PALAEONTOLOGICAL SPECIALIST ASSESSMENT: COMBINED DESKTOP & FIELD ASSESSMENT STUDY

Proposed photovoltaic energy plant on Farm Klipgats Pan (Portion 4 of Farm 117) near Copperton, Northern Cape Province

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1. EXECUTIVE SUMMARY

Mulilo Renewable Energy (Pty) Ltd, Cape Town, is proposing to construct a 100 MW capacity photovoltaic energy plant (PV4) on the farm Klipgats Pan (Portion 4 of Farm 117), situated some 60 km southwest of Prieska and 15 km south of the small mining village of Copperton, Northern Cape Province. The study area, currently used for stock farming, is largely underlain by Permo-Carboniferous glacial sediments of the Dwyka Group (Karoo Supergroup) that overlie granitoid Precambrian basement rocks of the Namaqua-Natal Metamorphic Province and are locally intruded by Karoo dolerites and narrow kimberlite dykes of Cretaceous age. These older bedrocks are widely covered by a range of superficial deposits of Pleistocene to Recent age, including alluvium, downwasted coarse gravels, calcrete hardpans, and sandy to silty soils and pan sediments.

Field assessment on Klipgats Pan suggests that the poorly-exposed upper Dwyka Group bedrocks in the study area do not contain rich trace fossil assemblages, petrified wood or other fossil material, and are therefore of low palaeontological sensitivity. The only fossils recorded from the Dwyka succession here are ice-transported erratic boulders of Precambrian limestone or dolomite that contain small stromatolites (microbial mounds or columns). The overlying superficial sediments are likewise of low palaeontological sensitivity for the most part. However, important assemblages of mammalian fossils of the Late Pleistocene Florisian Mammal Age (estimated 300-200 000 BP) have been recorded from pan sediments at Bundu Pan only 22km to the northwest of Copperton (Kiberd 2006), and somewhat younger fossil teeth from subsurface gravels on the adjacent farm Hoekplaas (Orton 2012). It is quite likely that comparable concentrations of Pleistocene vertebrate fossils are also preserved on buried palaeosurfaces and within alluvial gravels or pan sediments on farm Klipgats Pan. However, these occurrences are likely to be sparse and their distribution is largely unpredictable.

As far as fossil heritage is concerned, the impact significance of the proposed solar energy facility is considered to be LOW for the following reasons:

- The Karoo bedrocks here are deeply weathered and at most sparsely fossiliferous;
- The development footprints for both the preferred and alternative sites are small and largely underlain by superficial deposits of low palaeontological sensitivity;
- Significant fossil material (*e.g.* mammal remains) at or near surface is probably very sparsely distributed within the study area; and

- Extensive, deep bedrock excavations are not envisaged during the construction phase.

Potential impacts on fossil heritage are confined to the development footprint and are only anticipated, if at all, during the construction phase. There is no preference on fossil heritage grounds for the preferred *versus* alternative development area within Klipgats Pan. Neither of these sites has fatal flaws in palaeontological heritage terms. A number of other alternative energy projects – including both wind energy and solar energy facilities – have been proposed for the Copperton area. Given the generally low palaeontological sensitivity of the Karoo bedrocks and Pleistocene to Recent superficial sediments in the region as a whole, the cumulative impact of these developments is not considered to be of high significance.

It is recommended that:

- The Environmental Control Officer (ECO) responsible for the development should be aware of the possibility of important fossils (*e.g.* mammalian bones, teeth) being present or unearthed on site and should monitor all substantial excavations into superficial sediments as well as fresh (*i.e.* unweathered) sedimentary bedrock for fossil remains;

- In the case of any significant fossil finds (*e.g.* vertebrate teeth, bones, burrows, petrified wood) during construction, these should be safeguarded - preferably *in situ* - and reported by the ECO as soon as possible to the relevant heritage management authority (SAHRA, Cape Town) so that any appropriate mitigation (*i.e.* recording, sampling or collection) by a palaeontological specialist can be considered and implemented, at the developer's expense; and

- These recommendations should be incorporated into the Environmental Management Plan (EMP) for the Klipgats Pan PV4 solar energy facility project.

The palaeontologist concerned with mitigation work will need a valid collection permit from SAHRA. All 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 to the minimum standards for Phase 2 palaeontological studies currently being developed by SAHRA.

2. INTRODUCTION & BRIEF

The company Mulilo Renewable Energy (Pty) Ltd (Mulilo), Cape Town, is proposing to construct a 100 MW capacity photovoltaic energy plant (PV4) on the farm Klipgats Pan (Portion 4 of Farm 117), situated some 60 km southwest of Prieska and 15 km south of the small mining village of Copperton, Northern Cape Province (Fig. 1) (DEA REF. NO. 2/12/20/2501). The study area, currently used for stock farming, spans the R357 dust road from Prieska to Van Wyksvlei (Fig. 2). A preferred (Alternative 1) and an alternative (Alternative 2) development site, each of 300 ha extent and situated to the south of the R357, are under consideration (Fig. 2).

In addition to the PV module array, the following main infrastructural developments will be required:

- Upgrading of existing internal farm roads and construction of new roads to accommodate the construction vehicles and access to the site;

- Construction of a 132 kV transmission line to connect the proposed PV plant with Eskom's grid *via* the Kronos substation which is located on the eastern edge of the study area (Fig. 2);

- Construction of an electrical fence to prevent illegal trespassing, as well as to keep livestock from roaming between the solar arrays and causing accidental damage; and

- Construction of an office, connection centre and a guard cabin.

The Mulilo PV4 solar energy facility would be built over a period of 18 to 30 months and will have a lifetime of approximately 20 years.

Aurecon South Africa (Pty) Ltd (Aurecon) has been appointed to undertake the requisite environmental process as required in terms of the National Environmental Management Act (No. 107 of 1998), as amended, on behalf of Mulilo. Given the presence of exposures of potentially fossiliferous Karoo Supergroup sediments in the study area, a combined desktop and field-based palaeontological assessment for the project has been commissioned by Aurecon in accordance with the requirements of the National Heritage Resources Act, 1999. The terms of reference for this study, as defined by Aurecon, are briefly as follows:

- To undertake a Palaeontological Impact Assessment of the study site which would include:
  (1) Conducting a detailed desk-top level investigation to identify all palaeontological resources /features in the proposed development area;
  (2) Undertaking field work to verify results of the desktop investigation (Klipgats Pan (RE/146); and
  (3) Document (GPS coordinates and map) all sites identified on the proposed sites.

- To compile a report which would include:
  (1) Identification of palaeontological sites within the proposed development areas;
  (2) Assess the sensitivity and significance of palaeontological resources / features in the site;
  (2) Evaluation of the potential impacts of construction, operation and maintenance of the proposed development on palaeontological resources / features, in terms of the scale of impact (local, regional, national), magnitude of impact (low, medium or high) and the duration of the impact (construction, up to 10 years after construction (medium term), more than 10 years after construction (long term));
  (3) Recommendation of mitigation measures to ameliorate any negative impacts on areas of palaeontological importance; and
  (4) Consideration of relevant guidelines.

2.1. Project implications for palaeontological heritage & relevant legislation

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 Karoo Supergroup that are of Late Carboniferous to Early Permian age. The construction phase of the development will entail excavations into the superficial sediment cover (soils, alluvial gravels *etc*) and perhaps also into the underlying potentially fossiliferous bedrock. These notably include excavations for the PV tracker 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, 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 extent of the proposed development (over 5000 m^2) falls within the requirements for a Heritage Impact Assessment (HIA) as required by Section 38 (Heritage Resources Management) of the South African Heritage Resources Act (Act No. 25 of 1999). The various categories of heritage resources recognised as part of the National Estate in Section 3 of the Heritage Resources Act include, 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.

2.3. Approach to this palaeontological study

This report provides an assessment of the observed or inferred palaeontological heritage within the Copperton 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, (3) several previous palaeontological heritage assessments for alternative energy developments in the Copperton region (*e.g.* Almond 2010a, 2010b, 2011a, 2011b); and (4) a one-day field assessment of the study area carried out on 26 January 2012.

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.

The focus of the field-based assessment work is *not* simply to survey the development footprint or even the development area as a whole (*e.g.* farms or other parcels of land concerned in the development). Rather, the palaeontologist seeks to assess or predict the diversity, density and distribution of fossils within and beneath the study area, as well as their heritage or scientific interest. This is primarily achieved through a careful field examination of one or more representative exposures of all the sedimentary rock units present (*N.B.* Metamorphic and igneous rocks rarely contain fossils). The best rock exposures are generally those that are easily accessible, extensive, and fresh (*i.e.* unweathered) and include a large fraction of the stratigraphic unit concerned (*e.g.* formation). These exposures may be natural or artificial and include, for example, rocky outcrops in stream or river banks, cliffs, quarries, dams, dongas, open building excavations or road and railway cuttings. Uncemented superficial deposits, such as alluvium, scree or wind-blown sands, may occasionally contain fossils and should also be included in the scoping study where they are well-represented in the study area. It is normal practice for impact palaeontologists to collect representative, well-localized (*e.g.* GPS and stratigraphic data) samples of fossil material during scoping studies. All fossil material collected must be properly curated within an approved repository (usually a museum or university collection).

