PALAEONTOLOGICAL HERITAGE ASSESSMENT: COMBINED DESKTOP & FIELD-BASED STUDY

Proposed Gamma Solar Power Plant on the Remaining Extent of Portion 4 (Bos Kop), Farm Champions Kloof 731 near Vryburg, Naledi Local Municipality, North-West Province

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EXECUTIVE SUMMARY

The company Gamma Solar Power Plant (RF) (Pty) Ltd is proposing to develop up to 115MW photovoltaic solar facility, known as the Gamma Solar Power Plant, on the Remaining Extent of Portion 4 (Bos Kop) of the Farm Champions Kloof 731, HN Registration Division, Province of the North-West.

The northern and western portions of the Gamma Solar Power Plant study area are largely underlain by late Archaean (*c*. 2.6 billion year-old) sedimentary rocks of the Schmidtsdrif Subgroup (Ghaap Group, Transvaal Supergroup). These mainly comprise shallow marine carbonates and siliciclastic sediments of the Boomplaas Formation.

Densely-packed, well-preserved stromatolite assemblages are recorded within the Boomplaas Formation carbonate rocks in a small area of low-relief bedrock exposure just west of the farmstead. A range of stromatolitic growth forms is represented here. The Boomplaas Formation stromatolites recorded in the Vryburg area represent some of the oldest examples of these microbially-generated fossils in South Africa but they have yet to be comprehensively described while their stratigraphic and geographical distributions are poorly understood. Most of the Boomplaas Formation outcrop area on Champions Kloof 731 is mantled by soils and surface gravels of low palaeontological sensitivity. Stromatolitic horizons may be present within the underlying bedrocks but these are not easily accessible for scientific research and are in part protected by the superficial sediments above. The south-eastern portion of the Gamma study area is underlain by Permo-Carboniferous glacial deposits of the Dwyka Group (*c*. 300 million years old). The bedrocks, overlying soils and downwasted gravels here are not palaeontologically sensitive.

It is recommended that the small rocky area of Boomplaas Formation bedrocks west of the farmstead (outlined in yellow in Fig. 2) be excluded from the solar plant footprint, with a buffer zone of 20 m. The ECO should ensure that this area is clearly demarcated (*e.g.* using security tape) during the construction phase to prevent damage to the fossils by vehicles or personnel. *Provided* that these mitigation measures are fully implemented, the anticipated impact of the proposed solar plant is rated as **NEGATIVE LOW SIGNIFICANCE** in palaeontological heritage terms. These recommendations should be incorporated into the Environmental Management Programme for the Gamma Solar Power plant development.

There are no fatal flaws in the proposed solar power plant development, nor are there objections to its authorisation as far as fossil heritage conservation is concerned, *provided* that the mitigation recommendations outlined above are fully complied with. The no-go option (no solar development) will have a neutral impact on local palaeontological heritage resources.

1. INTRODUCTION & BRIEF

The company (Gamma Solar Power Plant (RF) (Pty) Ltd) is proposing to develop up to 115MW photovoltaic solar facility, known as the Gamma Solar Power Plant, on the Remaining Extent of Portion 4 (Bos Kop) of the Farm Champions Kloof 731, HN Registration Division, Province of the North-West. The land parcel measures 397.3052 hectares in area and is situated approximately 12 km southeast of the town of Vryburg, Naledi Local Municipality, North-West Province. The footprint of the proposed alternative energy project will be approximately 285 hectares (including supporting infrastructure).

The study site is situated on flat lying terrain in the north-eastern portion of the Farm Champions Kloof 731, *c.* 3 km east of the Droë Harts River and 3.75 km east of the N18 tar road from Vryburg to Kimberley. The location of the study area is shown on the map Fig. 1 and a satellite image of the area is shown in Fig. 2.

The proposed solar energy facility overlies potentially fossiliferous sediments of the Ghaap Group (Transvaal Supergroup) and Dwyka Group (Karoo Supergroup). Fossils preserved within the bedrock or superficial deposits may be disturbed, damaged or destroyed during the construction phase of the proposed project. 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 Heritage Resources Act (Act No. 25 of 1999). Ancient stromatolites (microbial mounds) have been recorded on an adjacent farm, Waterloo 992 (Almond 2013a).

The present combined desktop and field-based palaeontological study has accordingly been commissioned on behalf of the client by Gamma Solar Power Plant (RF) (Pty) Ltd (Contact details: Mr D.P.S. Berlijn**,** Managing Director. Phone: +27 10 500 3680. Mobile: +27742 488 488. Fax: +27 862 731 614. Address: 2nd Floor West Tower, Nelson Mandela Square, Maude Street, Sandown. PO Box 785553, Sandton, 2146, RSA).

The Terms of Reference for this palaeontological study, as defined by Gamma Solar Power Plant (RF) (Pty) Ltd, are as follows:

- A desktop investigation of the area, in which all geological maps, published scientific literature, previous paleontological impact studies in the same region and the author’s field of experience (consultation with professional colleagues as well as examination of institutional fossil collections and data) should be studied and used.

- Based on the outcome of the desktop study and the comments obtained from SAHRA, the need for a field assessment must be determined. The desktop investigation must be supplemented with a field assessment if required.

- Assess the potential impacts, based on a supplied methodology.

- Describe mitigation measures to address impacts during the construction, operation and decommissioning stages.

- Develop a protocol for any paleontological finds.

- Describe cumulative impacts of the project on paleontological resources in both the local study area, regional study area and the proponent’s plans to manage those effects.

- Supply the client with geo-referenced GIS shape files of any sensitive areas.

1.1. Legislative context of this palaeontological study

The various categories of heritage resources recognised as part of the National Estate in Section 3 of the National Heritage Resources Act (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 have been developed by SAHRA (2013).

2. APPROACH TO THE PALAEONTOLOGICAL HERITAGE ASSESSMENT

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

1. A short project outline and maps provided by Gamma Solar Power Plant (RF) Pty Ltd;

2. A review of the relevant scientific literature, including published geological maps, satellite images, and previous fossil heritage assessments in the region (*e.g.* Almond 2013a, 2013b, 2013c);

3. A half-day site visit by the author and one assistant on 13 January 2016.

4. The author's database on the formations concerned and their palaeontological heritage.

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

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

2.1. Assumptions & limitations

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

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

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

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

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

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

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

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

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

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

In the case of the present project area near Vryburg the main limitation for fossil heritage assessment is the generally low level of Precambrian and Palaeozoic bedrock exposure due to extensive cover by largely unfossiliferous superficial sediments as well as the limited access to much of the study area because of the sparse road network. However, confidence levels regarding the conclusions drawn following palaeontological field assessment are moderately good.

