PALAEONTOLOGICAL IMPACT ASSESSMENT: DESKTOP STUDY

AB's Wind Energy Facility near Indwe, Emalahleni Local Municipality, Eastern Cape Province

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1. SUMMARY

The proposed AB's wind energy facility comprising 24 wind turbines and associated infrastructure is situated on a 980 ha site *c*. 10km northeast of Indwe within the Emalahleni Local Municipality, Eastern Cape Province. The wind farm site is underlain by two units of potentially fossiliferous continental sediments in the upper, Mesozoic part of the Karoo Supergroup. These Karoo rocks are extensively intruded by unfossiliferous dolerites of the Early Jurassic Karoo Dolerite Suite. Among the Mesozoic units exposures of the Late Triassic to Early Jurassic Elliot Formation in the northern part of the study area are unlikely to be directly affected by the proposed development. Late Caenozoic alluvial sediments in the northwestern portion of the study area are of low palaeontological sensitivity.

In contrast, the Late Triassic Molteno Formation that underlies the central and southern parts of the study area is internationally famous for its remarkably rich assemblages of plant and insect fossils. These include the richest Triassic (*c*. 220 million year old) fossil floras recorded anywhere in the world, as well as some of the oldest known dinosaur trackways. Several key fossil sites are already recorded within the Molteno Formation to the northeast of the Indwe area. Excavations for new access roads and wind turbine emplacements may well disturb, damage or destroy scientifically valuable fossils during the construction phase of this development.

It is therefore recommended that a qualified palaeontologist be commissioned to carry out a field scoping study of the entire study area *before* construction commences. The main purpose of the field scoping study would be to identify any areas within the development footprint where specialist palaeontological mitigation during the construction phase might be required. Relocation of wind turbines, roads or other developments is unlikely to be necessary on palaeontological grounds alone *provided that* appropriate mitigation is ensured. Mitigation would involve the recording and judicious collection of fossil material and associated geological data.

Should substantial fossils – such as vertebrate remains of any sort or plant-rich beds - be exposed at any time during construction, the ECO should safeguard these - *in situ*, where feasible. SAHRA and / or a professional palaeontologist should then be alerted as soon as possible so that appropriate mitigation measures can be implemented.

2. INTRODUCTION & BRIEF

The company DNA Wind Farm (Pty) Ltd is proposing to develop a commercial wind energy facility and associated infrastructure on a 980 ha (10 km^2) site situated about 10km northeast of Indwe within the Emalahleni Local Municipality, Eastern Cape Province (Fig. 1). The following land parcels are included within the proposed development: Eenzaam (remaining extent), Begeer (remaining extent), Devon Bank (remaining extent), Noodshulp (remaining extent), Onverwagt (Portion 2 and remaining extent), Houtnek (remaining extent) and Spytfontein (remaining extent).

According to the Basic Information Document prepared by Savannah Environmental (Pty) Ltd the wind energy facility will comprise up to 24 wind turbines (*c*. 80m tall) as well as associated infrastructure including:

- Foundations to support the turbine towers;
- Underground cables between turbines;
- A substation; and
- Internal access roads to each wind turbine.

Since many of these developments will involve excavation into potentially fossiliferous bedrock of Karoo Supergroup, a palaeontological impact assessment for the project as part of a comprehensive EIA has been commissioned by Mr John von Meyer of Savannah Environmental (Pty) Ltd, Sunninghill, in accordance with the requirements of the National Heritage Resources Act, 1999. The various categories of heritage resources recognised as part of the National Estate in Section 3 of the Heritage Resources Act include, among others:

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

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.

2.1. General approach used for palaeontological impact desktop studies

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 *et al*. 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 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, a field scoping study by a professional palaeontologist is usually warranted. The main purpose of the field scoping study would be to identify any areas within the development footprint where specialist palaeontological mitigation during the construction phase might be required.