Before fieldwork commenced, a preliminary screening of satellite images and 1: 50 000 maps of the Beaufort West study area was conducted to identify sites of potentially good bedrock exposure to be examined in the field (See, for example, Fig. 3). Most of these sites, which were relatively few in number, were situated around the northern periphery of the broader study area, and well north of the proposed solar energy facility development footprint. The sites included both natural exposures (*e.g.* stream beds, steep escarpment slopes, gullies) as well as artificial exposures such as dams, borrow pits and quarries.

Note that while fossil localities recorded during fieldwork within the study area itself are obviously highly relevant, most fossil heritage here is embedded within rocks beneath the land surface or obscured by surface deposits (soil, alluvium *etc*) and by vegetation cover. In many cases where levels of fresh (*i.e.* unweathered) bedrock exposure are low, the hidden fossil resources have to be *inferred* from palaeontological observations made from better exposures of the same formations elsewhere in the region but outside the immediate study area. Therefore a palaeontologist might reasonably spend far *more* time examining road cuts and borrow pits close to, but outside, the study area than within the study area itself. Field data from localities even further afield (*e.g.* an adjacent province) may also be adduced to build up a realistic picture of the likely fossil heritage within the study area.

On the basis of the desktop and 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. 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.

2.4. 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 palaeontological field study in the Copperton region, the main limitation was the very high levels of bedrock cover by alluvial and colluvial soils, calcretes and gravels.

Since several good bedrock exposures are available in roadside borrow pits and small quarries for building stone within the study area, however, confidence levels in the conclusions presented here are moderately high.

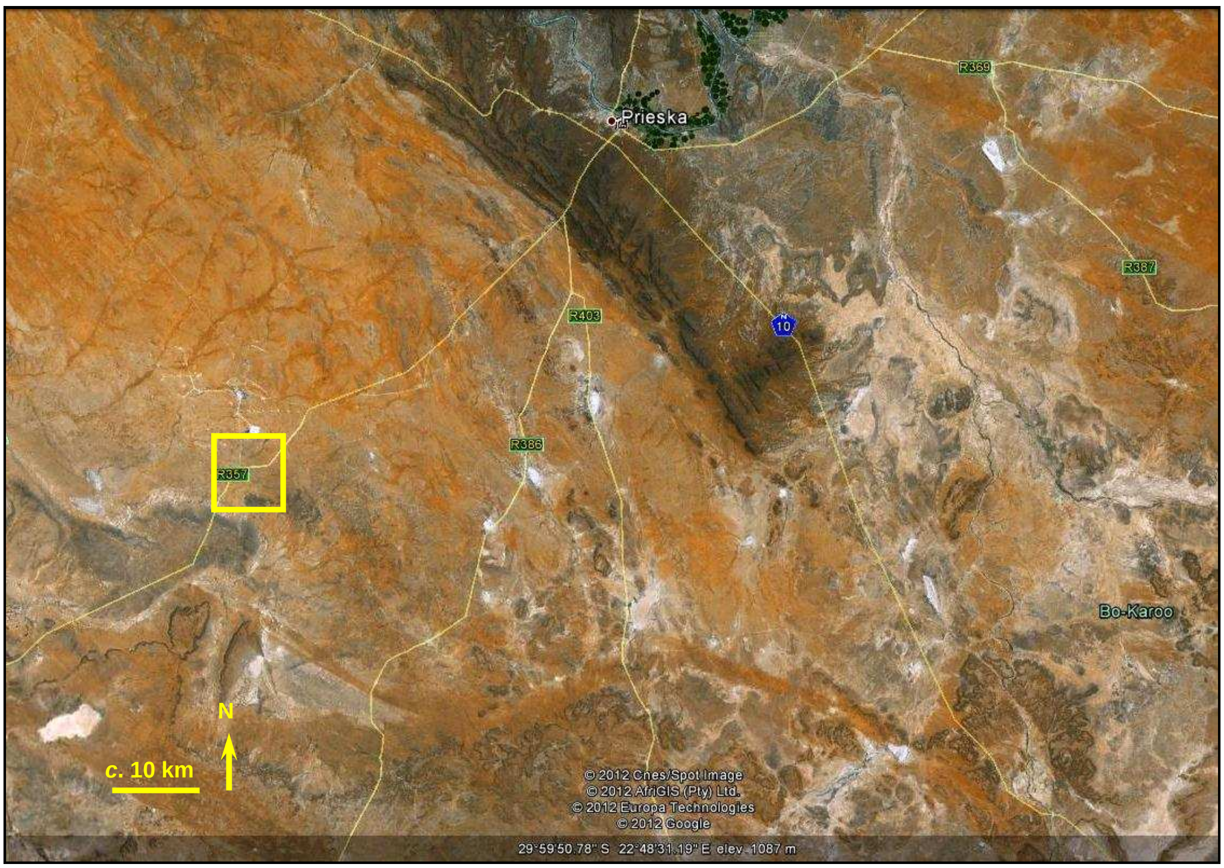

Fig. 1. Google Earth© satellite image of the Northern Cape study region showing the approximate location (yellow rectangle) of the proposed Mulilo PV4 energy plant study area on the farm Klipgats Pan, situated some 60 km southwest of the town of Prieska on the River Orange (top centre). The study area spans the R357 dust road from Prieska to Van Wyksvlei and the railway between Prieska and the Copperton mine (See also Fig. 2).

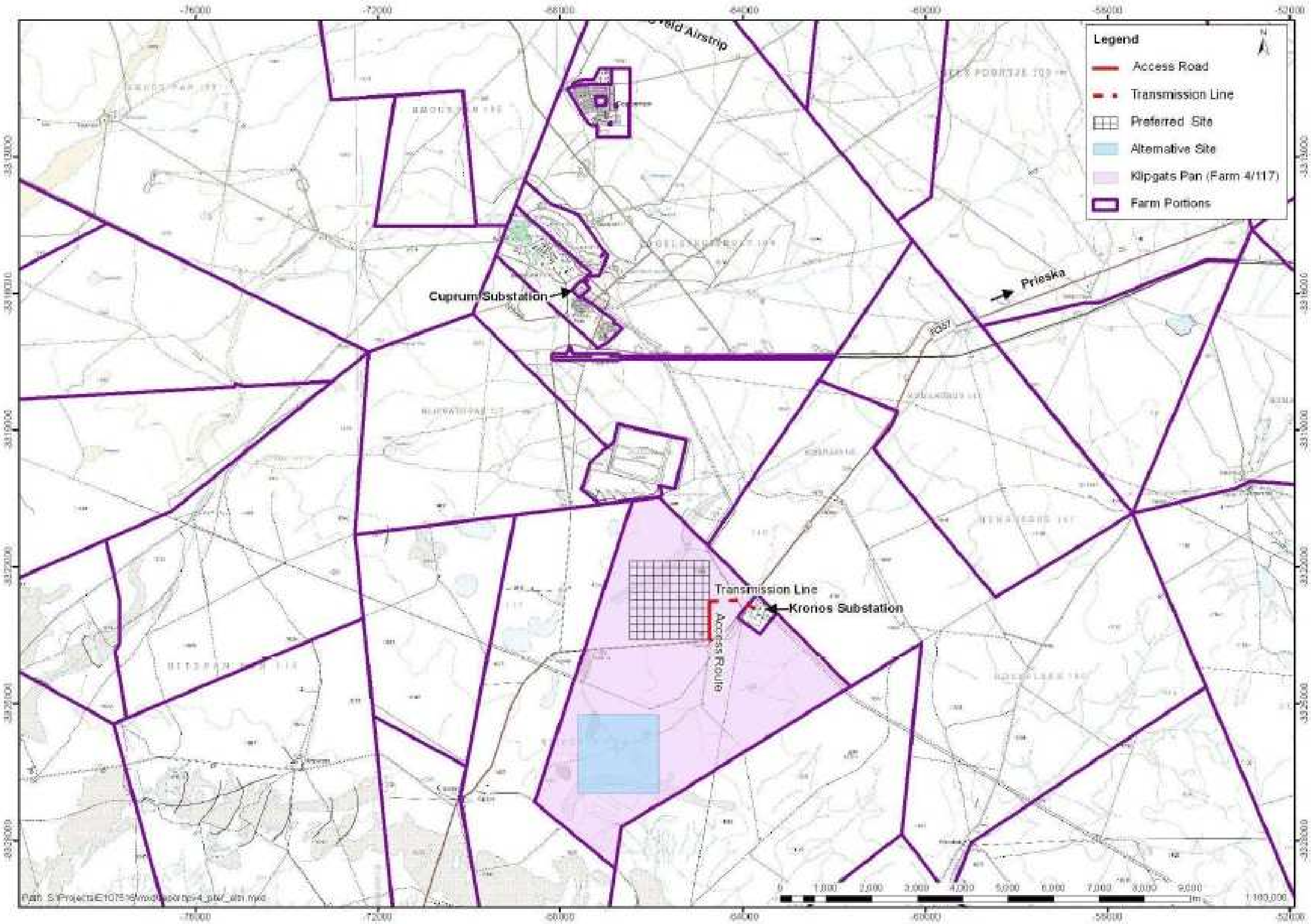

Fig. 2. Map showing the boundaries of the PV4 study area on farm Klipgats Pan, *c*. 15 km south of the mining village of Copperton (lilac area). The preferred and alternative sites for the proposed PV energy plant as well as a proposed short 132 kV transmission line to the nearby Kronos Substation (red line) are also shown (Image abstracted by the Final Scoping Report by Gresse & Corbett 2012, Aurecon South Africa (Pty) Ltd).

