PALAEONTOLOGICAL IMPACT ASSESSMENT

PROPOSED ABERDEEN 200 MW WIND FARM, CAMDEBOO LOCAL MUNICIPALITY, EASTERN CAPE.

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EXECUTIVE SUMMARY

Eskom Holdings (SOC) Limited is proposing to develop a 200 MW commercial wind energy facility and associated infrastructure on a site situated approximately 30 km west of the town of Aberdeen, Camdeboo Local Municipality, Eastern Cape. Electricity generated will feed into Eskom's grid at the existing Droërivier Substation near Beaufort West, approximately 140 km from the site, *via* a 400 kV overhead power line.

The entire wind farm study area is underlain at depth by fluvial sediments assigned to the lowermost part of the Teekloof Formation (Lower Beaufort Group) that are of Late Permian age (*c*. 260 million years old). The mudstone-rich succession of the Hoedemaker Member represented here is associated with moderately diverse fossil biotas of the *Tropidostoma* Assemblage Zone that include a range of mammal-like reptiles, true reptiles, fish, amphibians as well as plants and trace fossils. To the author's knowledge there are no previously identified fossil vertebrate finds within the study area, although a small lizard-like specimen was apparently found (probably preserved within a palaeocalcrete nodule) among surface gravels along its northern margin (Mnr Loots, pers. comm., Nov. 2014). The only fossil material recorded during the present field assessment comprises sparse blocks of well-preserved silicified wood that occur widely among surface gravels through much of the study area. Most of the fossil wood specimens have probably been downwasted from channel sandstones within the Hoedemaker Member itself, but some cherty fossil wood clasts may have been introduced from elsewhere within fluvial gravels. The general lack of fossil records in the Aberdeen *vlaktes* may well be due, in large part, to very low levels of bedrock exposure in this low-relief area, as well as due to local development of cleavage, near-surface calcrete veining and weathering. It is concluded that, while there is a significant chance that fossil vertebrate remains will be disturbed, destroyed or sealed-in by the proposed wind energy facility development, these are best mitigated by applying a chance find procedure. The operational and decommissioning phases of the wind farm are unlikely to involve further adverse impacts on local palaeontological heritage, however.

Given the inferred LOW impact significance of the proposed Aberdeen Wind Farm in the construction phase as far as palaeontological heritage is concerned, no further specialist palaeontological heritage studies or mitigation are considered necessary here, pending the discovery or exposure of substantial new fossil remains during development. The operational and decommissioning phases of the wind energy facility are unlikely to involve further adverse

impacts on local palaeontological heritage. The no-go option (*i.e.* no development of the wind farm) is of neutral impact significance for fossil heritage.

During the construction phase all deeper (> 1 m) bedrock excavations (*e.g.* for wind turbine foundations, turbine mounting areas, new access roads, 400 kV transmission line pylon footings, the on-site substation, foundations for the office / workshop, borrow pits and underground cables) should be monitored for fossil remains by the responsible ECO. Should substantial fossil remains such as vertebrate bones and teeth, plant-rich fossil lenses or dense fossil burrow assemblages be exposed during construction, the responsible Environmental Control Officer should safeguard these, preferably *in situ*, and alert the responsible provincial heritage management authority ECPHRA (Contact details: Mr Sello Mokhanya, 74 Alexander Road, King Williams Town 5600; Email: smokhanya@ecphra.org.za) so that appropriate action can be taken by a professional palaeontologist, at the developer's expense. Mitigation would normally involve the scientific recording and judicious sampling or collection of fossil material as well as associated geological data (*e.g.* stratigraphy, sedimentology, taphonomy) by a professional palaeontologist. All work should conform to international best practice for palaeontological fieldwork and the study (*e.g.* data recording fossil collection and curation, final report) should adhere to the minimum standards for Phase 2 palaeontological studies published by SAHRA (2013).

These mitigation recommendations should be incorporated into the Environmental Management Plan (EMP) for the Aberdeen Wind Farm.

1. INTRODUCTION & BRIEF

1.1. Project outline

Eskom Holdings (SOC) Limited is proposing to develop a 200 MW commercial wind energy facility and associated infrastructure on a site situated approximately 30 km west of the town of Aberdeen, Camdeboo Local Municipality, Eastern Cape. The broader study area of *c*. 8198 ha in extent comprises the following farm portions (Fig. 1):

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- Portion 2 of Klipdrift 73
- Portion 2 of Farm 94, and
- RE of Portion 2 of Farm 94

The main infrastructural components of the proposed Aberdeen Wind Farm (Fig. 2) include:

- Up to 100 wind turbines, the number depending on the technology chosen;
- Concrete foundations to support the turbine towers;
- Mounting area for the erecting of each turbine;
- Cabling between the turbines, to be laid underground where practical;
- An on-site substation to facilitate the connection between the facility and the electricity grid;
- An 400 kV overhead power line feeding into Eskom's electricity grid at the Droërivier Substation near Beaufort West, approximately 140 km from the site;
- Internal access roads;

- Borrow pits within the site for the construction of access roads;
- Office/Workshop area for operations, maintenance and storage;
- Information centre.

The present palaeontological heritage assessment of the Aberdeen Wind Farm project area – *excluding* the 140 km powerline to Beaufort West - has been commissioned as part of the broad-based Heritage and Environmental Impact Assessment that is being co-ordinated by Savannah Environmental (Pty) Ltd, Woodmead (Contact details: Ms Sheila Muniongo. Savannah Environmental (Pty) Ltd. 1st Floor, Block 2, 5 Woodlands Drive Office Park, Woodlands Drive, Woodmead, 2191. Tel: +27 11 656 3237. Fax: +27 86 684 0547. Cell: +27 73 517 6823. Email: sheila@savannahsa.com. Postal address: P.O. Box 148, Sunninghill, 2157).

1.2. Legislative context for palaeontological assessment studies

The proposed Aberdeen Wind Farm project is located in an area of the western Karoo that is underlain by potentially fossil-rich sedimentary rocks of the Karoo Supergroup that are of Permian age and are internationally famous for their rich fossil record. The construction phase of the development will entail excavations into the superficial sediment cover (soils, alluvial gravels *etc*) and also into the underlying fossiliferous bedrock. These notably include site clearance activities as well as excavations for the wind turbine foundations, mounting areas, buried cables, new internal access roads, transmission line pylon footings, on-site substation, office / workshop area and borrow pits. 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. Once constructed, the operational and decommissioning phases of the wind farm will not involve further adverse impacts on palaeontological heritage, however

The present combined desktop and field-based palaeontological heritage report falls under Sections 35 and 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.

Minimum standards for the palaeontological component of heritage impact assessment reports (PIAs) have recently been published by SAHRA (2013).

1.3. Approach to the palaeontological heritage study

The approach to a Phase 1 palaeontological heritage study is briefly as follows. Fossil bearing rock units occurring within the broader study area are determined from geological maps and satellite images. Known fossil heritage in each rock unit is inventoried from scientific literature, previous assessments of the broader study region, and the author's field experience and palaeontological database. Based on this data as well as field examination of representative exposures of all major sedimentary rock units present, the impact significance of the proposed development is assessed with recommendations for any further studies or mitigation.

In preparing a palaeontological desktop study the potentially fossiliferous rock units (groups, formations *etc*) represented within the study area are determined from geological maps and satellite images. 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 field assessment 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 significantly the extent of fresh bedrock excavation envisaged. When rock units of moderate to high palaeontological sensitivity are present within the development footprint, a Phase 1 field assessment study by a professional palaeontologist is usually warranted to identify any palaeontological hotspots and make specific recommendations for any mitigation required before or during the construction phase of the development.

On the basis of the desktop and Phase 1 field assessment studies, the likely impact of the proposed development on local fossil heritage and any need for specialist mitigation are then determined. Adverse palaeontological impacts normally occur during the construction rather than the operational or decommissioning phase. Phase 2 mitigation by a professional palaeontologist – normally involving the recording and sampling of fossil material and associated geological information (*e.g.* sedimentological data) may be required (a) in the pre-construction phase where important fossils are already exposed at or near the land surface and / or (b) 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 authorities, *i.e.* ECPHRA for the Eastern Cape (Contact details: Mr Sello Mokhanya, 74 Alexander Road, King Williams Town 5600; Email: smokhanya@ecphra.org.zaso). 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.

1.4. Assumptions & limitations

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

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

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

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

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

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

In the case of the present Aberdeen Wind Farm study area near Aberdeen in the Eastern Cape preservation of potentially fossiliferous bedrocks is favoured by the semi-arid climate but bedrock exposure is very limited indeed due to cover by extensive superficial deposits (*e.g.* alluvium, soils, surface gravels), especially in areas of low relief, as well as by pervasive *bossieveld* vegetation (Figs. 5 & 6).

1.5. Information sources

The present combined desktop and field-based palaeontological study was largely based on the following sources of information:

1. A brief project outline kindly supplied by Savannah Environmental (Pty) Ltd.

2. Relevant geological maps (3222 Beaufort West), sheet explanations (Johnson & Keyser 1979), and palaeontological literature (See References);

3. Several palaeontological heritage assessment reports by the present author for proposed developments in the Karoo region near Beaufort West, including the Eskom Gamma – Omega 765 kV transmission line (Almond 2010a), *plus* a number of alternative energy facilities and housing developments (Almond 2010b, 2010c, 2011);

3. A two-day field assessment of the study area during November 2014 by the author;

5. The author's previous field experience with the formations concerned and their palaeontological heritage (*cf* Almond & Pether 2008 and references listed above).

GPS data for all numbered localities mentioned in the text are provided in the Appendix.

