Palaeontological specialist assessment: desktop study

PROPOSED AEP SOLAR ENERGY FACILITY ON LEGOKO FARM 460 PORTION 0 NEAR KATHU, GAMAGARA MUNICIPALITY, NORTHERN CAPE

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EXECUTIVE SUMMARY

AEP Kathu Solar (Pty) Ltd is proposing to develop a commercial solar photovoltaic energy facility (SEF) of 75 MWAC capacity on Legoko Farm No 460 Portion 0 that is located *c*. 9 km southeast of Kathu, Kuruman District (Gamagara Local Municipality), Northern Cape. The estimated maximum footprint of the SEF site is *c*. 220 hectares.The solar facility will connect into the national grid *via* the new Sekgame Substation, to be situated approximately 5km south of Ferrum MTS. Two 5-6 km 132 kV grid corridor alternatives are under consideration.

According to geological maps, satellite images and recent palaeontological assessments in the Kathu area (*e.g.* Almond 2013a, 2014), the flat-lying study area is underlain by a considerable thickness of Plio-Pleistocene to Recent sediments of the Kalahari Group. The underlying Precambrian bedrocks – *viz*. dolomites, cherts and iron formations of the Transvaal Supergroup – are too deeply buried beneath the development footprint to be directly affected by the proposed development. The Kalahari Group succession near Kathu mainly comprises well-developed calcretes or surface limestones (Mokolanen Formation) that may total 30 m or more in thickness in the region, together with a thin (probably < 1 m) surface veneer of aeolian sands (Gordonia Formation), alluvial deposits and sparse near-surface gravels. In general the Kalahari Group calcretes and sands are of low palaeontological sensitivity, mainly featuring widely-occurring plant and animal trace fossils (*e.g.* invertebrate burrows, plant root casts). Recent palaeontological field assessments in the Sishen – Hotazel region by the author have not recorded significant fossil material within these near-surface Kalahari sediments. A very important fossil assemblage of Pleistocene to Holocene mammal remains - predominantly teeth with scarce bone material associated with Earlier, Middle and Later Stone Age artefacts, well-preserved peats and pollens - is recorded from unconsolidated doline (solution hollow) sediments at the well-known Kathu Pan site, located some 5.5 km northwest of Kathu. There are at present no obvious indications of comparable fossiliferous, tool-bearing solution hollow infills exposed at present within the study area but such sediments might conceivably be present but hidden beneath cover

sands. Banded iron formation (BIF) of the Kuruman Formation (Asbestos Hills Subgroup, Ghaap Grop) builds the low hills in the north-eastern corner of the property. These Precambrian sediments contain microfossil assemblages but are generally of very low palaeontological sensitivity and will not be directly impacted by the proposed SEF.

The overall impact significance of the proposed solar energy development, including the grid connection to the new Sekgame Substation, is rated as LOW as far as palaeontological heritage is concerned. Likewise, cumulative impacts are likely to be of LOW significance, given the scarcity of important fossils (especially vertebrate remains) within the sedimentary rock units concerned as well as the huge outcrop area of the Kalahari Group as a whole. There is no preference on palaeontological heritage grounds for CPV or PV module technology or for any particular transmission line route or access road corridor under consideration. The degree of confidence for this assessment is rated as medium because of the uncertainty surrounding the presence or absence of potentially fossiliferous buried doline infill deposits within the study area.

Due to the inferred low impact significance of the proposed Kathu Solar Energy Facility development as far as fossil heritage resources are concerned, no further specialist palaeontological studies or monitoring are recommended at this stage.

The following mitigation measures to safeguard chance fossil finds on site during the construction phase of the development are recommended:

- The ECO and / or the Site Engineer responsible for the development must remain aware that all sedimentary deposits have the potential to contain fossils and he / she should thus monitor all substantial excavations into sedimentary bedrock for fossil remains. If any substantial fossil remains (*e.g.* vertebrate bones, teeth, horn cores) are found during construction SAHRA should be notified immediately (Contact details: SAHRA, 111 Harrington Street, Cape Town. PO Box 4637, Cape Town 8000, South Africa. Phone: +27 (0)21 462 4502. Fax: +27 (0)21 462 4509. Web: www.sahra.org.za) so that appropriate mitigation (*i.e.* recording, sampling or collection) by a palaeontological specialist can be considered and implemented, at the developer's expense.

- A chance-find procedure should be implemented so that, in the event of fossils being uncovered, the ECO / Site Engineer will take the appropriate action, which includes:
    - Stopping work in the immediate vicinity and fencing off the area with tape to prevent further access;
    - Reporting the discovery to the provincial heritage agency and/or SAHRA;
    - Appointing a palaeontological specialist to inspect, record and (if warranted) sample or collect the fossil remains;
    - Implementing further mitigation measures proposed by the palaeontologist; and
    - Allowing work to resume only once clearance is given in writing by the relevant authorities.

If the mitigation measures outlined above are adhered to, the residual impact significance of any construction phase impacts on local palaeontological resources is considered to be low.

The mitigation measures proposed here should be incorporated into the Environmental Management Programme (EMP) for Kathu Solar Energy Facility project. The palaeontologist concerned with mitigation work will need a valid collection permit from SAHRA. All work would have to conform to international best practice for palaeontological fieldwork and the study (*e.g.* data recording fossil collection and curation, final report) should adhere to the minimum standards for Phase 2 palaeontological studies recently published by SAHRA (2013).

1. INTRODUCTION

1.1. Project outline and brief

The company AEP Kathu Solar (Pty) Ltd is proposing to develop a commercial solar photovoltaic energy facility (SEF) of 75 MWAC capacity on Legoko Farm No 460 Portion 0 that is located *c.* 9 km southeast of Kathu, Kuruman District (Gamagara Local Municipality), Northern Cape (Fig. 1). The estimated maximum footprint of the SEF site is *c.* 220 hectares.

The main infrastructal components of the proposed development include:

- concentrating photovoltaic (CPV) modules or photovoltaic (PV) modules mounted on tracking structures;
- inverter stations;
- internal electrical reticulation;
- internal gravelled roads (4-5 m wide) and gravelled access roads (6 m wide) (route options shown in green in Fig. 2);
- an on-site switching station / substation;
- a 132 kV overhead (OH) transmission line *c.* 5-6 km long connecting the SEF with the planned Sekgame Switching Station (SS) that is to be located *c.* 5km to the south of the existing Ferrum MTS. Two route alternatives for the 132 kV line are shown in Fig. 2 (dark and light blue);
- auxiliary buildings (*c.* 1 hectare footprint);
- construction laydown areas;
- perimeter fencing and security infrastructure.

The two layout alternatives for the SEF that have been assessed both lie within the red polygon in Fig. 2 on the southwestern side of Legoko Farm No 460 Portion 0.

