**PALAEONTOLOGICAL IMPACT ASSESSMENT: DESKTOP STUDY**

# Proposed Wind Energy Facility near Cookhouse, Eastern Cape Province

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## 1. SUMMARY

**Bedrock excavations during construction of the proposed wind energy facility east of Cookhouse will impact continental sediments of the Middleton and (especially) Balfour Formations of the Late Permian Beaufort Group (Karoo Supergroup). These sediments are renowned for their rich fossil heritage of terrestrial vertebrates (most notably mammal-like reptiles or therapsids), as well as fish, amphibians, molluscs, trace fossils (*eg* trackways) and plants (*eg* petrified wood). The Balfour Formation is of special palaeontological significance in that it contains a record of the most disastrous mass extinction event in the history of complex life on Earth - the end-Permian Event 251.4 million years ago. Caenozoic surface sediments in the study area (*eg* alluvium, colluvium) are generally of low palaeontological sensitivity, while the Karoo dolerite intrusions do not contain fossil remains at all.**

**Excavations undertaken into Beaufort Group bedrock in order to install the wind turbines and associated infrastructure are likely to expose, disturb or destroy valuable fossil heritage. Although the direct impact will be local, these fossils are of importance to national as well as international research projects on the fossil biota of the ancient Karoo and the end-Permian mass extinction.**

**It is therefore recommended that :**

**1. *Before* any major construction commences a thorough field scoping survey of natural and artificial rock exposures within the study region as a whole should be undertaken by a qualified palaeontologist to identify specific areas or horizons of palaeontological sensitivity on the ground.**
**2. On the basis of the initial scoping, a realistic, collaborative monitoring programme and protocol should be drawn up by the palaeontologist in conjunction with the developer.**
**3. Monitoring of selected bedrock excavations by the palaeontologist should be carried out during the construction phase of the wind energy facility.**

## 2. INTRODUCTION & BRIEF

African Clean Energy Developments (Pty) Ltd (ACED) are proposing to construct a wind energy facility between Cookhouse and Bedford on the northeastern margins of the Great Karoo *sensu sticto* (Figs. 1 & 2). The project would comprise up to 50 wind turbines as well as access roads.

The footprint of the proposed windfarm development is largely underlain by potentially fossil-rich sedimentary rocks of the Lower Beaufort Group (Karoo Supergroup). Excavations undertaken into bedrock in order to install the wind turbines and associated infrastructure are likely to expose, disturb or destroy valuable fossil heritage.

A desktop palaeontological impact assessment for the project has therefore been commissioned on behalf of ACED by Savannah Environmental (Pty) Ltd of Sunninghill, Gauteng in accordance with the requirements of the National Heritage Resources Act, 1999.

