

# PALAEONTOLOGICAL IMPACT ASSESSMENT: DESKTOP STUDY

## Proposed Solar Cape Photovoltaic Electricity Generation Facility near Kenhardt, Northern Cape Province

John E. Almond PhD (Cantab.)  
*Natura Viva* cc, PO Box 12410 Mill Street,  
Cape Town 8010, RSA  
naturaviva@universe.co.za

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### 1. SUMMARY

Solar Land cc, Wellington, is proposing to develop a 120 mw photovoltaic (PV) energy electricity generation facility on the farm Olyven Kolk 187, situated some 35km southwest of the town of Kenhardt, Siyanda District Municipality and KAI!GARIB! Municipality, Northern Cape Province, RSA. The site of the proposed PV facility is underlain by glacial-related sediments of the Permo-Carboniferous Dwyka Group (Mzibane Formation) that are generally of low palaeontological sensitivity. The main categories of fossils recorded from the Mbizane beds include a small range of interglacial trace fossils, petrified woods and other plant materials, palynomorphs and supposed stromatolites (the last possibly spurious). Quaternary aeolian sediments of the Gordonia Formation (Kalahari Group) as well as alluvial gravels and calcretes, all of low palaeontological sensitivity, may also be encountered near-surface in the study area. Two billion year-old granites and metasediments of the Namaqua-Natal Province crop out in the north-eastern portion of the study area but these rocks are unfossiliferous and in any case will not be directly affected by the proposed development.

Since the palaeontological sensitivity of the rock units within the study area is generally low, the development footprint is relatively small, and extensive bedrock excavations are not envisaged, the impact significance of the proposed Solar Cape PV facility as far as fossil heritage is concerned is likely to be very low. Therefore further specialist palaeontological mitigation of this project is not considered necessary. Should substantial fossil remains be exposed during construction, however, these should be recorded (GPS, photos), safeguarded if possible *in situ*, and SAHRA should be notified by the ECO so that appropriate mitigation can be considered.

### 2. INTRODUCTION & BRIEF

The company Solar Land cc, Wellington, is proposing to develop a photovoltaic (PV) energy electricity generation facility on the farm Olyven Kolk 187, situated some 35km southwest of the town of Kenhardt, Siyanda District Municipality and KAI!GARIB! Municipality, Northern Cape Province, RSA. The study area is located to the northwest of the R27 tar road between Kenhardt and Brandvlei and close to the Sishen-Saldanha railway line (Figs. 1, 2). The proposed PV electricity generation facility will comprise a number of fixed mounted solar panels covering an area of approximately 317-400 ha and have a total capacity of c. 120 MW. It will be linked to an existing 22 KVA Eskom powerline (the Aries Substation is located on the southwest edge of the study area) via a network of underground cables to be laid c. 1m below the surface. Construction will take place over a partially demolished construction camp relating to the Sishen-Saldanha railway that is

situated in the vicinity of the Olyvenhoutsolk farmstead. Ancillary developments include accommodation for management, a guest lodge as well as student accommodation.

The proposed development area overlies potentially fossiliferous bedrock of the Palaeozoic Dwyka Group as well as Quaternary sands of the Kalahari Group. A palaeontological impact assessment for the project is therefore necessary in compliance with the requirements of the National Heritage Resources Act, 1999. This desktop study has accordingly been commissioned by Cape Lowlands Environmental Services, Darling.

## 2.1. National Heritage Monuments Act

The extent of the proposed development (over 5000 m<sup>2</sup>) 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:

