# PALAEONTOLOGICAL HERITAGE ASSESSMENT: DESKTOP STUDY

# PROPOSED KOTULO TSATSI ENERGY SOLAR PARK, INCLUDING CONCENTRATED SOLAR POWER (TOWER & TROUGH TECHNOLOGIES) AND PHOTOVOLTAIC (PV) SOLAR FACILITIES, NEAR KENHARDT, NORTHERN CAPE

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

**May 2014**

## EXECUTIVE SUMMARY

Exheredo (Pty) Ltd trading as Kotulo Tsatsi Energy is proposing to develop (1) a Concentrating Solar Power (CSP) Facility, with generation capacity of up to approximately 1000 MW as well as a (2) a Photovoltaic (PV) Solar Energy facility, with a generation capacity of up to approximately 200 MW on Portion 1, Portion 2 and Portion 3 of the farm Styns Vley 280, as well as Melkbosch Vley 278 (RE of 278), Kopjes Vley 281 (Portion 2 of 281), Gemsbok Rivier 301(Portion 1 of 301) and Gemsbok Rivier 301(RE of 301), located *c*. 70 km southwest of Kenhardt, Siyanda District Municipality, Northern Cape Province.

The farms Styns Vlei 280, Gemsbok Rivier 301 and the southern portion of Melkbosch Vlei 228 are largely underlain by Early Permian marine sediments of the Prince Albert Formation (Ecca Group) that contain important fish, invertebrate and wood fossils in some parts of the Northern Cape (*e.g.* Douglas area). The Ecca sediments here have probably been locally baked by intrusive dolerites that crop out along the eastern margin of the farm. The remainder of the broader project site including footprints of the proposed approximate 30-km 132 kV transmission line to Aries Substation, pipeline and railway siding) lies within the outcrop area of the Permo-Carboniferous Dwyka Group. The Dwyka glacial tillites are of low palaeontological sensitivity while thin-bedded interglacial mudrocks may contain trace fossils, plant material, as well as rare fossil fish and invertebrates. However, exposure levels of the Dwyka sediments in the Kenhardt sheet area are generally poor. A substantial fraction of the Karoo Supergroup sediments within the broader study area are mantled by Late Caenozoic superficial deposits such as downwasted gravels (*e.g.* glacial erratics from the Dwyka tillites), alluvial and pan sediments as well as various soils. Most of these younger surface deposits are of low palaeontological sensitivity. Biostratigraphically and palaeoenvironmentally interesting fossil mammals remains have been recorded in association with stratified pan sediments in Bushmanland. Important Late Tertiary mammalian and other vertebrate fossils as well as petrified woods found in association with ancient drainage systems crossing Bushmanland, such as the Sakrivier system near Brandvlei, might also occur closer to Kenhardt.

As part of the EIA for this project a Phase 1 field-based assessment of palaeontological heritage resources on all land parcels within the broader study area should be carried out by a professional palaeontologist. The field study would focus on potentially fossiliferous sediments of the Ecca Group and Dwyka Group (interglacial beds), as well as any sections exposing older alluvium, pan deposits and calcretised units. The Phase 1 report would describe and map any fossil remains encountered, assess their heritage significance, and make appropriate

recommendations to SAHRA regarding further studies or mitigation required, if any, for the pre-construction and construction phases of the development.

All palaeontological specialist work should conform to international best practice for palaeontological fieldwork and the study (*e.g.* data recording fossil collection and curation, final report) should adhere as far as possible to the minimum standards for Phase 1 and 2 palaeontological studies recently developed by SAHRA (2013).

# 1. INTRODUCTION & BRIEF

## 1.1. Project outline

The company Exheredo (Pty) Ltd (trading as Kotula Tsatsi Energy) is proposing to develop (1) a Concentrating Solar Power (CSP) Facility with a generation capacity of up to approximately 1000MW using tower technology (three plants with the capacity to generate up to approximately 200MW) as well as a trough technology (two plants with the capacity to generate up to 200MW) and (2) a Photovoltaic (PV) Solar Energy facility (two plants with a generation capacity of up to approximately 100MW) on Portion 1, Portion 2 and Portion 3 of the farm Styns Vley 280, as well as Melkbosch Vley 278 (RE of 278), Kopjes Vley 281 (Portion 2 of 281), Gemsbok Rivier 301(Portion 1 of 301) and Gemsbok Rivier 301(RE of 301). The site is situated approximately 70 km southwest of Kenhardt, ZF Mgcawu District Municipality in the Northern Cape Province (Figs. 1 to 3).

The proposed **CSP tower facilities** will consist of a collector field (heliostats) and a Power Tower system with three central receivers. Infrastructure associated with the CSP (Tower) facilities includes:

- Three Concentrated Solar Tower Plants with a generation capacity of up to 200MW each;
- Power Plant: Power tower technology with three central receivers and a collector field (heliostats), including a molten salts storage system with dry cooling;
- Associated infrastructure: access roads, on-site substation, power line, water abstraction point and water supply pipe line, water storage tanks, packaged waste treatment plant, evaporation ponds, molten salts storage tanks, auxiliary fossil fuel boilers and workshop and office buildings.

The proposed **Concentrating Solar Power (CSP) Trough facilities** will consist of the following infrastructure:

- Two Concentrated Solar Trough Plants with a generation capacity of up to 200MW;
- A substation and switching station for each facility;
- One 400 kV substation and turn in and out of the existing Aries-Helios 400kV power line;
- One water pipeline from Kenhardt / Keimoes to the site (details have not been finalised at this stage);
- Associated infrastructure including:
  - Mancamp

- Batching plant and possibly borrow pit for initial construction work
- Cabling between the plant components, to be laid underground
- Evaporation ponds
- Access roads
- Protective fencing
- Workshops
- Offices
- Assembly plant and laydown area
- Subsoil and topsoil stockpiles from ground preparation work (especially from the trough power plants) that will have to be landscaped and rehabilitated as permanent altered landscape features.

The proposed **PV facility** will have a combined generation capacity of up to approximately 200 MW (as defined above) and will consist of the following infrastructure:

- Two arrays of photovoltaic (PV) panels, each with a generating capacity of up to 100 MW;
- Appropriate mounting structures (so far both tracking and fixed panel options are being considered);
- Cabling between the project components, to be laid underground where practical;
- A new on-site substation and 132 kV power line to evacuate the power from the facility into the Eskom grid;
- Internal access roads and fencing;
- Workshop area for maintenance, storage, and offices;
- Mancamp.

The grid connections of the solar facilities will be *via* power lines (132 kV or 400 kV power lines and substations) to the Aries substation that is located approximately 30 km away from the site. Only once the Grid Connection options has been awarded by Eskom will this option be finalised. However to date the following applications are being considered for connection of the facility to the National Grid:

- Proposed construction of two 132 kV power lines from the on-site substation ( 132 kV) on farm Styns Vley 280 to the Aries Substation;
- Proposed construction of a 400 kV power line turn in and 400 kV transformer substation on Farm Styns Vley 280 to connect to the Aries Substation**.**

It is also proposed to construct a pipeline and a railway siding from the Loop 10 Siding located along the existing railway line approximately 6-10 km away from the Project Site. The route for both the pipeline and siding has not been established.

The present palaeontological desktop assessment of the Kotulo Solar Energy Park study area has been commissioned as part of the broad-based Heritage and Environmental Impact Assessment that is being co-ordinated by Savannah Environmental (Pty) Ltd, Woodmead (Contact details: Ms Umeshree Naicker. Savannah Environmental (Pty) Ltd. 1st Floor, Block 2, 5 Woodlands Drive Office Park, Woodlands Drive, Woodmead, 2191. Tel: +27 11 656 3237. Fax: +27 86 684 0547. Cell: 072 334 2859. Email: umeshree@savannah.com. Postal address: P.O. Box 148, Sunninghill, 2157).

## 1.2. Legislative context for palaeontological assessment studies

The project area is located in an area that is underlain by potentially fossiliferous sedimentary rocks of Late Palaeozoic and younger, Late Tertiary or Quaternary, age (Section 3). The construction phase of the proposed developments will entail substantial excavations into the superficial sediment cover and locally into the underlying bedrock as well. These include, for example, excavations for the CSP tower foundations and power block infrastructure, water storage tanks, evaporation ponds, solar panel footings, underground cables, internal access roads, transmission line towers, the on-site substation(s), the pipeline, assembly plant, laydown areas and the railway siding and administrative facilities. All these developments may adversely affect potential fossil heritage within the study area by destroying, disturbing or permanently sealing-in fossils at or beneath the surface of the ground that are then no longer available for scientific research or other public good. The decommissioning phase of the solar energy facilities is unlikely to involve further adverse impacts on local palaeontological heritage.

The present combined desktop and field-based palaeontological heritage report falls under Sections 35 and 38 (Heritage Resources Management) of the South African Heritage Resources Act (Act No. 25 of 1999), and it will also inform the Environmental Management Plan for this project.

