PALAEONTOLOGICAL HERITAGE BASIC ASSESSMENT: DESKTOP STUDY

Proposed construction of a 132 kV power line and switchyard associated with the Redstone Solar Thermal Energy Plant near Postmasburg, Northern Cape Province

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EXECUTIVE SUMMARY

SolarReserve South Africa (Pty) Ltd is proposing to construct a 132 kV overhead distribution power line and switchyard associated with the Redstone Solar Thermal Energy Plant, located *c*. 30 km east of Postmasburg, Tsantsabane and Kgatelopele Local Municipalities, Northern Cape Province. The solar thermal energy plant has been granted environmental authorisation but has not yet been constructed. The proposed new 132kV overhead distribution power line would run from the Redstone Solar Thermal Energy Plant on the farm Humansrus (remainder of the Farm 469) to the existing Silverstreams Substation, near Lime Acres. Two solar photovoltaic power plants, known as Jasper and Lesedi, are also being proposed on the farm Humansrus. The proposed switchyards associated with each PV substation may therefore need to be extended to accommodate the proposed new 132kV power line.

The study area from Farm Humansrus 469 to Lime Acres is underlain by largely undeformed Precambrian sediments and lavas of the Transvaal Supergroup that are Late Archaean to Early Proterozoic in age (*c*. 2.25 to 2.22 billion years old). These principally comprise shallow marine carbonates (limestones / dolomites) of the Campbell Rand Subgroup in the east that are successively overlain towards the west by banded iron formations (BIF) of the Asbestos Hills Subgroup and then glacial diamictites (tillites) and lavas of the Postmasburg Group. The Precambrian bedrocks are overlain by a range of late Caenozoic superficial sediments including aeolian sands of the Gordonia Formation (Kalahari Group), calcrete hardpans, colluvium (*e.g.* surface rubble, scree), river alluvium and pan deposits.

Important fossil stromatolites (microbial mounds) as well as associated microfossil biotas are recorded from the upper formations of the Campbell Rand Subgroup that are mapped near Lime Acres. However, surface exposure of these rocks is often poor due to calcrete cover, apart from road cuttings, rocky outcrops and quarries. The overlying finely-laminated Asbestos Hills BIF are only known to contain microfossils. Presumed warm-water stromatolitic carbonates closely associated with glacial sediments are reported from the Makganyene Formation (Postmasburg Group), but not so far in its eastern outcrop area to the SE of Daniëlskuil. No fossils are recorded from the overlying Olgeluk Formation volcanic succession. Sparse to locally common trace fossils (*e.g.* calcified termitaria and other invertebrate burrows, plant root casts), molluscs, and rare vertebrate remains (mammalian teeth, bones) are known from diverse Late Caenozoic superficial sediments in the broader Kalahari region.

Of the two alternative locations under consideration for the new Redstone Solar Thermal Energy Plant **switchyard**, the site on the northern border of Humansrus 469 is probably underlain by Gordonia Formation sands overlying Makganyene Formation diamictites at depth. The site on the western border of Humansrus 469 is underlain by Ongeluk Formation lavas. The palaeontological sensitivity of

the former site is LOW (with a slight possibility of Makganyene stromatolites) and of the latter VERY LOW.

Power line corridor **Alternative 1A** traverses Campbell Rand carbonates at its eastern end near Lime Acres and the Silverstreams Substation. The bedrocks here are likely to be extensively mantled by superficial sediments (calcrete hardpan, soil, gravels, pan sediments) here. The majority of the corridor sector to the west, broadly following the railway line as far as Humansrus, crosses areas covered by Quaternary aeolian sands (Gordonia Formation). Small sectors near the Finch Diamond Mine in the SE and along the western border of Humansrus traverse the outcrop areas of the Kuruman Formation banded ironstones and Ongeluk lavas respectively. The final, north-western sector of the corridor along the northern edge of Humansrus, close to the R385 tar road, overlies Makganyene Formation diamictites and Daniëlskuil Formation BIF.

Power line corridor **Alternative 1B** traverses Campbell Rand carbonates at its eastern end near Lime Acres and the Silverstreams Substation. The bedrocks here are probably extensively mantled by superficial sediments (calcrete hardpan, soil, gravels, pan sediments) here. The majority of the corridor sector to the west, crossing the Rooiberg hills as far as Humansrus, is underlain by Asbestos Hills Subgroup BIF (Kuruman and Daniëlskuil Formations); the outcrop here is probably largely mantled by BIF colluvium (scree, soils). The north-western sector of the corridor, close to the R385 tar road, overlies Makganyene Formation diamictites and Gordonia Formation aeolian sands while the line traverses Ongeluk Formation lavas on the western borders of Humansrus.

The palaeontological sensitivity of both power line corridors is generally LOW, with areas of higher sensitivity in the vicinity of Lime Acres in the east (Campbell Rand Subgroup stromatolites) and overlying the Makganyene Formation on Farm Humansrus 469, close to the R385 tar road in the northwest (possibility of stromatolites associated with glacial tillites). These two more sensitive areas are indicated by yellow dotted lines in Fig. 3 herein. The Makganyene Formation outcrop area on Humansrus 469 is additionally of considerable scientific interest as an accessible part of the limited rock record for an Early Proterozoic (*c.* 2.3 billion years-old) “snowball earth” glacial event, when ice sheets may have covered much of the planet.

Adopting a precautionary approach, it is therefore recommended that a short field-based palaeontological assessment of the study area be commissioned by the developer, focussing on the two small areas of special fossil and geological interest outlined above. The study should document any surface occurrences of fossil material (notably well-preserved stromatolites) as well as geological features of unusual interest, and make recommendations for any further specialist palaeontological monitoring or mitigation required.

It is further recommended that:

- The Environmental Control Officer (ECO) responsible for the Redstone Solar Thermal Energy Plant and electrical infrastructure developments should be aware of the possibility of important fossils (*e.g.* well-preserved stromatolites, mammalian bones, teeth) being present or unearthed on site and should regularly monitor all substantial excavations into superficial sediments as well as fresh (*i.e.* unweathered) sedimentary bedrock for fossil remains;

- In the case of any significant fossil finds made during construction, these should be safeguarded - preferably *in situ* - and reported by the ECO as soon as possible to the relevant heritage management authority (South African Heritage Resources Agency. Contact details: SAHRA, 111 Harrington Street, Cape Town. PO Box 4637, Cape Town 8000,South Africa. Phone : +27 (0)21 462 4502. Fax: +27 (0)21 462 4509. Web : www.sahra.org.za) so that appropriate mitigation (*i.e.* recording, sampling or collection) by a palaeontological specialist can be considered and implemented, at the developer’s expense; and

- These recommendations should be incorporated into the Environmental Management Plan (EMP) for the Redstone Solar Thermal Energy Plant and associated electrical infrastructure projects.

The palaeontologist concerned with mitigation work will need a valid collection permit from SAHRA. All work would have to conform to international best practice for palaeontological fieldwork and the study (*e.g.* data recording fossil collection and curation, final report) should adhere to the minimum standards for Phase 2 palaeontological studies recently published by SAHRA (2013).

1. INTRODUCTION & BRIEF

The company SolarReserve South Africa (Pty) Ltd is proposing to construct a 132 kV overhead distribution power line and switchyard associated with the Redstone Solar Thermal Energy Plant, located *c*. 30-40 km east of Postmasburg in the Northern Cape Province (Fig. 1). The solar thermal energy plant has already been granted environmental authrorisation but has not yet been constructed. The proposed new 132 kV overhead distribution power line would run from the solar thermal energy plant on the farm Humansrus (remainder of the Farm 469) to the existing Silverstreams Substation near Lime Acres (Figs. 2 & 3). Two solar photovoltaic power plants, known as Jasper and Lesedi, are also being proposed on the farm Humansrus. The proposed switchyards associated with each PV substation may therefore need to be extended to accommodate the new proposed 132 kV power line. Land parcels concerned in the proposed electrical infrastructure developments are shown in Fig. 2 and variously fall under the Tsantsabane and Kgatelopele Local Municipalities.

