PALAEONTOLOGICAL ASSESSMENT: COMBINED DESKTOP & FIELD-BASED ASSESSMENT

Proposed Dobbin Solar Farm on Portion 1 of Farm Het Fortuin No. 66 near Cradock, Eastern Cape Province

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1. SUMMARY

Af-Rom Energy is proposing to develop a 75 MW photovoltaic solar farm on Portion 1 of Farm Het Fortuin No. 66, situated about 28 km northwest of Cradock, Eastern Cape Province. The Dobbin Solar Farm study area is underlain by fluvial sedimentary rocks of the Adelaide Subgroup (Lower Beaufort Group, Karoo Supergroup) that are known for their rich fossil heritage of terrestrial vertebrate remains of Middle to Late Permian age.

Field assessment shows that the Adelaide Subgroup sediments in the study area are almost entirely mantled in unfossiliferous superficial deposits such as soils and downwasted-surface gravels. Extensive baking of surrounding bedrocks by underlying dolerite intrusions may have further compromised fossil preservation. Only a few fossil plants (sphenophyte ferns) and low diversity trace fossil assemblages were observed within the very limited bedrock exposures seen within, as well as on the periphery of, the study area. Furthermore, there are very few previous records of vertebrate fossils from the broader study region northwest of Cradock.

In view of the overall VERY LOW significance of the proposed developments on palaeontological heritage resources, it is concluded that no further palaeontological heritage studies or specialist mitigation are required for this project, pending the exposure of any substantial fossil remains (*e.g.* vertebrate bones and teeth, large blocks of petrified wood) during the construction phase. The ECO responsible for these developments should be alerted to the possibility of fossil remains being found on the surface or exposed by fresh excavations during construction. Should substantial fossil remains be discovered during construction, these should be safeguarded (preferably *in situ*) and the ECO should alert SAHRA so that appropriate mitigation (*e.g.* recording, sampling or collection) can be taken by a professional palaeontologist.

The specialist involved would require a collection permit from SAHRA. Fossil material must be curated in an approved repository (*e.g.* museum or university collection) and all fieldwork and reports should meet the minimum standards for palaeontological impact studies developed by SAHRA.

These recommendations should be incorporated into the EMP for the Dobbin solar farm project.

Summary of palaeontological impact significance ratings for the Dobbin Solar Farm project

Impact	*Consequence*	*Probability*	*Significance*	*Status*	*Confidence*
Disturbance, damage or destruction of significant fossil remains exposed at the surface or buried beneath the surface within the development footprint during the construction phase	Low	Possible	Very Low	Negative	Medium
With mitigation	Low	Possible	Very Low	Negative	Medium

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.

2. INTRODUCTION & BRIEF

The company Af-Rom Energy is proposing to develop a 75 MW photovoltaic solar farm on a 516 ha parcel of land on Portion 1 of Farm Het Fortuin No. 66 which is situated about 28 km northwest of Cradock, Eastern Cape Province (Fig. 1). The study area lies on the eastern side of the N10 between Middelburg and Cradock and is transected by the electrified railway line between Cradock and De Aar (Fig. 2). The development footprint will lie between 150 and 250 hectares and the solar farm has an expected life span of 25 years.

The main elements of the proposed soar farm development include:

- Up to 75 MW of photovoltaic (PV) panels constructed in rows along an east/west axis. Anchoring of the PV panels to the ground will be by means of 1500 mm long galvanised steel posts;
- Inverter substations. Clusters of PV modules will be connected with underground cables to inverter substations;
- Step-up Substation;
- Internal cabling - medium voltage (MV) underground power lines will be installed from the inverter substations to a central collector/ step-up substation;
- An approximately 1 km long 132 kV overhead power line from the step-up substation to the Eskom Substation (attached to the Cradock to De Aar electrified rail line);
- Internal roads which are likely to be either natural tracks, or potentially gravel. A short access road from the nearest provincial road to the site will be required;
- A security fence and a fire break around the perimeter of the site. The area to be fenced is expected to be between 150 and 250 ha;
- Control room;
- A water reservoir (c. 50 000 l) for cleaning panels.

The study area overlies Permian bedrocks of the Beaufort Group (Karoo Supergroup) that are portentially fossiliferous. A Phase 1 palaeontological field assessment for the project has therefore been commissioned by SRK Consulting, Port Elizabeth, in accordance with the requirements of the National Heritage Resources Act, 1999 and the National Environmental Management Act 107 of 1998 (NEMA) (Contact details: SRK Consulting, Ground Floor, Bay Suites, 1a Humewood Rd, Humerail, Port Elizabeth, 6001;Tel: +27 (0) 41 509 4800; E-mail: portelizabeth@srk.co.za).