The proposed development area is underlain by potentially fossiliferous sedimentary rocks of Precambrian and Late Caenozoic age (Sections 2 and 3). The construction phase of the development may entail substantial surface clearance as well as excavations into the superficial sediment cover (*e.g.* forsolar panel footings, underground cables, building foundations, internal access roads, transmission line pylons). All these developments may adversely affect potential fossil heritage at or beneath the surface of the ground within the study area by destroying, disturbing or permanently sealing-in fossils that are then no longer available for scientific research or other public good.

All palaeontological heritage resources in the Republic of South Africa are protected by the National Heritage Resources Act (Act 25 of 1999) (See Section 1.2 below). Heritage resource management in the Northern Cape is the responsibility of the South African Heritage Resources Agency or SAHRA (Contact details: SAHRA, 111 Harrington Street, Cape Town. PO Box 4637, Cape Town 8000, South Africa. Phone: +27 (0)21 462 4502. Fax: +27 (0)21 462 4509. Web: www.sahra.org.za).

The present palaeontological heritage baseline (desktop) assessment for the Solar Energy Facility on Legoko Farm No 460 Portion 0has been commissioned as part of a HIA for this development byCape EAPrac, George (Contact details: Dale Holder. Cape EAPrac. 5 Progress Street, Eagle View Building, 1st floor. P.O. Box 2070, George, 6530. Tel: 044 874 0365. Fax: 044 874 0432) on behalf of the developer, Atlantic Renewable Energy Partners (Pty) Ltd (Contact details: David Peinke, Director, Atlantic Renewable Energy Partners (Pty) Ltd. 101, Block A, West Quay Building 7 West Quay Road, Waterfront, Cape Town, 8000. Mobile: + 27 (0) 84 401 9015. Fax: + 27 (0) 86 514 8184. Email: david@atlanticep.com).

1.2. Legislative context for palaeontological assessment studies

The various categories of heritage resources recognised as part of the National Estate in Section 3 of the National Heritage Resources Act (Act 25 of 1999) 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 desktop palaeontological heritage study

The approach to this desktop 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 (Table 1). 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 a 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 & Pether2008).

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 (*e.g.* SAHRA for the Northern Cape). It should be emphasized that, *provided that 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 present case, site visits to the various loop and borrow pit study areas in some cases considerably modified our understanding of the rock units (and hence potential fossil heritage) represented there.

In the case of the study areanear Kathu a major limitation for fossil heritage studies is the possible low level of surface exposure of potentially fossiliferous bedrocks such as any doline infills within the near-surface calcrete hardpans, as well as the paucity of previous specialist palaeontological studies in the Northern Cape region as a whole.

1.5. Information sources

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

1. A DSR Technical Layout Development Report for the project prepared by Atlantic Renewable Energy Partners (Pty) Ltd and dated May 2015;

2. A review of the relevant scientific literature, including published geological maps and accompanying sheet explanations as well as several desktop and field-based palaeontological assessment studies in the broader Sishen / Kathu / Hotazelregion of the Northern Cape by the author (*e.g.*Almond 2012, 2013a, 2013b, 2014);

3. Examination of relevant topographical maps and satellite images;

4. The author's previous field experience with the formations concerned and their palaeontological heritage (See also review of Northern Cape fossil heritage by Almond & Pether 2008).

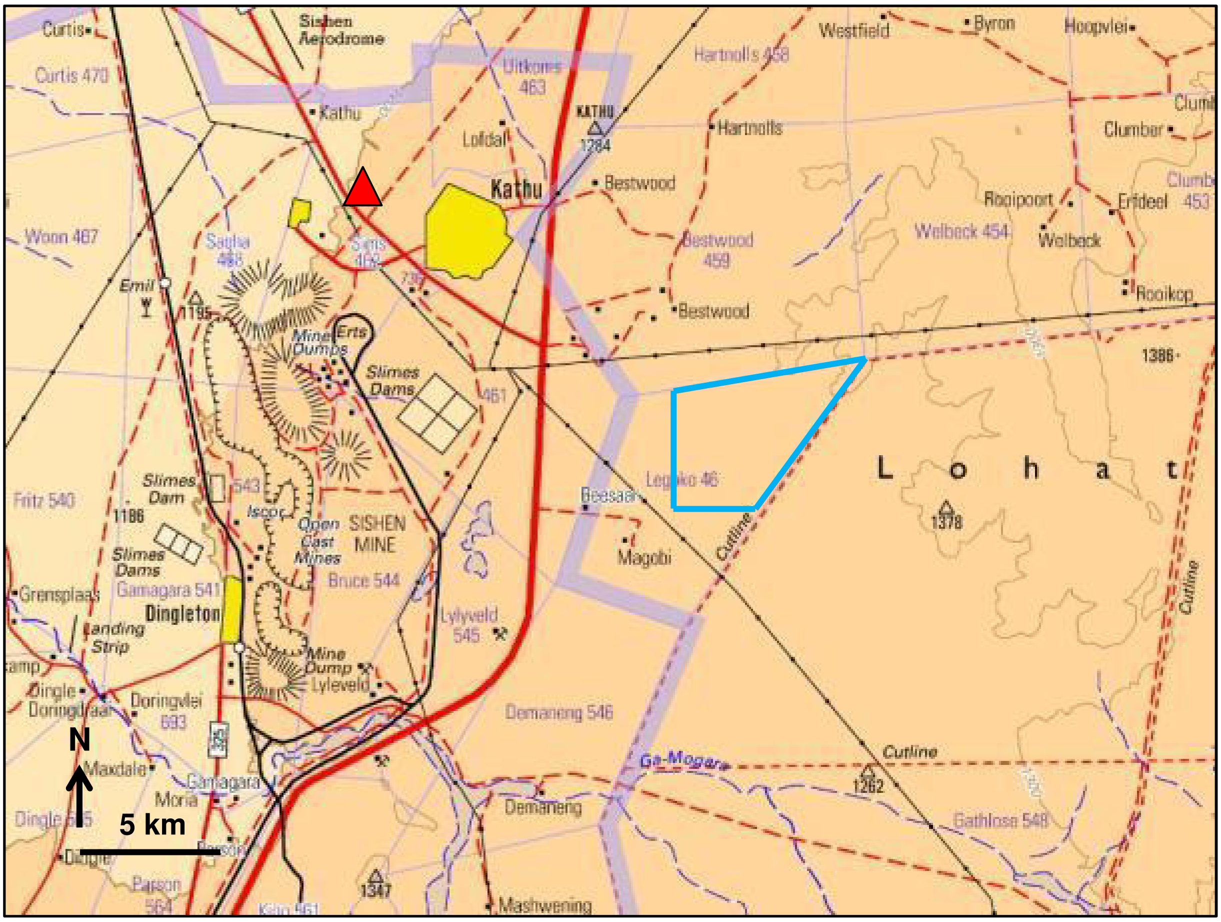

Fig. 1. Map showing the approximate location (blue polygon) of the study area for the proposed AEP Solar Energy Facility on Portion 0 of Farm 460 Legokoon the eastern side of the N14,*c*. 9 km to the southeast of the town of Kathu, Northern Cape (Extract from 1: 250 000 topographical map 2722 Kuruman, Courtesy of the Chief Directorate Surveys and Mapping, Mowbray). See Fig. 2 for a more accurate outline of the study area. The red triangle indicates the important Kathu Pan Pleistocenefossil site *c*. 5.5 km NW of Kathu.

