PALAEONTOLOGICAL HERITAGE ASSESSMENT: COMBINED DESKTOP & FIELD-BASED STUDY

PROPOSED SOLARRESERVE KOTULO TSATSI ENERGY CSP AND PV SOLAR ENERGY FACILITIES NEAR KENHARDT, NORTHERN CAPE PROVINCE

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EXECUTIVE SUMMARY

SolarReserve Kotulo Tsatsi Energy is proposing to develop a 1000 MW Solar Power Facility (consisting of three (3) CSP Central Receiver Tower Projects with a generation capacity of up to 200MW each and two (2) CSP Trough Projects with a generation capacity of up to 200MW each) as well as (2) Photovoltaic (PV) Solar Energy facilities 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, Hantam Local Municipality, Northern Cape Province. The present report is a palaeontological heritage assessment of the proposed solar energy facility development area with a total area of approximately 20,700 hectares.

Desktop analysis of the fossil records of the various sedimentary rock units underlying the broader SolarReserve Kotulo Tsatsi Energy study area, including the solar energy facility development area and transmission/distribution overhead power line corridor, combined with field assessment of numerous representative rock exposures within and close to this area, indicate that all of these units are of low to very low palaeontological sensitivity. The potentially fossiliferous Karoo Supergroup bedrocks (Dwyka and Ecca Groups) are deeply weathered and extensively calcretised near-surface. Over the majority of their outcrop areas the bedrocks are mantled by various superficial deposits that may reach thicknesses of several meters and that are of low palaeontological sensitivity. These include alluvium, colluvium, as well as a wide range of surface gravels, calcrete hardpans and pan sediments. The only fossil remains recorded during the field assessment are (1) small-scale fossil burrows within Prince Albert Formation mudrocks of Early Permian age, (2) downwasted, ice-transported blocks (erratics) of Precambrian stromatolitic carbonate within surface gravels overlying the Dwyka Group tillites, and (3) rare calcretised termitaria (termite nests) of probable Pleistocene or younger age embedded within weathered Dwyka bedrocks. These fossils are all of widespread occurrence within Bushmanland and Namaqualand. Special protection or mitigation measures for the very few known fossil sites within the study area are therefore not considered warranted. Because of the generally sparse occurrence of fossils within all of the bedrock formations concerned in the Exheredo Solar Energy Facility study area, as well as within the pervasive overlying superficial sediments (soil, alluvium, colluvium *etc*), the magnitude of impacts on local palaeontological heritage resources is conservatively rated as LOW.

The potentially fossiliferous sedimentary rock units represented within the present study area (*e.g.* Prince Albert Formation, calcretes) are of widespread occurrence and this is also likely to apply to most of the fossils they contain. It concluded that the cumulative impacts on fossil

heritage resources posed by the known solar energy developments in the Kenhardt region is *low*.
Given the low impact significance of the proposed Exheredo Solar Energy Facility development as far as palaeontological heritage is concerned, no further specialist palaeontological heritage studies or mitigation are considered necessary for this component of the alternative energy project, pending the discovery or exposure of substantial new fossil remains during development.

During the construction phase all deeper (> 1 m) bedrock excavations (*e.g.* excavations for the CSP central receiver tower foundations, molten salt storage tanks & power block and associated infrastructure, water storage tanks, evaporation ponds, heliostat footing, underground cables, internal access roads, distribution/transmission overhead power line towers, the on-site substation, pipeline, construction camps, laydown areas and assembly plant) should be monitored for fossil remains by the responsible ECO. Should substantial fossil remains such as vertebrate bones and teeth, plant-rich fossil lenses or dense fossil burrow assemblages be exposed during construction, the responsible Environmental Control Officer should safeguard these, preferably *in situ*, and alert SAHRA, *i.e.* The South African Heritage Resources Authority, as soon as possible (Contact details: Mrs Colette Scheermeyer, P.O. Box 4637, Cape Town 8000. Tel: 021 462 4502. Email: cscheermeyer@sahra.org.za) so that appropriate action can be taken by a professional palaeontologist, at the developer's expense. Mitigation would normally involve the scientific recording and judicious sampling or collection of fossil material as well as associated geological data (*e.g.* stratigraphy, sedimentology, taphonomy) by a professional palaeontologist.

These mitigation recommendations should be incorporated into the Environmental Management Programme (EMPr) for the proposed development.

1. INTRODUCTION & BRIEF

1.1. Project outline

Solarreserve Kotulo Tsatsi Energy is proposing to develop a 1000 MW Solar Power Facility (1) using concentrated solar power tower technology as well as (2) Photovoltaic (PV) Solar Energy technology 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 has a total area of approximately 20 700 hectares and is situated *c.* 70 km southwest of Kenhardt and *c*. 60 km northeast of Brandvlei, Hantam Local Municipality (part of the Namaqua District Municipality) in the Northern Cape (Figs. 1 to 3).

The proposed **CSP facilities** will have a combined generating capacity of 1000 MW and comprise the following main infrastructural components:

- Central Receiver Tower technology with a heliostat field, molten salt storage and dry cooling (Solarreserve Kotulo Tsatsi Energy CSP Tower Plants 1, 2 and 3, each with a generation capacity of up to 200 MW generation capacity);
- power block housing a steam turbine.
- on-site 400 kV substation and 400 kV power line to turn in and out of the Aries-Helios 400 kV power line that traverses the development site;
- cabling. Overhead distribution/transmission lines running to Aries (132kV)

- access roads & internal roads;
- water abstraction point and supply pipeline;
- water storage tanks;
- lined evaporation ponds;
- workshop and office buildings;
- laydown and assembly areas;
- man camps (50 ha per CSP plant);
- administration areas (15 ha per CSP plant);
- two x CSP parabolic trough facilities, totalling up to 400 MW generation capacity.

The proposed **PV facility** will have a combined generation capacity of 200 MW (2 x with a generation capacity of up to 100 MW each) and will consist of the following infrastructure:

- photovoltaic (PV) panels;
- on-site substation and 132 kV power lines to evacuate the power from the facility to the Eskom Grid;
- mounting structures, to be either rammed steel piles or piles with pre-manufactured concrete footings, to support the PV panels;
- cabling between the project components, to be laid underground where practical;
- internal access roads;
- fencing;
- workshop area for maintenance, storage, and offices.

The grid connections of the CSP 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 (Fig. 2). The following options are under consideration for the grid connection:

- The construction of a 132 kV double circuit power line from the on-site substation of each CSP facility to the Eskom Aries substation and / or;
- Construction of a single circuit power line with a 132 kV feeder bay at Aries and associated infrastructure on each project site;
- Construction of a turn-in power line from each CSP facility to the existing Aries – Helios power line, including a 400 kV switching station and associated infrastructure on the project site.

Approximately 250 000 m^3 of water will be required during the construction and operational phases of each solar energy facility. It is proposed to construct a reservoir of 20 000 m^3 storage capacity that will top up supply to individual 5 000 m^3 reservoirs for each CSP facility. Water will be obtained from one or more of the following sources:

- Municipal supply from the waste water works conveyed *via* a pipeline;
- Groundwater abstracted from existing boreholes on site;
- Water abstracted from the Orange River conveyed *via* a pipeline.

The present palaeontological heritage assessment of the Exheredo solar energy facility study area (CSP and PV development areas, as outline in Figs. 2 and 3) 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: Mr Steven Ingle. 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: 072 386 9815. Email: steven@savannahsa.com. Postal address: P.O. Box 148, Sunninghill, 2157).

Please note that the transmission line study area between the CSP and PV development area on Styns Vley 280 and the Aries Substation is the subject of a separate palaeontological heritage report attached hereto.

1.2. Legislative context for palaeontological assessment studies

The CSP 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 (Sections 2 & 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 associated infrastructure (power block), water storage tanks, evaporation ponds, solar panel footings, underground cables, internal access roads, transmission line towers, the on-site substation and the pipeline. All these developments may adversely affect potential fossil heritage within the study area by destroying, disturbing or permanently sealing-in fossils at or beneath the surface of the ground that are then no longer available for scientific research or other public good. The operational and decommissioning phases of the solar energy facilities are unlikely to involve further adverse impacts on local palaeontological heritage, however.

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

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

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

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

(5) When the responsible heritage resources authority has reasonable cause to believe that any activity or development which will destroy, damage or alter any archaeological or palaeontological site is under way, and where no application for a permit has been submitted and no heritage resources management procedure in terms of section 38 has been followed, it may—
(a) serve on the owner or occupier of the site or on the person undertaking such development an order for the development to cease immediately for such period as is specified in the order;
(b) carry out an investigation for the purpose of obtaining information on whether or not an archaeological or palaeontological site exists and whether mitigation is necessary;
(c) if mitigation is deemed by the heritage resources authority to be necessary, assist the person on whom the order has been served under paragraph *(a)* to apply for a permit as required in subsection (4); and
(d) recover the costs of such investigation from the owner or occupier of the land on which it is believed an archaeological or palaeontological site is located or from the person proposing to undertake the development if no application for a permit is received within two weeks of the order being served.

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

1.3. Approach to the palaeontological heritage study

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

In preparing a palaeontological desktop study the potentially fossiliferous rock units (groups, formations *etc*) represented within the study area are determined from geological maps and satellite images. The known fossil heritage within each rock unit is inventoried from the published scientific literature, previous palaeontological impact studies in the same region, and the author's field experience (consultation with professional colleagues as well as examination of institutional fossil collections may play a role here, or later following field assessment during the compilation of the final report). This data is then used to assess the palaeontological sensitivity of each rock unit to development (provisional tabulations of palaeontological sensitivity of all formations in the Western, Eastern and Northern Cape Province 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 project study area in the Kenhardt region of the Northern Cape Province preservation of potentially fossiliferous bedrocks is favoured by the semi-arid climate and sparse vegetation but bedrock exposure is largely 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 present combined desktop and field-based palaeontological study was largely based on the following sources of information:

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

2. Two short desktop palaeontological assessment reports for study areas near Kenhardt to the east of the present study area by the author (Almond 2011, 2014a);

3. An earlier desktop review of the relevant scientific literature, including published geological maps and accompanying sheet explanations, for the project near Kenhardt (Almond 2014b);

4. A four-day field assessment of the broader study area (including the transmission line corridor) during October 2014;

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

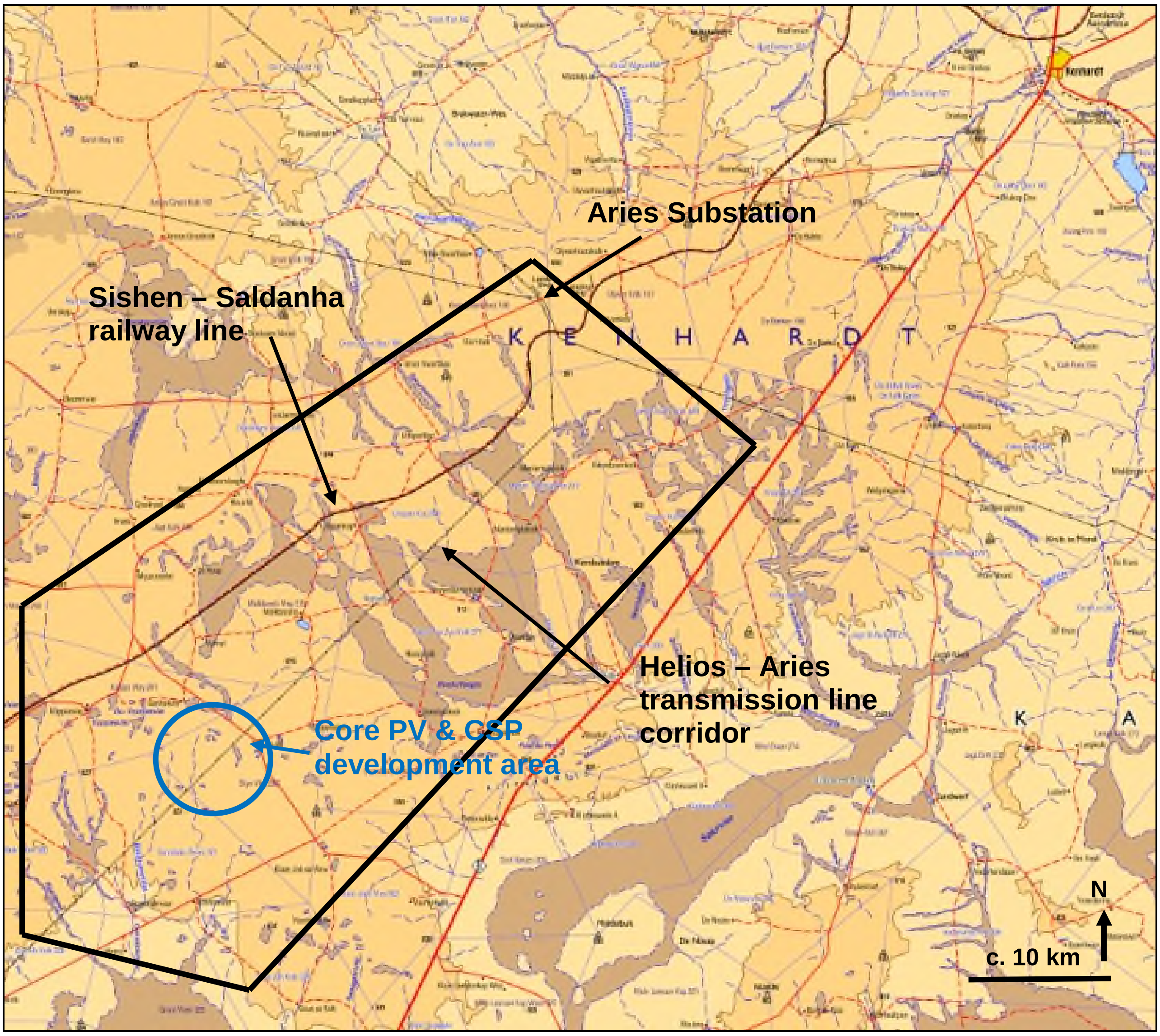

Fig. 1. Extract from 1: 250 000 topographical sheet 2920 Kenhardt showing the *approximate* location of the broader study area (black polygon) situated to the northwest of the R27 in eastern Bushmanland, *c.* 35 to 75 km southwest of Kenhardt, Northern Cape Province (Courtesy of the Chief Directorate of Surveys and Mapping, Mowbray). Note the existing Helios – Aries transmission line that traverses the study area from SW to NE. The present report covers the core PV and CSP development area in the southwest (blue ellipse).

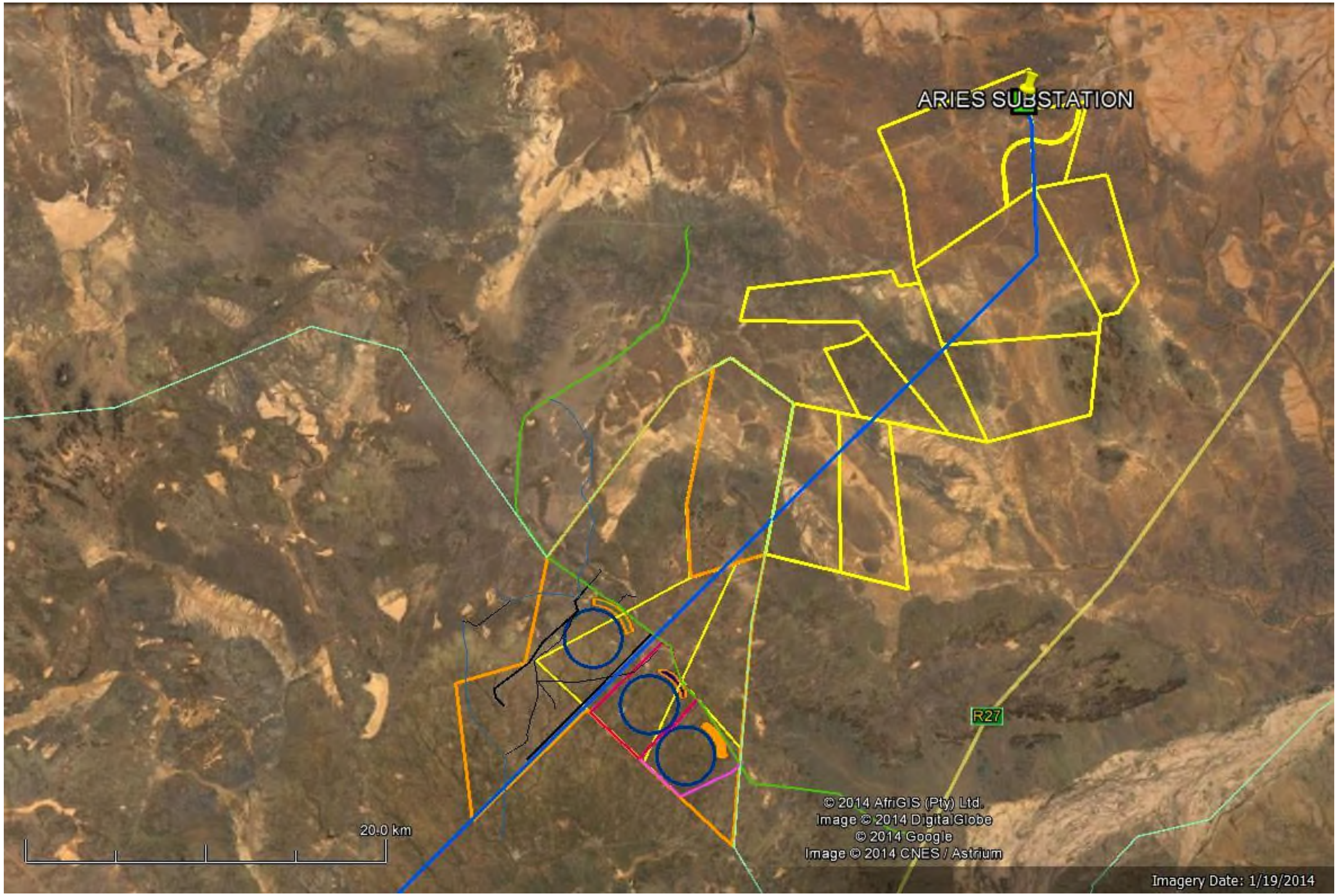

Fig. 2. Layout for the proposed CSP Solar Energy Facility near Kenhardt.

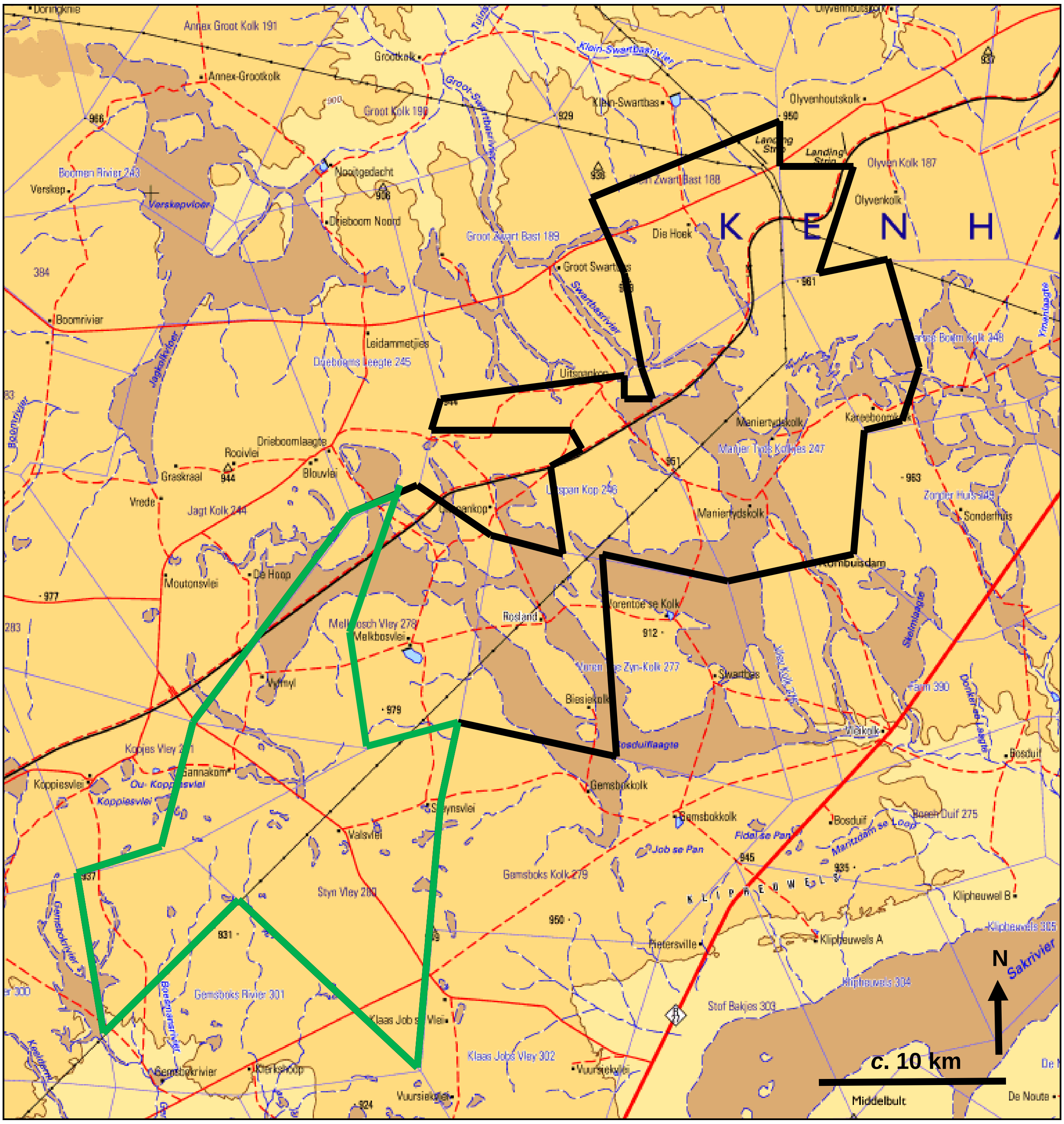

Fig. 3. Extract from 1: 250 000 topographical sheet 2920 Kenhardt showing the land parcels involved in the broader study area that includes the transmission line study area (black polygon) as well as the core study area for the proposed CSP and PV solar energy facilities themselves (green polygon) (Base map courtesy of the Chief Directorate of Surveys and Mapping, Mowbray).