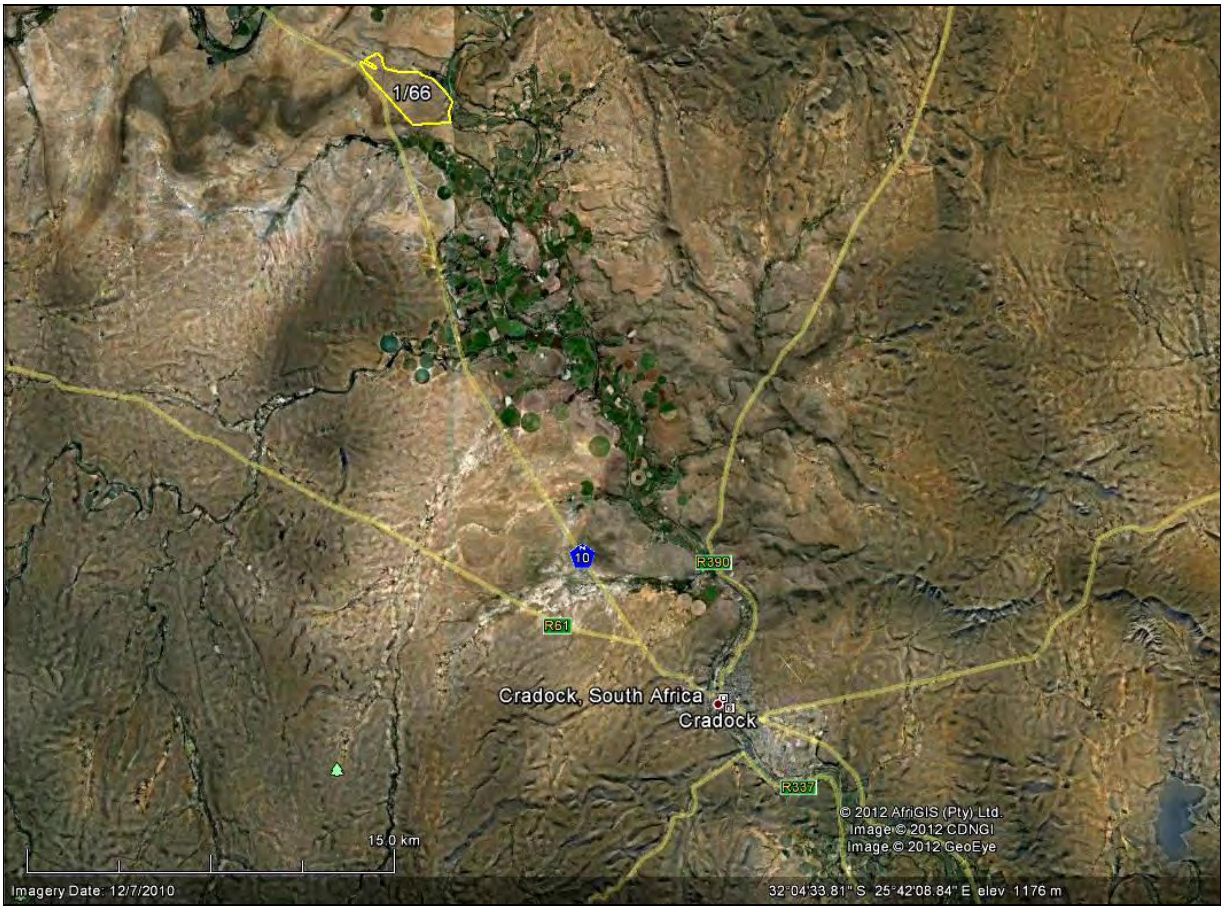

Fig. 1. Google earth© satellite image showing the location of the Dobbin Solar Farm study area on Portion 1 of Farm Het Fortuin No. 66, on the eastern side of the N10 and *c*. 28 km northwest of Cradock, Eastern Cape (yellow polygon). See Fig. 2 for a more detailed image of the study area.

2.1. National Heritage Resources Act

The extent of the proposed development (over 5000 m^2) falls within the requirements for a Heritage Impact Assessment (HIA) as required by Section 38 (Heritage Resources Management) of the South African National Heritage Resources Act (Act No. 25 of 1999). The various categories of heritage resources recognised as part of the National Estate in Section 3 of the 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

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 August 2011.

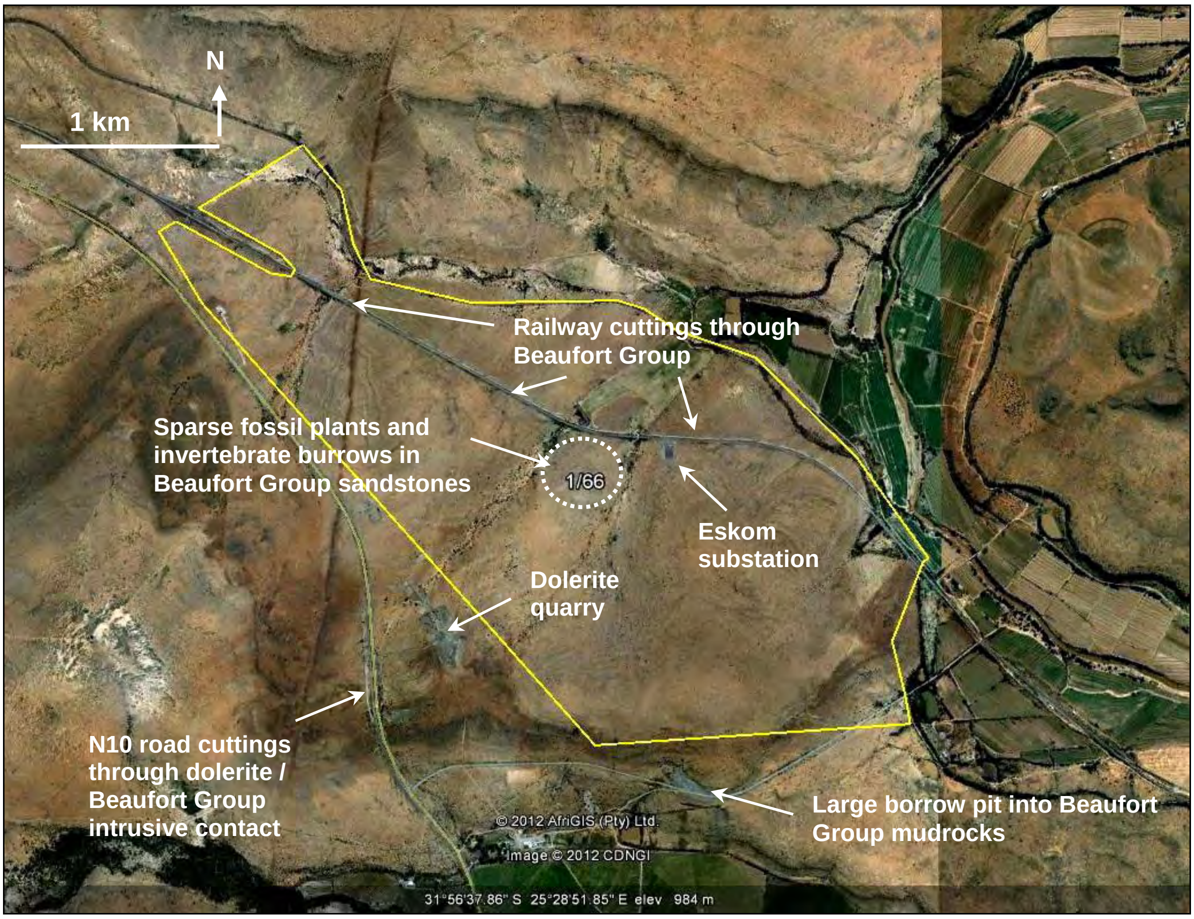

Fig. 2. Google earth© satellite image of the Dobbin Solar Farm study area (yellow polygon) showing generally low levels of bedrock exposure. The outcrop of the edge of a major dolerite sill underlying the study area appears as a prominent rusty brown zone. Key exposures of Beaufort Group sediments are also indicated.