3. GEOLOGICAL BACKGROUND

Satellite images of the PV4 study area some 15 km south of Copperton (Fig. 3) show that it largely consists of fairly flat-lying, arid, sandy to gravelly terrain lying at *c*. 1030 - 1060 m amsl with a small dolerite-capped plateau in the south-eastern corner. This region forms part of the low-relief *Kaiingveld* of eastern Bushmanland. Drainage is limited to small, intermittently active streams and pans, including Klipgats Pan itself. There is a net flow towards the west into old Tertiary drainage systems rather than the Orange River to the north. Vegetation cover is low, comprising spare bossies (dwarf shrubs) and summer grasses with taller, shrubby vegetation around pan margins and along water courses. Levels of bedrock exposure are very low due to pervasive cover by superficial sediments (*e.g.* soil, alluvium, gravels, calcrete). However, good sections through the superficial sediments are seen in roadside borrow pits along the R357 (Q1, Q2 in Fig. 3), and there are several small building stone quarries along the western plateau margin in the south east.

The geology of the study area around Copperton is shown on the 1: 250 000 geology map 3022 Britstown (Council for Geoscience, Pretoria; Fig. 4 herein). The various rock units mapped here are treated in some detail in the accompanying sheet explanation by Prinsloo (1989).

GPS data concerning all localities mentioned by number in the text are given in the appendix.

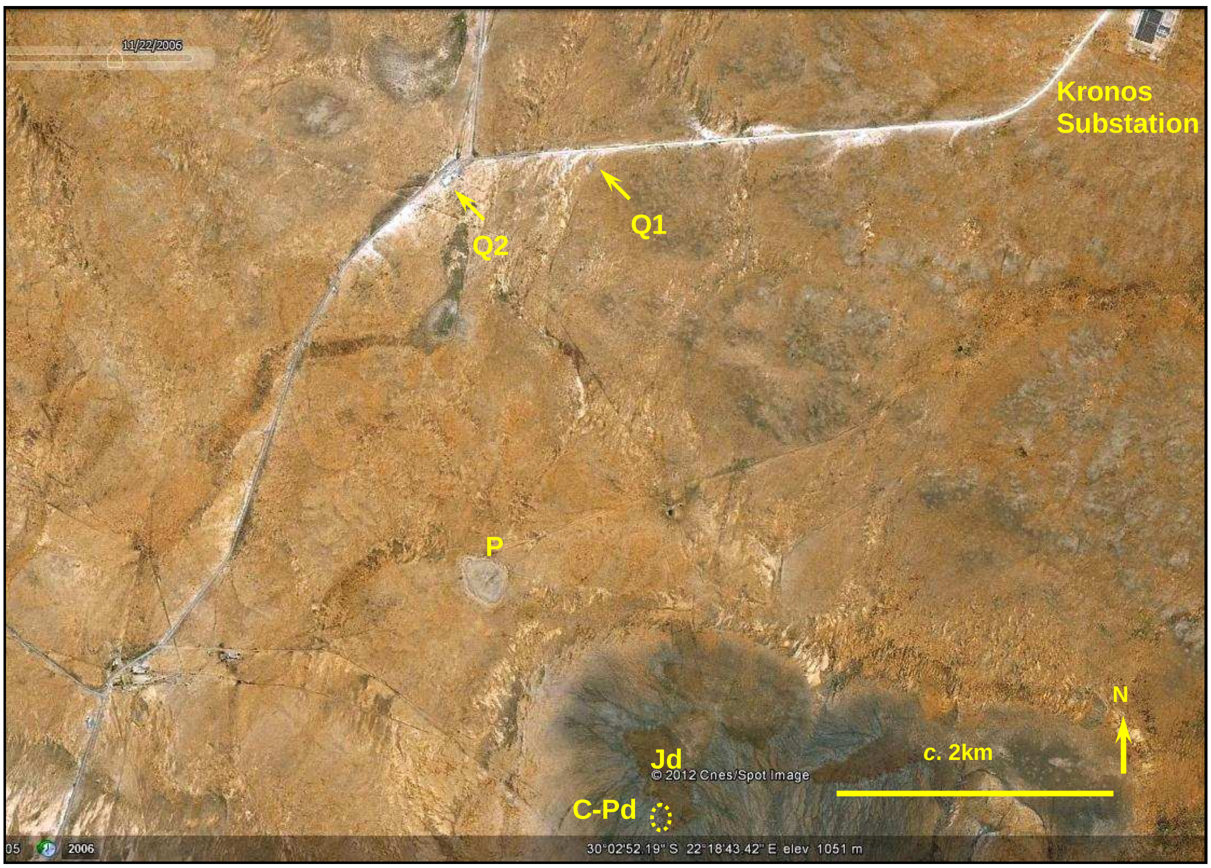

Fig. 3. Google Earth© satellite image of the Klipgats Pan study area to the south of the R357 dust road and *c*. 15 km south of Copperton (2006 historical image). Note small dolerite-capped plateau in SE corner of property (Jd), dark grey areas reflecting exposure of Dwyka Group glacial sediments (C-Pd), location of several small building stone quarries excavated into Dwyka dropstone laminites (dotted oval), large pan area (P) and two roadside borrow pits showing vertical sections through superficial sediments overlying weathered Dwyka saprolite (Q1, Q2).

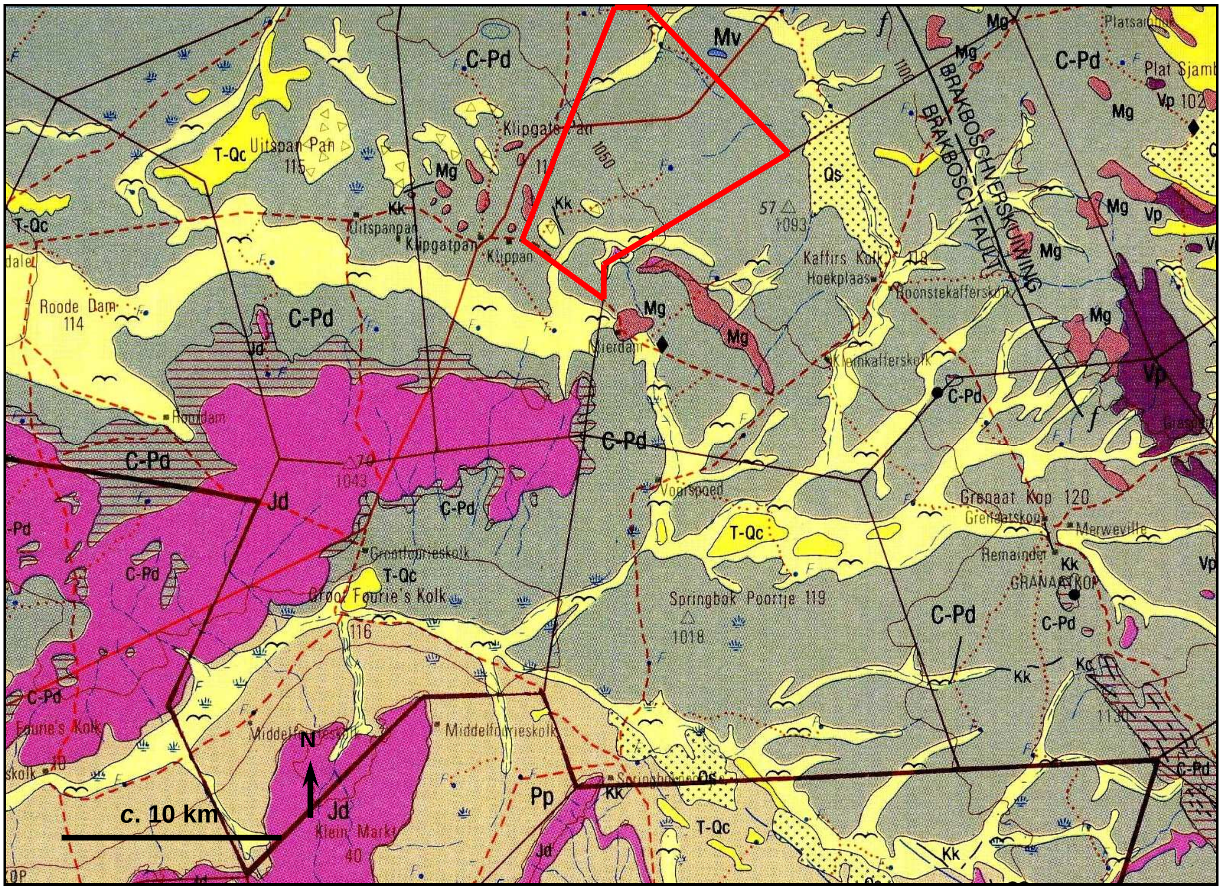

Fig. 4. Extract from 1: 250 000 geology map 3022 Britstown (Council for Geoscience, Pretoria) showing approximate outline of the proposed PV4 solar energy facility near Copperton (red polygon).

