Environmental Impact Assessment for the proposed Ubuntu Wind Energy Project near Jeffrey's Bay, Eastern Cape:
Draft Environmental Impact Assessment Report

Chapter 12:
Impact on Palaeontology

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CHAPTER 12. IMPACT ON PALAEONTOLOGY

12.1 INTRODUCTION

12.1.1 Approach to this Palaeontological Impact Assessment (PIA)

The present report forms part of the EIA for the proposed Ubuntu Wind Energy Project near Jeffrey's Bay, and it will also inform the Environmental Management Plan for this project. The extent of the proposed development (over 5000 m^2) falls within the requirements for a Heritage Impact Assessment (HIA) as required by Section 38 (Heritage Resources Management) of the South African Heritage Resources Act (Act No. 25 of 1999). The various categories of heritage resources recognised as part of the National Estate in Section 3 of the Heritage Resources Act include:

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

A desktop Palaeontological Impact Assessment (PIA) as part of the EIA and EMP for the Ubuntu Wind Energy Project has accordingly been commissioned by Environmental Management Services of the CSIR, Stellenbosch, on behalf of WKN-Windcurrent SA (Pty) Ltd.

Minimum standards for the palaeontological component of heritage impact assessment reports are currently being developed by SAHRA. The latest version of the SAHRA guidelines is dated May 2007.

This PIA 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; and (3) the author's extensive field experience with the formations concerned and their palaeontological heritage.

The potentially fossiliferous rock units (groups, formations etc) represented within the study area have been determined from geological maps. The currently recorded fossil heritage within each unit is determined from the published scientific literature and the author's field experience. These data are then used to assess the palaeontological sensitivity of each rock unit to development (N.B. A tabulation of palaeontological sensitivity of all formations in the Eastern Cape has already been compiled by Almond *et al*., 2008).

The likely impact of the proposed development on local fossil heritage is then determined on the basis of (1) the rock units concerned, and (2) the nature of the development itself, most notably the extent of fresh bedrock excavation envisaged. Adverse palaeontological impacts normally occur during the construction rather than operational 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. SAHRA for the Eastern Cape, 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.

12.1.2 Assumptions made for the PIA desktop study

Note that while fossil localities recorded within the study area itself are obviously highly relevant, most of the fossil heritage is buried beneath the land surface or obscured by surface deposits (soil, alluvium etc) and vegetation cover. The hidden fossil resources, therefore, have to be inferred from palaeontological observations made within the same formations elsewhere in the region, or even further afield (*e.g*. an adjacent province). Here it is assumed that fossil heritage is fairly uniformly distributed throughout the outcrop area of a given formation. Experience shows that this assumption does not always hold. This is because the original depositional setting across a formation that may extend over hundreds of kilometres may vary significantly, with palaeoecological implications (e.g, from a shallow to deeper water environment), while fossils are often patchy in their occurrence. Furthermore, the levels of tectonic deformation (folding, cleavage development etc), as well as the intensity and nature of metamorphism and weathering experienced by a given formation may change markedly across its outcrop area. These factors may seriously compromise the preservation of fossil remains present within the original sedimentary rock.