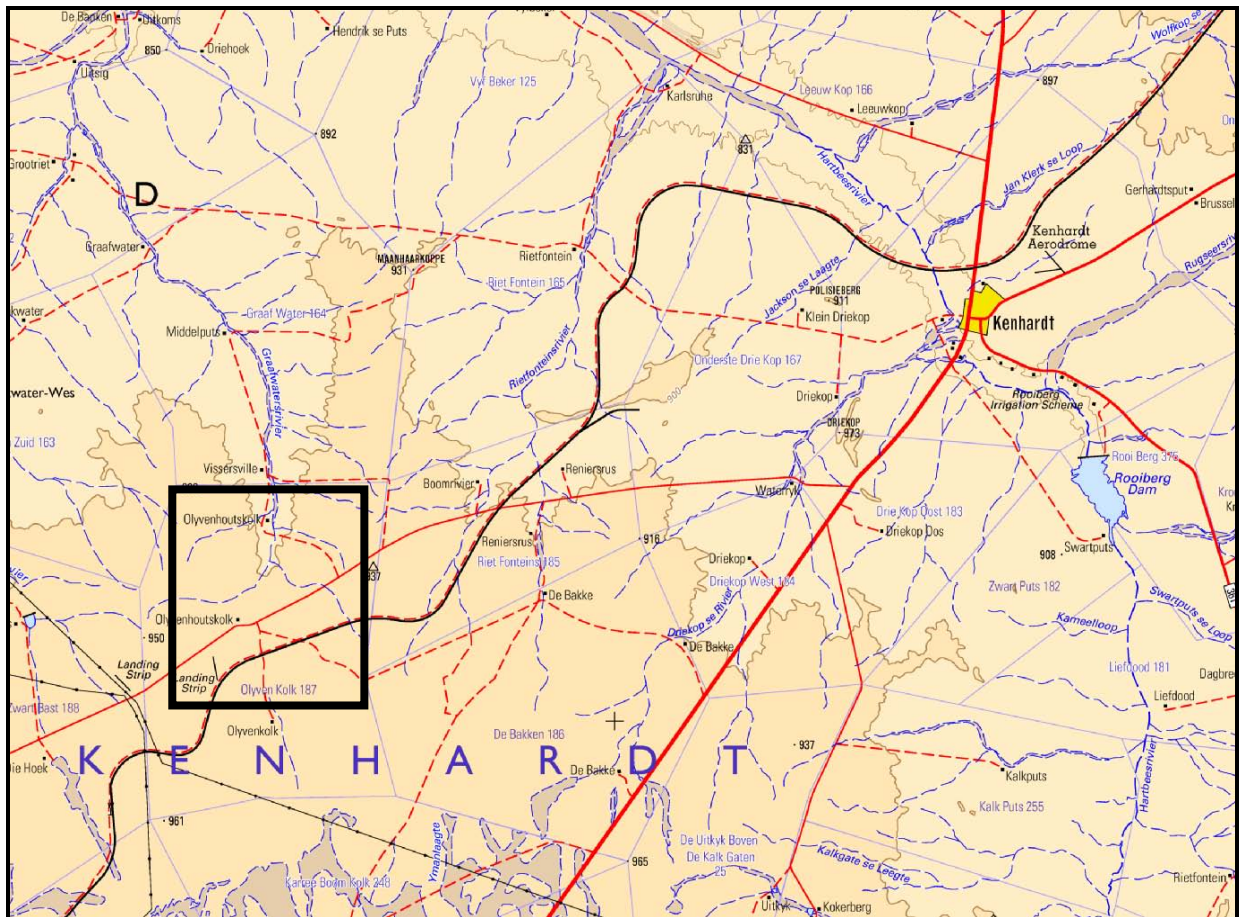
- geological sites of scientific or cultural importance
- palaeontological sites
- palaeontological objects and material, meteorites and rare geological specimens

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 May 2007.

## 2.2. General approach used for palaeontological impact desktop studies

In preparing a palaeontological desktop study the potentially fossiliferous rock units (groups, formations *etc*) represented within the study area are determined from geological maps. The known fossil heritage within each rock unit is inventoried from the published scientific literature, previous palaeontological impact studies in the same region, and the author's field experience (Consultation with professional colleagues as well as examination of institutional fossil collections may play a role here, or later during the compilation of the final report). This data is then used to assess the palaeontological sensitivity of each rock unit to development (Provisional tabulations of palaeontological sensitivity of all formations in the Western, Eastern and Northern Cape have already been compiled by J. Almond and colleagues; *e.g.* Almond & Pether 2008). The likely impact of the proposed development on local fossil heritage is then determined on the basis of (1) the palaeontological sensitivity of the rock units concerned and (2) the nature of the development itself, most notably the extent of fresh bedrock excavation envisaged.

