superficial deposits.
BOKKEVELD GROUP	CERES SUBGROUP	Several poorly differentiated formations (Gydo, Gamka, Voorstehoek, Hexrivier, Tra Tra & Boplaas Fms) Early – Mid Devonian	Shallow marine wackes ("dirty" sandstones) as well as clean-washed tempestite sandstones, predominantly grey, silty or clay-rich mudrocks Rich, diverse shelly biotas dominated by trilobites, brachiopods, molluscs and echinoderms plus various minor groups (e.g. fish) Primitive vascular plants in some sandstones. Microfossils within mudrocks (e.g. organic-walled acritarchs).	In study area fossil remains have been largely obliterated by intense tectonic deformation and chemical weathering. Bedrock exposure here very poor due to extensive superficial deposits.
TABLE MOUNTAIN GROUP		Skurweberg Formation 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, <i>Skolithos</i> "pipe rock", horizontal burrows) within more mudrock-rich part of succession (W. Cape). Microfossils likely within mudrocks (e.g. organic-walled acritarchs).	In study area fossil remains have been largely obliterated by intense tectonic deformation and chemical weathering. Exposure levels v. poor.

Table 1. Fossil record of the main rock units represented in the study area. The effective palaeontological sensitivity of all the rock units is rated as low to very low. This is often due to high levels of tectonic deformation and chemical weathering.

3 IMPACTS AND ISSUES IDENTIFICATION & ASSESSMENT

The proposed Langhoogte Wind Farm is located in an area that is underlain by potentially fossil-rich sedimentary rocks of Palaeozoic and younger, Tertiary or Quaternary age (Section 2). The construction phase of the development will entail substantial excavations into the superficial sediment cover as well as the underlying bedrock. These notably include excavations for the turbine foundations (17.3m diameter x 4m deep), underground cables, road material, a new 132 kV electricity transmission line and on-site substation, as well as new gravel access roads. In addition, substantial areas of bedrock will be sealed-in or sterilized by infrastructure such as hard standing areas for each wind turbine, any lay down areas (these may well be temporary, however) as well as the new gravel road system. All these developments may adversely affect potential fossil heritage within the study area by destroying, disturbing or permanently sealing-in fossils that are then no longer available for scientific research or other public good.

Inferred impacts during the construction phase of the proposed Langhoogte wind farm project on local palaeontological heritage resources are assessed in Table 2 below. Note that the operational and decommissioning phases of the wind energy facility will not involve further significant adverse or other impacts on palaeontological heritage.

The Bokkeveld Group formations that underlie the greater part of the Langhoogte wind farm study area are known to be richly fossiliferous elsewhere in the Western Cape. However, in the Botrivier – Caledon region their original fossil content appears to have been almost completely destroyed by a combination of intense tectonic deformation (folding, faulting, cleavage development) and deep chemical weathering. The Table Mountain Group formations represented in the extreme west of the study area (Houhoekberge) are only sparsely fossiliferous, and have also suffered intense chemical weathering. The effective palaeontological sensitivity of all the rock units represented within the study area is consequently low to very low (Table 1).

The impact significance of the alternative northern and southern routes for the proposed new 132 kV transmission line between the new on-site substation and the existing Botrivier substation is similar and low. There is consequently no preference for either route on palaeontological heritage grounds. The northern route is mainly underlain by sediments of the Table Mountain and Bokkeveld Group, while the southern route is underlain by Bokkeveld Group and alluvial sediments (including silcretised High Level Gravels). All these units are of low palaeontological sensitivity in the study region. The site of the proposed on-site substation on farm 361/1 is not palaeontologically sensitive.

Table 2: Assessment of impacts of the proposed Langhoogte wind farm project on local palaeontological heritage resources during the construction phase

Impact: Destruction, disturbance or sealing-in of fossils at exposed at the surface or embedded beneath the surface during construction (especially during excavations for turbine tower foundations, access roads, underground cables and quarrying for road material)	
Nature	Negative
Extent	Low
Duration	Medium
Intensity	Low
Degree of reversibility	Low
Potential for impact on irreplaceable resources	Low
Consequence	Low
Probability	Low
Significance	Low

The overall impact significance of the construction phase of the proposed Langhoogte wind farm project is assessed as low (*negative*) (Table 2). However, should fossils be discovered during construction and reported by the responsible ECO to a heritage management authority (Heritage Western Cape) for possible recording and collection, as recommended, the overall impact significance of the project would change to low (*positive*).

At least three other alternative energy developments have been proposed for the Botrivier – Caledon region, two of which are directly adjacent to the Langhoogte project area (Fig. 23). Since the bedrocks in this region are generally of low to very low palaeontological sensitivity, the impacts on fossil heritage of all the proposed windfarm developments here is likely to be low. The cumulative impact of the proposed developments on palaeontological heritage is therefore considered to be of low significance.

