PALAEONTOLOGICAL ASSESSMENT: COMBINED DESKTOP STUDY & FIELD ASSESSMENT

Proposed Metsimatala Photovoltaic Power and Concentrated Solar Power Facilities on Farm Groenwater, Francis Baard District Municipality near Postmasburg, Northern Cape

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

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1. SUMMARY

Afri-Devo Energy are proposing to develop both a Photovoltaic Power (PV) and a Concentrated Solar Power (CSP) facility, each of 50 MW generating capacity, on Portion 453 of Groenwater Farm, Francis Baard District Municipality, some 20 km ENE of the town of Postmasburg in the Northern Cape Province.

The proposed Metsimatala PV and CSP solar power facility study area is underlain by Precambrian iron-rich, basinal sediments of the Ghaap Group (Kuruman and Daniëlskuil Formations) as well as by glacial and volcanic rocks of the younger Postmasburg Group (Makganyene and Ongeluk Formations). These rocks are all extremely ancient - some 2.2 to 2.5 billion years old – and are unlikely to contain substantial macrofossil remains. Cherty layers (fine grained siliceous rocks) and carbonate rocks here may contain microfossil assemblages but these have not yet been recorded in the scientific literature.

Large stromatolites (microbial mounds) within the Makganyene Formation are of special scientific interest because they are intimately associated with cold-water glacial rocks (tillites), suggesting that tropical warm waters are not, as previously supposed, a pre-requisite for stromatolite reef development in early Precambrian times. However, these stromatolitic reefs do not seem to have developed in the shallower marine platform settings represented at Groenwater (Ghaap Plateau Sub-basin), and no carbonate rocks or stromatolites were observed here during field assessment.

Aeolian (wind-blown) sands of the Gordonia Formation (Kalahari Group) and other Quaternary to Recent superficial deposits overlying Precambrian bedrocks in the study region (*e.g.* alluvium, colluvium, surface gravels) are generally sparsely fossiliferous.

It is concluded that the proposed Metsimetala solar power facilities are very unlikely to have a significant impact on local palaeontological heritage resources. Should substantial fossil remains be exposed during construction, however, such as well-preserved stromatolites, the ECO should safeguard these, preferably *in situ*, and alert SAHRA as soon as possible so that appropriate action (*e.g.* recording, sampling or collection) can be taken by a professional palaeontologist.

2. INTRODUCTION & BRIEF

The company Afri-Devo Energy are proposing to develop both a Photovoltaic Power (PV) and a Concentrated Solar Power (CSP) facility, each of 50 MW generating capacity, on Portion 453 of Groenwater Farm, Francis Baard District Municipality, some 20 km ENE of the town of Postmasburg in the Northern Cape Province (Fig. 1). The land is owned by the Metsimatala CPA communities. The proposed projects have been named the Metsimatala PV Solar Farm and the Metsimatala CSP Solar Farm. The proposed activities would include the construction and operation of a Solar Energy facility and associated infrastructure.

The following main infrastructural components are envisaged for these solar energy projects:

- PV panels & inverters
- CSP mirrors and power block
- On-site Substation
- Transmission Line linking the facility with Eskom
- Wiring between PV panels/CSP Mirror and on-site substation
- Internal access roads
- Security infrastructure
- Storage Area

The proposed study area (Groenwater Farm) overlies Precambrian bedrocks of the Ghaap Group that is famous for its microfossils and stromatolites (microbial mounds and columns) as well as the overlying Postmasburg Group (Figs. 4 & 5). A combined desktop and field-based palaeontological impact assessment for the project has therefore been commissioned by Enviroworks (contact details: Suite 116, Private Bag X01, Brandhof 9324; 2 Chris Botha Street, Westdene; tel 086 198 8895; e-mail elbi@enviroworks.co.za) in accordance with the requirements of the National Heritage Resources Act, 1999. This palaeontological study forms part of a comprehensive HIA to be compiled by Ms Karen van Ryneveld of ArchaeoMaps (Postnet Suite 239, Private Bag X3, Beacon Bay, 5205; e-mail kvanryneveld@gmail.com; tel 084 871 1064).

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 desktop study

This report provides an assessment of the observed or inferred palaeontological heritage within the Groenwater 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 2010a, 2010b, 2012), (4) the author's field experience with the formations concerned and their palaeontological heritage, and (5) a one-day field assessment on 28 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 Groenwater 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, gullies) as well as artificial exposures such as quarries, dams and cuttings along farm tracks. In the case of Groenwater, only scattered small hill slope and hill crest exposures of basement rocks were identified.

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.

The major limitation on this study is the lack of published work on the palaeontology of the region as well as the very low levels of bedrock exposure of potentially fossiliferous rock units (notably the Makganyene Formation) within the study area. To compensate for the latter, exposures of the Makganyene Formation in road cuttings just to the east of the study area (as indicated on Figs. 1 and 3) were examined for fossils.