The proposed power line and switching station project consists of the following main activities:

- Construction of a switchyard directly adjacent to the proposed Redstone Solar Thermal Energy Plant Substation (2 alternative locations on Humansrus 469 indicated in Fig. 2);
- Construction of a 132 kV overhead power line from the proposed Redstone Solar Thermal Energy Plant Substation to Silverstreams Substation, near Lime Acres;
- Construction of a 132kV overhead power line from the proposed Redstone Solar Thermal Energy Plant Substation to each PV Power Plant switching station;
- Extension of the 132 kV busbar in the PV Power Plant switching stations;
- Installation of a 132 kV feeder bay in the PV Power Plant switching stations;
- Installion of 3 x 132 kV feeder bays in Siverstreams Substation;
- Creation of a loop-in configuration to Silverstreams Substation by reconfiguring the existing Olien – Karats 132 kV power line currently crossing Silverstreams Substation;
- Construction of a 3 x 40 MVA 11/132kV step-up substation with 2 x 132 kV feeder bays at the proposed the Redstone Solar Thermal Energy Plant.

The proposed 132 kV power line will consist of a series of towers located approximately 200 m apart, depending on the terrain and soil conditions. The exact tower type to be used will be determined (based on load and other calculations) during the final design stages of the power line. It is however likely that the single steel pole tower type will be used in combination with the steel lattice type towers at bend points and where greater distances need to be spanned. The single steel pole tower type is between 18 m and 25 m in height.

The exact location of the power line towers will be determined during the final design stages of the power line. The two route corridor alternatives, each approximately 500 m wide, are being assessed during the Basic Assessment for the proposed 132 kV power line. These are **Alternative 1A** (approximately 17 km long) and **Alternative 1B** (approximately 26 km long) and are shown in Fig. 2. While only a 31 m wide servitude will be required for the proposed 132 kV power line, 500 m wide corridors are being assessed for each route alternative to allow flexibility when determining the final route alignment.

A short palaeontological basic assessment for the farm Humansrus has already been submitted by Almond (2011a). The study area for the proposed additional electrical infrastructure projects overlies potentially fossiliferous sediments of the Transvaal Supergroup and Kalahari Group (Fig. 6). Fossils preserved within the bedrock or superficial deposits may be disturbed, damaged or destroyed during the construction phase of the development. 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).

A palaeontological heritage basic assessment for the proposed power line and switchyard developments associated with the Redstone Solar Thermal Pant has accordingly been commissioned on behalf of the developer by PGS Heritage (Contact details: 906 Bergarend Street, Waverley, Pretoria, 0186. PO Box 32542, Totiusdal, 0134. Tel: (012) 332 5305 Fax: (012) 332 2625. Email: wouter@gravesolutionas.co.za).

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 project outline and maps provided by PGS Heritage;

2. A review of the relevant scientific literature, including published geological maps, satellite images, and several previous desktop and field-based fossil heritage assessments in the area (Almond 2010b, 2011a, 2011b, 2012a, 2012b, 2013);

3. 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.* SAHRA for the Northern Cape (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 Redstone Solar Thermal Energy Plant and associated electrical infrastructure projects the major limitation for fossil heritage assessments is the paucity of previous specialist palaeontological field studies on Precambrian sedimentary rocks in this region of the Northern Cape (*cf* Almond 2012a, 2013) as well as the often low levels of bedrock exposure. The relevant geological explanation for 1: 250 000 sheet 2822 is printed on the map itself and is very brief, with almost no palaeontological data provided.

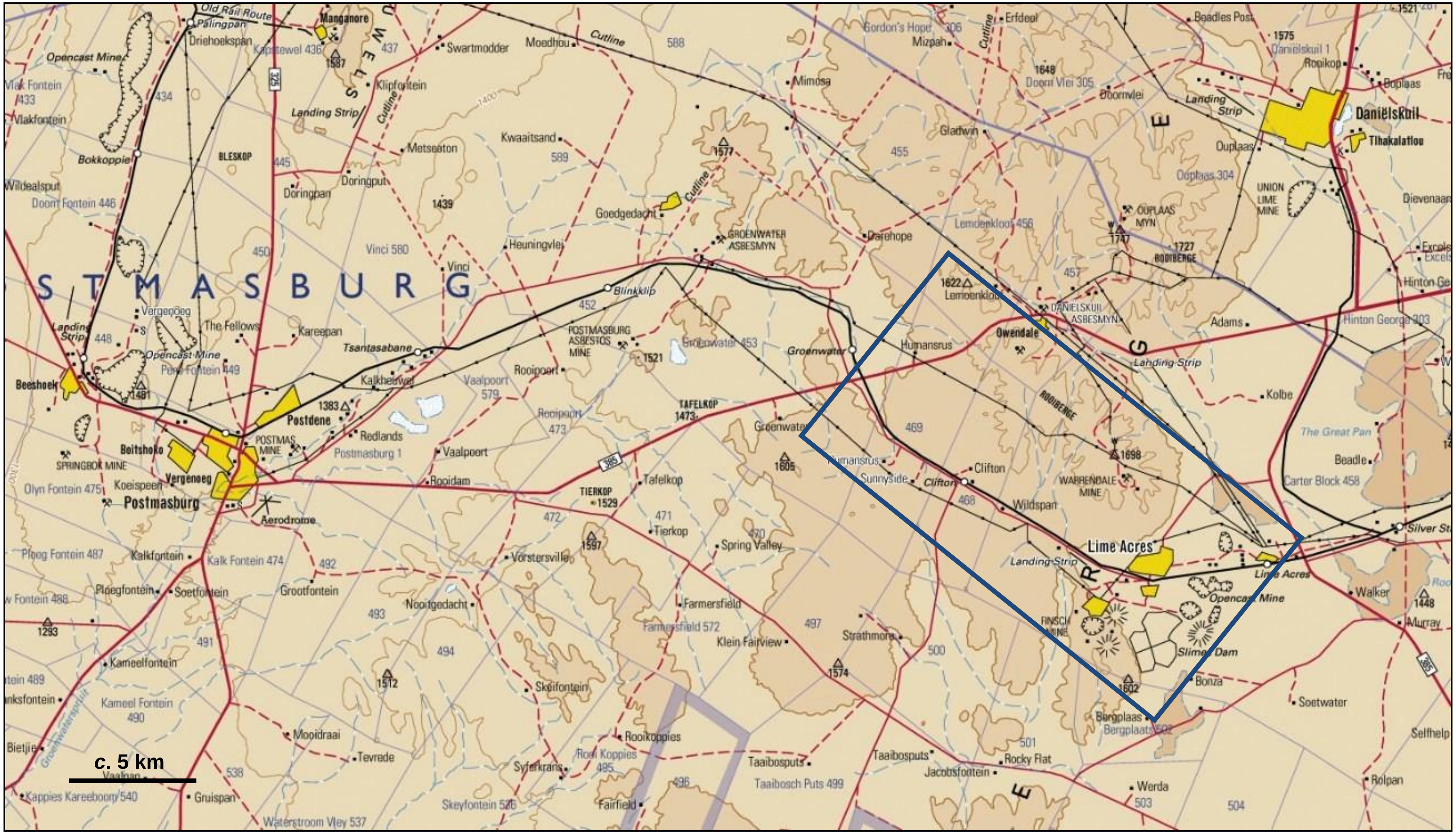

Fig. 1. **Extract from 1: 250 000 topographical map 2822 Postmasburg (courtesy of the Chief Directorate: National Geo-spatial Information, Mowbray) showing the broader study area (blue rectangle) some 30 km east of Postmasburg, Northern Cape, from Farm 469 (Humansrus) in the Asbesberge mountain range in the northwest and Lime Acres in the southeast (Tsantasbane and Kgatelopele Local Municipalities).**