2. GEOLOGICAL BACKGROUND

The broader study area - including the proposed transmission line to Aries Substation - is located to the northwest of R27 Brandvlei to Kenhardt tar road in semi-arid, low relief terrain between 900-1000 m amsl in the eastern Bushmanland region (*c*. 920 – 950 m amsl 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 existing 132 kV transmission line between Helios and Aries Substations 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 shallow 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 as well as a north-south zone of small *koppies* along the common border between Styns Vley 280 and Gemsboks Kolk 279.

The geology of the study area is outlined on the 1: 250 000 geology map 2920 Kenhardt (Council for Geoscience, Pretoria; Fig. 34 herein). An explanation to the Kenhardt geological map has been published by Slabbert *et al.* (1999) but gives little data on the sedimentary rocks. 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. 34) 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**). However, only the northernmost sector of the solar energy facility study area itself (green polygon in Fig. 34) is underlain by Dwyka rocks. The majority of the solar facility study area, including the entire development footprint on Styns 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 Styns 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 broader study area on the farm Karee Boom Kolk 248 and similar outcrops may also occur subsurface in the broder study area itself. These comprise two billion year old granitoid intrusions and highly metamorphosed sediments (*cf* Cornell *et al.* 2006); since they are entirely unfossiliferous, they are not dealt with further in this report.

The present field study shows that the Karoo Supergroup sediments, Karoo dolerites and any older basement rocks within the broader study area, including the solar energy facility development foorprint, are almost entirely mantled with a range of **Late Caenozoic superficial deposits**, mostly of Late Tertiary to Quaternary age. They include alluvium, pan sediments, calcrete hard pans as well as surface and subsurface gravels and may reach thicknesses of several meters or more. Where exposed in borrow pits along the major roads and the Sishen-Saldanha railway line and in other artificial excavations (*e.g.* farm dams), the bedrocks are often weathered and calcretised to a depth of several meters, reflecting periods of both drier and wetter climates in the geologically recent past. The projecting small *koppies* within the area consist largely of dolerite and occasionally of associated baked (thermally metamorphosed) country rocks.

In the following section of the report a summary of the main rock units represented within the broader study area (including solar energy facility study area as well as the transmission line corridor to Aries Substation) is given, together with a brief account of geological observations made during the palaeontological field assessment. This account is relevant to the solar energy facility study area because all these rock units are also represented there, albeit often hidden beneath superficial sediment cover. GPS data for all numbered localities mentioned in the text is given in the Appendix.

2.1. Dwyka Group

Permo-Carboniferous, glacially-related sediments of the **Dwyka Group** (**C-Pd**, grey in Fig. 34) underlie the thin, superficial cover of Late Caenozoic alluvium, pan sediments, soils and gravels over much of the north-eastern portion of the study area southwest of Kenhardt but only very rarely crop out naturally at surface. Dwyka rocks are also mapped in the northernmost sector of the solar energy facility study area (green polygon in Fig. 34). 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 ice sheets onto the continental highlands in the north. The valleys were then occupied by marine inlets within which drifting glaciers deposited dropstones onto the muddy sea bed ("boulder shales"). The upper Dwyka beds (**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 successions in Bushmanland 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.

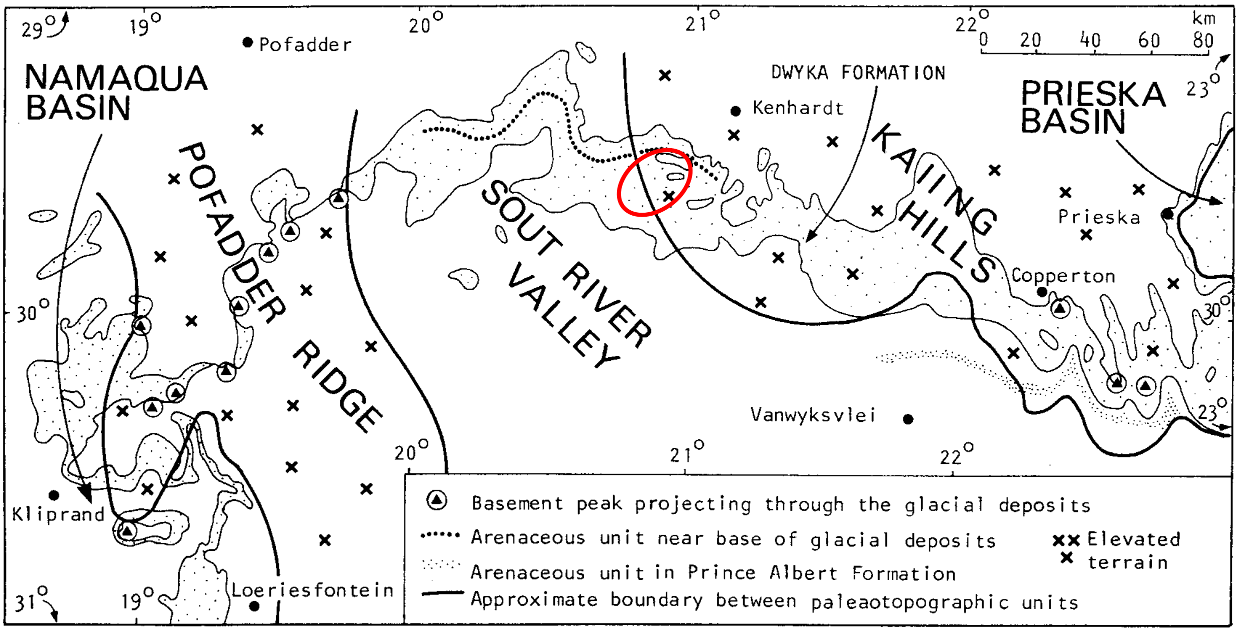

Fig. 4. Reconstruction of the topography along the northern margin of the Karoo Basin in Dwyka times showing location (red ellipse) of the study area to the SW of Kenhardt on a basement palaeo-high, the Kaaing Hills, with the Sout River palaeo-valley to the west (From Visser 1985).

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 190 m 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 near Kenhardt.

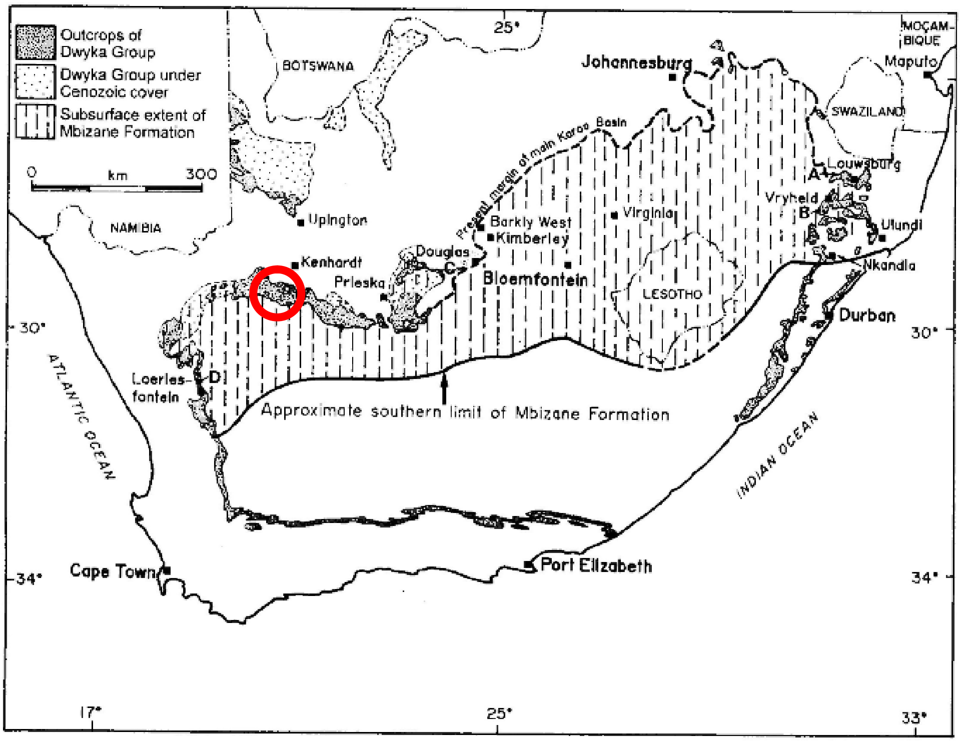

Fig. 5. Outcrop map of the Dwyka Group within the Main Karoo Basin of South Africa. Exposures in the study area southwest of Kenhardt (red circle) are assigned to the outcrop area of the Mbizane Formation (From Von Brunn & Visser 1999).

Natural exposures of Dwyka Group bedrocks were not observed within the study area; these sediments are easily weathered and eroded, so they are generally mantled here by up to several meters of superficial sediments.

Good exposures of weathered, friable, greyish, clast-poor Dwyka diamictites (tillites) are seen in several large borrow pits on Farms 278 and 246, close to the Sishen-Saldanha railway line (Locs. 043, 044, 045), as well as in deep cuttings along the railway line itself in the vicinity of the Aries Substation (Locs. 045, 048, 049) (Figs. 6 & 7). The sediments are generally massive but locally well-bedded, for example as seen in long railway cuttings on Klein Zwart Bast 188; these beds may represent submarine debris flow facies. Baking and reddening of Dwyka tillites is seen in railway cuttings at Loc. 048 (Tyds Kolkjes 247). No potentially fossiliferous interglacial mudrock laminites were observed, but packages of thin-bedded, grey-green siltstones mapped as Dwyka occur locally (*e.g.* Loc. 046) and may belong to the Mbizane Formation within the upper part of the Dwyka Group. Sphaeroidal pale yellowish diagenetic nodules of possible siliceous mineralogy are common within the massive to bedded diamitites, as are also large, sphaeroidal to irregular ferruginous carbonate concretions and lenses (Figs. 8 & 9).

Low exposures of well-jointed, well-consolidated, dark brown, medium-grained wackes observed on Melbosch Vlei 278 (Loc. 025; Fig. 10) probably belong to the heterolithic Mbizane

Formation. They include intervals of thin-bedded sandstones with small gravel dropstones, dispersed pebbly to cobbly erratics and calcareous concretions.

The weathered Dwyka bedrocks are pervasively mantled with silty alluvial soils (often calcretised in the subsurface) and characteristic polymict surface gravels (*e.g.* Locs. 033-035, Melbosch Vley 278) (Fig. 11). The latter comprise poorly-sorted, angular to well-rounded, pebbly to bouldery clasts dominated by more resistant-weathering rock types. They represent erratics weathered out from the underlying glacial beds and concentrated at the surface by downwasting processes, with a degree of fluvial reworking in places. They include a very wide range of rock types such as quartzites, conglomerates, lavas (*e.g.* several vesicular types), granitoids, banded ironstones, cherts, jaspilite and carbonates (dolomite, limestone), among others.Some of the boulder-sized clasts show well-developed glacial facetting and striation (Fig. 12).

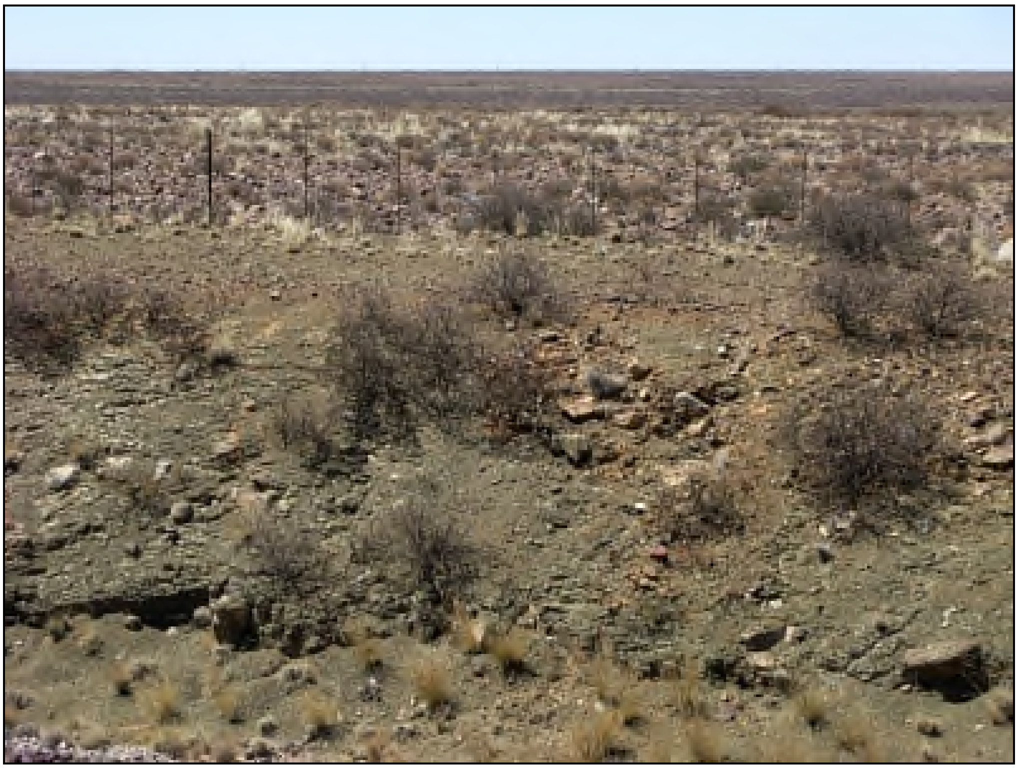

Fig. 6. Railway cutting exposure of clast-rich Dwyka Group tillites, Farm 278 (Loc. 045).

Fig. 7. Bedded clast-poor Dwyka diamictites exposed in a railway cutting on Zwart Bast 188, near Aries Substation (Loc. 049).

Fig. 8. Sphaeroidal carbonate diagenetic concretion from the Dwyka Group, borrow pit on Farm 278 (Specimen is *c*. 15 cm in diameter).

Fig. 9. Large, elongate concretion of brownish ferruginous carbonate within the Dwyka Group clast-poor diamictites, Farm 278 (Loc. 043) (Hammer = 30 cm).

Fig. 10. Low rocky exposure of brown-weathering wackes of the Mbizane Formation (Dwyka Group), Melkbosch Vley 278 (Loc. 025).

Fig. 11. Typical coarse polymict surface gravels overlying the Dwyka Group outcrop area, Melkbosch Vley 278 (Loc. 035).

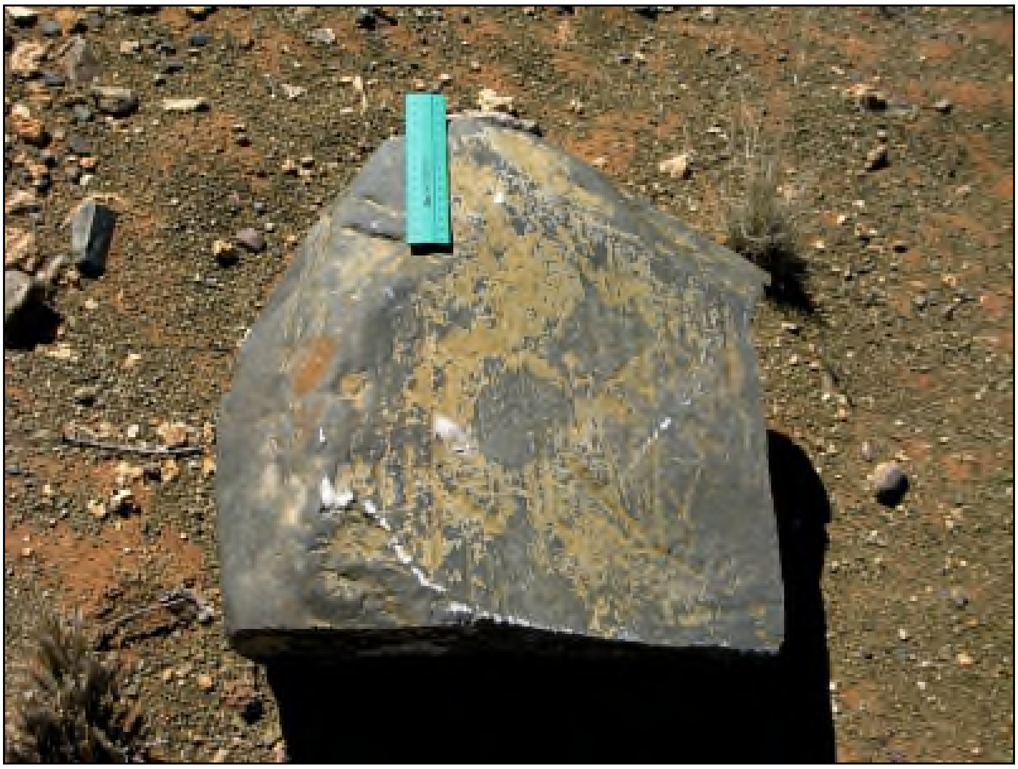

Fig. 12. Large glacially facetted and striated erratic from the Dwyka Group, Farm 278 (Loc. 045) (Scale = 15 cm).

2.2. Prince Albert Formation (Ecca Group)

The post-glacial basinal mudrocks of the Prince Albert Formation (Ppr, buff in Fig. 34) 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.

Prince Albert Formation mudrocks and fine-grained sandstones are mapped over the south-western portion of the broader study area. Including the great majority of the solar energy facility footprint on Styns Vley 280, where they are locally intruded and baked by Jurassic dolerite intrusions (Fig. 34). Natural surface exposure of fresh Ecca bedrocks within the study area is almost non-existent. However, good road cuttings through tabular-bedded, well-laminated and -jonted, grey-green to dark grey mudrocks of the Prince Albert Formation are seen in road cuttings along the R27 Calvinia – Brandvlei tar road (Loc. 051; Fig. 14). Rare glimpses into the subsurface Ecca bedrocks are also given in a pit excavation on Styns Vley 280 (Loc. 014). Here thin-bedded, grey-green to brownish, laminated to massive mudrocks are veined with calcrete to a depth of several meters and brecciated near surface. (Fig 15). Thin-bedded, well-jointed, calcrete-veined greenish siltstones of the same formation are seen near the dam wall at Loc. 016 (Styns Vlei 280).

The great majority of the Prince Albert Formation outcrop area is mantled with silty to sandy alluvial soils and downwasted surface gravels (Fig. 13). The latter include platy grey-green to brownish-weathering fine sandstone and siltstone, sometimes silicified or cherty, with subordinate black chert, rusty-hued ironstone, brown ferruginous carbonate concretion fragments, reworked calcrete, coarsely-crystalline vein quartz and dolerite, as well as anthropogenically imported quartzite and brownish-patinated hornfels (often flaked). In some areas the gravel clasts are extensively desert varnished (*e.g.* Loc. 030 Melkbosch Vley 278; Fig. 17) or contain numerous wind blasted (fluted, polished) ventifacts. Brown-patinated, platy fine sandstone and siltstone often forms a surface pavement or mosaic (*reg* or *serir*) overlying silty soils (*e.g.* Loc. 011, Styns Vley 280) with some clasts showing a near-vertical orientation (edgeways gravels) (Fig. 16). Surface gravels of baked dark brown, silicified sandstone (Loc. 009 on Styns Vley 280, Loc. 029 on Melkbosch Vley 278), irregular-fracturing orange-brown sandstone and silststone (Loc. 021, Styns Vley 280) or brown-patinated, dark-grey to black hornfels, frequently flaked (Locs. 028 and 032 on Melkbosch Vley 278), are seen in the vicinity of dolerite intrusions (Fig. 19).