## 3. GEOLOGICAL BACKGROUND

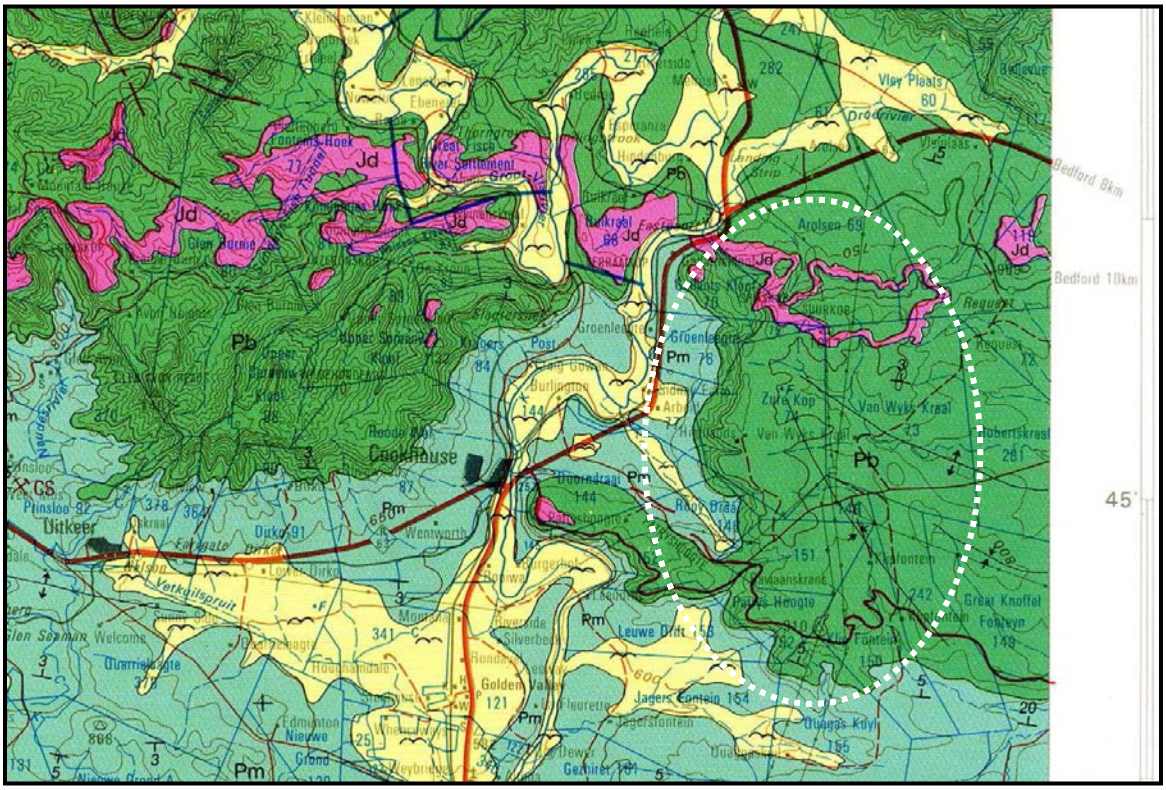


**Fig. 3. Extract from eastern edge of 1: 250 000 geological sheet 3224 Graaff-Reinet (Council for Geoscience, Pretoria) showing approximate extent of study area east of Cookhouse (dotted ellipse). Pm = Middleton Formation Pb = Balfour Formation Jd = Jurassic dolerite intrusions yellow = Caenozoic alluvium**

As shown on the relevant 1: 250 000 geological map, Sheet 3224 Graaff-Reinet published by the Council for Geoscience (Fig. 3), the study area is largely underlain by Late Permian continental sediments of the Lower Beaufort Group (Adelaide Subgroup, Karoo Supergroup). In particular the Karoo sediments belong to the **Middleton Formation** (**Pm**) and the overlying **Balfour Formation** (**Pb**) (Hill 1993, Cole *et al*. 2004, Johnson *et al*., 2006). In the northern part of the study area the latter is extensively intruded by major intrusive sills of the **Karoo Dolerite Suite** (**Jd**) of Early Jurassic age (*c*. 183 Ma). Dips of Beaufort Group sediments in the study region are generally shallow (3 to 5°), with small-scale E-W fold axes to the south and east of Cookhouse, so low levels of tectonic deformation and cleavage development are expected.

### 3.1. Middleton Formation

This formation forms the middle portion of the Adelaide Subgroup east of 24°E, including the Graaff-Reinet sheet area (Hill 1993, Johnson *et al*., 2006). The fluvial Middleton succession comprises greenish-grey to reddish overbank mudrocks with subordinate resistant-weathering, fine-grained channel sandstones deposited by large meandering river systems. Because of the dominance of recessive-weathering mudrocks, the Middleton Formation erodes readily to form low-lying *vlaktes* at the base of the Escarpment near Cookhouse and extensive exposures of fresh (unweathered) bedrock are rare.