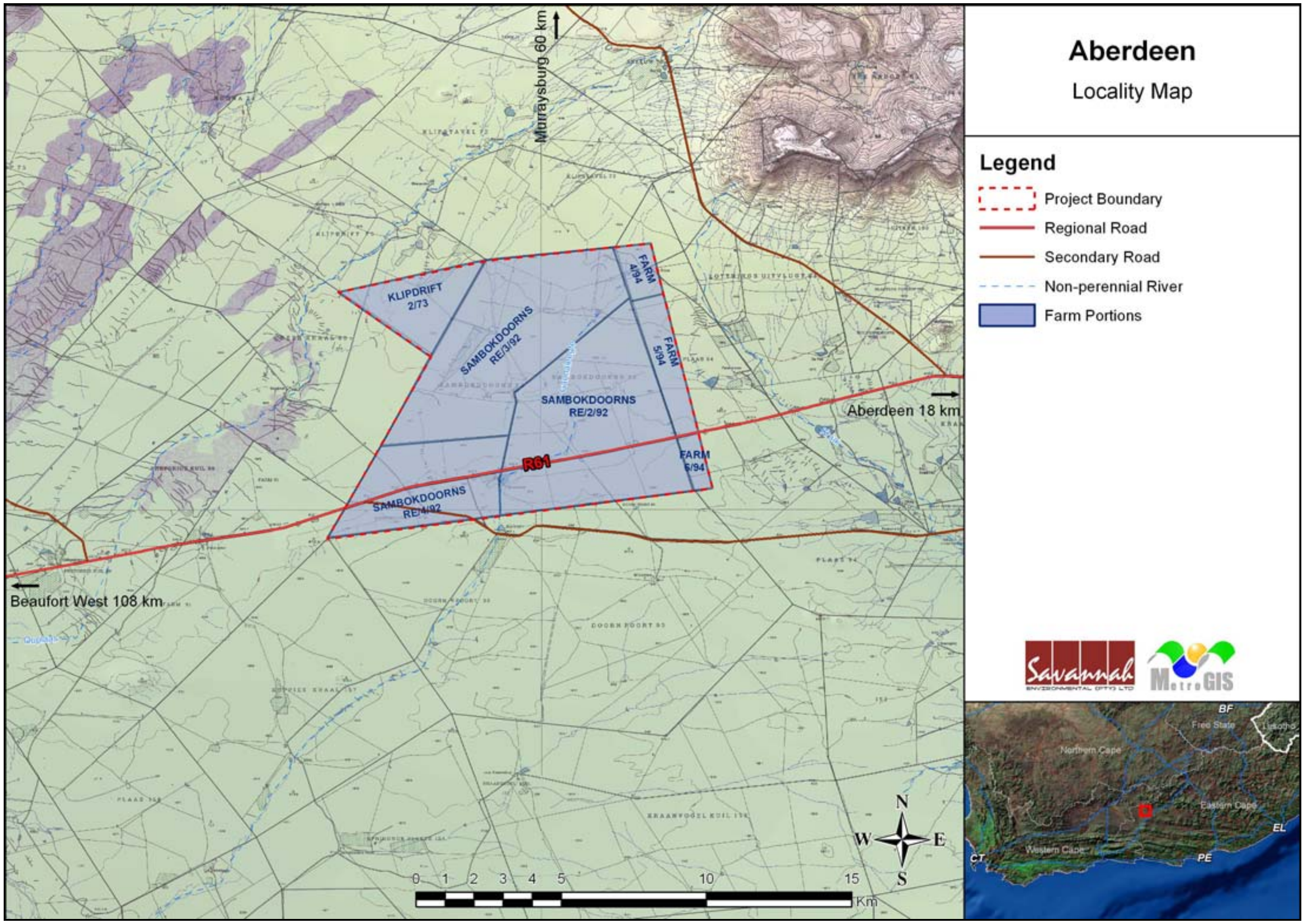

Fig. 1. Map showing the study area for the proposed Aberdeen Wind Farm situated *c.* 30 km west of Aberdeen, Eastern Cape (Image kindly provided by Savannah Environmental (Pty) Ltd).

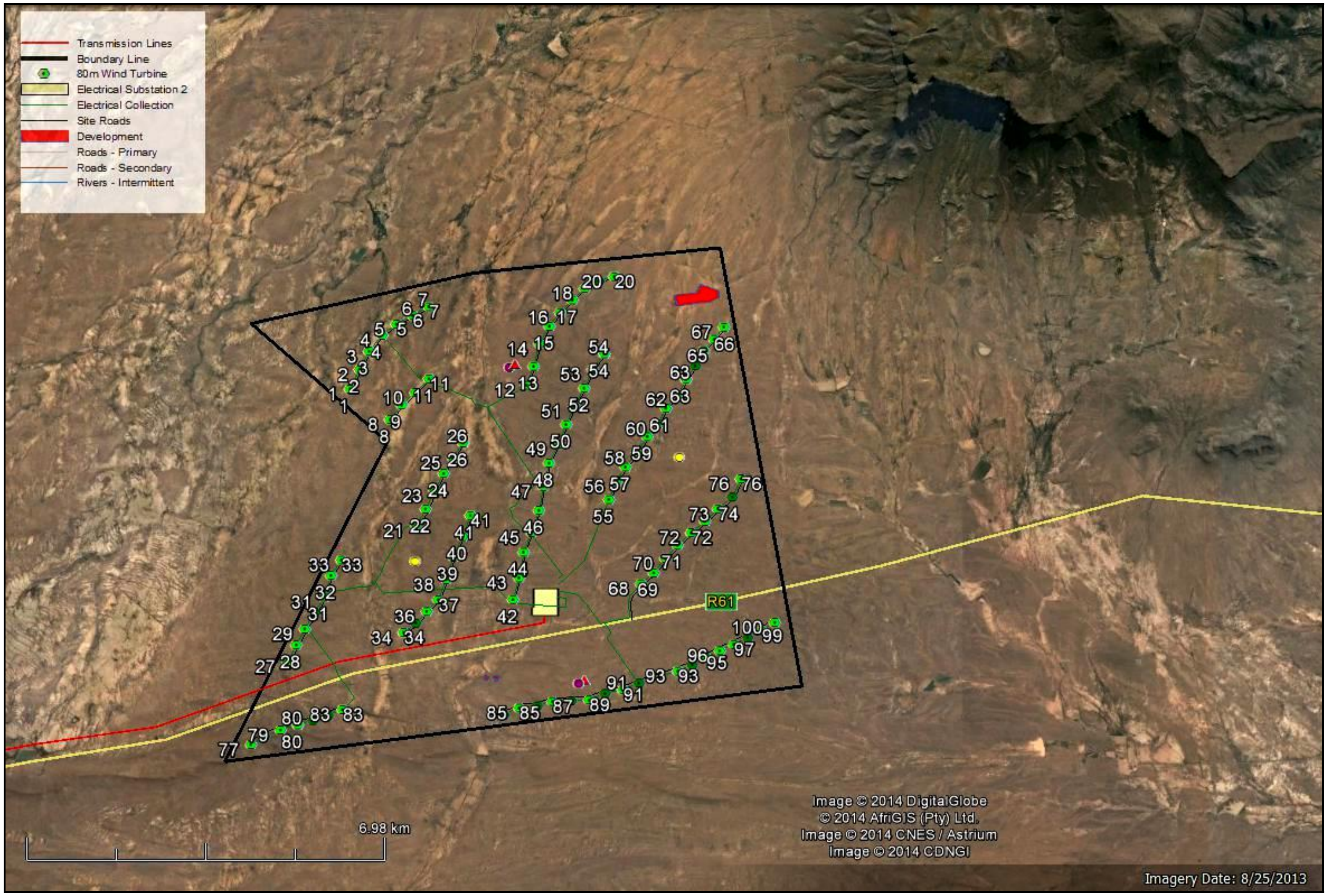

Fig. 2. Google Earth© satellite image of the Aberdeen Wind Farm study area (black polygon) *c*. 30 km west of Aberdeen and straddling the R61 tar road to Beaufort West. Proposed locations for the wind turbines are indicated in green, the on-site substation in pale yellow and the transmission line to Droërivier Substation near Beaufort West in red. Note the Kamdebooberg Escarpment just to the northeast of the study area which is situated on the edge of the Aberdeen *vlaktes* and traversed by several NNE-SSW trending drainage lines.

3. GEOLOGICAL BACKGROUND

The Aberdeen Wind Farm study area is situated in a flat-lying region situated at *c*. 850-930 m amsl with a gentle slope towards the southwest. It lies on the eastern edge of the Aberdeen *vlaktes* and close to the foot of the Great Escarpment that is represented here by the Kamdebooberg (*c*. 1770-1860 m amsl) (Figs. 2, 5 to 7). The area spans the R61 tar road between Aberdeen and Beaufort West and is traversed by several shallow NNE-SSW trending drainage lines constituting intermittently-flowing tributaries of the Gannaleegte drainage system that flows in turn into the Kariega River further to the southwest. Most of the area is currently managed for small-stock farming and is mantled with Karoo *bossieveld* vegetation. Levels of natural bedrock exposure are low to very low in such areas of low relief.

The geology of the area to the west of Aberdeen is depicted in 1: 250 000 geology sheet 3222 Beaufort West (Council for Geoscience, Pretoria; Johnson & Keyser 1979) (Fig. 3). The bedrocks underlying the study area belong to the lower portion of the **Teekloof Formation** (**Pt**) of the **Lower Beaufort Group** (Adelaide Subgroup, Karoo Supergroup) that is predominantly fluvial in origin (Johnson *et al.* 2006). This mudrock-dominated portion of the Teekloof succession is assigned to the **Hoedemaker Member** of Late Permian (Wuchiapingian) age (*c.* 260 Ma) (Smith & Keyser 1995, Rubidge 2005, Rubidge *et al.* 2013) (Fig. 4). Thin, closely-spaced, prominent-weathering sandstones of the overlying Oukloof Member can be seen within the slopes of the Kamdebooberg escarpment to the northeast (Fig. 7). The geology of the Hoedemaker Member, which is up to 240 m thick, has been outlined by Smith (1980, 1993a, b) and later by Smith and Keyser (1995) as well as Cole and Smith (2008). The Hoedemaker succession is dominated by greenish-grey to purple-brown overbank mudrocks, with occasional single-storey sheet sandstones. Palaeosol (ancient soil) horizons characterized by calcrete nodules and rhizocretions (root casts) are common, as are also lacustrine (transient to long-lived playa lake) sediments deposited in depressions on the Late Permian floodplain. These last are associated with limestone crusts, gypsum crystals ("desert roses") as well as a range of fine-scale sedimentary features such as wave rippled sandstones, falling water marks, mudcracks, and trace fossils (Stear 1978, Smith 1980, 1986, 1993a).

The clay-rich Hoedemaker Member bedrocks are readily weathered and eroded, especially away from dolerite intrusions; hence the low topographic relief in the Aberdeen *vlaktes* that have been referred to the Post-African 1 Land Surface of Partridge and Maud (1987). They are extensively mantled by **Late Caenozoic superficial sediments** such as alluvium, pedocretes, downwasted surface gravels, pan sediments and soils. Nevertheless, the superficial sediments in the study area are often thin so that geological features such as bedding (esp. of sandstone units) and folds can often be picked out on satellite images. An elongate intrusion of resistant-weathering dolerite of the Early Jurassic **Karoo Dolerite Suite** (Duncan & Marsh 2006) cuts through the south-western margin of the wind farm study area where it is expressed as a low rocky ridge just to the south of the R61 (870 m amsl). Major dolerite sills are also visible in the upper slopes of the Kamdebooberg Escarpment (Fig. 7).

Hoedemaker Member channel sandstones can be seen in several road cuttings and quarries along the R61 (*e.g.* Locs. 021, 050). A good quarry exposure through a thick, multi-storey channel sandstone package is seen just east of study area (Fig. 10). The beds are lenticular, thin to thick-bedded and composed of fine- to coarse-grained, grey-green sandstone, sometimes speckled or purplish-mottled. Sedimentary structures seen include mud flasers, current and climbing ripple cross lamination, trough cross-bedding, low-angle tabular cross-lamination and horizontal lamination of flaggy sandstones with primary current lineation. Laterally prograding accretion surfaces probably belong to point bar settings. Minor faulting is reflected in common mineral lineation on fracture surfaces (N-S strike). Low banks and beds of buff, well-jointed sandstone form low rocky ridges in the *veld*, with margins of angular colluvial rubble (*e.g.* Locs. 024,448) (Figs. 8 & 9). These ridges are well-seen in satellite images of the study area, picked out by deeper-rooted, taller shrubs, and outline the geological structure here. Locally the Lower Beaufort Group sandstones may be secondarily ferruginised to form brown *koffieklip* (*e.g.* Locs. 022, 035).

There are very few, and only small, natural exposures of the purple-brown and grey-green Hoedemaker Member mudrocks facies in the study area (Figs. 11 & 13). They are generally hackly-weathering to crumbly, and may be veined with calcrete near-surface (Locs. 021, 032) (Fig. 15). However, there are several good borrow pit exposures close to the R61 (*e.g.* Loc. 021a, 022, 035a, 036, 040) (Fig. 12). The mudrocks locally show fairly high dips and a well-developed cleavage (Locs. 035a, 036). They are interbedded with thin, tabular crevasse-splay sandstones with wave-rippled tops (Locs. 022 & 032) (Figs. 11 & 13). Mudrock horizons with grey or purple-brownish, sometimes secondarily ferruginous or silicified, sphaeroidal palaeocalcrete nodules and calcrete lenses are a major target for vertebrate fossil hunting (*e.g.* Loc. 040) (Figs. 14 & 30).