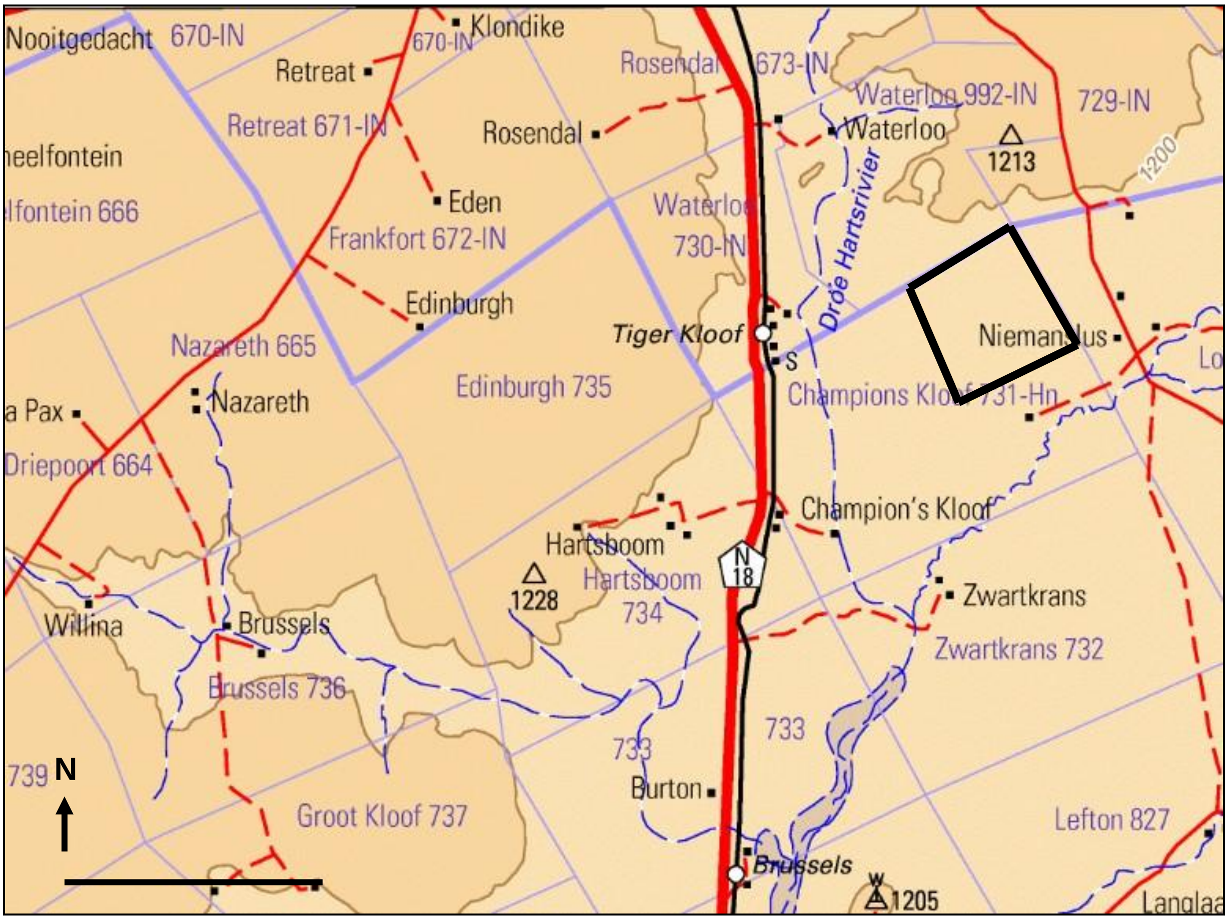

Fig. 1. Extracts from the 1: 250 000 topographical map 2724 Christiana (Courtesy of the Chief Directorate National Geo-spatial Information, Mowbray) showing approximate location of the proposed Gamma Solar Power Plant study area on Farm Champions Kloof 731, some 12 km southeast of Vryburg, North-West Province (black polygon). Scale bar is *c*. 5 km.

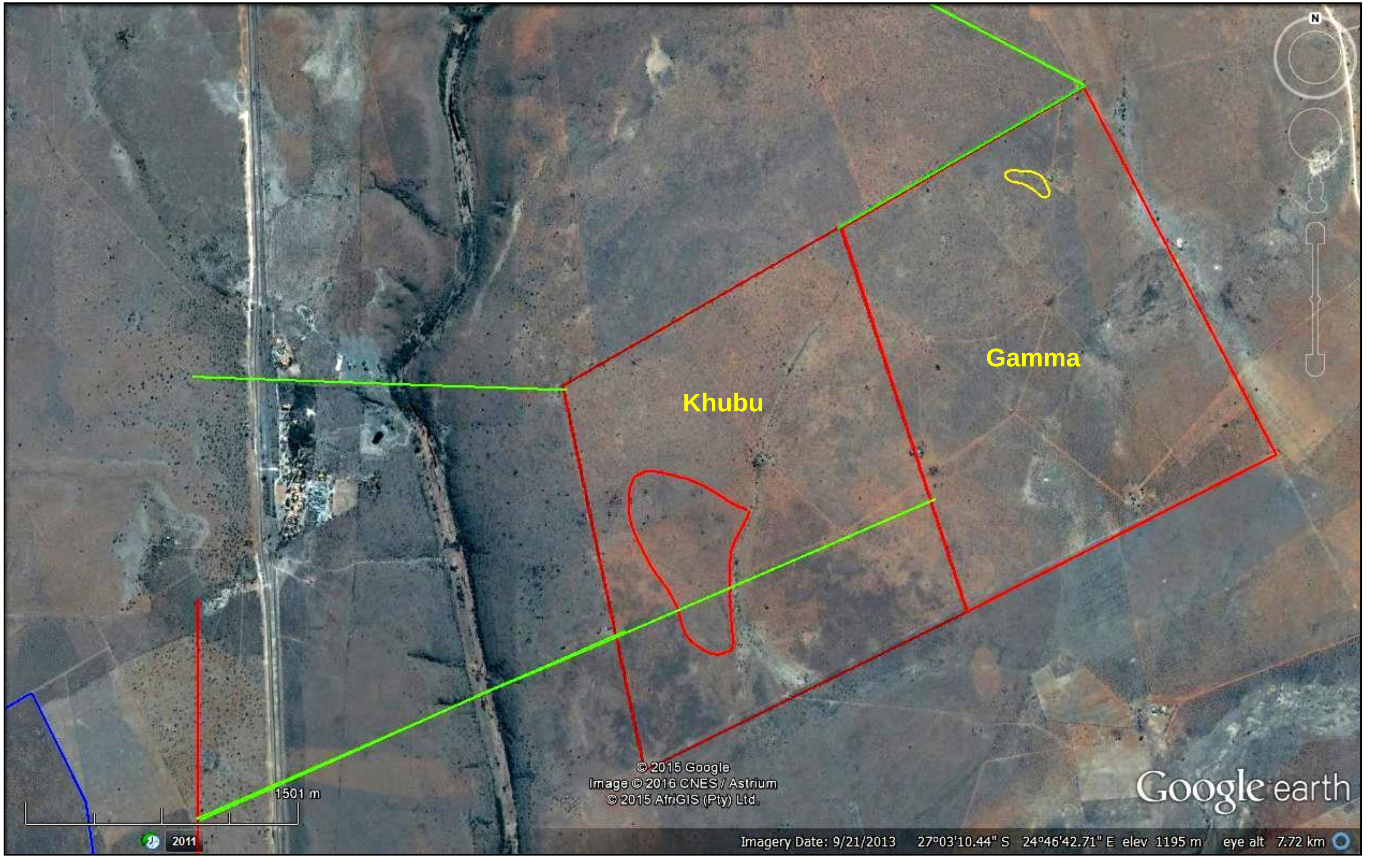

Fig. 2. Google earth© satellite image of the Gamma Solar Power Plant study area on Farm Champions Kloof 731 to the southeast of Vryburg, North-West Province (Red polygon on the right) (The Khubu Solar Power Plant project immediately to the west is the subject of a separate palaeontological assessment). The yellow and red areas indicate concentrations of well-preserved fossil stromatolites within surface exposures of the Boomplaas Formation. The green lines indicate transmission line connections currently under consideration.