### 3.2. Balfour Formation

The fluvial Balfour Formation comprises recessive weathering, grey to greenish-grey overbank mudrocks with subordinate resistant-weathering, grey, fine-grained channel sandstones deposited by large meandering river systems in the Late Permian Period (Hill 1993). Thin wave-rippled sandstones were laid down in transient playa lakes on the flood plain. Reddish mudrocks are comparatively rare, but increase in abundance towards the top of the Adelaide Subgroup succession near the upper contact with the Katberg Formation. The base of the Balfour succession is defined by a sandstone-rich zone, some 50m thick, known as the **Oudeberg Member**. The Oudeberg sandstones and interbedded mudrocks crop out along the edge of the low escarpment towards the western and southern edge of the study area. It is likely that at least the lowermost portion of the overlying mudrock-dominated **Daggaboersnek Member** underlies the interior portions of the study area, away from the escarpment edge (This requires confirmation in the field). Dark grey mudrocks with thin, tabular sandstones and wave ripples (formed in shallow lakes) within this member are well-exposed at higher elevations in Daggaboersnek itself along the main road between Cookhouse and Cradock (Hill 1993).

### 3.3. Caenozoic drift

Surface exposure of fresh Beaufort Group rocks within the development footprint itself is likely to be generally poor, judging from satellite images, apart from stream beds, dongas and steeper hillslopes. The hill slopes are typically mantled with a thin layer of **colluvium** or slope deposits (*eg* sandstone scree). Thicker accumulations of sandy, gravelly and bouldery **alluvium** of Late Caenozoic age (< 5Ma) are found in stream and river beds, such as along the western edge of the study area. These colluvial and alluvial deposits may be extensively calcretised (*ie* cemented with soil limestone or calcrete), especially in the neighbourhood of dolerite intrusions.

## 4. PALAEONTOLOGICAL HERITAGE

The overall palaeontological sensitivity of the Beaufort Group sediments is high (Almond *et al*. 2008). These continental sediments have yielded one of the richest fossil records of land-dwelling plants and animals of Permo-Triassic age anywhere in the world. A chronological series of mappable fossil biozones or assemblage zones (AZ), defined mainly on their characteristic tetrapod faunas, has been established for the Main Karoo Basin of South Africa (Rubidge 1995). Maps showing the distribution of the Beaufort assemblage zones within the Main Karoo Basin have been provided by Keyser and Smith (1979) and Rubidge (1995), and for the Graaff-Reinet sheet area they are available in Hill (1993).

## 4.1. Middleton Formation

The Middleton Formation comprises portions of three successive Beaufort Group fossil assemblage zones (AZ) that are largely based on the occurrence of specific genera and species of fossil therapsids. These are, in order of decreasing age, the *Pristerognathus*, *Tropidostoma* and *Cistecephalus* Assemblage Zones (Rubidge 1995). The three biozones have been assigned to the Wuchiapingian Stage of the Late Permian Period, with an approximate age range of 260-254 million years (Rubidge 2005). According to published maps showing the distribution of the Beaufort assemblage zones within the Main Karoo Basin (Keyser & Smith 1979, Hill 1993, Rubidge 1995), the upper Middleton Formation succession to the east of Cookhouse lies within the ***Cistecephalus* Assemblage Zone** (= upper *Cistecephalus* Biozone or *Aulacephalodon-Cistecephalus* Assemblage Zone of earlier authors; see table 2.2 in Hill 1993).