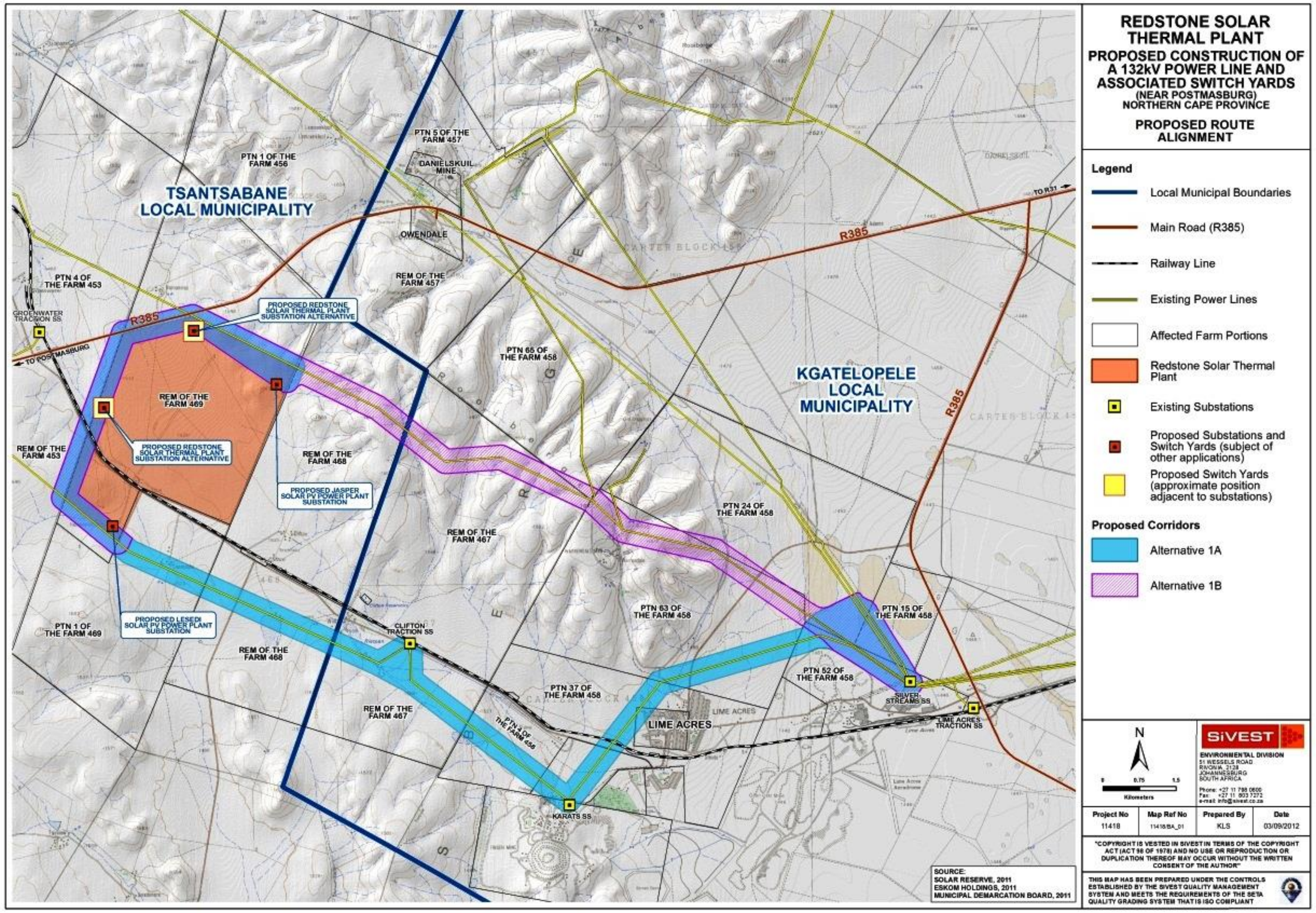

Fig. 2. Map showing the alternative route corridors for the proposed 132 kV power line (1A, blue; 1B, purple) between the Redstone Thermal Energy Plant on Farm 469 Humansrus (orange area) and the existing Silverstreams Substation near Lime Acres c. 14 km to the ESE. Proposed alternative sites for the new switchyard on Humansrus 469 are shown by the two larger yellow squares (Image kindly provided by PGS Heritage, Pretoria).