There are no fatal flaws with the proposed development on palaeontological heritage grounds.

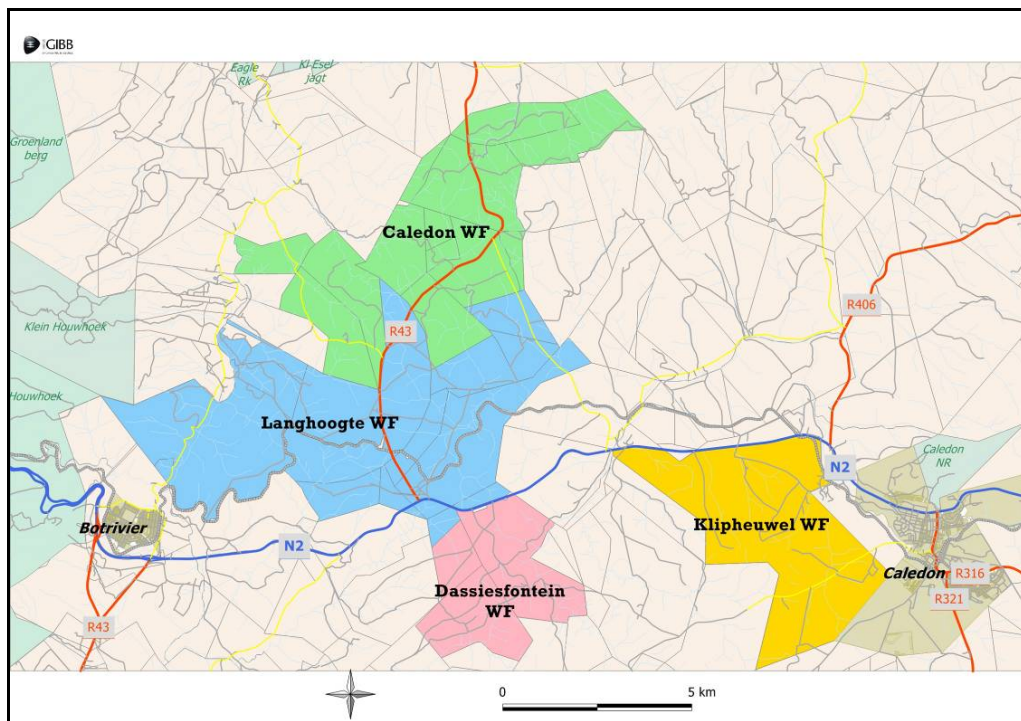


Fig. 23. Map showing the location of four proposed wind farm projects proposed for the Botrivier – Caledon region (Image kindly provided by Arcus Gibb).

This assessment is based on a two-day field study of the proposed development area as well as a preceding desktop study of relevant literature and maps and experience gained from several similar impact studies in the broader region. The degree of confidence in the assessment of the impacts on palaeontological heritage is consequently rated as high.

3.1 Potential Mitigation Measures

In view of the low significance of the proposed wind farm development on palaeontological heritage resources, there are no recommendations for specialist palaeontological mitigation for this project.

The ECO responsible for this development should be alerted to the possibility of fossil remains being found on the surface or exposed by fresh excavations during construction. Should substantial fossil remains be discovered or exposed during development, the responsible ECO should alert Heritage Western Cape so that appropriate mitigation measures may be considered. These measures would normally involve the recording and judicious sampling of fossil material by a professional palaeontologist at the developer's expense. The specialist involved would require a collection permit from SAHRA, fossil material must be curated in an approved repository, and all work carried out should meet the minimum standards for palaeontological impacts developed by SAHRA.

These recommendations should be incorporated into the EMP for the development.

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 (HWC) for professional recording and collection, as recommended here, the overall impact significance of the project would be further reduced. 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.

4 TERMS OF REFERENCE FOR THE IMPACT ASSESSMENT PHASE

The terms of reference for the present combined desktop study and field assessment report, as defined by Arcus Gibb Engineering and Science, Cape Town, are as follows:

The approach to the study will involve:

Review of existing project information;

Collection and review of relevant reports and baseline data on the area;

Identification and assessment of the key palaeontological issues and opportunities. In this regard the study will focus on identifying and assessing the potential impacts (negative and positive) associated with the construction and operational phase of the proposed project;

Consultation with the Environmental Assessment Practitioner concerning the findings of the assessment and mitigation;

Preparation of Draft Palaeontological Impact Assessment (PIA) Report for comment;

Finalisation of PIA Report based on (1) comments by the Environmental Assessment Practitioner and (2) the Client and (3) the public and Interested and Affected Parties. This report will feed into the Environmental Scoping Report;

Review and updating of the report if necessary during the Impact Assessment Phase and addressing any comments from the Environmental Assessment Practitioner, Client or Interested and Affected Parties.