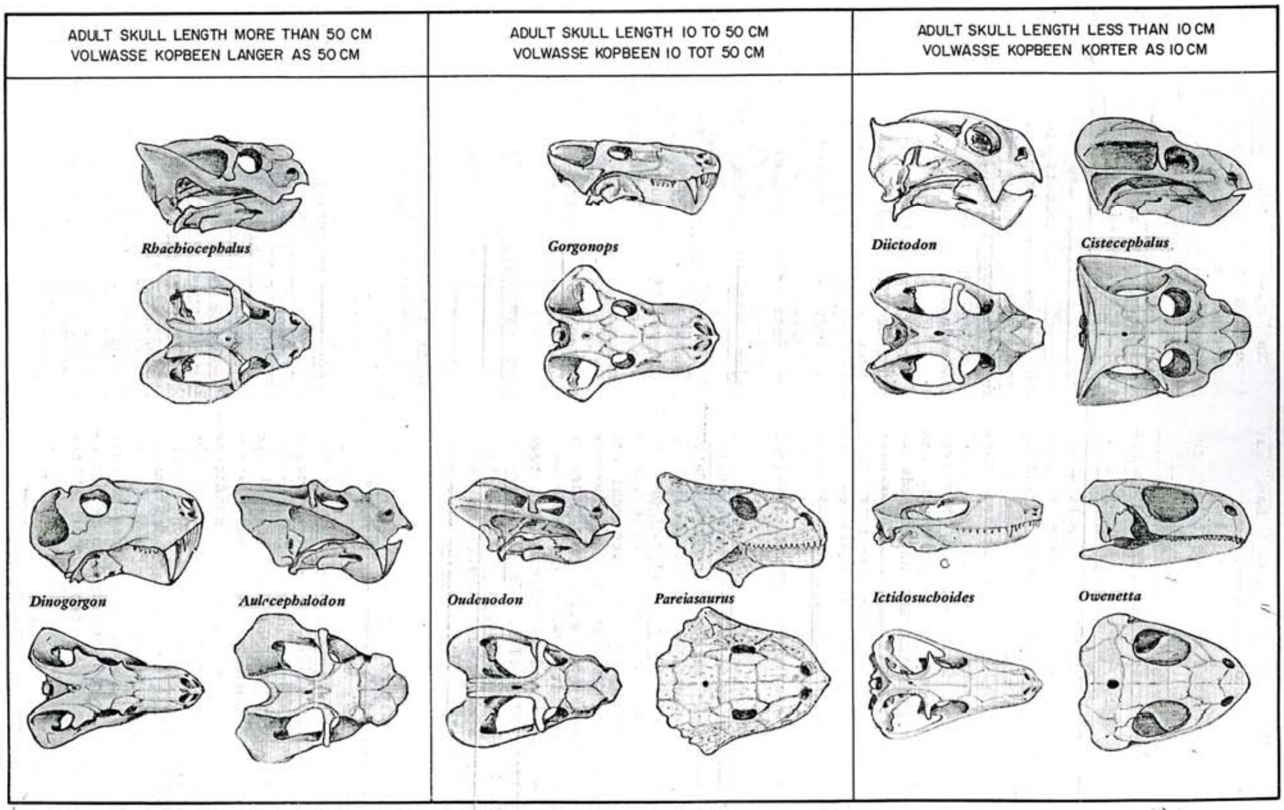


**Fig. 4. Skulls of characteristic fossil vertebrates from the *Cistecephalus* Assemblage Zone (From Keyser & Smith 1979). *Pareiasaurus* a large herbivore, and *Owenetta*, a small insectivore, are true reptiles. The remainder are therapsids or "mammal-like reptiles". Of these, *Gorgonops* and *Dinogorgon* are large flesh-eating**

**gorgonopsians, *Ictidosuchoides* is an insectivorous therocephalian, while the remainder are small – to large-bodied herbivorous dicynodonts.**

The following major categories of fossils might be expected within *Cistecephalus* AZ sediments in the study area (Keyser & Smith 1979, Anderson & Anderson 1985, Hill 1993, Smith & Keyser *in* Rubidge 1995, MacRae 1999, Cole *et al*., 2004, Almond *et al*. 2008):