The main geological units mapped within the PV4 study region are:

1. Precambrian (Mid Proterozoic / Mokolian) basement rocks (igneous / metamorphic):

Reddish-brown (Mg) = granitic and associated intrusive rocks

2. Late Carboniferous / Early Permian Karoo Supergroup sediments:

Grey (C-Pd) = Mbizane Formation (Dwyka Group)

3. Early Jurassic dolerite intrusions

Pink (Jd) = Karoo Dolerite Suite

4. Cretaceous kimberlite intrusions

Black line (Kk) = kimberlite dykes (not all mapped)

5. Late Caenozoic (Quaternary to Recent) superficial deposits:

Pale yellow with flying bird symbol = Quaternary to Recent alluvium, pan sediments

(*N.B.* calcrete hardpan extensively present in the subsurface and superficial soils and gravels are not mapped at this scale)

3.1. Precambrian basement rocks

The oldest rocks within the study area are various small, isolated inliers of Precambrian intrusive igneous rocks belonging to the **Namaqua-Natal Metamorphic Province**. They include small outcrops of various unnamed granites, gabbros and pegmatites of ill-defined Mokolian age (*i.e.* Mid Proterozoic, between 1000 and 2050 Ma) that are indicated on the map as **Mg** (Prinsloo 1989, Cornell *et al.* 2006). These ancient basement rocks were last metamorphosed some one billion or so years ago (1 – 1.2 Ga) and since they are entirely unfossiliferous they will not be considered further here.

3.2. Permo-Carboniferous Dwyka Group

Beneath the superficial sediment cover, Permo-Carboniferous glacial sediments of **Dwyka Group** (**C-Pd, Karoo Supergroup**) underlie almost the entire Klipgats Pan study area. Dwyka rocks may therefore be intersected by deeper excavations during development. The geology of the Dwyka Group has been summarized by Visser (1989), Visser *et al.* (1990) and Johnson *et al.* (2006), among others.

The Dwyka Group along the north-western margin of the Main Karoo Basin, including the Prieska Subbasin in particular, has been reviewed by Visser (1982, 1985). In Dwyka times the Prieska – Copperton area lay within a basement high region between the Sout River Valley in the west and the Prieska Basin in the east (Fig. 5). This area is referred to as the Kaiing Hills or Kaiing Veld Region by Visser and is characterized by a relatively thin Dwyka succession (normally < 50m). This mainly comprises massive clast-rich diamictites and clast–poor argillaceous diamictites ("boulder shale") overlain by a thin zone of laminated dropstone argillite with outsized clasts composed mainly of quartzite and gneiss (Visser 1985; Fig. 6 below). Note the presence of an isolated peak (*monadnock*) of Proterozoic basement rocks emerging through the Dwyka cover rocks to the southeast of Copperton (*ibid*.). Ice transport directions initially towards the south and later towards the southwest are reconstructed by Visser (1985, his Fig. 17). The source area of many of the exotic boulder erratics (*e.g.* stromatolitic carbonates of Griqualand West succession, amygdaloidal lavas of the Ventersdorp Supergroup) seen in the Dwyka succession near Copperton, as well as the Prieska Basin to the east, is the elevated Ghaap Plateau to the north of Prieska (Visser 1982, his Fig. 2).

Further detailed observations on the Dwyka beds on the northern edge of the Britstown 1: 250 000 sheet are provided by Prinsloo (1989). Good surface outcrops of the Dwyka beds are rare here due to extensive cover by thin surface gravels. Massive tillites at the base of the Dwyka succession were deposited by dry-based ice sheets in deeper basement valleys. Later climatic amelioration led to melting, marine transgression and the retreat of the ice sheets onto the continental highlands in the north. The valleys were then occupied by marine inlets within which drifting glaciers deposited dropstones onto the muddy sea bed ("boulder shales"). The upper Dwyka beds are typically heterolithic, with shales, siltstones and fine-grained sandstones of deltaic and / or turbiditic origin. These upper successions are typically upwards-coarsening and show extensive soft-sediment deformation (loading and slumping). Varved (rhythmically laminated) mudrocks with gritty to fine gravely dropstones indicate the onset of highly seasonal climates, with warmer intervals leading occasionally even to limestone precipitation.

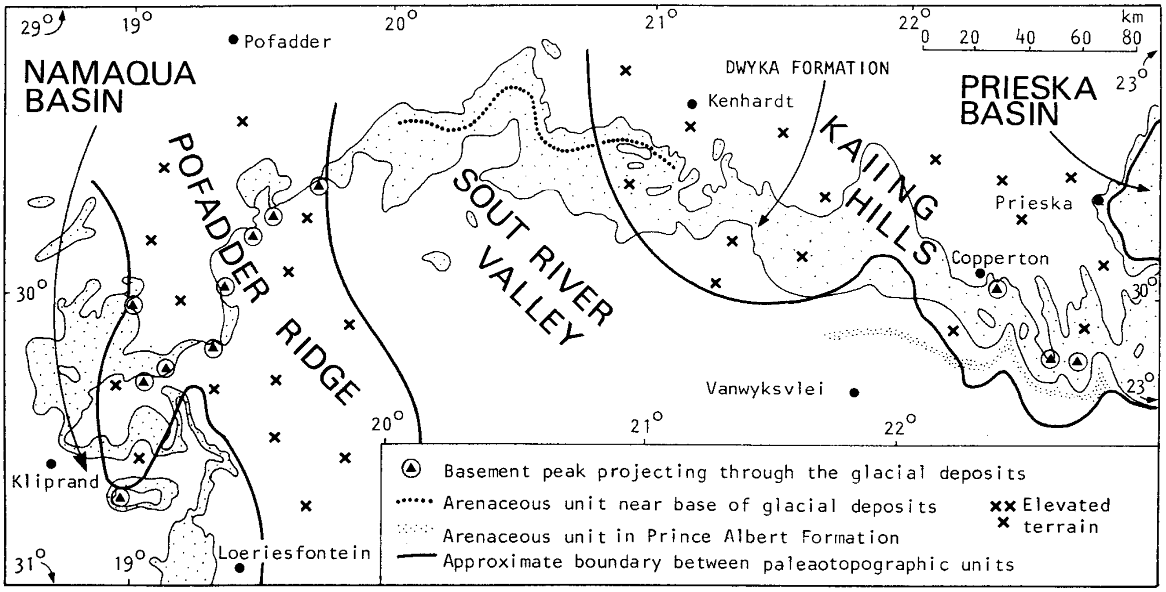

Fig. 5. Reconstruction of the topography along the northern margin of the Karoo Basin in Dwyka times showing location of the Prieska-Copperton area on a basement high with scattered peaks of basement rock projecting through the Dwyka glacial sediment cover (From Visser 1985).

According to maps in Visser *et al.* (1990) and Von Brunn and Visser (1999) the Dwyka rocks in the Prieska-Copperton area close to the northern edge of the Main Karoo Basin belong to the **Mbizane Formation**. This is equivalent to the Northern (valley and inlet) Facies of Visser *et al*. (1990). The Mbizane Formation, up to 190 m thick, is recognized across the entire northern margin of the Main Karoo Basin where it may variously form the whole or (as here) only the *upper* part of the Dwyka succession. It is characterized by its extremely heterolithic nature, with marked vertical and horizontal facies variation (Von Brunn & Visser 1999). The proportion of diamictite and mudrock is often low, the former often confined to basement depressions. Orange-tinted sandstones (often structureless or displaying extensive soft-sediment deformation, amalgamation and mass flow processes) may dominate the succession. The Mbizane-type heterolithic successions characterize the thicker Dwyka of the ancient palaeovalleys cutting back into the northern basement rocks.

Sediments of the upper Dwyka Group are exposed on gentle hillslopes in the south-eastern corner of farm Klipgats Pan (Fig. 3). Apparently massive, hackly-weathering greyish-green mudrocks contain scattered boulder-sized erratics of various lithologies (*e.g.* granites, mica schist, dark grey and pale grey limestones, quartzite, amydaloidal and porphyritic lavas) that have probably been transported by ice from basement areas and the Ghaap Plateau to the north (*cf* “boulder shales”, facies 2 in Fig. 6). The erratics vary from angular to well-rounded and occasional examples show faceting and striation. The largest boulders reach dimensions of 2.5 m or more (Fig. 7). Boulder beds can be traced along strike at some horizons. There are also subordinate thin (1 m or less in thickness) lenticles of pebbly to cobbly diamictite with a ferruginous sandy matrix that weather prominently. Large oblate to lenticular bodies of ferruginous carbonate (*koffieklip*), either massive or showing a stromatolite-like pseudolamination (also cone-in-cone structure) are common.

