PALAEONTOLOGICAL HERITAGE BASIC ASSESSMENT: DESKTOP STUDY

Proposed mineral prospecting on the farms Achambachs Puts 56, Plaas 53, Plaas 566 and Plaas 567 near Griekwastad, Siyancuma Local Municipality, Hay Magisterial District, Northern Cape

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EXECUTIVE SUMMARY

Leago Mining and Infrastructure Investments (Pty) Ltd, is proposing to undertake mineral prospecting on the farms Achambachs Puts 56, Plaas 53, Plaas 566 and Plaas 567, situated some 15 to 20 km NNW of the town of Griekwastad, Siyancuma Local Municipality, Hay Magisterial District, Northern Cape

The prospecting study area is underlain by largely undeformed Precambrian sediments and lavas of the Transvaal Supergroup that are Early Proterozoic in age (*c*. 2.5 to 2.22 billion years old). These principally comprise a thick succession of banded iron formations (BIF) of the Asbestos Hills Subgroup (Ghaap Group) that are overlain towards the northwest by glacial diamictites (tillites) and lavas of the Postmasburg Group. The latter are referred to the Makganyene Formation and Ongeluk Formation respectively. 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.

The finely-laminated Asbestos Hills BIF contain microfossils but no well-attested macrofossil remains. Presumed warm-water stromatolitic carbonates closely associated with glacial sediments are reported from thin limestone lenticles within the Makganyene Formation (Postmasburg Group) and might be present within the study region. Any stromatolite (*i.e.* fossil microbial mound) occurrences here would be of considerable scientific and conservation significance. The Makganyene Formation outcrop area is additionally of considerable geological interest as 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. No fossils are recorded from the overlying Ongeluk Formation volcanic succession, although there is evidence that some of these lavas were erupted underwater. Sparse to locally common trace fossils (*e.g.* calcified termitaria and other invertebrate burrows, plant root casts), molluscs, diatomite and rare vertebrate remains (mammalian teeth, bones) are known from diverse Late Caenozoic superficial sediments in the broader Kalahari region, such as calcretes and pan sediments.

It is concluded that the palaeontological sensitivity of the prospecting study area is generally LOW with the exception of small outcrop areas of (a) Makganyene Formation (two blue dotted areas indicated in satellite image Fig. 3, on the eastern edge of Achambachs Puts 56 as well as near Lockshoek farmstead on Plaas 53 and Plaas 567), (b) calcrete hardpans and pan sediments (Ql and P in Fig. 3, Plaas 567). Given, in addition, the very small footprint of the proposed prospecting operations, no further specialist palaeontological studies or mitigation are recommended for the prospecting phase of the mining development, pending the discovery of significant new fossil occurrences in the area (*e.g.* well-preserved stromatolites, mammalian bones and teeth).

It is recommended that:

- The Environmental Site Agent (ESA) responsible for the mining development 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. Examples of typical stromatolites are illustrated in the Appendix;

- In the case of any significant fossil finds made during prospecting, these should be safeguarded - preferably *in situ* - and reported by the ESA 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 mineral prospecting project.

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

1. INTRODUCTION & BRIEF

The company Leago Mining and Infrastructure Investments (Pty) Ltd, Bryanston, is proposing to undertake mineral prospecting on the farms Achambachs Puts 56, Plaas 53, Plaas 566 and Plaas 567 in a region some 15 to 20 km NNW of the town of Griekwastad and east of the R325 road between Griekwastad and Postmasburg, Siyancuma Local Municipality, Hay Magisterial District, Northern Cape (Figs. 1 to 3). The operation will involve the drilling of up to ten prospecting boreholes of 60 mm core diameter and up to 260 metres deep. The total area to be prospected is 900 ha and the exact location of the boreholes is not yet determined, pending feedback from the first boreholes.

The procedure for drilling each borehole would be:

- A 1000 m^2 area would be fenced with a wire fence for health and safety purposes;
- A 1.5 m x 1.5 m slab would be placed on the ground as part of the drilling rig. This would disturb vegetation over this 2.25 m^2 area per borehole. Nevertheless no trees or vegetation would be removed. A 1.5m x 1.5 m x 1m sump would also be excavated. There would be no disturbance of the ground beyond the 60 mm core drilled.

No scenic rock outcrops with potential scenic value would be damaged by the prospecting.

The following more detailed project description has been abstracted and slightly modified from the Environmental Management Plan prepared for the Department of Minerals & Energy:

The **main prospecting activities**:
Access roads: there will be no access roads created since there are existing roads that will be used to access drill sites.
Camp site: there will be no camp site. The drilling crew will be accommodated at lodges in the town of Griekwastad. This is to minimize the environmental impact cause by site preparation.
Sumps: there will a maximum of ten sumps dug in the proposed project. The sumps will be dug by hand using picks and shovels. The dimensions of the sumps will be approximately 1.5 m x 1.5 m x 1 m. There will be one sump *per* drill hole.
Topsoil storage: there will be ten topsoil storage sites created. These will be for storing the soil dug from the ten sumps. The topsoil will be stored in 1.5 m high piles to decrease the effect of compaction. A 5 m working buffer will be set to avoid disturbance and mixing of the topsoil.
Drill sites: there will be ten drill sites set up. These will be approximately 1000 square meters in size. This will allow for placing of the drill rig, sumps, small core logging tent and on-site core storage. The drill will be set up by hand using basic tools such as pick, shovels and hammer. No heavy equipment or excavators will be used.
Drill holes: there will be up to ten holes drilled, each hole with a 60 mm diameter and not exceeding 250 m in depth. The holes will be drilled using a truck mounted drill rig that drills a 60 mm diameter hole and will spend approximately one week *per* drill hole.