3. GEOLOGICAL & PALAEONTOLOGICAL BACKGROUND

The Gamma Solar Power Plant study area on Farm Champions Kloof 731 near Vryburg consists of typical flat-lying terrain of the Ghaap Plateau region at *c*. 1170 – 1200 m amsl that is currently used for agricultural purposes (principally cattle farming). The climate is semi-arid and the dense vegetation cover of grassy thornveld is mapped as Ghaap Plateau Vaalbosveld. The incised valley of the Droë Harts river runs north-south some 3 km to the west of the study area. Bedrock exposure within the study area is generally poor, apart from a small area of low rocky outcrops just to the west of the farmstead (See yellow polygon in Fig. 2). Elsewhere the bedrocks are generally mantled by reddish-brown sandy soils containing abundant gravel clasts, principally cherty material downwasted from the underlying Boomplaas Formation and erratic boulders from the Dwyka Group.

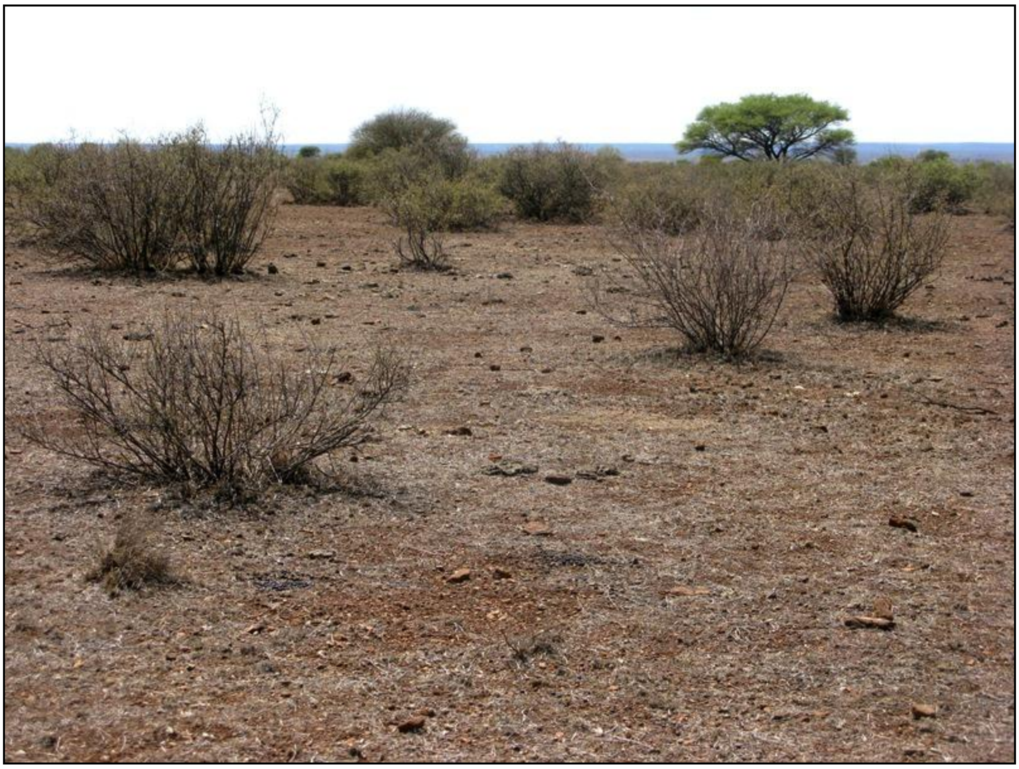

Fig. 3. Typical grassy Kalahari thornveld vegetation and flat-lying terrain of the Gamma study area on Champions Kloof 731 (Loc. 185).

The geology of the study area south of Vryburg is shown on the 1: 250 000 geology map 2724 Christiana (Council for Geoscience, Pretoria; Fig. 4 herein). An explanation for the Christiana geological map has been published by Schutte (1994) and that the adjoining Vryburg sheet 2624 to the north is also very relevant (Keyser & Du Plessis 1993). The northern and western sectors of the study area are underlain by ancient sedimentary rocks of the **Schmidtsdrif Subgroup** that are almost flat-lying, with a gentle dip towards the south. This is the basal subdivision of the Late Archaean to Early Proterozoic **Ghaap Group** (**Transvaal Supergroup**) in the Griqualand West Basin, Ghaap Plateau Subbasin (Fig. 5). 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.* (1993, 1995, 2006). The Ghaap Group represents some 200 Ma of chemical sedimentation - notably iron and manganese ores, cherts and carbonates with subordinate siliclastic rocks - within the Griqualand West Basin that was situated towards the western edge of the Kaapvaal Craton (See fig. 4.19 in McCarthy & Rubidge 2005).

The Ghaap Group on Farm Champions Kloof 731 is only represented by shallow marine carbonates (predominantly dolomites) and subordinate siliclastic sediments of the **Boomplaas Formation** (**Vb**). This mixed carbonate and siliciclastic succession is 100 – 185 m in thickness and is transitional between the predominantly continental Vryburg beds and the fully marine Campbell Rand platform carbonates of the Kaapvaal Craton. The Boomplaas beds are dominated by grey dolomites (weathering reddish-brown) with subordinate interbeds of limestone (weathering blue-grey), quartzite, flaggy sandstone and shale. Packages of oolitic and stromatolitic dolomite alternate with intervals of carbonaceous mudrocks (possibly lagoonal) containing interbeds of calcareous sandstone and mudclast breccias. Nearshore oolitic and stromatolitic facies with cherty layers and inclusions (probably secondary replacement of carbonate) predominate in the northern outcrop area of the Boomplaas Formation, as at Vryburg, while offshore mudrock facies are found towards the south. The Boomplaas beds are overlain by the grey- to khaki-hued mudrocks and interbedded dolomites, flagstones, tuffites and BIF-like cherts of the **Clearwater Formation** (**Vc**) (= Lokamonna Formation), the uppermost subunit of the Schmidtsdrif Subgroup. The finer mudrocks are pitch black and locally pyritic and calcitic while the carbonates may show crinkly stromatolitic textures. This last unit does not crop out on Farm Champions Kloof 731 but is mapped on the western side of the N18 tar road.