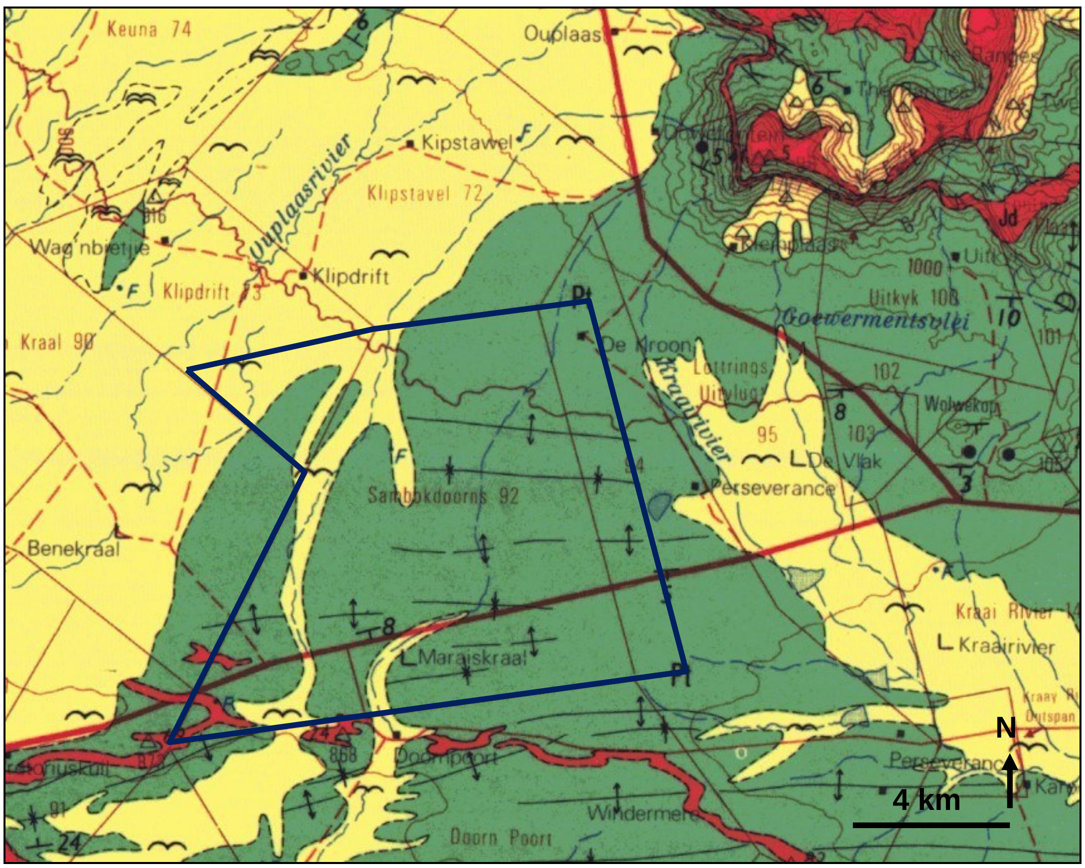

Fig. 3. Extract from 1: 250 000 geology sheet 3222 Beaufort West showing the approximate boundaries of the Aberdeen Wind Farm project study area *c.* 30 km west of Aberdeen (dark blue polygon). Note numerous W-E trending fold axes are indicated in this area. The main rock units represented within the study area include: Pt (green) = Teekloof Formation (Adelaide Subgroup, Lower Beaufort Group). Jd (red) = Karoo Dolerite Suite. Yellow with flying bird symbol = Quaternary superficial sediments, including alluvium, sheet wash, colluvium, soils, locally cemented by pedocretes such as calcrete. Older alluvial terrace gravels are mapped to the northwest of the study area (yellow with double flying bird symbol).

Small black dots indicate fossils within the *Cistecephalus* Assemblage Zone in the foothills of the Kamdebooberg Escarpment to the northeast of the study area. (See also Fig. 28).

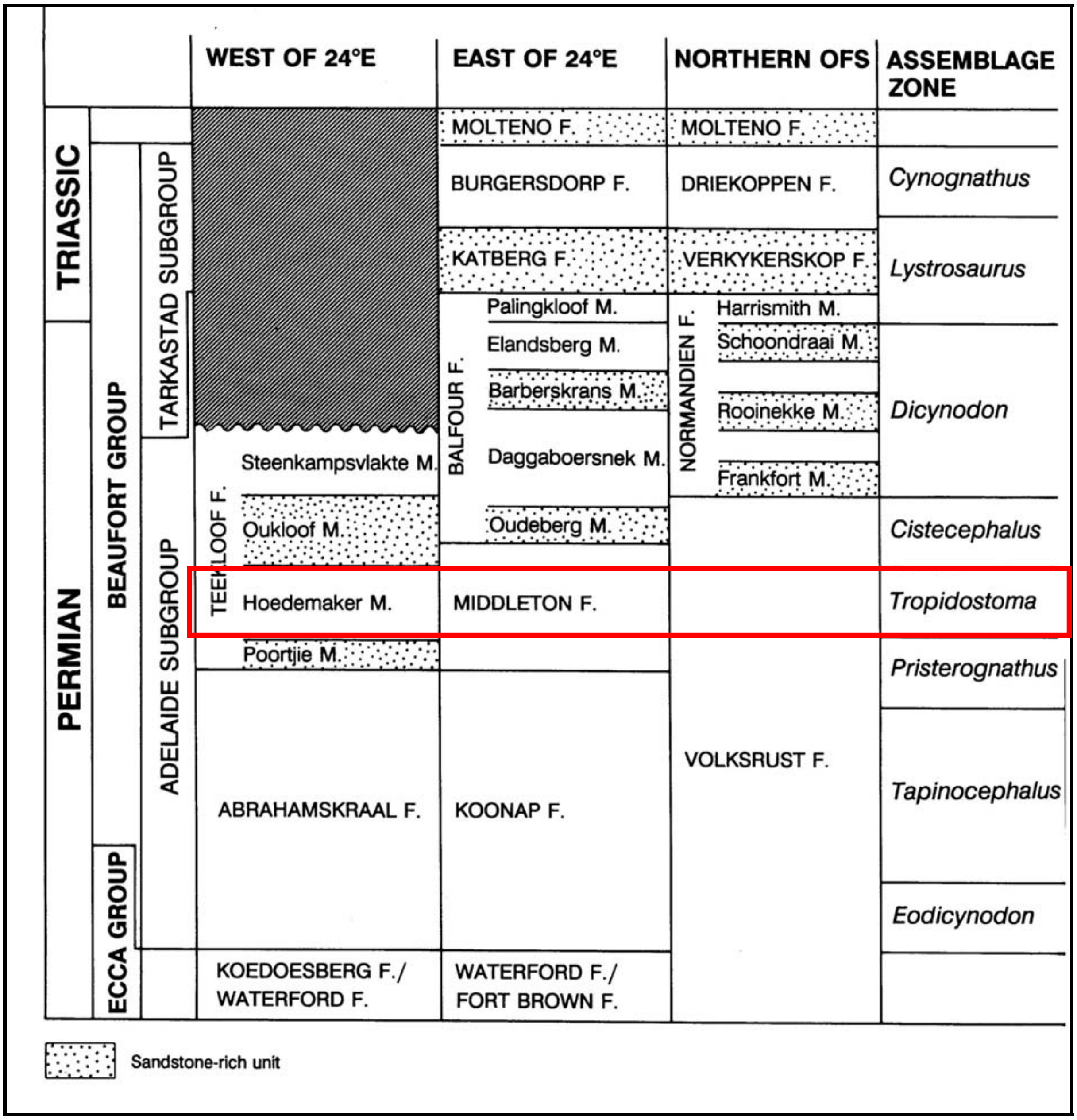

Fig. 4. Chart showing the lithostratigraphic and biostratigraphic subdivisions of the Beaufort Group (Modified from Rubidge 1995). Rock units represented in the present study area near Aberdeen are outlined in red, comprising the mudrock-dominated Hoedemaker Member of the Teekloof Formation. Fossil biotas here are referred to the Late Permian *Tropidostoma* Assemblage Zone.

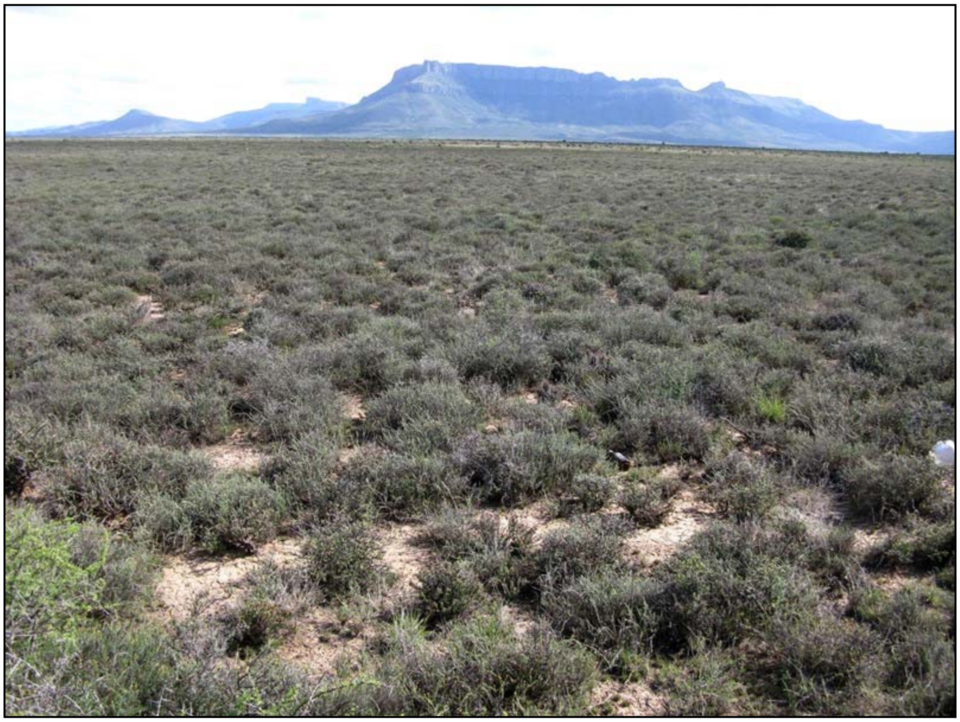

Fig. 5. Flat to gently undulating Karoo *bossieveld* that typifies much of the Aberdeen Wind Farm study area. View towards the Kamdebooberg Escarpment in the northeast.

Fig. 6. Tree-lined, shallow, impersistent watercourse with fine-grained alluvium up to several meters thick on its banks.

Fig. 7. View of the Kamdebooberg range from the west showing the package of closely-spaced, thin sandstones forming the Oukloof Member of the Teekloof Formation, directly overlying the mudrock-dominated Hoedemaker Member of the wind farm study area. The thick upper cliffs are formed by Karoo dolerite sills.

Fig. 8. West-east trending low ridge of well-jointed Hoedemaker Member sandstone (Loc. 024). Many such ridges can be seen in satellite images.

Fig. 9. Hoedemaker sandstone exposure with associated brownish, ferruginised *koffieklip* (Loc. 035). This area has yielded numerous petrified wood fragments, possibly weathered out of channel sandstones such as seen here.

Fig. 10. Thick package of Hoedemaker Member multi-storey channel sandstones showing trough cross-bedding. Quarry exposure close to the R61 (Loc. 050).

Fig. 11. One of only a few natural exposures of Hoedemaker Member mudrocks within the study area, showing thin sandstone interbeds (probably crevasse splays) (Loc. 032).

Fig. 12. Vertical section through hackly-weathering grey-green and purple-brown Hoedemaker Member mudrocks with a thin, tabular sandstone interbed (Hammer = 30 cm). Borrow pit close to the R61 (Loc. 022).