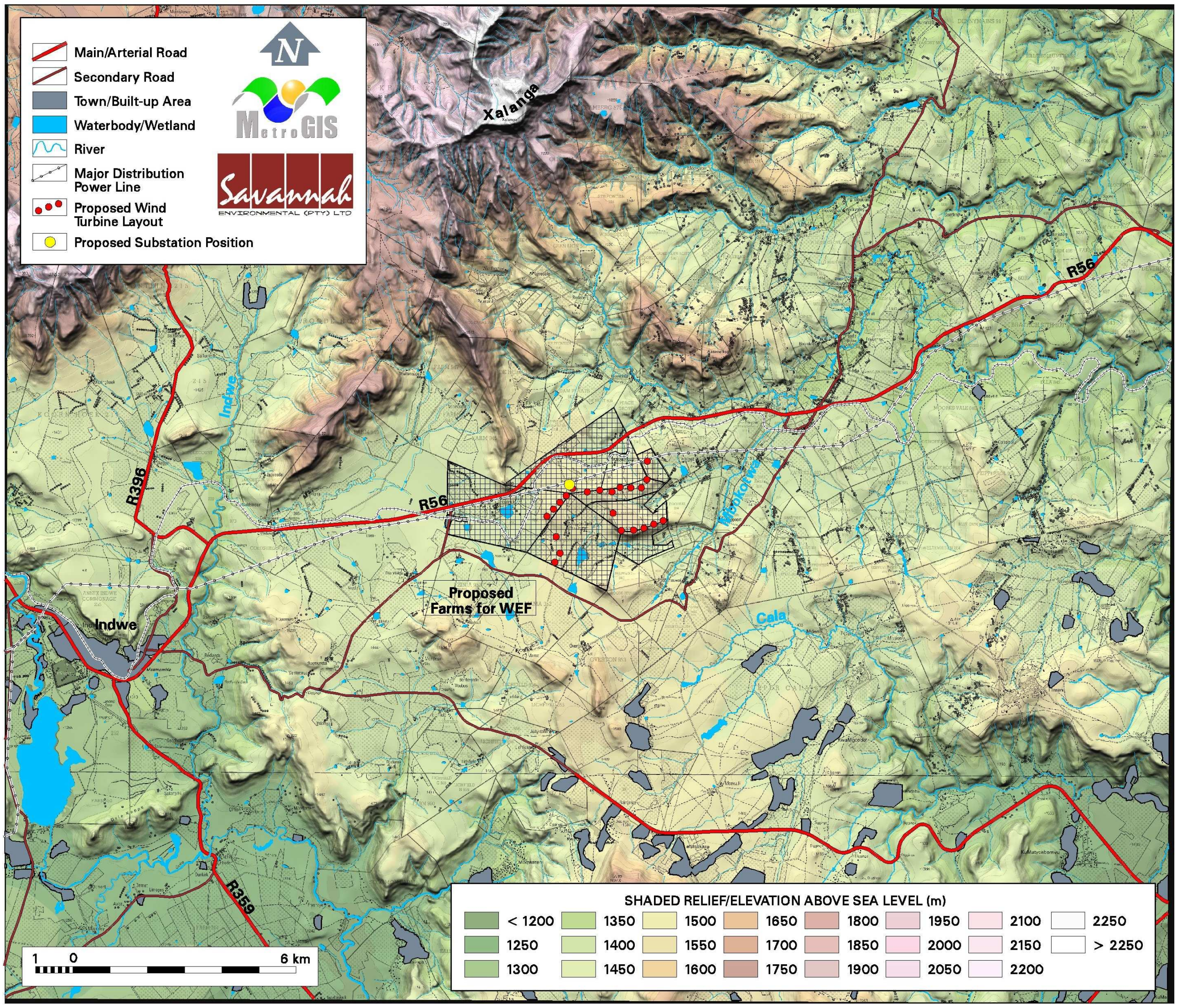

Fig. 1. **Topographic map showing location and extent of the proposed AB's wind energy facility below the escarpment plateau *c*. 10km northeast of Indwe, Eastern Cape Province. Image kindly provided by Savannah Environmental (Pty) Ltd.**

3. GEOLOGICAL BACKGROUND

The geology of the study area is depicted on the 1: 250 000 geology map sheet 3126 Queenstown (Council for Geoscience, Pretoria; Johnson 1984) (Fig. 2). The area is underlain by several units of Mesozoic continental sediments belonging to the upper part of the Karoo Supergroup, *i.e*. the **Stormberg Group**. These include:

- Late Triassic fluvial sediments and coals of the **Molteno Formation** (**TRm**) which underlie most of the low-lying central and southern areas where the wind farm is to be constructed;
- Late Triassic to Early Jurassic "red beds" of the **Elliot Formation** (**TRe**) that crops out in the north-central part of the study area.