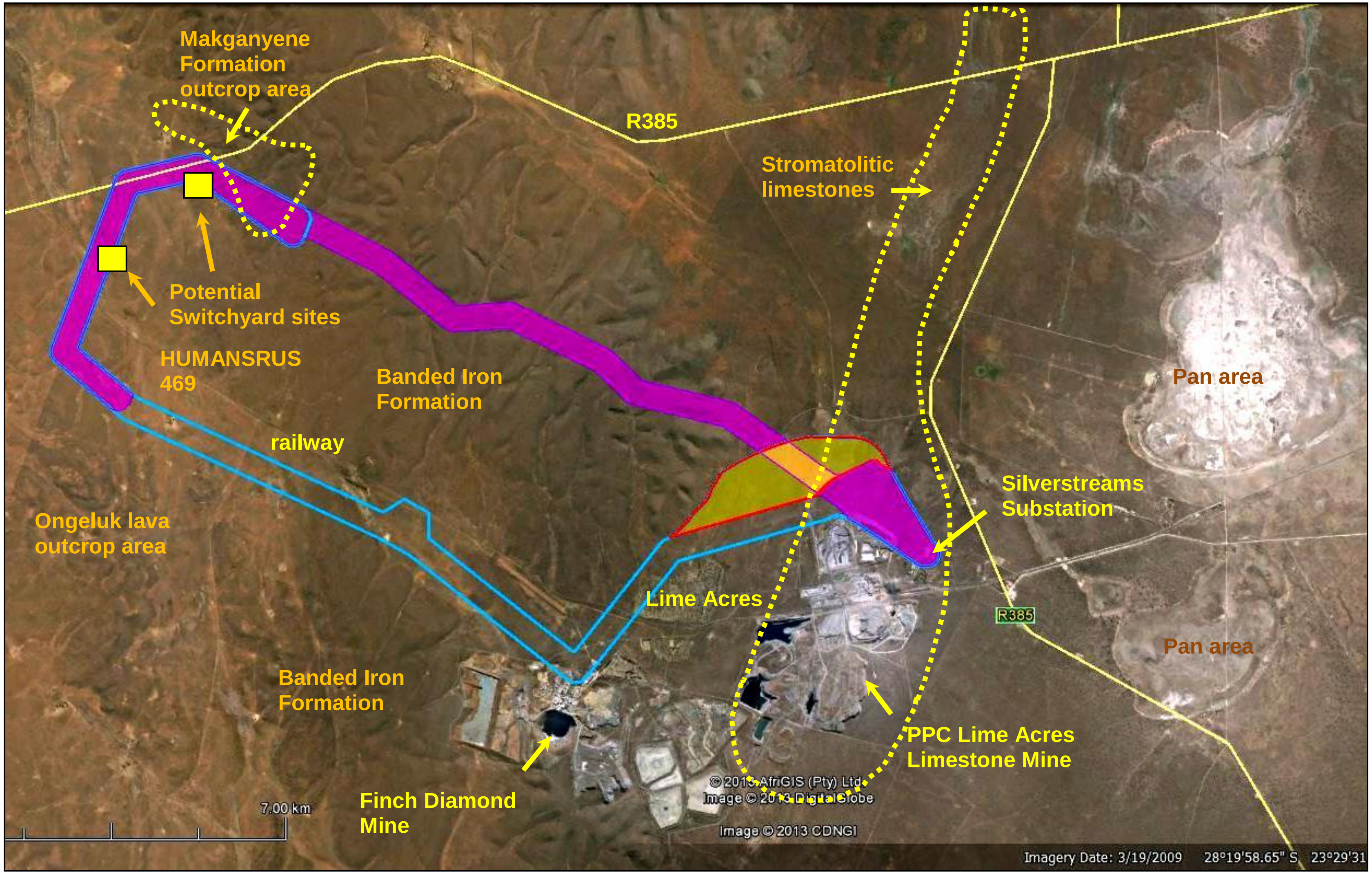

Fig. 3. Google earth© Satellite image of the study area from Farm 469 Humansrus in the west to Lime Acres in the east. Shown here are the two proposed corridors for the new 132 kV powerline between the planned Redstone Thermal Energy Plant and the existing Silverstreams Substation near Lime Acres (Alternative 1A in blue, Alternative 1B in purple) as well as possible switchyard sites on Humansrus 469. Two palaeontologically sensitive areas (possible fossil stromatolites) are indicated by the yellow dotted lines.

3. GEOLOGICAL BACKGROUND

The study area for the proposed Redstone Solar Thermal Energy Plant electrical infrastructure developments on and between Humansrus 469 and Lime Acres lies largely within the gently hilly region of the Asbesheuwels, some 30 km east of Postmasburg, Northern Cape. The study area is situated on the southern side of the R385 tar road between Postmasburg and Kimberley, on either side of the Transnet manganese ore railway line linking Sishen and the port of Ngqura (Figs. 1 & 2). The solar plant development area on Farm Humansrus 469 is flat to gently sloping, semi-arid terrain at *c*. 1500-1560 m amsl. The proposed alternative 132 kV power line corridors linking Humansrus with Lime Acres traverse the eastern portion of the Asbesheuwels range, here known as the Rooiberge, which reaches elevations of *c*. 1700 m amsl.

The geology of the study area is shown on 1: 250 000 geological map 2822 Postmasburg (Council for Geoscience, Pretoria) (Fig. 6). Brief explanatory notes are printed on the published map, but a comprehensive geological explanation for this sheet has not yet been written. The following geological notes have been largely abstracted from previous palaeontological heritage assessments in the region by the author (*e.g.* Almond 2010b, 2011a, 2011b, 2012a, 2012b, 2013).

The study area is entirely underlain by relatively undeformed sediments and subordinate lavas of the **Ghaap Group** and **Postmasburg Group** (**Transvaal Supergroup**) that are of Late Archaean to Early Proterozoic age. They form part of the thick Ghaap Plateau Sub-basin succession within the Griqualand West Basin, dipping and younging gradually towards the west. The stratigraphy of the relevant formations is shown in Fig. 4 below (Modified from Eriksson *et al.* 2006).

Useful reviews of the stratigraphy and sedimentology of the **Transvaal Supergroup** rocks have been given by Moore *et al.* (2001), Eriksson and Altermann (1998) as well as Eriksson *et al.* (1993, 1995, 2006), Sumner and Beukes (2006). The Ghaap Group represents some 200 Ma (million years) of chemical sedimentation - notably iron and manganese ores, cherts, carbonates and minor siliciclastics - within the Griqualand West Basin that was situated towards the western edge of the Kaapvaal Craton (See also fig. 4.19 in McCarthy & Rubidge 2005).

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

Carbonates (*i.e.* limestones, dolostones) of the "Ghaapplato Formation" ("Lime Acres Member", Vgl in geological map Fig. 6) underlie the eastern portions of the present study area, east of the Asbesheuwels foothills, in the vicinity of Lime Acres settlement and the PPC limestone mine. Here they form part of a NNE-SSW trending zone of potentially stromatolite-rich rocks extending from Daniëlskuil to Lime Acres and further southwards. Note that since the current 1: 250 000 geological maps were produced, the Campbell Rand succession has been subdivided into a series of formations, some of which were previously included within the older Schmidtsdrift Formation or Subgroup (Beukes 1980, 1986, Eriksson *et al.* 2006). Formations represented within the study area near Lime Acres, but not fully differentiated on the geological map, include the **Kogelbeen Formation** (with the **Lime Acres Member** at the top), the **Gamohaan Formation** and the **Tsineng Formation** (See stratigraphic table, Fig. 4). Short descriptions of these rock units are given by Altermann and Wotherspoon (1995) as well as Eriksson *et al.* (2006, p. 247), summarized as follows:

- **Kogelbeen Formation** (*c*. 450 m thick) – varied succession of dolomite, limestone and chert, with important horizons of stromatolites and microbial laminites; secondary chert replacement common.
- **Gamohaan Formation** (< 100 m thick) – microbial laminites (crinkly "algal mats") and stromatolites with minor dolarenite, tuff.
- **Tsineng Formation** (*c*. 30 m thick) – microbial laminites with abundant cherts, showing a transitional contact with the overlying deeper-water banded iron formations of the Asbestos Hills Subgroup.