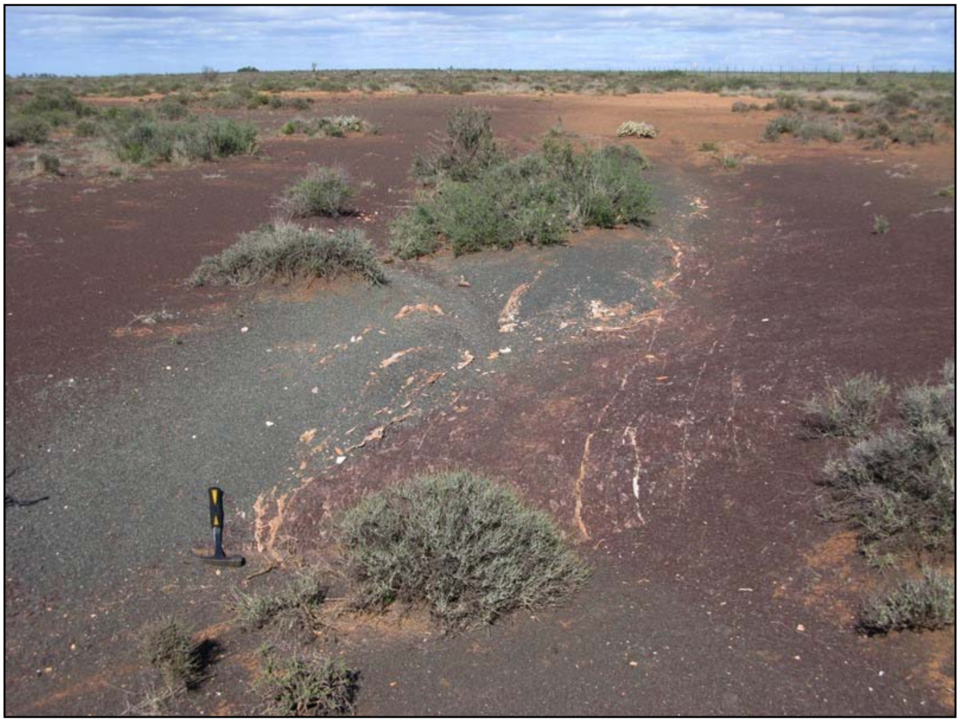

Fig. 13. Extensive gentle slopes of Hoedemaker Member mudrocks on the margins of a borrow pit (Hammer = 30 cm) (Loc. 021a). Note numerous thin calcrete veins. Such areas are a prime target for fossil hunting.

Fig. 14. Palaeosol (ancient soil) horizon within the Hoedemaker Member showing numerous rounded pedogenic calcrete concretions and lenses (Hammer = 30 cm) (Loc. 040). These fossil soils are an important target for vertebrate fossil recording.

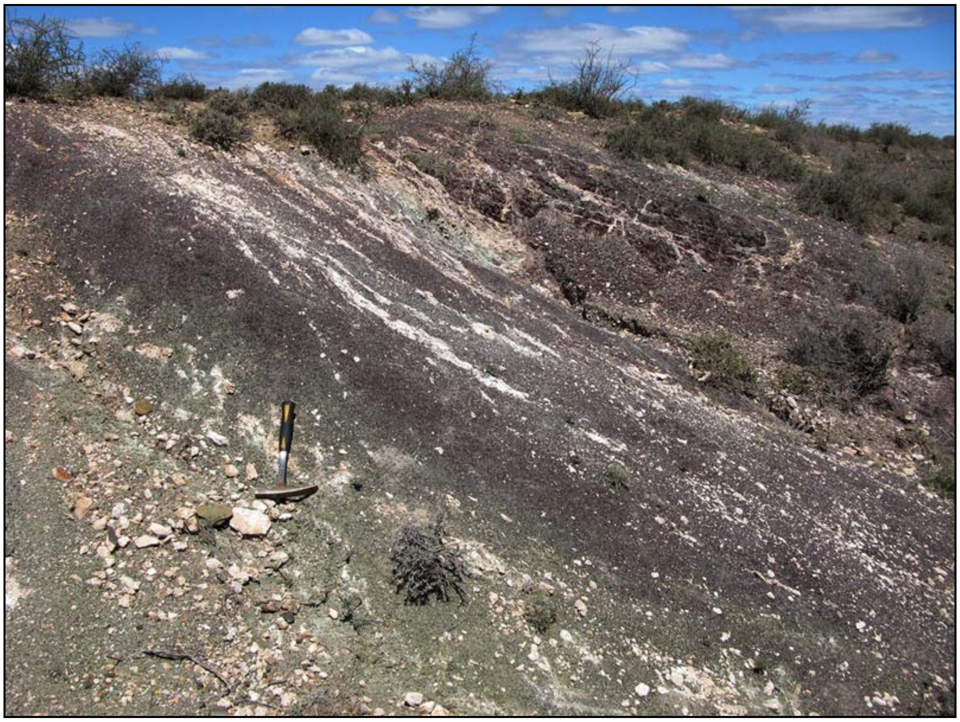

Fig. 15. Extensive near-surface calcrete veining of Hoedemaker Member mudrocks exposed in the walls of a borrow pit (Hammer = 30 cm)(Loc. 035a)

The great majority of sites examined within the study area for the Aberdeen Wind Farm are mantled in superficial deposits that vary from thin (few dm) to several meters thick. There are numerous flat washes on the *vlaktes*. These areas are without bossieveld vegetation, displaying bare silty alluvial soils and a thin veneer of fine sheetwash gravels or coarser downwasted and alluvial gravels (Figs. 21 to 24). The surface gravel clasts vary from angular to well-rounded and comprise a small range of lithologies of mostly local provenance, such as pale grey younger calcrete, denser palaeocalcrete nodules (including secondarily silicified calcrete), dolerite, sandstone, hornfels, pale metaquartzite (baked sandstone), vein quartz, sparse petrified / silicified wood (see Section 4.3), pale porcellanous or transluscent cherts, and rare blocks of pale greenish-grey tuff (*e.g.* Loc. 026). Hornfels gravels may be locally dominant ; the material is dark grey to black when fresh, usually with a brownish weathering patinata and is often anthropogenically flaked, often with subsequent rounding due to transport (*e.g.* Loc. 027).

Pale brown to orange-brown silty alluvium with sparse sheet wash gravels occurs along the margins of shallow drainage channels (*e.g.* Loc. 026) and is well exposed in vertical section in dongas (*e.g.* Loc. 044). At the last locality the alluvial deposits are *c*. 1.5 to 3 m thick with pebbly lenticles, directly overlying bedrock or with intervening basal gravels (Figs. 16 to 18). Banks and lenses of young gravelly alluvium are well seen here. Extensive to linear areas of older, coarser (pebbly, cobbly) surface gravels represent ancient water courses. The clasts are generally subrounded to well-rounded and form horizons that are only one to a few clasts thick (*e.g.* Locs. 029, 030, 038, 041, 042) (Figs. 19 & 20). Larger isolated clasts may be up to the size of small boulders (30-40 cm in diameter). The gravels are reworked clasts of the more resistant local lithologies - mainly sandstone but also dolerite, hornfels and pale metaquartzite *etc*. Some may have a provenance along the Great Escarpment to the northeast. Dolerite clasts, for example, appear to be commoner in the northeast.

Bedrock mudrocks beneath the superficial soil and gravel cover are often veined by thin younger calcrete horizons near-surface or exhumed at surface (*e.g.* Locs. 021a, 035a, 036, 042) (Fig. 15) . Well-developed calcrete hardpan have been formed within silty soils and subsurface gravels overlying Hoedemaker Member mudrocks at Loc. 037 - possibly a previous pan area (Fig. 25). Surface channels within the hardpan contain breccia of reworked calcrete.

Fig. 16. Gulley erosion exposure of thick orange-brown alluvial sediments overlying ridges of Lower Beaufort Group bedrocks (Loc. 044).

Fig. 17. Bank of pebbly alluvial gravels and sandy alluvium exposed in a modern water course (Hammer = 30 cm) (Loc. 044).

Fig. 18. Bare patches of silty alluvium with only very sparse surface gravels along the margins of an active water course (Loc. 026).

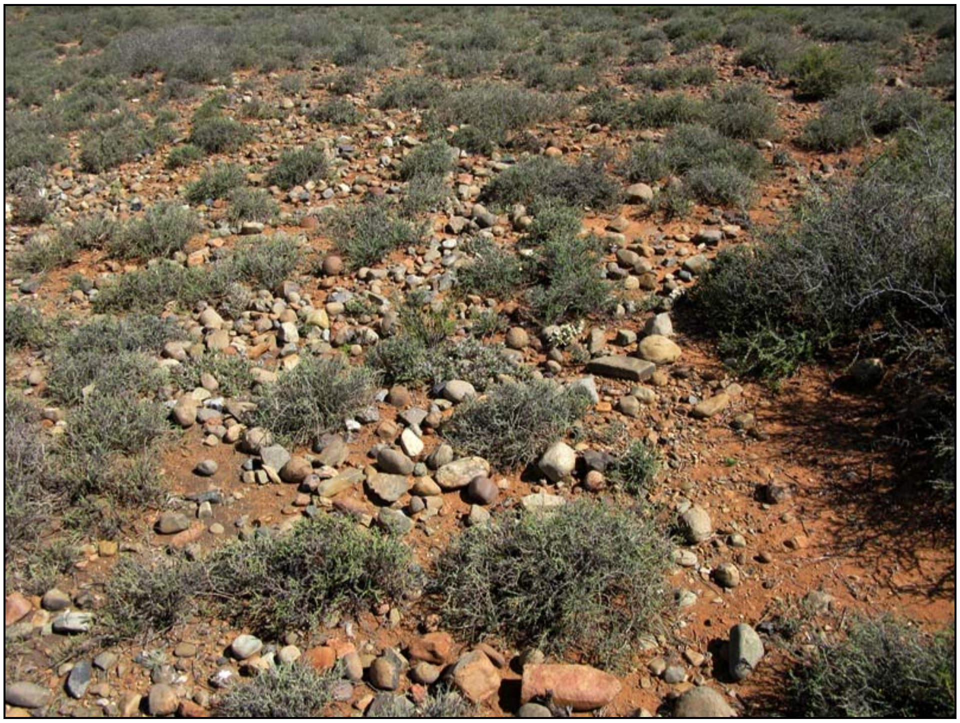

Fig. 19. Ancient coarse alluvial gravels, possibly relicts of an older, Pleistocene drainage system (Loc. 038).

Fig. 20. Detail of the well-rounded, polymict gravel clasts shown in the previous illustration (Hammer = 30 cm).

Fig. 21. One of numerous unvegetated washes within the study area showing the uneven mosaic of downwasted and sheet-washed surface gravels overlying silty alluvial soils (Loc. 030). These gravels are the main source of reworked petrified wood specimens recorded during the field study.

Fig. 22. Detail of downwasted surface gravels seen above, here including numerous dark grey hornfels clasts as well as brown Beaufort Group sandstone (Hammer = 30 cm).

Fig. 23. Concentrated sheetwashed surface gravels close to a tree-lined watercourse on the northern edge of Sambokdoorns RE/3/92 (Loc. 047).

Fig. 24. Examples of silicified pedogenic calcrete nodules from among the surface gravels shown above (Scale in cm and mm). The nodules may occasionally be fossiliferous (*cf* fossil "lizard" reported by landowner from this area).

Fig. 25. Calcrete hardpan developed within silty to gravelly alluvial soils (Hammer = 30 cm) (Loc. 037). Clasts of reworked calcrete suggest erosional reworking into shallow channels.

4. PALAEONTOLOGICAL HERITAGE

The fossil heritage recorded from the main sedimentary rock units represented in the Aberdeen Wind Farm study area is briefly outlined in this section of the report, together with palaeontological observations made during the present field assessment.