- isolated petrified bones as well as rare articulated skeletons of **terrestrial vertebrates** such as true **reptiles** (notably large herbivorous pareiasaurs, small insectivorous owenettids) and **therapsids** or "mammal-like reptiles" (*eg* diverse herbivorous dicynodonts, flesh-eating gorgonopsians, and insectivorous therocephalians) (Fig. 4)
- aquatic vertebrates such as large **temnospondyl amphibians** (*Rhinesuchus*, usually disarticulated), and **palaeoniscoid bony fish** (*Atherstonia*, *Namaichthys*, often represented by scattered scales rather than intact fish)
- freshwater **bivalves** (*Palaeomutela*)
- **trace fossils** such as worm, arthropod and tetrapod burrows and trackways, coprolites (fossil droppings)
- **vascular plant remains** including leaves, twigs, roots and petrified woods ("*Dadoxylon*") of the *Glossopteris* Flora (usually sparse, fragmentary), especially glossopterid trees and arthrophytes (horsetails).

As far as the biostratigraphically important tetrapod remains are concerned, the best fossil material is generally found within overbank mudrocks, whereas fossils preserved within channel sandstones tend to be fragmentary and water-worn (Rubidge 1995, Smith 1993). Many fossils are found in association with ancient soils (palaeosol horizons) that can usually be recognised by bedding-parallel concentrations of calcrete nodules.

### 4.2. Balfour Formation

The sandstone-dominated Oudeberg Member at the base of the Balfour Formation is also assigned to the *Cistecephalus* Assemblage Zone (Rubidge 1995) whose fossil biota has been treated above. The Assemblage Zone to which the overlying Daggaboersnek Member should be assigned is less clear (Cole *et al*., 2004). Le Roux and Keyser (1988) report *Cistecephalus* AZ fossils from this member in the Victoria West sheet area, whereas the Daggaboersnek Member in the Middelburg sheet area is assigned to the ***Dicynodon* Assemblage Zone** and this certainly applies to the greater part of the Balfour Formation (Rubidge 1995, Cole *et al*., 2004 p. 21). This younger biozone has been assigned to the Changhsingian Stage (= Late Tartarian), right at the end of the Permian Period, with an approximate age range of 253.8-251.4 million years (Rubidge 1995, 2005).

Good accounts, with detailed faunal lists, of the rich Late Permian fossil biotas of the *Dicynodon* Assemblage Zone have been given by Kitching (*in* Rubidge 1995) and by Cole *et al*. (2004). See also the reviews by Cluver (1978), MacRae (1999), McCarthy & Rubidge (2005) and Almond *et al*. (2008). In general, the following broad categories of fossils might be expected within the Balfour Formation in the Cookhouse - Bedford area:

- isolated petrified bones as well as articulated skeletons of terrestrial vertebrates such as true **reptiles** (notably large herbivorous pareiasaurs, small lizard-like millerettids and younginids) and **therapsids** (diverse dicynodonts such as *Dicynodon* and the much smaller *Diictodon*, carnivorous gorgonopsians,

therocephalians such as *Theriognathus* (= *Whaitsia*), primitive cynodonts like *Procynosuchus*, and biarmosuchians) (See Fig. 5 herein).
- aquatic vertebrates such as large, crocodile-like temnospondyl **amphibians** like *Rhinesuchus* (usually disarticulated), and palaeoniscoid **bony fish** (*Atherstonia*, *Namaichthys*)
- freshwater **bivalves** (*Palaeomutela*)
- **trace fossils** such as worm, arthropod and tetrapod burrows and trackways, coprolites (fossil droppings)
- **vascular plant remains** including leaves, twigs, roots and petrified woods ("*Dadoxylon*") of the *Glossopteris* Flora (usually sparse, fragmentary), especially glossopterids and arthrophytes (horsetails)

The abundance and variety of fossils within the *Dicynodon* Assemblage Zone decreases towards the top of the succession (Cole *et al*., 2004). From a palaeontological viewpoint, these diverse *Dicynodon* AZ biotas are of extraordinary interest in that they provide some of the best available evidence for the last flowering of ecologically-complex terrestrial ecosystems immediately preceding the catastrophic end-Permian mass extinction (*eg* Smith & Ward, 2001, Rubidge 2005, Retallack *et al*., 2006).