Within the Prince Albert Formation outcrop area also occur horizons of abundant large, oblate to lenticular, dark brown to olive-brown ferruginous carbonate diagenetic concretions that often show stromatolite-like cone-in-cone fabrics internally (Figs. 18, 38 & 39). The subrounded concretions are up to meter-sized in diameter and 20-30 cm thick, but irregular lenticles may be much larger.

Fig. 13. Typical topographically-subdued, surface gravel-mantled outcrop area of the Prince Albert Formation within the study area (here along the transmission line on Styns Vley 280, Loc. 019). Note abundant pale calcrete gravel clasts here.

Fig. 14. Good exposures of tabular-bedded, laminated basinal mudrocks of the Prince Albert Formation in R27 road cutting (Loc. 051) (Hammer = 30 cm).

Fig. 15. Weathered and secondarily calcretised Prince Albert mudrocks exposed in a deep pit excavation on Styns Vley 280 (Loc. 014).

Fig. 16. Desert pavement of platy siltstone and sandstone gravel clasts overlying the Prince Albert Formation on Styns Vley 280 (Loc. 011) (Hammer = 30 cm). Note zones of edgewise, subvertical gravel clasts also seen here.

Fig. 17. Area of desert-varnished, well-sorted surface gravels overlying silty soils in the Prince Albert Formation outcrop area (Loc. 021, Styns Vley 280) (Hammer = 30 cm).

Fig. 18. Prince Albert Formation outcrop area mantled by sandy soils and abundant fragments of ferruginous carbonate concretions, Styns Vley 280 (Loc. 008).

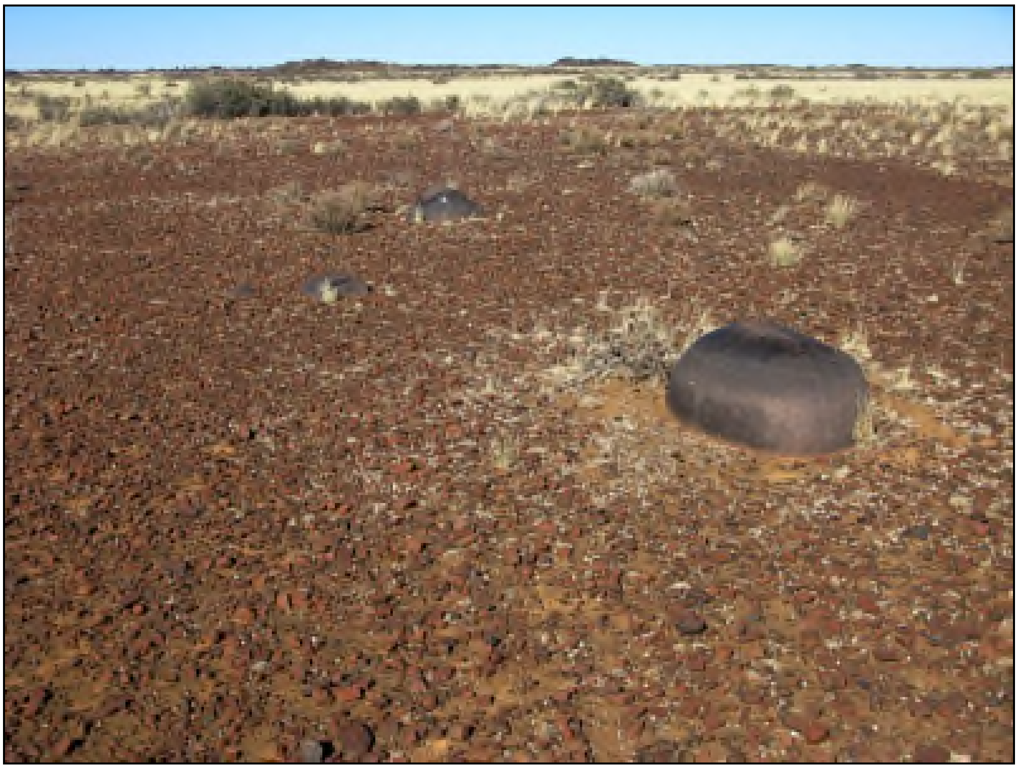

Fig. 19. Surface gravels of brown-patinated hornfels derived from baking of Prince Albert Formation mudrocks by dolerite intrusions, Melkbosch Vley 278 (Loc. 028).

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). Field studies in the broader study area show that these comprise a wide range of silty, sandy and gravelly alluvial deposits, colluvial rubble (*e.g.* dolerite scree on rocky hillslopes), surface gravels of various origins (*e.g.* downwasted products of bedrock weathering and erosion, such as the polymict bouldery erratics overlying the Dwyka Group outcrop area), pedocretes including widespread calcretes, pan sediments 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. 34) but aeolian sands of the Kalahari Group (Gordonia Formation) are not mapped here. They do occur closer to Kenhardt, however.

Subsurface nodular and hardpan calcretes occur widely within the study area within soils overlying the Dwyka and Ecca Groups as well as Karoo dolerite. Surface exposure of an extensive calcrete hardpan within the Prince Albert Formation outcrop area is seen on Styns Vley 280 (Loc. 013), although this might be related to hidden dolerite intrusion intrusion (Fig. 22). Several meters (locally > 3 m) of thick, pale brown to buff, silty soils with well-developed nodular calcretes in the upper portion overlie deeply-weathered dolerite *sabunga* threaded with calcrete veins in borrow pits on Styns Vley 280 (Loc. 010) and on Kopjes Vley 281 (Locs. 039 & 040). Extensive development of calcrete over dolerite and Dwyka rocks is well seen in a series of large borrow pits along the Sishen – Saldanha railway line as well as nearby railway cuttings (Locs. 042-050). Locally the calcrete horizons contain dispersed embedded, flaked, patinated hornfels artefacts (probably MSA) that also occur downwasted on the calcrete surface, suggesting a Pleistocene or younger age for these pedocretes. An especially well-developed nodular calcrete overlying weathered dolerite is seen in the borrow pit on Olyven Kolk 187 (Loc. 050; Fig. 20). This area may originally have formed part of a pan. The calcrete has a vertical nodular fabric, is sparsely gravelly and up to 1 m thick with a rubbly surface. Calcrete veins intrude into underlying *sabunga* (weathered dolerite). A conspicuous calcrete hardpan is associated with a small dolerite koppie near Stynsvlei homestead on Styns Vlei 280 (Loc 038; Fig. 21).

Stream alluvium in the study area is variously silty, sandy or gravelly (*e.g.* Melkbosch Vley 278, Loc. 036; Fig. 24). No well-consolidated older river terrace gravels were observed here. The wide spectrum of surface gravels of colluvial, sheet wash and downwasting origin have already been briefly mentioned with reference to the various underlying bedrock units considered previously. They overlie sandy to silty soils of probable alluvial origin. Silty soils without surface gravels are well seen on Kopjes Vley 281 where they are associated with Driedoring shrubs and grassy vegetation (Fig. 27). No good vertical sections through pan sediments were observed during the field study, with the possible exception of laminated silty sediments overlying weathered Dwyka in a borrow pit on Farm 246 (Loc. 046; Fig. 23). Pan surfaces elsewhere comprise sun-cracked silty mud with dispersed surface gravels. Hornfels and pale quartzite clasts among the latter are often anthropogenically flaked and may have been brought into the pan area by Stone Age humans (*e.g.* Stynsvlei, Loc. 005; Figs. 25 & 26). Of passing interest are occasional float blocks of Iceland spar (coarsely crystalline sparry calcite) that occur within surface gravels overlying the Prince Albert Formation in the vicinity of dolerite intrusions (*e.g.* Styns Vlei 280, Loc. 038; Fig. 28). Veins of calcite up to 3 m wide are reported from the Kenhardt sheet area – including on Gemsbok River 301 - in the basal chill zone of dolerite sills and are of hydrothermal origin (Slabbert *et al.* 1999).

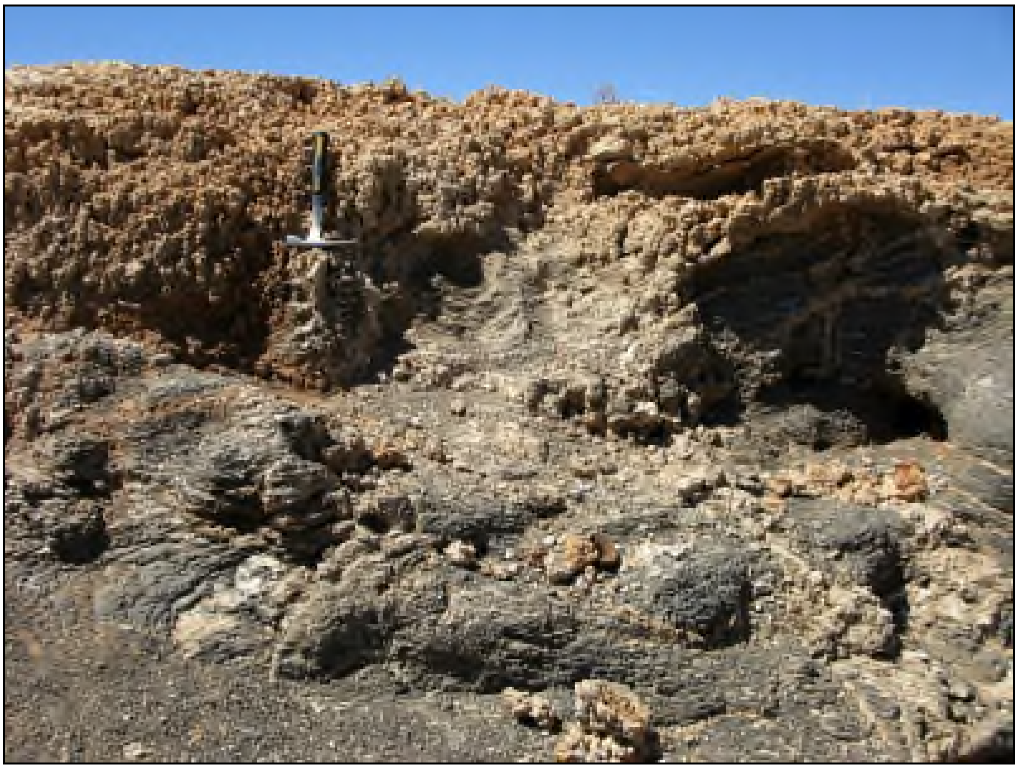

Fig. 20. Well-developed nodular calcrete overlying deeply-weathered dolerite, borrow pit on Olyven Kolk 187 (Loc. 050) (Hammer = 30 cm).

Fig. 21. Dense calcrete hardpan associated with dolerite koppie, Styns Vley 280 (Loc. 038).

Fig. 22. Partially exposed calcrete hardpan on Styns Vlei 280, perhaps associated with a hidden dolerite intrusion.

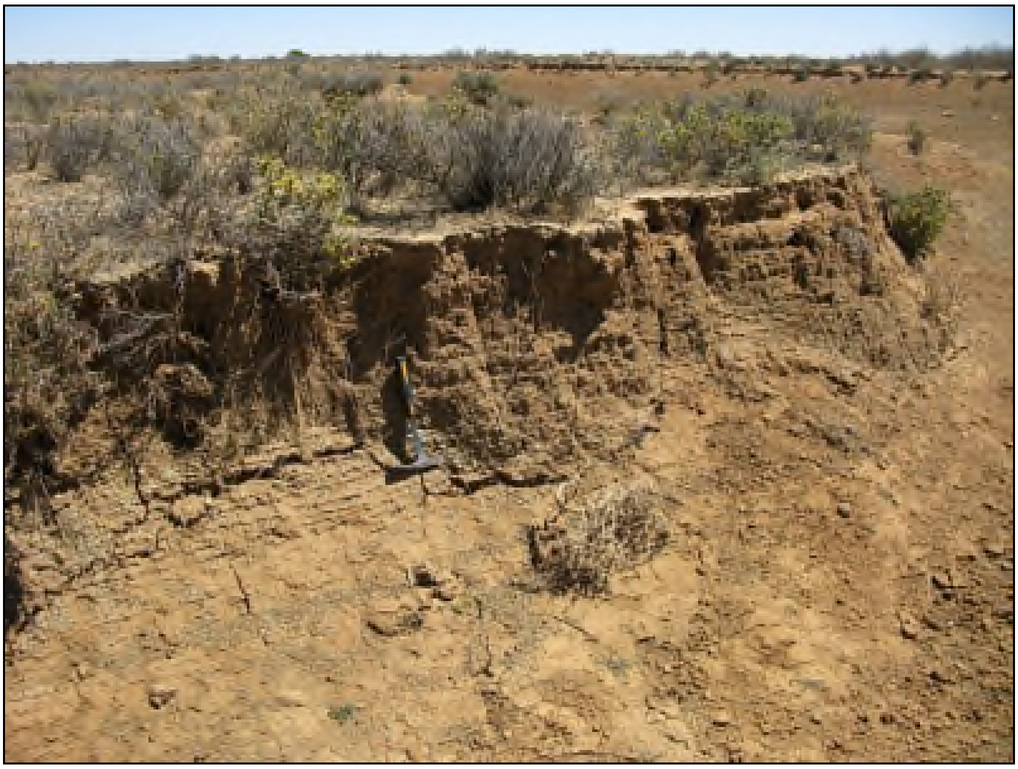

Fig. 23. Borrow pit section through thinly-bedded silty sediments overlying Dwyka bedrocks, perhaps related to a pan area, Farm 246 (Hammer = 30 cm).

Fig. 24. Shallow intermittent stream on Melkbosch Vlei 278 (Loc. 036) with fine gravelly to sandy alluvium and reworked blocks of ferruginous carbonate concretions.

Fig. 25. Sun-cracked silty sediments in the Stynsvlei pan with surface gravels of calcrete, dolerite and possibly introduced hornfels and quartzite, Styns Vley 280(Loc. 005).

Fig. 26. Surface gravels on the Stynsvlei pan (Loc. 005). The flaked hornfels and quartzite artefacts have probably been introduced by humans or perhaps sheetwash (Scale in cm).

Fig. 27. Silty alluvium without gravels, Kopjes Vley 281.

Fig. 28. Float block of coarsely-crystalline Iceland spa (*c*. 10 cm across) associated with a calcretised dolerite intrusion, Styns Vley 280 (Loc. 038).

2.4. Jurassic Karoo Dolerite Suite

Extensive sheets (sills) of Early Jurassic dolerite underlie sizeable portions of the broader study area and crop out in a north-south trending range of low koppies along the border of Styns Vley 280 and Gemsboks Kolk 279. The dolerite is expressed at surface as scatters or concentrations of black, desert-varnished boulders (relict corestones) or low bouldery black *koppies*, such as Spookkop, Katkop and Rosland se Kop, with a surrounding apron of dolerite gravelly colluvium, sometimes rubbly (Fig. 29 to 31). Elsewhere the dolerite is hidden beneath a blanked of superficial sediments but is frequently encountered in local boreholes, including in the Styns Vley 280 area (Koos Zandberg, pers. comm. 2014). Where exposed in borrow pits (*e.g.* Locs. 010, 041 042) it is usually deeply weathered near-surface (crumbly *sabunga*), with onionskin exfoliation structures and pseudolamination, and veined with calcrete (Fig. 33b). Typically the dolerite subcrop is overlain by thick to thin, heavily calcretised sandy to silty soils (Fig. 33a).

A good exposure of the intrusive contact between a transgressive dolerite sill and well-bedded country rocks of the Prince Albert Formation (or possibly Dwyka Group, as mapped) is seen in railway cuttings at Loc. 047 (Uitspan Kop 246). Here the baked Ecca mudrocks (hornfels) stand out due to their characteristic reddish-brown surface weathering patina (Fig. 32). Baking and reddening of clast-rich Dwyka tillite is seen at railway cuttings at Loc. 048 (Manier Tyds Kolkjes 247).

Fig. 29. Spookkop, a typical low, black, boulder dolerite koppie locate on the border between Styns Vley 280 and Gemsboks Kolk 279.

Fig. 30. Bouldery dolerite corestones overlying dolerite subcrop near Melkbosvlei homestead (Loc. 037). The black patina is desert varnish.

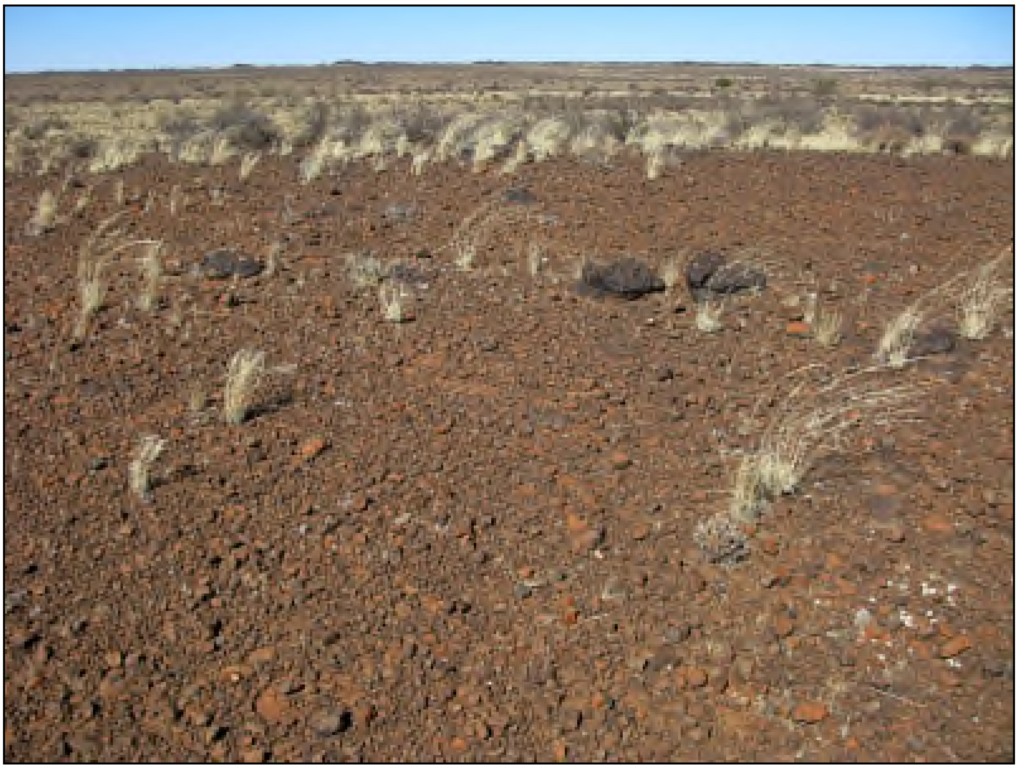

Fig 31. Rubbly colluvial gravels of weathered dolerite just southeast of Melbosvlei homestead, Melkbosch Vley 278.

Fig. 32. Railway cutting on Uitspan Kop 246 showing intrusive contact between a dolerite sill and bedded sediments of the Dwyka or Ecca Group (Loc. 047). The reddish-brown surface gravels are of dolerite and / or hornfels.

Fig. 33a. Deeply-weathered dolerite *sabunga* overlain by silty alluvial soils with nodular calcrete horizon, borrow pit on Kopjes Vley 281 (Loc. 040) (Hammer = 30 cm).

Fig. 33b. Extensive calcrete veining of deeply-weathered dolerite *sabunga* exposed in a borrow pit on Olyven Kolk 187 (Loc. 050).