12.1.3 Declaration of Independence

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

JOHN ALMOND

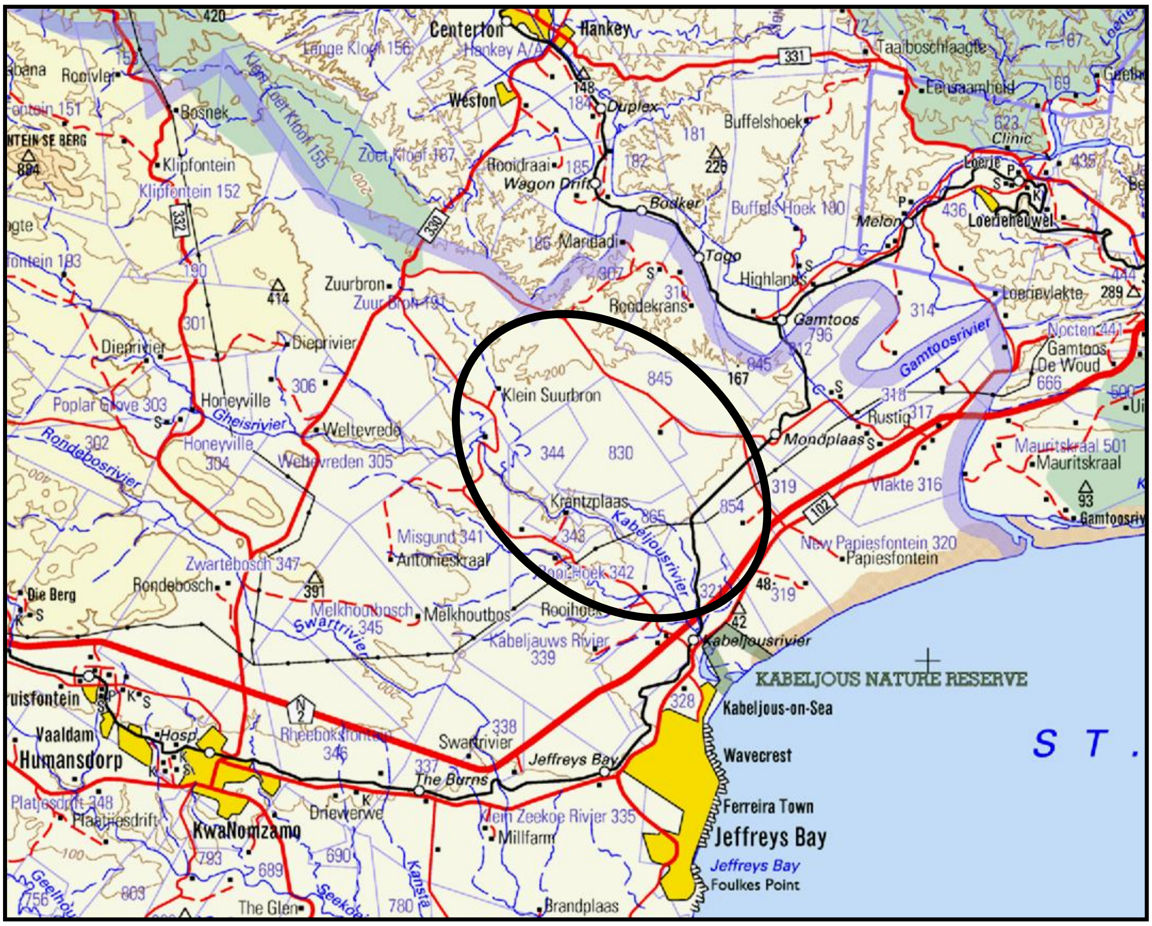
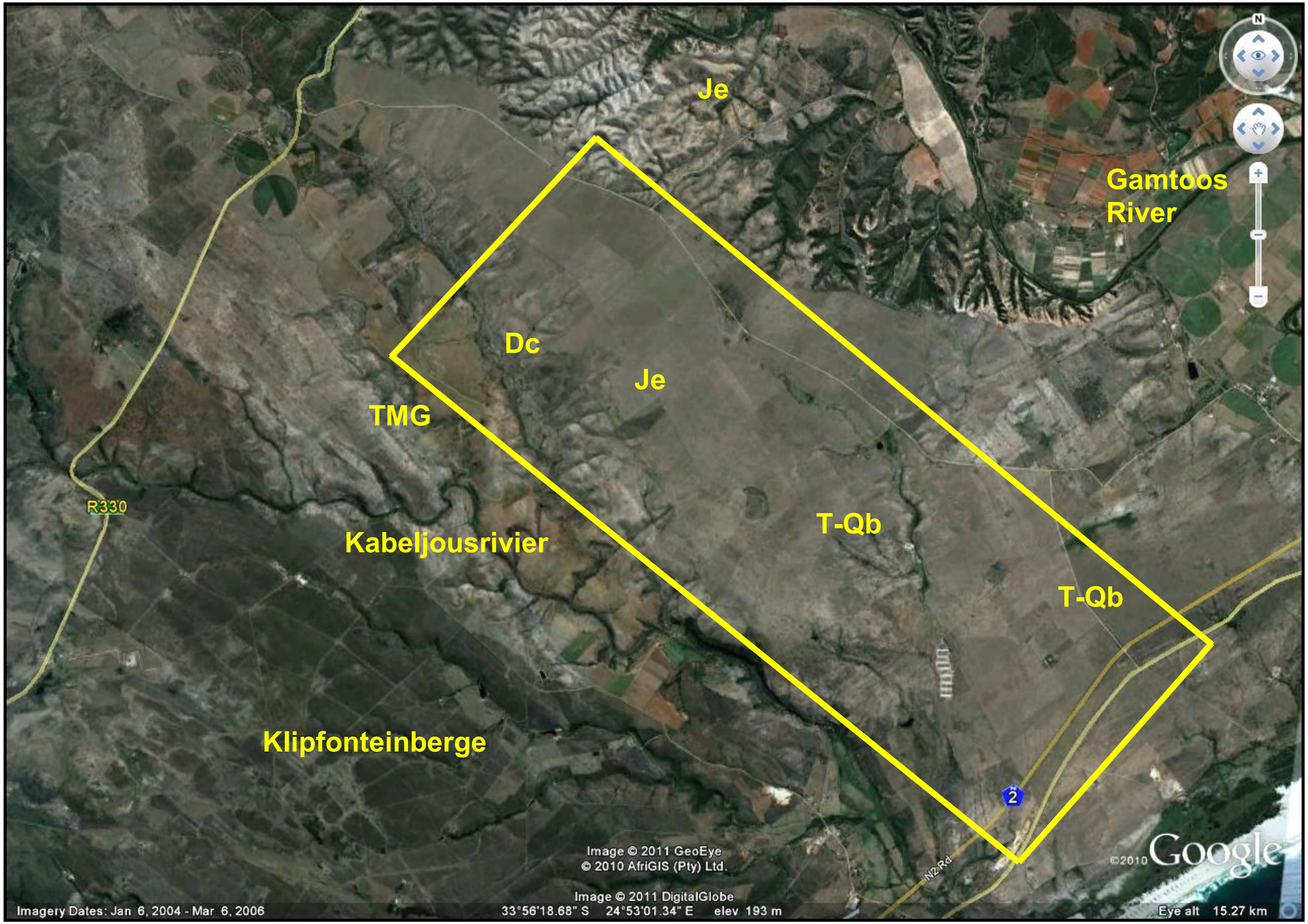