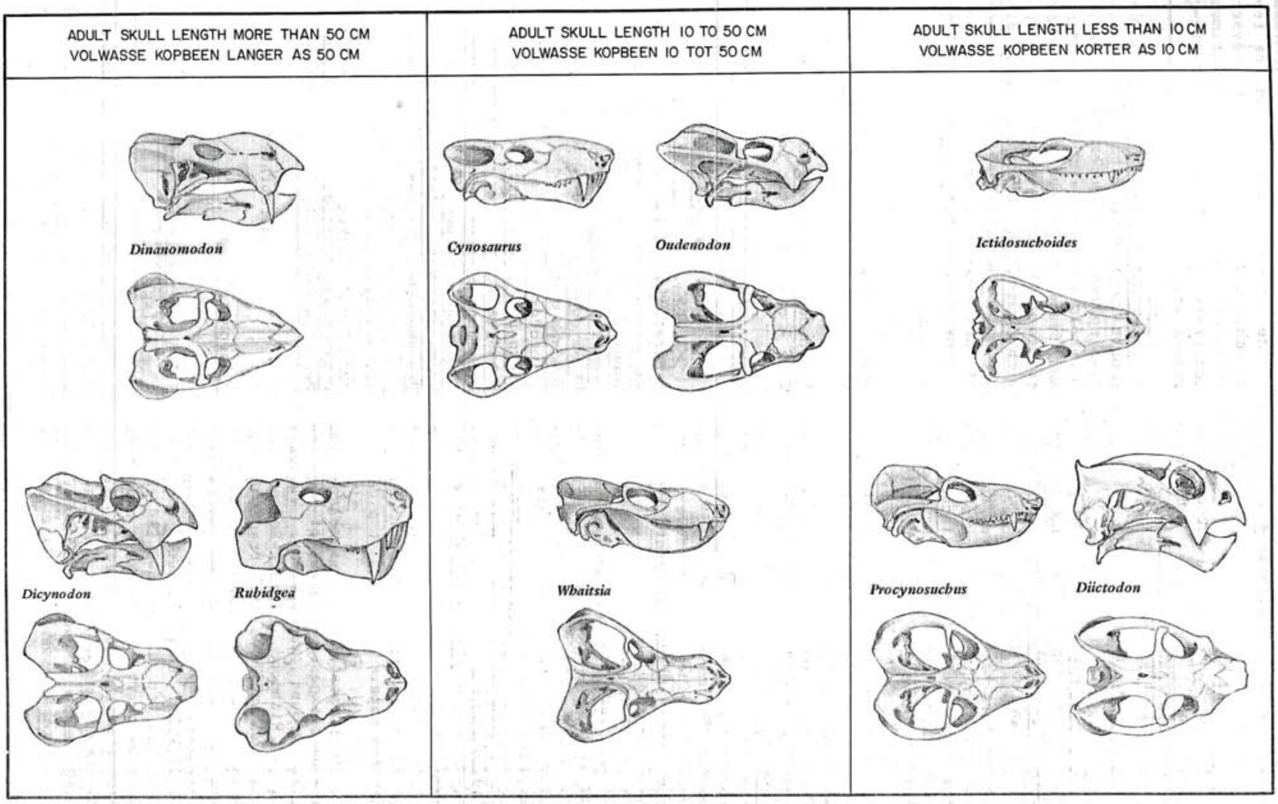


**Fig. 5. Skulls of characteristic fossil vertebrates – all therapsids - from the *Dicynodon* Assemblage Zone (From Keyser & Smith 1979). Among the dominant therapsids ("mammal-like reptiles"), *Rubidgea* and *Cynosaurus* are carnivorous gorgonopsians *Whaitsia* (now *Theriognathus*) is a predatory therocephalian while *Ictidosuchoides* is a small insectivorous member of the same group, *Procynosuchus* is a promitive cynodont, and the remainder are large- to small-bodied dicynodont herbivores.**