The Stormberg sediments are extensively intruded by tough-weathering dolerite sills and dykes of the Early Jurassic **Karoo Dolerite Suite** (**Jd** in Fig. 2) that preceded the break-up of the Gondwana supercontinent. These intrusions are briefly described by Johnson (1984) and form topographic ridges that are suitable for several wind turbine positions (Compare Figs. 1 and 2). The dolerites are responsible for thermal metamorphism (baking) of the adjacent Karoo bedrocks; for example, fine-grained mudrocks are metamorphosed to form black, flinty "lydianite" or hornfels that was extensively exploited by Stone Age hunter-gatherers in the Great Karoo as a raw material for stone tools. Colluvial debris (scree) from the dolerite outcrops mantles the adjacent Mesozoic sediments to some degree.

In addition to the Mesozoic bedrocks in the study region there is a small area of **alluvial (river) sediments** (pale yellow in Fig. 2) of probable Quaternary to Recent age in the northwest. Thicker accumulations of sandy, gravelly and bouldery alluvium of Late Caenozoic age (< 5Ma) can found in stream and river beds on the plateau and in the escarpment areas. These colluvial and alluvial deposits may be extensively calcretised (*i.e.* cemented with soil limestone or calcrete), especially in the neighbourhood of dolerite intrusions.

By comparing the topographic and geological maps in Figures 1 and 2 is it clear that the proposed turbine positions within the study area directly overlie only the Molteno Formation and Karoo dolerites. The fossiliferous Elliot Formation cropping out to the north of the development footprint is very unlikely to be directly affected by the construction of either wind turbines or access roads. This rock units will therefore not be considered further in this study, which focuses rather on the geology and fossils of the Molteno Formation which underlies a high proportion of the proposed development footprint and has a high palaeontological sensitivity (Section 4).

The **Molteno Formation** is a stratigraphically complex wedge of perennial braided alluvial sediments of estimated Late Triassic age that crops out around the margins of the Stormberg Group outcrop area centred on the Drakenberg highlands (Fig. 3). At its thickest, in the south, the formation reaches 600-650m and has been subdivided into a series of five members but it tapers rapidly towards the north (Note that thicknesses of 335-290m are reported respectively west and northwest of Sterkstroom by Johnson, 1984). The sandstone-rich Molteno succession is more resistant-weathering than the underlying and overlying rocks (Burgersdorp and Elliot Formations respectively) and therefore tends to form a topographic escarpment, as seen in the study region near Indwe (Fig. 1).

Useful short geological accounts of the Molteno Formation are given by Dingle *et al.* (1983), Visser (1984), Smith *et al.* (1998), Hancox (2000) and Johnson *et al.* (2006), while a short description of these rocks in the Queenstown 1: 250 000 geology sheet area is provided by Johnson (1984). Key technical papers include those by Turner (1975. 1983), Eriksson (1984), Christie (1981), Dingle *et al.* (1983), Cairncross *et al.* (1995), Anderson *et al.* (1998) and Hancox (1998); fuller geological references are provided by Hancox (2000).

The Molteno succession is made up of an alternation of laterally-persistent, erosive-based, medium- to coarse-grained, feldspathic sandstones and subordinate olive-grey to reddish mudrocks. These rocks were deposited in braided alluvial channels, overbank floodplains and lakes on an extensive, northwards-flowing alluvial braidplain. The sandstones typically show a "glittering" appearance due to extensive development of secondary quartz overgrowths. Internal sedimentary structures include trough and planar cross-bedding, flat-lamination and overturned cross-bedding. Numerous fining-upwards sequences of 5-50m thickness, averaging 20-30m, are commonly present within the Molteno succession (Johnson 1984). These sequences, which can be readily seen on aerial and satellite images, grade upwards from pebbly, coarse sandstones at the base through finer sandstones, siltstones and finally into carbonaceous, thinly-bedded to laminated claystones. These last may be highly fossiliferous. Thin, lenticular coals were formed in peaty swamp settings on the alluvial floodplain, but many so-called "coals" are effectively only carbonaceous mudstones. Humid, warm climates with a pronounced seasonality are suggested by the rich plant and insect life preserved in these sediments, especially the finer-grained mudrocks, as well as by the sedimentology and fossil soils (Hancox 2000). However, some authors infer an alternation of warm, dry summers and cool, wet winters (*e.g.* Anderson *et al.* 1998, Johnson *et al.* 2006). The precise age of the Molteno Formation has not yet been established, but a Late Triassic (Carnian, 228-216.5 Ma) age is favoured for at least the lower part of the formation by most recent authors on the basis of the fossil plants (*Dicroidium* Flora) and palynomorphs (*Allisporites / Falcisporites* assemblages) as well as biostratigraphic correlation with Australian Triassic successions (Hancox 2000, Rubidge 2005).