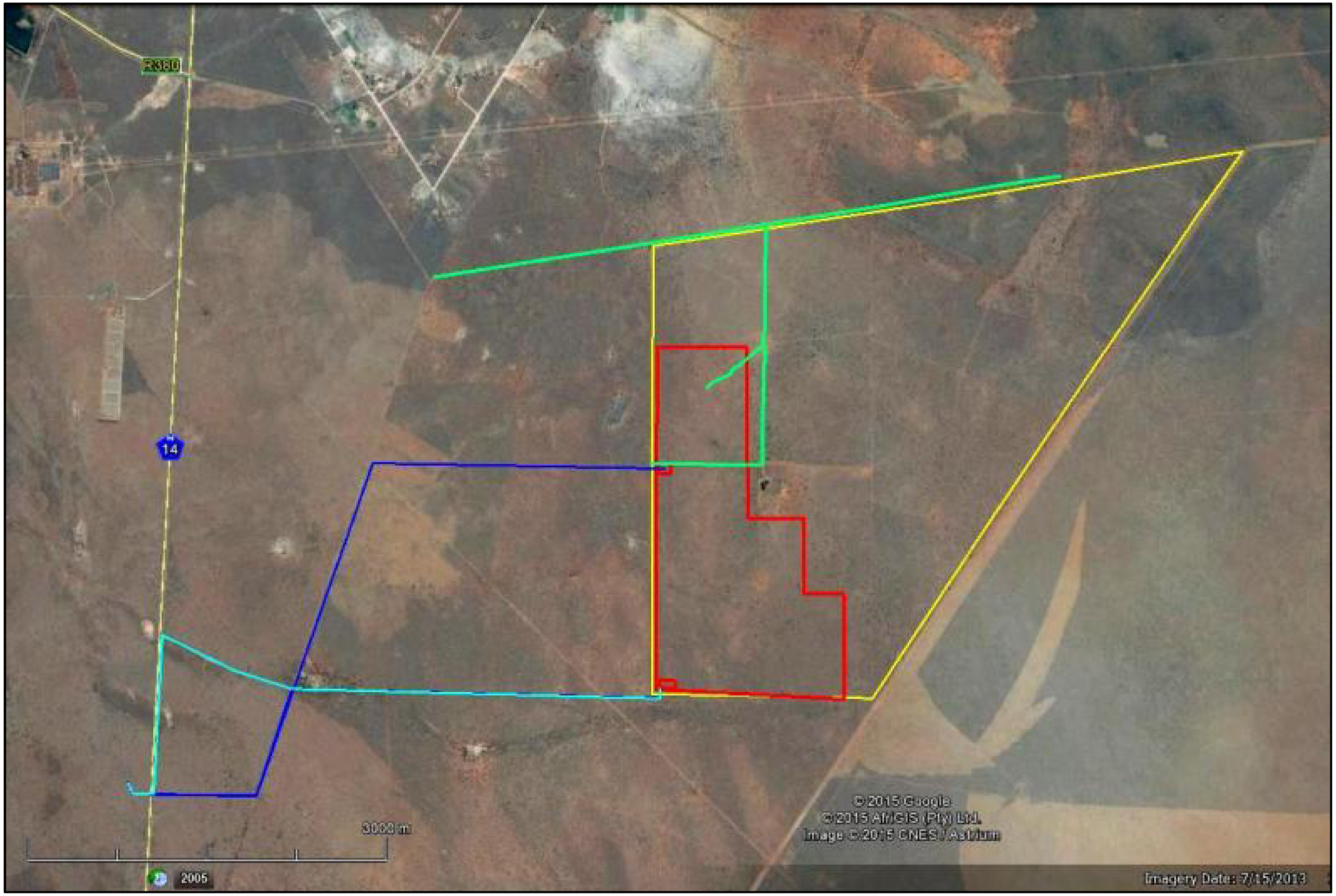

Fig. 2. Google earth© satellite image of the study area for the proposed AEP Solar Energy Facility on Portion 0 of Farm 460 Legoko (yellow polygon) on the eastern side of the N14, *c.* 9 km southeast of the town of Kathu, Northern Cape. The solar facility footprint study area is shown in red, access road options in green and alternative 132 kV HV transmission line connections to Sekgame Substation in pale and dark blue.

2. GEOLOGICAL OUTLINE OF THE STUDY AREA

The town of Kathu lies within a semi-arid, flat-lying region at 1200 – 1300m amsl that is situated between the Langberge mountain range in the west and the low-lying Kurumanheuwels in the east. This region is drained by the Ga-Mogara River which flows northwards into the Kuruman River to the north of Hotazel. The AEP LegokoSEF study area largely comprises very level terrain on the eastern side of the N14 tar road between Olifantshoek and Kuruman. The Sishen iron ore mine lies 8 km to the west and the mining town of Kathu lies 9 km to the northwest. The flat-lying land where the proposed SEF will be located is situated between 1240 to 1260 m amsl. The terrain here is fairly featureless on satellite images with no obvious pans or major drainage lines. However, older fluvial, doline (solution hollow) or pan deposits might be buried at shallow depths beneath younger surface sands here. Low rounded hills of banded iron formation in the north-eastern corner of the property, (darker grey on satellite images), outliers of the Kurumanheuwels, lie outside the development footprint and reach an elevation of *c*. 1340 m amsl.

The geology of the study region is shown on the 1: 250 000 geological sheet 2722 Kuruman (Council for Geoscience, Pretoria) (Fig. 3 herein). This map is now out of print and is not accompanied by a detailed sheet explanation (A brief explanation is printed on the map itself, however). According to the map, the great majority of the Legoko Farm 460 Portion 0 Solar Energy Facility study area is mantled by Pleistocene to Recent aeolian sands of the Gordonia Formation and underlying calcretes (surface limestones) of the Mokolanen Formation (Kalahari Group) that overlie Precambrian sedimentary bedrocks of the Transvaal Supergroup at depth. Other Kalahari Group superficial sediments are inferred to be present but not mapped at 1: 250 000 scale within the study area, such as surface gravels and alluvium. The low hills in the northeast are composed on banded iron formation (BIF) of the Kuruman Formation (Asbestos Hills Subgroup, Ghaap Group) of Precambrian age.