The various categories of heritage resources recognised as part of the National Estate in Section 3 of the National Heritage Resources Act include, among others:

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

According to Section 35 of the National Heritage Resources Act, dealing with archaeology, palaeontology and meteorites:
(1) The protection of archaeological and palaeontological sites and material and meteorites is the responsibility of a provincial heritage resources authority.
(2) All archaeological objects, palaeontological material and meteorites are the property of the State.
(3) Any person who discovers archaeological or palaeontological objects or material or a meteorite in the course of development or agricultural activity must immediately report the find to the responsible heritage resources authority, or to the nearest local authority offices or museum, which must immediately notify such heritage resources authority.
(4) No person may, without a permit issued by the responsible heritage resources authority—
*(a)* destroy, damage, excavate, alter, deface or otherwise disturb any archaeological or palaeontological site or any meteorite;
*(b)* destroy, damage, excavate, remove from its original position, collect or own any archaeological or palaeontological material or object or any meteorite;
*(c)* trade in, sell for private gain, export or attempt to export from the Republic any category of archaeological or palaeontological material or object, or any meteorite; or
*(d)* bring onto or use at an archaeological or palaeontological site any excavation equipment or any equipment which assist in the detection or recovery of metals or archaeological and palaeontological material or objects, or use such equipment for the recovery of meteorites.
(5) When the responsible heritage resources authority has reasonable cause to believe that any activity or development which will destroy, damage or alter any archaeological or palaeontological site is under way, and where no application for a permit has been submitted

and no heritage resources management procedure in terms of section 38 has been followed, it may—

*(a)* serve on the owner or occupier of the site or on the person undertaking such development an order for the development to cease immediately for such period as is specified in the order;

*(b)* carry out an investigation for the purpose of obtaining information on whether or not an archaeological or palaeontological site exists and whether mitigation is necessary;

*(c)* if mitigation is deemed by the heritage resources authority to be necessary, assist the person on whom the order has been served under paragraph *(a)* to apply for a permit as required in subsection (4); and

*(d)* recover the costs of such investigation from the owner or occupier of the land on which it is believed an archaeological or palaeontological site is located or from the person proposing to undertake the development if no application for a permit is received within two weeks of the order being served.

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

## 1.3. Approach to the palaeontological heritage study

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

In preparing a palaeontological desktop study the potentially fossiliferous rock units (groups, formations *etc*) represented within the study area are determined from geological maps and satellite images. The known fossil heritage within each rock unit is inventoried from the published scientific literature, previous palaeontological impact studies in the same region, and the author's field experience (consultation with professional colleagues as well as examination of institutional fossil collections may play a role here, or later following field assessment during the compilation of the final report). This data is then used to assess the palaeontological sensitivity of each rock unit to development (provisional tabulations of palaeontological sensitivity of all formations in the Western, Eastern and Northern Cape have already been compiled by J. Almond and colleagues; *e.g.* Almond & Pether 2008). The likely impact of the proposed development on local fossil heritage is then determined on the basis of (1) the palaeontological sensitivity of the rock units concerned and (2) the nature and scale of the development itself, most significantly the extent of fresh bedrock excavation envisaged. When rock units of moderate to high palaeontological sensitivity are present within the development footprint, a Phase 1 field assessment study by a professional palaeontologist is usually warranted to identify any palaeontological hotspots and make specific recommendations for any mitigation required before or during the construction phase of the development.

On the basis of the desktop and Phase 1 field assessment studies, the likely impact of the proposed development on local fossil heritage and any need for specialist mitigation are then determined. Adverse palaeontological impacts normally occur during the construction rather than the operational or decommissioning phase. Phase 2 mitigation by a professional palaeontologist – normally involving the recording and sampling of fossil material and associated geological information (*e.g.* sedimentological data) may be required (a) in the pre-construction phase where important fossils are already exposed at or near the land surface and / or (b) during the construction phase when fresh fossiliferous bedrock has been exposed by excavations. To carry out mitigation, the palaeontologist involved will need to apply for a palaeontological collection permit from the relevant heritage management authority, *i.e.* SAHRA (Contact details: Mrs Colette Scheermeyer, P.O. Box 4637, Cape Town 8000. Tel: 021 462 4502. Email: cscheermeyer@sahra.org.za). It should be emphasized that, *providing appropriate mitigation is carried out*, the majority of developments involving bedrock excavation can make a *positive* contribution to our understanding of local palaeontological heritage.

### 1.4. Assumptions & limitations

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

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

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

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

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

5. Absence of a comprehensive computerized database of fossil collections in major RSA institutions which can be consulted for impact studies. A Karoo fossil vertebrate database is now accessible for impact study work.

In the case of palaeontological desktop studies without supporting Phase 1 field assessments these limitations may variously lead to either:

(a) *underestimation* of the palaeontological significance of a given study area due to ignorance of significant recorded or unrecorded fossils preserved there, or

(b) *overestimation* of the palaeontological sensitivity of a study area, for example when originally rich fossil assemblages inferred from geological maps have in fact been destroyed by tectonism or weathering, or are buried beneath a thick mantle of unfossiliferous "drift" (soil, alluvium *etc*).

Since most areas of the RSA have not been studied palaeontologically, a palaeontological desktop study usually entails *inferring* the presence of buried fossil heritage within the study area from relevant fossil data collected from similar or the same rock units elsewhere, sometimes at localities far away. Where substantial exposures of bedrocks or potentially fossiliferous superficial sediments are present in the study area, the reliability of a palaeontological impact assessment may be significantly enhanced through field assessment by a professional palaeontologist.

In the case of the present study area in the Kenhardt region of the Northern Cape Province exposure of potentially fossiliferous bedrocks is favoured by the semi-arid climate and sparse vegetation but may be compromised by extensive superficial deposits in areas of low relief. Comparatively few academic palaeontological studies or field-based fossil heritage impact have been carried out in the region, so any new data from impact studies here are of scientific interest.

### 1.5. Information sources

The information used in this desktop study was based on the following:

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

2. A short desktop palaeontological assessment report for a broader study area to the east of the present study area by the author (Almond 2011);

3. A review of the relevant scientific literature, including published geological maps and accompanying sheet explanations (*e.g.* Slabbert *et al.* 1999);

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

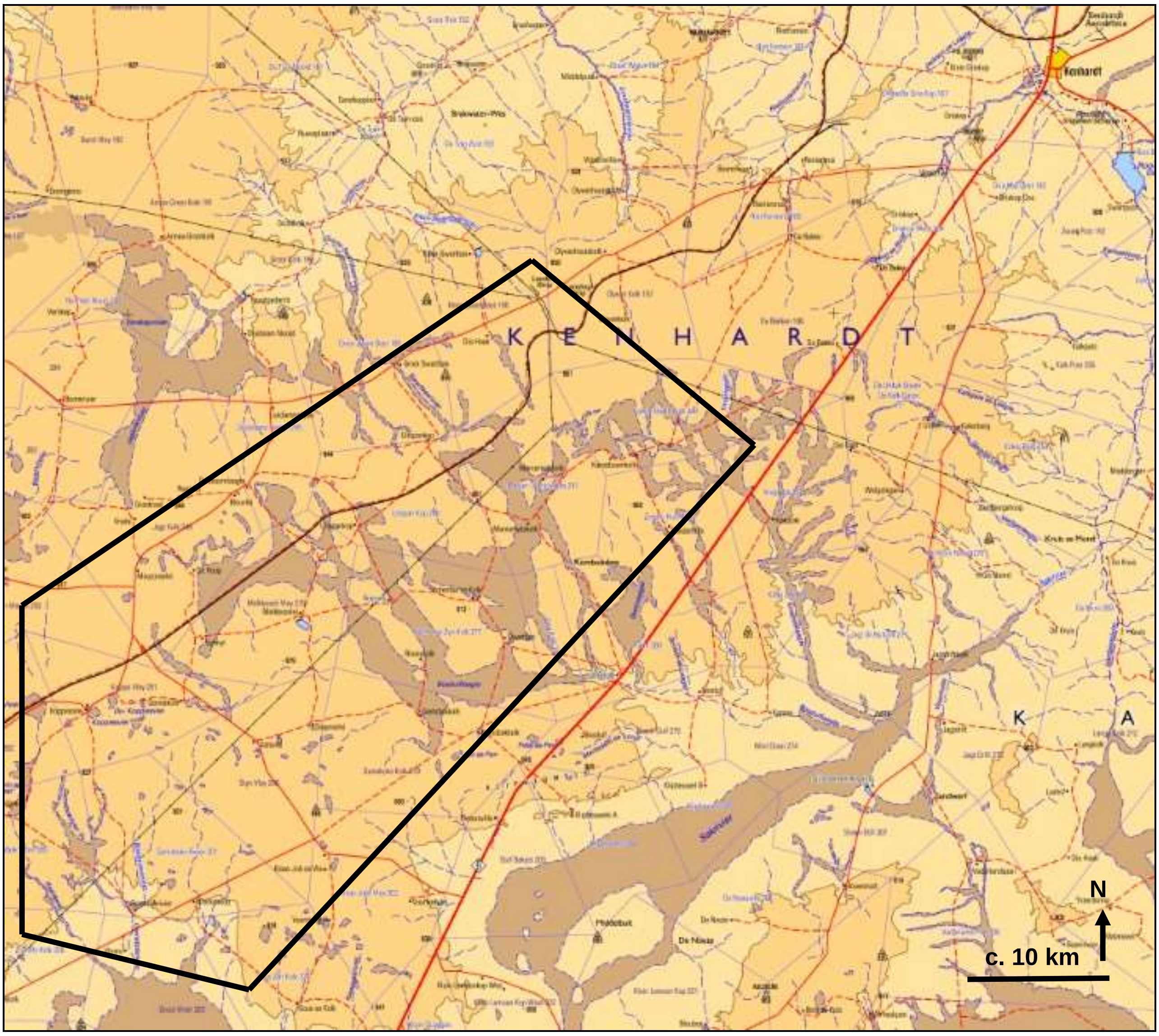


**Fig. 1. Extract from 1: 250 000 topographical sheet 2920 Kenhardt showing the approximate location of the broader solar energy facility study area situated to the northwest of the R27 in eastern Bushmanland, *c.* 35 to 75 km southwest of Kenhardt, Northern Cape Province (Courtesy of the Chief Directorate of Surveys and Mapping, Mowbray).**