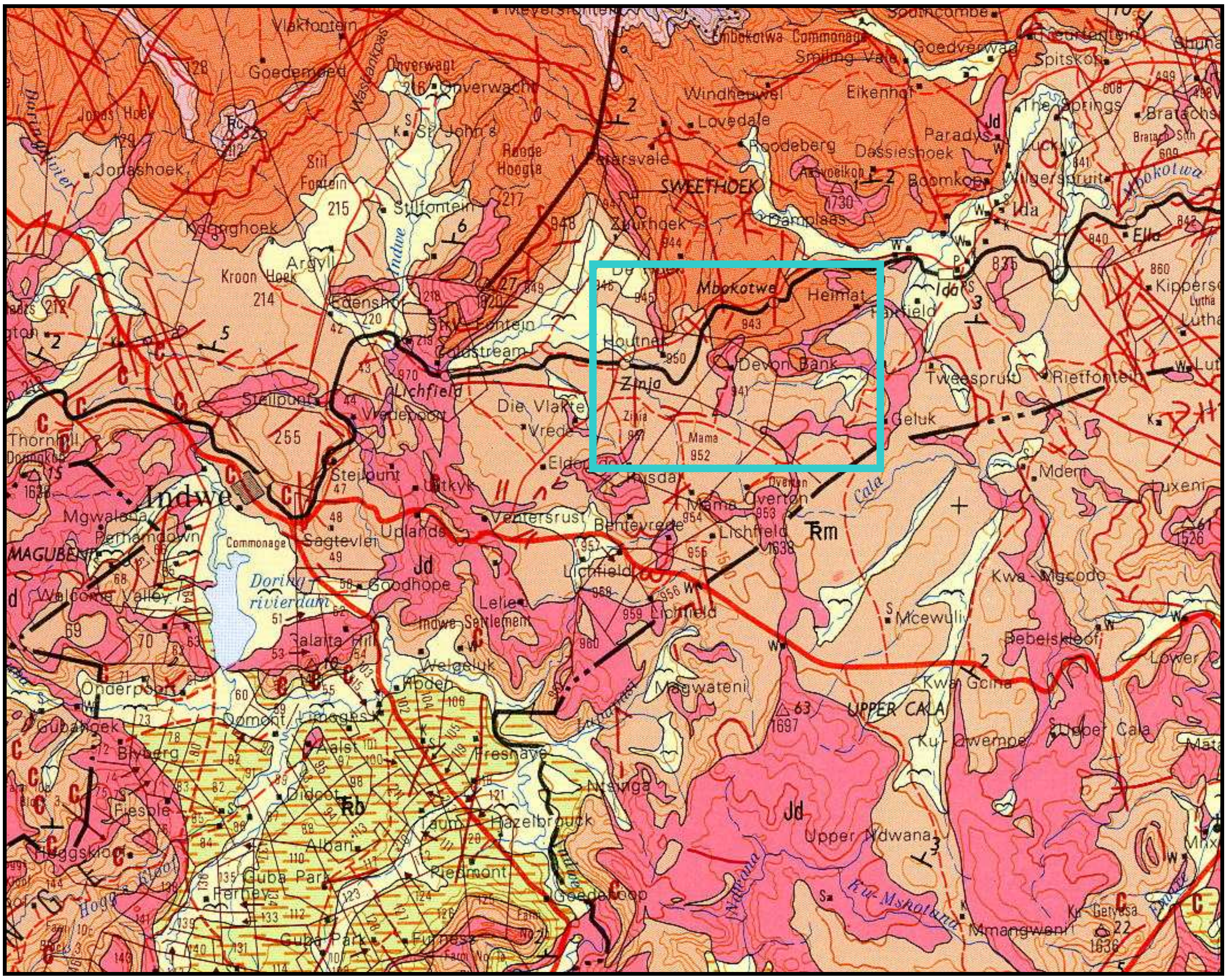

Fig. 2. Extract from 1: 250 000 geological map 3126 Queenstown (Council for Geoscience, Pretoria) showing approximate location and extent (blue rectangle) of the study area to the northeast of Indwe, Eastern Cape province (Please see Fig. 1 for an accurate depiction of the boundaries of the study area). Provisional wind turbine and substation locations overlie dolerite ridges as well as Molteno Formation rocks in the southern part of the area.

Major rock units represented within the study area include:

TRm (flesh pink) = Late Triassic Molteno Formation
TRe (red) = Late Triassic to Early Jurassic Elliot Formation
Jd (bright pink) = Early Jurassic intrusions of the Karoo Dolerite Suite
Pale yellow areas = Late Caenozoic alluvium

4. PALAEONTOLOGICAL HERITAGE

Since the igneous Karoo dolerites are entirely unfossiliferous while the Elliot Formation within the study area is unlikely to be affected by the proposed wind energy facility development, only the potentially highly fossiliferous Molteno Formation that underlies most of the development footprint will be considered in detail here.

In terms of plant and insect fossils, but not vertebrates or traces, the Molteno Formation is one of the most productive rock units within the Main Karoo Basin. Indeed, it has produced the richest known floras of Triassic age anywhere in the world and its palaeontological sensitivity towards development is correspondingly high (Almond & Pether 2008). Excellent reviews of the Molteno fossil biota have been provided by Cairncross *et al.* (1995), Anderson *et al.* (1998), Anderson and Anderson *in* MacRae (1999), Hancox (2000) and Anderson (2001). These key accounts include references to the extensive technical literature on the Molteno flora and fauna stretching back to pioneering work by Wyley (1856) and Stow (1871) on coals and petrified forests as well as by Alex du Toit in the early 1900s on fossil plant remains (See Hancox 2000 for early references). Here may be mentioned only key systematic and synthetic papers on the Molteno palaeoflora published by John and Heidi Anderson that are listed towards the end of this report.

The fossil biota recorded so far from the Molteno Formation may summarised as follows:

- A very rich **megaflora** of fossil foliage, fruits, seeds and stems, mostly preserved as carbonaceous compressions within mudrocks. The flora contains over sixty genera and is strongly dominated by "pteridophytes" (over 50 species of spore-bearing ferns, including horsetails) and a rich variety of gymnosperms (27 genera, 114 species, including ginkgophytes, cycads, conifers and "seed ferns"). The four dominant plant genera are the characteristic Triassic "seed fern" *Dicroidium* (Peltaspermales; Fig. 4), the maidenhair tree relative *Sphenobaiera* (Ginkgoales), the conifer *Heidiphyllum* (Voltziales) and the horsetail fern *Equisetum* (Equisetales). Over 200 plant species have been identified, including sixteen orders of gymnosperms alone. Minor groups include bryophytes such as mosses, liverworts and club-mosses;

- **Silicified woods**, including petrified tree trunks, now assigned to a range of gymnospermous genera (Bamford 1999, 2004);

- Poorly-studied **palynomorph assemblages** dominated by pteridophyte spores and gymnosperm pollens assigned to the Triassic *Allisporites / Falcisporites* assemblage (Hancox 2000 and refs. therein);

- Rare **fossil fish** belonging to four genera, representing the only vertebrate body fossils from the formation (Anderson *et al.* 1998);

- Relatively abundant and diverse **fossil insects** associated with compression floras in fine-grained mudrocks (Fig. 4). These important insect assemblages comprise several thousand specimens of about 350 species, mainly preserved as disarticulated wings but with some intact or partially intact bodies. They are dominated by cockroaches, beetles, bugs and dragonflies and include eighteen different insect orders. The only other terrestrial arthropods recorded so far are extremely rare spiders (Selden *et al.* 1999, Selden 2009);

- Rare shelly invertebrates including three genera of **conchostracans** (freshwater clam shrimps) and two genera of **bivalves**;

- Occasional **trace fossils** including dinosaur trackways (among the earliest indirect evidence for dinosaurs; Raath *et al.* 1990, Raath 1996), invertebrate burrows of the *Scolicia* Group, perhaps generated by gastropods (Turner 1975), *Skolithos* vertical burrows, arthropod traces and a few unnamed forms (Hancox 2000).