Since this geological map was published, there have been considerable revisions to the stratigraphic subdivision and assignment of the several Precambrian rock units represented within the Kuruman sheet area. Where possible, the recent stratigraphic account for the Transvaal Supergroup given by Eriksson *et al.* (2006) is followed here, but correlations for all the subdivisions indicated on the older maps are not always clear. The present study area lies close to the axis of a major, elongate NNW-SSE trending domal structure in the underlying Precambrian bedrocks that is known as the Maremane Anticline. The bedrocks here belong to the Late Archaean to Early Proterozoic **Transvaal Supergroup** and were deposited within the Ghaap Plateau Subbasin of the Griqualand West Basin (Eriksson *et al.* 2006). Useful reviews of the stratigraphy and sedimentology of these Transvaal Supergroup rocks have been given by Moore *et al.* (2001), Eriksson and Altermann (1998) as well as Eriksson *et al.* (2006). The **Ghaap Group** represents some 200 million years of chemical sedimentation - notably iron and manganese ores, cherts and carbonates - within the Griqualand West Basin that was situated towards the western edge of the Kaapvaal Craton (*c.* 2.6 – 2.4 Ga, Fig.

7; see also fig. 4.19 in McCarthy & Rubidge 2005). Carbonate sediments underlying the study area are assigned to the Campbell Rand Subgroup.

The Campbell Rand carbonates are overlain with a gradational contact by the thick Early Proterozoic banded iron formations of the **Asbestos Hills Subgroup** (Ghaap Group) that build the low-lying, highly-dissected hills in the north-eastern part of the study area and associated ranges of the Asbesheuwels. The Asbestos Hills Subgroup rocks are often poorly exposed due to extensive colluvial gravel cover. The basal **Kuruman Formation**of the Asbestos Hills Subgroup that is represented here (Vak in Fig. 3), consists predominantly of banded iron formations (BIF). These comprise rhythmically bedded, thinly composition- and colour-banded cycles of fine-grained mudrock, chert and iron minerals (siderite, magnetite, haematite). These fine-grained chemical sediments were laid down in an offshore, intermittently anoxic depository, the Griqualand West Basin. In the Ghaap Plateau Sub-basin to the north of the Griquatown Fault Zone the Kuruman BIF reaches thicknesses of up to 250 m (Eriksson *et al.* 2006, their fig. 2). BIF deposition characterizes the Late Archaean – Early Proterozoic interval (2600-2400 Ma), before the onset of well-oxygenated atmosphere and seas on planet Earth.

The **Campbell Rand Subgroup** (previously included within the Ghaapplato Formation) is a very thick (1.6 - 2.5 km) carbonate platform succession of dolomites, dolomitic limestones and cherts with minor tuffs that was deposited on the shallow submerged shelf of the Kaapvaal Craton roughly 2.6 to 2.5 Ga (billion years ago; see readable general account by McCarthy & Rubidge, pp. 112-118 and Fig. 4.10 therein). A range of shallow water facies, often forming depositional cycles reflecting sea level changes, are represented here, including stromatolitic limestones and dolomites, oolites, oncolites, laminated calcilutites, cherts and marls, with subordinate siliclastics (shales, siltstones) and minor tuffs (Eriksson *et al.* 2006).

Campbell Rand carbonates do not crop out at surface within the present study area where they are probably blanketed by thick superficial sediments. Note that since the 1: 250 000 geological maps were produced, the Campbell Rand succession has been subdivided into a series of formations, some of which were previously included within the older Schmidtsdrift Formation or Subgroup (Beukes 1980, 1986, Eriksson *et al.* 2006). It is unclear exactly which of these newer units are represented at depth beneath the present study area. However, this resolution is not critical for the current report since these older bedrocks are unlikely to be significantly impacted by the present development project. A siliceous / cherty breccia or manganese marker that lies at the top of the Campbell Rand succession may be a downwasted palaeoweathering product of secondarily mineralised Campbell Rand carbonates and cherts. An unidentified East-West trending linear feature indicated on the geological map by a dotted line on the southern side of the study area might be a dolerite dyke.

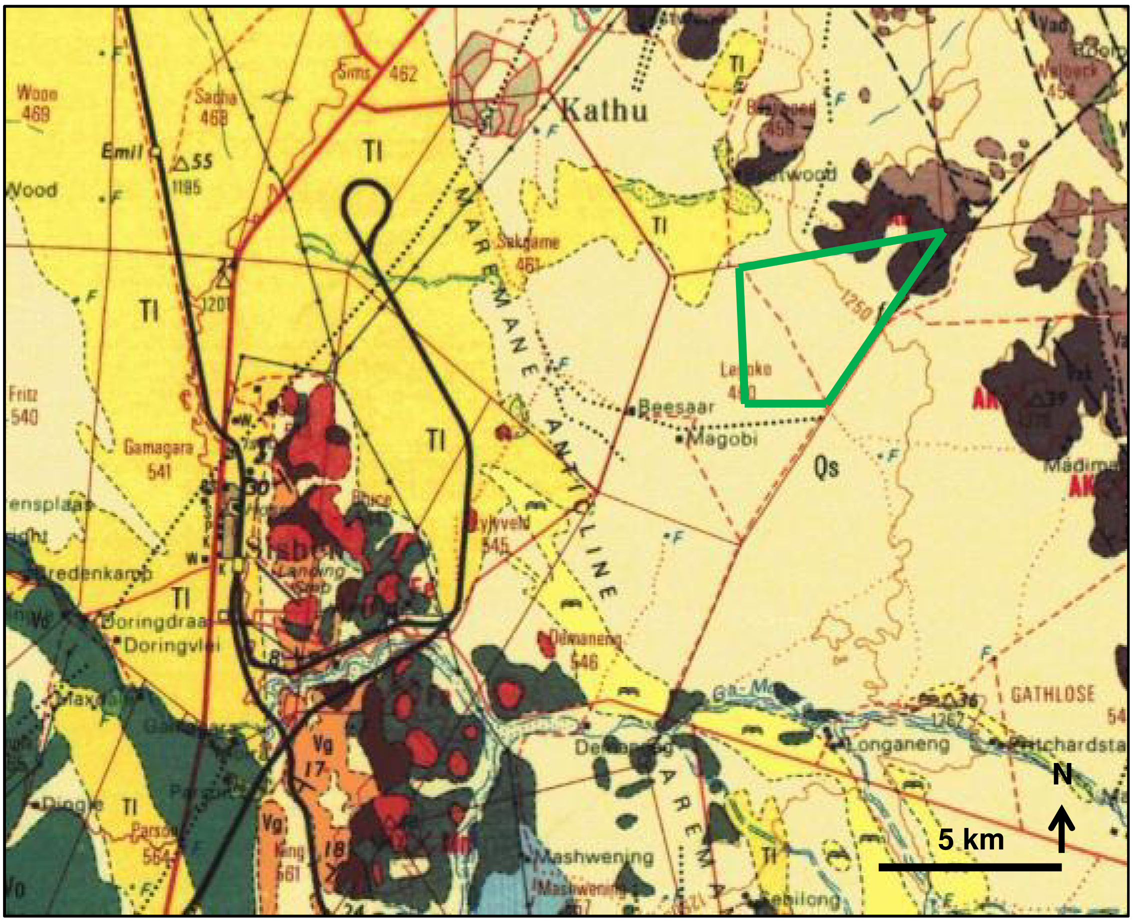

Fig. 3. Extract from 1: 250 000 geological map 2722 Kuruman (Council for Geoscience, Pretoria) showing the location of the study area for the proposed AEP Solar Energy Facility on Portion 0 of Farm 460 Legoko(green polygon), *c.* 9 kmto the southeast of Kathu and east of the Sishen Mine. Note that the road and railway networks shown here are out of date. Geological units represented within the broader study region on sheet 2722 Kuruman include the following (*N.B.* many of these units are only represented subsurface within the study area itself):