Fig. 12.1. **Approximate location and extent (black ellipse) of the proposed Ubuntu Wind Energy Project immediately north of Jeffrey's Bay in the Eastern Cape Province (Extract from 1: 250 000 topographical sheet 3324 Port Elizabeth, Courtesy of the Chief Directorate of Surveys & Mapping, Mowbray).**

Fig. 12.2. (following page). Satellite image (Google Earth©) of the region immediately north of Jeffrey's Bay showing the very approximate outline of the area (yellow rectangle) and major roads Compare this image with the geological map in Fig. 3 below where the geological symbols used here are also explained. Note that the greater part of the study area is underlain by a relatively flat, marine-planed platform lying between the Kabeljous and Gamtoos Rivers that is underlain by the Enon Formation (Ke), locally mantled with residual soils of the Bluewater Bay Formation (T-Qb). The highly dissected areas on the plateau margins are also underlain by Enon rocks. To the west occur Lower Bokkeveld Group sediments (Dc) on the floor of the Kabeljousrivier Valley (brown hues) and pale grey quartzitic rocks of the Table Mountain Group (TMG) on the marine-planed slopes of the Klipfonteinberge.



Je
Gamtoos
River
Dc
Je
TMG
R330
T-Qb
Kabeljousrivier
T-Qb
Klipfonteinberge
N2 Rd
Image © 2011 GeoEye
© 2010 AfriGIS (Pty) Ltd.
Image © 2011 DigitalGlobe
©2010 Google
Imagery Dates: Jan 6, 2004 - Mar 6, 2006
33°56'18.68" S 24°53'01.34" E elev 193 m
Eye alt 15.27 km

12.2 POTENTIAL IMPLICATIONS OF PROJECT FOR FOSSIL HERITAGE

The proposed Ubuntu Wind Energy Project is located in an area that is underlain by potentially fossil-bearing sedimentary rocks of Palaeozoic and younger age (Sections 12.3, 12.4). The construction phase of the development will entail numerous and extensive excavations into the superficial sediment cover as well as the underlying bedrock. These notably include excavations for the 33 to 50 turbine foundations, buried cables and any new gravel access roads. In addition, substantial areas of bedrock will be sealed-in or sterilized by infrastructure such as standing areas for each wind turbine, lay down areas as well as the new gravel road system. All these developments may adversely affect the 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. Once constructed, the operational and decommissioning phases of the wind energy project will not involve further adverse impacts on palaeontological heritage.

12.3 GEOLOGICAL BACKGROUND

12.3.1 General introduction to local geology

The proposed Ubuntu development site, located between three and twelve kilometres north of Jeffrey's Bay is situated along the western margin of the Mesozoic Gamtoos Basin, between the courses of the Kabeljous and Gamtoos Rivers (Figures 12.1 to 12.3). The study area is roughly rectangular (*c*. 12 km x 6 km), elongated NW-SE. The R330 lies to the northwest, and the N2 freeway along its southeastern edge. The major part of the site is occupied by a gently sloping coastal plateau that rises gradually from *c*. 50-60 m amsl in the southeast to *c*. 200 m amsl in the northwest. The higher-lying interior portion of this extensive surface is equivalent to the 180-280 m amsl marine-carved George Terrace recognised by Roberts *et al.* (2008) that stretches along the south coast as far east as Port Elizabeth. In the Eastern Cape the George Terrace is directly overlain by coastal (estuarine / shallow marine) sediments of the Miocene-Pliocene Alexandria Formation or alternatively – as in the present study area - conglomeratic weathering products of this last unit which are mapped on the 1: 250 000 geology sheet as the "Bluewater Bay Formation". The George terrace is tentatively related by Roberts *et al.* (2008) to an Early Tertiary, possibly Eocene, marine highstand, although it may alternatively represent a Late Tertiary (Miocene) marine-cut surface that has since been elevated by continental uplift.