A detailed, comprehensive account of the Neoarchaean stromatolites from the Boomplaas Formation of the Schmidtsdrif Subgroup has not been published, to the author's knowledge. Brief mention of large stromatolites from 50 cm up to 2 m across within the Boomplaas Formation in the Vryburg area is made by Keyser and Du Plessis (1993). Preferential north-south elongation seen in some examples may reflect dominant onshore-offshore, wave-generated currents scouring sediment from between the domes. Wright and Altermann (2000) discuss slumping and contortion of partially decomposed, pyrite-rich stromatolitic laminae as well as preservation of organic-walled filamentous cyanobacterial microfossils within stromatolites of the Boomplaas Formation. A shallow subtidal setting for large stromatolitic domes in the Transvaal Supergroup is inferred by Truswell and Eriksson (1973), with oolites generated in higher energy inshore settings, although they may subsequently have been reworked into deeper waters offshore (See also Eriksson & Altermann 1998, Altermann 2008). An important occurrence of small- to large-scale domical and other stromatolites within the Boomplaas Formation on Farm Waterloo 992, on the northern border of the present study area, is briefly described and illustrated by Almond (2013a).

The Vryburg Formation is treated as the basal unit of the Schmidtsdrif Subgroup by several recent authors (*e.g.* Altermann & Wotherspoon 1995, Sumner & Beukes 2006) but was previously placed below the base of the Ghaap Group succession (See stratigraphic column in Fig. 5). The Vryburg siliciclastics and overlying carbonate-rich Boomplaas Formation of the Griqualand West Basin have classically been correlated with the Black Reef Formation and overlying basal Malmani dolomites of the Transvaal Basin (*e.g.* Eriksson *et al.* 1995, 2006). However, recent sequence stratigraphic studies of the Transvaal Supergroup have demonstrated that the Vryburg / Boomplaas / Clearwater sequence is in fact older than the Black Reef Formation (Sumner & Beukes 2006). Lavas from the Vryburg Formation have been radiometrically dated to 2.64 Ga (billion years old), *i.e.* Late Archaean in age (Eriksson *et al.* 2006), and the overlying Boomplaas stromatolitic carbonates are likewise assigned a Neoarchaean age (Fig. 4).

The outcrop area of the Boomplaas Formation on Champions Kloof 731 is overlain in the south-eastern sector of the study area by **Dwyka Group** (**C-Pd**) rocks of Permo-Carboniferous age (Fig. 3). It is conceivable that the readily-weathered mudrocks of the Clearwater Formation overlying the Booplaas carbonates have been preferentially scoured out by pre-Dwyka erosion. A short description of the Dwyka Group succession on the 1: 250 000 geological map sheet 2724 Christiana is given by Schutte (1994). The best exposures here occur in low-lying areas along the Droë Hartsrivier, especially to the north of

Taung. The Dwyka rocks consist of tillite, boulder mudstone rich in a wide range of erratics, sandstone lenses and shale, this last including seasonally varved mudrocks. The Dwyka outcrop area is characterised by the widespread occurrence of downwasted glacial erratics.

The glacially-related Dwyka sediments were not observed at surface in the field where they tend to underlie flat, low-lying terrain mantled by **Late Caenozoic superficial deposits** such as downwasted gravels, soils, calcrete hardpans and pan sediments. Shallow pan areas associated with calcrete and minor drainage lines occur towards the southern edge and along the eastern edge of the Gamma study area where they appear as greyish patches in satellite images (Fig. 2). Since they are almost certainly unfossiliferous, the Dwyka bedrocks and superficial deposits will not be treated in any detail here.

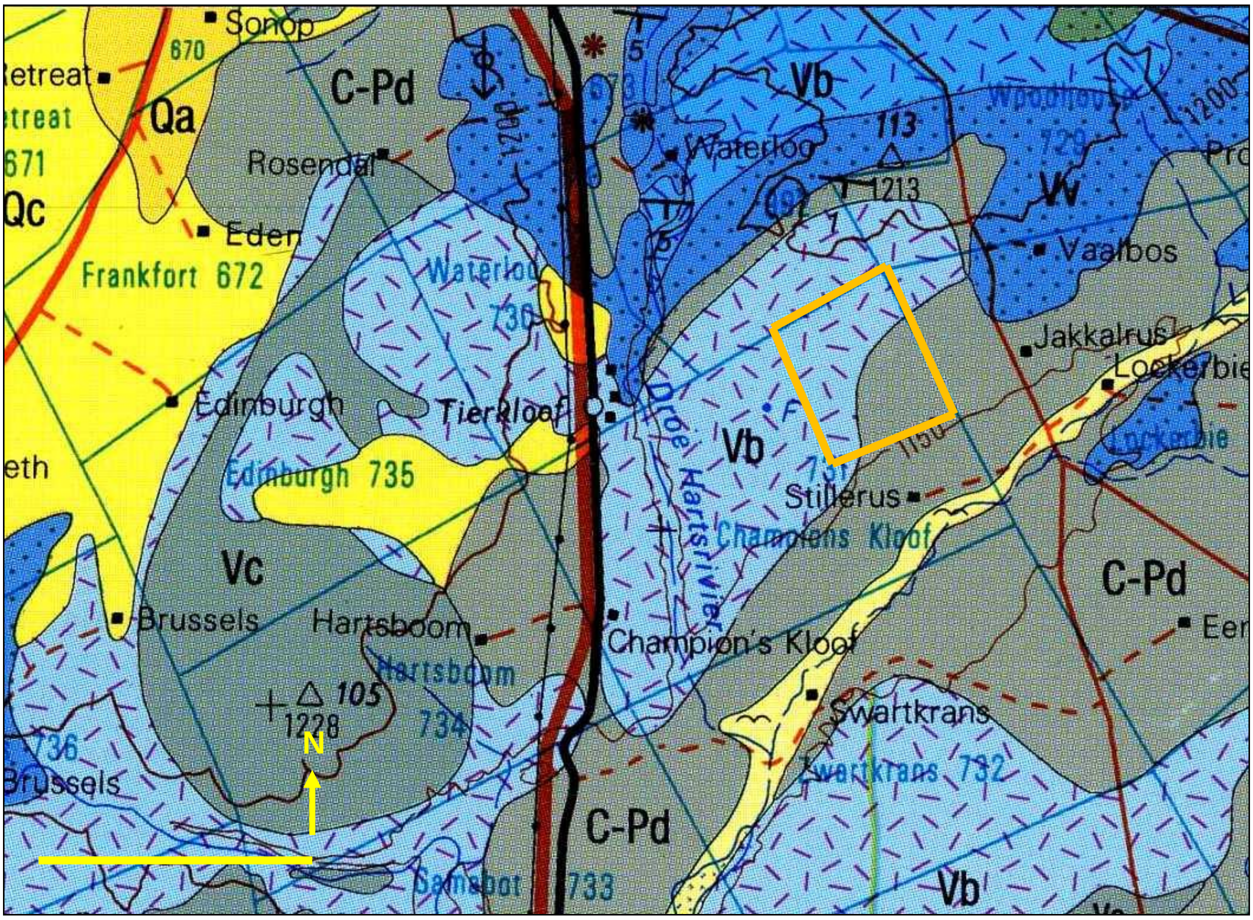

Fig. 4. Extract from the 1: 250 000 geological map 2724 Christiana (Council for Geoscience, Pretoria) showing the outline of the study area for the proposed Gamma Solar Power Plant study area on Farm Champions Kloof 731, some 12 km southeast of Vryburg (orange polygon). Scale bar = *c*. 5 km. The main geological units represented mapped the broader study region include:

Vryburg Formation (Vv, dark blue with stipple) – late Archaean fluvial and shallow marine quartzites, mudrocks, conglomerates with two intervals of andesitic volcanics

Boomplaas Formation (Vb, pale & middle blue with dashes) – late Archaean dolomites (locally stromatolitic or oolitic) interbedded with siliciclastics (quartzite, shale, flagstone)

Dwyka Group (C-Pd, middle grey) – Permocarboniferous glacial sediments

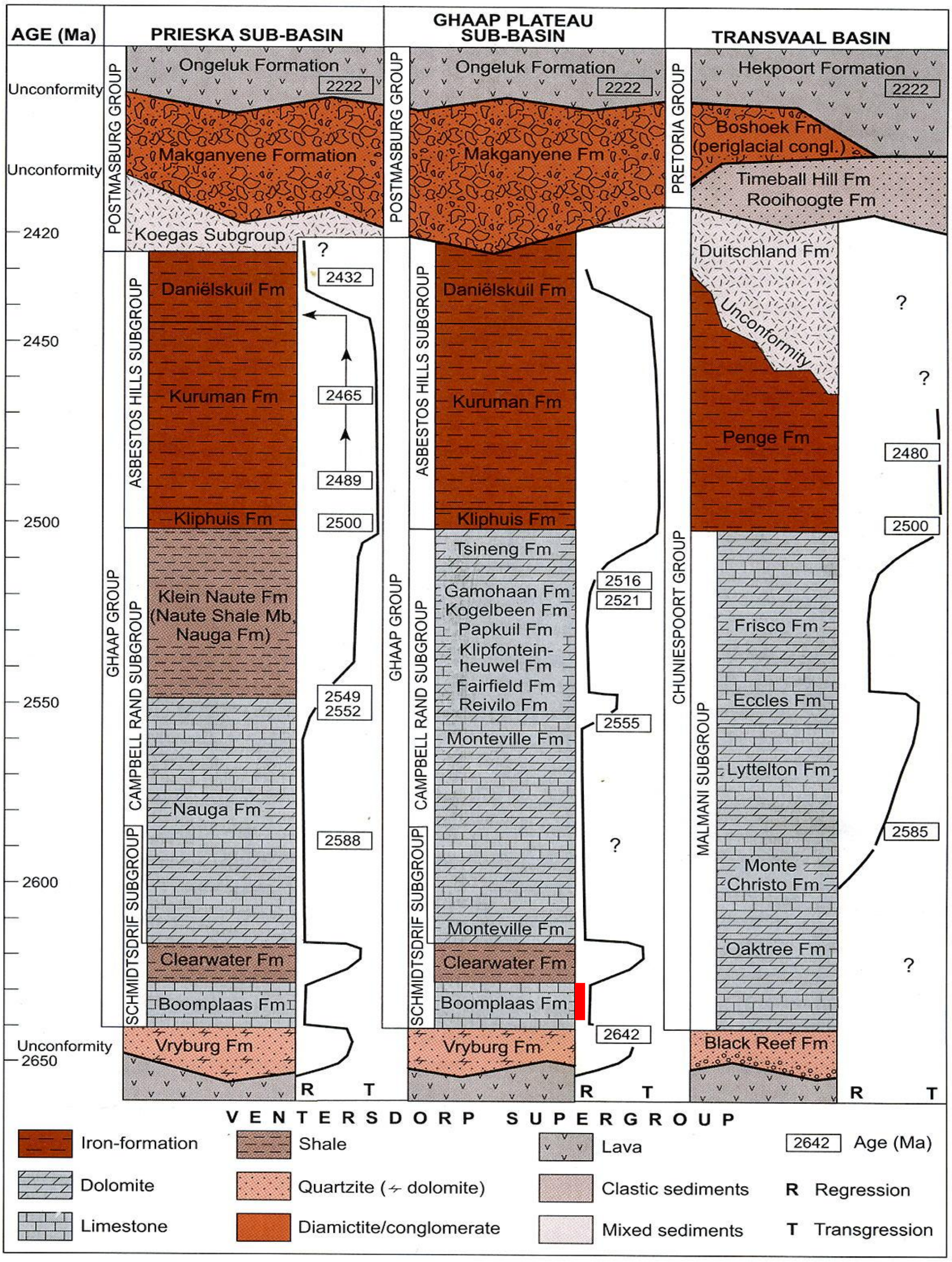

Fig. 5. Stratigraphy of the Transvaal Supergroup of the Ghaap Plateau Basin (central column) showing the position of the Boomplaas Formation that is represented in the study area (red line) (From Eriksson *et al.* 2006). Note that the underlying Vryburg Formation is incorporated within the base of the Schmidtsdrif Subgroup by some recent authors and is no longer correlated with the Black Reef Formation of the Transvaal Basin as shown here (*e.g.* Altermann & Wotherspoon 1995, Sumner & Beukes 2006).

4. FIELD OBSERVATIONS ON FARM CHAMPIONS KLOOF 731

Since Neoarchaean stromatolites have been reported from the Boomplaas Formations in North-West Province (in the latter case from the proposed development site itself), the field assessment of Farm Champions Kloof 731 concentrated on this stratigraphic unit. As mentioned earlier, surface exposures of the Dwyka Group were not encountered, while superficial deposits such as river alluvium, colluvial rubble and downwasted surface gravels are generally unfossiliferous, or at most sparsely fossiliferous, in this region.

GPS locations of sites mentioned by number in the text are listed in the Appendix.

4.1. Boomplaas Formation

Surface exposure of the Boomplaas Formation carbonate rocks is very limited indeed within the Gamma project study area. The main exposures seen comprise low, well-jointed rocky outcrops in a small area immediately west of the farmstead (area outlined in yellow in Fig. 2) (Figs. 6 & 7). Here the carbonates largely comprise gently-dipping, brown-weathering dolomites or greyish limestones showing local development of elephant skin solution weathering. A distinctive rectilinear pattern of jointing that has probably been enhanced by karst weathering can be picked out on satellite images and is used here as a proxy for determining the extent of near-surface carbonate bedrocks within study area.

The Boomplaas beds on Champions Kloof 731 mainly consist of well-bedded, brownish, massive to laminated non-stromatolitic and densely stromatolitic dolomites and sandy dolomites. Occasional heterolithic bands consist of interbedded laminated carbonates, thin-bedded sandstones and very finely-laminated dark grey mudrocks, these last showing stromatolite-like loading or convolute lamination. Pale grey horizons of fine-grained sandstone, siltstone and possible quartzite are rare.

Much of the Boomplaas succession encountered on Champions Kloof 731 is characterised by the extensive development of dense stromatolites (microbial mounds) (Figs. 10 to 14). They occur at various scales, from a few cm to several dm across, and have different shapes, but most are button-shaped, domical or conical in structure. They are variously exposed as positive dome-like or conical features with a smooth, pustulose or dimpled surface or in cross-section where they often appear like large onions. They are composed of agglutinated silt- or sand-grade particles; in some cases laminae of coarse, gritty sand may be incorporated. Warty features may represent trapped gas bubbles. Well-preserved lamination is most often seen within the outer cortex of the dome, while the core region is often structureless or mottled (*cf* clotted or thrombolitic texture of Proterozoic and Phanerozoic stromatolites). The core region may be preferentially hollowed-out to generate pot-like features. Secondary silicification of the core or cortex of the stromatolite is often patchy and may take the form of massive to finely-laminated, pale grey to very dark chert (locally exploited for stone artefacts) (Fig. 17). These cherts are a potential source of well-preserved microfossils (*cf* Wright & Altermann 2000).

