PALAEONTOLOGICAL HERITAGE: COMBINED DESKTOP STUDY & PHASE 1 FIELD ASSESSMENT

PROPOSED DISSELFONTEIN KEREN SOLAR PLANT NEAR HOPETOWN, NORTHERN CAPE

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May 2012

1. SUMMARY

Keren Energy Disselfontein (Pty) Ltd is proposing to develop a 10 MW capacity solar energy facility on the Remainder of Farm 77, Hopetown, Northern Cape. The study site for the Disselfontein Keren Solar Plant is located 23.5 km NW of Hopetown and close to the western banks of the Orange River.

Potentially fossiliferous rock units within the broader Hopetown - Douglas study region include Early Permian marine sediments of the lowermost Ecca Group (Prince Albert Formation) as well as Tertiary fluvial gravels of the Orange River. However, field assessment shows that neither of these rock units is represented within the Disselfontein study area, which is largely mantled by various superficial deposits (surface gravels, calcretes, aeolian sands) of low to very low palaeontological sensitivity. The only Karoo Supergroup rocks present are unfossiliferous glacial tillites that are additionally deeply weathered and calcretised.

It is concluded that the proposed Disselfontein Keren Solar Plant project does not pose a significant threat to local fossil heritage resources. Should substantial fossil remains (*e.g.* petrified wood, vertebrate bones and teeth) be exposed during development, these should be safeguarded, preferably *in situ*, and reported by the ECO to SAHRA so that appropriate recording or mitigation measures can be considered.

2. OUTLINE OF DEVELOPMENT

Keren Energy Disselfontein (Pty) Ltd is proposing to construct a 10 MW Concentrating Photovoltaic (CPV) Energy Generation Facility, the Disselfontein Keren Solar Plant, on a site (Remainder of Farm 77, Hopetown) close to the Orange River and 23.5 km northwest of Hopetown, Northern Cape (Figs. 1 & 13). The land is currently zoned for agriculture.

The proposed activity entails the construction of about 140 CPV solar panels with a footprint of about 20 ha. The CPV panels will be mounted on pedestals drilled and set into the ground. Extensive bedrock excavations are not envisaged, but some vegetation will need to be cleared from the site. Associated infrastructure includes a perimeter access road, single track internal access roads, trenches for underground cables, 2 to 4 transformer pads, a switching station, a maintenance shed, and a temporary construction camp. Connection with the grid will be *via* the Disselfontein 132 / 22kV substation that is situated on site.

The present combined desktop and field-based palaeontological heritage assessment has been commissioned by EnviroAfrica cc, Somerset West as part of a comprehensive Heritage Impact

Assessment of the proposed development (Contact details: Mr Bernard de Witt, EnviroAfrica cc, P. O. Box 5367, Helderberg, 7135; 29 St James St, Somerset West; mobile: +27 82 4489991; tel: +27 21 851 1616; fax: 086203308). This report augments an earlier desktop study for this project completed by the author in March 2012.

2.1. National Heritage Resources Act

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

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

Minimum standards for the palaeontological component of heritage impact assessment reports are currently being developed by SAHRA. The latest version of the SAHRA guidelines is dated August 2011.

2.2. Approach used for this palaeontological study

This report provides an assessment of the observed or inferred palaeontological heritage within the Disselfontein study area, with recommendations for any specialist palaeontological mitigation where this is considered necessary. The report is based on (1) a review of the relevant scientific literature, (2) geological maps, (3) previous palaeontological heritage assessments for alternative energy and other developments in the region (*e.g.* Almond 2010), (4) the author's field experience with the formations concerned and their palaeontological heritage, and (5) a one-day field assessment on 27 April 2012 carried out by the author.

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

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

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

Before fieldwork commenced, a preliminary screening of satellite images and 1: 50 000 maps of the Disselfontein study area was conducted to identify any sites of potentially good bedrock exposure to be examined in the field. These sites might include, for example, natural exposures (*e.g.* stream beds, rocky slopes, stream gullies) as well as artificial exposures such as quarries, dams and cuttings along farm tracks.