Description of construction, operational, and decommissioning phases:

Construction Phase
Rig Mobilization: a rig will be transported to the drill site. It will take approximately one day for the rig to be assembled on the first site.
Drill Site Establishment: There will be ten drill sites established, each approximately 1000 square meters in size. These will be fenced and demarcated. They will all be fitted with safety signs and PPE requirements, emergency alarm, first aid kit, fire extinguisher and Material Safety Data Sheet (MSDS) for all toxic material used on site. Ten sumps will be dug, one for each camp site and topsoil stored accordingly. A waste area will be demarcated and a chemical toilet will be erected.

Operational Phase
This phase will entail drilling which is the actual extraction of cored rock samples from beneath the surface. This will be done using a rig that applies a rotation motion and pressure into the ground and therefore penetrating the rock formation. The rock sample is then extracted *via* an inner tube as core. The core will be transported from site to the designated core yard. The drilling will take approximately one week *per* drill hole.

Decommissioning Phase
- Rid Demobilization
- Removal of all foreign material from all sites and camp
- Removal of all waste
- Removal of chemical toilet
- Dismantling of all fences and gates that were erected
- Sealing and capping of drill holes
- Backfill of all dug sumps
- Ripping of all compacted surfaces
- Re-vegetation and seeding

The study area for the proposed prospecting activities overlies potentially fossiliferous sediments of the Transvaal Supergroup and Kalahari Group (Sections 3 & 4, Fig. 4). Fossils preserved within the bedrock or superficial deposits may be disturbed, damaged or destroyed during prospecting activity. 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 prospecting project has accordingly been commissioned on behalf of the developer by Rosenthal Environmental, Rondebosch (Contact details: Philip Rosenthal. Postnet 114, P/Bag X18, Rondebosch, 7701. Tel (021) 685 4500 Fax: 0866164452. Cell 082 6768966. Email mail@PhilipRosenthal.com).

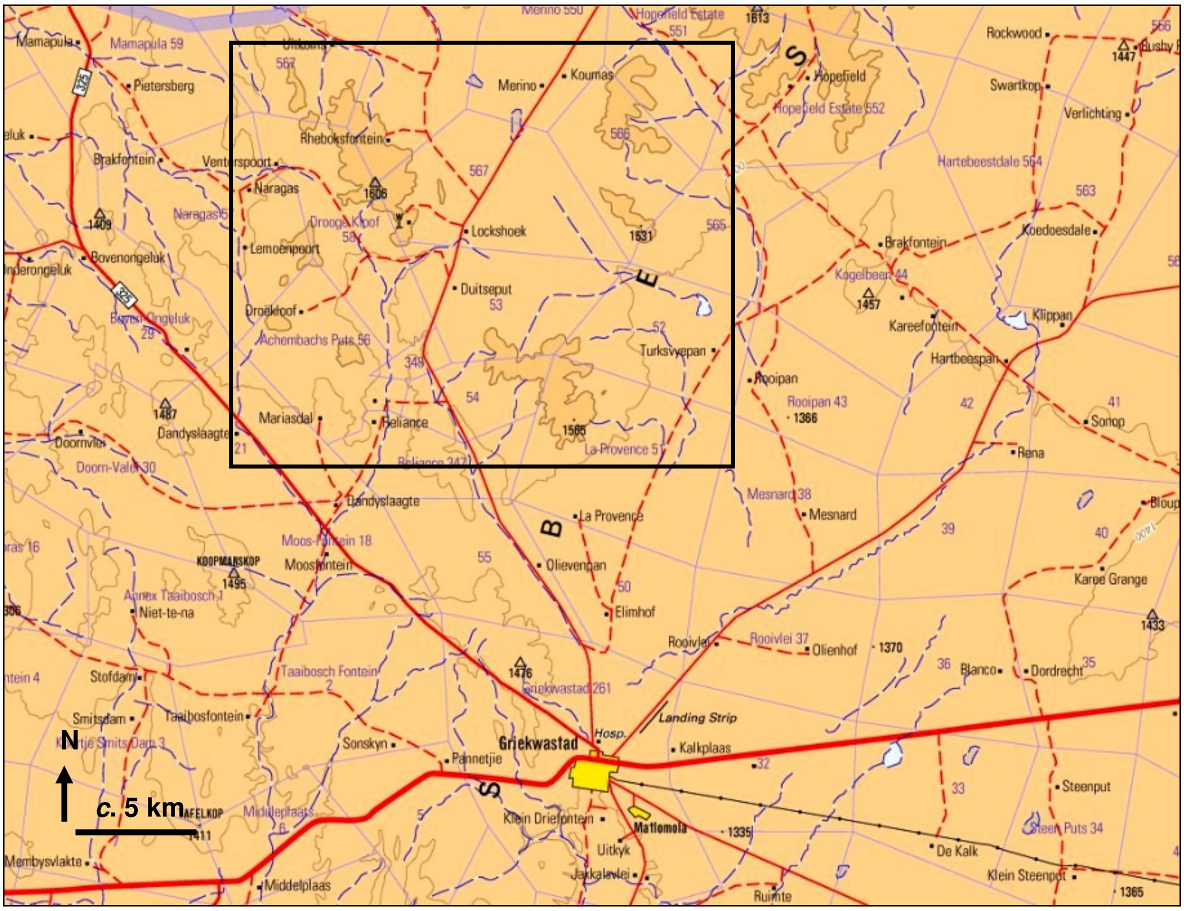

Fig. 1. Extract from 1: 250 000 topographical map 2822 Postmasburg (courtesy of the Chief Directorate: National Geo-spatial Information, Mowbray) showing the location of the broader study area (black rectangle) some 15-20 km NNW of Griekwastad, Northern Cape.