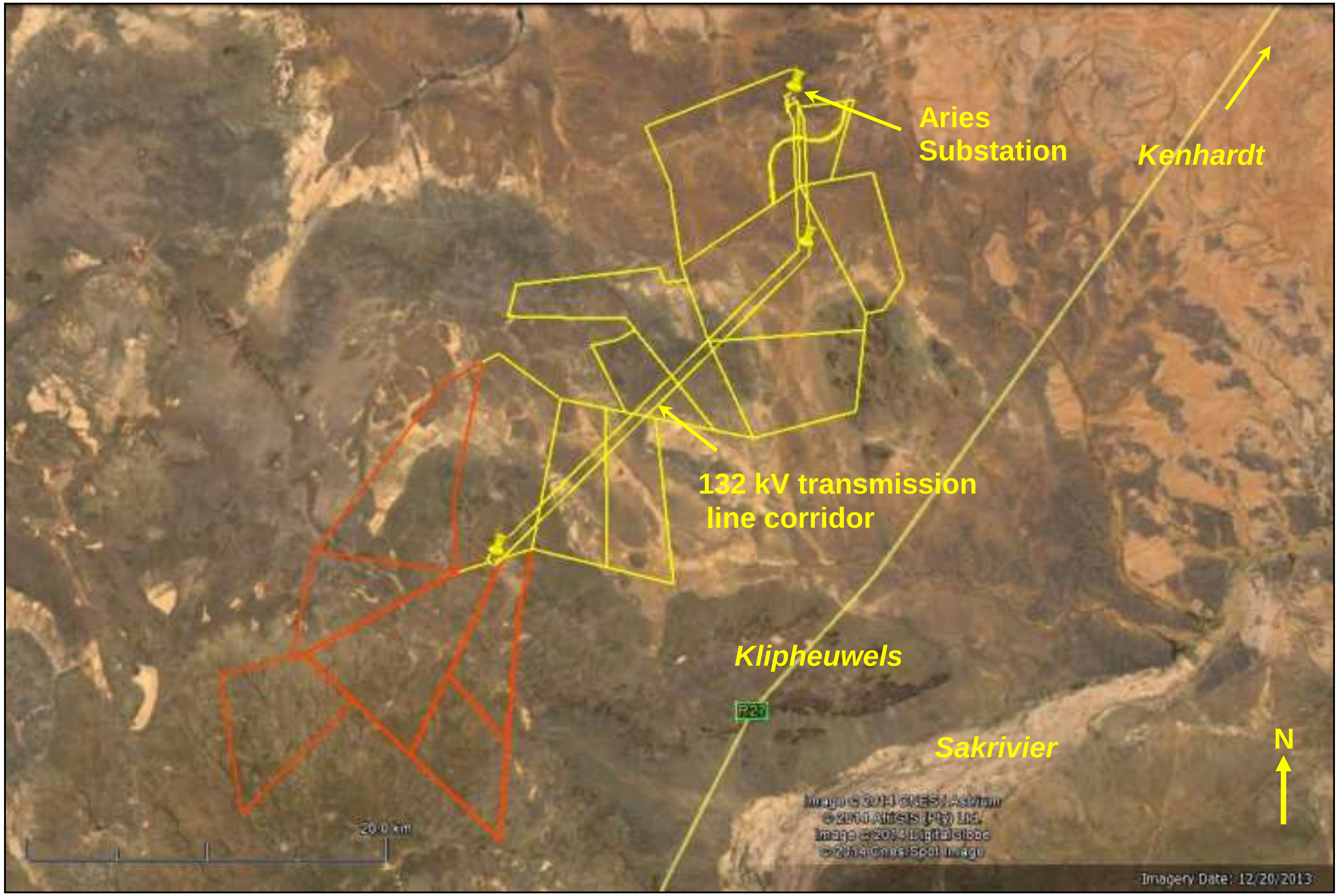


**Fig. 2. Google earth© satellite image of the eastern Bushmanland region showing the location of the solar energy facility study area on Farms Styns Vley 280, Melkbosch Vley 278 (RE of 278), Kopjes Vley 281 (Portion 2 of 281), Gemsbok Rivier 301(Portion 1 of 301) and Gemsbok Rivier 301(RE of 301) to the southwest of the town of Kenhardt, Northern Cape (orange polygon) as well as the proposed *c.* 30 km – long 132 kV transmission line corridor to the Aries Substation in the northeast.**

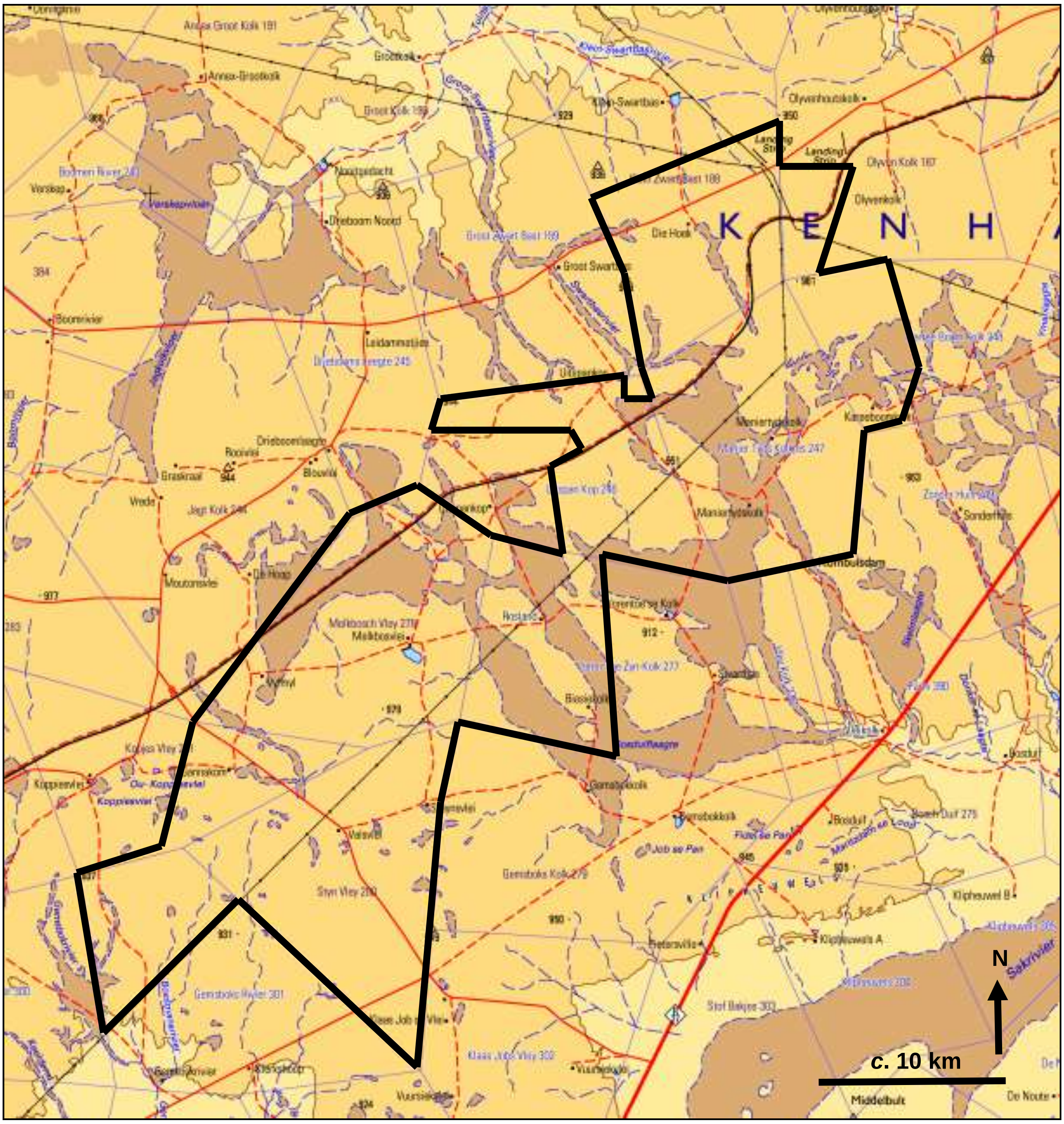


**Fig. 3. Extract from 1: 250 000 topographical sheet 2920 Kenhardt showing the land parcels involved in the broader solar energy facility study area, including the existing transmission line to the Aries Substation (black polygon)(Base map courtesy of the Chief Directorate of Surveys and Mapping, Mowbray).**

## 2. GEOLOGICAL BACKGROUND

The study area is located to the northwest of R27 Brandvlei to Kenhardt tar road in semi-arid, low relief terrain between 900-1000 mamsl in eastern Bushmanland (*c*. 920 – 950 mamsl on Styns Vlei 280 itself)(Figs. 1 to 3). The Sishen-Saldanha railway line and Pofadder to Kenhardt road traverse the northern margin of the area and the 132 kV transmission line to Aries Substation crosses the area from SW to NE. The railway line runs more or less along the watershed between dendritic, north-flowing tributaries of the Orange River (*e.g.* the Groot and Klein Swartbasriviere) and a primarily south-east flowing drainage network, largely defunct or impersistent, flowing into the Sakrivier to the southeast of the study area. The latter drains much of the study area and consists of numerous dry stream beds, gullies and elongate, low-lying *laagte* (*e.g.* Skelmlaagte, Bosduiflaagte) and *vleis* that are often sandy and connect a series of shallow pans. Low rocky hills occur in the regions underlain by resistant-weathering dolerite, including the Klipheuwels situated between the study area and the Sakrivier.