When rock units of moderate to high palaeontological sensitivity are present within the development footprint, a field scoping study by a professional palaeontologist is usually warranted. Most detrimental impacts on palaeontological heritage occur during the construction phase when fossils may be disturbed, destroyed or permanently sealed-in during excavations and subsequent construction activity. Where specialist palaeontological mitigation is recommended, this may take place before construction starts or, most effectively, during the construction phase while fresh, potentially fossiliferous bedrock is still exposed for study. Mitigation usually involves the judicious sampling, collection and recording of fossils as well as of relevant contextual data concerning the surrounding sedimentary matrix. It should be emphasised that, *provided* appropriate mitigation is carried out, many developments involving bedrock excavation actually have a *positive* impact on our understanding of local palaeontological heritage. Constructive collaboration between palaeontologists and developers should therefore be the expected norm.



**Fig. 1. Extract from 1: 250 000 topographical sheet 2920 Kenhardt showing approximate location of study area c. 35km southwest of Kenhardt, Northern Cape Province (Courtesy of the Chief Directorate of Surveys and Mapping, Mowbray).**





**Fig. 2.** *Google Earth*<sup>®</sup> satellite image showing the location (red circle) of the proposed Solar Cape photovoltaic power station c. 35km southwest of Kenhardt, Northern Cape Province. The dark grey area in the southwest is underlain by glacially-related sediments of the Dwyka Group. The pale buff area to the northeast is underlain by Mokolian basement rocks mantled with Quaternary aeolian sands of the Kalahari Group (Compare geological map in Fig. 3). Note extensive erosional dissection of the landscape in this region by tributaries of the Hartbeesrivier.

### 3. GEOLOGICAL BACKGROUND

The geology of the study area is outlined on the 1: 250 000 geology map 2920 Kenhardt (Council for Geoscience, Pretoria; Fig. 3 herein). An explanation to the Kenhardt geological map has been published by Slabbert *et al.* (1999). Several of the relevant rock units are also treated in the explanations for the adjacent 1: 250 000 sheets such as the Britstown sheet to the southeast (Prinsloo 1989), the Pofadder sheet to the west (Agenbacht 2007) and the Sakrivier sheet to the south (Siebrits 1989).

According to the Kenhardt 1: 250 000 geology map (Fig. 3) the construction site of the proposed Solar Cape PV power station is underlain by the Permocarbiniferous **Dwyka Group** (Karoo Supergroup, **C-Pd**). Dwyka sediments underlie most of the western portion of farm Olyven Kolk 187, with Quaternary alluvium lining the major water courses. Both these rock units are present in the vicinity of the Olyvenhoutsolk farmstead (black circle in Fig. 3) where most of the proposed construction will take place. Small exposures of Mokolian (Mid Proterozoic) basement rocks of the **Namaqua-Natal Province** (De Bakken Granite, **Mdk**, and the Kokerberg Formation, **Mko**) occur in the northeastern portion of farm Olyven Kolk 187. These two billion year old granitoid intrusions and highly metamorphosed sediments (*cf* Cornell *et al.* 2006) are largely mantled by Quaternary wind-blown sands and associated fluvial sediments and pedocretes of the **Gordonia Formation** (Kalahari Group, **Q**). Since the Mokolian basement rocks are unfossiliferous and will not be directly affected by the proposed development, they will not be considered further here. Satellite images (Fig. 2) show that the landscape in the study area is extensively dissected by distal tributaries of the Orange River, notably the Graafwatersriver that flows northwards into the Hartbeesrivier and thence into the Orange.