The PIA will include a palaeontological desktop study and field assessment.

In preparing the **palaeontological desktop study** the potentially fossiliferous rock units (groups, formations *etc*) represented within the study area will be determined from geological maps. The known fossil heritage within each rock unit will be inventoried from the published scientific literature, previous palaeontological impact studies in the same region, and the author's field experience (Consultation with professional colleagues as well as examination of institutional fossil collections may play a role here, or later during the compilation of the final report). This data will then used to assess the palaeontological sensitivity of each rock unit to development (Provisional tabulations of palaeontological sensitivity of all formations in the Western, Eastern and Northern Cape have already been compiled by J. Almond and colleagues). The likely impact of the proposed development on local fossil heritage will then be determined on the basis of (1) the palaeontological sensitivity of the rock units concerned and (2) the nature of the development itself, most notably the extent of fresh bedrock excavation envisaged.

It is expected that rock units of moderate to high palaeontological sensitivity will be present within the development footprint and therefore a field assessment study by a professional palaeontologist will also be undertaken.

Palaeontological field assessment might therefore either (a) identify and delineate areas within the development area of high palaeontological sensitivity that will trigger specialist mitigation, usually at the construction phase, or (b) exclude the need for any further mitigation concerning rock units that are often highly fossiliferous but which are found *in this particular region* to be too weathered, metamorphised or deformed to warrant special protection.

The **palaeontological field assessment report** will provide 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). Palaeontological sensitivity is highly dependent on rock formations whose distribution is depicted on geological maps. A geological map of the study area will therefore form a standard component of a PIA report. The report will also incorporate:

- identification and ranking of highlights and sensitivities to development of fossil heritage within the study area (e.g. distribution of sensitive formations and specific fossil sites)
- specific recommendations for further palaeontological mitigation (if any)
- recommendations and suggestions regarding fossil heritage management on site, including conservation measures as well as promotion of local fossil heritage (e.g. for public education, schools)

The final **PIA report** will set out the findings of the desktop study and field assessment report and include any necessary palaeontological mitigation.

5 CONCLUSION

Because the sedimentary rocks in the Langhoogte wind farm study area are either poorly fossiliferous, or their original fossil content has been largely destroyed by tectonic deformation and weathering, it is concluded that the proposed development will have a very low impact on the very limited local fossil heritage, whether during the construction phase or later.

The impact significance of the alternative northern and southern routes for the proposed new 132 kV transmission line between the new on-site substation and the existing Botrivier substation is similar and low. There is consequently no preference for either route on palaeontological heritage grounds. The site of the proposed on-site substation on farm 361/1 is not palaeontologically sensitive.

The operational and decommissioning phases of the wind energy facility will not involve significant adverse or other impacts on palaeontological heritage. The proposed development has no fatal flaws in terms of impacts on fossil heritage. Confidence levels for this assessment are high.

At least three other alternative energy developments have been proposed for the Botrivier – Caledon region. Since the bedrocks in this region are generally of low to very low palaeontological sensitivity, the cumulative impact of the proposed developments on fossil heritage is considered to be of low significance.

No further specialist studies or mitigation of palaeontological heritage for this project are recommended. However, should substantial fossil remains be exposed during development, the responsible ECO should alert Heritage Western Cape so that appropriate mitigation measures may be considered. These measures would normally involve the recording and judicious sampling of fossil material by a professional palaeontologist at the developer's expense.

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APPENDIX 1: GPS LOCALITY INFORMATION

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

Only those localities mentioned in the text are listed here.

LOCALITY NUMBER	SOUTH	EAST
149	34° 13' 27.6"	19° 17' 21.5"
150	34° 13' 38.6"	19° 16' 21.3"
152	34° 13' 43.7"	19° 16' 16.7"
154	34° 14' 02.7"	19° 14' 55.8"
155	34° 13' 59.0"	19° 14' 43.7"
157	34° 13' 54.9"	19° 14' 23.9"
162	34° 11' 17.7"	19° 14' 16.4"
163	34° 11' 19.2"	19° 14' 17.3"
164	34° 11' 23.5"	19° 14' 29.0"
165	34° 11' 30.9"	19° 13' 57.7"
166	34° 11' 27.7"	19° 14' 11.3"
167	34° 11' 52.9"	19° 14' 30.0"
168	34° 13' 27.6"	19° 17' 21.5"
169	34° 12' 55.8"	19° 16' 30.9"
170	34° 12' 09.4"	19° 19' 50.4"
171	34° 10' 27.4"	19° 18' 35.5"
172	34° 09' 48.6"	19° 18' 01.2"
173	34° 10' 33.3"	19° 16' 49.4"