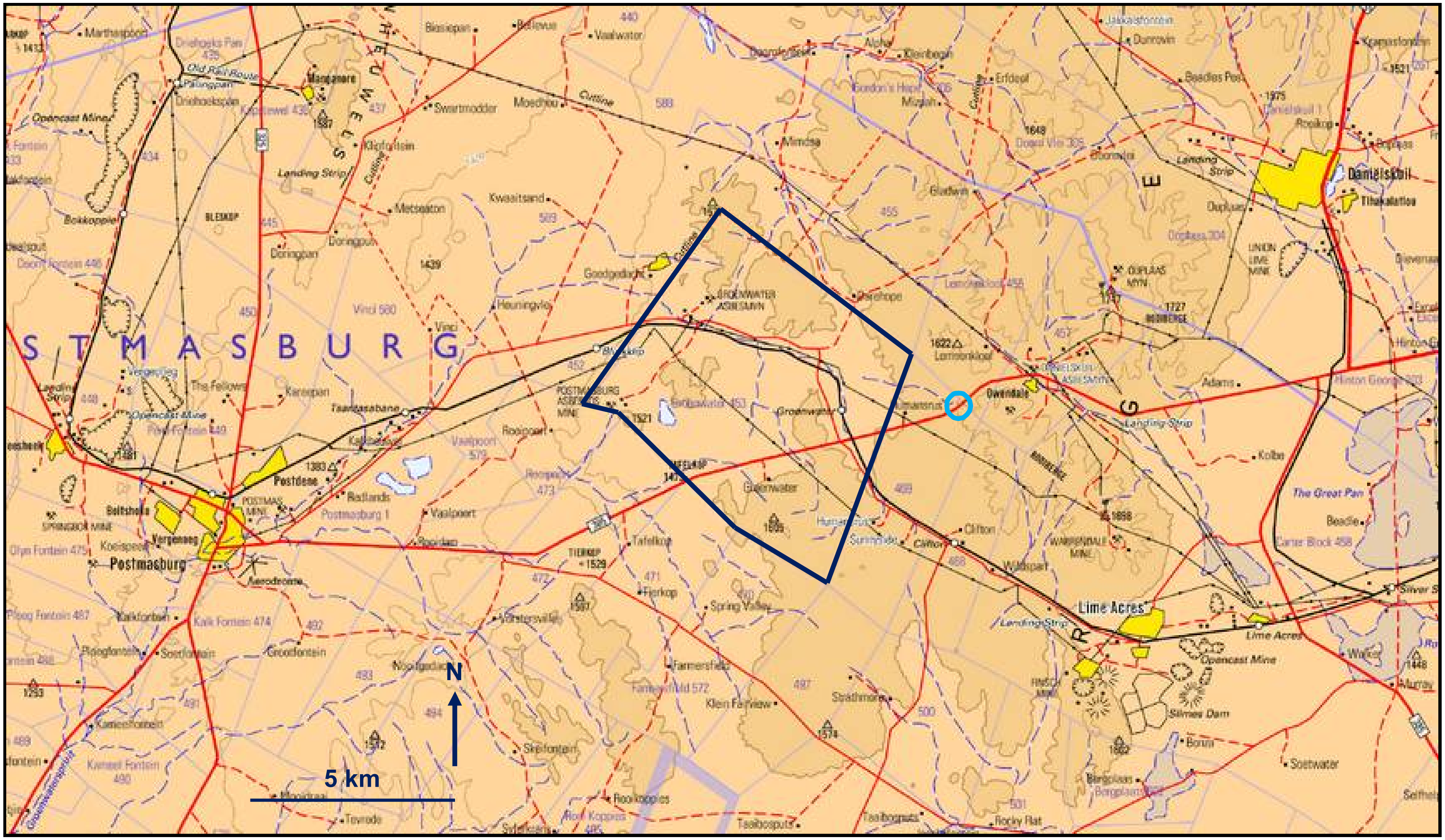

Fig. 1. Extract from 1: 250 000 topographical sheet 2822 Postmasburg showing location of the study area on Farm Groenwater, *c.* 20 km ENE of Postmasburg, Northern Cape Province (Map courtesy of the Chief Directorate of Surveys & Mapping, Mowbray). Important fossil stromatolite localities in the Campbell Rand Subgroup are recorded at Lime Acres to the south-east of the study area. Blue circle = road cuttings through the Makganyene Formation glacial succession along the R385.