The absence of fossilised bone and coprolites of vertebrates is notable and, at least in the former case, is attributed to the diagenetic dissolution of bone under humic, poorly-oxygenated and acid conditions that rather favour the preservation of plant remains (Anderson *et al.* 1998).

The Molteno fossil flora is of considerable palaeontological interest in documenting the explosive radiation of Mesozoic, gymnosperm-dominated floras in the later Triassic Period, while the associated rich insect fauna shows great promise in documenting early plant – insect interactions during this critical period in Earth history (See numerous references by J. & H Anderson listed below). Over one hundred Molteno plant fossil assemblages from some seventy localities have been recorded so far (Anderson 2001), with the richest assemblages yielding over seventy species. Insects are recorded from over forty localities. Fig. 3 below gives a rough idea of the distribution of fossil-rich localities within the outcrop area of the Molteno Formation. Note that there is a concentration of localities in the southern outcrop area to the northeast of Indwe and close to the Indwe wind energy facility study area (A more detailed map is presented by Anderson & Anderson 1985, map 2.13 therein). There is therefore a very real possibility that fossil-rich Molteno mudrocks present close to or at the surface within the study area may be compromised by excavations for new access roads and wind turbine installations during the construction phase of the proposed wind farm development.

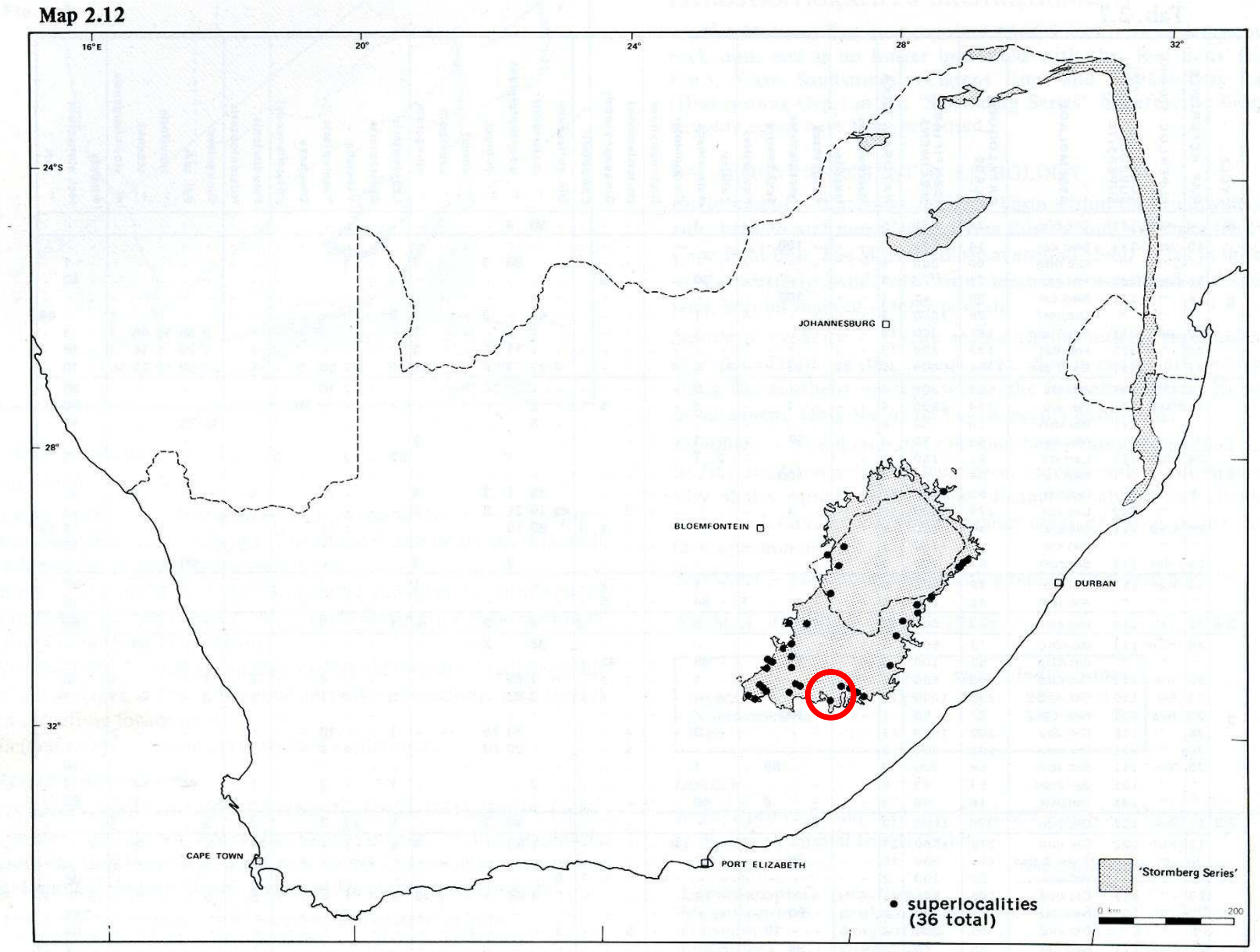

Fig. 3. Outline map showing the stippled outcrop area of the Triassic – Jurassic Stormberg Group and important fossil localities within the Molteno Formation (black dots). Note the concentration of fossil localities to the northeast of Indwe (red circle). Further fossil localities within the Molteno Formation have been identified since this map was published by Anderson and Anderson (1985).