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).

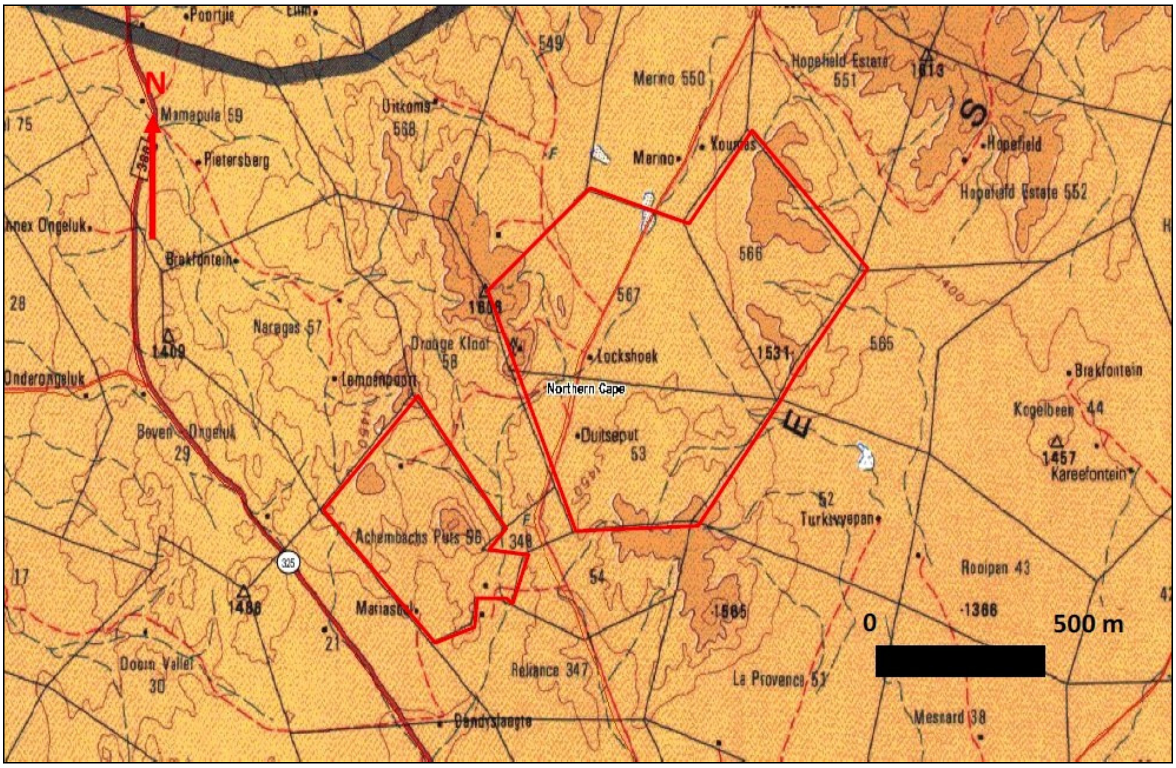

Fig. 2. Detail of the map shown in the previous figure showing the four land parcels involved in the current prospecting project outlined in red, *viz.* Achambachs Puts 56, Plaas 53, Plaas 566 and Plaas 567 (Image abstracted from Nkululeko Mzobe, Environmental Management Plan on behalf of Leago Mining and Infrastructure Investments Pty (Ltd), reference number: NC 30/5/1/1/2/10975 PR).