CAENOZOIC SUPERFICIAL DEPOSITS (Quaternary to Recent)
Tl (dark yellow) – calcretes (“surface limestone”) of the Kalahari Group
Qs (pale yellow) – aeolian sands of the Gordinia Formation, Kalahari Group
Blue stippled areas = pans

TRANSVAAL SUPERGROUP (Late Archaean to Palaeoproterozoic)
Vak (dark brown) – banded iron formation of the Kuruman Formation (Asbestos Hills Subgroup, Ghaap Group)
Vad (pale brown) – banded iron formation of the Daniëlskuil Formation (Asbestos Hills Subgroup, Ghaap Group)
Black dotted line = unidentified linear feature (possibly a dolerite dyke).

The Campbell Rand carbonates in the Kathu region are entirely mantled by Late Caenozoic calcretes(**Tl** for Tertiary Limestone in Fig. 3)and aeolian sands of the **Kalahari Group**. The pedogenic limestones reflect seasonally arid climates in the region over the last five or so million years and are briefly described by Truter *et al.* (1938) and in more detail by Haddon (2005). The surface limestones may reach thicknesses of over 20-30m, but are often much thinner, and are locally conglomeratic with clasts of reworked calcrete as well as exotic pebbles. The limestones may be secondarily silicified and incorporate blocks of the underlying Precambrian carbonate rocks. The older, Pliocene - Pleistocene calcretes in the broader Kalahari region, including sandy limestones and calcretised conglomerates, have been assigned to the **Mokalanen Formation** of the **Kalahari Group** (See stratigraphic column in Fig. 4). They are possibly related in large part to a globally arid time period between 2.8 and 2.6 million years ago, *i.e.* late Pliocene (Partridge *et al.* 2006). Calcretes are not mapped at surfacein the present study area but are likely to occur subsurface here.

Large areas of unconsolidated, reddish-brown aeolian (*i.e.* wind-blown) sands of the Quaternary **Gordonia Formation** (Kalahari Group; **Qs** in Fig. 3) are mapped in the Sishen - Kathu region, where their thickness is variable, including the most of the Legoko Solar Energy Facility study region. The geology of the Late Cretaceous to Recent Kalahari Group is reviewed by Thomas (1981), Dingle *et al.* (1983), Thomas & Shaw 1991, Haddon (2000& 2005) and Partridge *et al.* (2006). The Gordonia dune sands are considered to range in age from the Late Pliocene / Early Pleistocene to Recent, dated in part from enclosed Middle to Later Stone Age stone tools (Dingle *et al*., 1983, p. 291). Note that the recent extension of the Pliocene - Pleistocene boundary from 1.8Ma back to 2.588 Ma would place the Gordonia Formation almost entirely within the Pleistocene Epoch.

Haddon (2005) reports a total thickness of *about* 80 m of Kalahari Group sediments overlying the Precambrian bedrocks in the Sishen Iron Ore Mine, located a few kilometres west of the present study area. The lower-lying beds, which may be as old as Late Cretaceous (Partridge *et al.* 2006, p. 590) are assigned to the **Wessels Formation** (basal debris flow gravels associated with local faults) and **Budin Formation** (lacustrine calcareous clays with sparse suspended pebbles associated with palaeodrainage systems). The uppermost 15 m of the Kalahari succession here comprises well-indurated calcretised siltstones, pebbly horizons and clays with the development of solution hollows along joint surfaces within 10 m of the surface. Close to the surface calcretised silcretes showing *in situ*brecciation are also recognised. It is also noted that there is considerable, rapid horizontal variation in the Kalahari Group rocks, so it is unlikely that the succession underlying the present study area itself is identical.

Pale grey areas seen on satellite images of the broader study area (Fig. 2) indicate surface exposures of calcrete around pans and along water courses. Very thick (> 11 m), near-surface calcrete hardpans have been exposed by recent trenching in the Bestwood housing development area to the east of Kathu where the overlying Kalahari sands are generally less than a meter thick (Almond 2014).A recent field study associated with the manganese ore railway line (Sishen New Loop), some 16 km SW of the present study area, records a thick (> several meters) pale pinkish, karstified calcrete hardpan at surface that is partially mantled with a thin layer of downwasted surfaced gravels (*e.g.* calcrete rubble) and orange-brown Kalahari sands (Almond 2013a). Various calcrete facies are exposed in local stormwater trenches, including gravelly, pelleted, brecciated, silicified and honeycomb types. Several blocks contain well-defined, tubular to irregular solution pipes lined with pale brown calcareous silt. Consolidated, poorly-sorted calcrete gravel breccia and reddish-brown sands partially infill some of these solution hollows, but no associated fossil bones or teeth were observed within them.

At Kathu Pan, located some 5.5 km NW of Kathu town (27º 39' 50" S, 23º 0' 30" E; see red triangle in Fig. 3), an important succession of stratified, unconsolidated, fossiliferous Quaternary to Holocene sediments up to 12 m thick infilling a series of solution hollows (sinkholes / dolines) within a thick calcrete hardpan has been studied in some detail (*e.g.* Butzer 1984, Klein 1988, Beaumont 1990, Partridge & Scott 2000, Beaumont 2004, and refs. therein). Porat*et al.*(2010) provide important recent data on the sedimentology and dating of the site.The Kathu Pan site is indicated by a red triangle in Figure 1 herein. Boreholes within the pan area record a Kalahari Group succession here that is over 70 m thick, including 30 m of basal gravels, clays and sands (Wessels, Budin and possibly also Eden Formations) overlain by over 40 m of calcrete (Mokalanen Formation) and unconsolidated superficial sediments (*e.g.* Gordonia Formationaeolian sands). The various doline infill successions investigated at Kathu Pan comprise a variety of Mid to Late Pleistocene and Holocene sands, gravels, calcareous silty sands and several peat horizons. Several spring eyes can be identified. Apart from the sterile basal layers overlying the karstifiedcalcrete surface, the sediments are associated with a series of stone artefact assemblages ranging from Early Acheulean through Fauresmith and Middle Stone Age to Later Stone Age.