#### 3.2. Dwyka Group

Permocarbiniferous glacially-related sediments of the **Dwyka Group** (**C-Pd** in Fig. 3) underlie the thin, superficial cover of Gordonia sands, calcrete and Late Caenozoic alluvium both north and south of the Orange River and crop out at surface within the study area southwest of Kenhardt. The geology of the Dwyka Group has been summarized by Visser (1989), Visser *et al.* (1990) and Johnson *et al.* (2006), among others. The geology of the Dwyka Group along the north-western margin of the Main Karoo Basin as far east as Prieska has been reviewed by Visser (1985). Other studies on the Dwyka in or near the Prieska Basin include those by Visser *et al.* (1977-78; summarized by Zawada 1992) and Visser (1982). Fairly detailed observations by Prinsloo (1989) on the Dwyka beds on the northern edge of the Britstown 1: 250 000 geology sheet are in part relevant to the more proximal (near-source) outcrops at Kenhardt. Massive tillites at the base of the Dwyka succession (**Elandsvlei Formation**) were deposited by dry-based ice sheets in deeper basement valleys. Later climatic amelioration led to melting, marine transgression and the retreat of the icesheets 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 (**Mbizane Formation**) 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.



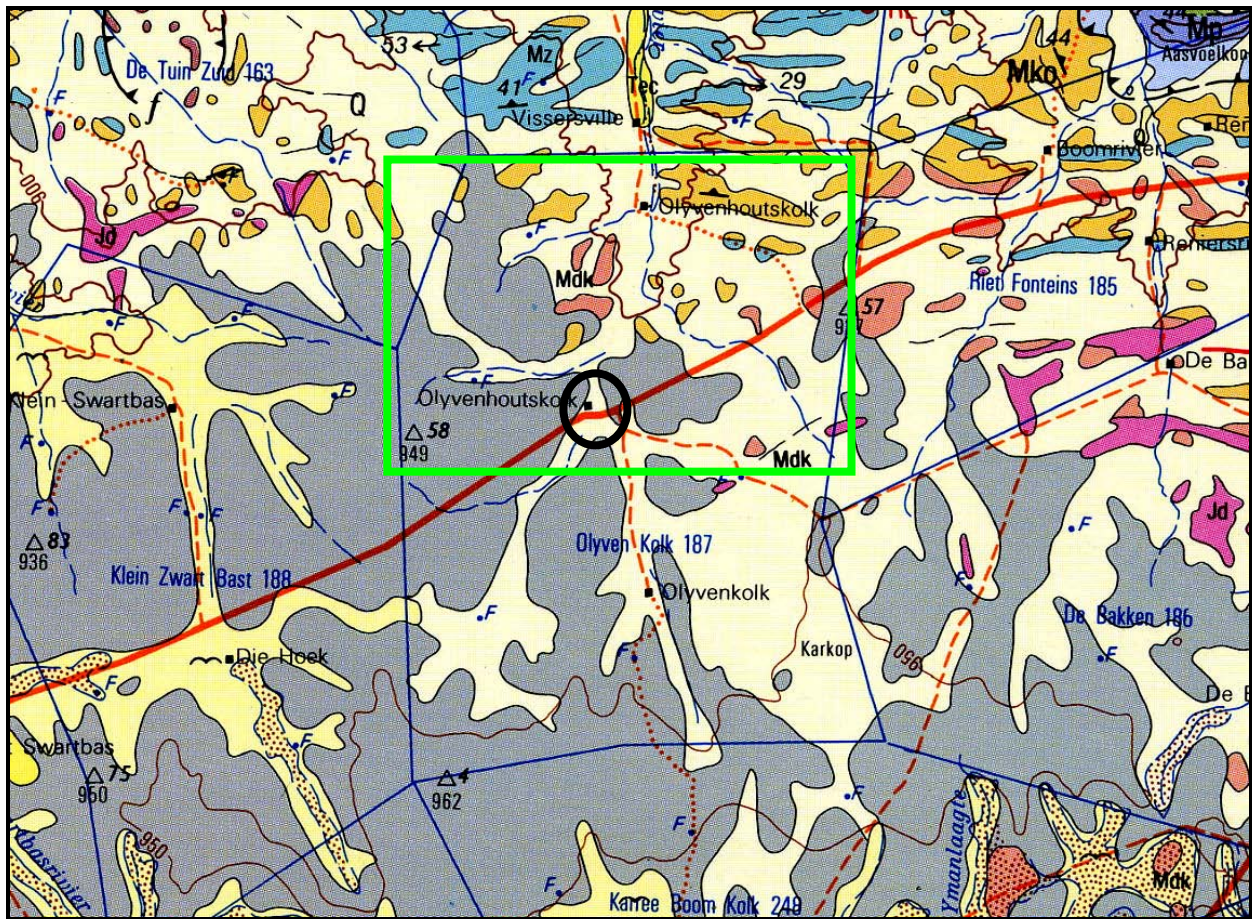


Fig. 3. Extract from 1: 250 000 geological map 2920 Kenhardt (Council for Geoscience, Pretoria) showing the approximate location of proposed Solar Cape study area on the northern part of farm Olyven Kolk 187 (Green rectangle). Construction will largely take place in the vicinity of the Olyvenhoutsolk farmstead (small black ellipse), in an area that is underlain by Quaternary alluvium (pale yellow) and Dwyka glacial deposits at depth (grey).

#### MAIN GEOLOGICAL UNITS:

Orange (Mdk) = De Bakken Granite (Mokolian Basement, De Kruis Fragment)

Dark yellow (Mko) = Kokerberg Formation (De Kruis Group, De Kruis Fragment of Mokolian Basement)

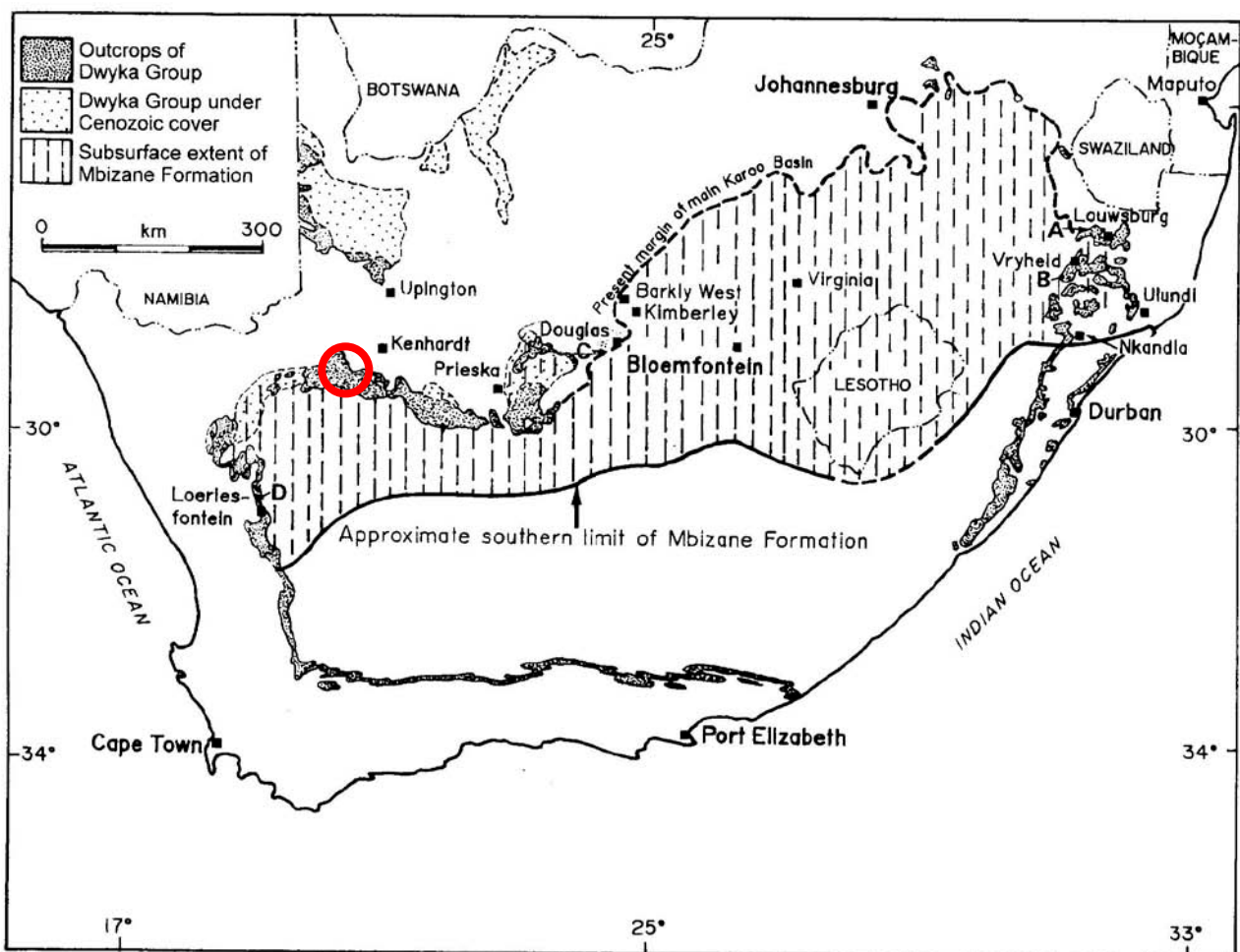
Grey (C-Pd) = Mbizane Formation (Permo-Carboniferous Dwyka Group, Karoo Supergroup)