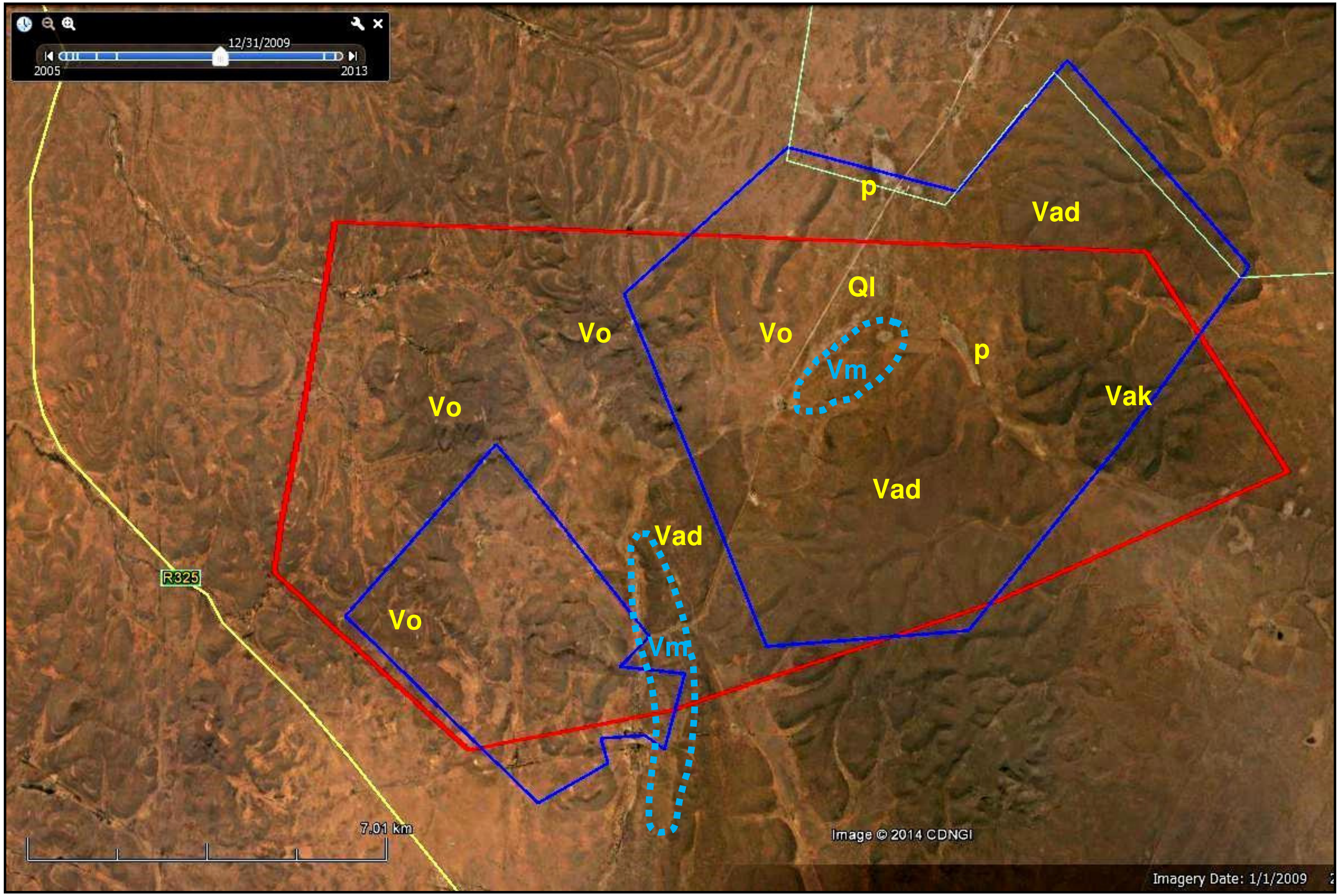

Fig. 3. Google earth© satellite image of the broader prospecting study area to the NNW of Griekwastad, Northern Cape (Blue polygons). Key outcrop areas of major rock units are indicated (See key in legend to geological map Fig. 4 below). Precambrian stromatolites might be associated with limestone lenticles within the Makgakyene Formation (Vm, areas marked with a blue dotted line). Fossils may occur within calcrete hardpans (Ql) and possible pans (P). Most of the remainder of the study area is of low palaeontological sensitivity.

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 Rosenthal Environmental;

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 2012a, 2013a, 2013b);

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 present mineral prospecting project near Griekwastad 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 2012b, 2013a, 2013b) as well as the frequently 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.

3. GEOLOGICAL BACKGROUND

The study area for the proposed mineral prospecting activities largely comprises semi-desert terrain with low hills (*c*. 1400-1500 m amsl) that are finely dissected by numerous small, intermittently-flowing streams. Many of these are tributaries of the Witleegte drainage system that flows southwards to the west of Griekwastad (Figs. 1 & 3). This hilly region forms part of the extensive SSW-NNE Asbesberge range in the Postmasberg – Kuruman region of the Northern Cape.

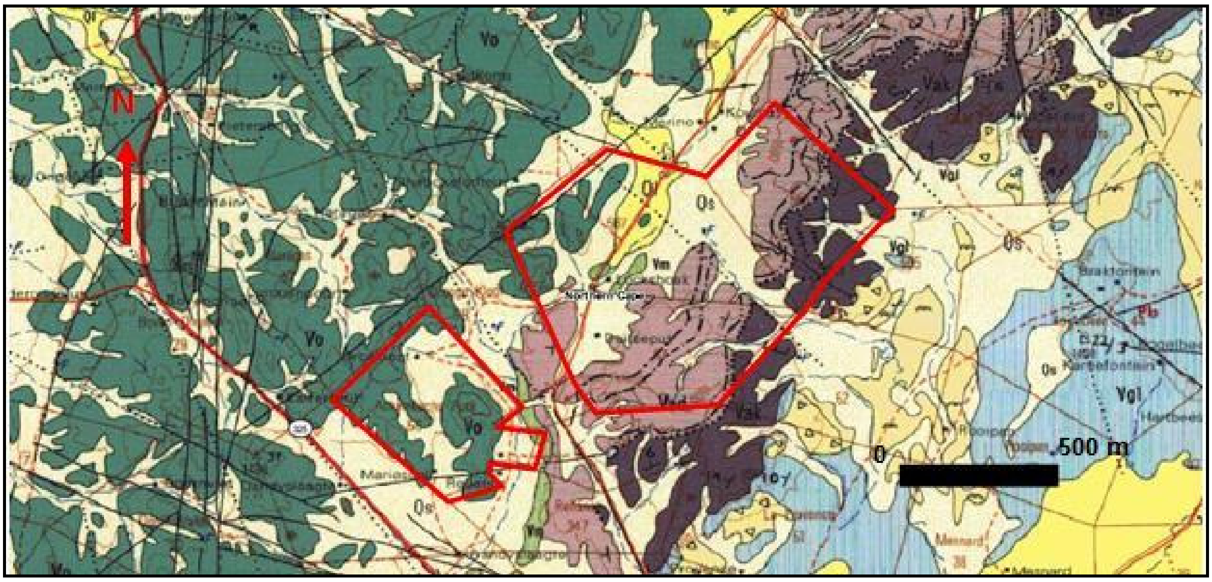

Fig. 4. Extract from 1: 250 000 geological map 2822 Postmasburg (Council for Geoscience, Pretoria) showing the geology of the prospecting area to the NNW of Griekwastad, Northern Cape, outlined in red (Image kindly provided by Nkululeko Mzobe, Geologist). The main geological units mapped within the broader study region include:

TRANSVAAL SUPERGROUP

Ghaap Group (CAMPBELL RAND SUBGROUP)
Vgl (pale blue) (formations not differentiated) (> 2.5 Ga)

Ghaap Group (ASBESTOS HILLS SUBGROUP):
Vak (dark purple) = Kuruman Formation (banded iron formation, 2.5 Ga).
Vad (purplish-grey) = Daniëlskuil Formation (banded iron formation, 2.4 Ga). Dashed lines indicate various lithostratigraphic marker beds.