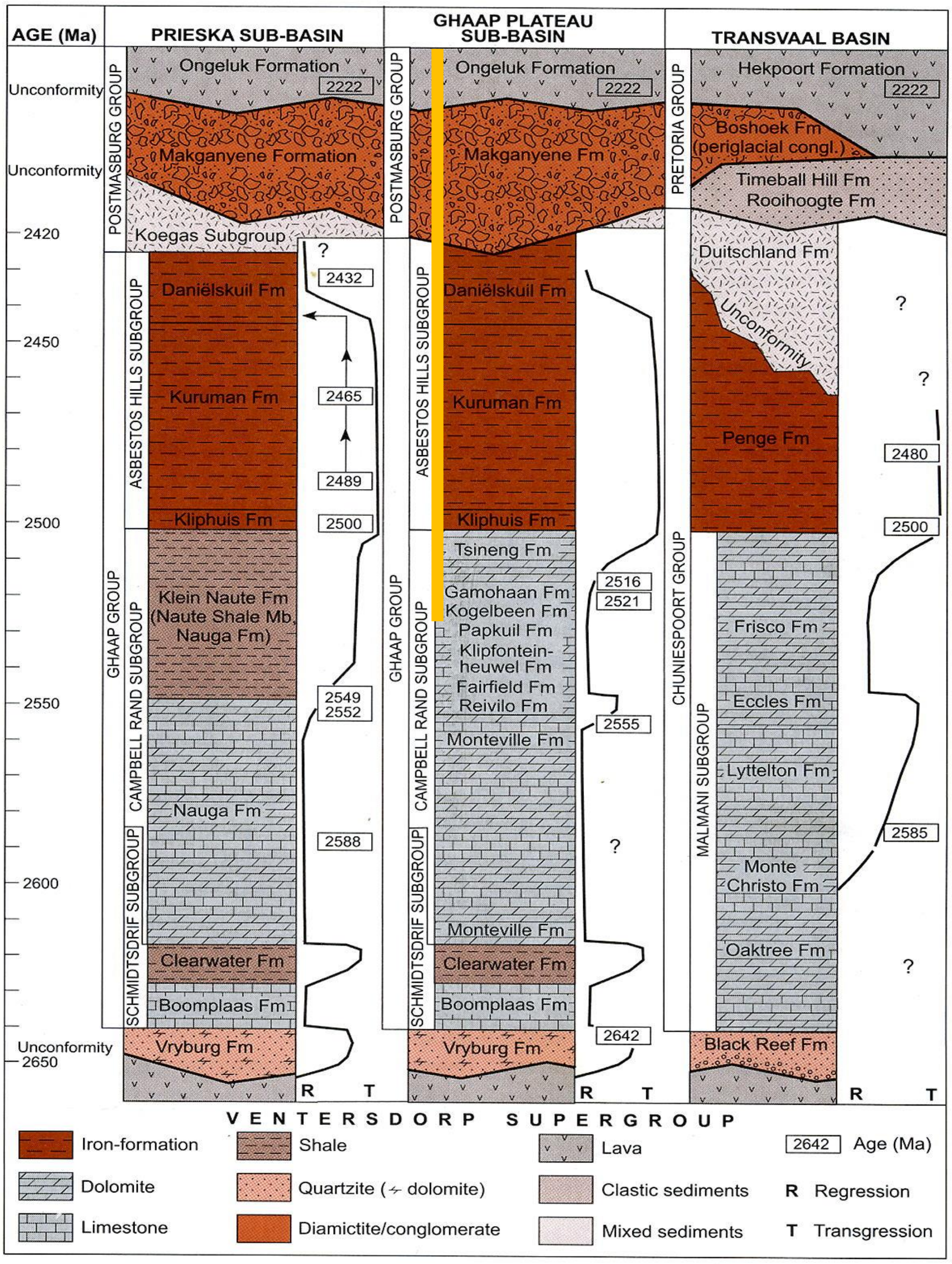

Fig. 4. Stratigraphy of the Transvaal Supergroup of the Ghaap Plateau Sub-basin (central column) showing rock units represented in the Humansrus to Lime Acres study area (thick orange line) (Modified from Eriksson *et al.* 2006). Figures in boxes indicate radiometric ages in millions of years (Ma).

Due to their solubility and low resistance to weathering, exposure levels of these carbonate sedimentary rocks are often very low. The outcrop area of chert-rich subunits is locally covered in downwasted, siliceous rock rubble in the Postmasburg sheet area (*cf* Almond 2013).

The Campbell Rand carbonates are overlain with a gradational contact by the thick Early Proterozoic banded iron formations of the **Asbestos Hills Subgroup** (Ghaap Group) that build the low-lying, highly-dissected hills of the Rooiberge and associated ranges of the Asbesheuwels in the Postmasburg – Daniëlskuil study area. The Asbestos Hills Group rocks are often poorly exposed due to extensive colluvial gravel cover.

The basal **Kuruman Formation** of the Asbestos Hills Subgroup, cropping out along the eastern foothills of the Rooiberg near Lime Acres (Vak in Fig. 6), consists predominantly of banded iron formations (BIF). These comprise rhythmically bedded, thinly composition- and colour-banded cycles of fine-grained mudrock, chert and iron minerals (siderite, magnetite, haematite). These fine-grained chemical sediments were laid down in an offshore, intermittently anoxic depository, the Griqualand West Basin. In the Ghaap Plateau Sub-basin to the north of the Griquatown Fault Zone the Kuruman BIF reaches thicknesses of up to 250 m (Eriksson *et al.* 2006, their fig. 2). BIF deposition characterizes the Late Archaean – Early Proterozoic interval (2600-2400 Ma), before the onset of well-oxygenated atmosphere and seas on planet Earth.

The overlying iron–rich succession of the **Daniëlskuil Formation** (Vad in Fig. 6), up to 200 m-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 Daniëlskuil Formation has been radiometrically dated to 2.43-2.49 Ga, *i.e.* Early Proterozoic (Eriksson *et al.* 2006). The Daniëlskuil Formation BIF tends to be more prominent weathering than the finer-grained underlying Kuruman BIF rocks. It builds the greater part of the Rooiberg range, especially the higher-lying terrain, in the present study area but bedrock exposure here is generally poor. Good cliff exposures of Daniëlskuil Formation rocks are seen on the Farm Groenwater that borders Humansrus on the north-western side (Almond 2012b). The fine-grained siliciclastics are brown to ochreous weathering, very tabular in geometry, laminated to thin-bedded (≤ 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 in the Groenwater area by the author.

The western portion of the study area - approximately the western half of Humansrus 469 - is underlain by glacial and volcanic rocks of the 2.4-2.2 Ga **Postmasburg Group** (uppermost Transvaal Supergroup). The Postmasburg succession overlies the older Ghaap Group rocks in the core of a broad NNE-SSW trending synclinal structure (Fig. 6) (Moore *et al.* 2012). Two contrasting rock units are mapped here. Basal diamictites of the **Makganyene Formation** (Vm in Fig. 6), which reaches a thickness of 500 m near Postmasburg, reflect a *c.* 250 million year - long 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. 5). 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.

Good exposures of Makganyene Formation rocks are seen on either side of the R385 tar road, southeast of Humansrus farmstead (outcrop area approximately indicated by the yellow dotted line in Fig. 3). Here lenticular bodies up to 2 m-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 (Almond 2012b). The Makganyene succession near Daniëlskuil has been discussed by Polteau *et al*. (2006). Here the glacial diamictites overlie a volcanic ash (tuff) and contain lenticular sandstone bodies but seemingly no carbonate lenticles with stromatolitic bioherms. These last are apparently confined to the more offshore parts of the basin preserved further to the southwest (= Prieska Sub-basin), but this requires further confirmation.

The glacially-related Makganyene rocks are overlain in the south-western portion of Humansrus 469 and further to the SW by basaltic to andesitic lavas of the **Ongeluk Formation** (Vo in Fig. 6) 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. Well-jointed, resistant-weathering Ongeluk Formation lavas seen just to the east of Metsimetala Village (Farm Groenwater 453) are massive, buff- to brown-weathering, fine-grained and speckled with occasional vugs / gas cavities (Almond 2012b).