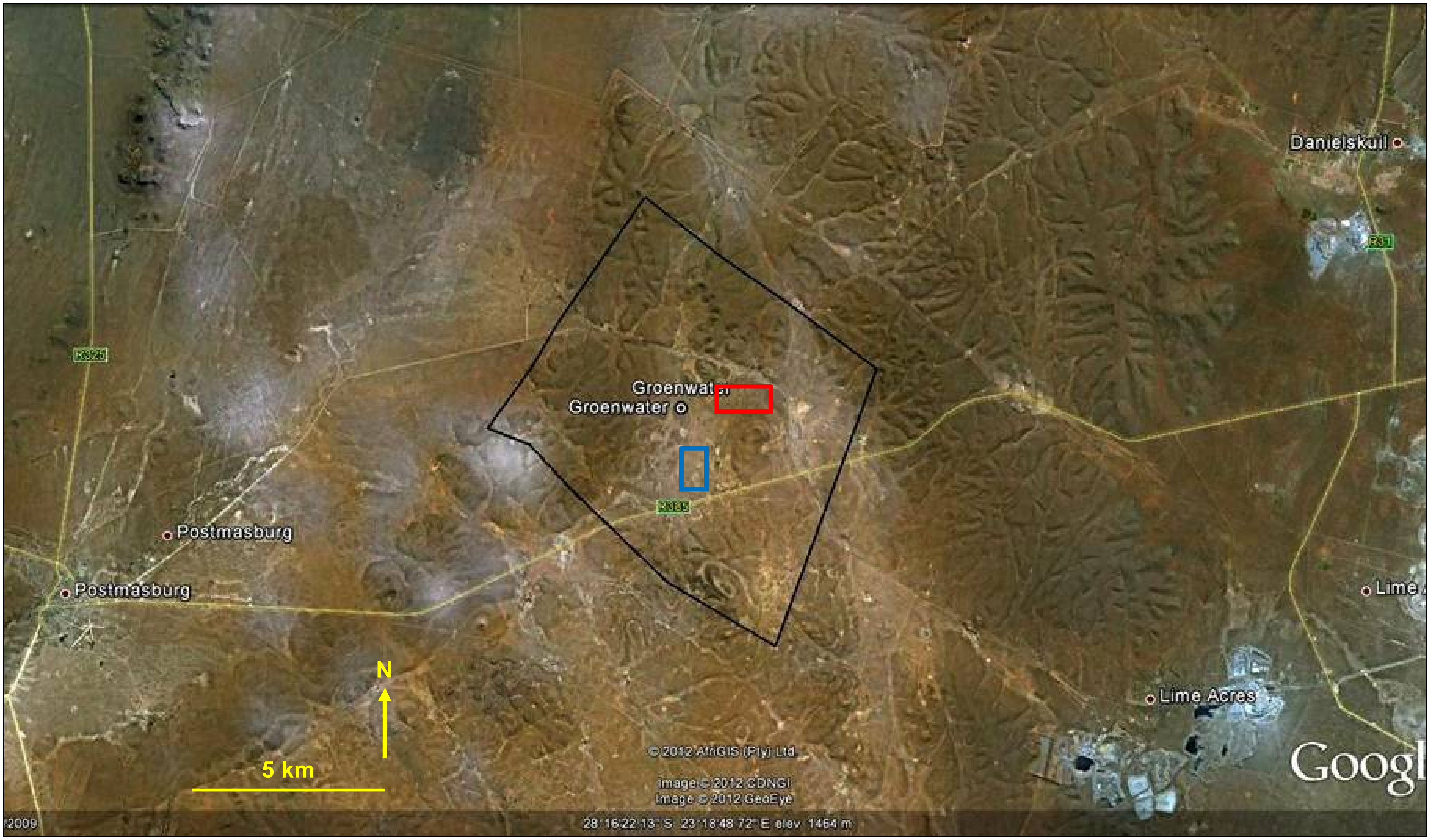

Fig. 2. *Google Earth*® satellite image showing the dissected hilly terrain within the Groenwater Farm study area (black polygon) for the proposed new photovoltaic power station (red rectangle) and CSP power station (blue rectangle), *c*. 20 km ENE of Postmasburg, Northern Cape Province.

3. GEOLOGICAL BACKGROUND

The Groenwater Farm study area situated some 20 km ENE of Postmasburg straddles the R385 tar road and rail link between Postmasberg and Daniëlskuil, Northern Cape (Figs. 1, 2). It comprises highly dissected, arid, rocky terrain between approximately 1400 and 1600m amsl on the western flanks of the Asbesberge range that runs north-south to the southwest of the towns of Daniëlskuil and Kuruman. The area is drained by intermittently flowing streams that flow westwards into the Groenwaterspruit at Postmasburg. There are two defunct asbestos mines on the property: the Postmasburg Mine in the west and the Groenwater Mine in the north-central part of the property.

The geology of the study area near Postmasburg is shown on the 1: 250 000 geology map 2822 Postmasburg (Council for Geoscience, Pretoria; Fig. 4 herein). A separate explanation for the Postmasburg geological map has not yet been published, while a short account of the geology is printed on the map itself.

The geology of the northern half of the study area on the western edge of the Asbesberge is dominated by ancient Precambrian sediments of the **Asbestos Hills Subgroup** (also referred to in the older literature as the Asbesheuwels Subgroup). This succession forms the upper part of the Late Archaean to Early Proterozoic **Ghaap Group** (**Transvaal Supergroup**) of the Griqualand West Basin (Ghaap Plateau Sub-basin) (See stratigraphic column in Fig. 5). Useful reviews of the stratigraphy and sedimentology of these Transvaal Supergroup rocks have been given by Moore *et al.* (2001) and Eriksson *et al.* (2006). The Ghaap Group represents some 200 Ma 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 (Fig. 5; see also fig. 4.19 in McCarthy & Rubidge 2005).

The **Kuruman Formation** (**Vak** in Fig. 4) of the Asbestos Hills Subgroup consists predominantly of banded iron formations (BIF) overlying the stromatolite-rich carbonate succession of Campbell Rand Subgroup (Fig. 5). These BIF rocks consist of rhythmically bedded, thinly composition- and colour-banded cycles of fine-grained mudrock, chert and iron minerals (siderite, magnetite, haematite) that were deposited in an offshore, intermittently anoxic 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. The recessive-weathering Kuruman Formation is not well exposed on Groenwater and no outcrops were examined during the field assessment.

The overlying iron–rich succession of the **Daniëlskuil Formation** (**Vad** in Fig. 4), up to 200m-thick, is interpreted as a current- or wave-reworked banded iron formation, as suggested by the abundance of BIF intraclasts and sedimentary structures (Beukes 1983, Klein & Beukes 1989, Beukes & Klein 1990). The base of the Danielskuil Formation has been radiometrically dated to 2.43-2.49 Ga, *i.e.* Early Proterozoic (Eriksson *et al.* 2006). The Daniëlskuil Formation BIF tend to be more prominent weathering than the finer-grained underlying Kuruman BIF rocks. Good cliff exposures of Daniëlskuil Formation rocks were examined on Groenwater at Locs. 500 and 501 (Figs. 6, 7). The fine-grained siliciclastics are brown to ochreous weathering, very tabular in geometry, laminated to thin-bedded (to *c*. 10-20cm), cherty (*e.g.* showing conchoidal fracture) with bands of iron minerals (reddish haematite, dark magnetite *etc*). Jointing is well developed. Sedimentary structures indicating current reworking or BIF intraclasts were not observed.

The southern half of the study area is underlain by glacial and volcanic rocks of the 2.4-2.2 Ga **Postmasburg Group** (Transvaal Supergroup) that overlie the older Ghaap Group rocks in the core of a broad NNE-SSW trending synclinal structure (Figs. 4 and 5) (Moore *et al.* 2012). Two contrasting rock units are mapped here. Basal diamictites of the **Makganyene Formation** (**Vm**), which reaches a thickness of 500m near Postmasburg, reflect a 250 million year glacial event of Palaeoproterozoic age (*c*. 2.3-2.2 Ga in Evans *et al.* 1997; *c*. 2.4 Ga in Polteau *et al.* 2006). This has been interpreted by some authors as a catastrophic global "Snowball Earth" event of Early

Proterozoic age triggered by the destruction of preceding methane-rich greenhouse atmospheres by oxygenic cyanobacterial photosynthesis (Kopp *et al.* 2005; but see also Coetzee *et al.* 2006). Sedimentary facies include massive to coarsely bedded diamictites, sandstones, shales, BIF and even manganese-rich carbonates with stromatolitic bioherms (reefs) (Fig. 3). The bioherms are often up to 5 m long and 3 m thick and are associated with a period of regression (lowered sea levels) within the basin (Kopp *et al.* 2005, Polteau 2000, 2005, Polteau *et al*. 2006). Most of the diamictite clasts are derived from the older Transvaal Supergroup succession (*e.g.* BIF, carbonates). Abundant striated clasts within the more proximal Makganyene facies support a glacial origin for the diamictites.