The geology of the Ubuntu study area is depicted on the 1: 250 000 scale geological map sheet 3324 Port Elizabeth (Figure 12. 3). In addition to the explanation for this map published by Toerien & Hill (1989), useful background information on local geology and palaeontology is also given in the older sheet explanation for the coastal belt near the Gamtoos Valley by Haughton *et al.* (1937). The extensive coastal plateau forming the core of the study area is underlain by conglomeratic fluvial sediments of the **Enon Formation** (Ke, Uitenhage Group) of Late Jurassic or Early Cretaceous age. In the southeastern half of the plateau area, the Enon sediments are overlain by a surface veneer of pebbly, reddish brown soils of the so-called **Bluewater Bay Formation** (T-Qb) that, as mentioned earlier, are now recognised as karstic weathering products of the Neogene (Late Tertiary) Alexandria Formation (Maud & Botha 2000, Goedhart and Hattingh 1997, Almond 2010). It seems likely on the basis of satellite images (Figure 12.2) that these "Bluewater Bay" residual deposits occur more extensively over the coastal plain than suggested by the 1: 250 000 geological map. The southwestern and northeastern margins of the

Enon plateau are typically highly dissected by numerous small streams, as clearly seen in satellite images. The near-coastal stretch of the Kabeljousrivier along the western margin of the Ubuntu study area is incised into readily-weathered, clay-rich sediments of the **Ceres Subgroup** (Dc = Lower Bokkeveld Group). These Early Devonian marine rocks appear as a brownish band in satellite images of the Kabeljousrivier Valley and have a sharp, unconformable contact with the overlying Uitenhage Group to the east (Figure 12.2). The northwestern corner of the Ubuntu study area (Farm Klein Zuurbron) extends for a short distance onto the more rugged uplands of Table Mountain Group rocks building the western wall of the Gamtoos Basin (pale grey on satellite images). The main rock unit represented here is the Early Devonian **Baviaanskloof Formation** (S-Db) of coastal fluvial to shallow marine origin at the top of the Table Mountain Group succession. The Baviaanskloof rocks consist mainly of impure sandstones (*wackes*) with minor mudrocks and resistant-weathering quartzites. A small area of Silurian braided fluvial sandstones and quartzites of the underlying **Skurweberg Formation** (Ss) may also be present in the extreme west. These cleaner-washed quartzitic sediments tend to weather more prominently and ruggedly than the more clay-rich Baviaanskloof "passage beds" directly above them.

The quartz-rich, resistant-weathering Table Mountain Group sediments to the west of the study area form the tapering southeastern portion or *nose* of a NW-SE trending mega-anticline (Klipfonteinberge) of the Cape Fold Belt that plunges southeastwards towards Jeffrey's Bay (Figure 12.3). As clearly seen from the zigzag trace of the Baviaanskloof Formation (S-Db), the termination of the mega-anticline is rippled or dissected into a series of smaller-scale SE-trending folds. Dips within the Table Mountain succession here are therefore likely to be highly variable, from horizontal to steep. As is clearly apparent from aerial and satellite images (Figure 12.2), the folded, resistant-weathering Table Mountain Group rocks have been extensively planed-off by erosion to form a gently seawards-sloping surface (pseudo-peneplain) at around 200m amsl. This corresponds to the marine-planed "George terrace" of ill-defined Tertiary age that extends eastwards across the Uitenhage Group infill of the Gamtoos Basin, as discussed earlier.

12.3.2 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 a*l., (1999), De Beer (2002), Thamm & Johnson (2006), and Tankard *et al*., (1982, 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). The Skurweberg and Baviaanskloof Formations are both subdivisions of the **Nardouw Subgroup**, the upper part of the Table Mountain Group (Malan & Theron 1989).

The **Skurweberg Formation (Ss)** is dominated by very pale, weathering-resistant 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 meter 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.

The **Baviaanskloof Formation (S-Db)** is typically less clean-washed than the older subunits of the Nardouw Subgroup, 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. 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 following section).