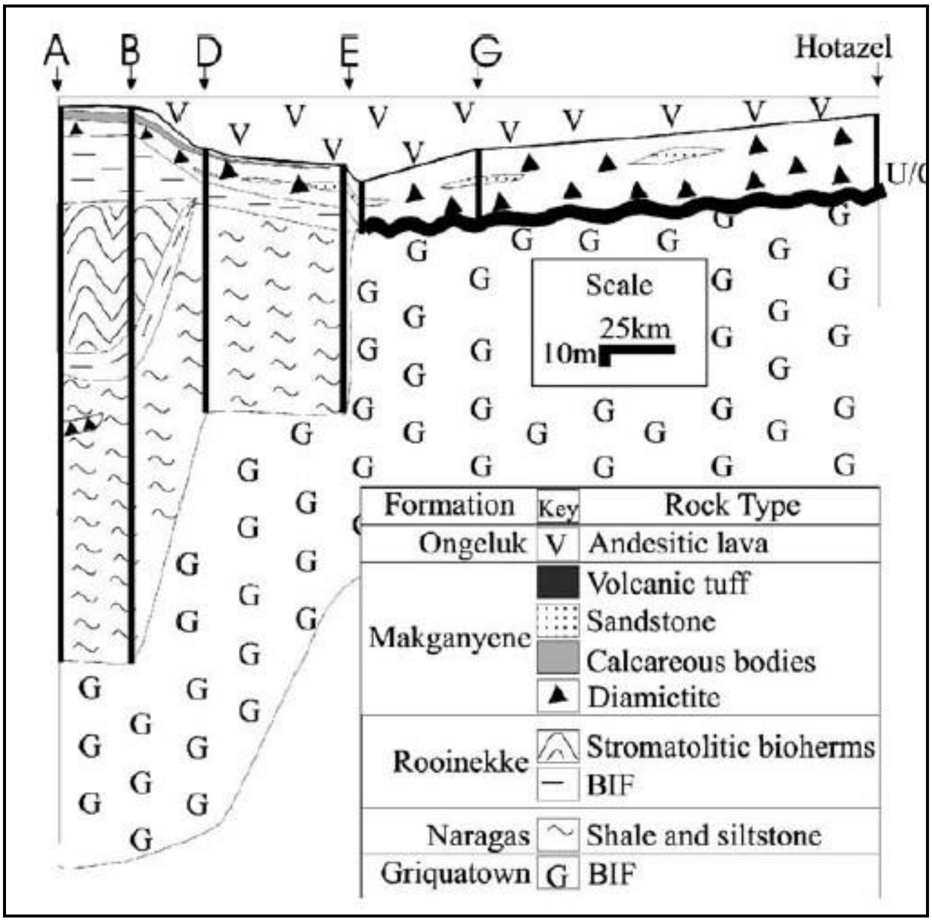

Fig. 5. Series of profiles through the Makganyene Formation (Postmasburg Group), roughly from SW to NE across the Griqualand Basin, Northern Province (From Polteau *et al.* 2006). Profile G, to the SW of Daniëlskuil, corresponds most closely to the Humansrus study area. Here, on the platform area to the NE of the major Griquatown Fault Zone (Ghaap Plateau Sub-basin), the Makganyene glacial diamictites overlie a volcanic ash (tuff) and contain lenticular sandstone bodies but apparently 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).

In the flatter, low-lying areas in the central portion of Humansrus, as well as the gap through the Rooiberg to Lime Acres that is followed by the railway line, the Precambrian bedrocks are mantled by wind-blown (aeolian) sands of the **Gordonia Formation** (Qs, Kalahari Group). 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). According to Bosch (1993) the Gordonia sands in the Kimberley area reach thicknesses of up to eight meters and consist of up to 85% quartz associated with minor feldspar, mica and a range of heavy minerals. The Gordonia Formation aeolian 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 1.8 Ma back to 2.588 Ma would place the Gordonia Formation almost entirely within the Pleistocene Epoch.

Other superficial sediments whose outcrop areas are often not indicated on geological maps include colluvial or slope deposits (scree, hillwash, debris flows *etc*), sandy, gravelly and bouldery river alluvium (*e.g.* small patch in SE corner of Humansrus), surface gravels of various origins (*e.g.* cherty "rubble" overlying Campbell Rand carbonates near Daniëlskuil), as well as spring and pan sediments (*e.g.* large pans to the NE of Lime Acres seen in satellite images, Fig. 3). The colluvial and alluvial deposits may be extensively calcretised (*i.e.* cemented with pedogenic limestone), especially in the neighbourhood of dolerite intrusions or overlying Ghaap Group carbonate rocks (Almond 2013).

Mappable exposures of **calcrete** or **surface limestone** (Ql, dark yellow, in Fig. 6) cover large portions of the Ghaap Group carbonates of the Ghaap Plateau in the Daniëlskuil – Lime Acres region (Almond 2013). These pedogenic limestone deposits reflect seasonally arid climates in the region over the last five or so million years and are briefly described by Truter *et al.* (1938) as well as Visser (1958) and Bosch (1993). The surface limestones may reach thicknesses of over 20 m, but are often much thinner, and are locally conglomeratic with clasts of reworked calcrete as well as exotic pebbles. The limestones may be secondarily silicified and incorporate blocks of the underlying Precambrian carbonate rocks. The older, Pliocene - Pleistocene calcretes in the broader Kalahari region, including sandy limestones and calcretised conglomerates, have been assigned to the **Mokalanen Formation** of the **Kalahari Group** and are possibly related to a globally arid time period between 2.8 and 2.6 million years ago, *i.e.* late Pliocene (Partridge *et al.* 2006). Thick deposits of calc-tufa ("*kranskalk*") occur along the margins of the Ghaap Plateau, as at Ulco, where lime-rich groundwaters reach the ground surface (Bosch 1993).

3.1. Geology underlying the electrical infrastructure footprint

Power line corridor **Alternative 1A** (dark and pale blue lines in Figs. 2 & 3) traverses Campbell Rand carbonates at its eastern end near Lime Acres and the Silverstreams Substation. These bedrocks are likely to be extensively mantled by superficial sediments (calcrete hardpan, soil, gravels, pan sediments) here. The majority of the corridor sector to the west, for example along the railway line as far as Humansrus, crosses areas covered by Quaternary aeolian sands (Gordonia Formation). Small sectors near the Finch Diamond Mine in the SE and along the western border of Humansrus traverse the outcrop areas of the Kuruman Formation banded ironstones and Ongeluk lavas respectively. The final, north-western sector of the corridor along the northern edge of Humansrus, close to the R385 tar road, overlies Makganyene Formation diamictites and Daniëlskuil Formation BIF.

Power line corridor **Alternative 1B** (purple and dark blue lines in Figs. 2 & 3) traverses Campbell Rand carbonates at its eastern end near Lime Acres and the Silverstreams Substation. These bedrocks are likely to be extensively mantled by superficial sediments (calcrete hardpan, soil, gravels, pan sediments) here. The majority of the corridor sector to the west, crossing the Rooiberg hills as far as Humansrus, is underlain by Asbestos Hills Subgroup BIF (Kuruman and Daniëlskuil Formations); the outcrop here is probably largely mantled by BIF colluvium (scree, soils). The north-western sector of the corridor, close to the R385 tar road, overlies Makganyene Formation diamictites and Gordonia Formation aeolian sands while the line traverses Ongeluk Formation lavas on the western borders of Humansrus.

Of the two locations under consideration for the new **switchyard** for the Redstone Solar Thermal Energy Plant (Figs. 2 & 3), the site on the northern border of Humansrus 469 is probably underlain by Gordonia Formation sands overlying Makganyene Formation diamictites at depth. The site on the western border of Humansrus 469 is underlain by Ongeluk Formation lavas.