The stromatolite domes are often very closely packed to touching with little interstitial sediment. Lenses of edgewise platy breccias (probably reworked stromatolitic carbonate) (Fig. 15) as well as more normal mudflake breccias may occur between adjacent stromatolitic domes, however. Bands and lenses of carbonate breccia cutting across or draping over stromatolitic beds may be storm deposits (tempestites) or overlie minor sequence boundaries. Small domes are nested within or are superimposed upon larger ones, or there may be multiple successive layers of small domes. Markedly asymmetrical growth of the stromatolitic laminae is very frequently seen (Figs. 11 & 12) and was probably related to local patterns of current action, scouring and sediment supply (perhaps more rapid growth in the upstream direction). A wide range of azimuths of preferential growth can be seen (*e.g.* 090º, 140º, 200º, 290º), perhaps reflecting a complex current pattern through or around the stromatolite reef patches on the sea bed.

In addition to the common domical stromatolites, the western outcrop area on Champions Kloof 731 features medium-sized conical microbial mounds with a coarser or poorly-defined lamination and a distinctive rugose (rough) surface texture. These stromatolites often show a high degree of lateral coalescence. Flat sheets of carbonate with a pronounced pustulose texture of presumed microbial origin also occur (Fig. 16). Occasional *in situ* beds and float blocks of oolitic carbonate occur within the Boomplaas Formation outcrop area. The ooliths are sometimes unusually large (up to 1.5 mm across) and may be secondarily silicified (Fig. 19).

Overlying the Boomplaas Formation outcrop area are thin, gravelly, reddish-brown skeletal soils and dispersed surface gravels dominated by angular clasts of greyish to brownish silicified carbonate and cherty material of local provenance, most of which are generated by downwasting following solution weathering (Figs, 8 & 9). There are also occasional quartzite clasts (sometimes anthropogenically flaked) that may derive from the Vryburg Formation. Close to shallow drainage lines well-rounded limestone and cherty pebbles of alluvial origin (some flaked) are seen. Occasional float blocks of ferruginised, silica-cemented breccias are probably Late Caenozoic in age and derived from previously more extensive ferricrete or silcrete pedocretes.

Fig. 6. Low ridge-like exposures of brownish Boomplaas Formation dolomites dissected by prominent WNW-ESE trending joints, situated just west of the farmstead.

Fig. 7. Typical low-relief exposures of brownish Boomplaas Formation dolomites with positive weathered-out domical stromatolites in the foreground.

Fig. 8. Angular surface gravels of pale brownish chert and silicified carbonate, downwasted from the Boomplaas Formation (Scale = *c*. 15 cm).

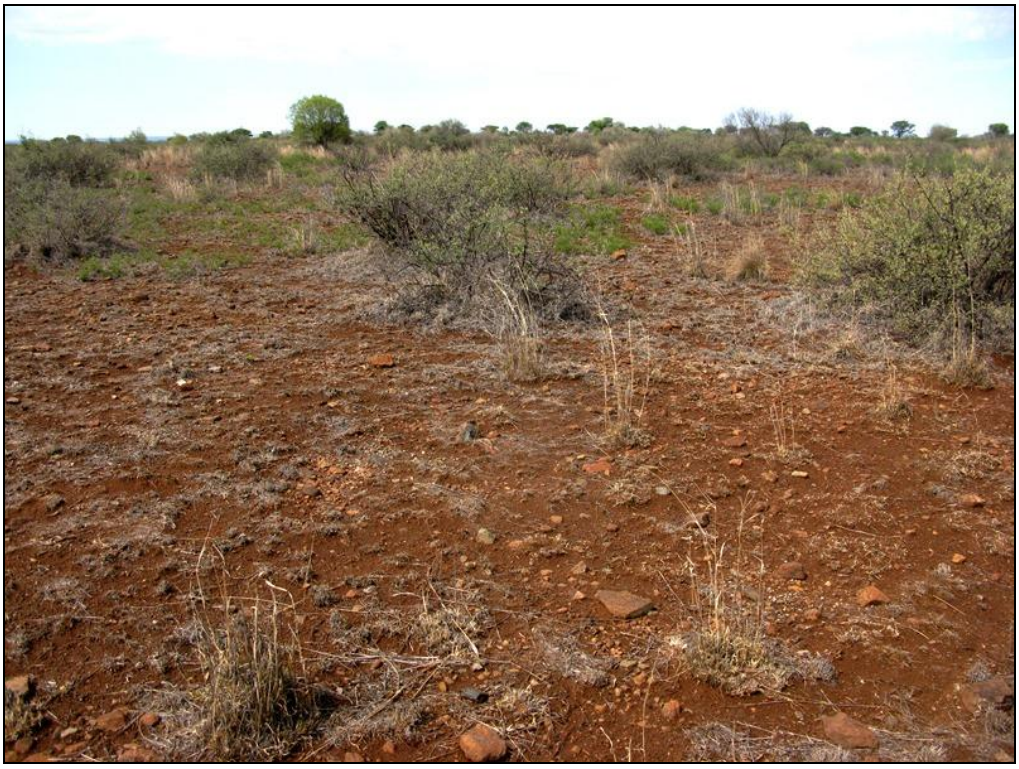

Fig. 9. Reddish-brown soils and surface gravels overlying the Boomplaas Formation outcrop area.

Fig. 10. Horizon of densely-packed small domical stromatolites showing variable degree of secondary silicification (Scale = *c*. 15 cm).

Fig. 11. Medium-sized domical stromatolites showing pronounced asymmetrical growth towards the right of the image (Scale in cm).

Fig. 12. Medium-sized domical stromatolites showing pronounced asymmetrical growth towards the top of the image (Scale in cm).

Fig. 13. Small domical stromatolites with smaller-scale bulges on their surfaces (Scale = *c.* 15 cm).

Fig. 14. Domical stromatolites showing nested sets of small "individuals" enclosed within larger ones (Scale = *c.* 15 cm).

Fig. 15. Thin-bladed edgewise breccias of possible tempetite origin infilling the gaps between domical stromatolites (Scale in cm).