### 4.3. Karoo Dolerite Suite

The dolerite outcrops in the northern part of the study area are in themselves of no palaeontological significance since these are high temperature igneous rocks emplaced at depth within the Earth's crust. However, as a consequence of their proximity to large dolerite intrusions in the Great Escarpment zone, the Beaufort Group sediments here may well have been thermally metamorphosed or "baked" (*ie*. recrystallised, impregnated with secondary minerals). Embedded fossil material of phosphatic composition, such as bones and teeth, is frequently altered by baking – bones may become blackened, for example - and can be very difficult to extract from the hard matrix by mechanical preparation (Smith & Keyser, p. 23 *in* Rubidge 1995). Thermal metamorphism by dolerite intrusions therefore tends to reduce the palaeontological heritage potential of Beaufort Group sediments.

### 4.4. Caenozoic alluvium

Various types of superficial deposits ("drift") of geologically young, Late Caenozoic (Miocene / Pliocene to Recent) age occur throughout the Great Karoo region. They include pedocretes (*eg* calcretes), colluvial slope deposits (dolerite scree *etc*), river alluvium, as well as spring and pan sediments (*eg* Partridge *et al*. 2006). These Karoo drift deposits have been comparatively neglected in palaeontological terms for the most part. However, alluvial sediments such as those expected in the study area (*eg* western boundary) may occasionally contain important fossil biotas, notably the bones, teeth and horn cores of mammals (*eg* Skead 1980, Klein 1984, MacRae 1999, Partridge & Scott 2000). Other late Caenozoic fossil biotas from these superficial deposits include non-marine molluscs (bivales, gastropods), ostrich egg shells, trace fossils (*eg* calcretised termitaria, coprolites), and plant remains such as peats or palynomorphs (pollens) in organic-rich alluvial horizons.

## 5. CONCLUSIONS & RECOMMENDATIONS

Bedrock excavations made during construction of the proposed wind energy facility east of Cookhouse will affect continental sediments of the Middleton and (especially) Balfour Formations of the Late Permian Beaufort Group. These sediments underlie the great majority of the study area and are renowned for their rich fossil heritage of terrestrial vertebrates (most notably mammal-like reptiles or therapsids), as well as fish, amphibians, molluscs, trace fossils (*eg* trackways) and plants (*eg* petrified wood). The Balfour Formation is of special palaeontological significance in that it contains a record of the most disastrous mass extinction event in the history of complex life on Earth - the end-Permian Event 251.4 million years ago. Caenozoic surface sediments in the study area (*eg* alluvium, colluvium) are generally of low palaeontological sensitivity, while the Karoo dolerite intrusions do not contain fossil remains at all.

Excavations undertaken into Beaufort Group bedrock in order to install the wind turbines and associated infrastructure are likely to expose, disturb or destroy valuable fossil heritage. Although the direct impact will be local, these fossils are of importance to national as well as international research projects on the fossil biota of the ancient Karoo and the end-Permian mass extinction. Therefore, the impact from disturbance and/or destruction of valuable fossil heritage of the Beaufort Group bedrock is of high significance (refer to the impact table below).

| ***Nature:*** Disturbance or destruction of valuable fossil heritage of the Beaufort Group bedrock | | |
|---|---|---|
| | **Without mitigation** | **With mitigation** |
| ***Extent*** | International (5) | International (5) |
| ***Duration*** | Permanent (5) | Permanent (5) |