4.1. Fossil heritage within the Lower Beaufort Group

Fossilised bones and teeth were first recorded from the Beaufort Group in the Beaufort West area in the 1820s. These were the earliest scientific records of such ancient vertebrate fossils from the Great Karoo (MacRae 1999). They represent the start of a strong scientific tradition in vertebrate palaeontology in South Africa that has now persisted for nearly two centuries and has established the Great Karoo as an area of unrivalled importance for understanding the evolution of the oldest known complex ecosystems on land (*cf*. Cluver 1978, MacRae 1999, McCarthy & Rubidge 2005).

The various formations and members of the Beaufort Group are distinguished on the basis of both *lithological* features (*i.e.* rock type and sedimentation patterns) as well as on *palaeontological* grounds (*i.e.* fossil content). A succession of fossil assemblage zones, also termed biozones, has been established by palaeontologists for the Beaufort Group succession and mapped out throughout the main Karoo Basin (Keyser & Smith 1977-78, Rubidge, 1995, MacRae 1999, Rubidge 2005, Van der Walt *et al.* 2010, Smith *et al.* 2012; Figs. 4, 28 and 29 herein). Each assemblage zone is characterised by a number of key fossil vertebrate taxa (zone fossils), some of which are restricted to that assemblage zone and are of special biostratigraphic significance – *i.e.* they can be used to identify sedimentary successions of closely comparable age both within and between sedimentary basins.

The relationship between the various lithostratigraphic formations and members of the Beaufort Group within the study area on the one hand and the biostratigraphic assemblage zones on the other is outlined in Fig. 4. Four successive fossil assemblage zones of Middle to Late Permian age are represented in the broader Aberdeen area and Great Escarpment: the *Pristerognathus*, *Tropidostoma*, *Cistecephalus* and *Dicynodon* Assemblage Zones (AZ) (Figs. 28 & 29). Comprehensive lists and illustrations of the fossil taxa within each assemblage zone are given in the references cited above (See especially MacRae 1999 for a readable, popular and well-illustrated account, as well as Rubidge 1995 and Smith *et al.* 2012 for recent authoritative but more technical accounts). Accessible, more "popular" reviews of Karoo fossils directly relevant to the Beaufort West area are given by Smith (1988, 1989) as well as in the recently upgraded Fossil Trail and the new Interpretive Centre within the Karoo National Park (*Natura Viva* cc, 2005).

On the basis of international faunal correlation, the *Pristerognathus*, *Tropidostoma* and *Cistecephalus* Assemblage Zones / Biozones of the Lower Beaufort Group have until recently all been assigned to the Wuchiapingian Stage of the Late Permian Period, with an approximate age range of 260-254 Ma (Rubidge 2005 and refs. therein). Terrestrial tetrapod faunas of comparable age are known from Russia and China in the northern, Laurasian portion of Pangaea as well as Karoo-type basins to the north of South Africa (Zimbabwe, Zambia, Malawi, Tanzania) and in India within the Gondwanan sector of Pangaea. Recently announced radiometric dates for the Teekloof Formation (Rubidge *et al.* 2010, 2013) assign a late Guadalupian (Capitanian) age to the *Pristerognathus* AZ (261-260.36 Ma), an early Lopingian (Wuchiapingian) age to the *Tropidostoma* AZ (259.3 Ma), and a later Wuchiapingian age to the *Cistecephalus* AZ (256.6-255.2Ma). This places the Mid / Late Permian boundary and End Guadalupian mass extinction event (if reflected on land) within the Teekloof Formation, between the *Pristerognathus* and *Tropidostoma* AZs, rather than at the base of the *Pristerognathus* AZ as previously assumed.

Late Permian age vertebrate fossil assemblages of the lower Beaufort Group are dominated by a variety of small to large true reptiles and – more especially – by a wide range of therapsids. The latter are also commonly, but misleadingly, known as "mammal-like reptiles" or protomammals (*e.g.* Cluver 1978, MacRae 1999, Rubidge 1995). By far the most abundant group among the Late Permian therapsids are the dicynodonts, an extinct group of two-tusked herbivorous therapsids. Aquatic animals include large, crocodile-like temnospondyl amphibians and various primitive bony fish (palaeoniscoids). Note that fossil dinosaurs are *not* found within the Beaufort West area; this group only evolved some thirty million years *after* the lower Beaufort Group sediments were deposited.

A high proportion of the tetrapod (*i.e.* four-limbed, terrestrial vertebrate) fossils from the Teekloof Formation are found within the overbank mudrocks. They are very commonly encased within calcrete or pedogenic limestone that often obscures their anatomy and makes such fossils difficult to recognise in the field, even for experienced palaeontologists (Smith 1993a,b). Rarer fossil specimens preserved within the Beaufort Group sandstones are usually disarticulated and fragmentary due to extensive, pre-burial transport. Occasionally vertebrate fossils are found embedded within baked (thermally metamorphosed) mudrocks or hornfels in the vicinity of dolerite intrusions. However, such fossils are extremely difficult to prepare out in the laboratory and so are generally of limited scientific value.

Key studies on the *taphonomy* (pre-burial history) of Late Permian vertebrate remains in the Great Karoo have been carried out in the Beaufort West area and have yielded a wealth of fascinating data on Late Permian terrestrial wildlife and palaeoenvironments (*e.g.* Smith 1980, 1993a). Therapsid fossils are most abundant and best preserved (well-articulated) within muddy and silty overbank sediments deposited on the proximal floodplain (*i.e.* close to the river channel). Here they are often associated with scoured surfaces and mature palaeosols (ancient soils), these last indicated by abundant calcrete nodules. In the distal floodplain sediments (far from water courses), fossils are rarer and mostly disarticulated. Channel bank sediments usually contain few fossils, mostly disarticulated, but occasionally rich concentrations of calcrete-encrusted remains, some well-articulated, are found. These dense bone assemblages may have accumulated in swale fills or chute channels which served as persistent water holes after floods (Smith 1993a). Such detailed interdisciplinary field studies re-emphasize how essential it is that fossil collecting be undertaken by experienced professionals with a good grasp of relevant sedimentology as well as palaeontology, lest invaluable scientific data be lost in the process.

Plant fossils in the lower Beaufort Group are poorly represented and often very fragmentary (*cf*. Anderson & Anderson 1985, dealing primarily with material from the eastern Karoo Basin, Gastaldo *et al*. 2005, dealing with Permo-Triassic boundary floras in the Main Karoo Basin). They belong to the *Glossopteris* Flora typical of Permian Gondwana and include reedy sphenophytes or "horsetails" (Arthrophyta, now recognised as a fern subgroup) and distinctive tongue-shaped leaves of the primitive, tree-sized gymnosperm *Glossopteris*. Well-preserved petrified wood ("*Dadoxylon*") occurs widely and may prove of biostratigraphic and palaeoecological value in future (*e.g.* Bamford 1999, who records only the genus *Australoxylon* from the Poortjie Member Teekloof Formation, and no identified woods from the overlying Hoedemaker Member). Elongate plant root casts or *rhizoliths* are frequently found associated with calcrete nodule horizons. Transported plant debris preserved within channel sandstones is often associated with secondary iron ("*kofffieklip*") and uranium mineralization, as seen for example within the Abrahamskraal Formation and Poortjie Member Member in the Beaufort West area (Cole & Smith 2008 and refs. therein).

Late Permian invertebrate fossils from the western Karoo Basin comprise almost exclusively relatively featureless, thin-shelled freshwater bivalves, while fairly low diversity insect faunas are recorded from plant-rich horizons further east. The most prominent vertebrate trace fossils in the Lower Beaufort Group are well-preserved tetrapod trackways attributed to various groups of reptiles and therapsids (Smith 1993b), as well as substantial, inclined to helical scratch burrows that were probably constructed by smaller therapsids as an adaptation to the highly seasonal, and occasionally extreme, continental climates at high palaeolatitudes of 60-70º S. (Smith 1987b). Invertebrate trace fossils from the Karoo National Park at Beaufort West include the locally abundant scratch burrows of the ichnogenus *Scoyenia* that are generally attributed to infaunal arthropods such as insects. A diverse freshwater ichnofauna (trace fossil assemblage) from the Beaufort West townlands with trails, burrows and trackways generated by fish, snails, arthropods, worms and other animals has been recorded by Smith (1993a).

4.1.1. Fossil heritage within the Hoedemaker Member (Teekloof Formation)

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 Kitching (1977), Keyser and Smith (1979), Rubidge (1995) as well as Van der Walt *et al.* (2010) (Figs. 28 & 29). Selected fossil tetrapod localities from these and other sources are marked on the 1: 250 000 Beaufort West geology sheet (*e.g.* fossil sites located along the base of the Great Escarpment a few kilometres north and northwest of the wind farm study area) (Fig. 3). These sources establish that the Aberdeen WEF study area lies within the ***Tropidostoma* Assemblage Zone** (AZ) that characterizes the Hoedemaker Member of the Teekloof Formation (Smith & Keyser, 1995). Fossils from this assemblage zone collected in the Karoo National Park at Beaufort West are illustrated by Almond (2006) and displayed at the park itself (Fossil Trail and Interpretive Centre).

The following major categories of fossils might be expected within *Tropidostoma* AZ sediments in the study area (Kitching 1977, Keyser & Smith 1977-78, Anderson & Anderson 1985, Smith & Keyser 1995, MacRae 1999, Cole *et al*., 2004, Almond *et al*. 2008, Smith *et al.* 2012):

- isolated petrified bones as well as rare articulated skeletons of **terrestrial vertebrates (tetrapods)** such as true **reptiles** (notably large herbivorous pareiasaurs, lizard-like archosauromorphs) and **therapsids** or "mammal-like reptiles" (*e.g.* diverse, small- to large-bodied herbivorous dicynodonts, flesh-eating gorgonopsians, carnivorous and insectivorous therocephalians, cynodonts) (Figs.26 & 27);
- aquatic vertebrates such as large **temnospondyl amphibians** (*Rhinesuchus* spp., usually disarticulated), and **palaeoniscoid bony fish** (*Atherstonia*, *Namaichthys*, often represented by scattered scales rather than intact fish);
- freshwater **bivalves** (*e.g. Palaeomutela*);
- **trace fossils** such as worm, arthropod and tetrapod burrows and trackways, coprolites (fossil droppings), fish swimming trails;
- **vascular plant remains** including leaves, twigs, roots and petrified woods ("*Dadoxylon*") of the *Glossopteris* Flora (usually sparse, fragmentary), especially glossopterid trees and arthrophytes (horsetails).

According to Smith and Keyser (1995) the tetrapod fauna of the *Tropidostoma* Assemblage Zone is dominated by the small burrowing dicynodont *Diictodon* that constitutes some 40% of the fossil remains recorded here. There are several genera of toothed dicynodonts (*e.g. Emydops, Pristerodon*) as well as medium-sized forms like *Rachiocephalus* and *Endothiodon* (*cf* Cluver & King 1983, Botha & Angielczyk 2007 for more details about these genera). Carnivores are represented by medium-sized gorgonopsians (*e.g. Lycaenops, Gorgonops*) as well as smaller, insectivorous therocephalians such as *Ictidosuchoides*. Among the large (2.3-3 m long), lumbering pareiasaur reptiles the genus *Pareiasaurus* replaces the more primitive *Bradysaurus* seen in older Beaufort Group assemblages.

The *Tropidostoma* AZ biota inhabited extensive, very low-relief alluvial plains traversed by several perennially flowing, meandering rivers bordered by levees in Late Permian times. Climates were highly seasonal (Smith *et al.* 2012 and refs. therein). As far as the biostratigraphically important tetrapod remains are concerned, the best fossil material within the Hoedemaker Member succession is generally found within overbank mudrocks, whereas fossils preserved within channel sandstones tend to be fragmentary and water-worn (Rubidge 1995, Smith 1993b). Many vertebrate fossils are found in association with ancient soils (palaeosol horizons) that can usually be recognised by bedding-parallel concentrations of calcrete nodules. Smith and Keyser (1995) report that in the *Tropidostoma* Assemblage Zone / Hoedemaker Member most tetrapod fossils comprise isolated disarticulated skulls and post-cranial bones, although well-articulated skeletons of the small dicynodont *Diictodon* are locally common, associated with burrows (See also Smith 1993b for a benchmark study of the taphonomy of vertebrate remains in the Hoedemaker Member).