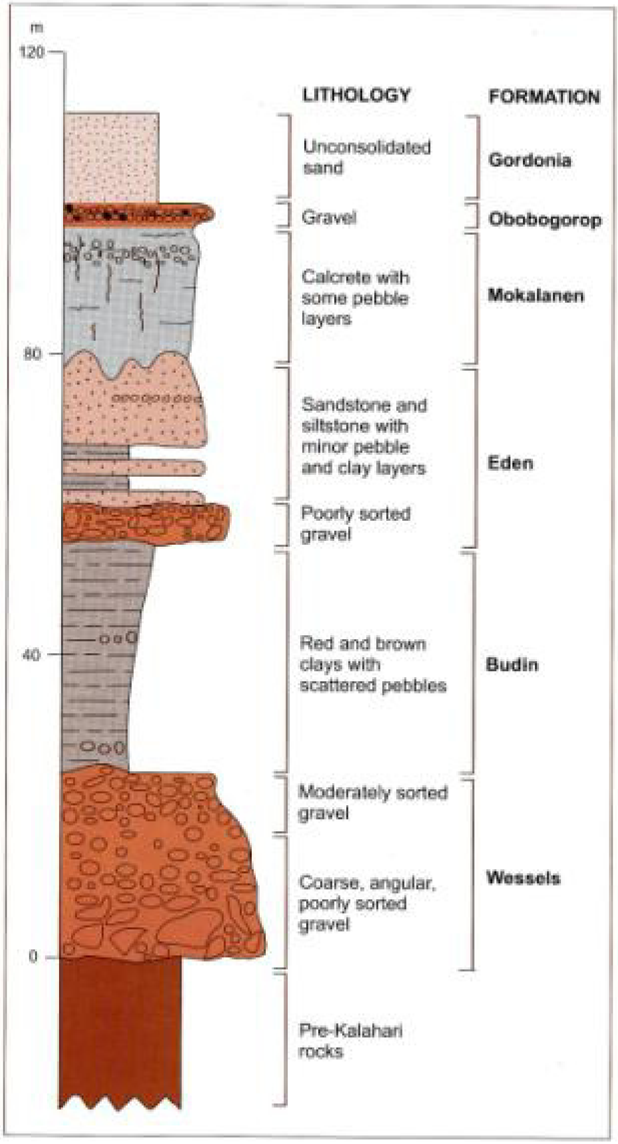

Fig. 4. Generalised stratigraphy of the Late Cretaceous to Recent Kalahari Group (From Partridge *et al.* 2006). Most or all of these rock units are represented within the Kathu – Sishen study region but only Plio-Pleistocene subsurface calcretes (Mokalanen Formation) and overlying Pleistocene to Recent aeolian sands of the Gordonia Formation are definitely represented in the present project area.

3. POTENTIAL PALAEONTOLOGICAL HERITAGE WITHIN THE STUDY AREA

Fossil biotas recorded from each of the main rock units mapped at surface within the study region are briefly reviewed in Table 1 (Based largely on Almond & Pether 2008 and references therein), where an indication of the palaeontological sensitivity of each rock unit is also given. Pervasive calcretisation and chemical weathering of many near-surface bedrocks in the Northern Cape has often compromised their original fossil heritage in many areas.

The deep water BIF facies of the Asbestos Hills Subgroup (**Kuruman** and **Daniëlskuil Formations**) have not yielded stromatolites which are normally restricted to the shallow water photic zone since they are constructed primarily by photosynthetic microbes. No convincing trace fossils, attributable to sizeable metazoans (multi-cellular animals), have been reported from BIF facies. However, there are several reports of microfossils from cherty sediments within the Kuruman Formation according to MacRae (1999) and Tankard *et al.* (1982 – see refs. therein by Fockema 1967, Cloud & Licari 1968, La Berge 1973. *N.B.* the stratigraphic position of these older records may require confirmation). It is likely that cherts within the Daniëlskuil Formation also contain scientifically interesting Early Proterozoic microfossil assemblages. The supposed fossil medusoid or jellyfish *Gakarusia* reported from the Asbestos Hills Subgroup by Haughton (1963) is almost certainly a pseudofossil (*cf*Haughton 1969, Haentzschel 1975).

The fossil record of the **Kalahari Group** is generally sparse and low in diversity. The **Gordonia Formation** dune sands were mainly active during cold, drier intervals of the Pleistocene Epoch that were inimical to most forms of life, apart from hardy, desert-adapted species. Porous dune sands are not generally conducive to fossil preservation. However, mummification of soft tissues may play a role here and migrating lime-rich groundwaters derived from the underlying bedrocks (including, for example, dolerite) 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 calcretizedrhizoliths (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. Underlying calcretes of the **Mokolanen Formation**might also contain trace fossils such as rhizoliths, termite and other insect burrows, or even mammalian trackways. Mammalian bones, teeth and horn cores (also tortoise remains, and fish, amphibian or even crocodiles in wetter depositional settings such as pans) may be expected occasionally expected within Kalahari Group sediments and calcretes, notably those associated with ancient, Plio-Pleistocene alluvial gravels, pans and solution cavity infills.

Important, taxonomically diverse Middle to Late Pleistocene mammalian macrofaunas have been recorded from multiple doline infill sediments at **Kathu Pan**, *c.* 5.5. km NW of Kathu town. The fauna mainly consists ofdelicate, fragmentary tooth material (caps or shells or dental enamel) but also include some bones with at least one almost intact ungulate skeleton (Fig. 5). Most teeth and associated artefacts are covered with a distinctive shiny silicate patina. The fossils are assigned to the Cornelian Mammal Age (*c.* 1.6 Ma to 500 ka) and Florisian Mammal Age (*c.* 200 to 12 ka) that are associated with Acheulean and MSA stone artefact assemblages respectively (Klein 1984, 1988, Beaumont *et al.* 1984, Beaumont 1990, Beaumont 2004, Porat*et al.* 2010 and refs. therein; see also MacRae 1999). Interesting Cornelian mammal taxa found here include the extinct *Elephasrecki* and *Hippopotamus gorgops* as well as various equids, white rhino and hartebeest / wildebeest-sized alcephalines. The dominance of grazers over browsers or mixed feeders among the Middle Pleistocene mammalian fauna suggests that the vegetation was grassy savannah at the time. Higher up in the succession the remains of typical Florisian forms such as *Pelorovisantiquus* the Giant Buffalo*, Megalotraguspriscus* the Giant Hartebeest and *Equuscapensis* the giant Cape Horsealso occur (Fig. 6). Many of the tooth fragments as well as the associated MSA stone artefacts in this younger horizon are abraded, suggesting fluvial reworking of material into the doline together with the gravelly sand matrix. Additional fossil material of biostratigraphic and palaeoecological interest from the Kathu Pan doline infills include fossil pollens from well-developed peat horizons(Scott 2000), bird fossils, ostrich egg shell fragments and terrestrial gastropods. The mammalian remains may belong to animals attracted to permanent waterholes (*e.g.* spring eyes), especially during drier phases of the Pleistocene Epoch. The close association of large mammal fossils with abundant stone tools as well as occasional evidence for butchering suggests that human hunters or scavengers may also have played a role as concentration agents.