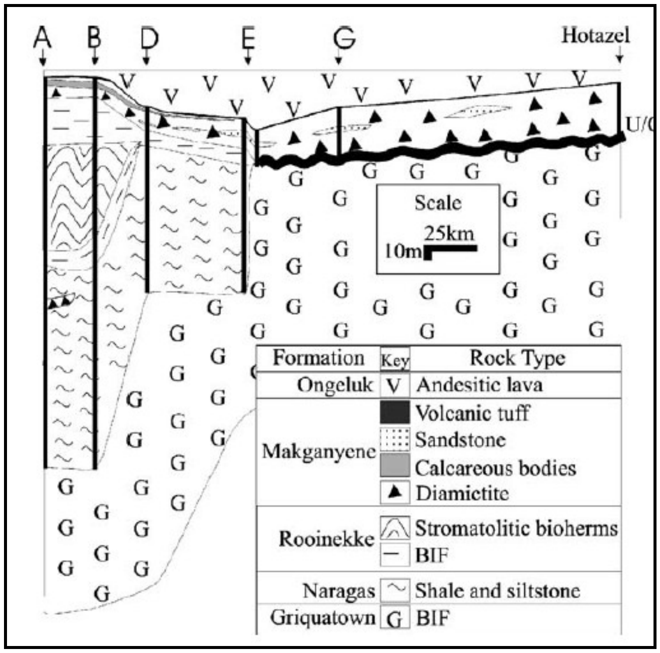

Fig. 3. Series of profiles through the Makganyene Formation, roughly from SW to NE across the Griqualand Basin, Northern Province (From Polteau *et al.* 2006). Profile G, to the SW of Danielskuil, corresponds most closely to the Groenwater study area. Here, on the platform area to the NE of the major Griquatown Fault Zone (Ghaap Plateau Sub-basin), the Makganyene glacial diamictites contain lenticular sandstone bodies but no carbonate lenticles with stromatolitic bioherms. These last are confined to the more offshore parts of the basin preserved further to the southwest (= Prieska Sub-basin).

During fieldwork no informative bedrock exposures could be found within the several small outcrop areas of Makganeye Formation rocks indicated on Groenwater Farm on the 1: 250 000 geological map (Fig. 4; *NB* some of the "green rocks" shown here are unrelated Precambrian dolerites, di). For example, the narrow west-east Makganyene outcrop area to the NE of Metsimetala Village appears on the ground as a low-lying valley blanketed in Kalahari sands and surface gravels (Fig. 8). Good exposures of Makganyene Formation rocks are seen, however, some 5.5 km to the ESE along the R385 tar road, southeast of Humansrus farmstead (see blue circle in Fig. 1) (Figs. 9 to 12). Here lenticular bodies up to 2m thick of massive, resistant-weathering diamictite containing small dispersed angular clasts of dark chert, BIF and carbonate are interbedded with laminated to thin-bedded mudrocks and fine sandstones. The entire succession shows a strong overprint of ochreous to rusty brown or metallic secondary iron and manganese mineralisation, most striking expressed in the form of well-developed colour banding (Liesegang rings) that transects the primary sedimentary structures such as bedding (Fig. 11). Joint surfaces are also heavily mineralised. Sparse angular clasts within thin-bedded mudrocks suggest periglacial to subglacial dropstone laminites, the gravels having melted out from the base of floating ice. No carbonate facies, fossil stromatolites or glacially striated clasts were observed in these road cuttings.

The glacially-related Makganyene rocks are overlain by basaltic to andesitic lavas of the **Ongeluk Formation** (**Vo**) dated to 2.2 Ga. The first part of this major flood basalt succession was extruded sub-aerially, but later lava flows show evidence of sub-aqueous extrusion (*e.g.* pillow lavas; Eriksson *et al.* 2006). Subordinate diamictites are found within the Ongeluk succession. Scattered small exposures of Ongeluk Formation lavas are seen on the crest of the low hill just east of Metsimetala Village. The well-jointed, resistant-weathering igneous rocks here are massive, buff- to brown-weathering, fine-grained and speckled with occasional vugs (cavities) (Fig. 13).

Unconsolidated aeolian (*i.e.* wind-blown) sands of the Quaternary **Gordonia Formation** (**Kalahari Group**) (**Qs** in Fig. 4), whose thickness here is uncertain, are also mapped in the central part of the Groenwater study area. The geology of the Late Cretaceous to Recent Kalahari Group is reviewed by Thomas (1981), Dingle *et al.* (1983), Thomas & Shaw 1991, Haddon (2000) and Partridge *et al.* (2006). The Gordonia dune sands are considered to range in age from the Late Pliocene / Early Pleistocene to Recent, dated in part from enclosed Middle to Later Stone Age stone tools (Dingle *et al*., 1983, p. 291). Note that the recent extension of the Pliocene - Pleistocene boundary from 1.8Ma back to 2.588 Ma would place the Gordonia Formation almost entirely within the Pleistocene Epoch. The intermittent water courses of the Groenwaterspruit drainage system are associated with various alluvial deposits (*e.g.* gravels, sands and silts) of probable Quaternary to Recent age. These superficial deposits, likewise the colluvial and downwasted surface gravels and calcrete pedocretes that can be expected to mantle much of the bedrock here, are not mapped separately at 1: 250 000 scale.