The geology of the study area is outlined on the 1: 250 000 geology map 2920 Kenhardt (Council for Geoscience, Pretoria; Fig. 6 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. 6) the north-eastern two thirds or so of the broader study area are underlain by glacially-related sediments of the Permo-carboniferous **Dwyka Group** (Karoo Supergroup, **C-Pd**). The south-western third of the area, including much of farm Steyns Vlei 280, is underlain by postglacial basinal mudrocks of the **Prince Albert Formation** (Karoo Supergroup, Ecca Group, Pp) of Early Permian age. The Karoo Supergroup sediments have been locally intruded and baked by extensive intrusive sheets or sills of the **Karoo Dolerite Suite** (Jd) which build a north-south trending zone of rocky terrain running along the eastern border of Steyn Vlei 280 as well as scattered outcrops further to the northeast and east (*e.g.* Klipheuwels). Small exposures of much older Precambrian (Mokolian / Mid Proterozoic) basement rocks of the **Namaqua-Natal Province** (*e.g.* De Bakken Granite, **Mdk**) are mapped to the east of the present study area on the farm Karee Boom Kolk 248 and similar outcrops may also occur subsurface in the study area itself. These comprise two billion year old granitoid intrusions and highly metamorphosed sediments (*cf* Cornell *et al.* 2006). The Karoo Supergroup sediments, Karoo dolerites and any older basement rocks are extensively mantled with a range of **Late Caenozoic superficial deposits** of probable Late Tertiary age, such as alluvium, pane sediments and surface gravels.

### 2.1. Dwyka Group

Permo-carboniferous, glacially-related sediments of the **Dwyka Group** (**C-Pd**, grey in Fig. 6) underlie the thin, superficial cover of Late Caenozoic alluvium, pan sediments, soils and gravels as well as cropping 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. 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 even leading occasionally to limestone precipitation.

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 that are briefly treated by Slabbert *et al.* (1999). The Dwyka succession in the Kenhardt 1: 250 000 sheet area consists mainly of dark grey to reddish-brown, clast-rich to clast-poor diamictites and is up to 100 m thick. Levels of Dwyka bedrock exposure are generally poor due to the readiness with which this unit is denuded by weathering and erosion; the outcrop area is mainly represented by a level surface mantled with downwasted glacial erratics. An upper and lower tillite zone separated by varved (seasonally laminated) interglacial mudrocks have been recognised by some authors.

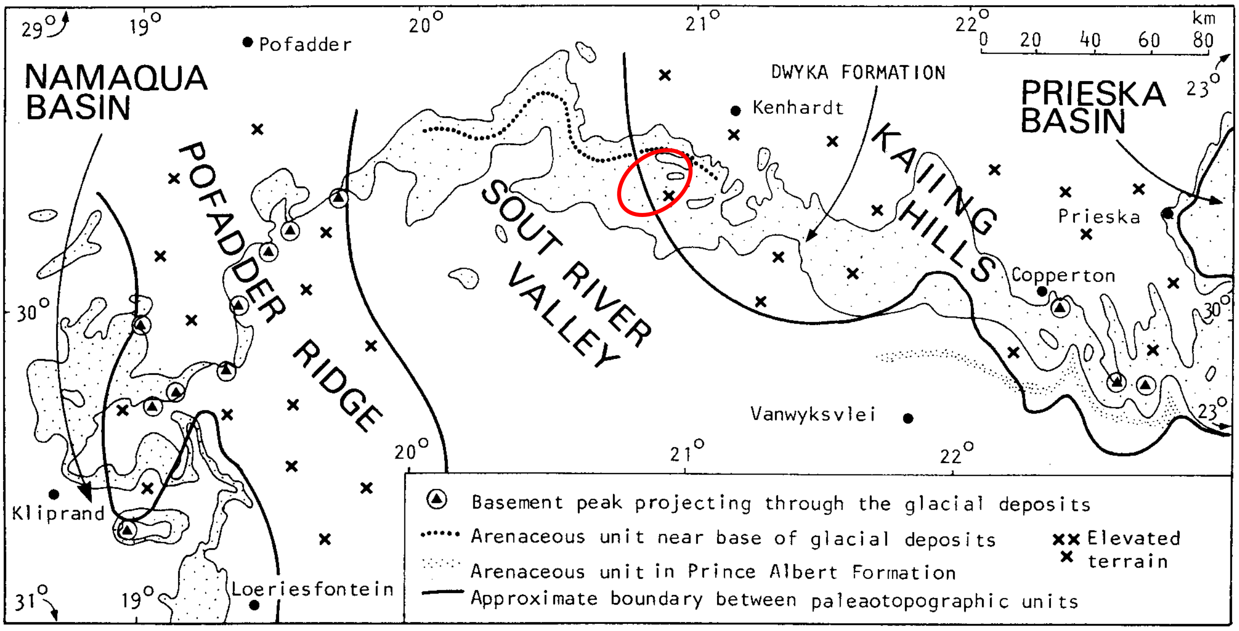


**Fig. 4. Reconstruction of the topography along the northern margin of the Karoo Basin in Dwyka times showing location (red ellipse) of the area to the SE of Kenhardt on a basement palaeo-high, the Kaaing Hills, with the Sout River palaeo-valley to the west (From Visser 1985).**

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 to the southwest of Kenhardt lies close to the eastern edge of the Sout River palaeo-valley identified by Visser (1985, fig. 4 herein). 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. A thinner Dwyka succession just to the east overlies the Kaaing Hills palaeo-high. Here basal massive clast-rich diamictites are overlain by massive but clast-poor diamitites followed by a thin succession of dropstone argillites before the post-glacial Ecca mudrocks. Slabbert *et al.* (1999, p. 107) report that the uppermost Dwyka beds in the Kenhardt sheet area may contain stromatolites, oolites and calcareous concretions.

According to maps in Visser *et al.* (1990) and Von Brunn and Visser (1999; Fig. 5 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 25-30 m 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) such as those represented in the south-western portion of the present study area.

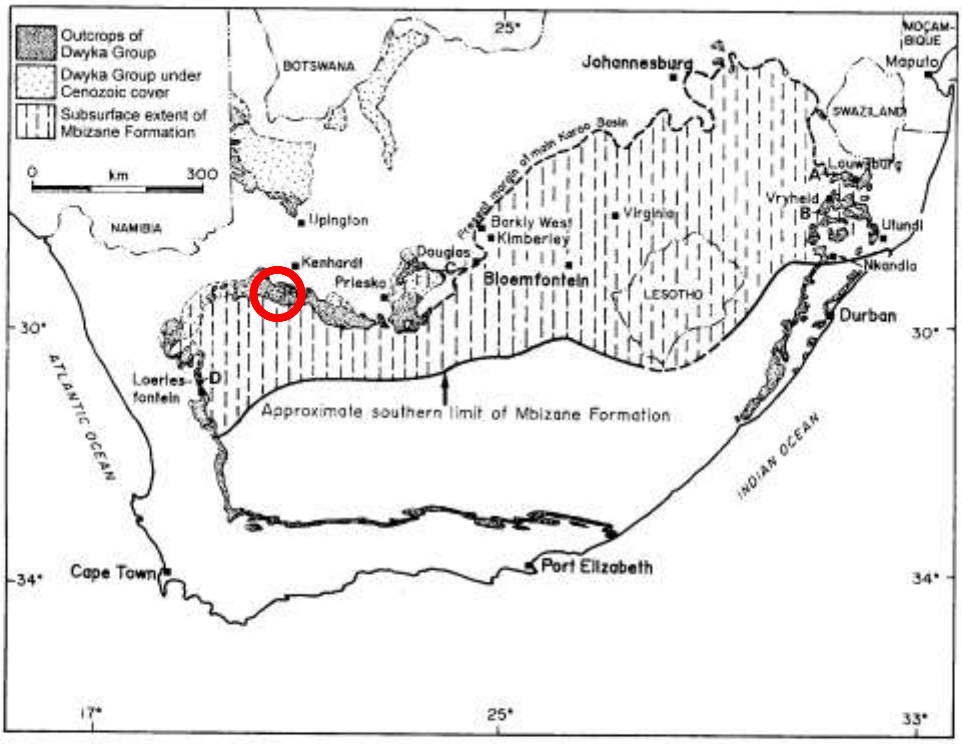


**Fig. 5. Outcrop map of the Dwyka Group within the Main Karoo Basin of South Africa. Exposures in the study area southwest of Kenhardt (red circle) are assigned to the outcrop area of the Mbizane Formation (From Von Brunn & Visser 1999).**

## 2.2. Prince Albert Formation (Ecca Group)

The post-glacial basinal mudrocks of the Prince Albert Formation (Ppr, buff in Fig. 6) form the lowermost subunit of the Ecca Group (Johnson *et al.* 2006). This thin-bedded to laminated, mudrock-dominated succession of Early Permian (Asselian / Artinskian) age was previously known as "Upper Dwyka Shales". Key geological accounts of this formation are given by Visser (1992) and Cole (2005). The Prince Albert succession consists mainly of tabular-bedded mudrocks of blue-grey, olive-grey to reddish-brown colour with occasional thin (dm) buff sandstones and even thinner (few cm), soft-weathering layers of yellowish water-lain tuff (*i.e.* volcanic ash layers). Extensive diagenetic modification of these sediments has led to the formation of thin cherty beds, pearly- blue phosphatic nodules, rusty iron carbonate nodules, as well as beds and elongate ellipitical concretions impregnated with iron and manganese minerals. The brittle rocks are well-jointed and often display a well-developed tectonic cleavage that results in sharp, elongate cleavage flakes ("pencil cleavage"). Extensive bedding planes are therefore rarely encountered in the southern outcrop area close to the Cape Fold Belt while Northern Cape outcrops are much less deformed.