2.2. Approach used for this palaeontological desktop study

This report provides an assessment of the observed or inferred palaeontological heritage within the Dobbin study area, with recommendations for any specialist palaeontological mitigation where this is considered necessary. The report is based on (1) a review of the relevant scientific literature, (2) geological maps, and (3) a site visit carried out on 26 March 2012. GPS data for localities mentioned by number in the text are given in the appendix.

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 Northern Cape have been compiled by Almond & Pether 2008). The likely impact of the proposed development on local fossil heritage is then determined on the basis of (1) the palaeontological sensitivity of the rock units concerned and (2) the nature and scale of the development itself, most notably the extent of fresh bedrock excavation envisaged. When rock units of moderate to high palaeontological sensitivity are present within the development footprint, a field-based assessment by a professional palaeontologist is usually warranted.

On the basis of the desktop study, the likely impact of the proposed development on local fossil heritage and any need for specialist mitigation are then determined. Adverse palaeontological impacts normally occur during the construction rather than the operational or decommissioning phase. Mitigation by a professional palaeontologist – normally involving the recording and sampling of fossil material and associated geological information (*e.g.* sedimentological data) – is usually most effective during the construction phase when fresh fossiliferous bedrock has been exposed by excavations, although pre-construction recording of surface-exposed material may sometimes be more appropriate. To carry out mitigation, the palaeontologist involved will need to apply for a palaeontological collection permit from the relevant heritage management authority (*i.e.* SAHRA, Cape Town). 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.

2.3. 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.

The only notable limitation on this study was the low level of bedrock exposure over most of the Dobbin study area due to cover by dense summer grasses and superficial deposits (soils, surface gravels *etc*). However, the bedrocks are very well-exposed in road cuttings, borrow pits and railway cuttings on the periphery of the development footprint, allowing the palaeontological sensitivity of the area to be assessed with a reasonable (moderate) degree of confidence.

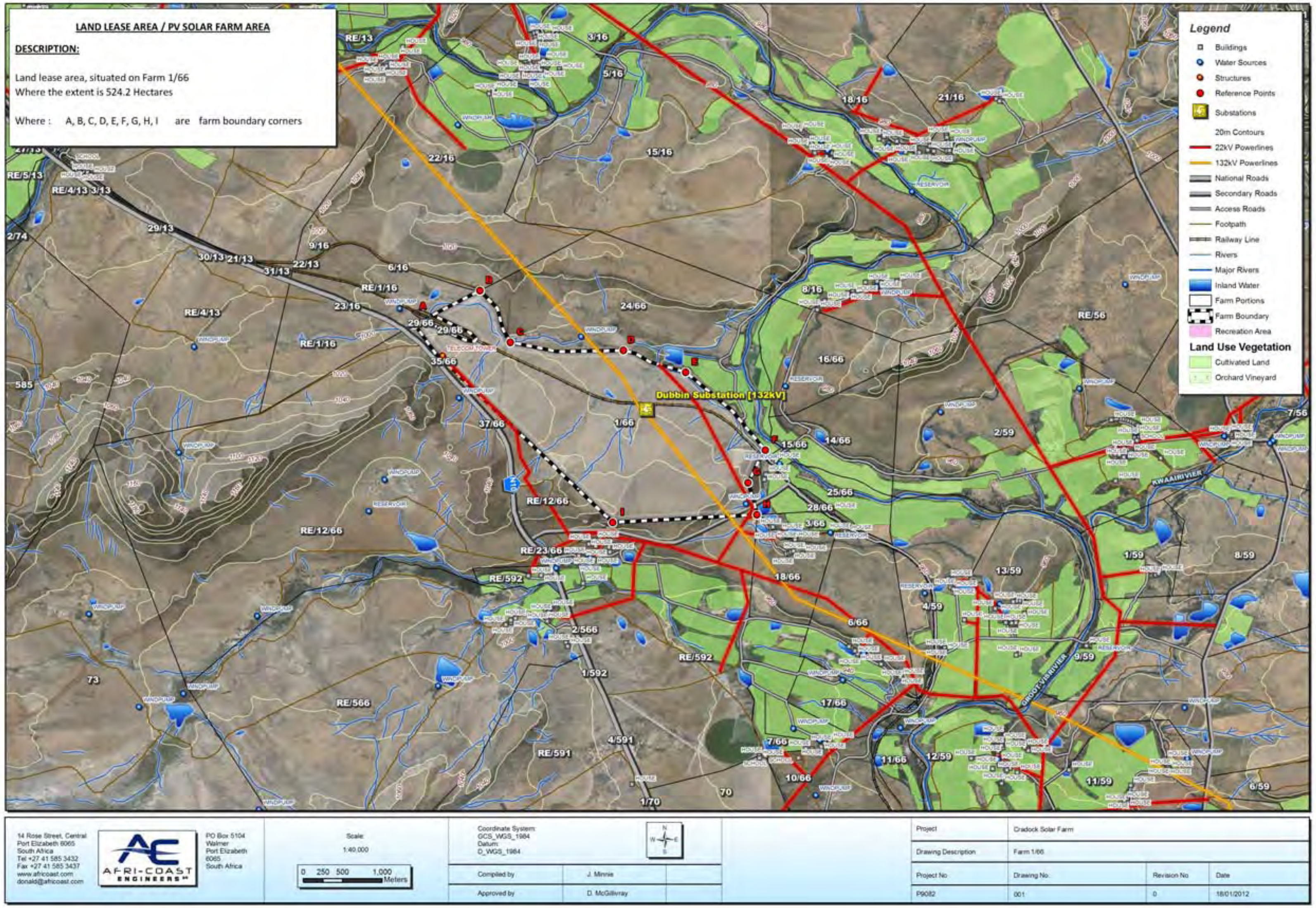

Fig. 3. Development area of the proposed Dobbin Solar Farm on Portion 1 of Farm Het Fortuin No. 66, *c*. 28 km northwest of Cradock (Image kindly supplied by SRK Consulting, Port Elizabeth).