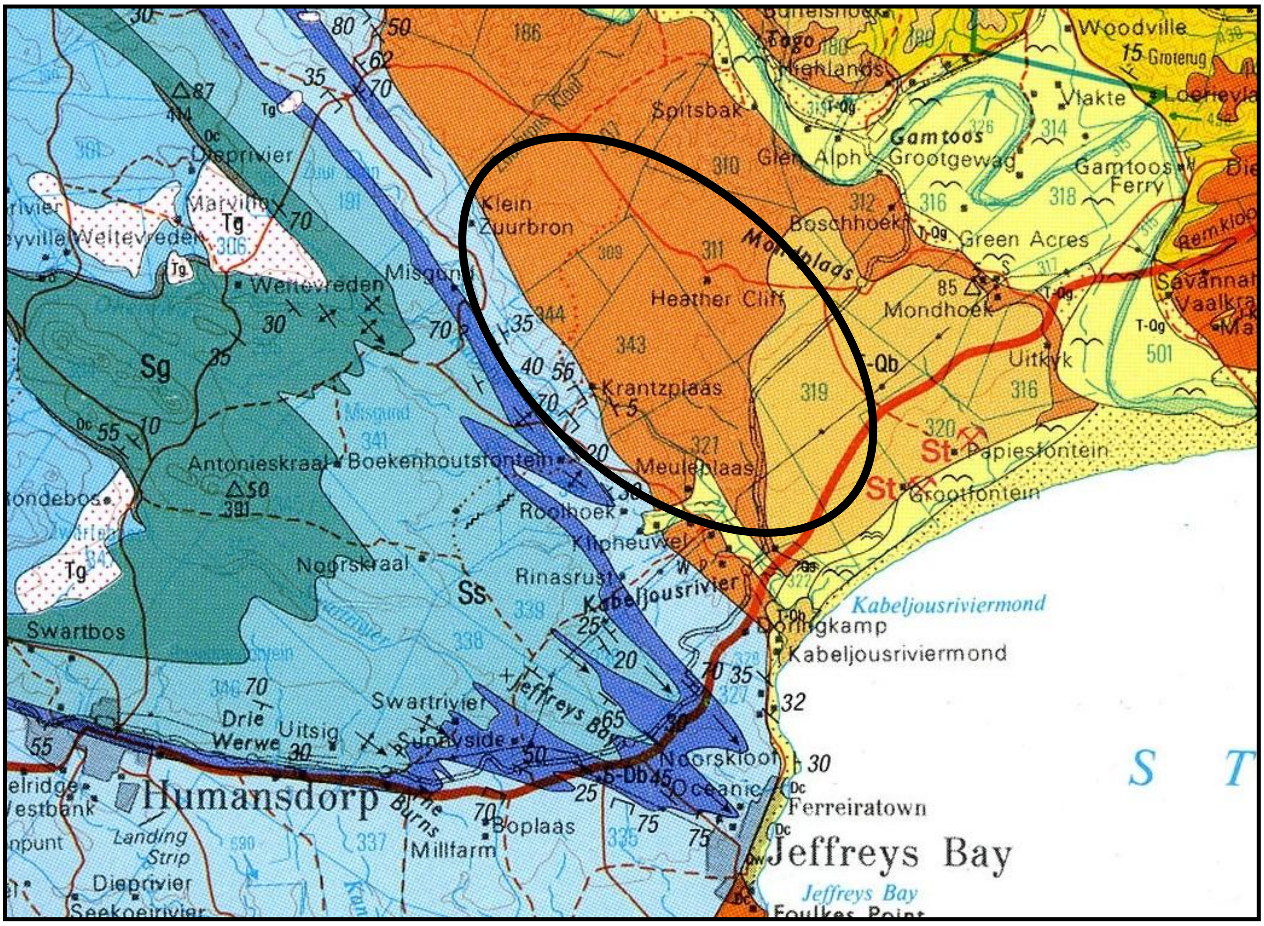


Fig. 12.3. **Geological map of the coastal region north of Jeffrey's Bay, Eastern Cape Province, extracted from 1: 250 000 geological map sheet 3324 Port Elizabeth (Council for Geoscience, Pretoria). The *approximate* location of the proposed Ubuntu Wind Energy Project is indicated by the black ellipse. *N.B.* The modern course of the N2 trunk road is not indicated on this map.**

MAJOR GEOLOGICAL UNITS:

Table Mountain Group:	Sg (greenish-blue) = Goudini Formation Ss (mid-blue) = Skurweberg Formation S-Db (dark blue) = Baviaanskloof Formation
Bokkeveld Group:	Dc (pale blue) = Ceres Subgroup (Lower Bokkeveld Group)
Uitenhage Group:	Ke (deep orange) = Enon Formation
Algoa group:	T-Qb (pale brown) = “Bluewaterbay Formation”, now recognised as weathering products of the Alexandria Formation

12.3.3 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).

The **Ceres Subgroup** (Dc) in the Port Elizabeth sheet area represents the Lower, Early to Mid Devonian portion of the Bokkeveld Group. It comprises three thick (300-500 m) units of dark grey mudrocks that alternate with thinner (50-200 m) sandstone-dominated units (Haughton *et al.* 1937, Le Roux 2000). The mudrocks are often silty, micaceous and highly cleaved. Sandstones (technically mostly impure wackes) frequently preserve sedimentological evidence of storm deposition, such as wave ripples and relicts of hummocky or swaley cross-lamination. Due to limited bedrock exposure, individual formations within the Ceres Subgroup are not mapped separately here. Levels of Cape-age (*i.e.* Permo-Triassic) tectonic deformation, including folding and cleavage, as well as of Tertiary weathering are generally high, often seriously compromising the palaeontological heritage of these beds (See Section 12.4.3 below).

12.3.4 Uitenhage Group

The continental sediments of the Uitenhage Group were laid down in a spectrum of depositional settings on or close to the margins of the newly developing African continent during the Late Jurassic to Early Cretaceous Period (Du Toit 1954, McLachlan & McMilllan 1976, Tankard *et al.* 1982, Dingle *et al.* 1983, Shone 2006). They include coarse breccio-conglomerates deposited in piedmont fans (“fanglomerates”) and highly energetic braided rivers, pebbly conglomerates and sandstones in meandering river channels, overbank mudrocks (mainly silty alluvium) with occasional lacustrine mudrocks too. Thin to 4 m-thick volcanic tuffs or tuffites (volcanic ash mixed with siliciclastic sediment) have also been recorded from the Uitenhage Group succession.