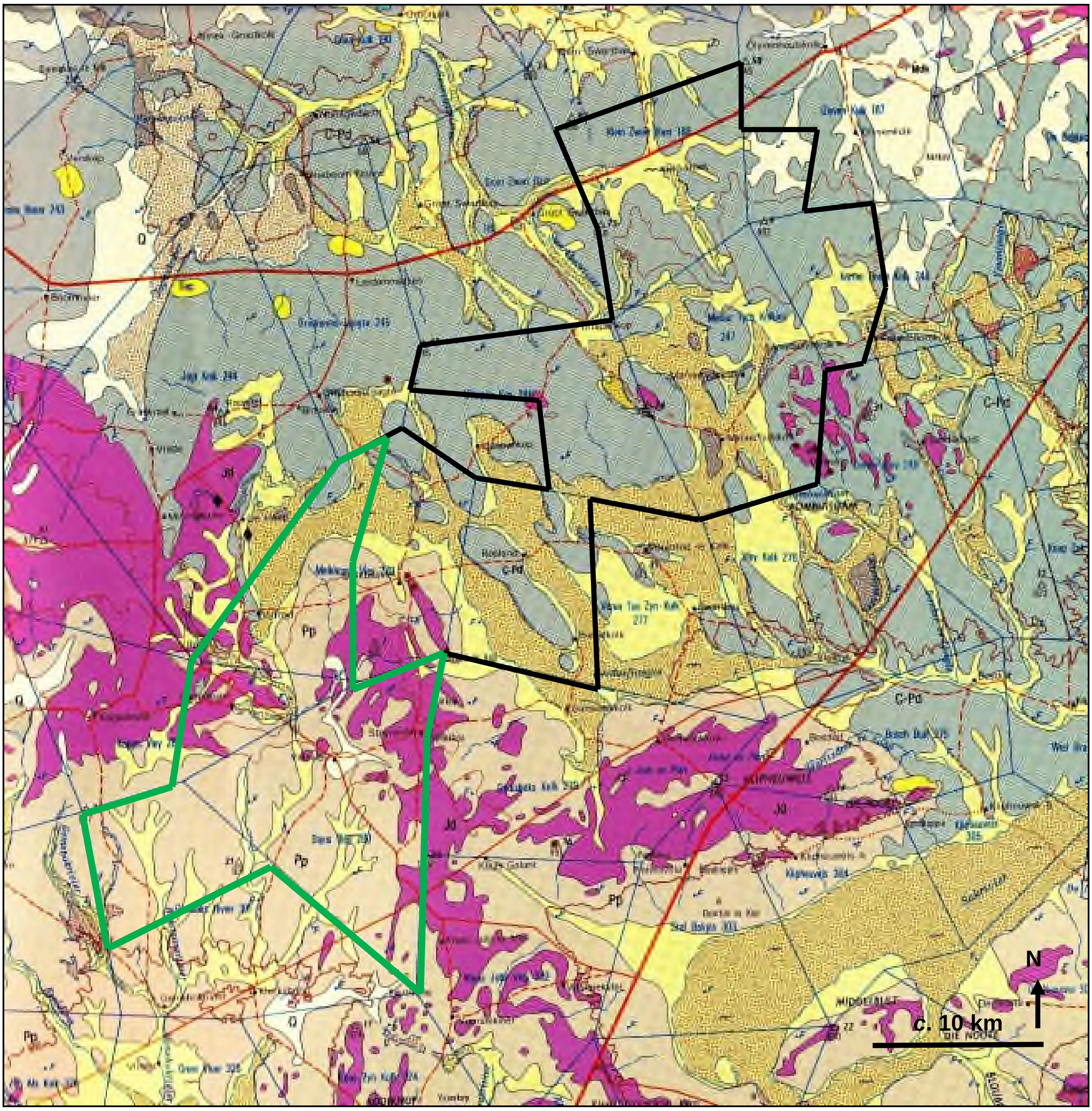

Fig. 34. **Extract from 1: 250 000 geological map 2920 Kenhardt (Council for Geoscience, Pretoria) showing the approximate outline of the broader Exheredo Solar Energy Facility study area, including land parcels involved in with 132 kV transmission line (black polygon) as well as the solar energy facility study area that is the subject of the present report (green 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 area near Kenhardt is outlined here (See also summary provided in Table 1 below). Fossils do not occur within igneous dolerite or the Precambrian basement rocks (Table 1).

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.

No fossil remains were observed within the Dwyka Group sediments of the broader study area, apart from occasional boulder-sized erratics of stromatolitic cherty dolomite that have probably been reworked from the Transvaal Supergroup (*e.g.* Ghaap Plateau region) (Fig. 35, Loc. 048). Diagenetic silicious and ferruginous carbonate concretions within the tillites (Figs. 8 & 9) are unfossiliferous, although the latter sometimes contain well-developed cone-in-cone structures that are superficially stromatolite-like (These abiogenic mineral structures or pseudofossils may well be responsible for occasional reports of stromatolites from the Dwyka Group; *e.g.* Slabbert *et al.* 1999). No potentially fossiliferous interglacial or post-glacial laminites were seen.

Fig. 35. Glacial erratic of cherty stromatolitic carbonate from the Dwyka Group, Manier Tyds Kolkjes 247 (Scale in cm).

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). Simple, narrow horizontal intrastratal and bedding plane fossil burrows are observed locally within the more platy-weathering Prince Albert sandstones and siltstones in the broader study area, for example on Styns Vley 280 (Locs. 013, 014) (Figs. 36 & 37).

Stromatolites (fossil laminated microbial mounds) up to one meter across are also reported from the Prince Albert Formation in the Kenhardt sheet area. However, it is likely that these records refer rather to abiogenic cone-in-cone structures within diagenetic concretions; *i.e.* they are a form of *pseudofossil*. Good examples of stromatolite-like cone-in-cone structures within ferruginous carbonate concretions were observed within the present study area on Styns Vley 280, Melkbosch Vley 278 (Locs. 008, 028, 031 & 036) (Figs. 38 & 39).

Fig. 36. Float blocks of Prince Albert Formation siltstone containing narrow intrastratal fossil burrows (Scale in cm), Styns Vley 280 (Loc. 014).

Fig. 37. Float block of Prince Albert Formation siltstone containing narrow intrastratal fossil burrows (Scale in cm), Styns Vley 280 (Loc. 016).

Fig. 38. Large oblate ferruginous carbonate concretion within the Prince Albert Formation showing misleading stromatolite-like appearance (Scale = 15 cm), Melkbosch Vley 278 (Loc. 027).

Fig. 39. Vertical section through 5 cm-thick ferruginous carbonate concretion showing abiogenic, stromatolite-like internal fabric due to cone-in-cone structure, Melkbosch Vley 278 (Loc. 027). These are *pseudofossils*.

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 Mid 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.

The only fossil remains recorded during fieldwork from superficial sediments within the broader study area near Kenhardt are rare globular calcretised termitaria of probable Pleistocene age. These occur embedded within crumbly Dwyka Group saprolite (weathered bedrock) on Farm 278 (Loc. 043) and are about 30 cm in diameter (Fig. 40). Reworked fragments of calcrete from surface gravels on Melkbosch Vley 278 (Loc. 030) show a complex stromatolite-like growth structure (Fig. 41). It is unclear if this fabric is biogenic - perhaps related to a calcertised insect burrow - or not.

Table 1: Fossil heritage recorded from the major rock units that are represented (or probably represented) in the broader CSP Solar Energy Facility study area near Kenhardt

GEOLOGICAL UNIT	ROCK TYPES & AGE	FOSSIL HERITAGE	PALAEONT-OLOGICAL SENSITIVITY
LATE CAENOZOIC SUPERFICIAL SEDIMENTS, **especially** **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** **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** **(*e.g.* Tertiary alluvium associated with old river courses)**
Prince Albert Formation **ECCA GROUP**	**marine to hyposaline basin plain mudrocks, minor volcanic ashes, phosphates and ironstones, post-glacial mudrocks at base** **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** **BUT LOCALLY HIGH IN N. CAPE**
KAROO DOLERITE SUITE	**intrusive dolerites (dykes, sills), associated diatremes** **EARLY JURASSIC**	**none**	**ZERO**
Mbizane Formation **DWYKA GROUP**	**tillites, interglacial mudrocks, deltaic & turbiditic sandstones, minor thin limestones** **LATE CARBONIFER-OUS – EARLY PERMIAN**	**sparse petrified wood & other plant remains, palynomorphs, trace fossils (*e.g.* arthropod trackways, fish trails, U-burrows), possible stromatolites in limestones**	**LOW TO MODERATE**
De Bakken Granite **NAMAQUA-NATAL PROVINCE**	**highly metamorphosed sediments, intrusive granites** **MID-PROTEROZOIC (*c.* 2 billion yrs old)**	**none**	**ZERO**

Fig. 40. ***In situ*** **calcretised fossil termitarium (termite nest) embedded within Dwyka saprolite, borrow pit on Farm 278 (Loc. 043) (Hammer = 30 cm).**

Fig. 41. Float block of complex laminated calcrete reworked from a hardpan or possibly a fossil burrow system from surface gravels on Melkbosch Vley 278 (Loc. 030) (Block is *c*. 6 cm across).

4. ASSESSMENT OF IMPACTS ON FOSSIL HERITAGE

The SolarReserve Kotulo Tsatsi Energy project area near Kenhardt is located in an area that is underlain by potentially fossiliferous sedimentary rocks of Late Palaeozoic and younger, Late Tertiary or Quaternary, age (Sections 2 & 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 associated infrastructure, water storage tanks, evaporation ponds, heliostat footings, underground cables, internal access roads, transmission line towers, the on-site substation and the pipeline. All these developments may adversely affect potential fossil heritage within the study area by destroying, disturbing or permanently sealing-in fossils at or beneath the surface of the ground that are then no longer available for scientific research or other public good. The operational and decommissioning phases of the solar energy facilities are unlikely to involve further adverse impacts on local palaeontological heritage, however.

Desktop analysis of the fossil records of the various sedimentary rock units underlying the broader study area, combined with field assessment of numerous representative rock exposures within and close to this area, indicate that all of these units are of low to very low palaeontological sensitivity (Section 3). The potentially fossiliferous Karoo Supergroup bedrocks (Dwyka and Ecca Groups) are deeply weathered and extensively calcretised near-surface. Over the majority of their outcrop areas the bedrocks are mantled by various superficial deposits that may reach thicknesses of several meters and that are of low palaeontological sensitivity. These include alluvium, colluvium, a wide range of surface gravels, calcrete hardpans and pan sediments. The only fossil remains recorded during the field assessment are (1) small-scale fossil burrows within Prince Albert Formation mudrocks of Early Permian age, (2) downwasted, ice-transported blocks (erratics) of Precambrian stromatolitic carbonate within surface gravels overlying the Dwyka Group tillites, and (3) rare calcretised termitaria of probable Pleistocene or younger age embedded within weathered Dwyka bedrocks. These fossils are all of widespread occurrence within Bushmanland and special protection or mitigation measures for the very few known fossil sites are therefore not considered warranted here.

Construction of the Solar Energy Facility and associated infrastructure, including proposed new overhead power lines to Aries Substation, is therefore unlikely to entail significant impacts on local fossil heritage resources. The operational and decommissioning phases of the solar energy facilities and transmission line are unlikely to involve further adverse impacts on local palaeontological heritage.

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

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

No areas or sites of exceptional fossil heritage sensitivity or significance have been identified within the study area. The majority of fossil sites recorded in the study region lie on the margins of the broader development area and outside the anticipated development footprint. The fossil remains identified in this study are mostly of widespread occurrence within the formations concerned (*i.e.* not unique to the study area). Irreplaceable loss of fossil heritage is therefore not anticipated. Should fossil remains be impacted by the proposed development, these impacts can be partially mitigated, as outlined in the following section of the report.

There are no fatal flaws in the Solar Energy Facility development proposal as far as fossil heritage is concerned. Due to the general scarcity of fossil remains, the high levels of bedrock weathering as well as the extensive superficial sediment cover observed within the entire study area, the overall impact significance of the construction phase of the proposed transmission line project is assessed as LOW.

It should be noted that should new fossil remains be discovered before or during construction and reported by the responsible ECO to the responsible heritage management authority (SAHRA) for professional recording and collection, as recommended here, the overall impact significance of the project would remain LOW. Residual negative impacts from loss of fossil heritage would be partially offset by an improved palaeontological database for the study region as a direct result of appropriate mitigation. This is a *positive* outcome because any new, well-recorded and suitably curated fossil material from this palaeontologically under-recorded region would constitute a useful addition to our scientific understanding of the fossil heritage here.

In the absence of comprehensive data on further alternative energy or other developments in the Kenhardt area, it is impossible to realistically assess cumulative impacts on fossil heritage resources. A recent palaeontological assessment for a solar project to the east of Kenhardt by the author (Almond 2014A) concluded that the palaeontological sensitivity of that area is low, but there are significant differences in the underlying geology concerned. The potentially fossiliferous sedimentary rock units represented within the present study area (*e.g.* Prince Albert Formation, calcretes) are of widespread occurrence and this is also likely to apply to most of the fossils they contain. It concluded that the cumulative impacts on fossil heritage resources posed by the known solar energy developments in the region is *low*.

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

Table 2: Assessment of impacts of the proposed Solar Energy Facility on fossil heritage resources during the construction phase of the development (*N.B.* Significant impacts are not anticipated during the operational and decommissioning phases).

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

5. RECOMMENDED MITIGATION AND MANAGEMENT ACTIONS

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

During the construction phase all deeper (> 1 m) bedrock excavations should be monitored for fossil remains by the responsible ECO. Should substantial fossil remains such as vertebrate bones and teeth, plant-rich fossil lenses or dense fossil burrow assemblages be exposed during construction, the responsible Environmental Control Officer should safeguard these, preferably *in situ*, and alert SAHRA, *i.e.* The South African Heritage Resources Authority, as soon as possible (Contact details: Mrs Colette Scheermeyer, P.O. Box 4637, Cape Town 8000. Tel: 021 462 4502. Email: cscheermeyer@sahra.org.za) so that appropriate action can be taken by a professional palaeontologist, at the developer's expense. Mitigation would normally involve the scientific recording and judicious sampling or collection of fossil material as well as associated geological data (*e.g.* stratigraphy, sedimentology, taphonomy) by a professional palaeontologist.

These mitigation recommendations should be incorporated into the Environmental Management Programme (EMPr) for the Solar Energy Facility.

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

Please note that:

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

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

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

6. RECOMMENDATIONS FOR THE DRAFT ENVIRONMENTAL MANAGEMENT PLAN

The following measures for inclusion in the Environmental Management Programme for the proposed Solar Energy Facility development near Kenhardt are outlined below (following page), according to the scheme developed by Savannah Environmental (Pty) Ltd.

Specialist palaeontological mitigation is only triggered should significant new fossil remains be exposed during the construction phase.

Note that the operational and decommissioning phases of the development are unlikely to have significant impacts on palaeontological heritage and no further recommendations are made in this regard.

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

Project component/s	Construction of solar energy facilities (CSP & PV).
Potential Impact	Disturbance, damage, destruction or sealing-in of scientifically valuable fossil material embedded within bedrock or weathered-out at ground surface
Activity/risk source	Extensive bedrock excavations and surface disturbance (*e.g.* CSP tower foundations and associated infrastructure, water storage tanks, evaporation ponds, solar panel footings, underground cables, internal access roads, transmission line towers, the on-site substations, laydown areas and construction camps).
Mitigation: Target/Objective	Recording, judicious sampling and curation of any important fossil heritage exposed during construction within the Exheredo Solar Energy Facility development area.

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

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

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QUALIFICATIONS & EXPERIENCE OF THE AUTHOR

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

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

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APPENDIX: GPS LOCALITY DATA

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

Locality number	South	East	Comments
004	S29 45 12.9	E20 37 14.6	Dolerite koppie and surrounding apron of gravels, Styns Vlei 280.
005	S29 45 17.9	E20 37 48.6	Stynsvlei pan sediments, Styns Vlei 280.
006	S29 45 34.6	E20 37 49.1	Surface gravels overlying Prince Albert Fm, in situ dolerite corestone boulders, nr stone buildings, Styns Vlei 280.
007	S29 46 05.5	E20 37 49.1	Thick calcretised sandy soils overlying dolerite, Styns Vlei 280.
008	S29 46 19.5	E20 37 50.0	Large ferruginous carbonate diagenetic concretions in Prince Albert Formation, Styns Vlei 280.
009	S29 47 26.6	E20 37 44.8	Blocky, angular surface gravels of baked Prince Albert sandstone, Styns Vlei 280.
010	S29 48 46.7	E20 37 22.6	Borrow pit into calcretised silty sediments overlying weathered dolerite, west of dust road, Styns Vlei 280.
011	S29 48 26.1	E20 36 43.3	Brown-patinated platy surface gravels overlying Prince Albert Fm, Styns Vlei 280.
013	S29 49 23.8	E20 34 38.3	Calcrete hardpan in Prince Albert outcrop area, Styns Vlei 280.
014	S29 47 55.6	E20 33 37.5	Artificial pit excavated into weathered, calcretised Prince Albert Fm mudrocks, Styns Vlei 280.
016	S29 47 51.5	E20 33 40.1	Small surface exposure of Prince Albert Fm near dam, calcrete-veined, Styns Vlei 280.
018	S29 46 07.1	E20 35 05.4	Platy surface gravels overlying Prince Albert Fm nr Valsvlei homestead, Styns Vlei 280.
019	S29 46 40.6	E20 33 34.8	Platy surface gravels and calcrete overlying Prince Albert Fm nr transmission line, Styns Vlei 280.
020	S29 46 57.4	E20 32 20.7	Platy surface gravels and calcrete overlying Prince Albert Fm nr transmission line, Styns Vlei 280
021	S29 46 33.1	E20 31 51.4	Desert varnished surface gravels, orange-brown sandstone gravels overlying Prince Albert Fm, Styns Vlei 280.
024	S29 43 03.9	E20 32 35.2	Pan area with surface gravels, Melkbosch Vley 278.
025	S29 42 11.7	E20 32 48.0	Low rocky exposure of dark brown Mbizane Fm (Dwyka Group) wackes, dropstone sandstones, Melbosch Vley 278.
026	S29 42 21.5	E20 33 17.9	Pan area with abundant flaked quartzite artefacts, Dwyka erratics, Dwyka brown wackes, Melkbosch Vlei 278.
027	S29 43 27.1	E20 33 26.2	Concentration of large ferruginous ironstone concretions in Prince Albert Fm, Melkbosch Vlei 278. Stromatolite-like cone-in-cone structures.
028	S29 42 17.7	E20 37 36.5	Hornfels surface gravels associated with dolerite intrusion, Melkbosch Vlei 278. Gravels composed of erratics from Dwyka Group nearby.

029	S29 42 01.9	E20 37 41.1	Hill slope colluvium of irregular-fracturing Prince Albert fine-grained sandstone, Melkbosch Vlei 278.
030	S29 41 48.2	E20 37 44.0	Fine-grained desert-varnished surface gravels on Prince Albert Fm. Reworked blocks of calcrete hardpan showing stromatolite-like internal lamination, Melkbosch Vlei 278.
031	S29 41 44.6	E20 37 43.6	Brownish diagenetic concretions within the Prince Albert Fm, Melkbosch Vlei 278
032	S29 41 02.2	E20 37 25.7	Surface gravels of patinated hornfels (many flaked), dolerite corestones near Melkbosvlei homestead, Melkbosch Vlei 278.
033	S29 40 23.1	E20 37 37.9	Polymict surface gravels of Dwyka erratic cobbles and boulders, Melkbosvlei 278.
034	S29 39 17.5	E20 38 03.1	Polymict surface gravels of Dwyka erratic cobbles and boulders, Melkbosch Vlei 278.
035	S29 38 59.3	E20 38 08.0	Coarse polymict surface gravels of Dwyka erratic cobbles and boulders, Melkbosch Vlei 278.
036	S29 41 01.9	E20 38 23.2	Shallow stream on Melkbosch Vlei 278 with reworked ferruginous carbonate concretions from Prince Albert Fm.
037	S29 41 04.9	E20 37 36.5	Bouldery dolerite ridge near Melkbosvlei homestead with Stone Age "factory site" exploiting local hornfels on crest (MSA, LSA artefacts), Melkbosch Vlei 278. Desert varnish, onionskin weathering in dolerites.
038	S29 45 05.9	E20 37 47.5	Thick calcrete hardpan development associated with dolerite koppie, Styns Vley 280. Float blocks of sparry calcite.
039	S29 44 42.9	E20 33 48.5	Well-developed nodular calcrete within superficial sediments overlying dolerite, roadside borrow pit, Kopjes Vlei 281.
040	S29 44 34.4	E20 33 38.7	Deeply-weathered dolerite overlain by silty alluvial soil with well-developed subsurface nodular calcrete, roadside borrow pit, Kopjes Vlei 281.
041	S29 41 45.2	E20 31 51.7	Large borrow pit excavated into weathered dolerite along Sishen-Saldanha railway line, Farm 244
042	S29 41 11.1	E20 32 47.9	Large borrow pit excavated into weathered dolerite along Sishen-Saldanha railway line, Farm 244
043	S29 40 22.6	E20 34 01.5	Large borrow pit excavated into weathered clast-poor Dwyka Group tillites along Sishen-Saldanha railway line, Farm 278. Siliceous and ferruginous carbonate concretions. Occasional spheroidal calcretised termitaria.
044	S29 39 35.6	E20 35 18.1	Large borrow pit excavated into weathered clast-poor Dwyka Group tillites along Sishen-Saldanha railway line, Farm 278.
045	S29 37 58.4	E20 37 46.0	Large borrow pit excavated into weathered clast-poor Dwyka Group tillites in borrow pit as well as cuttings along Sishen-Saldanha railway line, Farm 278.
046	S29 37 08.5	E20 39 42.7	Bedded alluvium or pan sediments overlying weathered bedded to massive Dwyka Group sediments, large borrow pit along Sishen-Saldanha railway line, Farm 246.