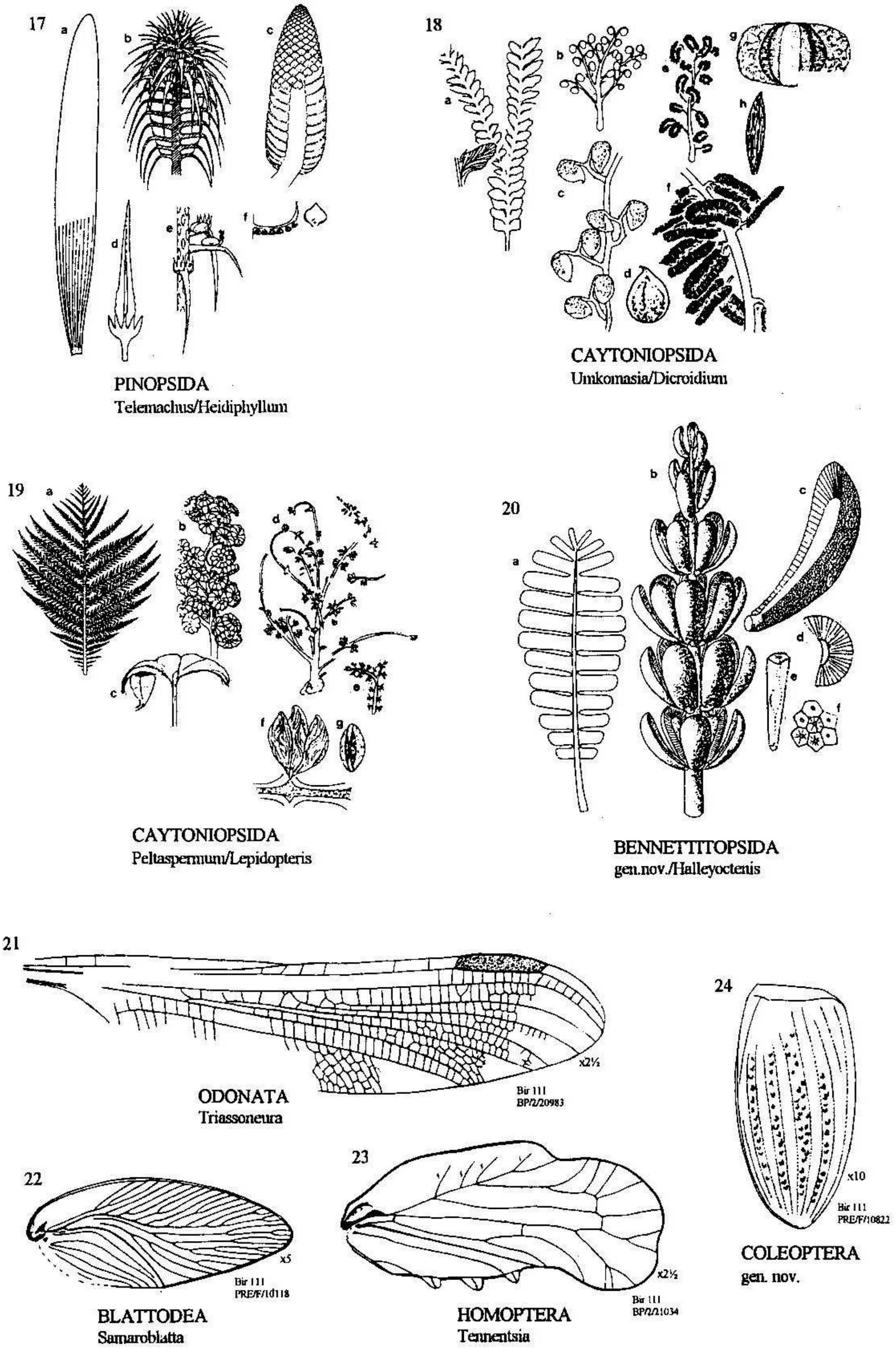

Fig. 4. Selection of Late Triassic plants (leaves and reproductive organs of gymnosperms) and insect remains (dragonflies, cockroaches, bugs and beetles) from the Molteno Formation of South Africa (From Anderson & Anderson 1997).

Quaternary to Recent superficial deposits (colluvium, gravels, silty alluvium *etc*) overlying the Karoo Supergroup bedrocks in the Karoo region have been comparatively neglected in palaeontological terms for the most part. However, they may occasionally contain important fossil biotas, notably the bones, teeth and horn cores of mammals (*e.g.* Skead 1980, Klein 1984, MacRae 1999, Partridge & Scott 2000, Partridge *et al.,* 2006). Other late Caenozoic fossil biotas from these superficial deposits include non-marine molluscs (bivalves, gastropods, rhizoliths), ostrich egg shells, trace fossils (*e.g.* calcretised termitaria, coprolites), and plant remains such as peats or palynomorphs (pollens) in organic-rich alluvial horizons.

5. CONCLUSIONS & RECOMMENDATIONS

The AB's wind energy facility study area near Indwe in the Eastern Cape is largely underlain by potentially fossiliferous continental sediments of the Triassic and Jurassic Periods belonging to the upper part of the Karoo Supergroup. These are intruded by Jurassic dolerites that, as igneous rocks, do not contain any fossils and have thermally metamorphosed the adjacent country rocks. Of the two Karoo sedimentary formations represented here, the Late Triassic to Early Jurassic Elliot Formation is unlikely to be directly affected by the proposed development, judging by the layout of provisional wind turbine positions. Late Caenozoic alluvial sediments in northwestern part of the study area are sparsely fossiliferous and therefore of low palaeontological sensitivity.