Pale yellow (Q) = Quaternary to Recent sands and sandy soil of the Gordonia Formation (Kalahari Group).

According to maps in Visser *et al.* (1990) and Von Brunn and Visser (1999; Fig. 4 herein) the Dwyka rocks in the Kenhardt 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 190m thick, is recognized across the entire northern margin of the Main Karoo Basin where it may variously form the whole or 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. The key Reference Stratotype C section for the valley fill facies of the Mbizane Formation is located a few kilometres west of Douglas on the northern side of the Vaal River (Von Brunn & Visser 1999).

The composite section, which overlies glacially-striated Precambrian bedrock, is some 25-30m thick. The lower part of the section consists of massive diamictites with subordinate conglomerates and siltstones. The upper half is dominated by laminated mudrocks with thin diamictites, lonestones (dropstones) and calcareous concretions. The section is conformably overlain by mudrocks of the Prince Albert Formation (Ecca Group) which is not represented in the study area.

For details of the Dwyka Group rocks in the Kenhardt area the reader is referred to the accounts of Visser (1985) and Slabbert *et al.* (1999). The study area c. 35km southwest of Kenhardt lies close to the eastern edge of the Sout River palaeovalley identified by Visser (1985, fig. 12 therein). The Dwyka succession in this area comprises both massive, muddy diamictites (“boulder shales”) as well as heterolithic intervals dominated by interbedded reddish-brown, pebbly sandstones, conglomerates, and diamictite (*ibid.*, figs. 2, 4). Slabbert *et al.* (1999, p. 107) report that the uppermost Dwyka beds contain stromatolites, oolites and calcareous concretions.



**Fig. 4. Outcrop map of the Dwyka Group within the Main Karoo Basin of South Africa. Exposures in the study area southwest of Kenhardt (red circle) are assigned to the outcrop area of the Mbizane Formation (From Von Brunn & Visser 1999).**

### 3.2. Superficial deposits: Kalahari Group sands, calcretes, alluvial gravels

Unconsolidated, reddish-brown aeolian (*i.e.* wind-blown) sands of the Quaternary **Gordonia Formation (Kalahari Group)** (Q in Fig. 3) blanket large areas of the landscape in the Kenhardt area (Slabbert *et al.* 1999). The geology of the Late Cretaceous to Recent Kalahari Group is



reviewed by Thomas (1981), Dingle *et al.* (1983), Thomas *et al.* (1988), Thomas & Shaw 1991, Haddon (2000) and Partridge *et al.* (2006). The Gordonia dune sands are considered to range in age from the Late Pliocene / Early Pleistocene to Recent, dated in part from enclosed Middle to Later Stone Age stone tools (Dingle *et al.*, 1983, p. 291). Note that the recent extension of the Pliocene - Pleistocene boundary from 1.8Ma back to 2.588 Ma would place the Gordonia Formation almost entirely within the Pleistocene Epoch.