047	S29 36 49.0	E20 41 29.1	Dolerite intruding well-bedded Prince Albert or Dwyka shales, cutting along Sishen-Saldanha railway line, Uitspan Kop 246.
048	S29 34 12.7	E20 46 02.2	Railway cuttings through reddened Dwyka Group tillites overlain by dolerite. Float block (glacial erratic) of stromatolitic cherty limestone, Manier Tyds Kolkjes 247..
049			Good railway cutting exposures of well-bedded Dwyka diamictites, Sishen Saldanha railway, Klein Zwart Bast 188 near Aries Substation.
050	S29 30 37.53	E20 49 06.76	Nodular calcrete hardpan overlying weathered dolerite, large borrow pit along Sishen-Saldanha railway, Olyven Kolk 187.
051	S29 45 21.9	E20 48 55.3	Road cutting through well-bedded Prince Albert Fm laminated mudrocks, R27 southwest of Kenhardt.

PALAEONTOLOGICAL HERITAGE ASSESSMENT: COMBINED DESKTOP & FIELD-BASED STUDY

PROPOSED TRANSMISSION LINE FOR THE SOLARRESERVE KOTULO TSATSI ENERGY CSP FACILITIES NEAR KENHARDT, NORTHERN CAPE PROVINCE

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EXECUTIVE SUMMARY

SolarReserve Kotulo Tsatsi Energy is proposing to develop (1) three 200 MW Concentrated Solar Power (CSP) Facilities as well as (2) Photovoltaic (PV) Solar Energy facilities 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, Hantam Local Municipality, Northern Cape. The present report is a palaeontological heritage assessment of the proposed 132 kV or 400 kV transmission line corridor between the solar energy facility development area and the existing Eskom Aries Substation situated some 30 km to the northeast.

Desktop analysis of the fossil records of the various sedimentary rock units underlying the broader Exheredo Solar Energy Facility study area, including the transmission line corridor, combined with field assessment of numerous representative rock exposures within and close to this area, indicate that all of these units are of low to very low palaeontological sensitivity. The potentially fossiliferous Karoo Supergroup bedrocks (Dwyka and Ecca Groups) are deeply weathered and extensively calcretised near-surface. Over the majority of their outcrop areas the bedrocks are mantled by various superficial deposits that may reach thicknesses of several meters and that are of low palaeontological sensitivity. These include alluvium, colluvium, as well as a wide range of surface gravels, calcrete hardpans and pan sediments. The only fossil remains recorded during the field assessment are (1) small-scale fossil burrows within Prince Albert Formation mudrocks of Early Permian age, (2) downwasted, ice-transported blocks (erratics) of Precambrian stromatolitic carbonate within surface gravels overlying the Dwyka Group tillites, and (3) rare calcretised termitaria (termite nests) of probable Pleistocene or younger age embedded within weathered Dwyka bedrocks. These fossils are all of widespread occurrence within Bushmanland and Namaqualand. Special protection or mitigation measures for the very few known fossil sites within the study area are therefore not considered warranted. Because of the generally sparse occurrence of fossils within all of the bedrock formations concerned in the Exheredo solar energy facility transmission line study area, as well as within the pervasive overlying superficial sediments (soil, alluvium, colluvium *etc*), the magnitude of impacts on local palaeontological heritage resources is conservatively rated as LOW.

The potentially fossiliferous sedimentary rock units represented within the present study area (*e.g.* Prince Albert Formation, calcretes) are of widespread occurrence and this is also likely to apply to most of the fossils they contain. It concluded that the cumulative impacts on fossil

heritage resources posed by the known solar energy developments in the Kenhardt region is *low*.
Given the low impact significance of the proposed Exheredo Solar Energy Facility transmission line development as far as palaeontological heritage is concerned, no further specialist palaeontological heritage studies or mitigation are considered necessary for this component of the alternative energy project, pending the discovery or exposure of substantial new fossil remains during development.

During the construction phase all deeper (> 1 m) bedrock excavations (*e.g.* for pylon footings, access roads, construction camps and laydown areas) should be monitored for fossil remains by the responsible ECO. Should substantial fossil remains such as vertebrate bones and teeth, plant-rich fossil lenses or dense fossil burrow assemblages be exposed during construction, the responsible Environmental Control Officer should safeguard these, preferably *in situ*, and alert SAHRA, *i.e.* The South African Heritage Resources Authority, as soon as possible (Contact details: Mrs Colette Scheermeyer, P.O. Box 4637, Cape Town 8000. Tel: 021 462 4502. Email: cscheermeyer@sahra.org.za) so that appropriate action can be taken by a professional palaeontologist, at the developer's expense. Mitigation would normally involve the scientific recording and judicious sampling or collection of fossil material as well as associated geological data (*e.g.* stratigraphy, sedimentology, taphonomy) by a professional palaeontologist.

These mitigation recommendations should be incorporated into the Environmental Management Plan (EMP) for the transmission line component of the Exheredo Solar Energy Facility development.

1. INTRODUCTION & BRIEF

1.1. Project outline

SolarReserve Kotulo Tsatsi Energy is proposing to develop (1) three 200 MW Concentrated Solar Power (CSP) Facilities as well as (2) Photovoltaic (PV) Solar Energy facilities 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 has a total area of approximately 20 700 hectares and is situated *c.* 70 km southwest of Kenhardt and *c*. 60 km northeast of Brandvlei, Hantam Local Municipality (part of the Namaqua District Municipality) in the Northern Cape (Figs. 1 to 3).

The grid connections of the new solar energy facilities will be *via* 132 kV or 400 kV transmission lines and substations to the existing Eskom Aries substation that is located approximately 30 km away from the CSP and PV development site itself (Fig. 2). The following options are under consideration for the grid connection:

- The construction of a 132 kV double circuit power line from the on-site substation of each CSP facility to the Eskom Aries substation and / or;
- Construction of a single circuit power line with a 132 kV feeder bay at Aries and associated infrastructure on each project site;
- Construction of a turn-in power line from each CSP facility to the existing Aries – Helios power line, including a 400 kV switching station and associated infrastructure on the project site.

The present palaeontological heritage assessment of the transmission line corridor for the Exheredo Solar Energy Facility 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: Mr Steven Ingle. 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: 072 386 9815. Email: steven@savannahsa.com. Postal address: P.O. Box 148, Sunninghill, 2157).

1.2. Legislative context for palaeontological assessment studies

The Exheredo Solar Energy Facility 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 (Sections 2 & 3). The construction phase of the proposed transmission line will entail substantial excavations into the superficial sediment cover and locally into the underlying bedrock as well. These include, for example, excavations and clearing for the new access roads, transmission line tower footings, the on-site substations, laydown areas and construction camps. 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 transmission line is unlikely to involve further adverse impacts on local palaeontological heritage, however.

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

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

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

According to Section 35 of the National Heritage Resources Act, dealing with archaeology, palaeontology and meteorites:
(1) The protection of archaeological and palaeontological sites and material and meteorites is the responsibility of a provincial heritage resources authority.
(2) All archaeological objects, palaeontological material and meteorites are the property of the State.
(3) Any person who discovers archaeological or palaeontological objects or material or a meteorite in the course of development or agricultural activity must immediately report the find to the responsible heritage resources authority, or to the nearest local authority offices or museum, which must immediately notify such heritage resources authority.
(4) No person may, without a permit issued by the responsible heritage resources authority—
(a) destroy, damage, excavate, alter, deface or otherwise disturb any archaeological or palaeontological site or any meteorite;
(b) destroy, damage, excavate, remove from its original position, collect or own any archaeological or palaeontological material or object or any meteorite;
(c) trade in, sell for private gain, export or attempt to export from the Republic any category of archaeological or palaeontological material or object, or any meteorite; or

(d) bring onto or use at an archaeological or palaeontological site any excavation equipment or any equipment which assist in the detection or recovery of metals or archaeological and palaeontological material or objects, or use such equipment for the recovery of meteorites.
(5) When the responsible heritage resources authority has reasonable cause to believe that any activity or development which will destroy, damage or alter any archaeological or palaeontological site is under way, and where no application for a permit has been submitted and no heritage resources management procedure in terms of section 38 has been followed, it may—
(a) serve on the owner or occupier of the site or on the person undertaking such development an order for the development to cease immediately for such period as is specified in the order;
(b) carry out an investigation for the purpose of obtaining information on whether or not an archaeological or palaeontological site exists and whether mitigation is necessary;
(c) if mitigation is deemed by the heritage resources authority to be necessary, assist the person on whom the order has been served under paragraph *(a)* to apply for a permit as required in subsection (4); and
(d) recover the costs of such investigation from the owner or occupier of the land on which it is believed an archaeological or palaeontological site is located or from the person proposing to undertake the development if no application for a permit is received within two weeks of the order being served.

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

1.3. Approach to the palaeontological heritage study

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

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

On the basis of the desktop and Phase 1 field assessment studies, the likely impact of the proposed development on local fossil heritage and any need for specialist mitigation are then determined. Adverse palaeontological impacts normally occur during the construction rather than the operational or decommissioning phase. Phase 2 mitigation by a professional palaeontologist – normally involving the recording and sampling of fossil material and associated geological information (*e.g.* sedimentological data) may be required (a) in the pre-construction phase where important fossils are already exposed at or near the land surface and / or (b) during the construction phase when fresh fossiliferous bedrock has been exposed by excavations. To carry out mitigation, the palaeontologist involved will need to apply for a palaeontological collection permit from the relevant heritage management 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 Exheredo Solar Energy Facility study area in the Kenhardt region of the Northern Cape preservation of potentially fossiliferous bedrocks is favoured by the semi-arid climate and sparse vegetation but bedrock exposure is largely 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 present combined desktop and field-based palaeontological study was largely based on the following sources of information:

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

2. Two short desktop palaeontological assessment reports for study areas near Kenhardt to the east of the present study area by the author (Almond 2011, 2014a);

3. An earlier desktop review of the relevant scientific literature, including published geological maps and accompanying sheet explanations, for the Exheredo alternative energy project near Kenhardt (Almond 2014b);

4. A four-day field assessment of the broader Exheredo Solar Energy Facility study area during October 2014;

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

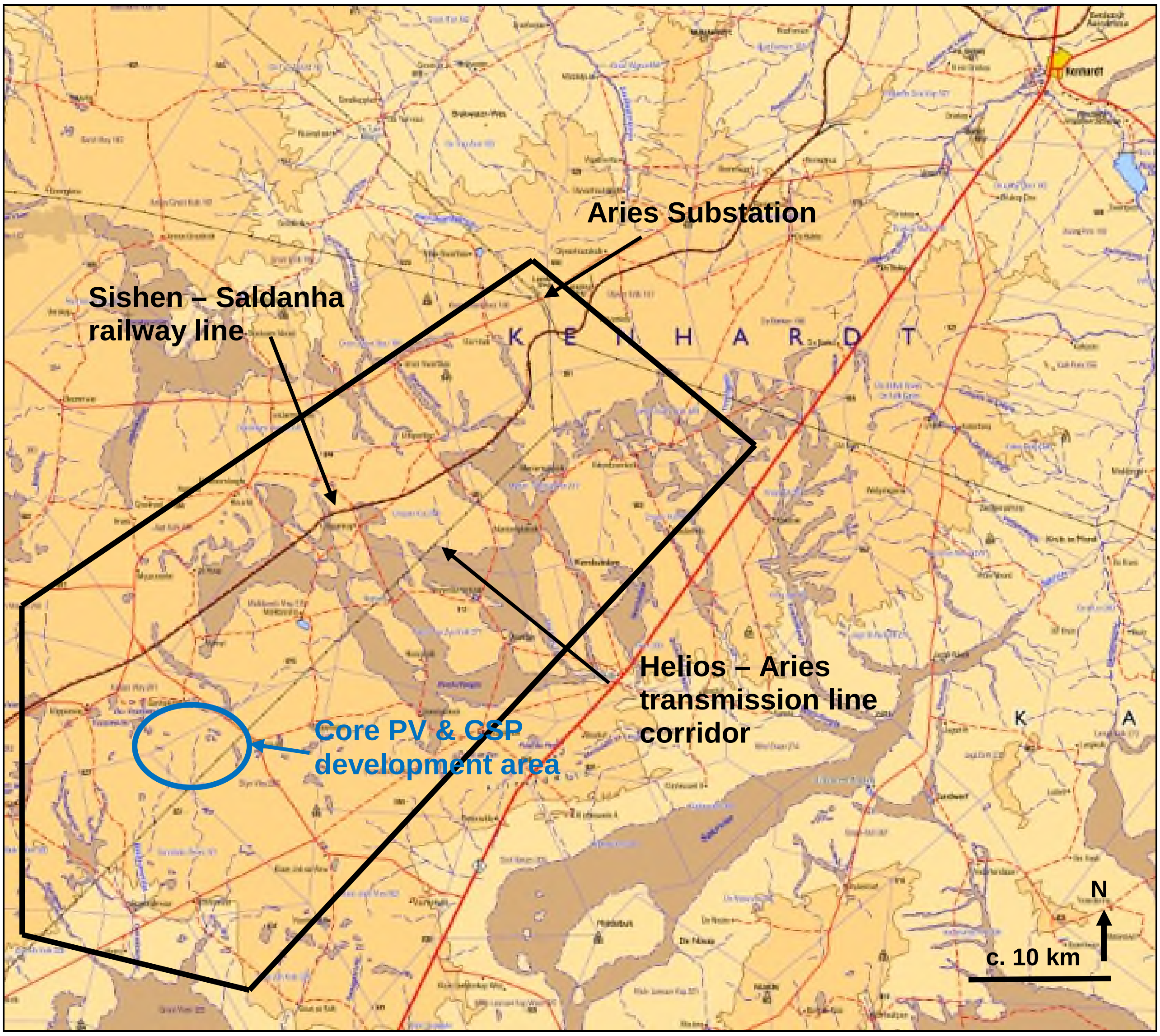

Fig. 1. Extract from 1: 250 000 topographical sheet 2920 Kenhardt showing the approximate location of the broader Exheredo Solar Energy Facility study area (black polygon) situated to the northwest of the R27 in eastern Bushmanland, *c.* 35 to 75 km southwest of Kenhardt, Northern Cape Province (Courtesy of the Chief Directorate of Surveys and Mapping, Mowbray). Note the existing Helios – Aries transmission line that traverses the study area from SW to NE.

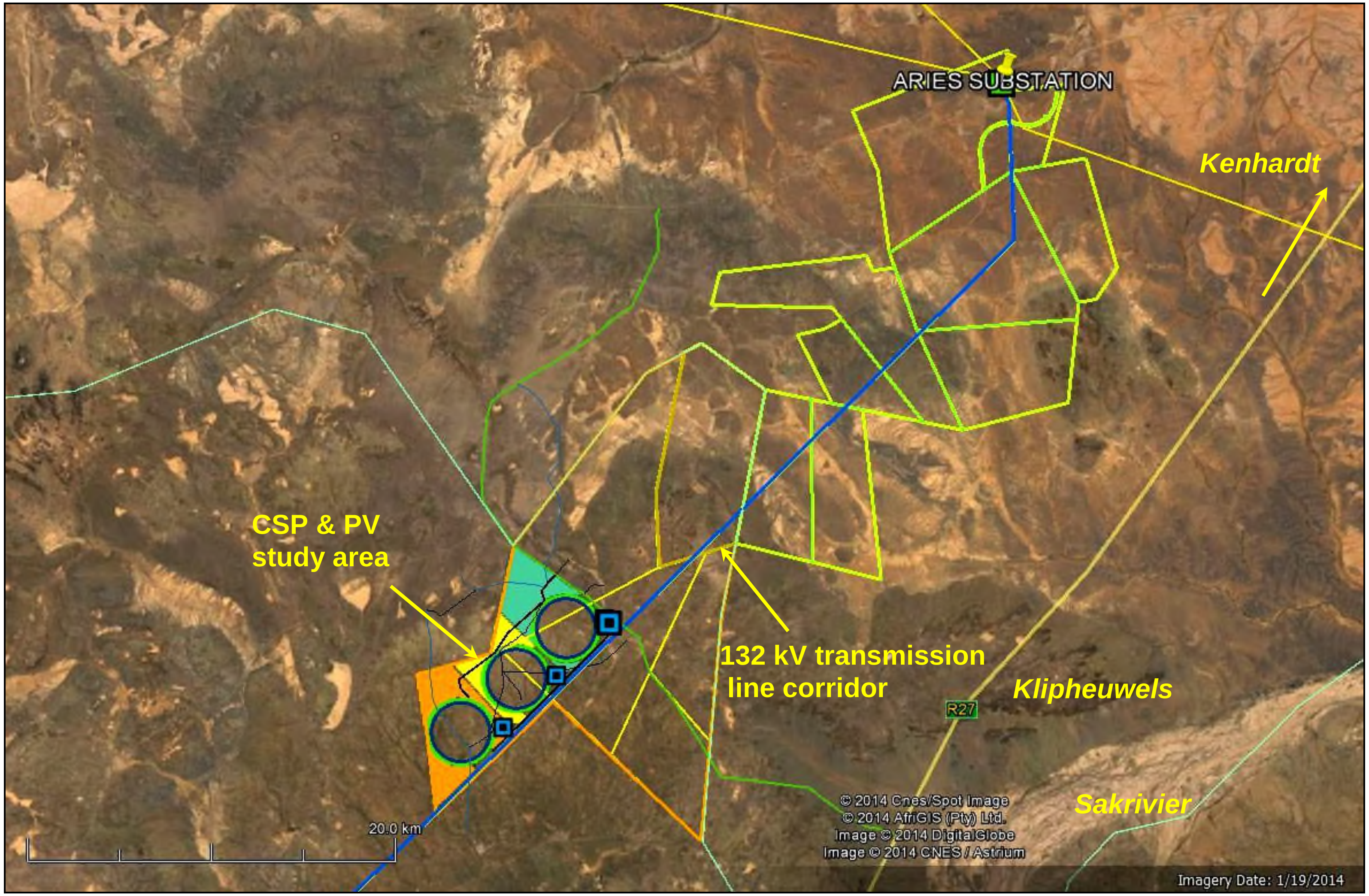

Fig. 2. Google earth© satellite image of the eastern Bushmanland region showing the location of the SolarReserve Kotulo Tsatsi Energy Facility study area on Farms Styns Vley 280, Melkbosch Vley 278 (RE of 278), Kopjes Vley 281 (Portion 2 of 281), Gemsbok Rivier 301 (Portion 1 of 301) and Gemsbok Rivier 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 (blue line).

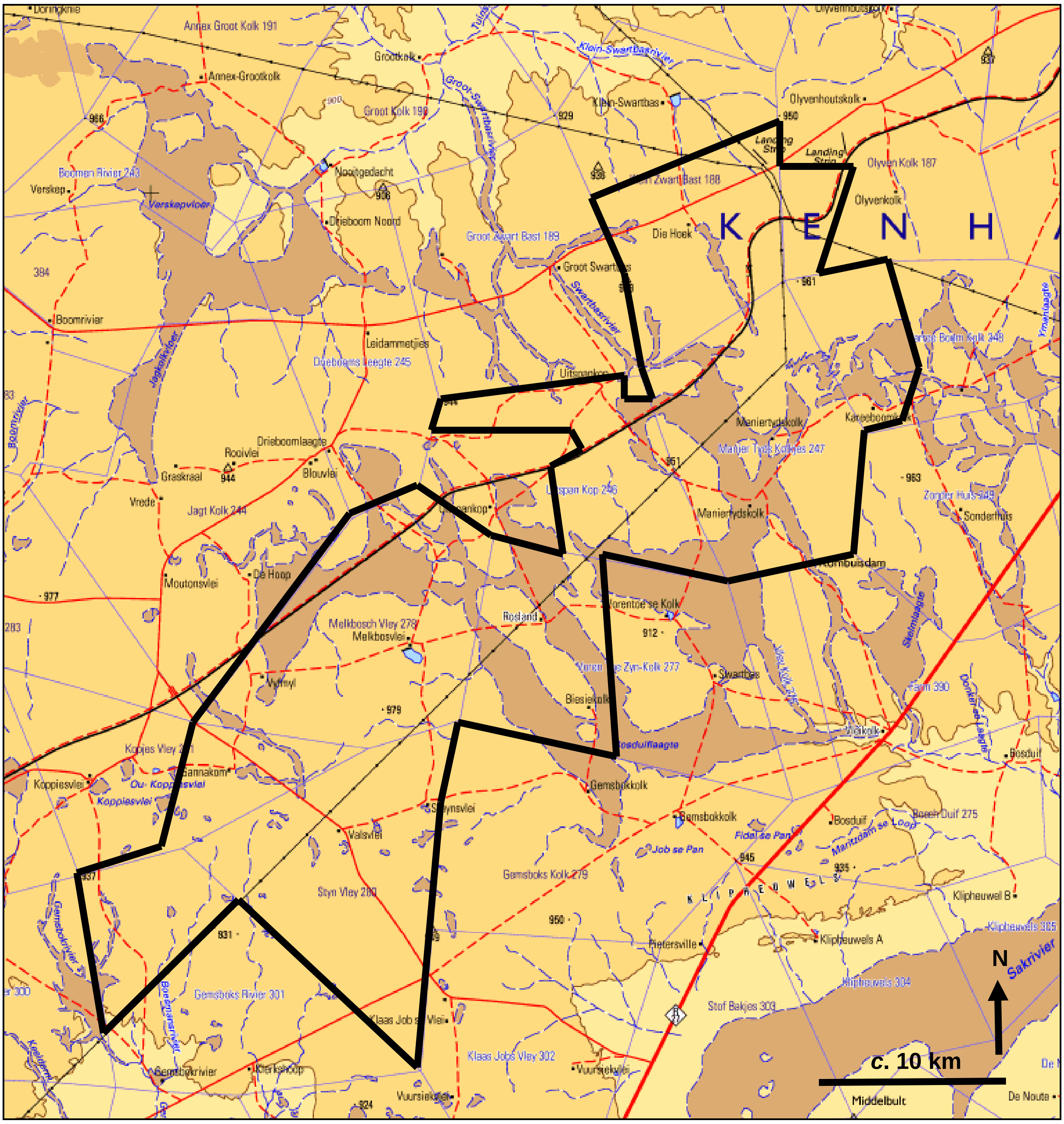

Fig. 3. Extract from 1: 250 000 topographical sheet 2920 Kenhardt showing the land parcels involved in the broader SolarReserve Kotulo Tsatsi Energy solar energy facility study area (black polygon), also showing the existing transmission line to the Aries Substation (Base map courtesy of the Chief Directorate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

2. GEOLOGICAL BACKGROUND

The broader Exheredo Solar Energy Facility study area - including the proposed transmission line to Aries Substation - is located to the northwest of R27 Brandvlei to Kenhardt tar road in semi-arid, low relief terrain between 900-1000 m amsl in the eastern Bushmanland region (*c.* 920 – 950 m amsl 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 existing 132 kV transmission line between Helios and Aries Substations 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 shallow 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 as well as a north-south zone of small *koppies* along the common border between Styns Vley 280 and Gemsboks Kolk 279.