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

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

GPS data for all localities mentioned in the text is provided in the Appendix.

2.3. Assumptions & limitations

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

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

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

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

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

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

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

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

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

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

Conditions for assessing the palaeontological sensitivity of the Disselfontein study area during the one day field visit were good. Vegetation cover is fairly low, and there is sufficient exposure of both bedrock units and superficial sediments in the area.

3. GEOLOGICAL BACKGROUND

The proposed Disselfontein Keren solar plant study area (29˚ 28' S, 23˚ 53' E) is situated on the eastern side of a minor dust road 23.5 km to the northwest of Hopetown, Northern CApe. The site is flat-lying at an elevation of *c*. 1080m amsl, some 50 m above the Orange River that flows 1.5 km to the northeast. Several small incised stream beds cross the site, draining to the northeast (Fig. 13).

The geology of the study area near Hopetown is shown on the 1: 250 000 geology map 2922 Prieska (Council for Geoscience, Pretoria; Fig. 1 herein). The explanation for the Prieska geological map has not yet been published and therefore critical details of the local stratigraphy relevant to the present impact study remain ambiguous. However, several of the rock units are treated in some detail in the explanations for the Britstown sheet to the south (Prinsloo, 1989) and the Koffiefontein sheet to the east (Zawada,1992).

The banks of the Orange River Valley in this region are underlain by ancient Precambrian lavas of the **Ventersdorp Supergroup** (**Allanridge Formation, Ra**) of Late Archaean age (*c*. 2.7 billion years old).This Late Archaean succession is almost entirely composed of resistant-weathering, dark green lavas and associated pyroclastic rocks that are dated to 2.7 Ga (Bosch 1993, Van der Westhuizen & De Bruiyn 2006 and refs. therein). Thin lenses of cross-bedded quartzite and conglomerate are recorded just above the base of the succession by Bosch (1993).

The Ventersdorp Group basement rocks are unconformably overlain by glacially-related sediments of the **Mbizane Formation** (**Dwyka Group, C-Pd**). The Mbizane Formation, up to 190m thick, is recognized across the entire northern margin of the Main Karoo Basin where it may variously form the whole or only the *upper* part of the Dwyka succession. It is characterized by its extremely heterolithic nature, with marked vertical and horizontal facies variation (Von Brunn & Visser 1999). The proportion of diamictite and mudrock is often low, the former often confined to basement depressions. Orange-tinted sandstones (often structureless or displaying extensive soft-sediment deformation, amalgamation and mass flow processes) may dominate the succession. The Mbizane-type heterolithic successions characterize the thicker Dwyka of the ancient palaeovalleys cutting back into the northern basement rocks. A number of **glacial pavements** – *i.e.* areas of glacially-striated and eroded bedrocks - of Dwyka age (*i.e.* Permo-Carboniferous, *c*. 300 Ma) are recorded from the Kimberley – Douglas region. These features, which here indicate consistent ice transport directions to the southwest, are of geological conservation significance.

Basinal sediments of the Lower Ecca Group are not separately mapped in the Douglas area on the 1:250 000 geology sheet 2922 Prieska, probably for reasons of scale. However, it is clear from detailed studies of the upper Dwyka succession near Douglas by McLachlan and Anderson (1973) as well as Von Brunn and Visser (1999) *plus* the more regional account of the Lower Karoo succession in the Kimberley – Britstown area by Visser *et al*. (1977-78) that the Dwyka Group is at least locally overlain here by laminated mudrocks of the **Prince Albert Formation** of the **Ecca Group**. This unit 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 Formation in the Kimberley - Britstown area consists predominantly of well-laminated basinal mudrocks (shales, siltstones) that are sometimes carbonaceous or pyritic and typically contain a variety of diagenetic concretions enriched in iron and carbonate minerals. Some of these carbonate concretions are richly fossilferous (Almond 2010 and refs. therein).