According to Slabbert *et al.* (1999, p. 109) Gordonia wind-blown sands in the Kenhardt area, far to the south of the main Kalahari Basin, are thin, rarely preserve longitudinal dune bedforms (these are seen along the Hartbeesrivier near Kenhardt but not further west), and are probably of Holocene age. In the study area the thin superficial blanket of sandy sediments is admixed with local weathering products of the Karoo and other bedrocks. According to these geological survey authors, the sands capping the plains west of the Hartbeesrivier might not in fact be correlated with the Gordonia Formation proper, although they are at least in part derived from the Kalahari Basin.

Late Caenozoic **alluvial deposits** of the Hartbeesrivier tributaries are not described or discussed in detail by Slabbert *et al.* (1999). In addition to finer-grained silts and sands, in the study area they probably include an admixture of coarser gravels derived from weathering of the Karoo rocks (*e.g.* polymict, bouldery erratics and pebbles from diamictites and conglomerates of the Dwyka Group). De Wit (1999) discusses the post-Gondwana evolution of the drainage systems in the Bushmanland region, including pans between Kenhardt and Brandvlei that fed floodwaters from the region *via* the Sakrivier and Hartbees Rivers into the Orange from at least the Plio-Pleistocene times (*Ibid.*, fig. 13. See also De Wit *et al.* 2000).

## 4. PALAEOLOGICAL HERITAGE

The fossil heritage recorded within each of the main sedimentary rock successions occurring within the study region near Kenhardt is outlined here (See also summary provided in Table 1 below).

### 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, Von Brunn & Visser 1999, Visser 2003, Almond & Pether 2008) is hardly surprising given the glacial climates that prevailed during much of the Late Carboniferous to 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 interglacial to post-glacial dropstone laminites and sporadic vascular plant remains (drifted wood and leaves of the *Glossopteris* Flora), 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). These are especially well known in the Kalahari Basin of southern Namibia but also occur sporadically within the Main Karoo Basin in South Africa (Oelofsen 1986, Visser 1989, 1997, Visser *et al.* 1997, Bangert *et al.* 1999 & 2000, Stollhofen *et al.* 2000, Almond 2008a, b). 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 2008a, 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). 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).

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 woods 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 while stromatolites are also recorded within the uppermost Dwyka beds in the Kenhardt area (Slabbert *et al.* 1999). 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). However, it should be noted that abiogenic cone-in-cone structures developed within ferruginous diagenetic carbonate nodules have also been frequently mistaken for stromatolites in the past. Some of these Karoo stromatolite records may therefore in fact refer to pseudofossils.

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, and the more proximal Mbizane Formation may be considered to be of moderate palaeontological sensitivity.

#### 4.2. Fossils within the superficial deposits

The fossil record of the **Kalahari Group** is generally sparse and low in diversity. The **Gordonia Formation** dune sands were mainly active during cold, drier intervals of the Pleistocene Epoch that were inimical to most forms of life, apart from hardy, desert-adapted species. Porous dune sands are not generally conducive to fossil preservation. However, mummification of soft tissues may play a role here and migrating lime-rich groundwaters derived from the underlying Dwyka Group may lead to the rapid calcretisation of organic structures such as burrows and root casts. Occasional terrestrial fossil remains that might be expected within this unit include calcretized rhizoliths (root casts) and termitaria (e.g. *Hodotermes*, the harvester termite), ostrich egg shells (*Struthio*) and shells of land snails (e.g. *Trigonephrus*) (Almond 2008a, Almond & Pether 2008). Other fossil groups such as freshwater bivalves and gastropods (e.g. *Corbula*, *Unio*) and snails, ostracods (seed shrimps), charophytes (stonewort algae), diatoms (microscopic algae within siliceous shells) and stromatolites (laminated microbial limestones) associated with local watercourses and pans. Microfossils such as diatoms may be blown by wind into nearby dune sands (Du Toit 1954, Dingle *et al.*, 1983). These Kalahari fossils (or subfossils) can be expected to occur sporadically but widely, and the overall palaeontological sensitivity of the Gordonia Formation is therefore considered to be low. Underlying **calcretes** might also contain trace fossils such as rhizoliths, termite and other insect burrows, or even mammalian trackways. Mammalian bones, teeth and horn cores (also tortoise remains, and fish, amphibian or even crocodiles in wetter depositional settings) may be expected occasionally expected within Kalahari Group sediments and calcretes, as well as in associated ancient alluvial gravels. A brief review of fossil biotas within Neogene alluvial deposits of the Loeriesfontein / Bushmanland region has been given by Almond (2008a; see also papers by Cooke 1949, Wells 1964, Butzer *et al.* 1973, Helgren 1977, Klein 1984, Macrae 1999). They include remains of fish, reptiles, mammals, freshwater molluscs, petrified wood and trace fossils (e.g. De Wit 1990, 1993, De Wit & Bamford 1993, Bamford 2000, Bamford & De Wit 1993, Senut *et al.* 1996).