Both the proposed PV and CSP development sites are blanketed by a substantial cover of bright orange-brown Kalahari sands (Gordonia Formation) and vegetation, with apparently no bedrock exposure (Figs. 14, 15). The lower slopes of the surrounding hills are also mantled with Kalahari sand, as seen in the borrow pit at Metsimetala Village (Fig. 17). Higher slopes have a surface layer of angular scree gravels or colluvium, which may form a substantial layer of downwasted resistant clasts such as BIF, cherts and Ongeluk lavas (Figs. 16, 18). Most clasts are angular, but occasional water-worn pebbles are also found. The underlying bedrock may be weathered *in situ* to a soft saprolite.

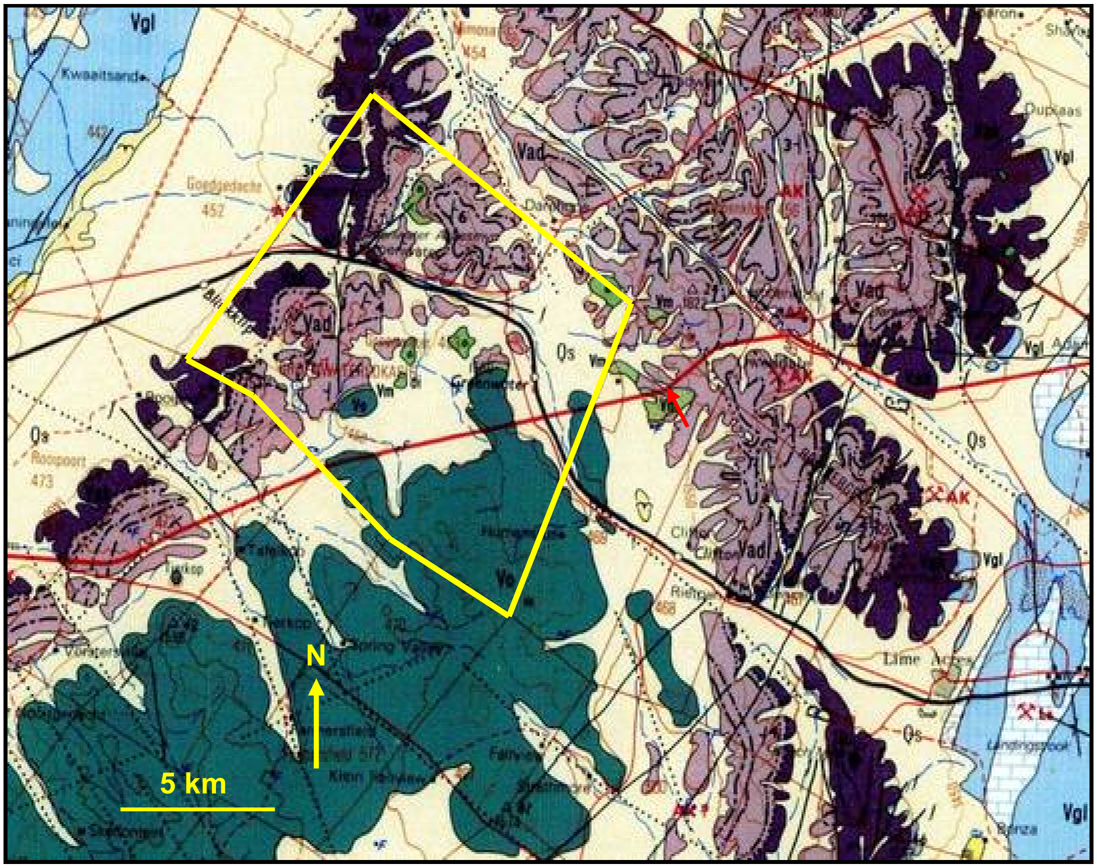

Fig. 4. Extract from 1: 250 000 geological map 2822 Postmasburg (Council for Geoscience, Pretoria) showing the location of the Metsimatala solar power project study area (yellow polygon) in the Asbesberge region to the east of Postmasburg. The locations of two defunct asbestos mines (Postmasburg and Groenwater Mines) within the study area are indicated in Fig. 1. The rock units mapped within the study area are:

GHAAP GROUP (ASBESTOS HILLS SUBGROUP)

Dark purple (Vak) = Kuruman Formation.
Pale purple (Vad) = Daniëlskuil Formation.

POSTMASBURG GROUP

Vm (middle green) = Makganyene Formation (glacial tillites); location of good road cutting exposures of this unit are arrowed (red)
Vo (dark green) = Ongeluk Formation

POST- TRANSVAAL SUPERGROUP DOLERITES

di (middle green) – dolerite or diabase (metamorphosed dolerite) intrusions of Precambrian (Proterozoic) age

SUPERFICIAL DEPOSITS

Pale yellow (Qs) = aeolian sand of Gordonia Formation (Kalahari Group).