The Precambrian basement lavas and overlying Karoo Supergroup rocks within the study area are mantled with various Late Caenozoic **superficial deposits**. Relict patches of **terrace gravels** (“High Level Gravels”) are mapped on the north-eastern side of the study area (medium yellow with double “flying bird” symbol in Fig. 1) but their status is problematic (see discussion below). These ancient elevated alluvial gravels are of uncertain age, perhaps Plio-Pleistocene (last 5 Ma) or maybe even older (Miocene; *cf* Almond 2009). **Quaternary sands** (**Qs**) mapped here may be aeolian in original and provisionally assigned to the **Gordonia Formation** of the **Kalahari Group**.

Following the initial desktop study the main focus of the palaeontological field assessment was to determine whether or not potentially fossiliferous sediments of (1) the lowermost Ecca Group (Prince Albert Formation) or (2) Tertiary alluvial gravels (“High Level Gravels”) were represented within the study area.

Fine-grained, grey-green lavas of the Allanridge Formation are exposed in stream incisions to the north of the Disselfontein substation (Fig. 2). The lavas are generally massive, but locally vuggy (with irregular cavities) or vesicular (bubbly texture) to amygdaloidal (with secondarily infilled gas bubbles). Quartzite beds were not observed *in situ* within the Allanridge succession but may well be present here, judging from the abundance of quartzite gravel clasts locally. The low hilly area along the eastern edge of the study area is mantled not with High Level Gravels (*cf* Fig. 1) but with monomict, coarse, blocky surface gravels generated by *in situ* weathering and downwasting of the well-jointed Allanridge bedrocks (Fig. 7). Between the angular to subrounded lava blocks are finer, more polymict gravels of quartzite, vein quartz and lava embedded in or overlying orange-hued Kalahari sands and calcrete (Fig. 8). Occasional well-rounded river cobbles and pebbles are found, but these are very sparse and no substantial High Level Gravels attributable to the Orange River appear to be preserved here.