3. GEOLOGICAL BACKGROUND

The study area on Farm Het Fortuin No. 66 near Cradock comprises gently hilly, semi-arid and rocky terrain at 970 to 1020m amsl lying between the N10 tar road from Middelburg to Cradock and the Great Fish River (Fig. 2). It is traversed by several shallow streams flowing north-eastwards into a small tributary of the Great Fish River that runs along the northern edge of the area. Levels of bedrock exposure are generally very poor due to the extensive mantle of rocky soils (Fig. 5), exacerbated by luxuriant growth of summer grasses during the March field visit.

The geology of the study area to the NW of Cradock is shown on 1: 250 000 sheet 3124 MIddelburg (Fig. 4; Cole *et al.* 2004). The area is largely underlain at depth by fluvial sediments of the Late Permian **Adelaide Subgroup** (**Pa**, Lower Beaufort Group, Karoo Supergroup) that are extensively intruded here by dykes and sills of the Early Jurassic **Karoo Dolerite Suite** (Johnson *et al.* 2006, Duncan & Marsh 2006). The Adelaide Subgroup is not subdivided on the Middelburg sheet map due to lack of key marker horizons. However, on the basis of palaeontological data the study area can be equated with the **Balfour Formation** of the Eastern Cape which is characterized by fossil faunas of the *Dicynodon* Assemblage Zone (See Cole et al. 2004, p. 19). The finely-stepped terrain, well seen on satellite images (Fig. 2), suggests that this part of the Adelaide Subgroup succession is rich in thin sandstone packages (*cf* Barberskrans Member). However, this may also reflect the regional thermal metamorphosis (baking) of the Beaufort Group rocks here by a substantial underlying dolerite sill, the margin of whose outcrop is clearly seen as a rusty brown zone on the satellite image towards the west of the study area.

Given the paucity of natural bedrock exposures, the best sections through the Adelaide Subgroup rocks here are seen along extensive railway cuttings (Figs. 6, 11), in N10 road cuttings (Fig. 12), in shallow irrigation ditches and in the walls of a large borrow pit just to the south of the area (Figs. 8, 9) (These sites are indicated on Fig. 2). The railway cuttings were not examined closely for reasons of safety and access, however. They show lenticular packets of channel sandstones (secondarily stained with rust from the railway) interbedded with hackly-weathering, grey-green to blue-grey mudrocks. Interesting sedimentological features seen here include probable abandoned meander channels infilled with thinly-laminated, dark mudrocks (possibly hosting fossil remains of aquatic fauna, such as bivalves, fish or amphibians) and large-scale epsilon cross-bedded sandstones reflecting lateral migration of sandy point bar deposits. In the borrow pit can be seen massive to thinly-bedded, blue-grey siltstones and darker claystones representing distal, fining-up floodplain deposits (Fig. 8); thin, lenticular channel sandstones also occur here. The mudrocks contain sparse, rusty-brown to speckled calcrete nodules that are occasionally concentrated along laterally-persistent zones reflecting ancient soil horizons (palaoesols; Fig. 9). The calcretes in the study region have generally been secondarily ferruginised and silicified as a consequence of dolerite intrusion. Curious isolated, sand-infilled bodies of lenticular cross-section and *c*. 1cm thickness within the much finer-grained overbank mudrocks might be fossil invertebrate burrows, though this is highly speculative.

On the gently-sloping hill slopes near the electrical substation where the solar farm will probably be developed the Adelaide Subgroup rocks are largely obscured by reddish brown soils and downwasted gravels largely composed of platy, angular sandstone clasts, with minor silicified calcrete nodules, quartzites (rarely flaked), hornfels, and dolerite (Fig. 5). Rare mudrock exposures show weathered olive green, hackly-weathered sediments, sometimes baked reddish-grey with a more splintery, hornfels fracture, and thin (cm-thick) distal crevasse splay sandstones (Fig. 10). More prominent-weathering, buff, sheet-like channel or crevasse-splay sandstones show well-developed ripple cross-laminated upper surfaces (Fig. 7). Occasional sandstone float blocks preserve small-scale (1-2cm wavelength) linear-crested wave ripples and were probably deposited within a playa lake on the Permian floodplain.