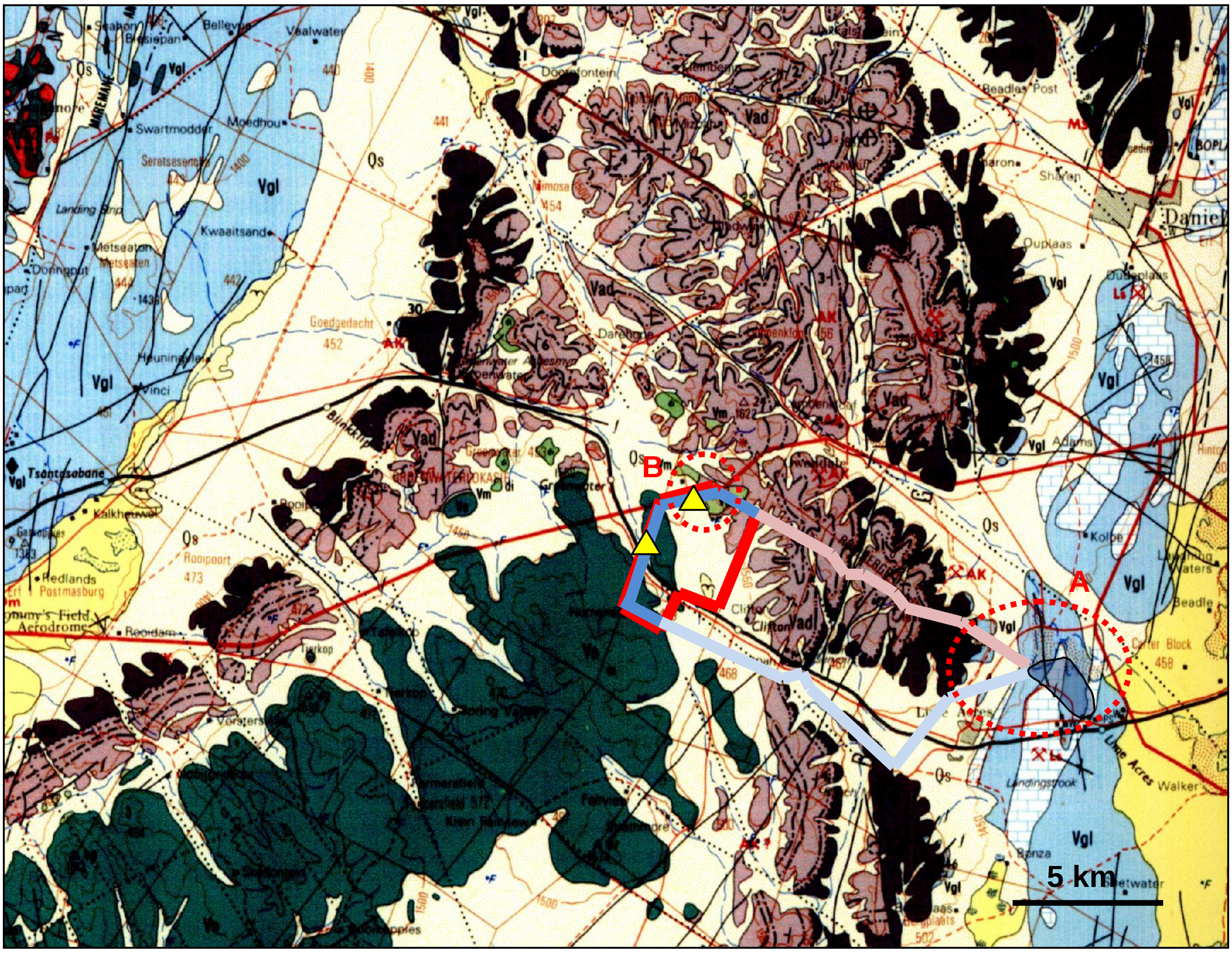

Fig. 6. Extract from 1: 250 000 geological map 2822 Postmasburg (Council for Geoscience, Pretoria) showing the geology of the Humansrus Farm 469 – Lime Acres study area in the Asbesberge near Postmasburg. The Redstone Solar Plant Study area is outlined in red. Alternative routes for the proposed new 132 kV powerline between this area and the existing Silverstreams Substation near Lime Acres are shown in pale blue (Alternative 1A) and purple (Alternative 1B), with sectors of overlap in the west and east shown in dark blue (Compare Figs. 2 & 3 above). Two areas (A with possible Campbell Rand stromatolites, B with possible Makganyene stromatolites) of higher palaeontological sensitivity in the eastern and north-western portions are of the study area are indicated by red dotted circles (See text for discussion). Yellow triangles indicate the two alternative locations under consideration for the new switchyard. Geological units mapped within the study area include:

TRANSVAAL SUPERGROUP

Ghaap Group (CAMPBELL RAND SUBGROUP)
Vgl (pale blue) = Kogelbeen, Gamohaan & Tsineng Formations (undifferentiated) (*c*. 2.5 Ga)

Ghaap Group (ASBESTOS HILLS SUBGROUP):
Vak (dark purple) = Kuruman Formation
Vad (purplish-grey) = Daniëlskuil Formation (banded iron formation, 2.4 Ga)

POSTMASBURG GROUP:
Vm (pale green) = Makganyene Formation (glacial diamictite) (*c.* 2.3 Ga)
Vo (dark green) = Ongeluk Formation (lavas, 2.2 Ga)

LATE CAENOZOIC DRIFT
Qs (pale yellow) = aeolian sand of the Gordonia Formation (Kalahari Group, Quaternary)
Ql (dark yellow) = calcrete hardpans or "surface limestone"
Middle yellow with flying bird symbol = alluvium

4. PALAEONTOLOGICAL HERITAGE

The fossil record of the Precambrian sediments of the Northern Cape has been briefly reviewed by Almond & Pether (2008). An outline of the palaeontological heritage recorded from the major rock units represented in the Humansrus – Lime Acres study area is given here (based largely on Almond 2012b, 2013).

4.1. Fossils within the Campbell Rand Subgroup

The shallow shelf and intertidal sediments of the carbonate-dominated lower part of the **Ghaap Group** (*i.e.* **Schmidtsdrif** and **Campbell Rand Subgroups**) are well known for their rich fossil biota of *stromatolites* or microbially-generated, finely-laminated sheets, mounds, columns and branching structures. Some stromatolite occurrences on the Ghaap Plateau of the Northern Cape are spectacularly well-preserved (*e.g.* Boetsap locality northeast of Daniëlskuil figured by McCarthy & Rubidge 2005, Eriksson *et al.* 2006). Detailed studies of these 2.6-2.5 Ga 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), and Altermann and Wotherspoon (1995), and Sumner (2002). The oldest, Archaean stromatolite occurrences from the Ghaap Group have been reviewed by Schopf (2006, with full references therein). Horizons of microbial mats as well as domal and columnar stromatolites are reported from the **Kogelbeen Formation**. Some of the oldest known (2.6 Ga) fossil microbial assemblages with filaments and coccoids have been recorded from stromatolitic cherty limestones of the **Lime Acres Member** (Kogelbeen Formation) at Lime Acres (Altermann & Schopf 1995, Altermann & Wotherspoon 1995). The **Gamohaan Formation** also features horizons of microbial mats, domal and columnar stromatolites (Eriksson *et al.* 2006). The **Tsineng Formation** at the top of the Campbell Rand carbonate succession has yielded stromatolites (previously assigned to the Tsineng Member of the Gamohaan Formation), microbial mats as well as filamentous microfossils named *Siphonophycus* that are thought to have developed in shallow waters of the photic zone that were no more than a few tens of meters deep (Klein *et al.* 1987, Altermann & Schopf 1995, Eriksson *et al*. 2006).

Road cuttings through the upper Campbell Rand Subgroup carbonate succession, with occasional stromatolites, are seen along the R385 tar road to the north of Lime Acres with low outcrops – probably stromatolitic - also visible along a slight east-facing escarpment to the south of the road, some 6 km to the NE of the present study area (Almond, pers. obs. 2013).

4.2. Fossils within the Asbestos Hills Subgroup

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

4.3. Fossils within the Postmasburg Group

The fossil record of the Postmasburg Group of the Transvaal Supergroup is still poorly known. Stromatolitic bioherms up to 5 m long and 3 m 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 100 m 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. 5). They have not been recorded from the more proximal, platform area that is represented in the study areato the southwest of Daniëlskuil, but this requires further confirmation in the field. 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**, although the middle and upper parts of the lava succession was probably extruded subaqueously. Subaerial eruptions are inferred for the basal lava flows overlying the Makganyene diamictites (Eriksson *et al.* 2006). 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.

4.4. 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. Young (Quaternary to Recent) surface gravels and colluvium are probably unfossiliferous.