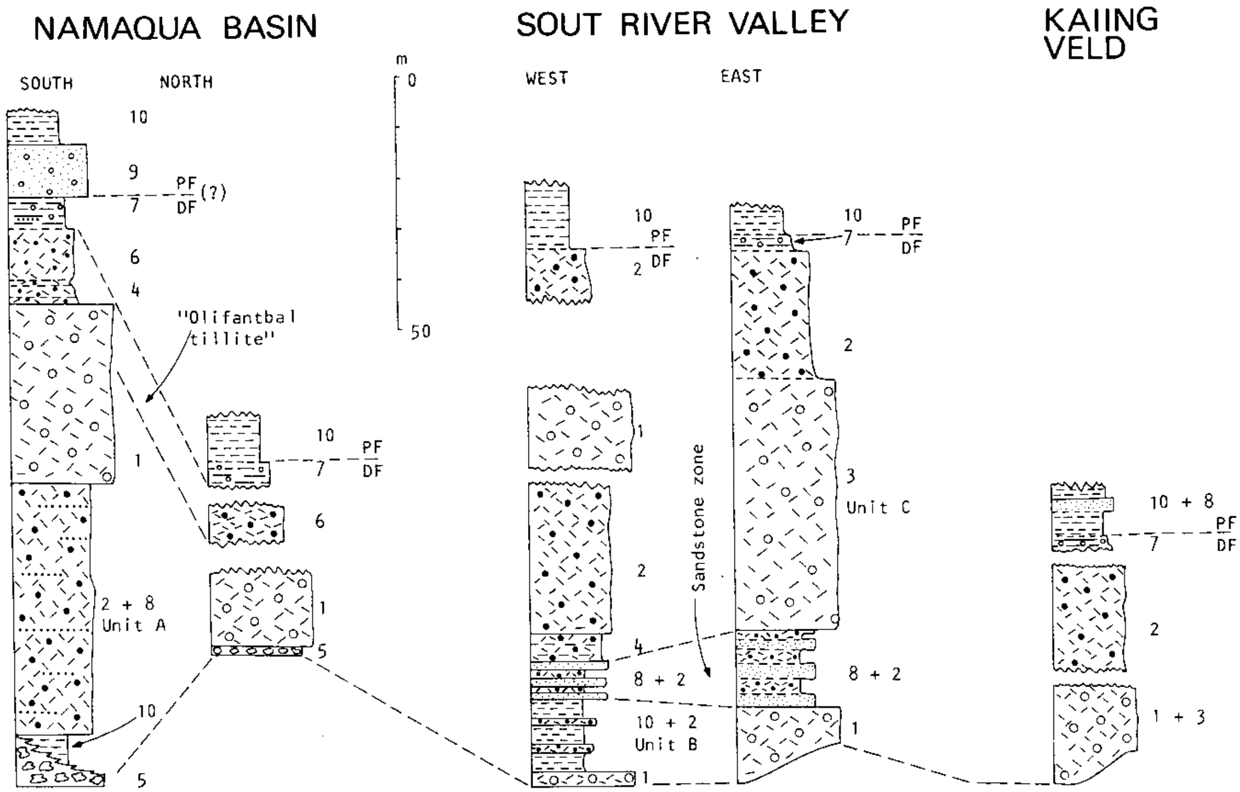

Figure 2

Regional stratigraphic sequences of the Dwyka Formation between Loeriesfontein and the Doringberg Range with the lithofacies indicated by numbers. 1. Massive clast-rich arenaceous diamictite. 2. Massive clast-poor argillaceous diamictite ("boulder shale"). 3. Massive diamictite (undifferentiated). 4. Bedded diamictite. 5. Brecciated basement rocks (local tillite). 6. Massive carbonate-rich diamictite ("olifantbal tillite"). 7. Dropstone argillite ("varved shale"). 8. Fine- to coarse-grained sandstone. 9. Pebbly sandstone. 10. Dark grey to black, micaceous shale and mudstone. Lithological units numbered A, B, and C will be referred to in the text. DF = Dwyka Formation, PF = Prince Albert Formation (see Fig. 1 for location of regions).

Fig. 6. Stratigraphic logs through the Dwyka Group along the northern margin of the Main Karoo Basin. The short Kaaing Veld log on the RHS, dominated by diamictite facies, is most relevant to the Copperton area (From Visser 1985). Boulder shales with sparse large erratics (facies 2) overlain by laminated dropstone argillite (facies 7) are observed in the south-eastern corner of Klipgats Pan.

These "boulder shales" are capped by a thin succession of "dropstone argillites" (facies 7 in Fig. 6) that crop out along the crest of the low hills in the south-eastern portion of Klipgats Pan (yellow dotted oval in Fig. 3). These uppermost Dwyka sediments have been thermally metamorphosed (baked) by the adjacent dolerite sill and are therefore quite tough. A 20 – 30 cm thick zone of flaggy siltstones and fine sandstones is exposed in several small quarries along the edge of the escarpment here (Fig. 8). The quarried stone has been used in the construction of several local farm buildings. The secondarily ferruginised bed is thinly-laminated in vertical section, with small-scale current ripples (rib-and-furrow structures) on the upper surface. Internal bedding surfaces show that it is a dropstone laminite, with abundant small, angular outsized clasts (many ferruginous) embedded in the grey-green mudrock matrix (Fig. 9). The dropstones are impressed into the underlying laminae and draped by the overlying ones. Some of the graded beds here with gravel-rich bases and rippled tops may be turbiditic in origin (*cf* Anderson 1975). The upper Dwyka succession here shows an overall coarsening- and thickening-upwards tendency.

Deeply-weathered, crumbly Dwyka mudrocks are also exposed in roadside borrow pits in the northern part of the study area (Q1, Q2 in Fig. 3). They contain sparse erratics and ferruginous diagenetic nodules, some of which retain the original pebbly diamictite fabric.

Fig. 7. Outsized (*c*. 2.5 m long) erratic boulder of quartzite embedded within Dwyka "boulder shales" in the south-eastern corner of Klipgats Pan (Loc. 302). White scale = 16cm.

Fig. 8. Thinly-laminated siltstones and fine sandstones exposed in small building stone quarry (Loc. 306). Upper surface of bed shows current ripple cross-lamination.

Fig. 9. Surface view of dropstone laminites showing scattered angular gravel-sized dropstones embedded within grey-green laminated mudrocks. The dropstones have melted out from the base of floating icesheets or icebergs during a late phase of the Dwyka glaciation.

3.3. Mesozoic intrusive igneous rocks

Small outcrop areas of intrusive igneous rocks mapped within the study area (map Fig. 4) include (1) erosional relicts of a dolerite sill belonging to the **Karoo Dolerite Suite** (**Jd**) of Early Jurassic age that caps the low plateau area in the south-eastern corner of Klipgats Pan (rusty-brown corestones at surface), and (2) narrow dykes of mica-rich **kimberlite** (**Kk**) of probable Cretaceous age that are mapped in the south-western corner of the property (Prinsloo 1989, Duncan & March 2006). A thin kimberlite dyke was also observed intruding Dwyka mudrocks in quarry Q2 in the more northern portion of the study area (Loc. 307). These various igneous intrusive rocks are unfossiliferous and will not be considered further here.

3.4. Late Caenozoic superficial sediments

A wide range of superficial sediments of probable Pleistocene to Recent age mantle the Precambrian and Palaeozoic bedrocks in the study area, but for the most part these are not mapped at 1: 250 000 scale (Fig. 4). Polymict, **boulder gravels** generated by downwasting of resistant weathering, exotic erratics from the underlying Dwyka glacial rocks may directly overlie the Dwyka bedrock or subsurface calcrete hardpans (Fig. 15). In some areas these surface gravels have been concentrated and reworked during Late Caenozoic times into fluvial gravels or other superficial sediments, including soils and calcretes. The gravels are angular to well-rounded and occasionally show glacial facetting and striation. They consist of a wide range of exotic lithologies (granites, gneisses, schists, quartzites, hornfels, jaspilitic banded iron formation, cherts, vein quartz, carbonates including limestone and dolomite, amygdaloidal and other lavas, reworked calcrete *etc*) and have locally been flaked. Many iron- or manganese-rich rock types have developed a shiny dark desert varnish.

Sandy to silty soils mantle a large portion of the study area and may reach thickesses of 1 – 2 m, but are usually much thinner (Figs. 11, 12, 13, 16). The superficial sandy soils are generally orange-brown and unconsolidated. It is likely that these soils have a substantial wind-blown (aeolian) component as seen in the Kalahari sands (Gordonia Formation, see Fig. 10) cropping out to the north. They are underlain by paler buff, better-consolidated silty soils that are often incipiently calcretised. The soils contain sparse gravel clasts that locally are concentrated into lenticular to laterally-persistent 10 to 40 cm thick horizons of fine gravels (occasionally flaked) accompanied by reworked, well-rounded calcrete clasts that clearly represent buried ancient palaeosurfaces (Fig. 12).

A well-developed massive and vuggy to laminated **calcrete hardpan** underlies the soil horizons over large parts of the study area, as can be seen in quarry excavations along the R357 (Locs. 306, 307) (Fig. 14). Extensive calcrete development is typical of the Ecca and Dwyka outcrop areas in Bushmanland, especially around pans (Prinsloo 1989). A horizon of poorly-sorted downwasted gravels usually occurs on the upper surface, beneath the superficial soil capping, and coarse gravels are often embedded within the calcrete hardpan. There have clearly been several phases of Late Caenozoic calcrete development in the region. Reworking of older calcretes into younger horizons is shown by lenticles of calcrete breccia and even well-developed conglomerates up to 2 m thick composed of well-rounded pebbly and cobbly calcrete clasts (Loc. 306). Sizeable solution hollows were not observed. Calcretisation extends several meters down as a network of veins into the underlying, deeply-weathered Dwyka mudrock saprolite (*in situ* weathered bedrock). The calcretes and overlying gravels may be tentatively equated with the Pleistocene **Mokalanen** and **Obogorop Formations** respectively of the **Kalahari Group** to the north (Fig. 10).