Potentially fossiliferous doline infill sediments similar to those at Kathu Pan are not apparent near-surface within the present development area on satellite images. However, the possibility that they are present but hidden beneath superficial sediments (*e.g.*aeolian sands) cannot be excluded.

Low diversity trace fossil assemblages attributable to invertebrates and plants are commonly associated with Kalahari Group calcrete horizons and are likely to be represented within the solar energy facility study area as well. Trace fossil assemblages recorded from calcretised upper Kalahari Group sediments in borrow pits near Witloop, *c.* 45 km NNW of Kathu, are probably attributable toinfaunal invertebrates (*e.g.* insects such as termites), plant root moulds (rhizoliths) as well as the densely-packed stems of reedy vegetation associated with damp, vlei-like areas in the almost-abandoned course of the Witloopleegte in Late Pleistocene or Holocene times (Almond 2013a). Similar trace fossil assemblages are probably of widespread occurrence within the Kalahari Group (*cf* Nash & McLaren 2003).

Well-developedKalahari calcrete hardpans exposed in quarries near Mamathwane, some 35 km NNW of Kathu, display a well-developed vuggy, bioturbated texture. Good calcrete burrow casts and rhizoliths (plant root casts) are seen within the main hardpan (Almond 2013b). Burrow casts are *c.* 1 cm wide and even in width, reaching lengths of over 50 cm. Subparallel, thin vertical structures are probable plant stem or root casts, probably related to reedy vegetation in vlei areas associated with palaeo-watercourses.

Networks of karstic solution hollows, such as observed within calcrete hardpans in the Sishen area, *c.* 15 km SW of the present study area, might have served as traps for vertebrates (*e.g.* small mammals and reptiles, reworked bones and teeth) as well as land snails in the Pleistocene Epoch (Almond 2013a). However, vertebrate or other fossil remains have not been recorded hitherto from such settings in the Kalahari region.

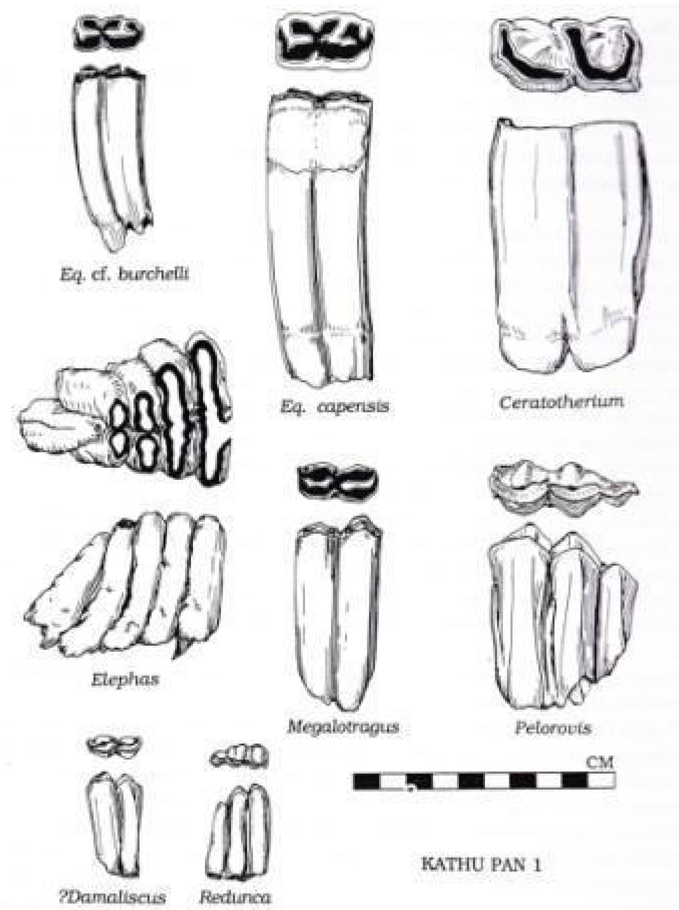

Fig. 5. Selection of Pleistocene large mammal teeth collected from solution cavity infills (dolines) at Kathu Pan, Northern Cape (From Klein 1988).

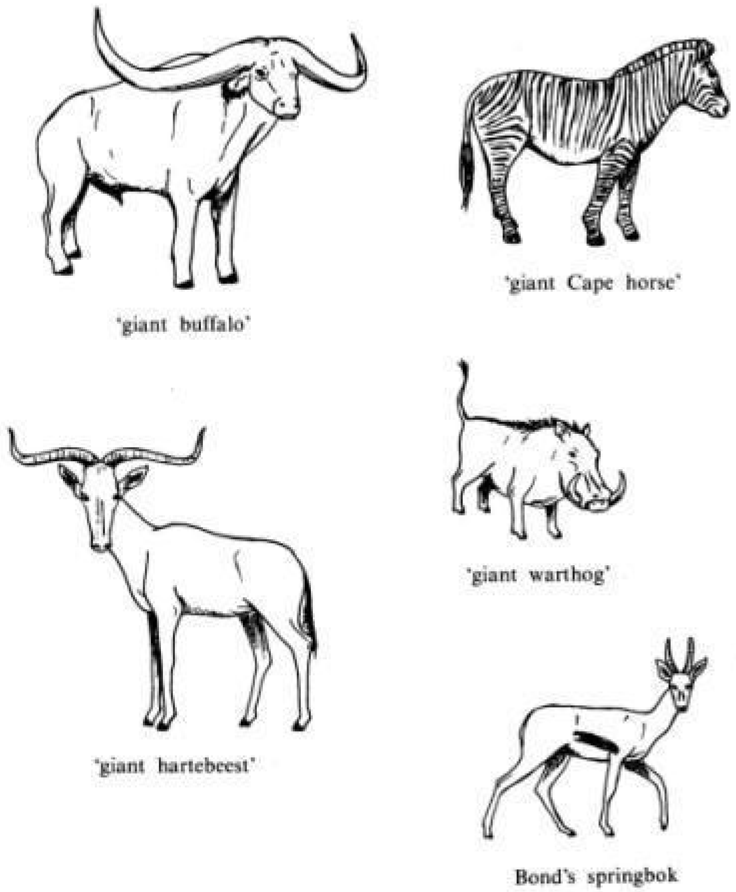

Fig. 6. Selection of extinct Pleistocene mammals of the Florisian Mammal Age, most of which are represented at Kathu Pan (From Klein 1984).