Surface limestones (calcrete hardpans) overlying Campbell Rand carbonates to the east of Lime Acres contain occasional horizons showing a porous, bioturbated fabric with dense networks of tubular hollows that may be attributed to insect burrowing, probably termites (Almond 2013). Downwasted and reworked blocks of black to dark grey Campbell Rand cherts and grey karst-weathered dolostone / limestone frequently contain small-scale domical stromatolites (*ibid*). Calcretised alluvial conglomerates overlying Campbell Rand bedrocks near Postmasburg also contain reworked clasts of stromatolitic dolomite or limestone (ibid.).

5. CONCLUSIONS & RECOMMENDATIONS

The study area from Farm Humansrus 469 to Lime Acres is underlain by largely undeformed Precambrian sediments and lavas of the Transvaal Supergroup that are Late Archaean to Early Proterozoic in age (*c*. 2.25 to 2.22 billion years old). These principally comprise shallow marine carbonates (limestones / dolomites) of the Campbell Rand Subgroup in the east that are successively overlain towards the west by banded iron formations (BIF) of the Asbestos Hills Subgroup and then glacial diamictites (tillites) and lavas of the Postmasburg Group. The Precambrian bedrocks are overlain by a range of late Caenozoic superficial sediments including aeolian sands of the Gordonia Formation (Kalahari Group), calcrete hardpans, colluvium (*e.g.* surface rubble, scree), river alluvium and pan deposits.

Important fossil stromatolites (microbial mounds) as well as associated microfossil biotas are recorded from the upper formations of the Campbell Rand Subgroup that are mapped near Lime Acres. However, surface exposure of these rocks is often poor due to calcrete cover, apart from road cuttings, rocky outcrops and quarries. The overlying finely-laminated Asbestos Hills BIF are only known to contain microfossils. Presumed warm-water stromatolitic carbonates closely associated with glacial sediments are reported from the Makganyene Formation (Postmasburg Group), but not so far in its eastern outcrop area to the SE of Daniëlskuil. No fossils are recorded from the overlying Olgeluk Formation volcanic succession. Sparse to locally common trace fossils (*e.g.* calcified termitaria and other invertebrate burrows, plant root casts), molluscs, and rare vertebrate remains (mammalian teeth, bones) are known from diverse Late Caenozoic superficial sediments in the broader Kalahari region.

Of the two alternative locations under consideration for the new Redstone Solar Thermal Energy Plant **switchyard**, the site on the northern border of Humansrus 469 is probably underlain by Gordonia Formation sands overlying Makganyene Formation diamictites at depth. The site on the western border of Humansrus 469 is underlain by Ongeluk Formation lavas. The palaeontological sensitivity of the former site is LOW (with a slight possibility of Makganyene stromatolites) and of the latter VERY LOW.

Power line corridor **Alternative 1A** traverses Campbell Rand carbonates at its eastern end near Lime Acres and the Silverstreams Substation. The bedrocks here are likely to be extensively mantled by superficial sediments (calcrete hardpan, soil, gravels, pan sediments) here. The majority of the corridor sector to the west, broadly following the railway line as far as Humansrus, crosses areas covered by Quaternary aeolian sands (Gordonia Formation). Small sectors near the Finch Diamond Mine in the SE and along the western border of Humansrus traverse the outcrop areas of the Kuruman Formation banded ironstones and Ongeluk lavas respectively. The final, north-western sector of the corridor along the northern edge of Humansrus, close to the R385 tar road, overlies Makganyene Formation diamictites and Daniëlskuil Formation BIF.

Power line corridor **Alternative 1B** traverses Campbell Rand carbonates at its eastern end near Lime Acres and the Silverstreams Substation. The bedrocks here are probably extensively mantled by superficial sediments (calcrete hardpan, soil, gravels, pan sediments) here. The majority of the corridor sector to the west, crossing the Rooiberg hills as far as Humansrus, is underlain by Asbestos Hills Subgroup BIF (Kuruman and Daniëlskuil Formations); the outcrop here is probably largely mantled by BIF colluvium (scree, soils). The north-western sector of the corridor, close to the R385 tar road, overlies Makganyene Formation diamictites and Gordonia Formation aeolian sands while the line traverses Ongeluk Formation lavas on the western borders of Humansrus.

The palaeontological sensitivity of both power line corridors is generally LOW, with areas of higher sensitivity in the vicinity of Lime Acres in the east (Campbell Rand Subgroup stromatolites) and overlying the Makganyene Formation on Farm Humansrus 469, close to the R385 tar road in the northwest (possibility of stromatolites associated with glacial tillites). These two more sensitive areas are indicated by yellow dotted lines in Fig. 3 herein. The Makganyene Formation outcrop area on Humansrus 469 is additionally of considerable scientific interest as an accessible part of the limited rock record for an Early Proterozoic (*c.* 2.3 billion years-old) “snowball earth” glacial event, when ice sheets may have covered much of the planet.

Adopting a precautionary approach, it is therefore recommended that a short field-based palaeontological assessment of the study area be commissioned by the developer, focussing on the two small areas of special fossil and geological interest outlined above. The study should document any surface occurrences of fossil material (notably well-preserved stromatolites) as well as geological features of unusual interest, and make recommendations for any further specialist palaeontological monitoring or mitigation required.

It is further recommended that:

- The Environmental Control Officer (ECO) responsible for the Redstone Solar Thermal Energy Plant and electrical infrastructure developments should be aware of the possibility of important fossils (*e.g.* well-preserved stromatolites, mammalian bones, teeth) being present or unearthed on site and should regularly monitor all substantial excavations into superficial sediments as well as fresh (*i.e.* unweathered) sedimentary bedrock for fossil remains;

- In the case of any significant fossil finds made during construction, these should be safeguarded - preferably *in situ* - and reported by the ECO as soon as possible to the relevant heritage management authority (South African Heritage Resources Agency. Contact details: SAHRA, 111 Harrington Street, Cape Town. PO Box 4637, Cape Town 8000,South Africa. Phone : +27 (0)21 462 4502. Fax: +27 (0)21 462 4509. Web : www.sahra.org.za) so that appropriate mitigation (*i.e.* recording, sampling or collection) by a palaeontological specialist can be considered and implemented, at the developer’s expense; and

- These recommendations should be incorporated into the Environmental Management Plan (EMP) for the Redstone Solar Thermal Energy Plant and associated electrical infrastructure projects.

The palaeontologist concerned with mitigation work will need a valid collection permit from SAHRA. All work would have to conform to international best practice for palaeontological fieldwork and the study (*e.g.* data recording fossil collection and curation, final report) should adhere to the minimum standards for Phase 2 palaeontological studies recently published by SAHRA (2013).

6. ACKNOWLEDGEMENTS

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8. QUALIFICATIONS & EXPERIENCE OF THE AUTHOR

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

Since 2002 Dr Almond has also carried out palaeontological impact assessments for developments and conservation areas in the Western, Eastern and Northern Cape under the aegis of his Cape Town-based company *Natura Viva* cc. He is a long-standing member of the Archaeology, Palaeontology and Meteorites Committee for Heritage Western Cape (HWC) and an advisor on palaeontological conservation and management issues for the Palaeontological Society of South Africa (PSSA), HWC and SAHRA. He is currently compiling technical reports on the provincial palaeontological heritage of Western, Northern and Eastern Cape for SAHRA and HWC. Dr Almond is an accredited member of PSSA and APHAP (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 project, application or appeal in respect of which I was appointed other than fair remuneration for work performed in connection with the activity, application or appeal. There are no circumstances that compromise the objectivity of my performing such work.

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