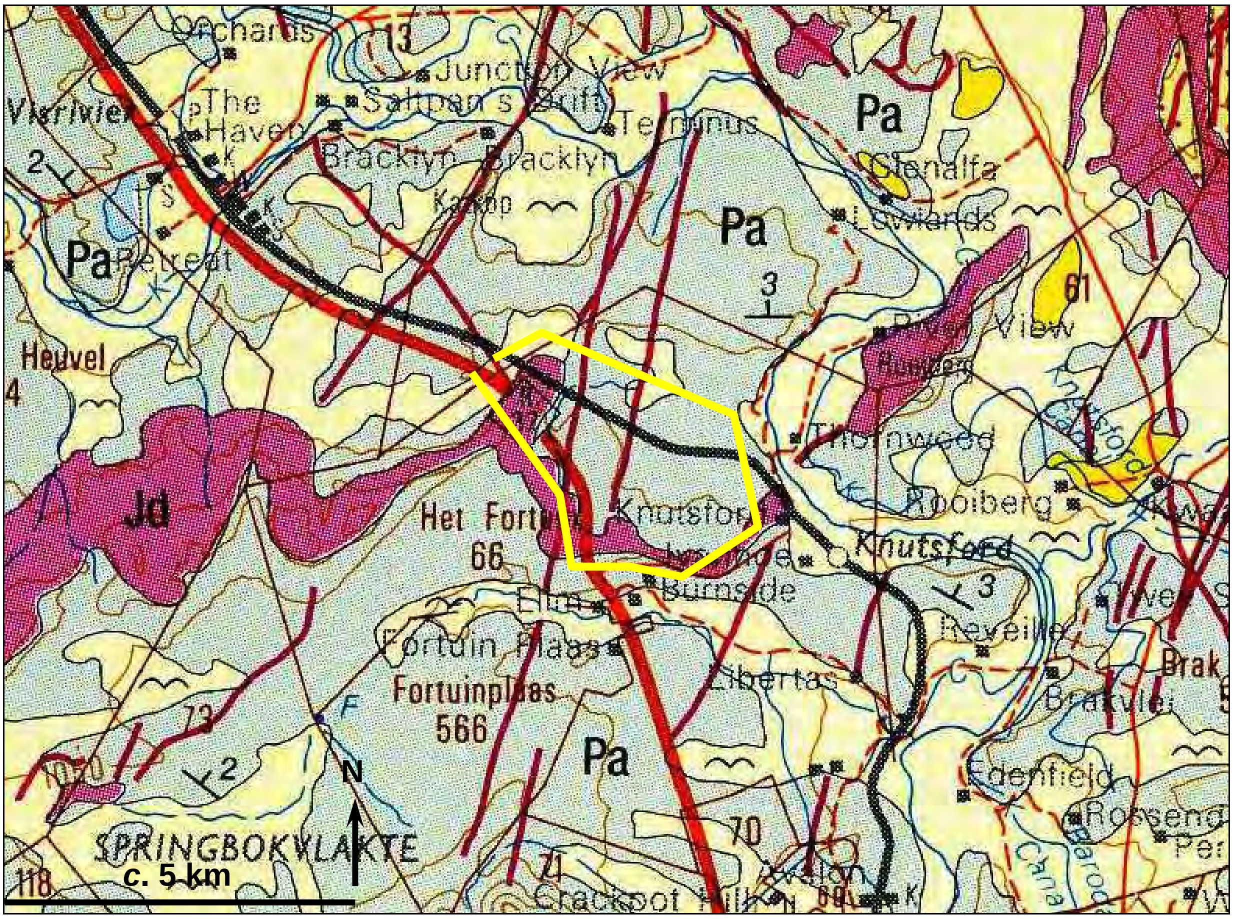

Fig. 4. Extract from 1: 250 000 geological map 3124 Middelburg (Council for Geoscience, Pretoria) showing *approximate* location of the Dobbin Solar Farm study area on Farm Het Fortuin No. 66 (yellow polygon), spanning the Cradock – De Aar railway line. Geological units represented in this region are the Late Permian Adelaide Subgroup of the Beaufort Group (Pa pale grey-green), Early Jurassic intrusive dykes of the Karoo Dolerite Suite (Jd, pink), and Late Caenozoic alluvium (pale yellow with "flying bird" symbol).

A major dolerite sill and a swarm of NNE-SSW trending dolerite dykes are mapped intruding the Beaufort Group sediments in the study region (Fig. 4). As discussed earlier, a high proportion of the Beaufort sediments within the study area must have experienced thermal metamorphism and attendant chemical alteration (metasomatism) during dolerite intrusion in Early Jurassic times. Clear sections through one of the main, steeply inclined dolerite dykes are seen in railway cuttings (Fig. 11) while the sharp contact between massive to well-jointed, dark-grey dolerite of the main sill and the overlying baked, well-bedded Beaufort Group sediments is well-exposed in road cuttings along the N10 (Fig. 12). Small, obliquely-inclined dolerite dykes leading off from the main sill are also seen here. The mudrocks have been metamorphosed to hornfels, while the channel sandstones are altered to pale quartzites. A substantial abandoned quarry excavated into the main dolerite body is situated just west of the study area (Fig. 2).

Good sections through the rocky superficial sediments are exposed along the edges of the main borrow pit (Figs. 8, 13). The Beaufort Group bedrocks here and elsewhere are mantled by soils containing numerous dispersed, subhorizontal platy clasts of sandstone within a matrix of mudrock fragments. Downwasting of these deposits, which are perhaps of colluvial origin, leads to the surface mantle of platy sandstone gravels that covers much of the study area. Coarse, bouldery, calcrete-cemented alluvial gravels, mainly of sandstone, are exposed in shallow stream beds traversing the study area (Fig. 14).

Fig. 5. Mantle of soil and downwasted surface gravels of angular, platy sandstone blocks, study area *c*. 300 m west of the Eskom substation.

Fig. 6. Good vertical sections through Adelaide Subgroup sediments along railway cuttings. Lenticular channel sandstones (secondarily coated with rust) are interbedded with grey-green overbank mudrocks.

Fig. 7. Limited exposure of flaggy, buff-coloured sandstones showing ripple cross-laminated upper surfaces, with sandstone surface gravels (Hammer = 32 cm).

Fig. 8. Thinly interbedded blue-grey siltstones and darker claystones of the overbank mudrock succession exposed in a large borrow pit (Loc. 422). Note surface mantle of platy sandstone clasts.

Fig. 9. Laterally persistent palaeosol horizon within overbank mudrocks that is marked by secondarily ferruginised calcrete nodules (Loc. 422) (Hammer = 32 cm).

Fig. 10. Rare natural exposure of weathered, olive-green Adelaide Subgroup mudrocks with thin crevasse splay sandstone interbeds.

Fig. 11. Contact between steeply-dipping dolerite dyke (rusty brown) and grey-green Adelaide Subgroup sediments in railway cutting at NW edge of study area.

Fig. 12. Sharp contact between roof of a major dolerite sill (dark grey, jointed rocks below white dashed line) and horizontally-bedded, thermally metamorphosed country rocks of the Beaufort Group, road cutting along N10 (Loc. 423).

Fig. 13. Adelaide Subgroup channel sandstone overlain by thick mantle of skeletal soil (mainly mudrock flakes) with well-dispersed platy sandstone clasts (Loc. 422) (Hammer = 32 cm).

Fig. 14. Shallow stream bed just west of the Eskom substation showing coarse, poorly sorted alluvium dominated by subangular blocks of Beaufort Group sandstone, partially cemented by white calcrete.