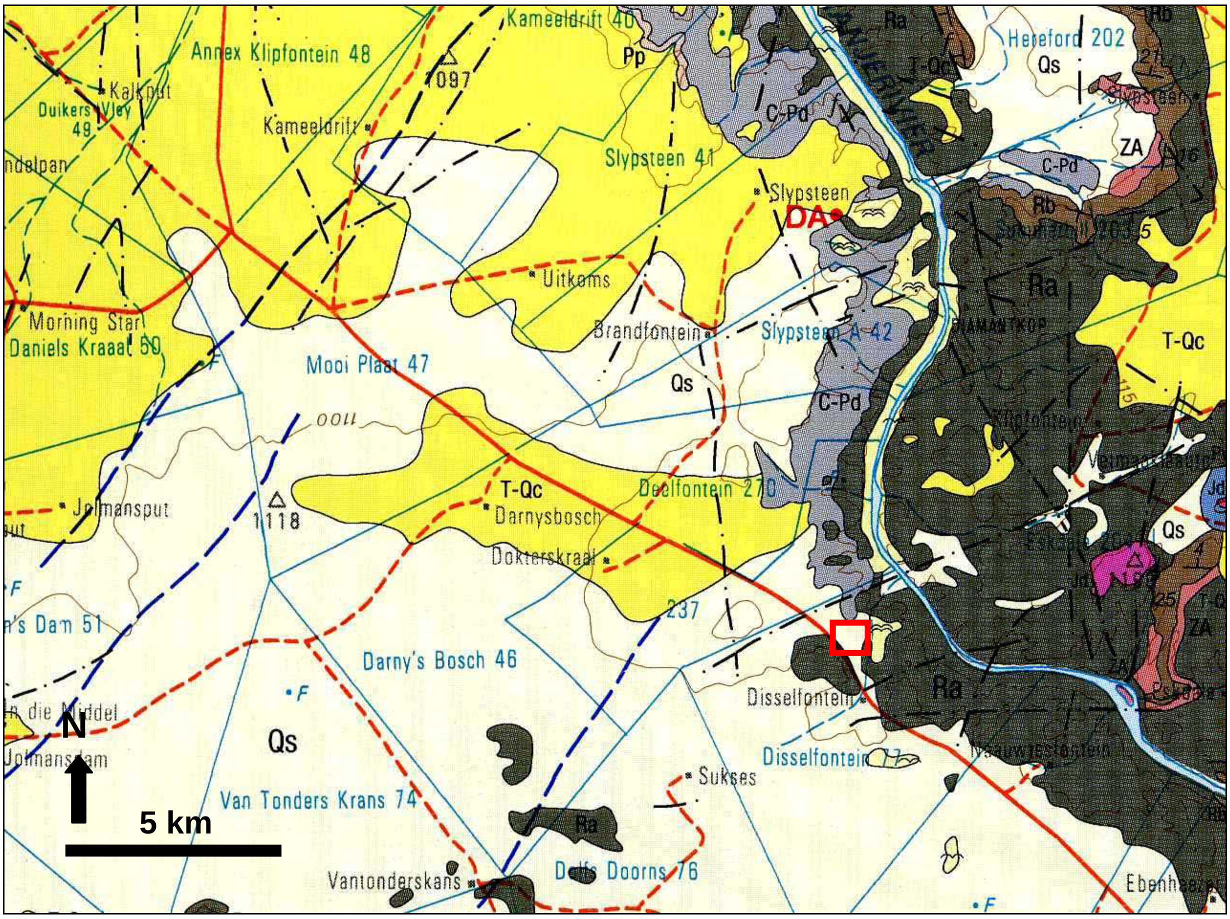

Fig. 1. Extract from 1: 250 000 geological map 2922 Prieska (Council for Geoscience, Pretoria) showing approximate location of proposed Disselfontein Keren Solar Plant study area some 1.5 km from the Orange River and 23.5 km to the NW of Hopetown, Northern Cape Province (small red rectangle). The study area is underlain at depth by Precambrian (Late Archaean) lavas of the Ventersdorp Group (Ra – dark green: Allanridge Formation) and/ or glacial or post-glacial sediments of the basal Karoo Supergroup (C-Pd - grey: Mbizane or Prince Albert Formations). In this region the basement lavas and Karoo sediments are largely overlain by Quaternary sands (Qs – pale yellow) and / or ancient river gravels of the Orange River (yellow with two flying –bird symbols).

Much of the western portion of the study area appears to be underlain at depth by grey boulder mudstones or tillites of the Dwyka Group. Over much of the area these are mantled by superficial deposits, but good exposures are seen in the sizeable quarry at the southern edge of the study area (Loc. 494). The Dwyka sediments here are massive to bedded with sparse to concentrated boulder-sized and smaller erratics of various exotic and local rock types (Fig. 3). Scattered lenticles of grey-brown diagenetic carbonate, often calcrete-coated, are present. The Dwyka rocks are weathered and pervasively calcretised for a depth of up to several meters (Figs. 4 & 5). No evidence of dark, laminated basinal mudrocks of the Prince Albert Formation (lowermost Ecca Group) was seen here.

The Dwyka outcrop area is capped by a pale cream to whitish calcrete hardpan, massive to crudely bedded and up to two meters or more thick (Fig. 10). The calcretes contain abundant embedded gravel clasts up to boulder size that originally downwasted from the Dwyka bedrocks below. The upper surface of the calcrete is usually mantled with coarse polymict gravels, angular to subrounded, that have in turn eroded out of the underlying hardpan (Fig. 5). The irregular contact between the hardpan and overlying orange-brown gravelly soils suggests one or more episodes of karstic weathering with pothole and doline formation (Fig. 10). Bedded units of angular grey mudrock chips (probably of Dwyka provenance) as well as lenticles of poorly-sorted but occasionally well-rounded gravels are seen within or above the calcretes, suggesting local fluvial input. Artificially flaked quartzite clasts are quite common within the subsurface gravels, implying a Pleistocene or later age (Fig. 6). The calcretes and gravels are variously mantled by reddish-brown gravelly soils, finer brown soils or Kalahari sands. Shallow stream bed exposures of subsurface calcrete and coarse gravels are seen at Loc. 498 (Fig. 11).