The Uitenhage Group sediments on the western side of the Gamtoos Basin near Jeffrey's Bay are mapped on the 1: 250 000 Port Elizabeth sheet as belonging to the **Enon Formation** (**J-Ke**), unconformably overlying the Lower Bokkeveld Group rocks to the west (Figure 12.3). The Enon Formation is characterized by coarse, immature fanconglomerates or breccio-conglomerates of Late Jurassic to Early Cretaceous age. Successions with intermittent cross-bedded sandstone interbeds and well-developed pebble imbrication were deposited within high-energy braided river systems. Larger clasts consist primarily of poorly-sorted Cape Supergroup quartzites, are often well-rounded and secondarily stained with iron oxides, and may be cracked as a result of overburden pressure. The Enon Formation within the Gamtoos Basin reaches thicknesses of some two kilometres or more (Toerien & Hill 1989). In the vicinity of the Kabeljous River Haughton *et al.* (1937, p. 29) mention basal Uitenhage beds consisting of "greenish and buff sandy marls which may represent weathered Bokkeveld rocks almost *in situ*". Within the Ubuntu study area the Enon Formation is likely to be poorly exposed over much of the gently sloping coastal plateau, where it is additionally mantled by a veneer of Bluewater Bay residual soils (see below). Exposure levels are likely to be better in the gullied terrain along the western margin of the plateau (*i.e.* eastern slopes of the Kabeljousrivier Valley).

12.3.5 Algoa Group

Geologically recent karstic (*ie* solution) weathering of the lime-rich, coastal-marine **Alexandria Formation** has led to the development of pebbly, reddish-brown residual soils over much of its inland outcrop area (Maud & Botha 2000, Almond 2010). These weathering products were formerly identified as a separate, bipartite *fluvial* unit of Plio-Pleistocene age with calcrete horizons that was named the **Bluewater Bay Formation** (Le Roux 1987, 1989). This unit is mapped as such (T-Qb) on the 1: 250 000 Port Elizabeth geology sheet but not on the later 1: 50 000 scale geological maps where it is indicated as pedogenic gravels overlying the Alexandria Formation (circular symbols). Incised "channels" cutting into the Alexandria Formation and infilled with cross-bedded coarse "Bluewater Bay" gravels are illustrated by Le Roux (1989). Maud and Botha (2000) suggest that these surface deposits comprise a composite of *in situ* karstic weathering products (including coarse solution-hollow infills) as well as fluvial sediments of late Neogene age. Goedhart and Hattingh (1997) have developed an explanatory scheme showing how residual pebbly and sandy weathering products of the Alexandria Formation infill solution cavities within the calcretised limestones following periods of humid climate leaching. In the Port Elizabeth area the superficial "Bluewater Bay" deposits average 1.2 m in thickness, but this varies greatly due to the presence of numerous incised channel-fill and solution pipe structures up to 7 m deep (Le Roux 1987c, 1989, 2000).

12.4 PALAEONTOLOGICAL HERITAGE

In this section of the PIA report the recorded fossil record of each geological formation that is mapped within the study area, as listed in Section 12.3 above, is outlined, together with an indication of its overall sensitivity to development (Based on Almond *et al*., 2008; see also the summary of the fossil heritage in Table 12.1).

The bulk of the thick **Table Mountain Group** succession is composed of quartz arenites and pebbly sandstones of alluvial braidplain facies that are unlikely to yield fossils, especially given their early to mid-Palaeozoic age and the poor exposure of mudrock units. Biostratigraphically significant body fossils are recorded from marine-dominated parts of the succession, *i.e.* the Cederberg Formation of latest Ordovician (Hirnantian) age and the Baviaanskloof Formation of Early Devonian (Lochkovian / Pragian) age (Broquet 1992, Hiller 1992, Theron 1993). Only the second of these is represented in the study area.

It should be emphasized that the Table Mountain Group rocks within the southern Cape Fold Belt have frequently experienced fairly extreme levels of tectonism, including intense folding, faulting, jointing, brecciation and cleavage development, the last especially within finer-grained facies (*i.e.* mudrocks). These effects, combined with low grade regional or dynamic metamorphism and deep, intense weathering since the break-up of Gondwana (*e.g.* leaching, secondarily mineralization, notably by iron and manganese compounds), have conspired to severely compromise the preservation of fossils even within that minority of Table Mountain Group rocks that may originally have contained a fairly rich palaeontological heritage.

12.4.1 Skurweberg Formations (Silurian) (Ss)

Overall palaeontological sensitivity = LOW

The fossil record of the lower 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 *Arthrophycus*, 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.

12.4.2 Baviaanskloof Formation (Early Devonian) (S-Db)

Overall palaeontological sensitivity = MODERATE

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 "gastropods" and bryozoans also occur within impure brownish-weathering wackes (Haughton *et al.,* 1937, 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). Haughton *et al.* (1937) record "numerous moulds of small lamellibranchs" within the Baviaanskloof Formation of the Elands River Valley, to the northwest of Port Elizabeth. Whether these truly represent small bivalves, or rather rounded mudflake impressions or brachiopod moulds, remains to be confirmed.