POSTMASBURG GROUP:
Vm (pale green) = Makganyene Formation (glacial diamictite *etc*) (*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 double flying bird symbol = older (Tertiary) alluvium
Middle yellow with triangles = rock rubble

The geology of the study area near Griekwastad is shown on 1: 250 000 geological map 2822 Postmasburg (Council for Geoscience, Pretoria) (Fig. 4). Brief explanatory notes are printed on the published map, but a comprehensive geological explanation for this sheet has not yet been written. The area is also covered by the older 1: 125 000 scale geological map sheet 175 Griquatown for which there is a short sheet explanation by Visser (1958). The following geological notes have been largely abstracted from previous palaeontological heritage assessments in the region by the author (*e.g.* Almond 2010a, 2010b, 2011a, 2011b, 2012a, 2012b, 2013a, 2013b).

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 northwest. The stratigraphy of the relevant formations is shown in Fig. 5 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), Eriksson *et al.* (1993, 1995, 2006) as well as 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). Potentially fossiliferous carbonates (*i.e.* limestones, dolostones) of the "Ghaapplato Formation" ("Lime Acres Member", Vgl in geological map Fig. 4) crop out just to the east of the present study area, east of the Asbesheuwels foothills. Due to their solubility and low resistance to weathering, exposure levels of these carbonate sedimentary rocks are often very low. However, the Campbell Rand carbonates are unlikely to be affected by the proposed prospecting activity so these older sedimentary rocks will not be considered further here. The outcrop area of chert-rich carbonate subunits is locally covered in downwasted, **siliceous rock rubble** in the Postmasburg sheet area (middle yellow areas with triangular symbols in map Fig. 4; *cf* Almond 2013a).

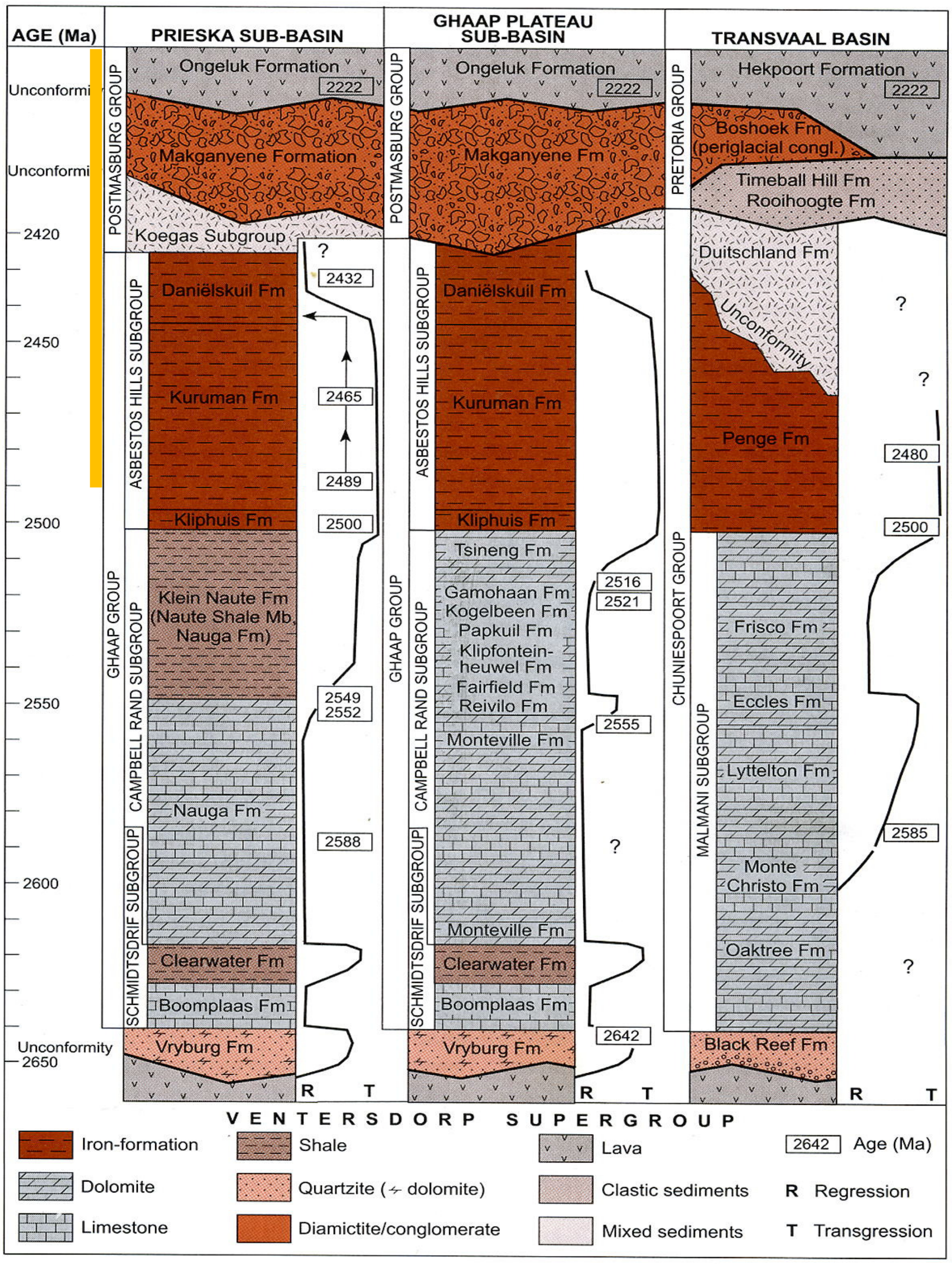

Fig. 5. Stratigraphy of the Transvaal Supergroup of the Prieska Sub-basin (LHS column) showing rock units represented in the Griekwastad study area (thick orange line) (Modified from Eriksson *et al.* 2006). Figures in boxes indicate radiometric ages in millions of years (Ma).