The Prince Albert Formation in the Kenhardt sheet area consists predominantly of greenish to greenish-brown, massive-bedded, friable mudrocks without glacial dropstones according to Slabbert *et al.* (1999). Towards the base occur darker, well-laminated basinal mudrocks (shales, siltstones) with minor thin-bedded fine-grained sandstone and siltstone beds and lenses (Visser 1985). The mudrocks are sometimes micaceous, carbonaceous or pyritic and typically contain a variety of diagenetic concretions enriched in iron and carbonate minerals (Visser *et al.* 1977, Zawada 1992, Bosch 1993). Some of these carbonate concretions are richly fossilferous elsewhere in the Northern Cape (See Section 3.2 below). Thin (*c*. 10 cm), laterally extensive dolomitic limestone horizons also occur. Some of the Ecca shale outcrop within the study area may have been modified by near-surface calcretization as well as baking by Karoo dolerite intrusions.

### 2.3. Late Caenozoic superficial deposits

The Late Caenozoic superficial deposits of the Kenhardt sheet area are not described or discussed in detail by Slabbert *et al.* (1999). Judging from satellite images and maps of the study area these comprise a range of silty, sandy and gravelly alluvial deposits, colluvial rubble (*e.g.* scree on rocky hillslopes), surface gravels of various origins (*e.g.* downwasted products of bedrock weathering and erosion, such as the polymict boldery erratics overlying the Dwyka Group outcrop area), pedocretes including calcrete, and soils. 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, Partridge & Scott 2000). Small areas of sandy soils are differentiated within the study area on the 1: 250 000 geological map (Q, white in Fig. 6) but aeolian sands of the Kalahari Group (Gordonia Formation) are not mapped here.

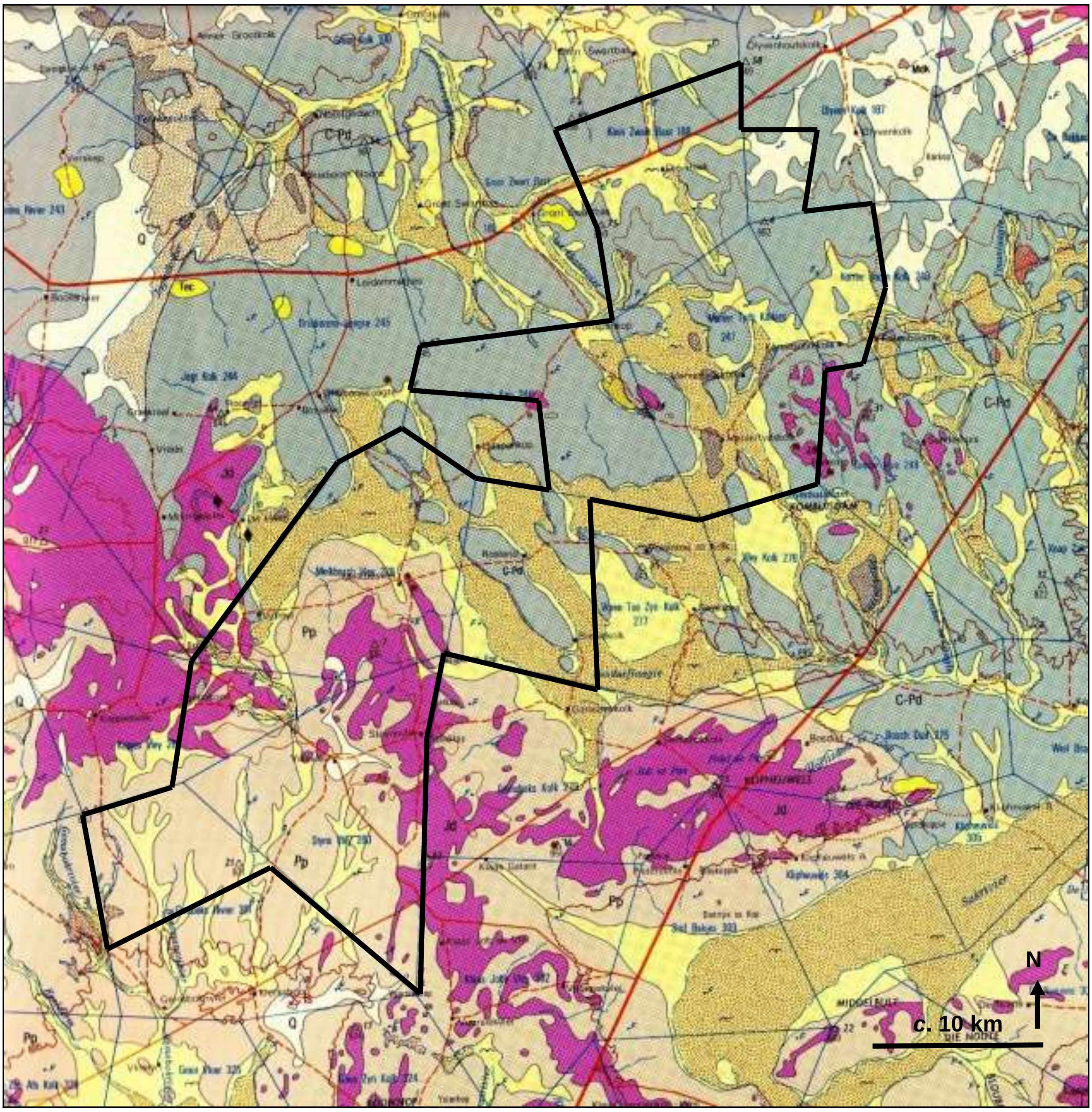


**Fig. 6. Extract from 1: 250 000 geological map 2920 Kenhardt (Council for Geoscience, Pretoria) showing the approximate outline of the solar energy facility study area, including land parcels invoved in with 132 kV transmission line (black polygon). The main geological units mapped here include:**

**Orange (Mdk) = De Bakken Granite (Mokolian Basement, De Kruis Fragment)**
**Grey (C-Pd) = Mbizane Formation (Permo-Carboniferous Dwyka Group, Karoo Supergroup)**
**Buff (Pp) = Prince Albert Formation (Early Permian, Ecca Group, Karoo Supergroup)**
**Pink (Jd) = Karoo Dolerite Suite (Early Jurassic)**
**Pale yellow (with or without stipple) = Late Caenozoic alluvium and pan sediments**
**White (Q) = sandy and reddish-brown sandy soil**

## 3. PALAEONTOLOGICAL HERITAGE

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

### 3.1. 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 – perhaps including those reported from the upper Dwyka beds in the Kenhardt sheet area (Slabbert *et al.* 1999, p. 107) - 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.

### 3.2. Fossils in the Prince Albert Formation

The fossil biota of the Prince Albert Formation is usefully summarized by Cole (2005). The typical *Umfolozia / Undichna* – dominated trace fossil assemblages of the non-marine *Mermia* ichnofacies commonly found in basinal mudrock facies of the Prince Albert Formation throughout the Ecca Basin have been briefly reviewed by Almond (2008a, 2008b). Diagenetic nodules containing the remains of palaeoniscoids (primitive bony fish), sharks, spiral bromalites (coprolites *etc*) and wood have been found in the Ceres Karoo and rare shark remains (*Dwykaselachus*) near Prince Albert on the southern margin of the Great Karoo (Oelofsen 1986). Microfossil remains in this formation include sponge spicules, foraminiferal and radiolarian protozoans, acritarchs and miospores.

The most diverse as well as biostratigraphically, palaeobiogeographically and palaeoecologically interesting fossil biota from the Prince Albert Formation is that described from calcareous concretions exposed along the Vaal River in the Douglas area of the Northern Cape, some 300 km ENE of the present study area (McLachlan and Anderson 1973, Visser *et al.,* 1977-78). The important Douglas biota contains petrified wood (including large tree trunks), palynomorphs (miospores), orthocone nautiloids, nuculid bivalves, articulate brachiopods, spiral and other "coprolites" (probably of fish, possibly including sharks) and fairly abundant, well-articulated remains of palaeoniscoid fish. Most of the fish have been assigned to the palaeoniscoid genus *Namaichthys* but additional taxa, including a possible acrolepid, may also be present here (Evans 2005). The invertebrates are mainly preserved as moulds.

Invertebrate trace fossils assigned to the ichnogenera *Chondrites* and *Thalassinoides* are recorded from the Kenhardt and Sakrivier sheet areas (Slabbert *et al.* 1999, Siebrits 1989). Stromatolites up to one meter across are also reported from the Prince Albert Formation in the Kenhardt sheet area, but these records need checking since some of them may refer rather to cone-in-cone structures within diagenetic nodules.