In contrast, the Late Triassic Molteno Formation that underlies the central and southern parts of the study area is internationally famous for its impressively rich plant and insect fossils. These include the richest Triassic fossil floras recorded anywhere in the world, as well as some of the oldest known dinosaur trackways. Several key fossil sites are already recorded within the Molteno Formation to the northeast of Indwe. Excavations for new access roads and wind turbine emplacements may well disturb, damage or destroy scientifically valuable fossils during the construction phase of this development. It is therefore recommended that a qualified palaeontologist be commissioned to carry out a field scoping study of the entire study area *before* construction commences. The main purpose of the field scoping study would be to identify any areas within the development footprint where specialist palaeontological mitigation during the construction phase might be required. Relocation of wind turbines, roads or other developments is unlikely to be necessary on palaeontological grounds alone *provided that* appropriate mitigation is ensured. Mitigation would involve the recording and judicious collection of fossil material and associated geological data.

Should substantial fossils – such as vertebrate remains or any sort or plant-rich beds - be exposed at any time during construction, the ECO should safeguard these - *in situ*, where feasible. SAHRA and / or a professional palaeontologist should then be alerted as soon as possible so that appropriate mitigation measures can be implemented.

6. ACKNOWLEDGEMENTS

Mr John von Meyer of Savannah Environmental (Pty) Ltd, Sunninghill, is thanked for commissioning this study and for kindly providing the necessary background information.

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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).

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 farm development projects, 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.

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