As a consequence of their proximity to large dolerite intrusions in the Great Escarpment zone, some of the Beaufort Group sediments in the study region have been thermally metamorphosed or "baked" (*i.e*. 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.

4.2. Fossil heritage within Quaternary to Recent alluvium

The Quaternary to Recent superficial or "drift" deposits 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). These may include ancient human remains of considerable palaeoanthropological significance (*e.g*. Grine *et al.,* 2007). Other late Caenozoic fossil biotas from these superficial deposits include non-marine molluscs (bivalves, gastropods), ostrich egg shells, trace fossils (*e.g.* calcretised termitaria, coprolites, rhizoliths), and plant remains such as peats or palynomorphs (pollens) in fine-grained, organic-rich alluvial horizons. Quaternary alluvial sediments may contain reworked Stone Age artifacts that are useful for constraining their maximum age.

4.3. Fossils recorded within the Aberdeen Wind Farm study area

No vertebrate or other fossil remains were recorded actually *in situ* from the Lower Beaufort Group bedrocks within the study area during the present field assessment. This is probably due to some extent to the very limited exposure levels of the Karoo bedrocks (especially the mudrock facies), to local tectonic cleavage development, as well as to the weathering and calcrete veining near-surface.

However, numerous fragments of Permian silicified fossil wood were recorded within the Late Caenozoic (Quaternary to Recent) surface gravels here (Figs. 31 to 34). These cherty blocks have clearly weathered-out of the Lower Beaufort Group bedrocks and been secondarily concentrated, together with other resistant-weathering rock types, within alluvial gravels and downwasted surface gravels. The fossil wood specimens were recorded from a majority of surface gravel exposures examined and are clearly of widespread occurrence. However, they are usually quite scarce in any one area, with higher concentrations only being notes at a few sites (*e.g.* Locs. 025, 034, 035). The woods display a range of hues, including creamy, buff, brown and reddish-brown. The blocks vary in size from fine gravels to cobble-sized (*c.* 15 cm maximum dimension) and are generally angular to subangular; well-rounded examples were not seen. Many show excellent preservation of the original woody tissue (*e.g.* seasonal growth rings, radial rings of tracheids) while others are fairly structureless, or show islands of well-preserved wood embedded within an amorphous cherty matrix (Fig. 34). The latter might represent biodegraded woody tissue that was already largely decomposed (*e.g.* by fungi) at the time of silicification (Perhaps traces of fungal or arthropod structures might be preserved in such specimens). It is considered probably that most or all of the fossil wood material observed is of local provenance, rather than transported from a higher stratigraphic level in the nearby Escarpment zone; *i.e.* it is derived from the Hoedemaker Member rather than younger units of the Teekloof Formation. Supporting evidence for a local origin of most of the petrified wood material observed within the study area includes:

- Angular nature of many blocks, and their occasionally fairly substantial size.
- Local concentrations of wood fragments. Some of these are possibly associated with channel sandstone exposures (*e.g.* Loc. 035); the bases of river channel infills are the most likely source of petrified logs.
- Higher concentrations of fossil wood in the southwestern *vlaktes* rather than closer to the Escarpment area in the northeast of the study area.

A specimen of fossil *akkedis* (lizard) has been reported by the farmer Mnr Loots from a patch of surface gravels close to the northern edge of Farm Sambokdoorns RE/3/92 (Mnr Loots, pers. comm., Nov. 2014) (Locs. 446-447) (Fig. 23). These surface gravels include occasional reworked palaeocalcrete nodules, some pale green and silicified, one of which may have contained the fossil mentioned, possibly a small therapsid or reptile (Fig. 24). However, no further fossil vertebrate material was seen during the present field assessment and such specimens are clearly rare.

Fig. 26. Late Permian vertebrates of the *Tropidostoma* Assemblage Zone.

1, 2 – skull and skeleton of a saber-toothed carnivore, the gorgonopsian *Lycaenops*
3 – the heavily-built plant-eating reptile *Pareiasaurus* (*c*. 2.5m long)
4, 5 – reconstruction and skull of the large temnospondyl amphibian, *Rhinesuchus*, a top predator in freshwater lakes and rivers

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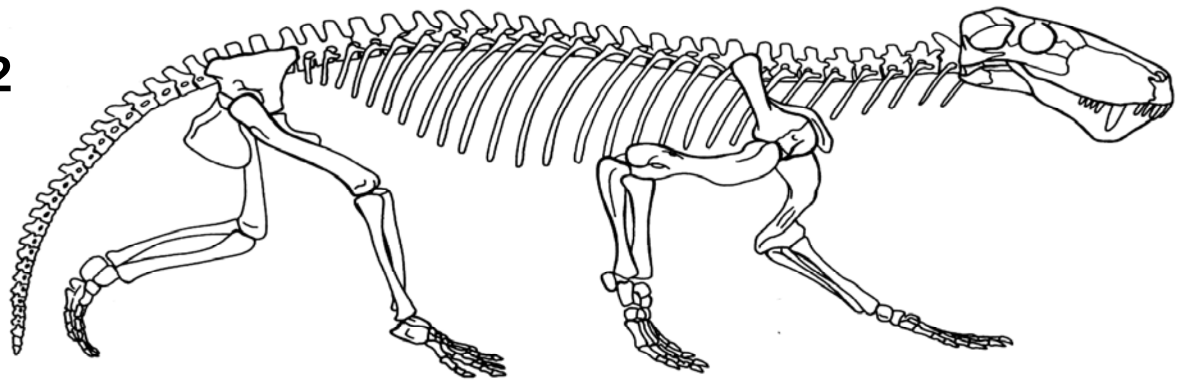

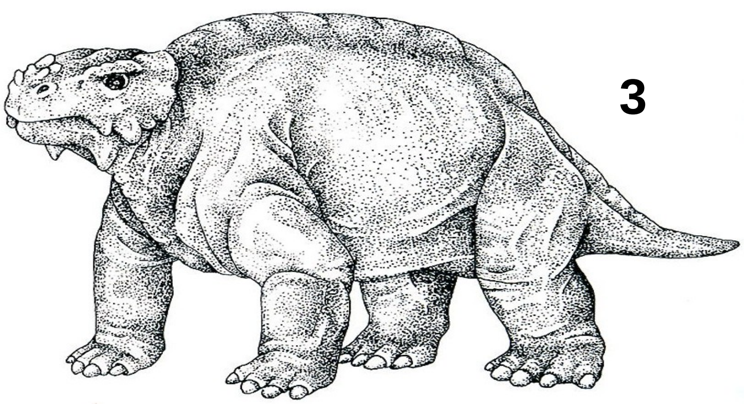

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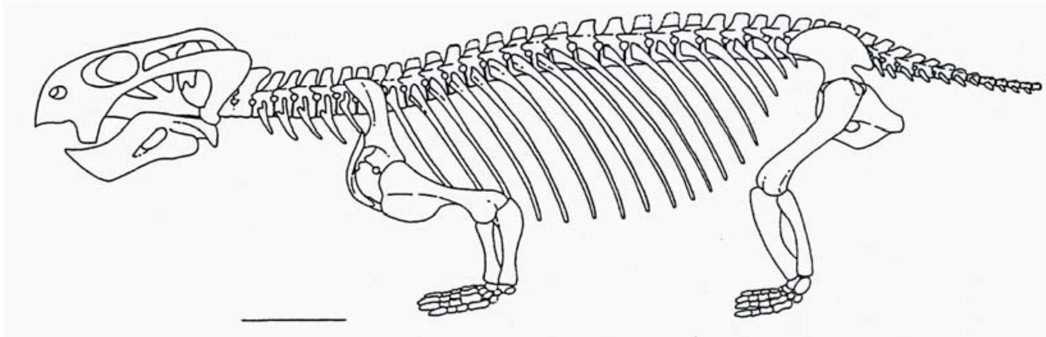

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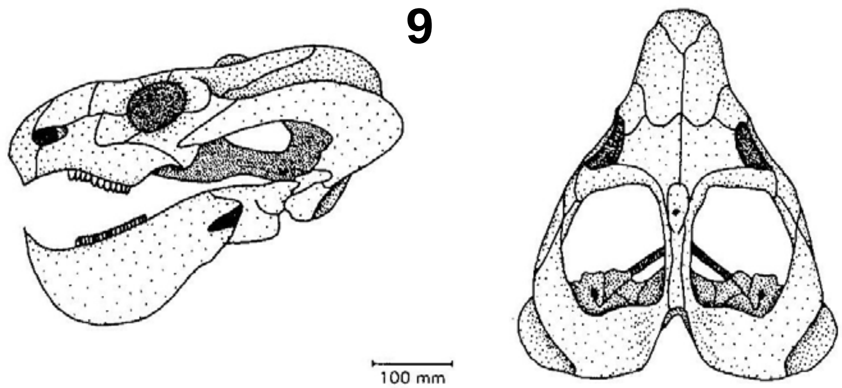

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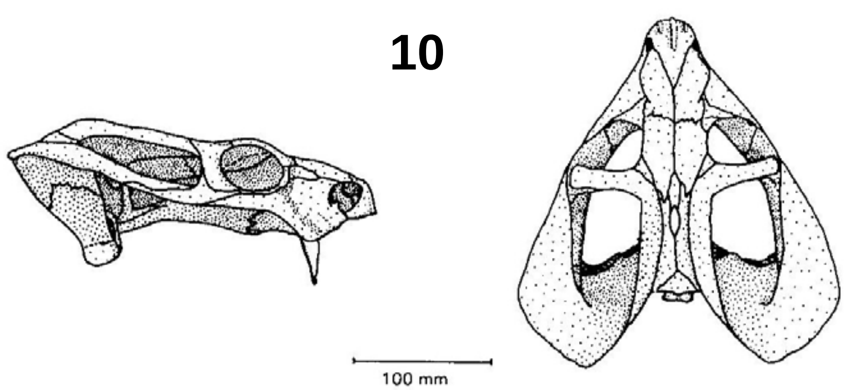

Fig. 27. Late Permian vertebrates of the *Tropidostoma* Assemblage Zone *continued*.