4. PALAEONTOLOGICAL HERITAGE

The overall palaeontological sensitivity of the Beaufort Group sediments in general is high to very high (Almond & Pether 2008). These continental sediments have yielded one of the richest fossil records of land-dwelling plants and animals of Permo-Triassic age anywhere in the world (*e.g.* MacRae 1999, Rubidge 2005, McCarthy & Rubidge 2005). 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) and, most recently, by Van der Walt *et al.* (2010). According to the latest biozonation map the region between Middelburg and Cradock is largely underlain by sediments of the *Dicynodon* Assemblage Zone (Fig. 16). This biozone has been assigned to the Changhsingian Stage (= Late Tartarian), right at the end of the Permian Period, with an approximate age range of 253.8-251.4 million years (Rubidge 1995, 2005).

Good accounts, with detailed faunal lists, of the rich Latest Permian fossil biotas of the *Dicynodon* Assemblage Zone have been given by Kitching (*in* Rubidge 1995) and for the Middelburg sheet area by Cole *et al*. (2004). See also the reviews by Cluver (1978), MacRae (1999), McCarthy & Rubidge (2005), Almond *et al*. (2008) and Nicolas & Rubidge (2010). In general, the following broad categories of fossils might be expected within the Adelaide Subgroup sediments in the study area:

- isolated petrified bones as well as articulated skeletons of terrestrial vertebrates such as true **reptiles** (notably large herbivorous pareiasaurs, small lizard-like millerettids and younginids) and **therapsids** (diverse dicynodonts such as *Dicynodon* and the much smaller *Diictodon*, carnivorous gorgonopsians, therocephalians such as *Theriognathus* (= *Whaitsia*), primitive cynodonts like *Procynosuchus*, and biarmosuchians) (See Fig. 15 herein);

- aquatic vertebrates such as large, crocodile-like temnospondyl **amphibians** like *Rhinesuchus* (usually disarticulated), and palaeoniscoid **bony fish** (*Atherstonia*, *Namaichthys*);

- freshwater **bivalves** (*Palaeomutela*);

- **trace fossils** such as worm, arthropod and tetrapod burrows and trackways, coprolites (fossil droppings);

- **vascular plant remains** including leaves, twigs, roots and petrified woods ("*Dadoxylon*") of the *Glossopteris* Flora (less sparse here than in many other Beaufort group biozones, perhaps due to wetter climates), especially glossopterids and arthrophytes (horsetail ferns).

From a palaeontological viewpoint, these diverse *Dicynodon* AZ biotas are of extraordinary interest in that they provide some of the best available evidence for the last flowering of ecologically-complex terrestrial ecosystems immediately preceding the catastrophic end-Permian mass extinction (*e.g.* Smith & Ward, 2001, Rubidge 2005, Retallack *et al*., 2006).

As far as the biostratigraphically important tetrapod remains are concerned, the best fossil material is generally found within overbank mudrocks, whereas fossils preserved within channel sandstones tend to be fragmentary and water-worn (Kitching 1995, Smith 1993). Many fossils are found in association with ancient soils (palaeosol horizons) that can usually be recognised by bedding-parallel concentrations of calcrete nodules. The abundance and variety of fossils within the *Dicynodon* Assemblage Zone decreases towards the top of the succession (Cole *et al*., 2004).

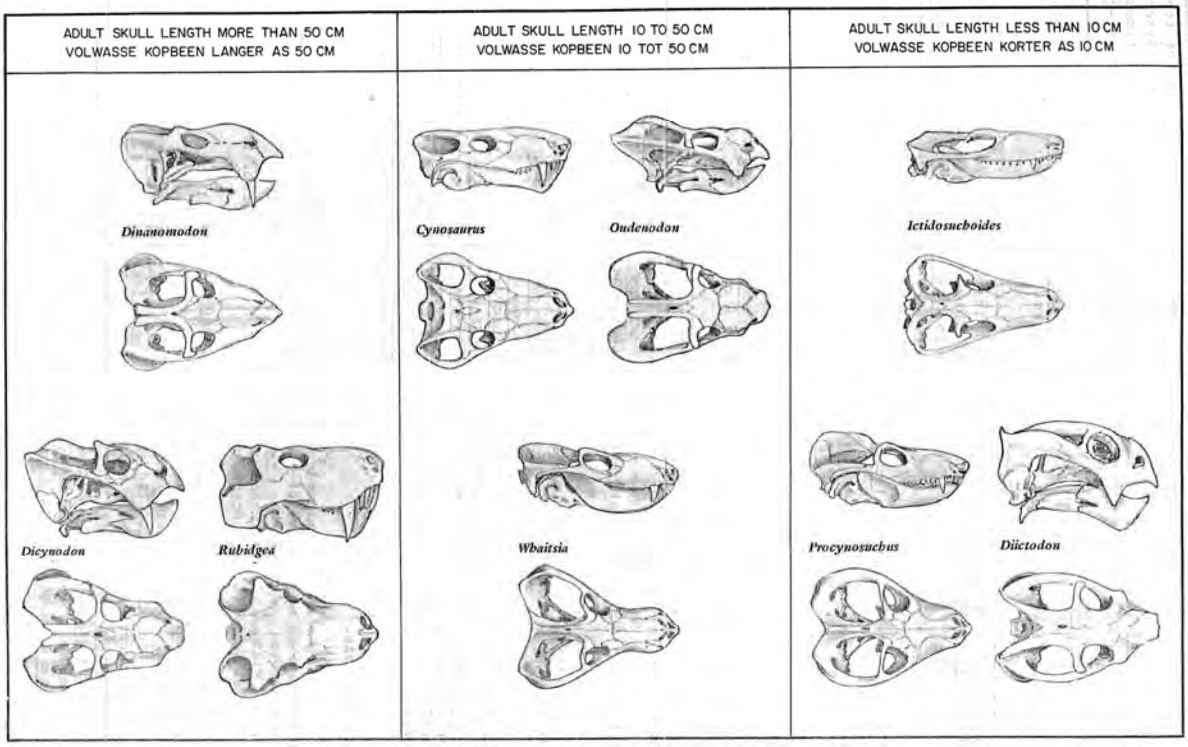

Fig. 15. Skulls of characteristic fossil vertebrates – all therapsids - from the *Dicynodon* Assemblage Zone (From Keyser & Smith 1979). Among the dominant therapsids ("mammal-like reptiles"), *Rubidgea* and *Cynosaurus* are carnivorous gorgonopsians, *Whaitsia* (now *Theriognathus*) is a predatory therocephalian while *Ictidosuchoides* is a small insectivorous member of the same group, *Procynosuchus* is a primitive cynodont, and the remainder are large- to small-bodied dicynodont herbivores.