### 3.3. Fossils within the superficial deposits

The diverse superficial deposits within the South African interior have been comparatively neglected in palaeontological terms. However, sediments associated with ancient drainage systems, springs and pans in particular may occasionally contain important fossil biotas, notably the bones, teeth and horn cores of mammals as well as remains of reptiles like tortoises (*e.g.* Skead 1980, Klein 1984b, 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, Brink & Rossouw 2000, Rossouw 2006). Other late Caenozoic fossil biotas that may occur within these superficial deposits include non-marine molluscs (bivalves, gastropods), ostrich egg shells, trace fossils (*e.g.* calcretised termitaria, coprolites, invertebrate burrows, rhizocretions), and plant material such as peats or palynomorphs (pollens) in organic-rich alluvial horizons (Scott 2000) and diatoms in pan sediments. 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). Ancient solution hollows within extensive calcrete hardpans may have acted as animal traps in the past. As with coastal and interior limestones, they might occasionally contain mammalian bones and teeth (perhaps associated with hyaena dens) or invertebrate remains such as snail shells.

Diverse fossils associated with the ancient Tertiary drainage systems of the Karoo and Bushmanland region have been summarized by Almond in Macey *et al.* (2008. See also articles 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).

In the Brandvlei area to the southwest of Kenhardt lies the north-south trending Geelvloer Palaeo-valley, a Mid Tertiary palaeodrainage system that links up with the Commissioners Pan – Koa Valley system to the northwest. Here calcretised basal alluvial facies contain bones of hippopotamus-like artiodactyls called anthracotherids indicating a Miocene age (De Wit 1993, 1999, De Wit *et al*. 2000). Anthracotherids are an extinct group of amphibious mammalian herbivores only distantly related to true hippos that were widespread in the Miocene of Africa (Schneider & Marais 2004). Early to Middle Miocene silicified woods from Brandvlei are referable to a number of extant tree families, including the Dipterocarpaceae that mainly inhabit tropical forests in Africa and Asia today. The fossil woods and associated sediments indicate that warm, tropical to subtropical climates prevailed in the Mid Miocene and that perennial, low-sinuousity braided river systems supported lush riparian forests (De Wit & Bamford 1993, Bamford & De Wit 1993, Bamford 2000b). Wet, weakly seasonal climates are suggested by the structure (indistinct growth rings) and dimensions (trunk diameters of over 50 cm) of the fossil woods (Bamford 2000).

Abraded Plio-Pleistocene fossil woods from relict alluvial terraces of the Sak River just north of Brandvlei include members of the Family Polygalaceae and also indicate humid growth conditions (Bamford & De Wit 1993). These terraces were formed by meandering rivers during intermittent pluvial (*i.e.* wetter), but still semi-arid, episodes following the onset of generally arid conditions in the western portion of southern Africa towards the end of the Miocene. So far fossils have not been recorded from the Sakrivier system closer to Kenhardt.

Pan sediments in BUshmanland have also recently yielded interesting Pleistocene mammalian faunas in association with age-diagnostic archaeological material. 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 the farm Hoekplaas near Copperton. 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.

## 4. CONCLUSIONS & RECOMMENDATIONS

The farms Steyn Vlei 280, Gemsbok Rivier 301 and the southern portion of Melkbosch Vlei 278 are largely underlain by Early Permian marine sediments of the Prince Albert Formation (Ecca Group) that contain important fish, invertebrate and wood fossils in some parts of the Northern Cape (*e.g.* Douglas area). The Ecca sediments here have probably been locally baked by intrusive dolerites that crop out along the eastern margin of the farm. The remainder of the broader study area (including footprints of the proposed approximate 30-km 132 kV transmission line to Aries Substation, pipeline and railway siding) lies within the outcrop area of the Permo-Carboniferous Dwyka Group. The Dwyka glacial tillites are of low palaeontological sensitivity while thin-bedded interglacial mudrocks may contain trace fossils, plant material, as well as rare fossil fish and invertebrates. However, exposure levels of the Dwyka sediments in the Kenhardt sheet area are generally poor. A substantial fraction of the Karoo Supergroup sediments within the broader study area are mantled by Late Caenozoic superficial deposits such as downwasted gravels (*e.g.* glacial erratics from the Dwyka tillites), alluvial and pan sediments as well as various soils. Most of these younger surface deposits are of low palaeontological sensitivity. Biostratigraphically and palaeoenvironmentally interesting fossil mammals remains have been recorded in association with stratified pan sediments in Bushmanland. Important Late Tertiary mammalian and other vertebrate fossils as well as petrified woods found in association with ancient drainage systems crossing Bushmanland, such as the Sakrivier system near Brandvlei, might also occur closer to Kenhardt.

As part of the EIA for this project a Phase 1 field-based assessment of palaeontological heritage resources on all land parcels within the broader study area should be carried out by a professional palaeontologist. The field study would focus on potentially fossiliferous sediments of the Ecca Group and Dwyka Group (interglacial beds), as well as any sections exposing older alluvium, pan deposits and calcretised units. The Phase 1 report would describe and map any fossil remains encountered, assess their heritage significance, and make appropriate recommendations to SAHRA regarding further studies or mitigation required, if any, for the pre-construction and construction phases of the development.

All palaeontological specialist work should conform to international best practice for palaeontological fieldwork and the study (*e.g.* data recording fossil collection and curation, final report) should adhere as far as possible to the minimum standards for Phase 1 and 2 palaeontological studies recently developed by SAHRA (2013).

**Table 1: Fossil heritage recorded from the major rock units that are represented (or probably represented) in the broader solar energy facility study area near Kenhardt**

| GEOLOGICAL UNIT | ROCK TYPES & AGE | FOSSIL HERITAGE | PALAEONT-OLOGICAL SENSITIVITY |
|---|---|---|---|
| **LATE CAENOZOIC SUPERFICIAL SEDIMENTS,<br><br>especially<br><br>ALLUVIAL & PAN SEDIMENTS** | **fluvial, pan, lake and terrestrial sediments, including diatomite (diatom deposits), pedocretes (*e.g.* calcrete), colluvium (slope deposits such as scree), aeolian sands<br><br>LATE TERTIARY, PLEISTOCENE TO RECENT** | **bones and teeth of wide range of mammals (*e.g.* mastodont proboscideans, rhinos, bovids, horses, micromammals), fish, reptiles (crocodiles, tortoises), ostrich egg shells, fish, freshwater and terrestrial molluscs (unionid bivalves, gastropods), crabs, trace fossils (*e.g.* calcretised termitaria, horizontal invertebrate burrows, stone artefacts), petrified wood, leaves, rhizoliths, stromatolites, diatom floras, peats and palynomorphs.** | **GENERALLY LOW BUT LOCALLY HIGH<br><br>(*e.g.* Tertiary alluvium associated with old river courses)** |
| **Prince Albert Formation<br><br>ECCA GROUP** | **marine to hyposaline basin plain mudrocks, minor volcanic ashes, phosphates and ironstones, post-glacial mudrocks at base<br><br>EARLY PERMIAN** | **low diversity marine invertebrates (bivalves, nautiloids, brachiopods), palaeoniscoid fish, sharks, fish coprolites, protozoans (foraminiferans, radiolarians), petrified wood, palynomorphs (spores, acritarchs), non-marine trace fossils (especially arthropods, fish, also various "worm" burrows), possible stromatolites, oolites** | **MEDIUM<br><br>BUT LOCALLY HIGH IN N. CAPE** |
| **KAROO DOLERITE SUITE** | **intrusive dolerites (dykes, sills), associated diatremes<br><br>EARLY JURASSIC** | **none** | **ZERO** |
| **Mbizane Formation<br><br>DWYKA GROUP** | **tillites, interglacial mudrocks, deltaic & turbiditic sandstones, minor thin limestones<br><br>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** | **LOW TO MODERATE** |
| **De Bakken Granite<br><br>NAMAQUA-NATAL PROVINCE** | **highly metamorphosed sediments, intrusive granites<br><br>MID-PROTEROZOIC (*c.* 2 billion yrs old)** | **none** | **ZERO** |

## 5. ACKNOWLEDGEMENTS

Ms Umeshree Naicker of Savannah Environmental (Pty) Ltd, Woodmead, is thanked for commissioning this study and for kindly providing all the necessary background information.

## 6. REFERENCES

AGENBACHT, A.L.D. 2007. The geology of the Pofadder area. Explanation of 1: 250 000 geology sheet 2918. 89 pp. Council for Geoscience, Pretoria.

ALMOND, J.E. 2008a. Fossil record of the Loeriesfontein sheet area (1: 250 000 geological sheet 3018). Unpublished report for the Council for Geoscience, Pretoria, 32 pp.

ALMOND, J.E. 2008b. Palaeozoic fossil record of the Clanwilliam sheet area (1: 250 000 geological sheet 3218). Unpublished report for the Council for Geoscience, Pretoria, 49 pp. (To be published by the Council in 2009).

ALMOND, J.E. 2009. Contributions to the palaeontology and stratigraphy of the Alexander Bay sheet area (1: 250 000 geological sheet 2816), 117 pp. Unpublished technical report prepared for the Council for Geoscience by Natura Viva cc, Cape Town.

ALMOND, J.E. 2011. Proposed Solar Cape Photovoltaic Electricity Generation Facility near Kenhardt, Northern Cape Province. Palaeontological impact assessment: desktop study, 18 pp. Natura Viva cc, Cape Town.

ALMOND, J.E. & PETHER, J. 2008. Palaeontological heritage of the Northern Cape. Interim SAHRA technical report, 124 pp. Natura Viva cc., Cape Town.

ANDERSON, A.M. 1974. Arthropod trackways and other trace fossils from the Early Permian lower Karoo Beds of South Africa. Unpublished PhD thesis, University of Witwatersrand, Johannesburg, 172 pp.

ANDERSON, A.M. 1975. Turbidites and arthropod trackways in the Dwyka glacial deposits (Early Permian) of southern Africa. Transactions of the Geological Society of South Africa 78: 265-273.