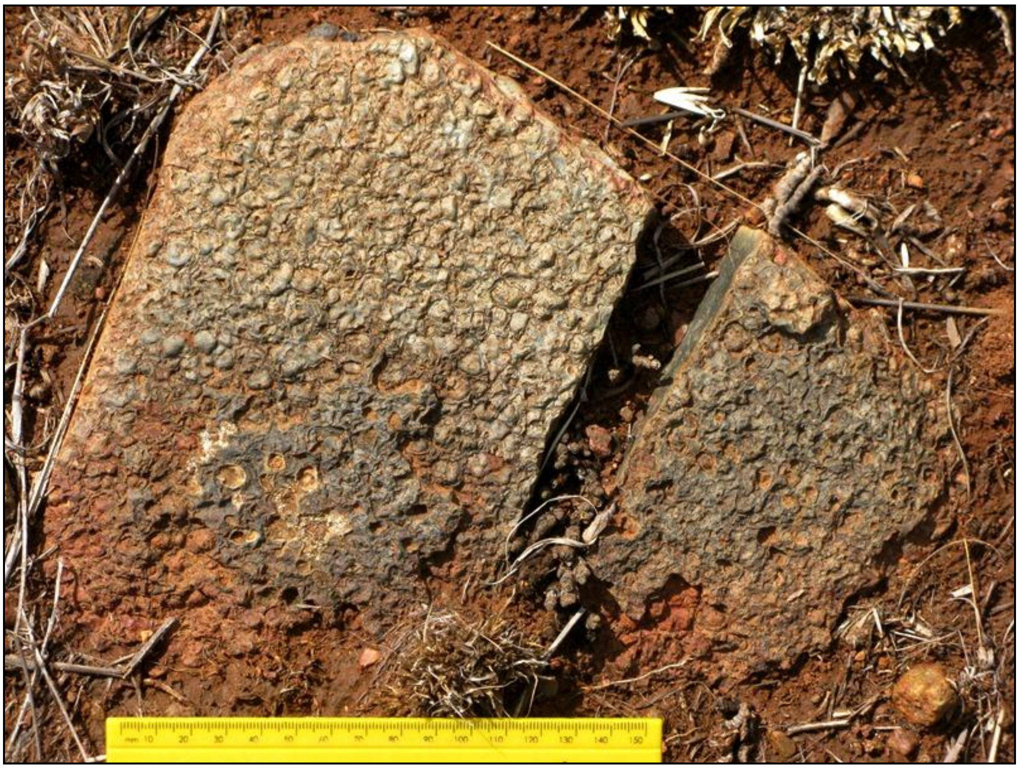

Fig. 16. Flat bedding planes of Boomplaas Formation carbonate showing a pustulose or crinkled surface texture that is probably attributable to microbial mats (Scale in cm).

Fig. 17. Section through a stromatolitic body showing faint primary lamination within the dark silicified core region in contrast to the cavernous-weathering cortex (Block is *c*. 15 cm across).

Fig. 18. Float block of silicified oolitic carbonate from the Boomplaas Formation (Scale in cm).

4.2. Dwyka Group

The flat and featureless terrain in the south-eastern sector of the study area overlies the Dwyka Group outcrop area. No bedrock exposure was seen here (Fig. 20). The contact between the tougher Boomplaas carbonates and the softer-weathering Dwyka beds is marked by a distinct gentle slope with a concentration of surface gravels composed of cherty and pale yellowish sandstone clasts as well as karstified carbonate rubble (The yellowish sandstone bed noted here is of uncertain stratigraphic position). The typical orange-brown soils mantling the Dwyka bedrocks feature numerous downwasted, cobbly to bouldery erratics. They are typically highly polymict (*e.g.* amygdaloidal Ventersdorp lavas, pale quartzites, cherts, breccias *etc*) and often well-rounded.

Subsurface pale cream calcrete hardpans occur widely in the Dwyka Group outcrop area, especially along drainage lines and around pans. Here surface calcrete rubble or hardpans with embedded erratics are exposed locally (Fig. 19).

Fig. 19. Surface exposures of creamy calcrete hardpan with scattered glacial erratics overlying the Dwyka Group outcrop area (Loc. 204).

Fig. 20. Typical flat-lying terrain in the Dwyka Group outcrop area in the south-eastern portion of Champions Kloof 731 showing abundant downwasted glacial erratics representing many different rock types (Loc. 205).

5. SIGNIFICANCE OF POTENTIAL IMPACTS ON PALAEONTOLOGICAL HERITAGE

A brief assessment of the impact significance of the construction phase of the proposed Gamma Solar Power Plant on local fossil heritage resources on Farm Champions Kloof 731 is presented here. Please note that further impacts are not anticipated during the operational and decommissioning phase of the development.

- **Nature of the impact**

Bedrock excavations and site clearance for the proposed PV panels, control building, any buried cables, the electrical substation as well as the internal site roads and powerline infrastructure may adversely affect potential fossil heritage within the study area – principally stromatolites (laminated microbial mounds) - by damaging, destroying, disturbing or permanently sealing-in fossils at or below the ground surface that are then no longer available for scientific research or other public good.

- **Geographical extent and duration of the impact**

Significant impacts on fossil heritage are limited to the development site and to the construction phase when site clearance and excavations into fresh, potentially fossiliferous bedrock may take place. No further significant impacts are anticipated during the operational or decommissioning phases of the solar facility. Impacts on fossil heritage are generally permanent.

- **Probability of the impact occurring**

Dense concentrations of small to large stromatolites are recorded on Champions Kloof 731 where the Boomplaas Formation is exposed at the surface. If these relatively small areas (area outlined in yellow in Fig. 2) are not excluded from the development footprint, the probability of significant impacts on palaeontological heritage during the construction phase is high (definite).

- **Intensity / magnitude of impact**

Without mitigation the intensity of the impact on fossil heritage is rated as high. With mitigation impact intensity should be reduced to low.

- **Degree to which the impact can be reversed**

Impacts on fossil heritage are generally irreversible. Well-documented new records and further palaeontological studies of any fossils revealed during construction would represent a positive impact from a scientific viewpoint.

- **Degree to which the impact may cause irreplaceable loss of resources**

Since little is known about the stratigraphic and geographical distribution of Late Archaean stromatolites within the Schmidtsdrift Subgroup, including the Boomplaas Formation, it is not yet possible to accurately assess the uniqueness of the stromatolite assemblages present on Champions Kloof 731. Dense stromatolite occurrences have already been reported on Farm Waterloo 992 just to the north (Almond 2013a) but these are in part of a different character to those seen in the present study area.

Adopting a precautionary approach, a significant loss of fossil resources is anticipated should the sensitive areas outlined in Fig. 2 be included within the development footprint.

- **Degree to which the impact can be mitigated**

In the case of a solar power plant project on the neighboring Farm Waterloo 992, the recommended mitigation of inevitable damage and destruction of fossil stromatolites within the proposed development area involves the surveying, recording, description and judicious sampling of well-preserved fossil occurrences within the development footprint by a professional palaeontologist (Almond 2013a). This work should take place after initial vegetation clearance has taken place but *before* the ground is leveled for construction.

However, given the relatively small portion of the proposed development area featuring well-preserved stromatolites on Champions Kloof 731, in this case it is recommended that these sensitive areas (yellow in Fig. 2) be (1) excluded from the development footprint, and (2) protected by a 20 m buffer zone. The ECO should ensure that this sensitive area is clearly demarcated (*e.g.* using security tape) during the construction phase to prevent damage to the fossils by vehicles or personnel. These mitigation actions, if fully implemented, would conserve the majority of accessible stromatolite occurrences for future scientific study.