Kitching (1977) does not list indicate any fossil sites in the study area northwest of Cradock. Recent maps of Beaufort Group fossil localities in Nicolas (2007) show sporadic fossil localities along the N10 between Cradock and Middelburg, but an "information gap" in the Dobbin study area (Fig. 17). Levels of bedrock exposure, often limited by doleritic or sandstone scree in this sector of the Karoo, is probably a more important control than fossil abundance.

Very few, sparsely scattered fossil occurrences were noted in the study area during the recent field assessment. No fossil bones or teeth were noted in association with occasional palaeosol horizons marked by calcrete nodules (Fig. 9). Float blocks of buff sandstone in the region *c*. 0.5 km west of the Eskom substation contain local concentrations of fragmentary sphenophytes (equisetalean ferns or "horsetails") (Fig. 18, Loc. 421). These are preserved as moulds within baked sandstone and do not show any preferential orientation. In the same area thin, ripple cross-laminated sheet sandstones of probable crevasse splay origin display a small range of horizontal to oblique cylindrical burrows on their upper surfaces (Fig. 19, Loc. 420). Some of the cm-wide scratch burrows are attributable to the ichnogenus *Scoyenia* and were probably generated by arthropods or oligochaete worms in moist, firm sediments on the flood plain or around a playa lake.

The Karoo Dolerite Suite intrusions in the study area are unfossiliferous, and the superficial sediments mantling the bedrocks are at most very sparsely fossiliferous. No fossils were seen within these younger surface sediments during the field visit.

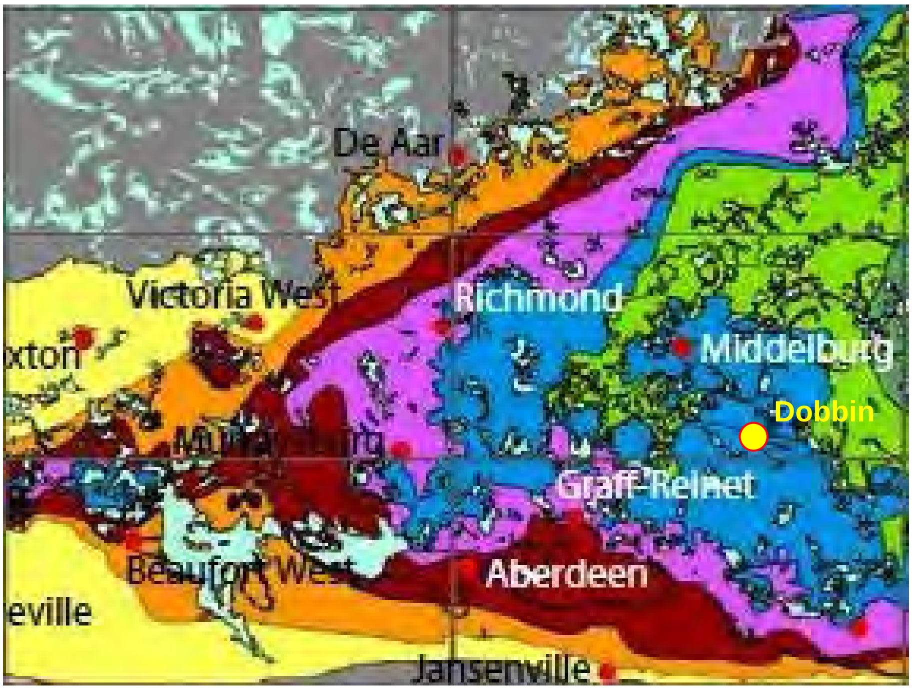

Fig. 16. Extract from recent fossil assemblage zone map for the Main Karoo Basin published by Van der Walt *et al.* (2010). The area between Middelburg and Cradock is largely assigned to the Late Permian *Dicynodon* Assemblage Zone (blue). It is likely that the map will be refined in future in the light of new vertebrate fossil discoveries.