The geology of the study area is outlined on the 1: 250 000 geology map 2920 Kenhardt (Council for Geoscience, Pretoria; Fig. 34 herein). An explanation to the Kenhardt geological map has been published by Slabbert *et al.* (1999) but gives little data on the sedimentary rocks. 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. 34) the north-eastern two thirds or so of the broader Exheredo Solar Energy Facility 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 the main solar energy development footprint on Styns 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 Styns 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); since they are entirely unfossiliferous, they are not dealt with further in this report.

The present field study shows that the Karoo Supergroup sediments, Karoo dolerites and any older basement rocks within the broader Exheredo Solar Energy Facility study area are almost entirely mantled with a range of **Late Caenozoic superficial deposits**, mostly of Late Tertiary to Quaternary age They include alluvium, pan sediments, calcrete hard pans as well as surface and subsurface gravels and may reach thicknesses of several meters or more. Where exposed in borrow pits along the major roads and the Sishen-Saldanha railway line and in other artificial excavations (*e.g.* farm dams), the bedrocks are often weathered and calcretised to a depth of several meters, reflecting periods of both drier and wetter climates in the geologically recent past. The projecting small *koppies* within the area consist largely of dolerite and occasionally of associated baked (thermally metamorphosed) country rocks.

In the following section of the report a summary of the main rock units represented within the broader Exheredo Solar Energy Facility study area (including the transmission line corridor to Aries Substation) is given, together with a brief account of geological observations made during the palaeontological field assessment. GPS data for all numbered localities mentioned in the text is given in the Appendix.

2.1. Dwyka Group

Permo-Carboniferous, glacially-related sediments of the **Dwyka Group** (**C-Pd**, grey in Fig. 34) underlie the thin, superficial cover of Late Caenozoic alluvium, pan sediments, soils and gravels over much of the north-eastern portion of the study area southwest of Kenhardt but only very rarely crop out naturally at surface. 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 ice sheets onto the continental highlands in the north. The valleys were then occupied by marine inlets within which drifting glaciers deposited dropstones onto the muddy sea bed ("boulder shales"). The upper Dwyka beds (**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 successions in Bushmanland 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.

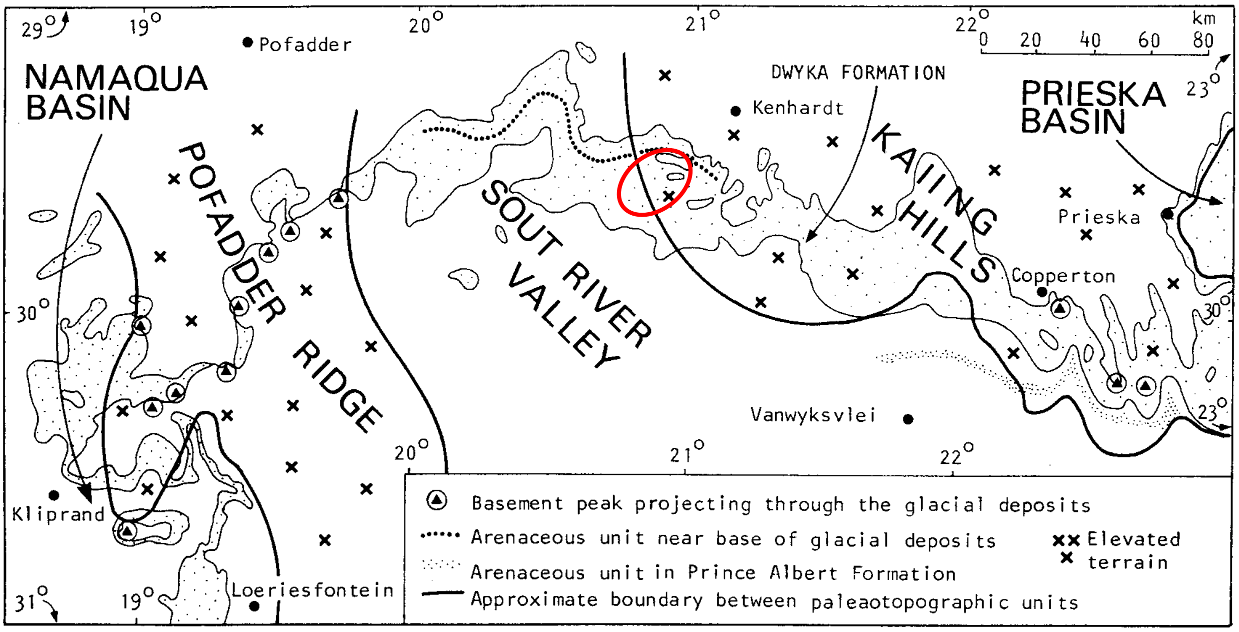

Fig. 4. Reconstruction of the topography along the northern margin of the Karoo Basin in Dwyka times showing location (red ellipse) of the study area to the SW of Kenhardt on a basement palaeo-high, the Kaaing Hills, with the Sout River palaeo-valley to the west (From Visser 1985).

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 190 m 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 near Kenhardt.

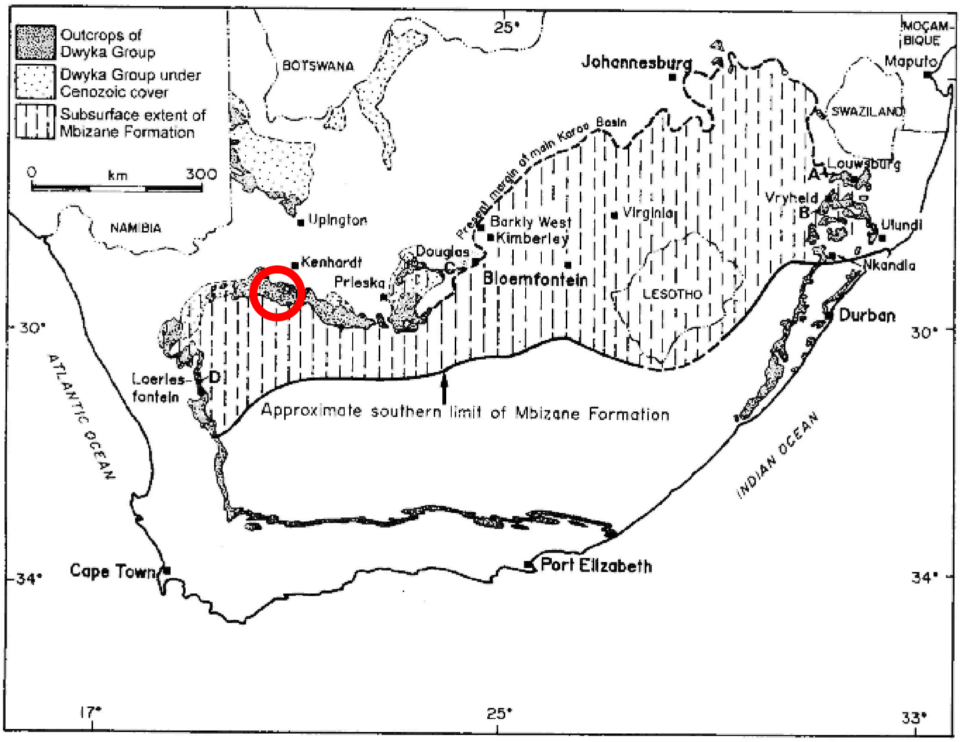

Fig. 5. Outcrop map of the Dwyka Group within the Main Karoo Basin of South Africa. Exposures in the study area southwest of Kenhardt (red circle) are assigned to the outcrop area of the Mbizane Formation (From Von Brunn & Visser 1999).

Natural exposures of Dwyka Group bedrocks were not observed within the Exheredo study area; these sediments are easily weathered and eroded, so they are generally mantled here by up to several meters of superficial sediments.

Good exposures of weathered, friable, greyish, clast-poor Dwyka diamictites (tillites) are seen in several large borrow pits on Farms 278 and 246, close to the Sishen-Saldanha railway line (Locs. 043, 044, 045), as well as in deep cuttings along the railway line itself in the vicinity of the Aries Substation (Locs. 045, 048, 049) (Figs. 6 & 7). The sediments are generally massive but locally well-bedded, for example as seen in long railway cuttings on Klein Zwart Bast 188; these beds may represent submarine debris flow facies. Baking and reddening of Dwyka tillites is seen in railway cuttings at Loc. 048 (Tyds Kolkjes 247). No potentially fossiliferous interglacial mudrock laminites were observed, but packages of thin-bedded, grey-green siltstones mapped as Dwyka occur locally (*e.g.* Loc. 046) and may belong to the Mbizane Formation within the upper part of the Dwyka Group. Sphaeroidal pale yellowish diagenetic nodules of possible siliceous mineralogy are common within the massive to bedded diamitites, as are also large, sphaeroidal to irregular ferruginous carbonate concretions and lenses (Figs. 8 & 9).

Low exposures of well-jointed, well-consolidated, dark brown, medium-grained wackes observed on Melbosch Vlei 278 (Loc. 025; Fig. 10) probably belong to the heterolithic Mbizane

Formation. They include intervals of thin-bedded sandstones with small gravel dropstones, dispersed pebbly to cobbly erratics and calcareous concretions.

The weathered Dwyka bedrocks are pervasively mantled with silty alluvial soils (often calcretised in the subsurface) and characteristic polymict surface gravels (*e.g.* Locs. 033-035, Melbosch Vley 278) (Fig. 11). The latter comprise poorly-sorted, angular to well-rounded, pebbly to bouldery clasts dominated by more resistant-weathering rock types. They represent erratics weathered out from the underlying glacial beds and concentrated at the surface by downwasting processes, with a degree of fluvial reworking in places. They include a very wide range of rock types such as quartzites, conglomerates, lavas (*e.g.* several vesicular types), granitoids, banded ironstones, cherts, jaspilite and carbonates (dolomite, limestone), among others.Some of the boulder-sized clasts show well-developed glacial facetting and striation (Fig. 12).

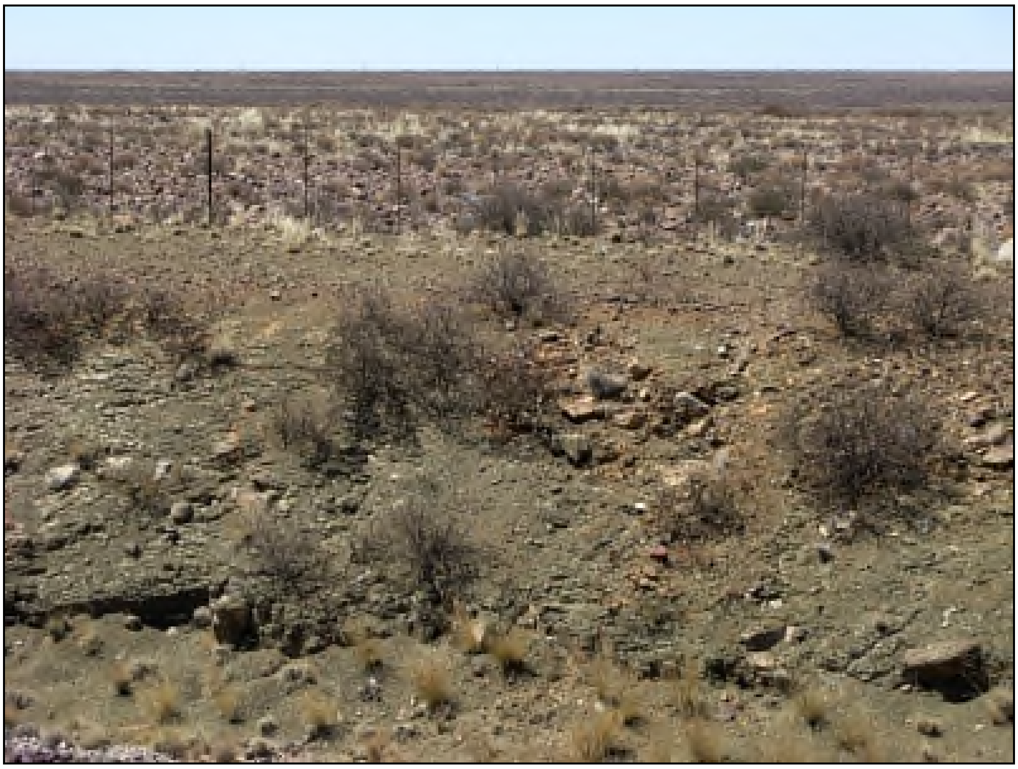

Fig. 6. Railway cutting exposure of clast-rich Dwyka Group tillites, Farm 278 (Loc. 045).

Fig. 7. Bedded clast-poor Dwyka diamictites exposed in a railway cutting on Zwart Bast 188, near Aries Substation (Loc. 049).

Fig. 8. Sphaeroidal carbonate diagenetic concretion from the Dwyka Group, borrow pit on Farm 278 (Specimen is *c*. 15 cm in diameter).

Fig. 9. Large, elongate concretion of brownish ferruginous carbonate within the Dwyka Group clast-poor diamictites, Farm 278 (Loc. 043) (Hammer = 30 cm).

Fig. 10. Low rocky exposure of brown-weathering wackes of the Mbizane Formation (Dwyka Group), Melkbosch Vley 278 (Loc. 025).

Fig. 11. Typical coarse polymict surface gravels overlying the Dwyka Group outcrop area, Melkbosch Vley 278 (Loc. 035).

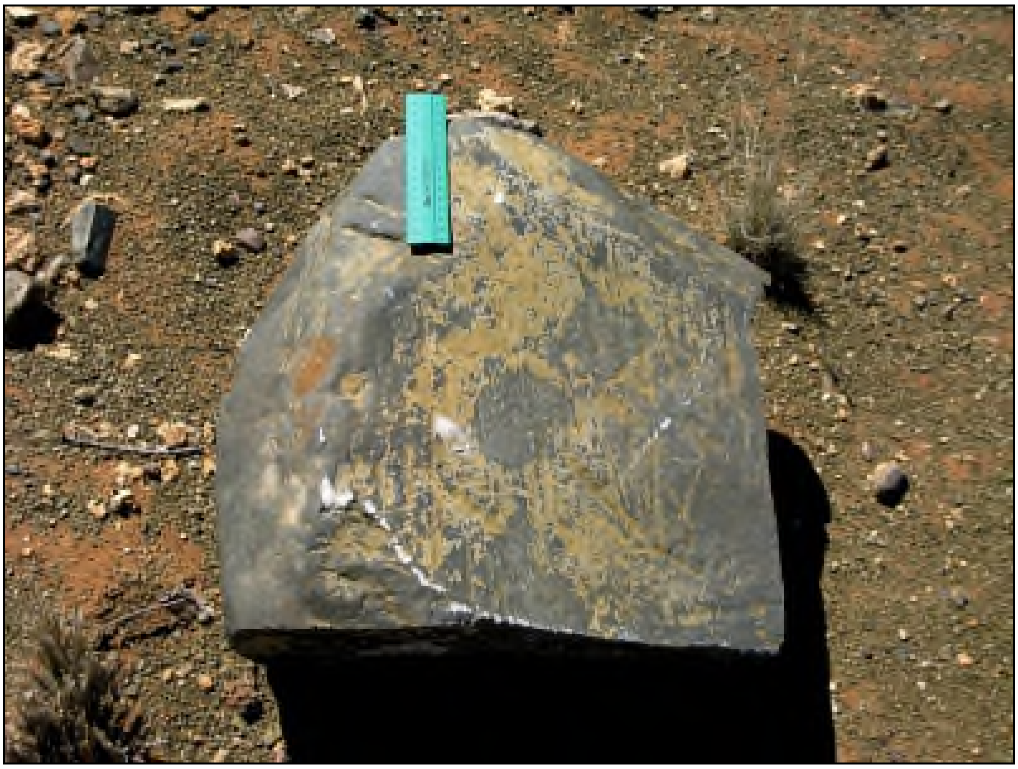

Fig. 12. Large glacially facetted and striated erratic from the Dwyka Group, Farm 278 (Loc. 045) (Scale = 15 cm).

2.2. Prince Albert Formation (Ecca Group)

The post-glacial basinal mudrocks of the Prince Albert Formation (Ppr, buff in Fig. 34) 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.

Prince Albert Formation mudrocks and fine-grained sandstones are mapped over the south-western portion of the Exheredo Solar Energy Facility study area where they are extensively intruded and baked by Jurassic dolerite intrusions (Fig. 34). Natural surface exposure of fresh Ecca bedrocks within the study area is almost non-existent. However, good road cuttings through tabular-bedded, well-laminated and -jonted, grey-green to dark grey mudrocks of the Prince Albert Formation are seen in road cuttings along the R27 Calvinia – Brandvlei tar road (Loc. 051; Fig. 14). Rare glimpses into the subsurface Ecca bedrocks are also given in a pit excavation on Styns Vley 280 (Loc. 014). Here thin-bedded, grey-green to brownish, laminated to massive mudrocks are veined with calcrete to a depth of several meters and brecciated near surface. (Fig 15). Thin-bedded, well-jointed, calcrete-veined greenish siltstones of the same formation are seen near the dam wall at Loc. 016 (Styns Vlei 280).

The great majority of the Prince Albert Formation outcrop area is mantled with silty to sandy alluvial soils and downwasted surface gravels (Fig. 13). The latter include platy grey-green to brownish-weathering fine sandstone and siltstone, sometimes silicified or cherty, with subordinate black chert, rusty-hued ironstone, brown ferruginous carbonate concretion fragments, reworked calcrete, coarsely-crystalline vein quartz and dolerite, as well as anthropogenically imported quartzite and brownish-patinated hornfels (often flaked). In some areas the gravel clasts are extensively desert varnished (*e.g.* Loc. 030 Melkbosch Vley 278; Fig. 17) or contain numerous wind blasted (fluted, polished) ventifacts. Brown-patinated, platy fine sandstone and siltstone often forms a surface pavement or mosaic (*reg* or *serir*) overlying silty soils (*e.g.* Loc. 011, Styns Vley 280) with some clasts showing a near-vertical orientation (edgeways gravels) (Fig. 16). Surface gravels of baked dark brown, silicified sandstone (Loc. 009 on Styns Vley 280, Loc. 029 on Melkbosch Vley 278), irregular-fracturing orange-brown sandstone and silststone (Loc. 021, Styns Vley 280) or brown-patinated, dark-grey to black hornfels, frequently flaked (Locs. 028 and 032 on Melkbosch Vley 278), are seen in the vicinity of dolerite intrusions (Fig. 19).

Within the Prince Albert Formation outcrop area also occur horizons of abundant large, oblate to lenticular, dark brown to olive-brown ferruginous carbonate diagenetic concretions that often show stromatolite-like cone-in-cone fabrics internally (Figs. 18, 38 & 39). The subrounded concretions are up to meter-sized in diameter and 20-30 cm thick, but irregular lenticles may be much larger.

Fig. 13. Typical topographically-subdued, surface gravel-mantled outcrop area of the Prince Albert Formation within the study area (here along the transmission line on Styns Vley 280, Loc. 019). Note abundant pale calcrete gravel clasts here.