6 – small (40 cm), social dicynodont *Diictodon*
7 – skull of the dicynodont *Tropidostoma* in dorsal view
8 – two curled-up specimens of *Diictodon* within a burrow infill
9, 10 – skulls of two medium-sized dicynodonts, *Endothiodon* (10) and *Tropidostoma* (11)

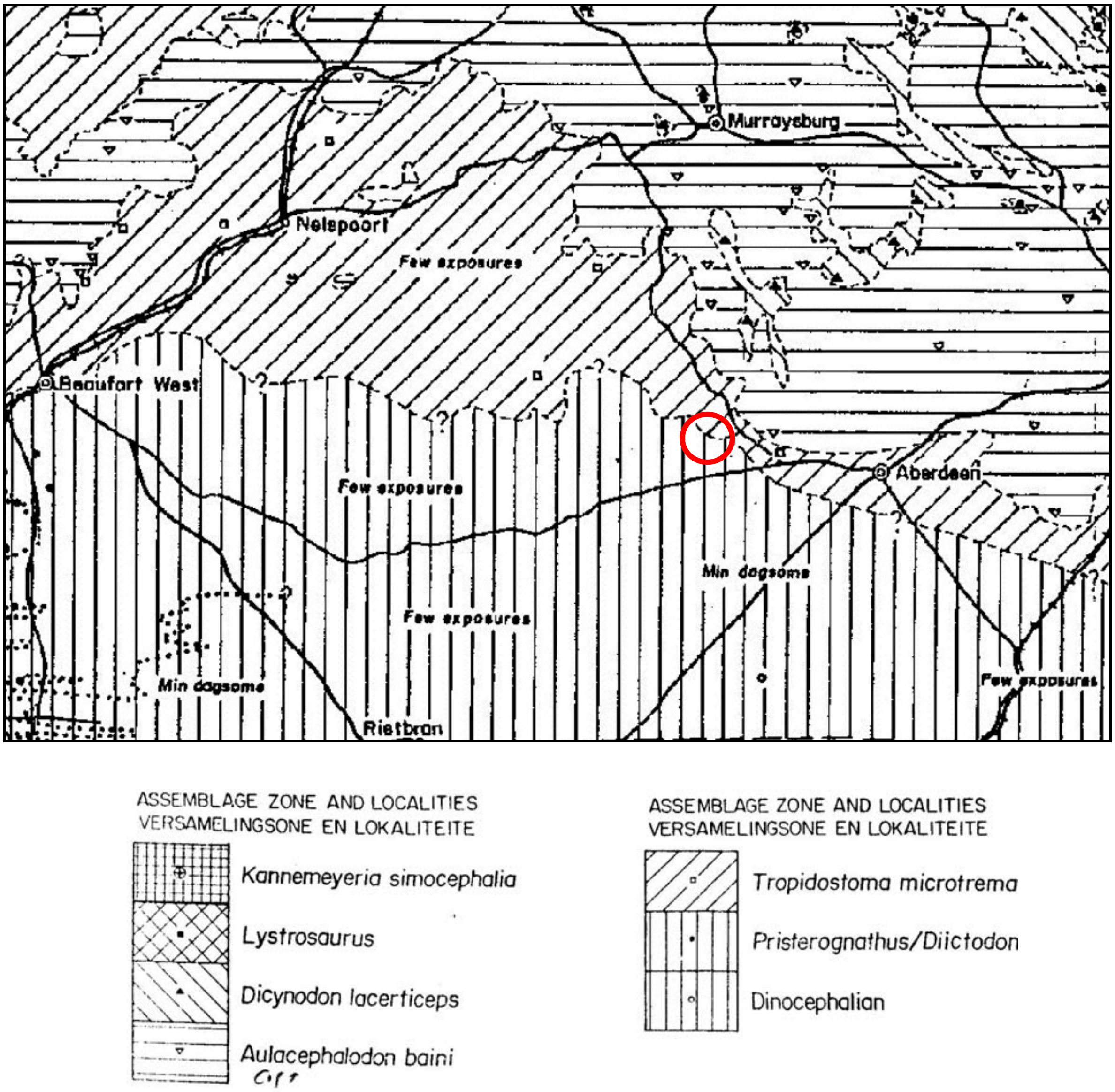

Fig. 28. Biostratigraphical map of the Beaufort Group in the Great Karoo between Beaufort West and Aberdeen showing the distribution of the various palaeontological Assemblage Zones, mainly based on tetrapod fossils (Keyser & Smith 1977-78). According to this map the present study area *c*. 30 km west of Aberdeen (blue circle) lies close to the contact of the *Tropidostoma* and *Cistecephalus* (previously *Aulacephalodon*) Assemblage Zones. Fossil members of both assemblage zones have been recorded close to the dust road between the R61 tar road and Murraysburg, at the foot of and along the Kamdebooberg Escarpment. The area of the *Pristerognathus* Assemblage Zone near Aberdeen has been reduced in later biozonation maps (See next figure).

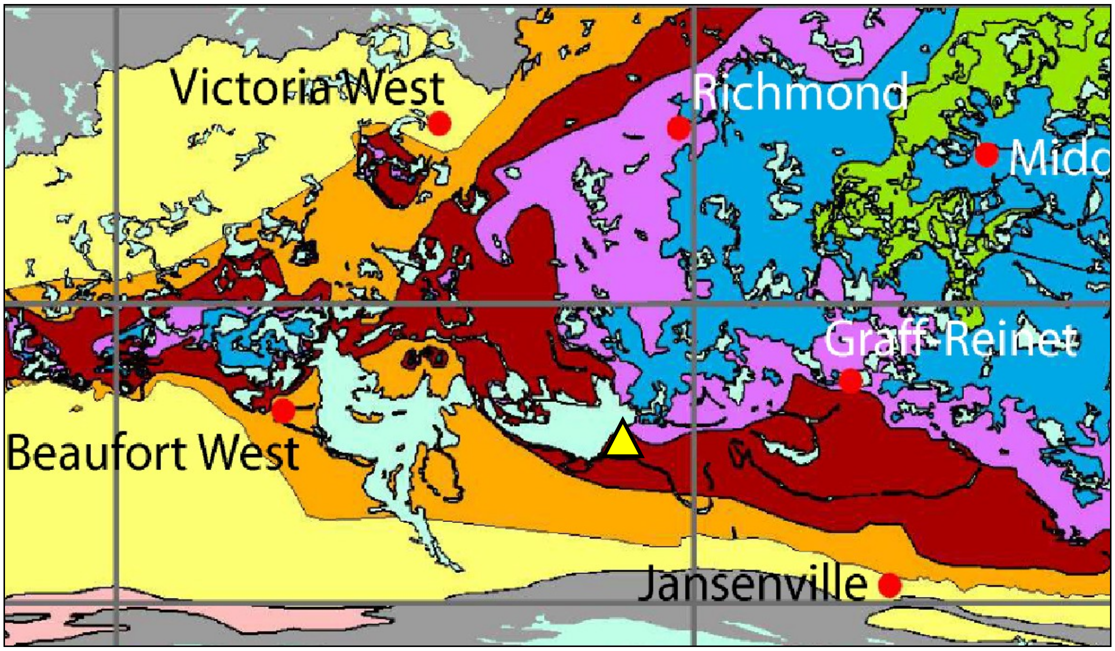

Figure 29. Extract from the latest fossil assemblage zone map for the Main Karoo Basin (Van der Walt *et al*., 2010) showing the location of the Aberdeen Wind Farm study area (yellow triangle) within the *Tropidostoma* Assemblage Zone (reddish-brown). Pale blue areas represent extensive superficial deposits of the Aberdeen *vlaktes*. The darker blue are represents the *Cistecephalus* Assemblage Zone which is recorded in the Kamdebooberg Escarpment just to the northeast of the wind farm study area.

Fig. 30. Palaeocalcrete nodules, some secondarily silicified, from among surface gravels at Locs. 046-047. Such pedogenic nodules may occasionally contain vertebrate fossils.

Fig. 31. Asssortment of cherty clasts of petrified wood from surface gravels at Loc. 034 (Scale in cm and mm). Note lack of rounding suggesting limited transport.

Fig. 32. Sizeable blocks of silicified wood from surface gravels at Loc. 035 where they may have weathered out from a locally exposed channel sandstone (See Fig. 9). Scale in cm.

Fig. 33. Close-up of well-preserved silicified wood from Loc. 034 (See Fig. 31) showing the prominent seasonal growth rings as well as fine radial rows of xylem cells (tracheids). The block is 7 cm across.

Fig. 34. Sizeable chunk of petrified wood showing a core of well-preserved, darker wood surrounded by creamy amorphous cherty material – possibly decomposed woody tissue (Loc. 036). The block is 9.5 cm across.

5. ASSESSMENT OF IMPACTS AND IDENTIFICATION OF MANAGEMENT ACTIONS

5.1. Assessment of impact significance

The study area for the proposed Aberdeen Wind Farm near Aberdeen is underlain by potentially fossiliferous sedimentary rocks of Permian and younger, Quaternary to Holocene age (Sections 3 & 4). The construction phase of the proposed alternative energy development will entail surface clearance as well as substantial excavations into the superficial sediment cover and into the underlying bedrock as well. These include, for example, excavations for wind turbine foundations, turbine mounting areas, new access roads, 400 kV transmission line pylon footings, the on-site substation, foundations for the office / workshop, borrow pits and underground cables. All these developments may adversely affect potential fossil heritage within the study area by destroying, disturbing or permanently sealing-in fossils at or beneath the surface of the ground that are then no longer available for scientific research or other public good. The operational and decommissioning phases of the wind energy facility are unlikely to involve further adverse impacts on local palaeontological heritage, however.

The entire wind farm study area is underlain at depth by fluvial sediments assigned to the lowermost part of the Teekloof Formation (Lower Beaufort Group) that are of Late Permian age (*c*. 260 million years old). The mudstone-rich succession of the Hoedemaker Member represented here is associated with moderately diverse fossil biotas of the *Tropidostoma* Assemblage Zone that include a range of mammal-like reptiles, true reptiles, fish, amphibians as well as plants and trace fossils. To the author's knowledge there are no previously identified fossil vertebrate finds within the study area, although a small lizard-like specimen was apparently found (probably preserved within a palaeocalcrete nodule) among surface gravels along its northern margin (Mnr Loots, pers. comm., Nov. 2014). The only fossil material recorded during the present field assessment comprises sparse blocks of well-preserved silicified wood that occur widely among surface gravels through much of the study area. Most of the fossil wood specimens have probably been downwasted from channel sandstones within the Hoedemaker Member itself, but some cherty fossil wood clasts may have been introduced from elsewhere within fluvial gravels. The general lack of fossil records in the Aberdeen *vlaktes* may well be due, in large part, to very low levels of bedrock exposure in this low-relief area, as well as due to local development of cleavage, near-surface calcrete veining and weathering. It is concluded that, while there is a significant chance that fossil vertebrate remains will be disturbed, destroyed or sealed-in by the proposed wind energy facility development, these are best mitigated by applying a chance find procedure. The operational and decommissioning phases of the wind farm are unlikely to involve further adverse impacts on local palaeontological heritage, however.

The inferred impact of the proposed wind energy development on local fossil heritage resources is analysed in Table 1 below, based on the system developed by Savannah Environmental (Pty) Ltd. This assessment applies only to the construction phase of the development since further impacts on fossil heritage during the operational and decommissioning phases of the facilities are not anticipated.

In general, the destruction, damage or disturbance out of context of fossils preserved at the ground surface or below ground that may occur during construction represents a *negative* impact that is limited to the development footprint. Such impacts can usually be mitigated but cannot be fully rectified or reversed (*i.e. permanent, irreversible*). Most of the sedimentary formations represented within the study area contain fossils of some sort, so impact on fossil heritage are *probable*. However, because of (a) the generally sparse occurrence of fossils within the bedrocks concerned here, as well as within the overlying superficial sediments (soil, alluvium, colluvium *etc*), (b) the widespread occurrence of the fossils concerned (primarily reworked petrified wood), and (c) the mantling of the bedrocks with thick superficial sediments in some areas, the magnitude of these impacts is conservatively rated as *low*.

No areas or sites of exceptional fossil heritage sensitivity or significance have been identified within the study area. The fossil remains identified in this study are mostly of widespread occurrence within the study area itself as well as within the outcrop area of the formations concerned (*i.e.* not unique to the study area). Irreplaceable loss of fossil heritage is therefore not anticipated. Should fossil remains be impacted by the proposed development, these impacts can be partially mitigated by a chance-find procedure, as outlined in the following section of the report.

There are no fatal flaws in the Aberdeen Wind Farm development proposal as far as fossil heritage is concerned. Due to the general scarcity of fossil remains, the moderately high levels of near-surface bedrock weathering, the local development of tectonic cleavage as well as the extensive superficial sediment cover observed within the entire study area, the overall impact significance of the construction phase of the proposed alternative energy project is assessed as LOW. The no-go option (*i.e.* no development of the wind farm) is of neutral impact significance for fossil heritage.