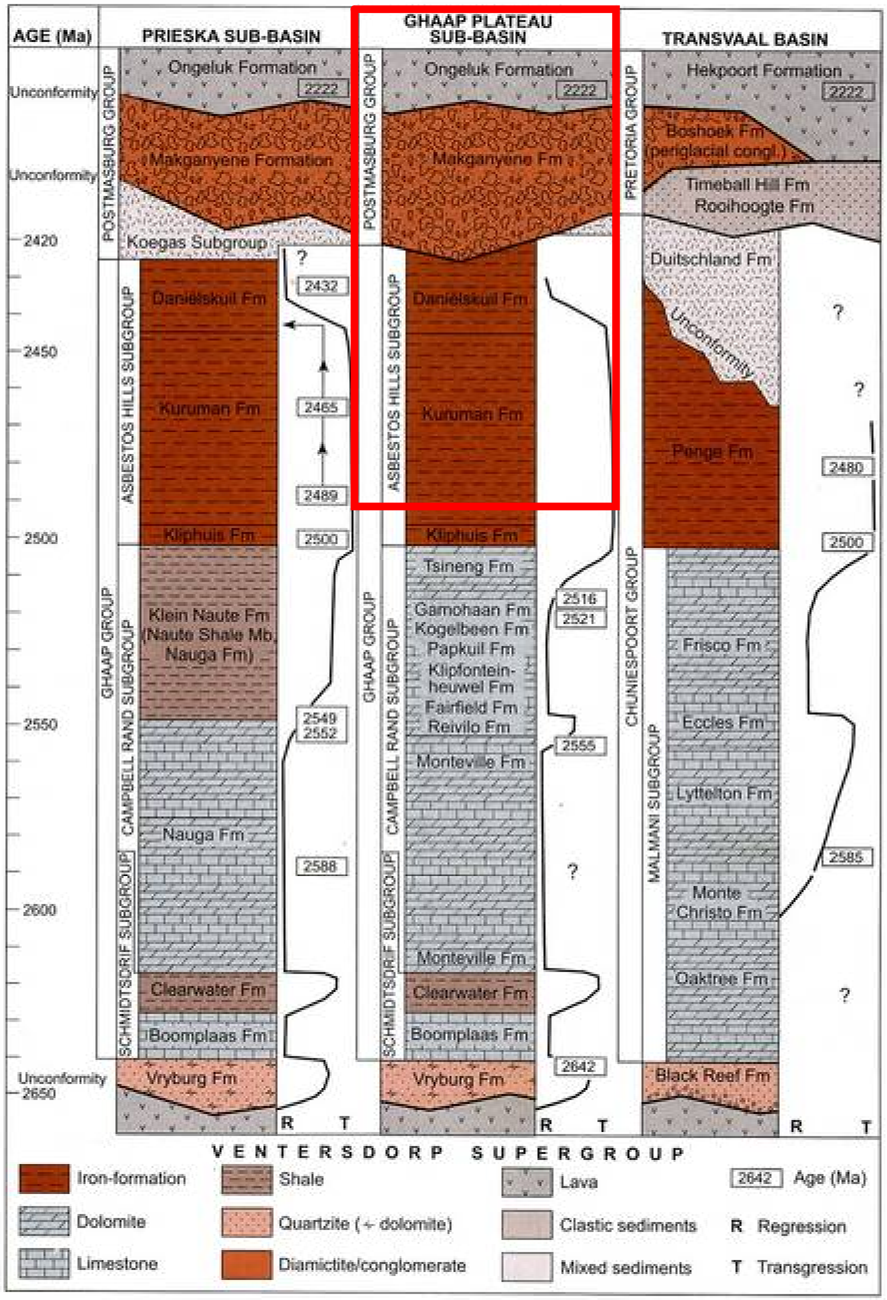

Fig. 5. Stratigraphy of the Late Archaean to Early Proterozoic Ghaap and Postmasburg Groups of the Transvaal Supergroup (From Eriksson *et al.* 2006). The stratigraphic position of the Precambrian bedrocks represented in the study area is indicated by the red rectangle (Ghaap Plateau Sub-basin of Griqualand West Basin).

Fig. 6. North-facing hillslope cliff exposure of tabular-bedded Daniëlskuil Formation banded iron formation, just northwest of PV study area (Loc. 501).

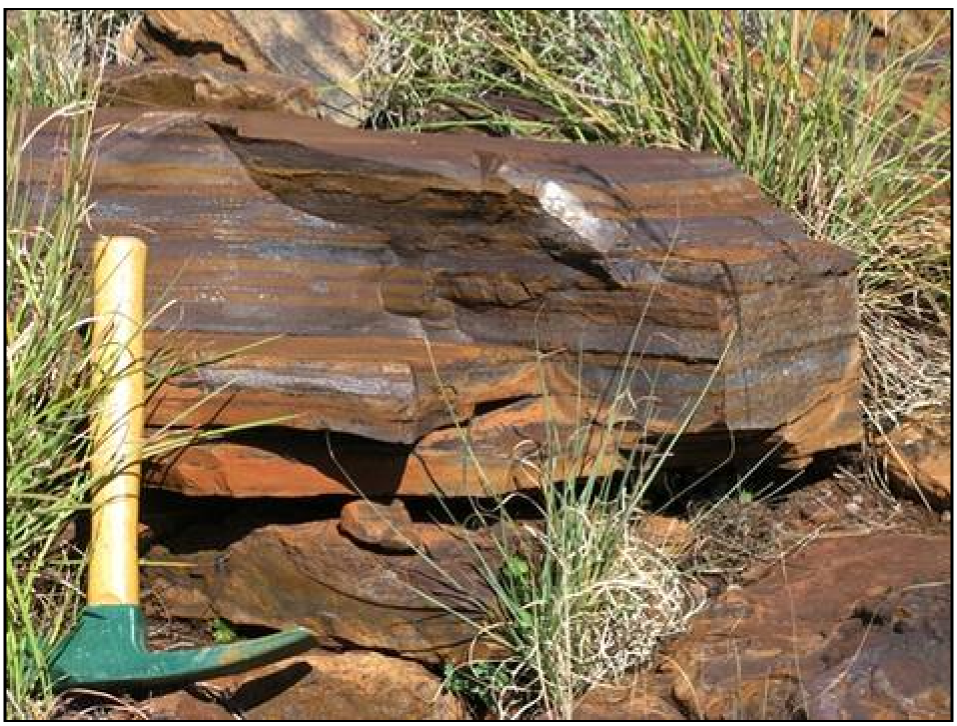

Fig. 7. Detail of laminated banded iron formation, Daniëlskuil Formation (Loc. 501) (Hammer = 27 cm).

Fig. 8. View northwards across possible outcrop area of Makganyene Formation NE of Metsimatala Village on Farm Groenwater*, i.e.* low-lying region between ridge of BIF hills in the middle distance and Ongeluk lavas in the foreground (Photo taken from Loc. 506).

Fig. 9. Lenticular bodies of resistant-weathering diamictite interbedded with thin-bedded siliciclastic sediments, Makganyene Formation road cutting east of Humansrus farmstead (Loc. 508) (Hammer = 27 cm).