Table 1: Fossil heritage of rock units represented in the Kathu study region (From Almond & Pether 2008)

GEOLOGICAL UNIT	ROCK TYPES & AGE	FOSSIL HERITAGE	PALAEONT-OLOGICAL SENSITIVITY	RECOMMENDED MITIGATION
OTHER LATE CAENOZOIC TERRESTRIAL DEPOSITS OF THE INTERIOR (Most too small to be indicated on 1: 250 000 geological maps)	Fluvial, pan, lake and terrestrial sediments, including diatomite (diatom deposits), pedocretes, spring tufa / travertine, cave deposits, peats, colluvium, soils, surface gravels including downwasted rubble MOSTLY QUATERNARY TO HOLOCENE (Possible peak formation 2.6-2.5 Ma)	Bones and teeth of wide range of mammals (*e.g.* mastodont proboscideans, rhinos, bovids, horses, micromammals), reptiles (crocodiles, tortoises), ostrich egg shells, fish, freshwater and terrestrial molluscs (unionid bivalves, gastropods), crabs, trace fossils (*e.g.* termitaria, horizontal invertebrate burrows, stone artefacts), petrified wood, leaves, rhizoliths, diatom floras, peats and palynomorphs. calcareous tufas at edge of Ghaap Escarpment might be highly fossiliferous (*cf*Taung in NW Province – abundant Makapanian Mammal Age vertebrate remains, including australopithecines)	LOW Scattered records, many poorly studied and of uncertain age	Any substantial fossil finds to be reported by ECO to SAHRA
Gordonia Formation (Qs) KALAHARI GROUP *plus* SURFACE CALCRETES (Tl / Qc)	Mainly aeolian sands *plus* minor fluvial gravels, freshwater pan deposits, calcretes PLEISTOCENE to RECENT	Calcretisedrhizoliths&termitaria, ostrich egg shells, land snail shells, rare mammalian and reptile (*e.g.* tortoise) bones, teeth (e.g. doline infills) freshwater units associated with diatoms, molluscs, stromatolites *etc.*	LOW	Any substantial fossil finds to be reported by ECO to SAHRA
Kuruman Formation GHAAP GROUP ASBESTOS HILLS SUBGROUP	Banded iron formation EARLY PROTEROZOIC (*c.* 2.5 Ga)	Microfossils	VERY LOW	None

4. CONCLUSIONS AND RECOMMENDATIONS

According to geological maps, satellite images and recent palaeontological assessments in the Kathu area (*e.g.* Almond 2013a, 2014), the flat-lying LegokoSolar Energy Facility (SEF) study area is underlain by a considerable thickness of Plio-Pleistocene to Recent sediments of the Kalahari Group. The underlying Precambrian bedrocks – *viz.* dolomites, cherts and iron formations of the Transvaal Supergroup – are too deeply buried beneath the development footprint to be directly affected by the proposed development. The Kalahari Group succession near Kathu mainly comprises well-developed calcretes or surface limestones (Mokolanen Formation) that may total 30 m or more in thickness in the region, together with a thin (probably < 1m) surface veneer of aeolian sands (Gordonia Formation), alluvial deposits and sparse near-surface gravels. In general the Kalahari Group calcretes and sands are of low palaeontological sensitivity, mainly featuring widely-occurring plant and animal trace fossils (*e.g.* invertebrate burrows, plant root casts). Recent palaeontological field assessments in the Sishen – Hotazel region by the author have not recorded significant fossil material within these near-surface Kalahari sediments. A very important fossil assemblage of Pleistocene to Holocene mammal remains - predominantly teeth with scarce bone material associated with Earlier, Middle and Later Stone Age artefacts, well-preserved peats and pollens - is recorded from unconsolidated doline (solution hollow) sediments at the well-known Kathu Pan site, located some 5.5 km northwest of Kathu. There are at present no obvious indications of comparable fossiliferous, tool-bearing solution hollow infills exposed at present within the study area but such sediments might conceivably be present but hidden beneath cover sands. Banded iron formation (BIF) of the Kuruman Formation (Asbestos Hills Subgroup, Ghaap Grop) builds the low hills in the north-eastern corner of the property. These Precambrian sediments contain microfossil assemblages but are generally of very low palaeontological sensitivity and will not be directly impacted by the proposed SEF.

The overall impact significance of the proposed solar energy development, including the grid connection to the new Sekgame Substation, is rated as LOW as far as palaeontological heritage is concerned. Likewise, cumulative impacts are likely to be of LOW significance, given the scarcity of important fossils (especially vertebrate remains) within the sedimentary rock units concerned as well as the huge outcrop area of the Kalahari Group as a whole. There is no preference on palaeontological heritage grounds for CPV or PV module technology or for any particular transmission line route or access road corridor under consideration. The degree of confidence for this assessment is rated as mediumbecause of the uncertainty surrounding the presence or absence of potentially fossiliferous buried doline infill deposits within the study area.

Due to the inferred low impact significance of the proposed Legoko Solar Energy Facility development as far as fossil heritage resources are concerned, no further specialist palaeontological studies or monitoring are recommended at this stage.

The following mitigation measures to safeguard chance fossil finds on site during the construction phase of the development are recommended:

- The ECO and / or the Site Engineer responsible for the development must remain aware that all sedimentary deposits have the potential to contain fossils and he/she should thus monitor all substantial excavations into sedimentary bedrock for fossil remains. If any substantial fossil remains (*e.g.* vertebrate bones, teeth, horn cores) are found during construction SAHRA should be notified immediately (Contact details: SAHRA, 111 Harrington Street, Cape Town. PO Box 4637, Cape Town 8000, South Africa. Phone: +27 (0)21 462 4502. Fax: +27 (0)21 462 4509. Web: www.sahra.org.za) so that appropriate mitigation (*i.e.* recording, sampling or collection) by a palaeontological specialist can be considered and implemented, at the developer's expense.

- A chance-find procedure should be implemented so that, in the event of fossils being uncovered, the ECO/Site Engineer will take the appropriate action, which includes:
    - Stopping work in the immediate vicinity and fencing off the area with tape to prevent further access;
    - Reporting the discovery to the provincial heritage agency and/or SAHRA;
    - Appointing a palaeontological specialist to inspect, record and (if warranted) sample or collect the fossil remains;
    - Implementing further mitigation measures proposed by the palaeontologist; and
    - Allowing work to resume only once clearance is given in writing by the relevant authorities.

If the mitigation measures outlined above are adhered to, the residual impact significance of any construction phase impacts on local palaeontological resources is considered to be low.

The mitigation measures proposed here should be incorporated into the Environmental Management Programme (EMP) for the LegokoSolar Energy Facility project. The palaeontologist concerned with mitigation work will need a valid collection permit from SAHRA. All work would have to conform to international best practice for palaeontological fieldwork and the study (*e.g.* data recording fossil collection and curation, final report) should adhere to the minimum standards for Phase 2 palaeontological studies recently published by SAHRA (2013).

6. ACKNOWLEDGEMENTS

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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, Free State, Limpopo and Northwest Province under the aegis of his Cape Town-based company *Natura Viva* cc. He has been a long-standing member of the Archaeology, Palaeontology and Meteorites Committee for Heritage Western Cape (HWC) and an advisor on palaeontological conservation and management issues for the Palaeontological Society of South Africa (PSSA), HWC and SAHRA. He is currently compiling technical reports on the provincial palaeontological heritage of Western, Northern and Eastern Cape for SAHRA and HWC. Dr Almond is an accredited member of PSSA and APHP (Association of Professional Heritage Practitioners – Western Cape).

Declaration of Independence

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

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