It should be noted that should new fossil remains be discovered before or during construction and reported by the responsible ECO to the responsible heritage management authority (ECPHRA) for professional recording and collection, as recommended below, the overall impact significance of the project would remain LOW. Residual negative impacts from loss of fossil heritage would be partially offset by an improved palaeontological database for the study region 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.

In the absence of comprehensive data on palaeontological heritage studies for alternative energy or other developments in the Aberdeen area, it is impossible to realistically assess cumulative impacts on fossil heritage resources; no desktop or field-based palaeontological studies are represented on the SAHRIS database for the Aberdeen area. The potentially fossiliferous sedimentary rock units represented within the present study area (*e.g.* Hoedemaker Member, alluvium, calcretes, surface gravels) are of widespread occurrence and this is also likely to apply to most of the fossils they contain. It concluded that the cumulative impact on fossil heritage resources posed by potential alternative energy developments in the region is *low*.

Because of the generally low levels of bedrock exposure within the study area, confidence levels for this palaeontological heritage assessment are only MODERATE following the field assessment of representative rock exposures.

5.2. Recommended mitigation and management actions

Given the low impact significance of the proposed Aberdeen Wind Farm near Aberdeen as far as palaeontological heritage is concerned, no further specialist palaeontological heritage studies or mitigation are considered necessary for this project, pending the discovery or exposure of substantial new fossil remains during development.

During the construction phase all deeper (> 1 m) bedrock excavations should be monitored for fossil remains by the responsible ECO. Should substantial fossil remains such as vertebrate bones and teeth, plant-rich fossil lenses or dense fossil burrow assemblages be exposed during construction, the responsible Environmental Control Officer should safeguard these, preferably *in situ*, and alert ECPHRA so that appropriate action can be taken by a professional palaeontologist, at the developer's expense (Contact details: Mr Sello Mokhanya, 74 Alexander Road, King Williams Town 5600; Email: smokhanya@ecphra.org.za). Mitigation would normally involve the scientific recording and judicious sampling or collection of fossil material as well as associated geological data (*e.g.* stratigraphy, sedimentology, taphonomy) by a professional palaeontologist.

These mitigation recommendations should be incorporated into the Environmental Management Plan (EMP) for the Aberdeen Wind Farm.

Provided that the recommended mitigation measures are carried through, it is likely that any potentially negative impacts of the proposed transmission line development on local fossil resources will be substantially reduced. Furthermore, they will be partially offset by the *positive* impact represented by increased understanding of the palaeontological heritage of the Great Karoo region.

Please note that:

- All South African fossil heritage is protected by law (South African Heritage Resources Act, 1999) and fossils cannot be collected, damaged or disturbed without a permit from SAHRA or the relevant Provincial Heritage Resources Agency (in this case, ECPHRA);

- The palaeontologist concerned with mitigation work will need a valid fossil collection permit from ECPHRA and any material collected would have to be curated in an approved depository (*e.g.* museum or university collection);

- All palaeontological specialist work would have to conform to international best practice for palaeontological fieldwork and the study (*e.g.* data recording fossil collection and curation, final report) should adhere as far as possible to the minimum standards for Phase 2 palaeontological studies recently developed by SAHRA (2013).

Table 1: Assessment of impacts of the proposed Aberdeen Wind Farm on fossil heritage resources during the construction phase of the development (*N.B.* Significant impacts are not anticipated during the operational and decommissioning phases).

<table>
<tr><td colspan="3">Nature of impact: Disturbance, damage, destruction or sealing-in of fossil remains preserved at or beneath the ground surface within the development area, most notably by bedrock excavations during the construction phase of the solar energy facilities.</td></tr>
<tr><td></td><td>Without mitigation</td><td>With mitigation</td></tr>
<tr><td>Extent</td><td>Local (1)</td><td>Local (1)</td></tr>
<tr><td>Duration</td><td>Permanent (5)</td><td>Permanent (5)</td></tr>
<tr><td>Magnitude</td><td>Low (1)</td><td>Low (1)</td></tr>
<tr><td>Probability</td><td>Probable (3)</td><td>Probable (3)</td></tr>
<tr><td>Significance</td><td>Low (21)</td><td>Low (21)</td></tr>
<tr><td>Status</td><td>Negative</td><td>Negative (loss of fossils) & positive (improved fossil database following mitigation)</td></tr>
<tr><td>Reversibility</td><td>Irreversible</td><td>Irreversible</td></tr>
<tr><td>Irreplaceable loss of resources?</td><td>No, since the limited fossil resources concerned are also represented outside the development area (i.e. not unique)</td><td>No, since the limited fossil resources concerned are also represented outside the development area (i.e. not unique)</td></tr>
<tr><td>Can impacts be mitigated?</td><td>Yes</td><td>Yes.</td></tr>
<tr><td colspan="3">Mitigation: Monitoring of all substantial bedrock excavations for fossil remains by ECO, with reporting of substantial new palaeontological finds (notably fossil vertebrate bones & teeth) to ECPHRA for possible specialist mitigation.</td></tr>
<tr><td colspan="3">Cumulative impacts: Unknown (Insufficient data on local alternative energy and other developments available) but probably low.</td></tr>
<tr><td colspan="3">Residual impacts: Negative impacts due to loss of local fossil heritage will be partially offset by positive impacts resulting from mitigation (i.e. improved palaeontological database).</td></tr>
</table>

Table 2: Recommendations concerning fossil heritage management during the construction phase for inclusion into the draft EMP for the proposed Aberdeen Wind Farm (*N.B.* Significant impacts are not anticipated during the operational and decommissioning phases).

OBJECTIVE: Safeguarding, recording and sampling of any important fossil material exposed.

Project component/s	Construction of wind energy facility.
Potential Impact	Disturbance, damage, destruction or sealing-in of scientifically valuable fossil material embedded within bedrock or weathered-out at ground surface.
Activity/risk source	Extensive bedrock excavations and surface disturbance (*e.g.* wind turbine foundations, turbine mounting areas, new access roads, 400 kV transmission line pylon footings, the on-site substation, foundations for the office / workshop, borrow pits and underground cables).
Mitigation: Target/Objective	Recording, judicious sampling and curation of any important fossil heritage exposed during construction within the Aberdeen Wind Farm development area.

Mitigation: Action/control	**Responsibility**	**Timeframe**
1. Monitoring of all bedrock excavations for fossil remains. Fossil finds to be safeguarded and reported to ECPHRA for possible mitigation.	ECO	Construction phase
2. Recording and judicious sampling of representative as well as any exceptional fossil material from the development footprint.	Professional palaeontologist assisted by ECOs	Construction phase
3. Curation of fossil specimens at an approved repository (*e.g.* museum).	Professional palaeontologist	Following mitigation
4. Final technical report on palaeontological heritage within study area	Professional palaeontologist	Following mitigation and preliminary analysis of fossil finds

Performance Indicator	Identification of any new palaeontological hotspots within broader development footprint by ECO. Cumulative acquisition of geographically and stratigraphically well-localised fossil records, samples and relevant geological data from successive subsections of the development area. Submission of interim and final technical reports to ECPHRA by palaeontologist involved with any mitigation work.
Monitoring	Monitoring during construction phase of fresh bedrock exposures within development footprint by ECO and, if necessary, by professional palaeontologist.

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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 alternative 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.

Dr John E. Almond
Palaeontologist
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APPENDIX: GPS LOCALITY DATA

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

Locality number	South	East	Comments
021	S32 28 34.2	E23 47 54.3	R61 road cutting through Hoedemaker Mb channel sandstone, mineral lineations.
021a	S32 28 36.7	E23 47 50.6	Hoedemaker mudrock exposures south of R61. Sparse silicified wood fragments in surface gravels.
022	S32 28 46.6	E23 46 41.8	Extensive borrow pit into Hoedemaker Mb mudrocks N of R61.
023	S32 28 38.1	E23 46 39.5	Bare patches between Karoo bossies showing sparse sheetwash and downwasted surface gravels.
024	S32 28 09.6	E23 46 34.6	Low W-E ridge of buff Hoedekaker Mb sandstone, colluvial rubble.
025	S32 28 05.4	E23 46 34.1	Concentration of petrified wood fragments within surface gravels.
026	S32 27 47.3	E23 46 22.5	Shallow drainage line with silty alluvium, sheetwash surface gravels
027	S32 27 30.7	E23 46 02.2	Concentration of patinated hornfels surface gravels, many anthropogenically flaked.
028	S32 27 24.5	E23 46 04.6	Polymict surface gravels, including well-preserved silicified fossil wood fragments.
029	S32 27 18.3	E23 46 05.1	Polymict coarse gravels of probable relict alluvial origin.
030	S32 27 08.3	E23 46 05.2	Silty alluvium with sparse surface gravels, including rare clasts of petrified wood.
031	S32 27 33.4	E23 44 50.5	Pan-like areas of open silty soil in veld with surface gravels, including petrified wood.
032	S32 27 48.5	E23 44 33.8	Natural exposure of purple brown Hoedemaker mudrocks with thin sandstone interbeds near dam.
033	S32 28 36.0	E23 45 13.7	Pebbly to cobbly surface alluvial gravels, including petrified wood.
034	S32 28 47.2	E23 45 24.4	Calcrete-rich surface gravels, locally common petrified wood.
035	S32 29 00.0	E23 45 36.9	Low exposures of Hoedemaker Mb sandstones, mineral lineations, *koffieklip*, locally common petrified wood.
035a	S32 29 02.3	E23 45 40.1	Exposure of cleaved grey-green and purple-brown Hoedemaker Mb mudrocks in borrow pit, extensive calcrete veining near-surface, petrified wood in surface gravels.
036	S32 29 19.4	E23 44 06.2	Extensive exposure of cleaved grey-green and purple-brown Hoedemaker Mb mudrocks in borrow pit, calcrete veins.
037	S32 29 26.6	E23 43 44.0	Borrow pit exposure of well-developed calcrete

			hard pan within silty and gravelly alluvium. Surface gravels with petrified wood fragments.
038	S32 29 40.9	E23 42 29.0	Pebbly to cobbly alluvial gravels just south of R61.
039	S32 29 59.1	E23 42 34.5	Pebbly to cobbly surface gravels modified by sheet wash.
040	S32 29 50.3	E23 41 47.5	Borrow pit exposure of Hoedemaker Mb mudrocks, horizons of palaeocalcrete nodules.
041	S32 25 40.6	E23 46 28.1	Extensive area of pebbly to cobbly alluvial surface gravels.
042	S32 25 42.8	E23 46 14.4	Coarse alluvial surface gravels.
044	S32 25 28.7	E23 46 03.9	Extensive, thick silty to sandy alluvial sediment, gravel lenticles, exposed in washes and through donga erosion.
045	S32 25 14.0	E23 45 25.5	Extensive surface gravels, abundant hornfels but no fossil wood recorded.
046	S32 25 19.5	E23 44 25.2	Patches of surface gravels overlying silty soils, including calcrete nodules, some silicified. Possible site of "fossil *akkedis*" (lizard) reported by land owner. Rare fossil wood.
047	S32 25 20.3	E23 44 19.1	Patches of surface gravels overlying silty soils, including calcrete nodules, some silicified. Possible site of "fossil *akkedis*" (lizard) reported by land owner.
048	S32 26 16.6	E23 45 01.0	Extensive low exposure of Hoedemaker Mb channel sandstone, associated sandstone surface rubble, surrounding trig beacon.
049	S32 26 45.0	E23 43 58.8	Pebbly to cobbly surface gravels, well-rounded, with common dolerite clasts.
050	S32 28 18.1	E23 49 02.6	Quarry exposure through thick Hoedemaker Mb channel sandstone package, adjacent to the R61, outside and just east of study area