Fig. 10. Resistent-weathering bed of Makganyene diamictite containing dispersed angular clasts of BIF overlying thin-bedded siltstones (Loc. 508) (Hammer = 27 cm). The entire succession is heavily stained by secondary iron and manganese mineralisation.

Fig. 11. As above, showing strong secondary overprinting by concentric-banded secondary minerals known as Liesegang rings, some of which superficially resemble fossil stromatolites (Loc. 508) (Hammer = 27 cm).

Fig. 12. Detail of laminated, iron- and manganese-stained siltstones showing sparse dropstones – *i.e.* glacial or interglacial dropstone laminites (Loc. 508).

Fig. 13. Blocky-jointed, brown-weathering massive lavas of the Ongeluk Formation (Loc. 507) (Hammer = 27 cm).

Fig. 14. View westwards across PV solar project area towards low hills of Daniëlskuil Formation BIF in the background (See Fig. 6). Note low relief and absence of rocky exposures in foreground, largely blanketed by Kalahari sands (Loc. 502).

Fig. 15. View south-westwards from Loc. 504 towards flat-lying area west of Metsimatala village, the proposed CSP solar site. Note carpet of surface gravels in foreground. The CPS site is covered in Kalahari sands.

Fig. 16. Borrow pit into thick surface gravels and underlying weathered BIF, north of Metsimetala Village (Loc. 503) (Hammer = 27 cm).

Fig. 17. Borrow pit into typical orange-brown Kalahari sands of the Gordonia Formation at Metsimetala Village (Loc. 504) (Hammer = 27 cm). The hillslope behind is built of Ongeluk Formation lavas.

Fig. 18. Coarse, angular colluvial gravels of Ongeluk Formation lavas overlying Kalahari sands and Ongeluk saprolite (*in situ* weathered bedrock).

4. PALAEONTOLOGICAL HERITAGE

The fossil heritage recorded within each of the main sedimentary rock successions occurring within the study region near Postmasburg is briefly outlined here (See also Table 1, and Almond & Pether 2008).

4.1. Fossils within the Ghaap Group

The fossil record of the Precambrian sediments of the Northern Cape has been briefly reviewed by Almond & Pether (2008). The shallow shelf and intertidal sediments of the carbonate-dominated lower part of the Ghaap Group (*i.e.* **Schmidtsdrif** and **Campbell Rand Subgroups**), outside the present study area, are famous for their rich fossil biota of *stromatolites* or microbially-generated, finely laminated mounds and branching structures. Some stromatolite occurrences on the Ghaap Plateau of the Northern Cape are spectacularly well-preserved (*e.g.* Boetsap locality figured by McCarthy & Rubidge 2005, Eriksson *et al.* 2006). Detailed studies of these 2.6-2.5Ga carbonate sediments and their stromatolitic biotas have been presented by Young (1932), Beukes (1980, 1983), Eriksson & Truswell (1974), Eriksson & Altermann (1998), Eriksson *et al.* (2006), Altermann and Herbig (1991), Altermann and Wotherspoon (1995).

An important fossil stromatolite site occurs at Lime Acres situated only some 15-20 km to the southeast of the Groenwater study area (see map Fig. 1 and satellite image Fig. 2) (Altermann & Wotherspoon 1995). Some of the oldest known (2.6 Ga) fossil microbial asemblages with filaments and coccoids have been recorded from stromatolitic cherty limestones of the Lime Acres Member, Kogelbeen Formation at Lime Acres (Altermann & Schopf 1995). The Archaean stromatolite occurrences from the Ghaap Group have been reviewed by Schopf (2006, with full references therein). The Tsineng Formation just below the base of the Asbestos Hills succession has yielded both stromatolites (previously assigned to the Tsineng Member of the Gamohaan

Formation) as well as filamentous microfossils named *Siphonophycus* (Klein *et al.*1987, Altermann & Schopf 1995).

The overlying 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. However, there are several reports of microfossils from cherty sediments within the Kuruman Formation, just below the Daniëlskuil 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. No macrofossils were observed in the well-exposed Daniëlskuil Formation outcrops on Groenwater.

4.2. Fossils within the Postmasburg Group

The fossil record of the Postmasburg Group of the Transvaal Supergroup is still poorly known. Stromatolitic bioherms up to 5m long and 3m thick that are made up of manganese-rich laminated carbonates and contain chert clasts (presumably glacial dropstones) are recorded from the glacially-influenced **Makganyene Formation** by Polteau *et al.* (2006). These carbonate rocks are interbedded with glacial diamictites in the Prieska Subbasin. The intimate association of supposed warm-water carbonates and cold-water glacial deposits at low palaeolatitudes is of considerable palaeoclimatic and palaeobiological significance (See also Polteau 2000, 2005). An alternative view is that these Early Proterozoic stromatolites actually developed within cold, glacial waters, rather than in tropical Bahamas-like settings as previously assumed. Large conical stromatolites generated by cyanobacteria ("blue-green algae") have recently been discovered growing at depths of up to 100m beneath permanent ice cover in an Antarctic alkaline freshwater lake, a possible modern analogue for the Makganyene fossils (Andersen *et al.* 2011). Any fossil occurrences of Makganyene stromatolites in association with glacial rocks are therefore of special research and conservation significance.

According to Polteau *et al.* (2006) the stromatolitic carbonate bodies within the Makganyene Formation are restricted to the more distal Prieska Sub-basin, southwest of the Griquatown Fault Zone (Fig. 3). They have not been recorded from the more proximal, platform area that is represented near Groenwater. During field assessment carbonate facies were not observed in the Makganyene Formation outcrop areas. Striking exampes of Liesegang rings (Fig. 11) related to diagenetic (post-depositional) iron / manganese mineralisation are seen here, however, and might conceivably be mistaken for stromatolitic lamination.

There are contested records of possible trace fossils from contemporary 2.2 Ga sediments of the Postmasburg Group in the Transvaal Basin (Pretoria Group; Almond & Pether 2008).