Fig. 14. Good exposures of tabular-bedded, laminated basinal mudrocks of the Prince Albert Formation in R27 road cutting (Loc. 051) (Hammer = 30 cm).

Fig. 15. Weathered and secondarily calcretised Prince Albert mudrocks exposed in a deep pit excavation on Styns Vley 280 (Loc. 014).

Fig. 16. Desert pavement of platy siltstone and sandstone gravel clasts overlying the Prince Albert Formation on Styns Vley 280 (Loc. 011) (Hammer = 30 cm). Note zones of edgewise, subvertical gravel clasts also seen here.

Fig. 17. Area of desert-varnished, well-sorted surface gravels overlying silty soils in the Prince Albert Formation outcrop area (Loc. 021, Styns Vley 280) (Hammer = 30 cm).

Fig. 18. Prince Albert Formation outcrop area mantled by sandy soils and abundant fragments of ferruginous carbonate concretions, Styns Vlei 280 (Loc. 008).

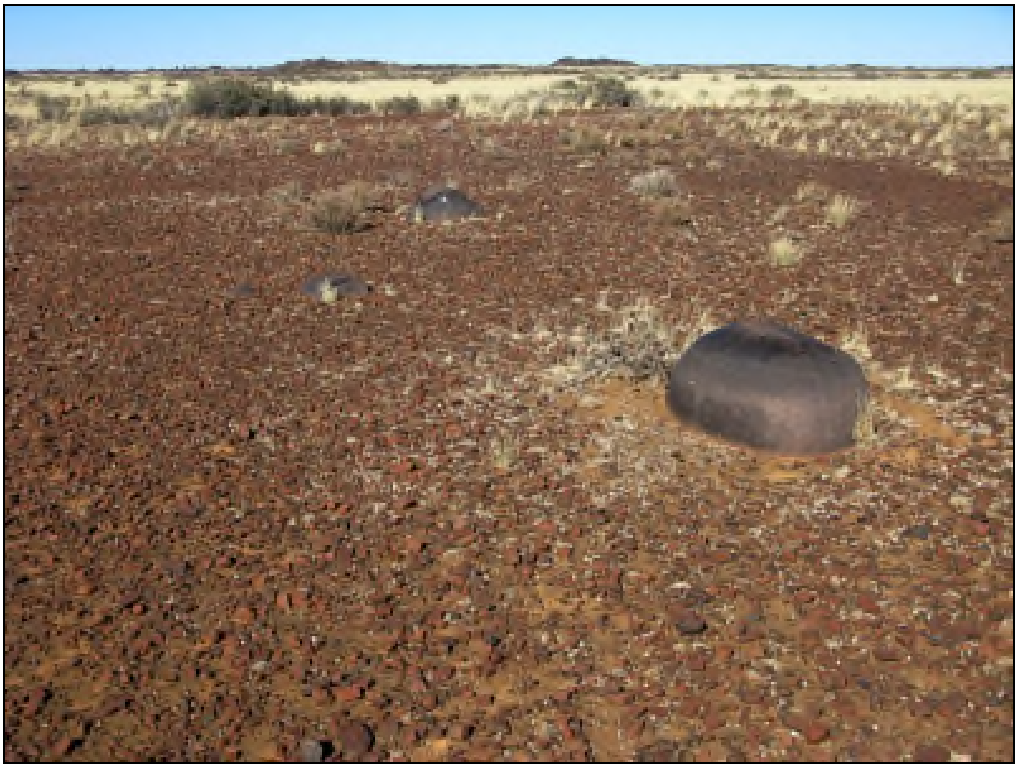

Fig. 19. Surface gravels of brown-patinated hornfels derived from baking of Prince Albert Formation mudrocks by dolerite intrusions, Melkbosch Vley 278 (Loc. 028).

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). Field studies in the broader Exheredo Solar Energy Facility study area show that these comprise a wide range of silty, sandy and gravelly alluvial deposits, colluvial rubble (*e.g.* dolerite scree on rocky hillslopes), surface gravels of various origins (*e.g.* downwasted products of bedrock weathering and erosion, such as the polymict bouldery erratics overlying the Dwyka Group outcrop area), pedocretes including widespread calcretes, pan sediments 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. 34) but aeolian sands of the Kalahari Group (Gordonia Formation) are not mapped here. They do occur closer to Kenhardt, however.

Subsurface nodular and hardpan calcretes occur widely within the study area within soils overlying the Dwyka and Ecca Groups as well as Karoo dolerite. Surface exposure of an extensive calcrete hardpan within the Prince Albert Formation outcrop area is seen on Styns Vley 280 (Loc. 013), although this might be related to hidden dolerite intrusion intrusion (Fig. 22). Several meters (locally > 3 m) of thick, pale brown to buff, silty soils with well-developed nodular calcretes in the upper portion overlie deeply-weathered dolerite *sabunga* threaded with calcrete veins in borrow pits on Styns Vley 280 (Loc. 010) and on Kopjes Vley 281 (Locs. 039 & 040). Extensive development of calcrete over dolerite and Dwyka rocks is well seen in a series of large borrow pits along the Sishen – Saldanha railway line as well as nearby railway cuttings (Locs. 042-050). Locally the calcrete horizons contain dispersed embedded, flaked, patinated hornfels artefacts (probably MSA) that also occur downwasted on the calcrete surface, suggesting a Pleistocene or younger age for these pedocretes. An especially well-developed nodular calcrete overlying weathered dolerite is seen in the borrow pit on Olyven Kolk 187 (Loc. 050; Fig. 20). This area may originally have formed part of a pan. The calcrete has a vertical nodular fabric, is sparsely gravelly and up to 1 m thick with a rubbly surface. Calcrete veins intrude into underlying *sabunga* (weathered dolerite). A conspicuous calcrete hardpan is associated with a small dolerite koppie near Stynsvlei homestead on Styns Vlei 280 (Loc 038; Fig. 21).

Stream alluvium in the study area is variously silty, sandy or gravelly (*e.g.* Melkbosch Vley 278, Loc. 036; Fig. 24). No well-consolidated older river terrace gravels were observed here. The wide spectrum of surface gravels of colluvial, sheet wash and downwasting origin have already been briefly mentioned with reference to the various underlying bedrock units considered previously. They overlie sandy to silty soils of probable alluvial origin. Silty soils without surface gravels are well seen on Kopjes Vley 281 where they are associated with Driedoring shrubs and grassy vegetation (Fig. 27). No good vertical sections through pan sediments were observed during the field study, with the possible exception of laminated silty sediments overlying weathered Dwyka in a borrow pit on Farm 246 (Loc. 046; Fig. 23). Pan surfaces elsewhere comprise sun-cracked silty mud with dispersed surface gravels. Hornfels and pale quartzite clasts among the latter are often anthropogenically flaked and may have been brought into the pan area by Stone Age humans (*e.g.* Stynsvlei, Loc. 005; Figs. 25 & 26). Of passing interest are occasional float blocks of Iceland spar (coarsely crystalline sparry calcite) that occur within surface gravels overlying the Prince Albert Formation in the vicinity of dolerite intrusions (*e.g.* Styns Vlei 280, Loc. 038; Fig. 28). Veins of calcite up to 3 m wide are reported from the Kenhardt sheet area – including on Gemsbok River 301 - in the basal chill zone of dolerite sills and are of hydrothermal origin (Slabbert *et al.* 1999).

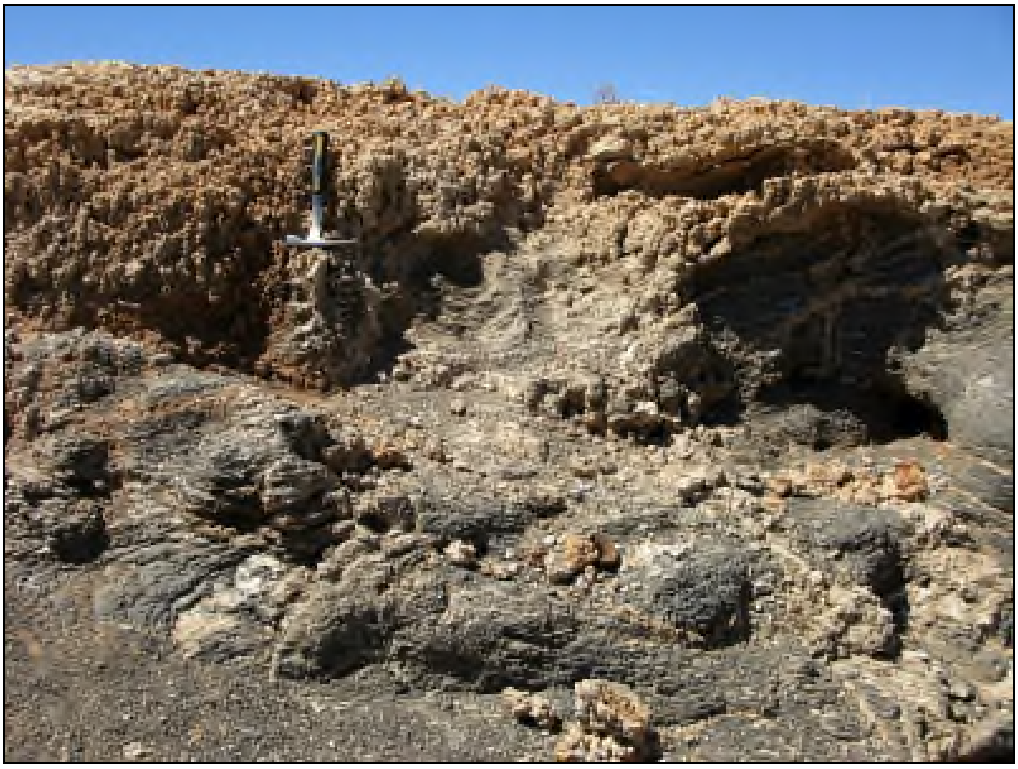

Fig. 20. Well-developed nodular calcrete overlying deeply-weathered dolerite, borrow pit on Olyven Kolk 187 (Loc. 050) (Hammer = 30 cm).

Fig. 21. Dense calcrete hardpan associated with dolerite koppie, Styns Vley 280 (Loc. 038).

Fig. 22. Partially exposed calcrete hardpan on Styns Vlei 280, perhaps associated with a hidden dolerite intrusion.

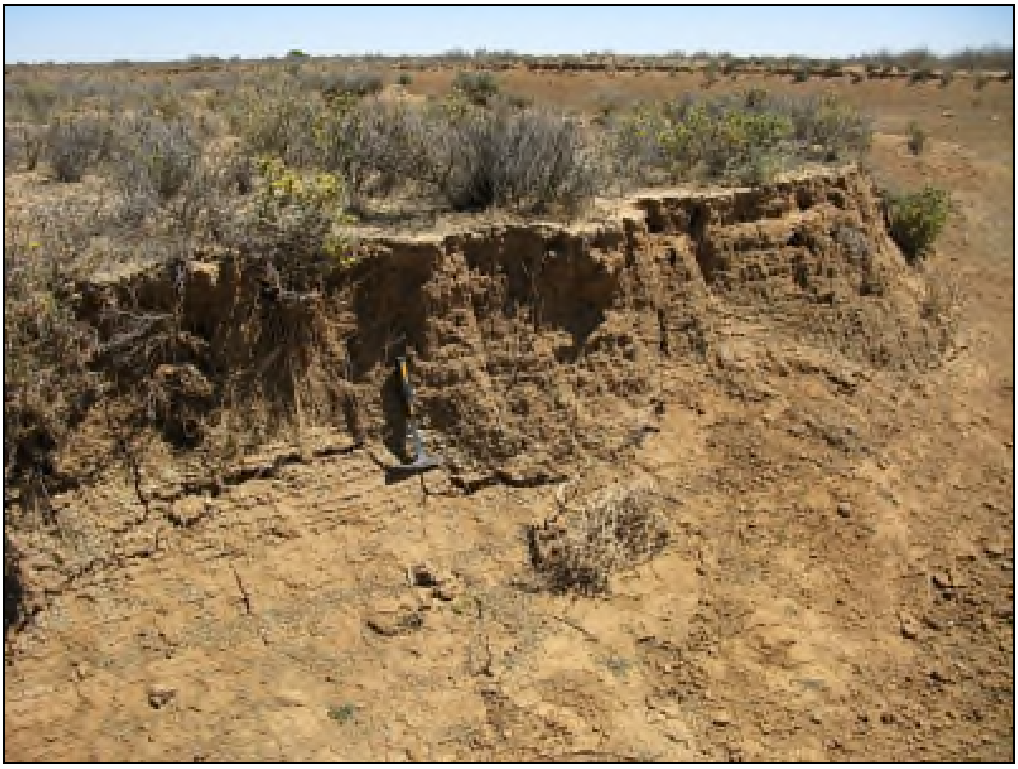

Fig. 23. Borrow pit section through thinly-bedded silty sediments overlying Dwyka bedrocks, perhaps related to a pan area, Farm 246 (Hammer = 30 cm).

Fig. 24. Shallow intermittent stream on Melkbosch Vlei 278 (Loc. 036) with fine gravelly to sandy alluvium and reworked blocks of ferruginous carbonate concretions.

Fig. 25. Sun-cracked silty sediments in the Stynsvlei pan with surface gravels of calcrete, dolerite and possibly introduced hornfels and quartzite, Styns Vley 280(Loc. 005).

Fig. 26. Surface gravels on the Stynsvlei pan (Loc. 005). The flaked hornfels and quartzite artefacts have probably been introduced by humans or perhaps sheetwash (Scale in cm).

Fig. 27. Silty alluvium without gravels, Kopjes Vley 281.

Fig. 28. Float block of coarsely-crystalline Iceland spa (*c.* 10 cm across) associated with a calcretised dolerite intrusion, Styns Vley 280 (Loc. 038).

2.4. Jurassic Karoo Dolerite Suite

Extensive sheets (sills) of Early Jurassic dolerite underlie sizeable portions of the broader Exheredo Solar Energy Facility study area and crop out in a north-south trending range of low koppies along the border of Styns Vley 280 and Gemsboks Kolk 279. The dolerite is expressed at surface as scatters or concentrations of black, desert-varnished boulders (relict corestones) or low bouldery black *koppies*, such as Spookkop, Katkop and Rosland se Kop, with a surrounding apron of dolerite gravelly colluvium, sometimes rubbly (Fig. 29 to 31). Elsewhere the dolerite is hidden beneath a blanked of superficial sediments but is frequently encountered in local boreholes. Where exposed in borrow pits (*e.g.* Locs. 010, 041 042) it is usually deeply weathered near-surface (crumbly *sabunga*), with onionskin exfoliation structures and pseudolamination, and veined with calcrete (Fig. 33b). Typically the dolerite subcrop is overlain by thick to thin, heavily calcretised sandy to silty soils (Fig. 33a).

A good exposure of the intrusive contact between a transgressive dolerite sill and well-bedded country rocks of the Prince Albert Formation (or possibly Dwyka Group, as mapped) is seen in railway cuttings at Loc. 047 (Uitspan Kop 246). Here the baked Ecca mudrocks (hornfels) stand out due to their characteristic reddish-brown surface weathering patina (Fig. 32). Baking and reddening of clast-rich Dwyka tillite is seen at railway cuttings at Loc. 048 (Manier Tyds Kolkjes 247).

Fig. 29. Spookkop, a typical low, black, boulder dolerite koppie locate on the border between Styns Vley 280 and Gemsboks Kolk 279.

Fig. 30. Bouldery dolerite corestones overlying dolerite subcrop near Melkbosvlei homestead (Loc. 037). The black patina is desert varnish.

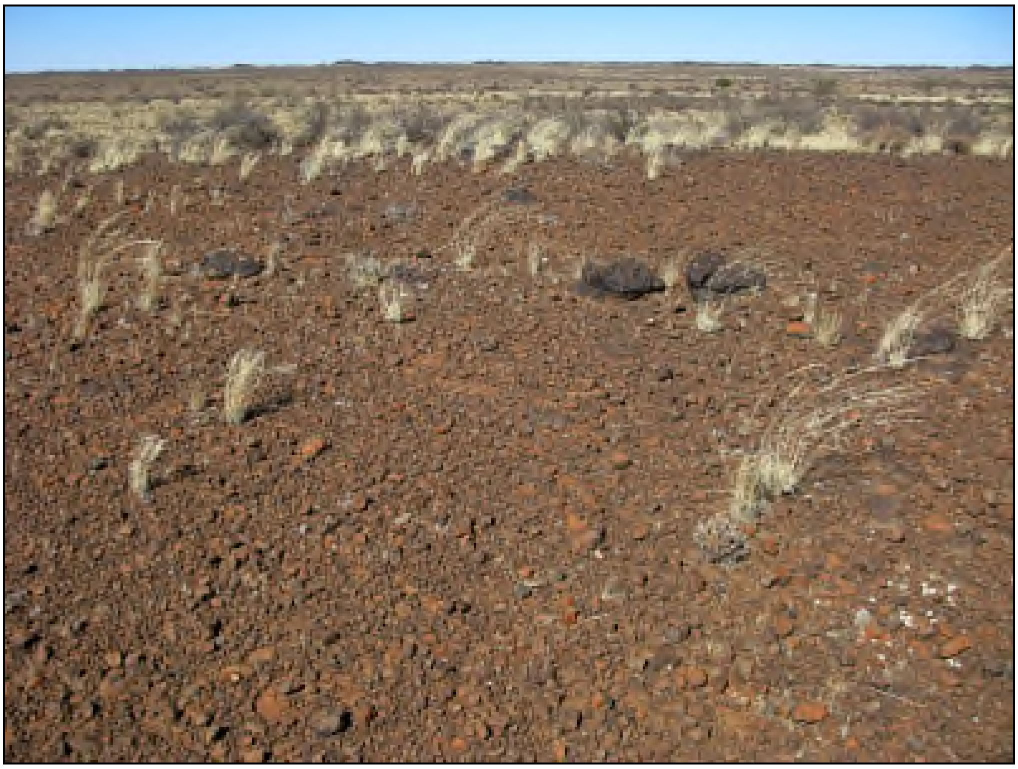

Fig 31. Rubbly colluvial gravels of weathered dolerite just southeast of Melbosvlei homestead, Melkbosch Vley 278.

Fig. 32. Railway cutting on Uitspan Kop 246 showing intrusive contact between a dolerite sill and bedded sediments of the Dwyka or Ecca Group (Loc. 047). The reddish-brown surface gravels are of dolerite and / or hornfels.

Fig. 33a. Deeply-weathered dolerite *sabunga* overlain by silty alluvial soils with nodular calcrete horizon, borrow pit on Kopjes Vlei 281 (Loc. 040) (Hammer = 30 cm).

Fig. 33b. Extensive calcrete veining of deeply-weathered dolerite *sabunga* exposed in a borrow pit on Olyven Kolk 187 (Loc. 050).