Trace fossils within the Baviaanskloof Formation 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 (Dr Mark Goedhart, Council for Geoscience, Port Elizabeth, pers. comm., 2008, *cf* Hoeg 1930, Anderson & Anderson 1985). These are currently the oldest known fossil vascular plants in southern Africa and are likely to co-occur with organic-walled microfossils such as spores, though these have not been looked for to date.

12.4.3 Ceres Subgroup (Early Devonian) (Dc)

Overall palaeontological sensitivity = HIGH

The lower part of the Ceres Subgroup, especially in the less deformed outcrop areas of the Western Cape, 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. These shelly fossil assemblages – generally preserved as impressions or moulds – are especially abundant within the finer-grained, mudrock-dominated units such as the Gydo and Voorstehoek 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 Bokkeveld Group (Swart 1950, Theron 1972, Oosthuizen 1984, Almond 1998a, 1998b, De Beer *et al*. 2002, Almond 2008).

Shelly fossils have not been extensively recorded from the more distal, southern outcrop area of the Bokkeveld Group, however, including the Port Elizabeth sheet area (*cf* Le Roux 2000). This may be due to the prevalence here of offshore, deeper water facies but important secondary influences include:

- deep chemical weathering of sediments beneath the "African Surface" which has obliterated many of the 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); and
- the extensive mantle of drift deposits (including alluvium, downwasted lag gravels, soil and pedocretes) covering the Bokkeveld bedrock.

It is, therefore, notable that Haughton *et al.* (1937, p. 24) record a low diversity shelly invertebrate faunule from "Bokkeveld slates west of the Kabeljouws River". The faunule consists entirely of distorted articulate and inarticulate brachiopods, including *Australoceolia*, chonetids, *Schuchertella* ("*Orthothetes*"), *Australospirifer* and *Orbiculoidea*. Any further, well-localized records of Bokkeveld fossils from new excavations in this region would be of scientific interest.

12.4.4 Enon Formation (Late Jurassic / Early Cretaceous) (Ke)

Overall palaeontological sensitivity = LOW

The palaeontological heritage of the coarse-grained facies (conglomerates, breccias) within the Uitenhage Group is currently unclear because of the uncertain stratigraphic position of many records with respect to currently accepted lithostratigraphy. Key references to the earlier literature are given by Du Toit (1956), McLachlan and McMillan (1976), Tankard *et al.* (1982) and Dingle *et al.* (1983). In general, the proximal Uitenhage "red bed" sediments deposited in colluvial fans and energetic braided river systems such as the Enon Formation are fossil-poor. In the eastern Gamtoos Basin lignites, pollens and a range of plant compression fossils are recorded from the Uitenhage Group beds, but these appear to stem from the Kirkwood Formation rather than the Enon Formation proper (These two units were not distinguished by Haughton *et al*., 1937; the reference by Le Roux, 2000, to fossil wood from the Enon is, therefore, probably erroneous; *cf* also McLachlan & McMillan 1976, Dingle *et al.* 1983). Silicified wood has been recorded, however, from conglomerates of the Enon Formation near Worcester and Nuy in the Western Cape (Sönghe 1934, McLachlan & McMillan 1976, Gresse & Theron 1992). Charred wood fragments are also reported as common within the Enon of the Algoa Basin (Rogers & Du Toit 1909, Haughton & Rogers 1924) while unidentifiable carbonized miospores from borehole cores in the same basin are mentioned by Scott (1976a, b). The "greenish and buff sandy marls" at the base of the Enon succession at the Kabeljousrivier are of potential palaeontological interest and should be monitored for fossils (*e.g.* plant compressions) if these beds are intersected by excavations during construction of the proposed wind energy facility.

12.4.5 Caenozoic superficial deposits

Overall palaeontological sensitivity = LOW

Neogene to Recent alluvial deposits, such as those along the Kabeljousrivier, may also contain fossil remains of various types (Table 12.1). 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 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. Elevated, 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.

12.5 IMPACT AND RECOMMENDATIONS

The Ubuntu Wind Energy Project study area is largely underlain by coarse fluvial conglomerates and sandstones of the Late Mesozoic Enon Formation (Uitenhage Group) that are very sparsely fossiliferous. In the southeastern, near-coastal sector of the study area the Enon sediments of the plateau are covered by a thin mantle of Bluewater Bay residual soils (Late Caenozoic Algoa Group) that are also relatively unfossiliferous. Therefore the impact of construction work on the coastal plateau, where most of the wind turbines and associated infrastructure are likely to be situated, is likely to be **very low** and specialist palaeontological mitigation is not recommended here. This also applies to the small outcrop area of Table Mountain Group rocks on the western side of the study area, close to the Kabeljousrivier Valley.

On the other hand, beds of sandy marls towards the base of the Enon succession near the Kabeljousrivier may prove to be fossil-rich (e.g. plant compressions). Marine sediments of the Devonian Bokkeveld Group underlying the Kabeljousrivier Valley on the western margin of the study area have yielded invertebrate fossils (various brachiopods) in the past. Any substantial fresh excavations into Enon and Bokkeveld rocks in the Kabeljousrivier Valley area should be sampled, recorded and monitored by a qualified palaeontologist during the construction phase of this development, at the developers expense.