A variety of gravelly, sandy and silty **alluvial sediments** line shallow, intermittently-flowing water courses, while pan areas typically contain fine-grained silts and calcrete-rich subsoils (*cf* Partridge & Scott 2000, Partridge *et al.* 2006) (Fig. 16). In areas of sparse vegetation where the soil surface has been ablated by wind and / or sheetwash processes, extensive sheets of sparse gravels clasts are present. Many of these are too large to have been moved by sheetwash processes, and must have downwasted more or less *in situ* as the Dwyka outcrop was denuded by erosion.

The detailed description of the superficial sediment stratigraphy at Bundu Pan, located only some 22 km northwest of Copperton, by Kiberd (2006 and refs. therein) is very relevant to the present study area. Seven stratigraphic units (Groups 1-7), some of them fossiliferous, were recognised in trenches into the pan area. Among these, the uppermost four units bear close comparison with deposits observed within borrow pits in the Copperton study area. These are, in ascending order, Group 4 (laminated to massive calcrete hardpan, locally silcretised), Group 3 (pebbly and cobbly gravels, locally calcretised), Group 2 (sands / silts with horizons of gravels) and Group 1 (reddish surface sands).

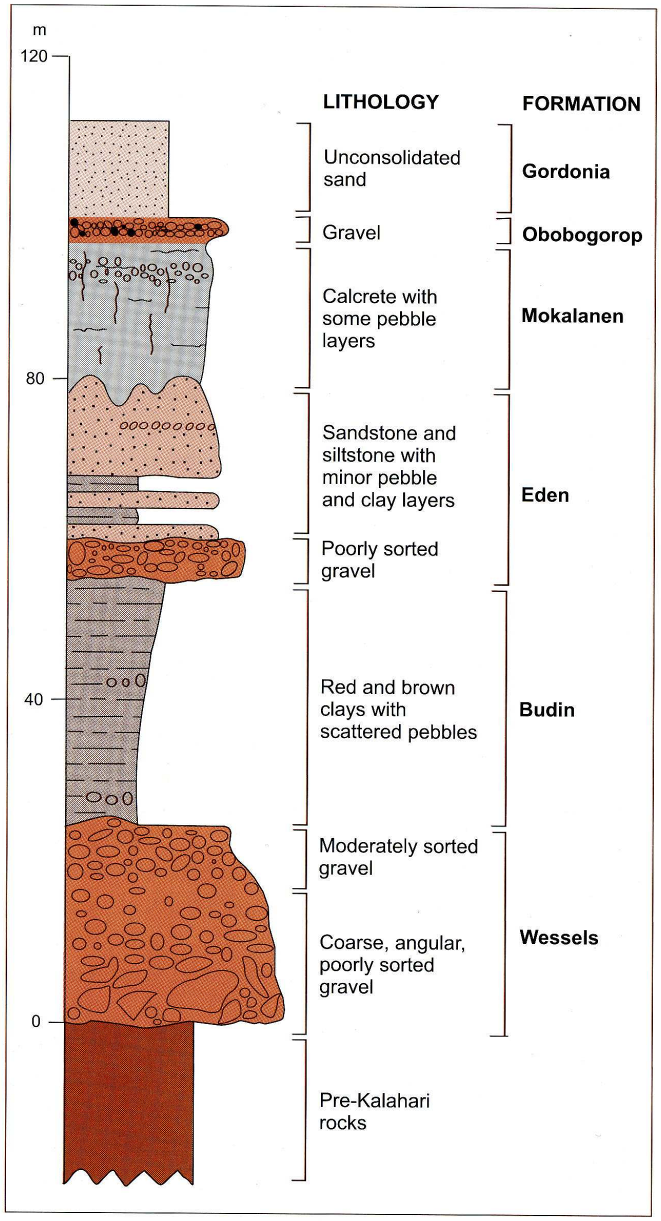

Fig. 10. Stratigraphy of the Kalahari Group (From Partridge *et al.,* 2006). Superficial sediments within the study area are tentatively equated with the uppermost three formations of the Kalahari Group, although well-developed aeolian sands of the Gordonia Formation are not represented here.

Fig. 11. Orange-brown, poorly-consolidated sandy soils overlying older calcretised soils and deeply-weathered Dwyka mudrocks in roadside quarry Q2 (Loc. 307). Recent cross-bedded stream sediments are exposed in the donga wall beneath the hammer (latter is 30 cm long).

Fig. 12. Detail of upper succession shown in previous figure. Laterally-persistent fine gravels at level of hammer are rich in calcrete and contain sparse flaked stone artefacts (Hammer = 30cm).

Fig. 13. Downwasted surface gravels overlying thin orange-brown soils and deeply-weathered, calcretised Dwyka boulder mudstones, Quarry 1 (Loc. 306) (Hammer = 30 cm).

Fig. 14. Thick, vuggy calcrete hardpan with embedded boulder erratics overlying deeply-weathered, calcretised Dwyka mudrocks, Quarry 1 (Hammer = 30 cm).

Fig. 15. Bouldery surface gravels eroded out of the Dwyka Group and later downwasted onto the upper surface of a calcrete hardpan. Only smaller clasts have been reworked by sheetwash processes.

Fig. 16. View towards main pan on Klipgats Pan (flat grassy area in background) showing sparsely gravelly, sandy, orange-brown surface soils in foreground.

4. PALAEONTOLOGICAL HERITAGE

The fossil heritage recorded within each of the main sedimentary rock units mapped at surface within the study area is outlined here in order of increasing geological age (See also summary of fossil heritage in Table 1 below). Note that the Precambrian basement rocks as well as the Mesozoic intrusive igneous rocks (Karoo dolerites, Cretaceous kimberlites) are not treated here since they are entirely unfossiliferous. Baking of Karoo country rocks by hot intrusive magmas in Mesozoic times may have locally compromised their fossil heritage.

4.1. Fossils in the Dwyka Group

The generally poor fossil record of the Dwyka Group (McLachlan & Anderson 1973, Anderson & McLachlan 1976, Visser 1989, Visser *et al*., 1990, Visser 2003, Almond & Pether 2008) is hardly surprising given the glacial climates that prevailed during much of the Late Carboniferous to Early Permian Periods in southern Africa. However, most Dwyka sediments were deposited during periods of glacial retreat associated with climatic amelioration. Sparse, low diversity fossil biotas from the Mbizane Formation in particular mainly consist of arthropod trackways associated with dropstone laminites and sporadic vascular plant remains, while palynomorphs (organic-walled microfossils) are also likely to be present within finer-grained mudrock facies. Glacial diamictites (tillites or "boulder mudstones") are normally unfossiliferous but do occasionally contain fragmentary transported plant material as well as palynomorphs in the fine-grained matrix. There are interesting records of limestone glacial erratics from tillites along the southern margins of the Great Karoo (Elandsvlei Formation) that contain Cambrian eodiscid trilobites as well as archaeocyathid sponges. Such derived fossils provide important data for reconstructing the movement of Gondwana ice sheets (Cooper & Oosthuizen 1974, Stone & Thompson 2005).

A limited range of marine fossils are associated with the later phases of several of the four main Dwyka deglaciation cycles (DSI to DSIV), especially in the Kalahari Basin of southern Namibia but also in some cases within the Main Karoo Basin in South Africa (Oelofsen 1986, Visser 1989, 1997, Visser *et al*. 1997, Bangert *et al*. 1999, Stollhofen *et al*. 2000, Almond 2008). These deglaciation sequences are estimated to have lasted five to seven million years on average (Bangert *et al*. 1999). A range of stenohaline (*i.e.* exclusively salt water) invertebrate fossils indicates that fully marine salinities prevailed at the end of each sequence, at least in the western outcrop area (Namibia, Northern Cape). These invertebrates include echinoderms (starfish, crinoids, echinoids), cephalopods (nautiloids, goniatites), articulate brachiopods, bryozoans, foraminiferans, and conulariids, among others. Primitive bony fish (palaeoniscoids), spiral "coprolites" attributable to sharks or eurypterids, as well as wood and trace fossils are also recorded from mudrock facies at the tops of DSII (Ganikobis Shale Member), DS III (Hardap Member) and DSIV (Nossob Shale Member, as well as base of the Prince Albert Formation (Ecca Group) in southern Namibia and, in the last case at least, in the Northern Cape near Douglas (McLachlan and Anderson 1973, Veevers *et al*. 1994, Grill 1997, Bangert *et al*. 1999, Pickford & Senut 2002, Evans 2005). The Ganikobis (DSII) fauna has been radiometrically dated to *c*. 300 Ma, or end-Carboniferous (Gzhelian), while the Hardap fauna (DSIII) is correlated with the *Eurydesma* transgression of earliest Permian age (Asselian) that can be widely picked up across Gondwana (Dickens 1961, 1984, Bangert *et al*. 1999, Stollhofen *et al*. 2000). The distinctive thick-shelled bivalve *Eurydesma*, well known from the Dwyka of southern Namibia, has not yet been recorded from the main Karoo Basin, however (McLachlan and Anderson 1973). The upper part of DSIV, just above the Dwyka / Ecca boundary in the western Karoo Basin (*i.e.* situated within the basal Prince Albert Formation), has been radiometrically dated to 290-288 Ma (Stollhofen *et al*. 2000).