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 Asbesheuwels in the Griekwastad - Postmasburg – Daniëlskuil 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 north-eastern margins of the study area (Vak in Fig. 4), 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 Prieska Sub-basin within the Griquatown Fault Zone the Kuruman BIF reaches thicknesses of several hundred meters (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. 4), 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 central portion of the main, eastern part of the study area, especially the higher-lying hilly terrain, but bedrock exposure here is generally poor. The fine-grained siliciclastics are brown to ochreous weathering, very tabular in geometry, laminated to thin-bedded (≤ 10-20 cm), cherty (*e.g.* showing conchoidal fracture) with bands of iron minerals (reddish haematite, dark magnetite *etc*). Jointing is well developed. Various distinctive lithostratigraphic horizons are marked on the geological map by dashed lines.

Glacial and volcanic rocks of the 2.4-2.2 Ga **Postmasburg Group** (uppermost Transvaal Supergroup) underlie most of the western portion of the study area (Achambachs Puts 56) as well as the NW portion of the eastern part of the study area. The Postmasburg succession here overlies the older Ghaap Group rocks in the core of a broad NNE-SSW trending synclinal structure (Moore *et al.* 2012). Two contrasting rock units are mapped here.

Basal diamictites of the **Makganyene Formation** (Vm, pale green in Fig. 4), 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. 6). 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. The Makganyene "tillite zone" has been briefly described by Visser (1958) for the region to the NW of Griekwastad where the glacial beds are locally well-developed. The valley between the Asbesheuwels and the Ongeluk Hills to the west has been largely incised along the tillite zone but exposure levels here are often poor.

Carbonate lenticles with stromatolitic bioherms are recorded from the Makganyene Formation of the Griqualand West Basin where they are apparently confined to the more offshore parts of the basin preserved further to the southwest (= Prieska Sub-basin). Thin, potentially fossiliferous carbonate horizons may be present towards the top of the Makganyene succession in the study region to the NW of Griekwastad (Polteau et al. 2006; see Fig.6 herein and areas demarcated with blue dotted lines in satellite image Fig. 3).

The glacially-related Makganyene rocks are overlain in study area by basaltic to andesitic lavas of the **Ongeluk Formation** (Vo, dark green in Fig. 4) 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, Poteau *et al.* 2006). Subordinate diamictites are found within the Ongeluk succession. Visser (1958) describes the Ongeluk rocks NW of Griekwastad as mainly "composed of a monotonous succession of greyish-green andesitic lava", occasionally amydaloidal, with individual flows identifiable locally. Pyroclastic facies such as agglomerates and tuffs are uncommon.