## **5. CONCLUSIONS & RECOMMENDATIONS**

The site of the proposed Kenhardt Solar PV power station site is directly underlain by Permocarboniferous glacial-related sediments of the Dwyka Group (Mzibane Formation) that are generally of low palaeontological sensitivity. Quaternary aeolian sediments of the Gordonia Formation (Kalahari Group) as well as alluvial gravels and calcretes, both of low palaeontological sensitivity, may also be encountered near-surface in the study area.

Since the palaeontological sensitivity of the rock units within the study area is generally low, the development footprint is fairly small, and extensive bedrock excavations are not envisaged, the impact significance of the proposed Solar Cape PV facility as far as fossil heritage is concerned is likely to be very small. Therefore further specialist palaeontological mitigation of this project is not considered necessary. Should substantial fossil remains be exposed during construction, however, these should be recorded (GPS, photos), safeguarded if possible *in situ*, and SAHRA should be notified by the ECO so that appropriate mitigation can be considered.

## **6. ACKNOWLEDGEMENTS**

Mr Nicolaas Hanekom of Cape Lowlands Environmental Services, Darling, is thanked for commissioning this study and for kindly providing all the necessary background information.



**TABLE 1: FOSSIL HERITAGE IN THE KENHARDT AREA**

<b>GEOLOGICAL UNIT</b>	<b>ROCK TYPES &amp; AGE</b>	<b>FOSSIL HERITAGE</b>	<b>PALAEONTOLOGICAL SENSITIVITY</b>	<b>RECOMMENDED MITIGATION</b>
Quaternary alluvium	sands, silts, gravels	sparse remains of fish, reptiles, mammals, freshwater molluscs, petrified wood and trace fossils	LOW	none recommended  any substantial fossil finds to be reported by ECO to SAHRA
Gordonia Formation  KALAHARI GROUP  <i>plus</i>  SURFACE CALCRETE	mainly aeolian sands <i>plus</i> minor fluvial gravels, freshwater pan deposits, calcretes  PLEISTOCENE to RECENT	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	LOW	none recommended  any substantial fossil finds to be reported by ECO to SAHRA
Mbizane Formation  DWYKA GROUP	tillites, interglacial mudrocks, deltaic & turbiditic sandstones, minor thin limestones  LATE CARBONIFEROUS – EARLY PERMIAN	sparse petrified wood & other plant remains, palynomorphs, trace fossils (e.g. arthropod trackways, fish trails, U-burrows) possible stromatolites in limestones	LOW TO MODERATE	none recommended  any substantial fossil finds to be reported by ECO to SAHRA
De Bakken Granite & Kokerberg Formation  NAMAQUA-NATAL PROVINCE	highly metamorphosed sediments, intrusive granites  MID-PROTEROZOIC (c. 2 billion yrs old)	none	ZERO	none recommended

## 7. REFERENCES

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## QUALIFICATIONS & EXPERIENCE OF THE AUTHOR

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

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

### Declaration of Independence

I, John E. Almond, declare that I am an independent consultant and have no business, financial, personal or other interest in the proposed 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.



**Dr John E. Almond**  
**Palaeontologist**  
***Natura Viva* cc**