ANDERSON, A.M. 1976. Fish trails from the Early Permian of South Africa. Palaeontology 19: 397-409, pl. 54.

ANDERSON, A.M. 1981. The *Umfolozia* arthropod trackways in the Permian Dwyka and Ecca Groups of South Africa. Journal of Paleontology 55: 84-108, pls. 1-4.

ANDERSON, A.M. & MCLACHLAN, I.R. 1976. The plant record in the Dwyka and Ecca Series (Permian) of the south-western half of the Great Karoo Basin, South Africa. Palaeontologia africana 19: 31-42.

ANDERSON, J.M. 1977. The biostratigraphy of the Permian and the Triassic. Part 3: A review of Gondwana Permian palynology with particular reference to the northern Karoo Basin, South Africa. Memoirs of the Botanical Survey of South Africa 45, 14-36.

ANDERSON, J.M. & ANDERSON, H.M. 1985. Palaeoflora of southern Africa. Prodromus of South African megafloras, Devonian to Lower Cretaceous, 423 pp, 226 pls. Botanical Research Institute, Pretoria & Balkema, Rotterdam.

BAMFORD, M.K. 2000. Fossil woods of Karoo age deposits in South Africa and Namibia as an aid to biostratigraphical correlation. Journal of African Earth Sciences 31, 119-132.

BAMFORD, M.K. 2004. Diversity of woody vegetation of Gondwanan South Africa. Gondwana Research 7, 153-164.

BAMFORD, M.K. & DE WIT, M.C.J. 1993. Taxonomic description of fossil wood from Cainozoic Sak River terraces, near Brandvlei, Bushmanland, South Africa. Palaeontologia africana 30: 71-80.

BANGERT, B., STOLLHOFEN, H., LORENTZ, V. & ARMSTRONG, R. 1999. The geochronology and significance of ash-fall tuffs in the glacigenic Carboniferous – Permian Dwyka Group of Namibia and South Africa. Journal of African Earth Sciences 29: 33-49.

BANGERT, B., STOLHOFEN, H., GEIGER, M. & LORENZ, V. 2000. Fossil record and high resolution tephrostratigraphy of Carboniferous glaciomarine mudstones, Dwyka Group, southern Namibia. Communications of the Geological Survey of Namibia 12, 235-245.

BANGERT, B. & BAMFORD, M. 2001. Carboniferous pycnoxylic woods from the Dwyka Group of southern Namibia. Palaeontologia africana 37, 13-23.

BENDER, P.A. & BRINK, J.S. 1992. A preliminary report on new large mammal fossil finds from the Cornelia-Uitzoek site. South African Journal of Science 88: 512-515.

BOUSMAN, C.B. et al. 1988. Palaeoenvironmental implications of Late Pleistocene and Holocene valley fills in Blydefontein Basin, Noupoort, C.P., South Africa. Palaeoecology of Africa 19: 43-67.

BRINK, J.S. 1987. The archaeozoology of Florisbad, Orange Free State. Memoirs van die Nasionale Museum 24, 151 pp.

BRINK, J.S. et al. 1995. A new find of Megalotragus priscus (Alcephalini, Bovidae) from the Central Karoo, South Africa. Palaeontologia africana 32: 17-22.

BRINK, J.S. & ROSSOUW, L. 2000. New trial excavations at the Cornelia-Uitzoek type locality. Navorsinge van die Nasionale Museum Bloemfontein 16, 141-156.

BUATOIS, L. & MANGANO, M.G. 1995. The paleoenvironmental and paleoecological significance of the lacustrine *Mermia* ichnofacies: an archetypal subaqueous nonmarine trace fossil assemblage. Ichnos 4: 151-161.

BUATOIS, L. & MANGANO, M.G. 2004. Animal-substrate interactions in freshwater environments: applications of ichnology in facies and sequence stratigraphic analysis of fluvio-lacustrine successions. In: McIlroy, D. (Ed.) The application of ichnology to palaeoenvironmental and stratigraphic analysis. Geological Society, London, Special Publications 228, pp 311-333.

BUTZER, K.W., HELGREN, D.M., FOCK, G. & STUCKENRATH, R. 1973. Alluvial terraces of the Lower Vaal River, South Africa: a re-appraisal and re-investigation. Journal of geololgy 81, 341-362.

CHURCHILL, S.E. et al. 2000. Erfkroon: a new Florisian fossil locality from fluvial contexts in the western Free State, South Africa. South African Journal of Science 96: 161-163.

COLE, D.I. 2005. Prince Albert Formation. SA Committee for Stratigraphy, Catalogue of South African Lithostratigraphic Units 8: 33-36.

COOKE, H.B.S. 1949. Fossil mammals of the Vaal River deposits. Memoirs of the geological Survey of South Africa 35, 1-117.

COOPER, M.R. & OOSTHUIZEN, R. 1974. Archaeocyathid-bearing erratics from Dwyka Subgroup (Permo-Carboniferous) of South Africa, and their importance to continental drift. Nature 247, 396-398.

DE WIT, M.C.J. 1990. Palaeoenvironmental interpretation of Tertiary sediments at Bosluispan, Namaqualand. Palaeoecology of Africa and the surrounding islands 21: 101-118.

DE WIT, M.C.J. 1993. Cainozoic evolution of drainage systems in the north-western Cape. Unpublished PhD thesis, University of Cape Town, Cape Town, 371 pp.

DE WIT, M.C.J. 1999. Post-Gondwana drainage and the development of diamond placers in western South Africa. Economic Geology 94: 721-740.

DE WIT, M.C.J. & BAMFORD, M.K. 1993. Fossil wood from the Brandvlei area, Bushmanland as an indication of palaeoenvironmental changes during the Cainozoic. Palaeontologia africana 30: 81-89.

DE WIT, M.C.J., MARSHALL, T.R. & PARTRIDGE, T.C. 2000. Fluvial deposits and drainage evolution. In: Partridge, T.C. & Maud, R.R. (Eds.) The Cenozoic of southern Africa, pp.55-72. Oxford University Press, Oxford.

DICKENS, J.M. 1961. *Eurydesma* and *Peruvispira* from the Dwyka Beds of South Africa. Palaeontology 4: 138-148, pl. 18.

DICKENS, J.M. 1984. Late Palaeozoic glaciation. BMR Journal of Australian Geology and Geophysics 9: 163-169.

DINGLE, R.V., SIESSER, W.G. & NEWTON, A.R. 1983. Mesozoic and Tertiary geology of southern Africa. viii + 375 pp. Balkema, Rotterdam.

DU TOIT, A. 1954. The geology of South Africa. xii + 611pp, 41 pls. Oliver & Boyd, Edinburgh.

ERIKSSON, P.G., ALTERMANN, W. & HARTZER, F.J. 2006. The Transvaal Supergroup and its precursors. In: Johnson, M.R., Anhaeusser, C.R. & Thomas, R.J. (Eds.) The geology of South Africa, pp. 237-260. Geological Society of South Africa, Marshalltown.

EVANS, F.J.E. 2005. Taxonomy, palaeoecology and palaeobiogeography of some Palaeozoic fish of southern Gondwana. Unpublished PhD thesis, University of Stellenbosch, 628 pp.

GRILL, H. 1997. The Permo-Carboniferous glacial to marine Karoo record in southern Namibia: sedimentary facies and sequence stratigraphy. Beringeria 19: 3-98, 1 pl.

HADDON, I.G. 2000. Kalahari Group sediments. In: Partridge, T.C. & Maud, R.R. (Eds.) The Cenozoic of southern Africa, pp. 173-181. Oxford University Press, Oxford.

HELGREN, D.M. 1977. Geological context of the Vaal River faunas. South African Journal of Science 73, 303-307.

HERBERT, C.T. & COMPTON, J.S. 2007. Depositional environments of the lower Permian Dwyka diamictite and Prince Albert shale inferred from the geochemistry of early diagenetic concretions, southwest Karoo Basin, South Africa. Sedimentary Geology 194: 263-277.

JOHNSON, M.R., VAN VUUREN, C.J., VISSER, J.N.J., COLE, D.I., De V. WICKENS, H., CHRISTIE, A.D.M., ROBERTS, D.L. & BRANDL, G. 2006. Sedimentary rocks of the Karoo Supergroup. In: Johnson, M.R., Anhaeusser, C.R. & Thomas, R.J. (Eds.) The geology of South Africa, pp. 461-499. Geological Society of South Africa, Marshalltown.

KIBERD, P. 2006. Bundu Farm: a report on archaeological and palaoenvironmental assemblages from a pan site in Bushmanland, Northern Cape, South Africa. South African Archaeological Bulletin 61, 189-201.

KLEIN, R. 1980. Environmental and ecological implications of large mammals from Upper Pleistocene and Hoocene sites in southern Africa. Annals of the South African Museum 81, 223-283.

KLEIN, R.G. 1984a. The large mammals of southern Africa: Late Pliocene to Recent. In: Klein, R.G. (Ed.) Southern African prehistory and paleoenvironments, pp 107-146. Balkema, Rotterdam.

KLEIN, R.G. 1984b. Palaeoenvironmental implications of Quaternary large mammals in the Fynbos region. In: Deacon, H.J., Hendey, Q.B., Lambrechts, J.J.N. (Eds.) Fynbos palaeoecology: a preliminary synthesis. South African National Scientific Programmes Report No. 10, pp. 116-133.

KLEIN, R. 2000. The Earlier Stone Age in southern Africa. The South African Archaeological Bulletin 40, 107-122.