| | | |
|---|---|---|
| ***Magnitude*** | Very high (10) | Very high (10) |
| ***Probability*** | Highly probable (4) | Probable (3) |
| ***Significance*** | **High (80)** | **Medium to high (60)** |
| ***Status (positive or negative)*** | Negative | Negative |
| ***Reversibility*** | None | None |
| ***Irreplaceable loss of resources?*** | Yes | Yes |
| ***Can impacts be mitigated?*** | Yes – but to a limited extent | |
| ***Mitigation:***<br>» Before any major construction commences a thorough field scoping survey of natural and artificial rock exposures within the study region as a whole should be undertaken by a qualified palaeontologist to identify specific areas or horizons of palaeontological sensitivity on the ground.<br>» A realistic, collaborative monitoring programme and protocol should be drawn up by the palaeontologist in conjunction with the developer.<br>» Monitoring of selected bedrock excavations by the palaeontologist should be carried out during the construction phase of the wind energy facility. | | |
| ***Cumulative impacts:*** Any construction activities have the potential to impact on the valuable fossil heritage of the Beaufort Group bedrock | | |
| ***Residual Impacts:*** N/A | | |

It is therefore recommended that

1. Following approval of the project and *before* any major construction (*ie* substantial bedrock excavation) commences a thorough field scoping survey of natural and already existing artificial rock exposures (*eg* dams, roadcuts) within the study region as a whole should be undertaken by a qualified palaeontologist to identify specific areas or horizons of palaeontological sensitivity on the ground. For those sites or areas of inferred high palaeontological sensitivity, repositioning of excavations should not be necessary except in very exceptional cases, but monitoring of excavations by a specialist palaeontologist may well be required.

2. On the basis of the initial scoping, a realistic, collaborative monitoring programme and protocol should be drawn up by the palaeontologist in conjunction with the developer and SAHRA so that any important fossil heritage on site may be conserved cost-effectively.

3. Monitoring of selected bedrock excavations by the palaeontologist should be carried out during the construction phase of the wind energy facility. Given the scale of the development (*eg* large number of turbines) and the lengthy period during which bedrock excavations are likely to be made, a judicious sampling approach will almost certainly be necessary here.

Note that the palaeontologist involved will be required to obtain a palaeontological collection permit from SAHRA and to arrange a suitable respository for any fossils collected (*eg* Albany Museum, Grahamstown).

**OBJECTIVE: Conservation of Paleontological Resources during Construction**

| | |
|---|---|
| Project component/s | List of project components affecting the objective<br>» wind turbines<br>» substations<br>» power lines<br>» access roads |
| Potential Impact | » Destruction of potential fossil / palaeontological resources and contextual information from geological data |
| Activity/risk source | » Excavations to install wind turbines and associated infrastructure |
| Mitigation: Target/Objective | » Limited and controlled impacts on valuable fossil heritage. The opportunity to collect exposed fossils and relocate to a suitable respository. |

| Mitigation: Action/control | Responsibility | Timeframe |
|---|---|---|
| Before any major construction commences a thorough field scoping survey of natural and artificial rock exposures within the study region as a whole should be undertaken by a qualified palaeontologist to identify specific areas or horizons of palaeontological sensitivity on the ground. | ACED, ACED Contractor & Specialist consultant | Pre-Construction |
| A realistic, collaborative monitoring programme and protocol should be drawn up by the palaeontologist in conjunction with the developer and SAHRA so that any important fossil heritage on site may be conserved cost-effectively | ACED, ACED Contractor & Specialist consultant | Pre-Construction |
| Monitoring of bedrock excavations for newly exposed fossil material. Substantial finds to be recorded (location, photographs) and reported to specialist consultant for possible collection. | ECO, Specialist consultant | Construction |

| | |
|---|---|
| Performance Indicator | Limited and controlled impacts on valuable fossil heritage. The opportunity to collect exposed fossils and relocate to a suitable respository. |
| Monitoring | Monitoring of selected bedrock excavations by the palaeontologist should be carried out during the construction phase of the wind energy facility. |

# 6. ACKNOWLEDGEMENTS

Ms Karen Jodas of Savannah Environmental (Pty) Ltd, Sunninghill, is thanked for commissioning this study, for kindly providing all the necessary maps and background information, and for editorial input.

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## QUALIFICATIONS & EXPERIENCE OF THE AUTHOR

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

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