Low diversity ichnoassemblages dominated by non-marine arthropod trackways are widely associated with cold water periglacial mudrocks, including dropstone laminites, within the Mbizane Formation in the Main Karoo Basin (Von Brunn & Visser, 1999, Savage 1970, 1971, Anderson 1974, 1975, 1976, 1981, Almond 2008, 2009). They are assigned to the non-marine / lacustrine *Mermia* ichnofacies that has been extensively recorded from post-glacial epicontinental seas and large lakes of Permian age across southern Gondwana (Buatois & Mangano 1995, 2004). These Dwyka ichnoassemblages include the arthropod trackways *Maculichna*, *Umfolozia* and *Isopodichnus*, the possible crustacean resting trace *Gluckstadtella*, sinuous fish-fin traces (*Undichna*) as well as various unnamed horizontal burrows. The association of these interglacial or post-glacial ichnoassemblages with rhythmites (interpreted as varvites generated by seasonal ice melt), the absence of stenohaline marine invertebrate remains, and their low diversity suggest a restricted, fresh- or brackish water environment. Herbert and Compton (2007) also inferred a freshwater depositional environment for the Dwyka / Ecca contact beds in the SW Cape based on geochemical analyses of calcareous and phosphatic diagenetic nodules within the upper Elandsvlei and Prince Albert Formations respectively. Well-developed U-shaped burrows of the ichnogenus *Rhizocorallium* are recorded from sandstones interbedded with varved mudrocks within the upper Dwyka Group (Mbizane facies) on the Britstown sheet (Prinsloo 1989) (Fig. 17). Similar *Rhizocorallium* traces also described from the Dwyka Group of Namibia (*e.g* .the Hardap Shale Member, Miller 2008). References to occurrences of the complex helical spreiten burrow *Zoophycos* in the Dwyka of the Britstown sheet and elsewhere (*e.g.* Prinsloo 1989) are probably in error, since in Palaeozoic times this was predominantly a shallow marine to estuarine ichnogenus (Seilacher 2007). Visser (1982) makes brief but unspecific references to bioturbation and trace fossils within the Dwyka sediments of the Prieska Basin, for example within his sandstone-siltstone-shale and (late glacial to post-glacial) varved mudrock facies.

Fig. 17. Large U-burrows of the ichnogenus *Rhizocorallium* in ripple-marked sandstones of the upper Dwyka Group, Britstown sheet area (From Prinsloo, 1989).

Scattered records of fossil vascular plants within the Dwyka Group of the Main Karoo Basin record the early phase of the colonisation of SW Gondwana by members of the *Glossopteris* Flora in the Late Carboniferous (Plumstead 1969, Anderson & McLachlan 1976, Anderson & Anderson 1985 and earlier refs. therein). These records include fragmentary carbonized stems and leaves of the seed ferns *Glossopteris* / *Gamgamopteris* and several gymnospermous genera (*e.g. Noeggerathiopsis, Ginkgophyllum*) that are even found within glacial tillites. More "primitive" plant taxa include lycopods (club mosses) and true mosses such as *Dwykea*. It should be noted that the depositional setting (*e.g.* fluvial *versus* glacial) and stratigraphic position of some of these records are contested (cf Anderson & McLachlan 1976). Petrified woods with well-developed seasonal growth rings are recorded from the upper Dwyka Group (Mbizane Formation) of the northern Karoo Basin (*e.g.* Prinsloo 1989) as well as from the latest Carboniferous of southern Namibia. The more abundant Namibian material (*e.g. Megaporoxylon*) has recently received systematic attention (Bangert & Bamford 2001, Bamford 2000, 2004) and is clearly gymnospermous (pycnoxylic, *i.e.* dense woods with narrow rays) but most cannot be assigned to any particular gymnosperm order.

Borehole cores through Dwyka mudrocks have yielded moderately diverse palynomorph assemblages (organic-walled spores, acanthomorph acritarchs) as well as plant cuticles. These mudrocks are interbedded with diamictites in the southern Karoo as well as within Dwyka valley infills along the northern margin of the Main Karoo Basin (McLachlan & Anderson 1973, Anderson 1977, Stapleton 1977, Visser 1989, Anderson & Anderson 1985). Thirty one Dwyka palynomorph species are mentioned by the last authors, for example. Anderson's (1977) Late Carboniferous to Early Permian Biozone 1 based on Dwyka palynomorph assemblages is characterized by abundant *Microbaculispora*, monosaccate pollens (*e.g. Vestigisporites*) and nontaeniate bisaccate pollens (*e.g. Pityosporites*) (Stephenson 2008). Prinsloo (1989) mentions stromatolitic limestone lenses within the uppermost Dwyka Group in the Britstown sheet area. These may be comparable to interglacial microbial mats and mounds described from the Ganikobis Shale Member (DSII) of southern Namibia by Grill (1997) and Bangert *et al.* (2000).

Although a wide range of fossils are now known from the Dwyka Group, most sediments assigned to this succession are unfossiliferous (with the possible exception of microfossils). The overall palaeontological sensitivity of the Dwyka Group is therefore rated as low (Almond & Pether 2008). Any interglacial mudrocks and heterolithic successions (*i.e.* interbedded sandstones and mudrocks) are worth investigating for fossils, however. Since the Prieska-Copperton area lay on a basement high in Dwyka times (Fig. 5), interglacial mudrocks are unlikely to be well represented here. Late-glacial or post-glacial mudrocks, such as those containing a fairly rich shelly fossil record at Douglas in the Northern Cape (McLachlan & Anderson 1973) have apparently been lost to erosion in the Prieska region.

The only fossils observed within the Dwyka Group sediments on Klipgats Pan are small domincal to columnar stromatolites within bouldery erratics grey carbonate (probably dolomite) (Fig. 18, Loc. 301). These have probably been transported by ice movement from the Campbell Rand Subgroup (Ghaap Group) that crops out in the Ghaap Plateau to the north of Prieska.

Fig. 18. Small Dwyka erratic boulder of pale grey laminated carbonate (probably dolomite) showing small stromatolitic domes or columns (Loc. 301). This clast probably comes from the Precambrian Campbell Rand Subgroup of the Ghaap Plateau (Scale in cm).

4.2. Fossils in the superficial sediments

Apart from the aeolian sands of the Kalahari Group (Gordonia Formation), which do not outcrop within the present study area, the various superficial “drift deposits” of the Bushmanland and Karoo regions of South Africa, including alluvium and pan deposits, have been comparatively neglected in palaeontological terms. However, they may occasionally contain important fossil biotas, notably the bones, teeth and horn cores of mammals as well as remains of reptiles like tortoises. Good examples are the Pleistocene mammal faunas at Florisbad, Cornelia and Erfkroon in the Free State and elsewhere (Wells & Cooke 1942, Cooke 1974, Skead 1980, Klein 1984, Brink, J.S. 1987, Bousman *et al.* 1988, Bender & Brink 1992, Brink *et al*. 1995, MacRae 1999, Meadows & Watkeys 1999, Churchill *et al*. 2000 Partridge & Scott 2000). 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), and plant remains such as peats or palynomorphs (pollens, spores) in organic-rich alluvial horizons (Scott 2000) and siliceous diatoms in pan sediments. Calcrete hardpans might also contain trace fossils such as rhizoliths, termite nests and other insect burrows, or even mammalian trackways. Solution hollows within well-developed calcrete horizons may have acted as fossil traps in the past, as seen in Late Caenozoic limestones near the coast and Precambrian carbonate successions of the Southern African interior. Dense concentrations of vertebrate remains (*e.g.* small mammals, reptiles) or terrestrial molluscs, for example, are a possibility here. In Quaternary deposits, fossil remains may be associated with human artefacts such as stone tools and are also of archaeological interest (*e.g.* Smith 1999 and refs. therein). Stone artefacts of Pleistocene and younger age may additionally prove useful in constraining the age of superficial deposits such as gravelly alluvium and pedocretes within which they are occasionally embedded.