The flat area to the northeast of the Disselfontein substation is mantled with polymict surface gravels, including clasts of lava, quartzite, chert and abundant calcrete (Fig. 9). Numerous well-rounded clasts point to a substantial fluvial component, modified by downwasting.

Orange-hued Kalahari sands (probably Gordonia Formation equivalents) are well seen in the western portion of the study area (Fig. 12). Stream incision indicates sand thicknesses of several meters or more, thickening westwards away from the Orange River. The sands contain thin fine gravels (*e.g.* calcrete chips) and sparse boulders of probable Dwyka or Allanridge provenance.

Fig. 2. Stream incision into greenish-grey, blocky-jointed lavas of the Allanridge Formation to the north of substation (Loc. 496).

Fig. 3. Good quarry exposure of massive to thin-bedded grey Dwyka tillites with brownish diagenetic carbonate lenses (bottom LHS), sparse boulder-sized erratics and mantle of calcrete, well-bedded reddish-brown gravels and sandy soils (Loc. 494).

Fig. 4. Weathered and secondarily calcretised Dwyka Group tillites containing boulder-sized erratics and capped by reddish-brown gravelly soils (Loc. 494).

Fig. 5. Detail of upper, pervasively calcretised Dwyka Group sediments, overlying reddish-brown gravels and brown surface soils (Loc. 494) (Hammer = 27 cm.).

Fig. 6. Poorly sorted gravel lens overlying Dwyka outcrop. Clasts vary from angular to well-rounded and several are flaked (arrows), suggesting a Pleistocene or younger age (Loc. 494) (Hammer = 27 cm).

Fig. 7. Angular blocky surface gravels overlying the outcrop area of the Allanridge Formation on the eastern edge of the study area. These surface deposits, generated by *in situ* weathering and downwasting, appear to be mapped as fluvial High Level Gravels in Fig. 1.

Fig. 8. Finer gravels on surface between the large blocks seen in the previous figure (Scale in cm). Gravels here consist of Allanridge lavas, vein quartz and quartzite (many of the quartzite clasts are flaked) overlying orange-brown Kalahari sands.

Fig. 9. Polymict surface gravels in the flat area due NE of the substation. Note some well-rounded clasts of probably fluvial origin as well as abundant reworked pale calcrete fragments (Loc. 497).

Fig. 10. Secton through thick calcrete hardpan capping the Dwyka outcrop area. The irregular undulating contact with overlying reddish brown gravelly soils suggests karstic solution weathering (Loc. 494).

Fig. 11. Shallow stream incision through surface Kalahari sands to expose pale calcretes and downwasted coarse gravels beneath (Loc. 498).

Fig. 12. Deep orange-hued Kalahari aeolian (wind-blown) sands mantling the western portion of the study area.

4. PALAEONTOLOGICAL HERITAGE

The Precambrian **Allanridge Formation** (Ventersdorp Group) lavas are not palaeontologically sensitive. However, well-preserved glacial pavements that are sometimes incised into these ancient rocks record the movement of the Dwyka ice sheets across the area some 300 million years ago and warrant recording and protection as geo-conservation sites. No glacial pavements were noted during the field assessment.

Sparse, low diversity fossil biotas from the **Mbizane Formation** (Dwyka Group) mainly consist of arthropod trackways associated with 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 (Almond 2008, 2009, 2010). 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.

The most diverse as well as biostratigraphically, palaeobiogeographically and palaeoecologically interesting fossil biota from the **Prince Albert Formation** (Ecca Group) is that described from calcareous concretions exposed along the Vaal River in the Douglas area of the Northern Cape. The most famous localities are known as Zand Bult and Blaauw Kranz, situated *c*. 55 km north of the 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. The invertebrates are mainly preserved as moulds.