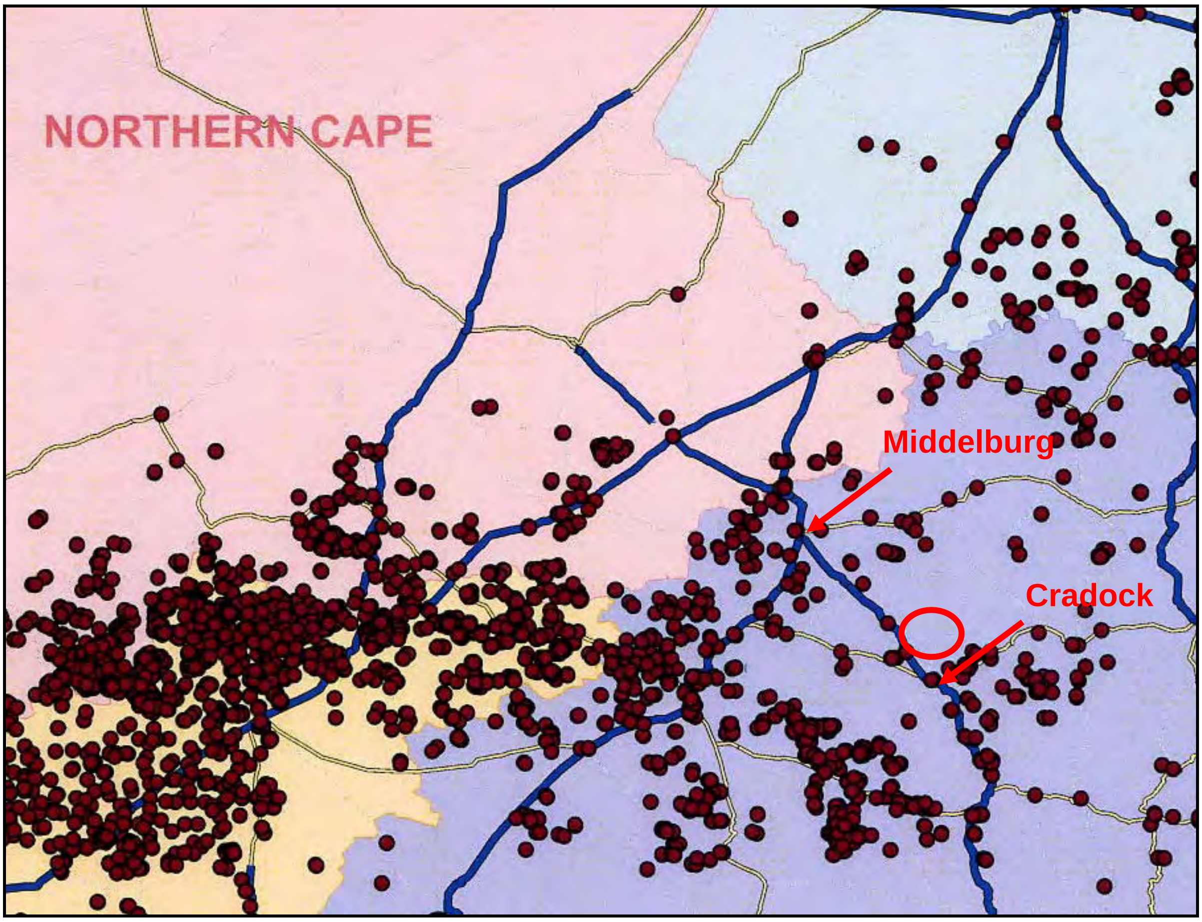

Fig. 17. Distribution map of recorded vertebrate fossil sites within the Beaufort Group of the Great Karoo (From Nicolas 2007). Note the lack of fossil sites from the study region northeast of Cradock (red ellipse).

Fig. 18. Compressions of sphenophyte ferns preserved within float blocks of baked Adelaide Group sandstones (Loc. 421) (Scale in cm).

Fig. 19. Flaggy Adelaide Subgroup sandstones showing abundant, poorly preserved horizontal burrows, probably of the ichnogenus *Scoyenia* (Loc. 420) (Scale in cm and mm).

5. ASSESSMENT OF IMPACT SIGNIFICANCE

The construction phase of the proposed solar farm development will entail excavations into the superficial sediment cover (soils, surface gravels *etc*) and perhaps also into the underlying potentially fossiliferous Beaufort Group bedrock. These notably include excavations for the PV panel support structures, buried cables, internal access roads, any new power line pylons and associated infrastructure. All these developments may adversely affect potential fossil heritage within the study area by destroying, damaging, 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 PV power station will not involve further adverse impacts on palaeontological heritage, however.

The significance of anticipated impacts on fossil heritage resources in the study area as a consequence of the proposed solar farm development are assessed for the construction phase in Table 1 according to the scheme developed by SRK Consulting.

Table 1. Assessment of impacts on fossil heritage of the proposed Dobbin solar farm (construction phase)

	Spatial extent	***Intensity***	***Duration***	***Consequence***	***Probability***	***Significance***	***Status***	***Confidence***
Without mitigation	Local	Low	Long-term	Low	Possible	Very Low	-ve	Medium
With mitigation	Local	Low	Long-term	Low	Possible	Very Low	-ve	Medium

Given the very low significance of anticipated impacts on palaeontological heritage mitigation would only be triggered if substantial fossil remains (*e.g.* assemblages of fossil vertebrate remains, petrified wood) were encountered or freshly exposed during the construction phase of development. In this case the ECO should safeguard the fossil material, preferably *in situ*, and alert SAHRA as soon as possible so that appropriate action (*e.g.* recording, sampling or collection) can be taken by a professional palaeontologist. If triggered, these mitigation actions are considered to be essential.

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.

6. CONCLUSIONS & RECOMMENDATIONS

The proposed solar energy facility is located in an area of the Main Karoo Basin of South Africa that is underlain by potentially fossiliferous sedimentary rocks of the Lower Beaufort Group (Karoo Supergroup) that are of Late Permian age. Field assessment of the Dobbin solar farm study area shows that the Adelaide Subgroup sediments here are almost entirely mantled in unfossiliferous superficial deposits such as soils and downwasted-surface gravels. Baking of surrounding bedrocks by dolerite intrusions may well have further compromised fossil preservation here. Only a few fossil plants and low diversity trace fossil assemblages were observed within the very limited bedrock exposures seen within, as well as on the periphery of, the study area. Furthermore, there are very few previous records of vertebrate fossils from the broader study region northwest of Cradock.

In view of the overall very low significance of the proposed developments on palaeontological heritage resources, it is concluded that no further palaeontological heritage studies or specialist mitigation are required for this project, pending the exposure of any substantial fossil remains (*e.g.* vertebrate bones and teeth, large blocks of petrified wood) during the construction phase. The

ECO responsible for these developments should be alerted to the possibility of fossil remains being found on the surface or exposed by fresh excavations during construction. Should substantial fossil remains be discovered during construction, these should be safeguarded (preferably *in situ*) and the ECO should alert SAHRA so that appropriate mitigation (*e.g.* recording, sampling or collection) can be taken by a professional palaeontologist.

The specialist involved would require a collection permit from SAHRA. Fossil material must be curated in an approved repository (*e.g.* museum or university collection) and all fieldwork and reports should meet the minimum standards for palaeontological impact studies developed by SAHRA.

These recommendations should be incorporated into the EMP for the Dobbin solar farm project.

6. ACKNOWLEDGEMENTS

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APPENDIX: GPS LOCALITY DATA FOR SITES LISTED IN TEXT

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
420	31° 56’ 39.6”	25° 28’ 55.8”
421	31° 56’ 47.3”	25° 28’ 47.8”
422	31° 57’ 30.4”	25° 29’ 15.9”
423	31° 57’ 14.4”	25° 28’ 33.4”

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, Limpopo, Gauteng and Free State for SAHRA and HWC. Dr Almond is an accredited member of PSSA and APHP (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 development 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.

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