No fossils are recorded from the volcanic **Ongeluk Formation**. Stromatolitic dolomites are recorded from the **Mooidraai Formation** at the top of the Postmasburg Group succession (Beukes 1986, Eriksson *et al.* 2006), but these younger rocks are not represented within the present study area.

4.3. Fossils within the Kalahari Group

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 underlying lime-rich bedrocks 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*), tortoise remains 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** might also contain trace fossils such as rhizoliths, termite and other insect burrows, or even mammalian trackways. Mammalian bones, teeth and horn cores (also tortoise remains, and fish, amphibian or even crocodiles in wetter depositional settings) may be expected occasionally expected within Kalahari Group sediments and calcretes, notably those associated with ancient alluvial gravels.

Younger (Quaternary to Recent) surface gravels and colluvium are probably unfossiliferous. No fossil remains were observed within the superficial deposits on Groenwater during field assessment.

5. CONCLUSIONS & RECOMMENDATIONS

Impacts on fossil heritage are normally confined to the construction phase of a solar power development. This phase development will normally entail shallow excavations into the superficial sediment cover (soils, alluvial gravels *etc*) and perhaps also into the underlying potentially fossiliferous bedrock. These notably include excavations for the PV / CSP panel support structures, buried cables, access roads, any new power line pylons and foundations for associated infrastructure. All these developments may adversely affect potential fossil heritage 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. Once constructed, the operational and decommissioning phases of the PV / CSP power station will not involve further adverse impacts on palaeontological heritage, however.

The proposed Metsimatala solar power facility study area is underlain by Precambrian iron-rich basinal sediments of the Ghaap Group (Kuruman and Daniëlskuil Formations) as well as by glacial and volcanic rocks of the younger Postmasburg Group (Makganyene and Ongeluk Formations) (Table 1) . These rocks are extremely ancient - some 2.2 -2.5 billion years old – and in most cases are unlikely to contain substantial macrofossil remains. Cherty layers (fine grained siliceous rocks) and carbonate rocks here may contain microfossil assemblages but these have not yet been recorded in the scientific literature. Large stromatolites (microbial mounds) within the Makganyene Formation have recently become the focus of research interest because they are intimately associated with cold-water glacial rocks, suggesting that tropical warm waters are not, as previously supposed, a pre-requisite for stromatolite reef development in Proterozoic times. However, these stromatolitic reefs do not seem to have developed in the shallower marine platform settings represented at Groenwater, and no carbonate rocks or stromatolites were observed during field assessment.

Aeolian (wind-blown) sands of the Gordonia Formation (Kalahari Group) and other Quaternary to Recent superficial deposits overlying Precambrian bedrocks in the study region (*e.g.* alluvium, colluvium, surface gravels, wind-blown sands) are generally sparsely fossiliferous. No fossils were observed within the various superficial sediments during field assessment.

It is concluded that the proposed Metsimetala solar power facilities are very unlikely to have a significant impact on local palaeontological heritage resources. Should substantial fossil remains be exposed during construction, such as well-preserved stromatolites, the ECO should safeguard these, preferably *in situ*, and alert SAHRA as soon as possible so that appropriate action (*e.g.* recording, sampling or collection) can be taken by a professional palaeontologist.

Table 1: Fossil heritage in the Postmasburg study area

GEOLOGICAL UNIT	ROCK TYPES & AGE	FOSSIL HERITAGE	PALAEONT-OLOGICAL SENSITIVITY	RECOMMENDED MITIGATION
Gordonia Formation **KALAHARI GROUP** ***plus*** **SURFACE CALCRETE**	Mainly aeolian sands *plus* minor fluvial gravels, freshwater pan deposits, calcretes PLEISTOCENE to RECENT	calcretised rhizoliths & termitaria, ostrich egg shells, land snail shells, rare mammalian and reptile (*e.g.* tortoise) bones, teeth freshwater units associated with diatoms, molluscs, stromatolites *etc*	LOW	none recommended any substantial fossil finds to be reported by ECO to SAHRA
Makganyene & Ongeluk Fms **POSTMASBURG GROUP**	Glacial diamictites (tillites), volcanic lavas, dolomites, ironstones EARLY PROTEROZOIC (*c*. 2.2 Ga)	Stromatolites associated with glacial deposits within the Makganyene Formation (Prieska Sub-basin)	GENERALLY LOW with exception of stromatolitic units	reporting and documentation of ancient stromatolites in surface exposures of Makganyene Fm
Asbestos Hills Subgroup (Kuruman & Daniëlskuil Fms) **GHAAP GROUP**	BIF (banded iron formations) with cherty bands EARLY PROTEROZOIC (*c*. 2.5-2.4 Ga)	important early microfossil biotas	LOW	none recommended

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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. number	South	East	Comments
500	S28 14 54.8	E23 17 28.0	Danielskuil Fm- roadside cliff exposure
501	S28 15 15.1	E23 18 21.5	Danielskuil Fm – hillslope exposure
502	S28 15 48.8	E23 19 25.0	Kalahari sands in PV solar project area
503	S28 16 12.2	E23 18 54.6	Borrow pit showing weathered BIF and overlying gravels
504	S28 17 01.8	E23 18 55.6	Borrow pit into Kalahari sands at Metsimetala Village
505	S28 17 24.0	E23 19 04.6	Hill slope exposure of colluvial gravels
506	S28 16 31.7	E23 19 30.6	Hilltop exposure of Ongeluk Fm lavas
507	S28 16 31.8	E23 19 30.6	Ditto
508	S28 16 50.9	E23 22 58.0	Roadcutting through Makganyene Fm
509	S28 16 51.9	E23 22 55.7	Ditto

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, Gauteng, Limpopo and Free State for SAHRA and HWC. Dr Almond is an accredited member of PSSA and APHP (Association of Professional Heritage Assessment Practitioners – Western Cape).

Declaration of Independence

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