Should significant fossil remains - such as well-preserved stromatolites - be exposed during construction, the responsible Environmental Control Officer should safeguard these, preferably *in situ*. The South African Heritage Resources Authority (SAHRA) should be alerted as soon as possible (Contact details: Mrs Colette Scheermeyer, P.O. Box 4637, Cape Town 8000, Tel: 021 462 4502, Email: cscheermeyer@sahra.org.za), so that appropriate action can be taken by a professional palaeontologist, at the developer's expense. Mitigation would normally involve the scientific recording and judicious sampling or collection of fossil material as well as associated geological data (*e.g.* stratigraphy, sedimentology, taphonomy) by a professional palaeontologist. The palaeontologist concerned with mitigation work will need a valid fossil collection permit from SAHRA and any material collected would have to be curated in an approved depository (*e.g.* museum or university collection). These recommendations should be included within the EMPr for the proposed solar power plant development.

- **Cumulative impacts**

  Cumulative impacts could arise as other similar projects are constructed in the area. According to the Energy Blog's database only one other solar PV plant has been granted preferred bidders status within close proximity to the proposed Gamma PV plant:

  Waterloo Solar Park with a capacity of 75MW near Vryburg, North West Province (Approvals, planning and financing phase).

  According to the Department's database numerous other solar plants have been proposed in relative close proximity to the proposed activity, namely:

  - The proposed Carocraft Solar Park near Vryburg, North West Province (14/12/16/3/3/2/374);
  - Construction of the 75MW Photovoltaic facility and associated infrastructure in Naledi (14/12/16/3/3/2/390).
  - The proposed Tiger Kloof Solar Photovoltaic energy facility near Vryburg, North West Province (14/12/16/3/3/2/535).
  - The proposed Keren Energy Bosh Pan Solar Plant, Northern Cape Province (14/12/16/3/3/1/563);
  - The proposed renewable energy generation project. Carocraft Solar Park in North West Province (14/12/16/3/3/2/699);
  - The proposed Renewable Energy Generation Project rem farm Elda, North West (14/12/16/3/3/2/750);
  - The proposed Renewable Energy Project on Farm Doornbult 29 and Doornbult 33, North West (14/12/16/3/3/2/751);

  Environamics and other environmental consultants are also in the process of applying for Environmental Authorisation for other PV projects in the area, namely:

  - The proposed Protea Solar Power Plant near Vryburg, North West Province.
  - The proposed Gamma Solar Power Plant near Vryburg, North West Province.
  - The proposed Alpha Solar Power Plant near Vryburg, North West Province.
  - The proposed Meerkat Solar Power Plant near Vryburg, North West Province.
  - The proposed Sonbesie Solar Power Plant near Vryburg, North West Province.
  - Three PV Solar Energy facilities on the farm Klondike - AMDA Developments

  The potential for cumulative impacts may therefore exist. The Environmental Impact Assessment (EIA) Report will include a detailed assessment of the potential cumulative impacts associated with the proposed development.

6. CONCLUSIONS & RECOMMENDATIONS

The northern and western portions of the Gamma Solar Power Plant study area are largely underlain by late Archaean (*c*. 2.6 billion year-old) sedimentary rocks of the Schmidtsdrif Subgroup (Ghaap Group, Transvaal Supergroup). These mainly comprise shallow marine carbonates and siliciclastic sediments of the Boomplaas Formation.

Densely-packed, well-preserved stromatolite assemblages are recorded within the Boomplaas Formation carbonate rocks in a small area of low-relief bedrock exposure just west of the farmstead. A range of stromatolitic growth forms is represented here. The Boomplaas Formation stromatolites recorded in the Vryburg area represent some of the oldest examples of these microbially generated fossils in South Africa but they have yet to be comprehensively described while their stratigraphic and geographical distributions are poorly understood. Most of the Boomplaas Formation outcrop area on Champions Kloof 731 is mantled by soils and surface gravels of low palaeontological sensitivity. Stromatolitic horizons may be present within the underlying bedrocks but these are not easily accessible for scientific research and are in part protected by the superficial sediments above. The south-eastern portion of the Gamma study area is underlain by Permo-Carboniferous glacial deposits of the Dwyka Group (*c*. 300 million years old). The bedrocks, overlying soils and downwasted gravels are not palaeontologically sensitive.

It is recommended that the small rocky area of Boomplaas Formation bedrocks west of the farmstead (outlined in yellow in Fig. 2) be excluded from the solar plant footprint, with a buffer zone of 20 m. The ECO should ensure that this area is clearly demarcated (*e.g.* using security tape) during the construction phase to prevent damage to the fossils by vehicles or personnel. *Provided* that these mitigation measures are fully implemented, the anticipated impact of the proposed solar plant is rated as **NEGATIVE LOW SIGNIFICANCE** in palaeontological heritage terms. These recommendations should be incorporated into the Environmental Management Programme for the Gamma Solar Power plant development.

7. ACKNOWLEDGEMENTS

Mr Dick Berlijn of Gamma Solar Power Plant (RF) Pty Ltd is thanked for commissioning this study. I am grateful to his colleague Ms Claire Phutieagae for kindly providing all the necessary background information, for facilitating our field visit, as well as for introducing us to the study area. Field assistance, logistical backup and companionship from Ms Madelon Tusenius is, as always, much appreciated.

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9. 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, Limpopo, Northwest and the Free State under the aegis of his Cape Town-based company *Natura Viva* cc. He has served as 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**

APPENDIX: GPS LOCALITY DATA FOR NUMBERED SITES LISTED IN TEXT

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

Gamma waypoints (Jan 2016)

Loc.	GPS data	Comments
178	S27° 02' 26.2" E24° 47' 54.9"	Extensive low-relief surface exposure of brown-weathering Boomplaas Fm carbonates with abundant small-scale stromatolites, just west of farmstead.
179	S27° 02' 26.0" E24° 47' 53.9"	Closely-packed stromatolitic domes.
180	S27° 02' 25.7" E24° 47' 51.2"	Good examples of asymmetrical growth of domal stromatolites.
181	S27° 02' 25.5" E24° 47' 51.6"	Non-stromatolitic sandy carbonate beds with breccias of brownish carbonate intraclasts.
182	S27° 02' 25.1" E24° 47' 52.6"	Ditto. Capped by brownish-weathering stromatolitic carbonate.
183	S27° 02' 25.5" E24° 47' 48.5"	Domal stromatolites showing asymmetrical growth patterns.
184	S27° 02' 25.6" E24° 47' 48.6"	Ditto.
185	S27° 02' 37.4" E24° 47' 08.4"	Float blocks of silicified oolitic carbonate. MSA (quartzite) and LSA (cherty) artefacts on surface.
202	S27° 03' 23.0" E24° 48' 12.1"	Dwyka Group outcrop area with near-surface calcrete, boulder surface gravels.
203	S27° 03' 11.0" E24° 47' 54.8"	Contact zone between Boomplaas Fm carbonates and overlying Dwyka Group. Coarse gravels of cherty material overlying pale yellow fine-grained sandstone (stratigraphic level uncertain). Associated with karstified rubble at top of Boomplaas Fm.
204	S27° 02' 37.4" E24° 48' 19.9"	Exposure of calcrete hardpan overlying Dwyka Group. Polymict surface gravels (downwasted glacial erratics) – mainly Ventersdorp lavas, clasts of Boomplaas carbonates.
205	S27° 02' 49.5" E24° 48' 27.5"	Typical polymict boulder gravels overlying the Dwyka Group *(cf* Mokalanen Fm).