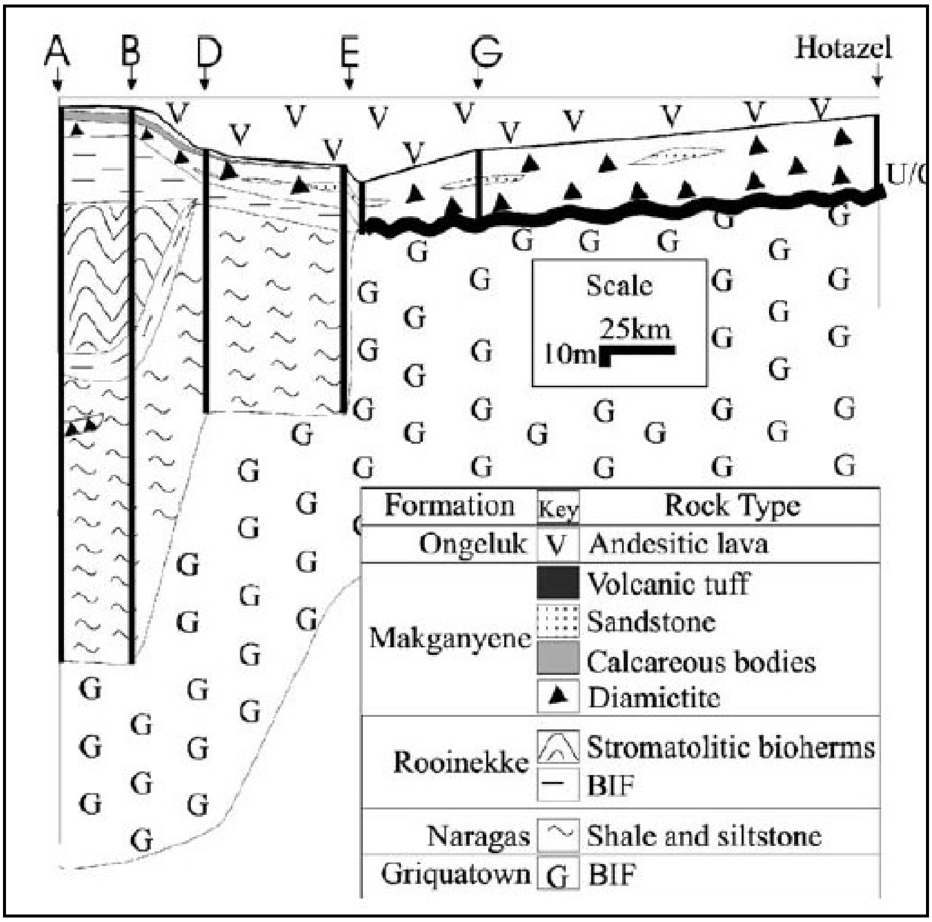

Fig. 6. Series of profiles through the Makganyene Formation (Postmasburg Group), roughly from SW to NE across the Griqualand Basin, Northern Province (From Polteau *et al.* 2006). Profile E, to the NW of Griekwastad, corresponds most closely to the present prospecting study area. Here, on the edge of the Prieska Sub-basin to the SW of the major Griquatown Fault Zone / hinge zone, the Makganyene glacial diamictites overlie BIF. The Makganyene succession here contains lenticular sandstone bodies (stippled) as well as thin carbonate lenticles (grey), the latter possibly containing stromatolitic bioherms, towards the top.

In the flatter, low-lying stream valleys and *vlaktes* within the study area the Precambrian bedrocks are mantled by wind-blown (aeolian) sands of the **Gordonia Formation**, **Kalahari Group** (Qs, pale yellow in Fig. 4). 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. Much thinner aeolian sands of only a few meters or less are reported in the eastern portion of the 1: 125 000 Griquatown sheet by Visser (1958). 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 1: 250 000 scale geological maps include colluvial or slope deposits (scree, hillwash, debris flows *etc*), sandy, gravelly and bouldery river **alluvium** (*e.g.* area of older Tertiary alluvium to the SE of the study area), surface gravels of various origins (*e.g.* **cherty "rubble"** overlying Campbell Rand carbonates to the SE of the study area), as well as spring and **pan sediments** (including diatomite or *Kieselguhr*; *cf* Visser 1958). Elongate pale areas visible along major stream valleys on satellite images of the study area may represent ancient (perhaps Quaternary) pan sediments (See areas marked “P” in satellite image Fig. 3). Thick scree deposits characterize many valleys in the Asbesheuwels (Visser 1958). 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 (Visser 1958, Almond 2013a).

Mappable exposures of **calcrete** or **surface limestone** (Ql, dark yellow, in Fig. 4) cover large portions of the Ghaap Group carbonates of the Ghaap Plateau to the east of the study area (Almond 2013) and are also mapped within the northern part of the area itself, perhaps associated with older alluvium and pan sediments (See areas marked “Ql” and “P” in satellite image Fig. 3). 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).

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 prospecting study area is given here (based largely on Almond 2012b, 2013b).

4.1. 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)

4.2. Fossils within the Postmasburg Group

The fossil record of the Postmasburg Group of the Transvaal Supergroup is still poorly known. Stromatolitic bioherms up to 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 potentially fossiliferous carbonate rocks are interbedded with glacial diamictites in the Prieska Subbasin and may occur within the upper part of the Makganyene succession in the region NW of Griekwastad (calcareous bodies shown in Fig. 6 herein; see areas demarcated with blue dotted lines in satellite image Fig. 3). 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. 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 directly overlying the Makganyene diamictites (Eriksson *et al.* 2006, Polteau *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 (See "P" in Fig. 3). 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.

5. CONCLUSIONS

The mineral prospecting study area to the NNW of Griekwastad is underlain by largely undeformed Precambrian sediments and lavas of the Transvaal Supergroup that are Early Proterozoic in age (*c.* 2.5 to 2.22 billion years old). These principally comprise a thick succession of banded iron formations

(BIF) of the Asbestos Hills Subgroup (Ghaap Group) that are overlain towards the northwest by glacial diamictites (tillites) and lavas of the Postmasburg Group. These are referred to the Makganyene Formation and Ongeluk Formation respectively. 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.

The prospecting study area is underlain by largely undeformed Precambrian sediments and lavas of the Transvaal Supergroup that are Early Proterozoic in age (*c.* 2.5 to 2.22 billion years old). These principally comprise a thick succession of banded iron formations (BIF) of the Asbestos Hills Subgroup (Ghaap Group) that are overlain towards the northwest by glacial diamictites (tillites) and lavas of the Postmasburg Group. The latter are referred to the Makganyene Formation and Ongeluk Formation respectively. 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.

The finely-laminated Asbestos Hills BIF contain microfossils but no well-attested macrofossil remains. Presumed warm-water stromatolitic carbonates closely associated with glacial sediments are reported from thin limestone lenticles within the Makganyene Formation (Postmasburg Group) and might be present within the study region. Any stromatolites occurrences here would be of considerable scientific and conservation significance. The Makganyene Formation outcrop area is additionally of considerable geological interest as 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. No fossils are recorded from the overlying Ongeluk Formation volcanic succession, although there is evidence that some of these lavas were erupted underwater. Sparse to locally common trace fossils (*e.g.* calcified termitaria and other invertebrate burrows, plant root casts), molluscs, diatomite and rare vertebrate remains (mammalian teeth, bones) are known from diverse Late Caenozoic superficial sediments in the broader Kalahari region, such as calcretes and pan sediments.

It is concluded that the palaeontological sensitivity of the prospecting study area is generally LOW with the exception of small outcrop areas of (a) Makganyene Formation (two blue dotted areas indicated in satellite image Fig. 3, on the eastern edge of Achambachs Puts 56 as well as near Lockshoek farmstead on Plaas 53 and Plaas 567), (b) calcrete hardpans and pan sediments (Ql and P in Fig. 3, Plaas 567). Given, in addition, the very small footprint of the proposed prospecting operations, no further specialist palaeontological studies or mitigation are recommended for the prospecting phase of the mining development, pending the discovery of significant new fossil occurrences in the area (*e.g.* well-preserved stromatolites, mammalian bones and teeth).