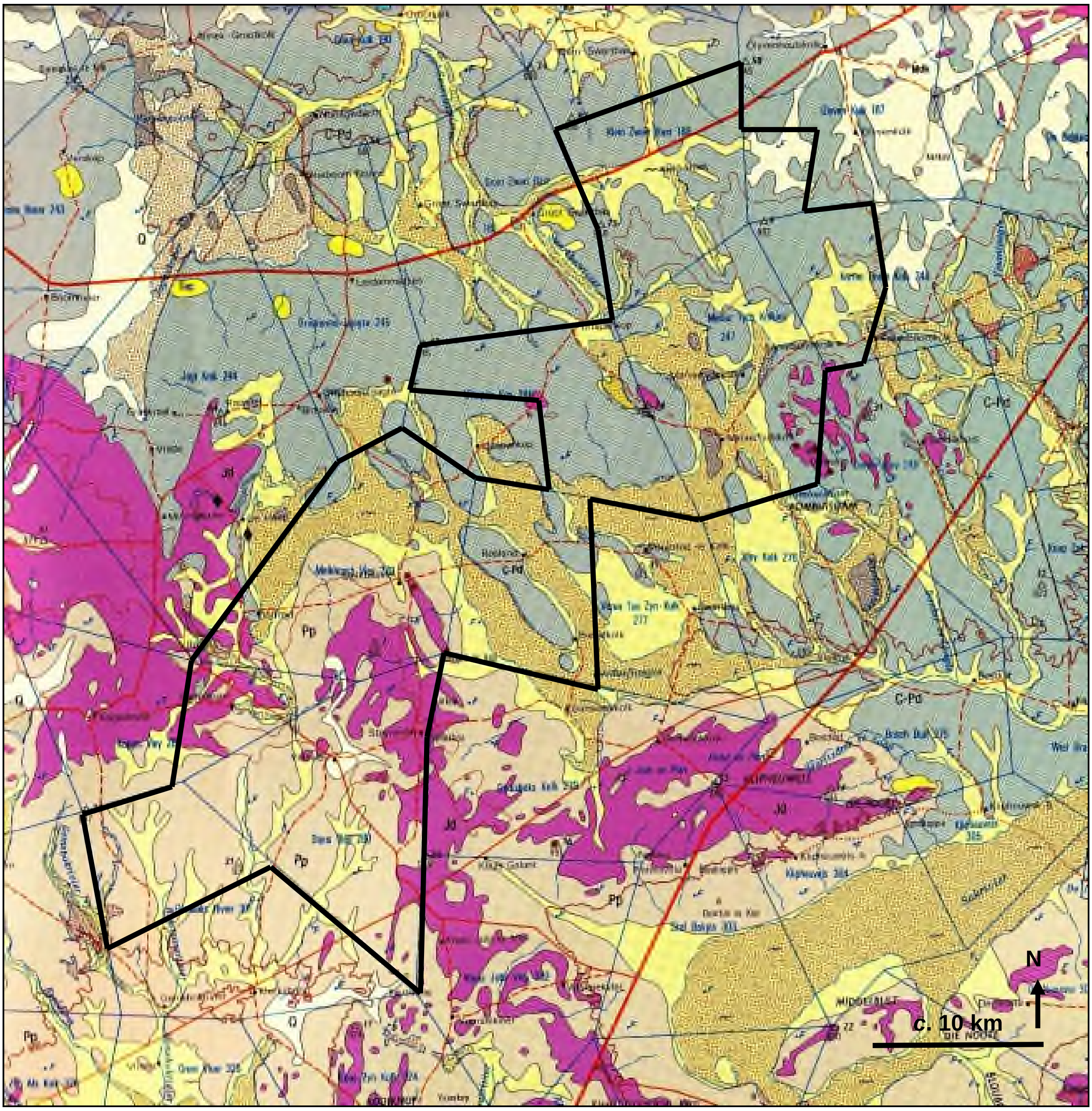

Fig. 34. Extract from 1: 250 000 geological map 2920 Kenhardt (Council for Geoscience, Pretoria) showing the approximate outline of the broader Exheredo Solar Energy Facility study area, including land parcels involved in with 132 kV transmission line (black polygon). The main geological units mapped 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 Exheredo Solar Energy Facility transmission line study region near Kenhardt is outlined here (See also summary provided in Table 1 below). Fossils do not occur within igneous dolerite or the Precambrian basement rocks (Table 1).

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.

No fossil remains were observed within the Dwyka Group sediments of the Exheredo study area, apart from occasional boulder-sized erratics of stromatolitic cherty dolomite that have probably been reworked from the Transvaal Supergroup (*e.g.* Ghaap Plateau region) (Fig. 35, Loc. 048). Diagenetic silicious and ferruginous carbonate concretions within the tillites (Figs. 8 & 9) are unfossiliferous, although the latter sometimes contain well-developed cone-in-cone structures that are superficially stromatolite-like (These abiogenic mineral structures or pseudofossils may well be responsible for occasional reports of stromatolites from the Dwyka Group; *e.g.* Slabbert *et al.* 1999). No potentially fossiliferous interglacial or post-glacial laminites were seen.

Fig. 35. Glacial erratic of cherty stromatolitic carbonate from the Dwyka Group, Manier Tyds Kolkjes 247 (Scale in cm).

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). Simple, narrow horizontal intrastratal and bedding plane fossil burrows are observed locally within the more platy-weathering Prince Albert sandstones and siltstones in the broader Exheredo Solar Energy Faility study area, for example on Styns Vlei 280 (Locs. 013, 014) (Figs. 36 & 37).

Stromatolites (fossil laminated microbial mounds) up to one meter across are also reported from the Prince Albert Formation in the Kenhardt sheet area. However, it is likely that these records refer rather to abiogenic cone-in-cone structures within diagenetic concretions; *i.e.* they are a form of *pseudofossil*. Good examples of stromatolite-like cone-in-cone structures within ferruginous carbonate concretions were observed within the present study area on Styns Vley 280, Melkbosch Vley 278 (Locs. 008, 028, 031 & 036) (Figs. 38 & 39).

Fig. 36. Float blocks of Prince Albert Formation siltstone containing narrow intrastratal fossil burrows (Scale in cm), Styns Vlei 280 (Loc. 014).

Fig. 37. Float block of Prince Albert Formation siltstone containing narrow intrastratal fossil burrows (Scale in cm), Styns Vlei 280 (Loc. 016).

Fig. 38. Large oblate ferruginous carbonate concretion within the Prince Albert Formation showing misleading stromatolite-like appearance (Scale = 15 cm), Melkbosch Vley 278 (Loc. 027).

Fig. 39. Vertical section through 5 cm-thick ferruginous carbonate concretion showing abiogenic, stromatolite-like internal fabric due to cone-in-cone structure, Melkbosch Vley 278 (Loc. 027). These are *pseudofossils*.

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 Mid 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.

The only fossil remains recorded during fieldwork from superficial sediments within the broader Exheredo study area are rare globular calcretised termitaria of probable Pleistocene age. These occur embedded within crumbly Dwyka Group saprolite (weathered bedrock) on Farm 278 (Loc. 043) and are about 30 cm in diameter (Fig. 40). Reworked fragments of calcrete from surface gravels on Melkbosch Vley 278 (Loc. 030) show a complex stromatolite-like growth structure (Fig. 41). It is unclear if this fabric is biogenic - perhaps related to a calcertised insect burrow - or not.

Table 1: Fossil heritage recorded from the major rock units that are represented (or probably represented) in the broader Exheredo Solar Energy Facility study area near Kenhardt

GEOLOGICAL UNIT	ROCK TYPES & AGE	FOSSIL HERITAGE	PALAEONT-OLOGICAL SENSITIVITY
LATE CAENOZOIC SUPERFICIAL SEDIMENTS, especially 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 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 (*e.g.* Tertiary alluvium associated with old river courses)**
Prince Albert Formation ECCA GROUP	**marine to hyposaline basin plain mudrocks, minor volcanic ashes, phosphates and ironstones, post-glacial mudrocks at base 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 BUT LOCALLY HIGH IN N. CAPE**
KAROO DOLERITE SUITE	**intrusive dolerites (dykes, sills), associated diatremes EARLY JURASSIC**	**none**	**ZERO**
Mbizane Formation DWYKA GROUP	**tillites, interglacial mudrocks, deltaic & turbiditic sandstones, minor thin limestones LATE CARBONIFER-OUS – EARLY PERMIAN**	**sparse petrified wood & other plant remains, palynomorphs, trace fossils (*e.g.* arthropod trackways, fish trails, U-burrows), possible stromatolites in limestones**	**LOW TO MODERATE**
De Bakken Granite NAMAQUA-NATAL PROVINCE	**highly metamorphosed sediments, intrusive granites MID-PROTEROZOIC (*c.* 2 billion yrs old)**	**none**	**ZERO**

Fig. 40. ***In situ*** **calcretised fossil termitarium (termite nest) embedded within Dwyka saprolite, borrow pit on Farm 278 (Loc. 043) (Hammer = 30 cm).**

Fig. 41. Float block of complex laminated calcrete reworked from a hardpan or possibly a fossil burrow system from surface gravels on Melkbosch Vley 278 (Loc. 030) (Block is *c*. 6 cm across).

4. ASSESSMENT OF IMPACTS ON FOSSIL HERITAGE

The Exheredo Solar Energy Facility transmission line 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 power line will entail substantial excavations into the superficial sediment cover and locally into the underlying bedrock as well. These include, for example, excavations and clearing for the new access roads, transmission line tower footings, the on-site substations, laydown areas and construction camps. 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.

Desktop analysis of the fossil records of the various sedimentary rock units underlying the broader Exheredo study area, combined with field assessment of numerous representative rock exposures within and close to this area, indicate that all of these units are of low to very low palaeontological sensitivity (Section 3). The potentially fossiliferous Karoo Supergroup bedrocks (Dwyka and Ecca Groups) are deeply weathered and extensively calcretised near-surface. Over the majority of their outcrop areas the bedrocks are mantled by various superficial deposits that may reach thicknesses of several meters and that are of low palaeontological sensitivity. These include alluvium, colluvium, a wide range of surface gravels, calcrete hardpans and pan sediments. The only fossil remains recorded during the field assessment are (1) small-scale fossil burrows within Prince Albert Formation mudrocks of Early Permian age, (2) downwasted, ice-transported blocks (erratics) of Precambrian stromatolitic carbonate within surface gravels overlying the Dwyka Group tillites, and (3) rare calcretised termitaria of probable Pleistocene or younger age embedded within weathered Dwyka bedrocks. These fossils are all of widespread occurrence within Bushmanland and special protection or mitigation measures for the very few known fossil sites are therefore not considered warranted here.

Construction of the Exheredo Solar Energy Facility and associated infrastructure, including proposed new overhead power lines to Aries Substation, is therefore unlikely to entail significant impacts on local fossil heritage resources. The operational and decommissioning phases of the solar energy facilities and transmission line are unlikely to involve further adverse impacts on local palaeontological heritage.

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

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

No areas or sites of exceptional fossil heritage sensitivity or significance have been identified within the study area. The majority of fossil sites recorded in the study region lie on the margins of the broader development area and outside the anticipated development footprint. The fossil remains identified in this study are mostly of widespread occurrence within the formations concerned (*i.e.* not unique to the study area). Irreplaceable loss of fossil heritage is therefore not anticipated. Should fossil remains be impacted by the proposed development, these impacts can be partially mitigated, as outlined in the following section of the report.

There are no fatal flaws in the Exheredo Solar Energy Facility development proposal as far as fossil heritage is concerned. Due to the general scarcity of fossil remains, the high levels of bedrock weathering as well as the extensive superficial sediment cover observed within the entire study area, the overall impact significance of the construction phase of the proposed transmission line project is assessed as LOW.

It should be noted that should new fossil remains be discovered before or during construction and reported by the responsible ECO to the responsible heritage management authority (SAHRA) for professional recording and collection, as recommended here, the overall impact significance of the project would remain LOW. Residual negative impacts from loss of fossil heritage would be partially offset by an improved palaeontological database for the study region as a direct result of appropriate mitigation. This is a *positive* outcome because any new, well-recorded and suitably curated fossil material from this palaeontologically under-recorded region would constitute a useful addition to our scientific understanding of the fossil heritage here.

In the absence of comprehensive data on further alternative energy or other developments in the Kenhardt area, it is impossible to realistically assess cumulative impacts on fossil heritage resources. A recent palaeontological assessment for a solar project to the east of Kenhardt by the author (Almond 2014A) concluded that the palaeontological sensitivity of that area is low, but there are significant differences in the underlying geology concerned. The potentially fossiliferous sedimentary rock units represented within the present study area (*e.g.* Prince Albert Formation, calcretes) are of widespread occurrence and this is also likely to apply to most of the fossils they contain. It concluded that the cumulative impacts on fossil heritage resources posed by the known solar energy developments in the region is *low*.

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

Table 2: Assessment of impacts of the proposed Exheredo Solar Energy Facility transmission line on fossil heritage resources during the construction phase of the development (*N.B.* Significant impacts are not anticipated during the operational and decommissioning phases).

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

5. RECOMMENDED MITIGATION AND MANAGEMENT ACTIONS

Given the low impact significance of the proposed Exheredo Solar Energy Facility transmission line development near Kenhardt as far as palaeontological heritage is concerned, no further specialist palaeontological heritage studies or mitigation are considered necessary for this project, pending the discovery or exposure of substantial new fossil remains during development.

During the construction phase all deeper (> 1 m) bedrock excavations should be monitored for fossil remains by the responsible ECO. Should substantial fossil remains such as vertebrate bones and teeth, plant-rich fossil lenses or dense fossil burrow assemblages be exposed during construction, the responsible Environmental Control Officer should safeguard these, preferably *in situ*, and alert SAHRA, *i.e.* The South African Heritage Resources Authority, as soon as possible (Contact details: Mrs Colette Scheermeyer, P.O. Box 4637, Cape Town 8000. Tel: 021 462 4502. Email: cscheermeyer@sahra.org.za) so that appropriate action can be taken by a professional palaeontologist, at the developer's expense. Mitigation would normally involve the scientific recording and judicious sampling or collection of fossil material as well as associated geological data (*e.g.* stratigraphy, sedimentology, taphonomy) by a professional palaeontologist.

These mitigation recommendations should be incorporated into the Environmental Management Plan (EMP) for the Exheredo Solar Energy Facility transmission line.

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

Please note that:

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

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

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

6. RECOMMENDATIONS FOR THE DRAFT ENVIRONMENTAL MANAGEMENT PLAN

The following measures for inclusion in the Environmental Management Plan for the proposed Exheredo Solar Energy Facility transmission line development near Kenhardt are outlined below (following page), according to the scheme developed by Savannah Environmental (Pty) Ltd.

Specialist palaeontological mitigation is only triggered should significant new fossil remains be exposed during the construction phase.

Note that the operational and decommissioning phases of the development are unlikely to have significant impacts on palaeontological heritage and no further recommendations are made in this regard.

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

Project component/s	Construction of new transmission line to Aries Substation.
Potential Impact	Disturbance, damage, destruction or sealing-in of scientifically valuable fossil material embedded within bedrock or weathered-out at ground surface
Activity/risk source	Extensive bedrock excavations and surface disturbance (*e.g.* new access roads, transmission line towers, the on-site substations, laydown areas and construction camps).
Mitigation: Target/Objective	Recording, judicious sampling and curation of any important fossil heritage exposed during construction within the Exheredo Solar Energy Facility transmission line development area.

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

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

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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.

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Declaration of Independence

I, John E. Almond, declare that I am an independent consultant and have no business, financial, personal or other interest in the proposed development project, application or appeal in respect of which I was appointed other than fair remuneration for work performed in connection with the activity, application or appeal. There are no circumstances that compromise the objectivity of my performing such work.

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APPENDIX: GPS LOCALITY DATA

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

Locality number	South	East	Comments
004	S29 45 12.9	E20 37 14.6	Dolerite koppie and surrounding apron of gravels, Styns Vlei 280.
005	S29 45 17.9	E20 37 48.6	Stynsvlei pan sediments, Styns Vlei 280.
006	S29 45 34.6	E20 37 49.1	Surface gravels overlying Prince Albert Fm, in situ dolerite corestone boulders, nr stone buildings, Styns Vlei 280.
007	S29 46 05.5	E20 37 49.1	Thick calcretised sandy soils overlying dolerite, Styns Vlei 280.
008	S29 46 19.5	E20 37 50.0	Large ferruginous carbonate diagenetic concretions in Prince Albert Formation, Styns Vlei 280.
009	S29 47 26.6	E20 37 44.8	Blocky, angular surface gravels of baked Prince Albert sandstone, Styns Vlei 280.
010	S29 48 46.7	E20 37 22.6	Borrow pit into calcretised silty sediments overlying weathered dolerite, west of dust road, Styns Vlei 280.
011	S29 48 26.1	E20 36 43.3	Brown-patinated platy surface gravels overlying Prince Albert Fm, Styns Vlei 280.
013	S29 49 23.8	E20 34 38.3	Calcrete hardpan in Prince Albert outcrop area, Styns Vlei 280.
014	S29 47 55.6	E20 33 37.5	Artificial pit excavated into weathered, calcretised Prince Albert Fm mudrocks, Styns Vlei 280.
016	S29 47 51.5	E20 33 40.1	Small surface exposure of Prince Albert Fm near dam, calcrete-veined, Styns Vlei 280.
018	S29 46 07.1	E20 35 05.4	Platy surface gravels overlying Prince Albert Fm nr Valsvlei homestead, Styns Vlei 280.
019	S29 46 40.6	E20 33 34.8	Platy surface gravels and calcrete overlying Prince Albert Fm nr transmission line, Styns Vlei 280.
020	S29 46 57.4	E20 32 20.7	Platy surface gravels and calcrete overlying Prince Albert Fm nr transmission line, Styns Vlei 280
021	S29 46 33.1	E20 31 51.4	Desert varnished surface gravels, orange-brown sandstone gravels overlying Prince Albert Fm, Styns Vlei 280.
024	S29 43 03.9	E20 32 35.2	Pan area with surface gravels, Melkbosch Vley 278.
025	S29 42 11.7	E20 32 48.0	Low rocky exposure of dark brown Mbizane Fm (Dwyka Group) wackes, dropstone sandstones, Melbosch Vley 278.
026	S29 42 21.5	E20 33 17.9	Pan area with abundant flaked quartzite artefacts, Dwyka erratics, Dwyka brown wackes, Melkbosch Vlei 278.
027	S29 43 27.1	E20 33 26.2	Concentration of large ferruginous ironstone concretions in Prince Albert Fm, Melkbosch Vlei 278. Stromatolite-like cone-in-cone structures.
028	S29 42 17.7	E20 37 36.5	Hornfels surface gravels associated with dolerite intrusion, Melkbosch Vlei 278. Gravels composed of erratics from Dwyka Group nearby.

029	S29 42 01.9	E20 37 41.1	Hill slope colluvium of irregular-fracturing Prince Albert fine-grained sandstone, Melkbosch Vlei 278.
030	S29 41 48.2	E20 37 44.0	Fine-grained desert-varnished surface gravels on Prince Albert Fm. Reworked blocks of calcrete hardpan showing stromatolite-like internal lamination, Melkbosch Vlei 278.
031	S29 41 44.6	E20 37 43.6	Brownish diagenetic concretions within the Prince Albert Fm, Melkbosch Vlei 278
032	S29 41 02.2	E20 37 25.7	Surface gravels of patinated hornfels (many flaked), dolerite corestones near Melkbosvlei homestead, Melkbosch Vlei 278.
033	S29 40 23.1	E20 37 37.9	Polymict surface gravels of Dwyka erratic cobbles and boulders, Melkbosvlei 278.
034	S29 39 17.5	E20 38 03.1	Polymict surface gravels of Dwyka erratic cobbles and boulders, Melkbosch Vlei 278.
035	S29 38 59.3	E20 38 08.0	Coarse polymict surface gravels of Dwyka erratic cobbles and boulders, Melkbosch Vlei 278.
036	S29 41 01.9	E20 38 23.2	Shallow stream on Melkbosch Vlei 278 with reworked ferruginous carbonate concretions from Prince Albert Fm.
037	S29 41 04.9	E20 37 36.5	Bouldery dolerite ridge near Melkbosvlei homestead with Stone Age "factory site" exploiting local hornfels on crest (MSA, LSA artefacts), Melkbosch Vlei 278. Desert varnish, onionskin weathering in dolerites.
038	S29 45 05.9	E20 37 47.5	Thick calcrete hardpan development associated with dolerite koppie, Styns Vley 280. Float blocks of sparry calcite.
039	S29 44 42.9	E20 33 48.5	Well-developed nodular calcrete within superficial sediments overlying dolerite, roadside borrow pit, Kopjes Vlei 281.
040	S29 44 34.4	E20 33 38.7	Deeply-weathered dolerite overlain by silty alluvial soil with well-developed subsurface nodular calcrete, roadside borrow pit, Kopjes Vlei 281.
041	S29 41 45.2	E20 31 51.7	Large borrow pit excavated into weathered dolerite along Sishen-Saldanha railway line, Farm 244
042	S29 41 11.1	E20 32 47.9	Large borrow pit excavated into weathered dolerite along Sishen-Saldanha railway line, Farm 244
043	S29 40 22.6	E20 34 01.5	Large borrow pit excavated into weathered clast-poor Dwyka Group tillites along Sishen-Saldanha railway line, Farm 278. Siliceous and ferruginous carbonate concretions. Occasional spheroidal calcretised termitaria.
044	S29 39 35.6	E20 35 18.1	Large borrow pit excavated into weathered clast-poor Dwyka Group tillites along Sishen-Saldanha railway line, Farm 278.
045	S29 37 58.4	E20 37 46.0	Large borrow pit excavated into weathered clast-poor Dwyka Group tillites in borrow pit as well as cuttings along Sishen-Saldanha railway line, Farm 278.
046	S29 37 08.5	E20 39 42.7	Bedded alluvium or pan sediments overlying weathered bedded to massive Dwyka Group sediments, large borrow pit along Sishen-Saldanha railway line, Farm 246.

047	S29 36 49.0	E20 41 29.1	Dolerite intruding well-bedded Prince Albert or Dwyka shales, cutting along Sishen-Saldanha railway line, Uitspan Kop 246.
048	S29 34 12.7	E20 46 02.2	Railway cuttings through reddened Dwyka Group tillites overlain by dolerite. Float block (glacial erratic) of stromatolitic cherty limestone, Manier Tyds Kolkjes 247..
049			Good railway cutting exposures of well-bedded Dwyka diamictites, Sishen Saldanha railway, Klein Zwart Bast 188 near Aries Substation.
050	S29 30 37.53	E20 49 06.76	Nodular calcrete hardpan overlying weathered dolerite, large borrow pit along Sishen-Saldanha railway, Olyven Kolk 187.
051	S29 45 21.9	E20 48 55.3	Road cutting through well-bedded Prince Albert Fm laminated mudrocks, R27 southwest of Kenhardt.