Field assessment of the Disselfontein study area found no evidence of Lower Ecca sediments above the Dwyka Group outcrop area. The Dwyka sediments are dominated by massive tillites, are deeply weathered and probably unfossiliferous.

Alluvial gravels of the Orange River of Miocene and younger, Plio-Pleistocene age are locally highly fossiliferous (*e.g.* Hendy 1984, Schneider & Marias 2004, Almond 2009 and extensive references therein). Important fossil elements include a wide range of large to small mammals, reptiles (*e.g.* crocodiles, tortoises), freshwater molluscs, trackways and petrified wood. The "High Level Gravels" along the Vaal River have likewise yielded important fossil assemblages of Plio-Pleistocene age (Almond 2010 and references therein).

Aeolian sands of the **Gordonia Formation** dune sands are not generally conducive to fossil preservation. However, mummification of soft tissues may play a role here and migrating lime-rich groundwaters derived from the underlying Dwyka Group may lead to the rapid calcretisation of organic structures such as burrows and root casts. Occasional terrestrial fossil remains that might be expected within this unit include calcretized rhizoliths (root casts) and termitaria (*e.g. Hodotermes*, the harvester termite), ostrich egg shells (*Struthio*) and shells of land snails (*e.g. Trigonephrus*) (Almond 2008, Almond & Pether 2008). Other fossil groups such as freshwater bivalves and gastropods (*e.g. Corbula, Unio*) and snails, ostracods (seed shrimps), charophytes (stonewort algae), diatoms (microscopic algae within siliceous shells) and stromatolites (laminated microbial limestones) are associated with local watercourses and pans. Microfossils such as diatoms may be blown by wind into nearby dune sands (Du Toit 1954, Dingle *et al*., 1983). These Kalahari fossils (or subfossils) can be expected to occur sporadically but widely, and the overall palaeontological sensitivity of the Gordonia Formation is therefore considered to be low.

There is no evidence for well-preserved ancient alluvial gravels of the Orange River within the study area. No fossil remains were observed among the surface gravels or within the other superficial deposits noted on site.

5. CONCLUSIONS & RECOMMENDATIONS

Potentially fossiliferous rock units within the broader Hopetown - Douglas study region include Permian marine sediments of the lowermost Ecca Group (Prince Albert Formation) as well as Tertiary fluvial gravels of the Orange River. However, field assessment shows that neither of these rock units is represented within the Disselfontein study area, which is largely mantled by various superficial deposits (surface gravels, calcretes, aeolian sands) of low to very low palaeontological sensitivity. The only Karoo Supergroup rocks present are unfossiliferous glacial tillites that are additionally deeply weathered and calcretised.

It is concluded that the proposed Disselfontein Keren Solar Plant project does not pose a significant threat to local fossil heritage resources. Should substantial fossil remains (*e.g.* petrified wood, vertebrate bones and teeth) be exposed during development, these should be safeguarded, preferably *in situ*, and reported by the ECO to SAHRA so that appropriate recording or mitigation measures can be considered.

6. ACKNOWLEDGEMENTS

Mr Bernard de Witt of EnviroAfrica cc, Somerset West is thanked for commissioning this study. I am very grateful to Ms Madelon Tusenius for assistance with GPS data handling.