Important fossil mammalian remains assigned to the Florisian Mammal Age (*c*. 300 000 – 12 000 BP; MacRae 1999) have recently been documented from stratigraphic units designated Group 4 to Group 6 (*i.e.* calcrete hardpan and below) at Bundu Pan, some 22 km northwest of Copperton (Kiberd 2006 and refs. therein). These are among very few Middle Pleistocene faunal records from stratified deposits in the southern Africa region (Klein 1980, 1984a, 1984b, 2000) and are therefore of high palaeontological significance. Characteristic extinct Pleistocene species recorded at Bundu Pan are the giant Cape Horse or Zebra (*Equus capensis*) and the Giant Hartebeest (*Megalotragus priscus*). Other extant to extinct taxa include species of warthog, blesbok, black wildebeest, springbok and baboon. There is additionally trace fossil evidence for hyaenids (tooth marks) as well as ostrich egg shell. Preliminary dating and the inferred ecology of the fossil taxa present suggests the presence of standing water within a grassy savanna setting during the 200 - 300 000 BP interval when the Bunda Pan faunal assemblage accumulated. A sequence of Earlier, Middle and Later Stone Age (MSA and LSA, respectively) artefact assemblages is also recorded from this site. Stratigraphic Groups 4 to 6 (*i.e.* calcrete hardpan and below) contain a Final Acheulian or transitional Earlier Stone Age (ESA) / MSA artefact assemblage, while Groups 2 - 3 above the calcrete horizon contain a MSA artefact assemblage. Orton (2012) recorded a single fossil equid tooth associated with a rich MSA artefact assemblage from gravels overlying a calcrete hardpan on farm Hoekplaas, immediately east of the present study site. This horizon is probably equivalent to Group 3 of Kiberd’s stratigraphy at Bundu Pan, and therefore somewhat younger than the Florisian mammal fauna reported there.

No fossil remains were observed within the superficial sediments on Klipgats Pan. It is quite likely that fossil bones and teeth of mammals are preserved within buried Pleistocene fluvial and pan sediments, as seen at Hoekplaas and Bundu Pan in the same region. However, such fossil sites are likely to be sparsely distributed and their locations difficult to predict, given the extensive younger sedimentary cover.

Table 1: Fossil heritage in the Copperton area

GEOLOGICAL UNIT	ROCK TYPES & AGE	FOSSIL HERITAGE	PALAEONT-OLOGICAL SENSITIVITY	RECOMMENDED MITIGATION
Unassigned superficial sediments **(including possible equivalents of KALAHARI GROUP)**	Surface aeolian sands, sandy and silty soils, calcrete hardpans, downwasted gravels, *Plus* fluvial gravels, alluvium, freshwater pan deposits MAINLY PLEISTOCENE	Calcretised rhizoliths & termitaria, ostrich egg shells, land snail shells, rare mammalian and reptile (*e.g.* tortoise) bones & teeth, freshwater units associated with diatoms, molluscs, stromatolites *etc*	GENERALLY LOW BUT LOCALLY HIGH (*e.g.* concentrations of mammalian fossils, molluscs in pan and fluvial sediments)	Any substantial fossil finds (*e.g.* mammalian bones, teeth) to be reported by ECO to SAHRA
Kimberlite intrusions	Mica-rich kimberlite dykes	NONE	ZERO	None
KAROO DOLERITE SUITE	Dolerite sills & dykes Early Jurassic	NONE	ZERO	None
Mbizane Formation **DWYKA GROUP**	Tillites, interglacial mudrocks, deltaic & turbiditic sandstones, minor thin limestones LATE CARBONIFER-OUS – EARLY PERMIAN	Sparse petrified wood & other plant remains, palynomorphs, trace fossils (*e.g.* arthropod trackways, fish trails, U-burrows) possible stromatolites in limestones, fossiliferous erratics (*e.g.* stromatolitic limestones / dolomites)	LOW	Any substantial fossil finds (*e.g.* petrified wood) to be reported by ECO to SAHRA
NAMAQUA-NATAL METAMORPHIC PROVINCE	Unnamed granitic and high grade metamorphic basement rocks MID PROTEROZOIC	NONE	N/A	None

5. ASSESSMENT OF SIGNIFICANCE OF PALAEONTOLOGICAL HERITAGE IMPACTS

The significance of impacts on palaeontological heritage resources within the Klipgats Pan photovoltaic energy plant study area is assessed for the construction phase in Table 2 below. Please note that the operational and decommissioning phases of the solar energy facilities will not involve further significant adverse or other impacts on palaeontological heritage.

Table 2: Evaluation of impacts of proposed PV4 photovoltaic energy plant (Alternative 1 and Alternative 2) on farm Klpgats Pan near Copperton on local fossil heritage resources

CRITERIA	STATUS	COMMENTS
Scale	Local (site specific)	Limited to development footprint
Magnitude	Low	Karoo bedrocks here are deeply weathered and at most sparsely fossiliferous. Development footprint is largely underlain by superficial deposits of low palaeontological sensitivity. Significant fossil material (*e.g.* mammal remains) at or near surface level is probably very sparsely distributed within the study area. Development footprint is small. Extensive, deep bedrock excavations are not envisaged during the construction phase.
Duration	Long term	Permanent.
Significance	Low	Specialist monitoring or mitigation measures therefore not proposed for this project.
Probability	Unlikely	Within development footprint the potentially fossiliferous sediments are usually buried beneath superficial deposits which may be one or more meters thick (*e.g.* calcrete hardpan, soils).
Confidence	Moderately high	Limited by low levels of bedrock exposure within study area (This is partially compensated by study of better exposures elsewhere)
Reversibility	Irreversible	Loss of fossil heritage is generally permanent. Appropriate mitigation of any significant fossil finds (reporting by ECO, recording by professional palaeontologist) will lead to positive impact in terms of increased palaeontological knowledge.

6. CONCLUSIONS & RECOMMENDATIONS

Field assessment suggests that the poorly-exposed upper Dwyka Group bedrocks in the Klipgats Pan study area do not contain rich trace fossil assemblages, petrified wood or other fossil material, and are therefore of low palaeontological sensitivity. The only fossils recorded from the Dwyka succession here are ice-transported erratic boulders of Precambrian limestone or dolomite that contain small stromatolites (microbial mounds or columns). The study area is largely mantled by Pleistocene to Recent superficial sediments (soils, alluvium, calcretes, gravels *etc*) that are likewise generally of low palaeontological sensitivity (Almond & Pether 2008). However, important mammal fossil remains assigned to the Late Pleistocene Florisian Mammal Age (estimated 300 - 200 000 BP) have been recorded from pan sediments at Bundu Pan only 22 km to the northwest of Copperton (Kiberd 2006), and somewhat younger fossil teeth have been reported from subsurface gravels on the adjacent farm Hoekplaas (Orton 2012). It is quite likely that comparable concentrations of Pleistocene vertebrate fossils are also preserved on buried palaeosurfaces and within alluvial gravels or pan sediments on Klipgats Pan. However, these occurrences are likely to be sparse and their distribution is largely unpredictable.

As far as fossil heritage is concerned, the impact significance of the proposed solar energy facility is considered to be LOW for the following reasons:

- The Karoo bedrocks here are deeply weathered and at most sparsely fossiliferous;
- The development footprints for both the preferred and alternative sites are small and largely underlain by superficial deposits of low palaeontological sensitivity;
- Significant fossil material (*e.g.* mammal remains) at or near surface level is most likely very sparsely distributed within the study area; and
- Extensive, deep bedrock excavations are not envisaged during the construction phase.

Potential impacts on fossil heritage are confined to the development footprint and are only anticipated, if at all, during the construction phase. There is no preference on fossil heritage grounds for the preferred *versus* alternative development area within Klipgats Pan. Neither of these sites has fatal flaws in palaeontological heritage terms. A number of other alternative energy projects – including both wind energy and solar energy facilities – have been proposed for the Copperton area (*cf* Almond 2010a, 2010b, 2011a, 2011b). Given the generally low palaeontological sensitivity of the Karoo bedrocks and Pleistocene to Recent superficial sediments in the region as a whole, the cumulative impact of these developments is not considered to be of high significance.

It is recommended that:

- The ECO responsible for the development should be aware of the possibility of important fossils (*e.g.* mammalian bones, teeth) being present or unearthed on site and should monitor all substantial excavations into superficial sediments as well as fresh (*i.e.* unweathered) sedimentary bedrock for fossil remains;
- In the case of any significant fossil finds (*e.g.* vertebrate teeth, bones, burrows, petrified wood) during construction, these should be safeguarded - preferably *in situ* - and reported by the ECO as soon as possible to the relevant heritage management authority (SAHRA, Cape Town) so that any appropriate mitigation (*i.e.* recording, sampling or collection) by a palaeontological specialist can be considered and implemented, at the developer's expense; and
- These recommendations should be incorporated into the EMP for the Klipgats Pan PV4 solar energy facility project.

The palaeontologist concerned with mitigation work will need a valid collection permit from SAHRA. All 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 to the minimum standards for Phase 2 palaeontological studies currently being developed by SAHRA.

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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.

Only those localities mentioned in the text are listed here.

LOCALITY NUMBER	SOUTH	EAST
299	30º 02’ 48.4”	22º 16’ 57.6”
300	30º 04’ 07.3”	22º 18’ 28.3”
301	30º 04’ 07.7”	22º 18’ 27.2”
302	30º 04’ 05.6”	22º 18’ 26.1”
303	30º 03’ 51.0”	22º 18’ 30.0”
304	30º 03’ 18.2”	22º 17’ 48.6”
305	30º 02’ 26.7”	22º 18’ 02.1”
306	30º 01’ 58.5”	22º 18’ 09.5”
307	30º 01’ 58.4”	22º 17’ 37.9”

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, Gauteng, Limpop and the Free State for SAHRA and HWC. Dr Almond is an accredited member of PSSA and APHP (Association of Professional Heritage 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.

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