Should substantial fossil remains be exposed at any stage during development, these should be safeguarded - *in situ*, if feasible – and recorded by the responsible ECO (photos, GPS readings). SAHRA should be alerted as soon as possible so that appropriate mitigation measures may be considered.

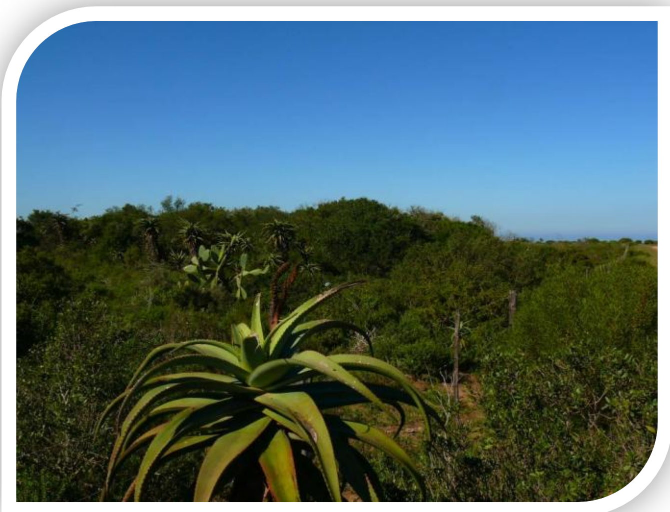


Table 12.1. Fossil record of rock units represented in the Ubuntu study area, largely modified from the SAHRA palaeotechnical report on the Palaeontological Heritage of the Eastern Cape (Almond *et al.*, 2008). The palaeontological sensitivity of formations indicated in blue is rated as LOW, whereas that of formations indicated in green is rated as MODERATE and red indicates (originally) HIGH palaeontological sensitivity (See also following page).

GROUP	***FORMATION & AGE***	***ROCK TYPES***	***FOSSIL BIOTA***	***COMMENTS***
UNNAMED	**Alluvium** Neogene - Recent	Bouldery to pebbly alluvial gravels, sands,silts	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.
ALGOA GROUP	**"Bluewater Bay Formation" (T-Qb)** Late Caenozoic	Reddish-brown, pebbly residual soils, downwasted and fluvial conglomerates	Rare fossil shells weathered out from original Alexandria Formation limestones *plus* land snails, freshwater mussels	Now recognised as weathering product of the Miocene – Pliocene Alexandria Formation
UITENHAGE GROUP	**Enon Formation (Ke)** Late Jurassic / Early Cretaceous	Coarse pebbly to bouldery fanglomerates and braided river conglomerates with minor lenticular sandstones, often reddened	Very sparse transported fragments of bone, teeth, silicified or coalified wood. Microfossils include palynomophs.	Some older "Enon" fossil records probably refer rather to the slightly younger, finer-grained Kirkwood Formation.
BOKKEVELD GROUP	**Ceres Subgroup (Dc)** Early to Mid Devonian	Shallow marine siliciclastics (interbedded mudrock- and sandstone-dominated formations)	Diverse shelly invertebrate biotas and trace fossils, rare fish remains and vascular plants; microfossils (*e.g.* foraminiferans).	Fossil heritage in coastal zone often compromised by tectonic deformation (*e.g.* folding, cleavage), deep weathering and low levels of bedrock exposure.

GROUP		*FORMATION & AGE*	*ROCK TYPES*	*FOSSIL BIOTA*	*COMMENTS*
TABLE MOUNTAIN GROUP	NARDOUW SUBGROUP	**Baviaanskloof Fm (Sb, S-Db)** Early Devonian	Shallow marine "dirty" sandstones and subordinate mudrocks	Low diversity, brachiopod-dominated shelly marine faunas (also bivalves, trilobites, tentaculitids, bryozoans, gastropods, crinoids, trace fossils). Possible primitive vascular plants. Microfossils likely within mudrocks (*e.g.* organic-walled acritarchs).	Correlated with Rietvlei Fm in the western Cape Basin Early Devonian age well-established on fossil evidence.
		Skurweberg Fm (Ss, Sk) Silurian	Braided fluvial pebbly sandstones with thin subordinate mudrocks, especially in shallow marine- /estuarine- influenced parts of succession and towards the east	Sparse marine / estuarine or possibly fluvial trace fossil assemblages (trilobite burrows, Skolithos "pipe rock", horizontal burrows) within more mudrock-rich part of succession (W. Cape). Microfossils likely within mudrocks (e.g. organic-walled acritarchs).	Previously also known as the Kouga Fm (Sk)

TABLE 12.1 continued. Fossil record of rock units represented in the Ubuntu study area, largely modified from the SAHRA palaeotechnical report on the Palaeontological Heritage of the Eastern Cape (Almond *et al*., 2008). The palaeontological sensitivity of formations indicated in blue is rated as LOW, whereas that of formations indicated in green is rated as MODERATE and red indicates (originally) HIGH palaeontological sensitivity.