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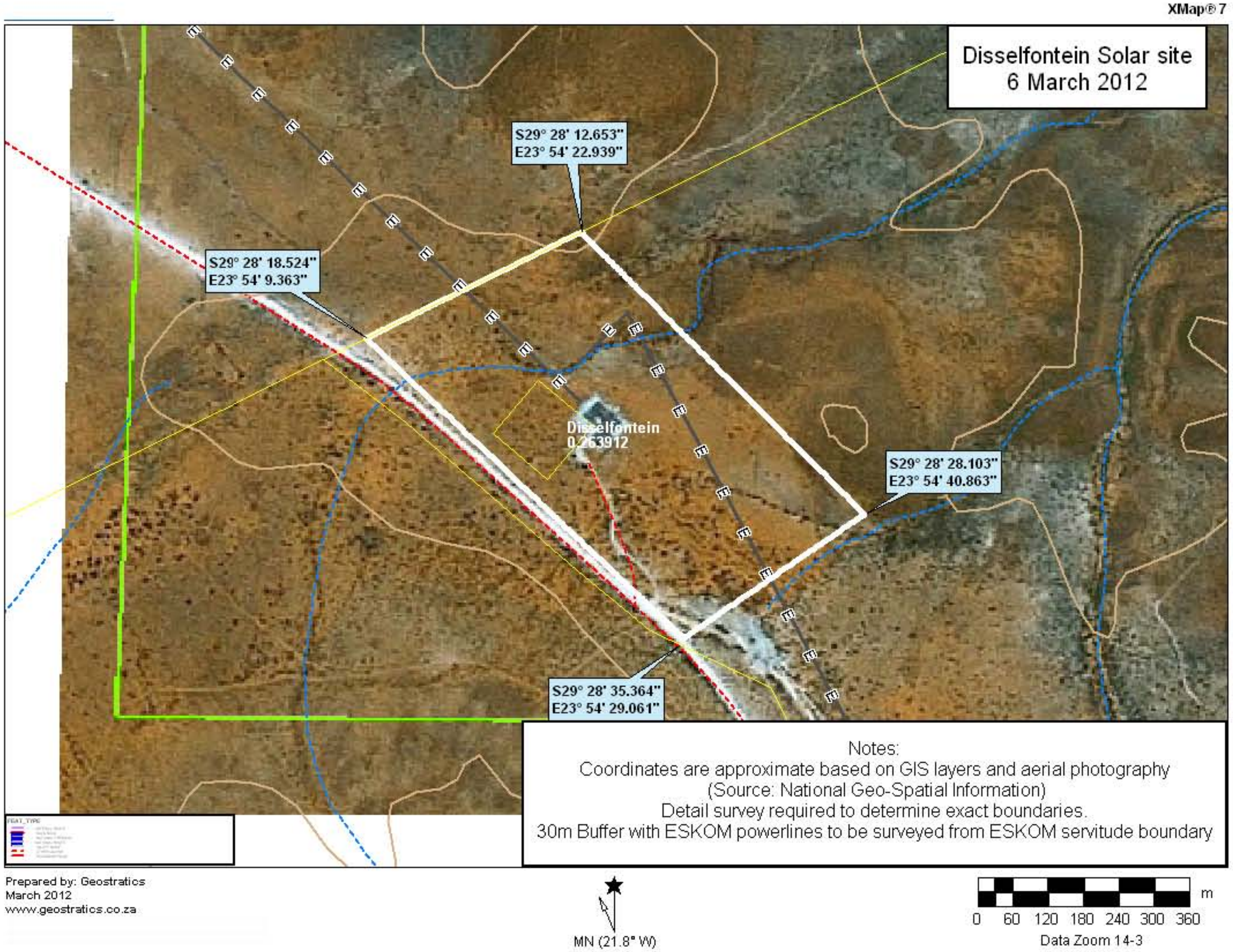

Fig. 13. Satellite image showing the study area for the Disselfontein Keren Solar Plant situated on the Remainder of Farm 77, Hopetown, close to the west bank of the Orange River and 23.5 km NW of Hopetown, Northern Cape (Image prepared by Geostratics 2012).

8. 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 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.

Loc. No.	South	East	Comments
493	S29 28 31.9	E23 54 27.5	Kalahari sands, SW corner of study area
494	S29 28 34.0	E23 54 33.5	Quarry into Dwyka Group at southern edge of study area; calcretes, alluvial gravels
495	S29 28 25.9	E23 54 37.0	Bouldery outcrop area of Allanridge Fm lavas
496	S29 28 14.3	E23 54 30.9	Stream bed incised into Allanridge Fm
497	S29 28 19.8	E23 54 27.6	Polymict surface gravels in flat area to NE of substation
498	S29 28 25.7	E23 54 30.8	Shallow stream gully exposure of boulder calcretes beneath Kalahari sands