MACEY, P.H., SIEGFRIED, H.P., MINNAAR, H., ALMOND, J. AND BOTHA, P.M.W. 2011. The geology of the Loeriesfontein Area. Explanation to 1: 250 000 Geology Sheet 3018 Loeriesfontein, 139 pp. Council for Geoscience, Pretoria.

MACRAE , C. 1999. Life etched in stone. Fossils of South Africa. 305 pp. The Geological Society of South Africa, Johannesburg.

MCLACHLAN, I.R. & ANDERSON, A. 1973. A review of the evidence for marine conditions in southern Africa during Dwyka times. Palaeontologia africana 15: 37-64.

MEADOWS, M.E. & WATKEYS, M.K. 1999. Palaeoenvironments. In: Dean, W.R.J. & Milton, S.J. (Eds.) The karoo. Ecological patterns and processes, pp. 27-41. Cambridge University Press, Cambridge.

MILLER, R.M. 2008. Karoo Supergroup, pp. 16-1 to 16-115 *in* Miller, R.G. The geology of Namibia. Volume 3. Upper Palaeozoic to Cenozoic. Geological Survey, Namibia.

OELOFSEN, B.W. 1986. A fossil shark neurocranium from the Permo-Carboniferous (lowermost Ecca Formation) of South Africa. In: Uyeno, T, Arai, R., Taniuchi, T & Matsuura, K. (Eds.) Indo-Pacific fish biology. Proceedings of the Second International Conference on Indo-Pacific Fishes. Ichthyological Society of Japan, Tokyo, pp 107-124.

ORTON, J. 2012. Heritage impact assessment for a proposed solar energy facility on the farm Hoekplaas near Copperton, Northern Cape, 32 pp. Archaeology Contracts Office, University of Cape Town, Cape Town.

PARTRIDGE, T.C. & SCOTT, L. 2000. Lakes and Pans. In: Partridge, T.C. & Maud, R.R. (Eds.) The Cenozoic of southern Africa, pp.145-161. Oxford University Press, Oxford.

PARTRIDGE, T.C., BOTHA, G.A. & HADDON, I.G. 2006. Cenozoic deposits of the interior. In: Johnson, M.R., Anhaeusser, C.R. & Thomas, R.J. (Eds.) The geology of South Africa, pp. 585-604. Geological Society of South Africa, Marshalltown.

PICKFORD, M. & SENUT, B. 2002. The fossil record of Namibia. 39 pp. The Geological Survey of Namibia.

PLUMSTEAD, E.P. 1969. Three thousand million years of plant life in Africa. Alex Du Toit Memorial Lectures No. 11. Transactions of the Geological Society of South Africa, Annexure to Volume 72, 72pp. 25 pls.

PRINSLOO, M.C. 1989. Die geologie van die gebied Britstown. Explanation to 1: 250000 geology Sheet 3022 Britstown, 40 pp. Council for Geoscience, Pretoria.

ROSSOUW, L. 2006. Florisian mammal fossils from erosional gullies along the Modder River at Mitasrust Farm, Central Free State, South Africa. Navorsinge van die Nasionale Museum Bloemfontein 22, 145-162.

SAHRA 2013. Minimum standards: palaeontological component of heritage impact assessment reports, 15 pp. South African Heritage Resources Agency, Cape Town.

SAVAGE, N.M. 1970. A preliminary note on arthropod trace fossils from the Dwyka Series in Natal. IUGS Second Gondwana Symposium, South Africa, 1970, Proceedings and Papers, pp 627-635, pls. 1-5.

SAVAGE, N.M. 1971. A varvite ichnocoenosis from the Dwyka Series of Natal. Lethaia 4: 217-233.

SCHNEIDER, G. & MARAIS, C. 2004. Passage through time. The fossils of Namibia. 158 pp. Gamsberg MacMillan, Windhoek.

SCOTT, L. 2000. Pollen. In: Partridge, T.C. & Maud, R.R. (Eds.) The Cenozoic of southern Africa, pp.339-35. Oxford University Press, Oxford.

SEILACHER, A. 2007. Trace fossil analysis, xiii + 226pp. Springer Verlag, Berlin.

SENUT, B., PICKFORD, M., WARD, J., DE WIT, M., SPAGGIARI, R. & MORALES, J. 1996. Biochronology of the Cainozoic sediments at Bosluis Pan, Northern Cape Province, South Africa. South African Journal of Science 92: 249-251.

SIEBRITS, L.B. 1989. Die geologie van die gebied Sakrivier. Explanation of 1: 250 000 geology sheet 3020, 19 pp. Council for Geoscience, Pretoria.

SKEAD, C.J. 1980. Historical mammal incidence in the Cape Province. Volume 1: The Western and Northern Cape, 903pp. Department of Nature and Environmental Conservation, Cape Town.

SLABBERT, M.J., MOEN, H.F.G. & BOELEMA, R. 1999. Die geologie van die gebied Kenhardt. Explanation to 1: 250 000 geology Sheet 2920 Kenhardt, 123 pp. Council for Geoscience, Pretoria.

STAPLETON, R.P. 1977. Carboniferous unconformity in southern Africa. Nature 268, 222-223.

STEPHENSON, M.H. 2008. A review of the palynostratigraphy of Gondwanan Late Carboniferous to Early Permian glacigene successions. In: Fielding, C.R., Frank, T.D. & Isbell, J.L. (eds). Resolving the Late Paleozoic Ice Age in time and space. Geological Society of America Special Paper 441, 317-330.

STOLLHOFEN, H., STANISTREET, I.G., BANGERT, B. & GRILL, H. 2000. Tuffs, tectonism and glacially-related sea-level changes, Carboniferous-Permian, southern Namibia. Palaeogeography, Palaeoclimatology, Palaeoecology 161: 127-150.

STONE, P. & THOMSON, M.R.A. 2005. Archaeocyathan limestone blocks of likely Antarctic origin in Gondwanan tillite from the Falkland Islands. Geological Society, London, Special Publications 246, 347-357.

THOMAS, M.J. 1981. The geology of the Kalahari in the Northern Cape Province (Areas 2620 and 2720). Unpublished MSc thesis, University of the Orange Free State, Bloemfontein, 138 pp.

THOMAS, R.J., THOMAS, M.A. & MALHERBE, S.J. 1988. The geology of the Nossob and Twee Rivieren areas. Explanation for 1: 250 000 geology sheets 2520-2620. 17pp. Council for Geoscience, Pretoria.

THOMAS, D.S.G. & SHAW, P.A. 1991. The Kalahari environment, 284 pp. Cambridge University Press.

VEEVERS, J.J., COLE, D.I. & COWAN, E.J. 1994. Southern Africa: Karoo Basin and Cape Fold Belt. Geological Society of America, Memoir 184: 223-279.

VISSER, J.N.J. 1982. Upper Carboniferous glacial sedimentation in the Karoo Basin near Prieska, South Africa. Palaeogeography, Palaeoclimatology, Palaeoecology 38, 63-92.

VISSER, J.N.J. 1985. The Dwyka Formation along the north-western margin of the Karoo Basin in the Cape Province, South Africa. Transactions of the Geological Society of South Africa 88, 37-48.

VISSER, J.N.J. 1989. The Permo-Carboniferous Dwyka Formation of southern Africa: deposition by a predominantly subpolar marine ice sheet. Palaeogeography, Palaeoclimatology, Palaeoecology 70, 377-391.

VISSER, J.N.J. 1992. Deposition of the Early to Late Permian Whitehill Formation during a sea-level highstand in a juvenile foreland basin. South African Journal of Geology 95: 181-193.

VISSER, J.N.J. 1997. Deglaciation sequences in the Permo-Carboniferous Karoo and Kalahari Basins of southern Africa: a tool in the analysis of cyclic glaciomarine basin fills. Sedimentology 44: 507-521.

VISSER, J.N.J. 2003. Lithostratigraphy of the Elandsvlei Formation (Dwyka Group). South African Committee for Stratigraphy, Lithostratigraphic Series No. 39, 11 pp. Council for Geoscience, Pretoria.

VISSER, J.N.J., LOOCK, J.C., VAN DER MERWE, J., JOUBERT, C.W., POTGIETER, C.D., MCLAREN, C.H., POTGIETER, G.J.A., VAN DER WESTHUIZEN, W.A., NEL, L. & LEMER, W.M. 1977-78. The Dwyka Formation and Ecca Group, Karoo Sequence, in the northern Karoo Basin, Kimberley-Britstown area. Annals of the Geological Survey of South Africa 12, 143-176.

VISSER, J.N.J., VON BRUNN, V. & JOHNSON, M.R. 1990. Dwyka Group. Catalogue of South African Lithostratigraphic Units 2, 15-17. Council for Geoscience, Pretoria.

VISSER, J.N.J., VAN NIEKERK, B.N. & VAN DER MERWE, S.W. 1997. Sediment transport of the Late Palaeozoic glacial Dwyka Group in the southwestern Karoo Basin. South African Journal of Geology 100: 223-236.

VON BRUNN, V. & VISSER, J.N.J. 1999. Lithostratigraphy of the Mbizane Formation (Dwyka group). South African Committee for Stratigraphy, Lithostratigraphic Series No. 32, 10 pp. Council for Geoscience, Pretoria.

WELLS, L.H. 1964. The Vaal River 'Younger Gravels" faunal assemblage: a revised list. South African Journal of Science 60, 92-94.

ZAWADA, P.K. 1992. The geology of the Koffiefontein area. Explanation of 1: 250 000 geology sheet 2924 Koffiefontein, 30 pp. Council for Geoscience, Pretoria.

**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 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 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**