6. RECOMMENDATIONS

It is recommended that:

- The Environmental Site Agent (ESA) responsible for the mining development 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. Examples of typical stromatolites are illustrated in the Appendix;

- In the case of any significant fossil finds made during prospecting, these should be safeguarded - preferably *in situ* - and reported by the ESA 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 mineral prospecting project.

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

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8. REFERENCES

ALMOND, J.E. 2008. Fossil record of the Loeriesfontein sheet area (1: 250 000 geological sheet 3018). Unpublished report for the Council for Geoscience, Pretoria, 32 pp.

ALMOND, J.E. 2010a. Prospecting application for iron ore and manganese between Sishen and Postmasburg, Northern Cape Province: farms Jenkins 562, Marokwa 672, Thaakwaneng 675, Driehoekspan 435, Doringpan 445 and Macarthy 559. Palaeontological impact assessment: desktop study, 20 pp. Natura Viva cc, Cape Town.

ALMOND, J.E. 2010b. Proposed voltaic power station adjacent to Welcome Wood Substation, Owendale near Postmasburg, Northern Cape Province. Palaeontological impact assessment: desktop study, 12 pp. Natura Viva cc, Cape Town.

ALMOND, J.E. 2011a. Proposed concentrated solar power development on Farm 469 (Humansrus), near Postmasburg, Northern Cape Province. Recommended exemption from further palaeontological studies, 5 pp. Natura Viva cc, Cape Town.

ALMOND, J.E. 2011b. Proposed Solar Thermal Energy Power Park on Farm Arriesfontein, near Daniëlskuil, Postmasburg District, Northern Cape Province. Palaeontological specialist study: desktop assessment, 14 pp. Natura Viva cc, Cape Town.

ALMOND, J.E. 2012a. Proposed PV power stations Welcome Wood II and III adjacent to Welcome Wood Substation, near Daniëlskuil, Northern Cape Province. Palaeontological impact assessment: desktop study, 14 pp.

ALMOND, J.E. 2012b. Proposed Metsimatala Photovoltaic Power and Concentrated Solar Power Facilities on Farm Groenwater, Francis Baard District Municipality near Postmasburg, Northern Cape. Palaeontological assessment: combined desktop study & field assessment, 26 pp. Natura Viva cc, Cape Town.

ALMOND, J.E. 2013a. Proposed 16 Mtpa expansion of Transnet's existing manganese ore export railway line & associated infrastructure between Hotazel and the Port of Ngqura, Northern & Eastern

Cape. Part 1: Hotazel to Kimberley, Northern Cape. Palaeontological specialist assessment: combined desktop and field-based study, 85 pp. Natura Viva cc, Cape Town.

ALMOND, J.E. 2013b. Proposed construction of a 132 kV power line and switchyard associated with the Redstone Solar Thermal Energy Plant near Postmasburg, Northern Cape Province. Palaeontological specialist assessment: desktop study, 25 pp. Natura Viva cc, Cape Town.

ALMOND, J.E. & PETHER, J. 2008. Palaeontological heritage of the Northern Cape. Interim SAHRA technical report, 124 pp. Natura Viva cc., Cape Town.

ALTERMANN, J. & HERBIG 1991. Tidal flats deposits of the Lower Proterozoic Campbell Group along the southwestern margin of the Kaapvaal Craton, Northern Cape province, South Africa. Journal of African Earth Science 13: 415-435.

ALTERMANN, W. & SCHOPF, J.W. 1995. Microfossils from the Neoarchaean Campbell Group, Griqualand West Sequence of the Transvaal Supergroup, and their paleoenvironmental and evolutionary implications. Precambrian Research 75, 65-90.

ALTERMANN, W. & WOTHERSPOON, J. McD. 1995. The carbonates of the Transvaal and Griqualand West sequences of the Kaapvaal craton, with special reference to the Limje Acres limestone deposit. Mineralium Deposita 30, 124-134.

ANDERSEN, D.T., SUMNER, D.Y., HAWES, I., WEBSTER-BRWON, J. & MCKAY, C.P. 2011. Discovery of large conical stromatolites in Lake Untersee, Antarctica. Geobiology 9, 280-293.

BERTRAND-SARFATI, J. 1977. Columnar stromatolites from the Early Proterozoic Schmidtsdrift Formation, Northern Cape Province, South Africa – Part 1: systematic and diagnostic features. Palaeontologia Africana 20, 1-26.

BEUKES, N.J. 1980. Stratigraphie en litofasies van die Campbellrand-Subgroep van die Proterofitiese Ghaap-Group, Noord-Kaapland. Transactions of the Geological Society of South Africa 83, 141-170.

BEUKES, N.J. 1983. Palaeoenvironmental setting of iron formations in the depositional basin of the Transvaal Supergroup, South Africa. In: Trendall, A.F. & Morris, R.C. (Eds.) Iron-formation: facts and problems, 131-210. Elsevier, Amsterdam.

BEUKES, N.J. 1986. The Transvaal Sequence in Griqualand West. In: Anhaeusser, C.R. & Maske, S. (Eds.) Mineral deposits of Southern Africa, Volume 1, pp. 819-828. Geological Society of South Africa.

BEUKES, N.J. & KLEIN, C. 1990. Geochemistry and sedimentology of facies transition from the microbanded to granular iron-formation in the Early Proterozoic Transvaal Supergroup, South Africa. Precambrian Research 47, 99-139.

BOSCH, P.J.A. 1993. Die geologie van die gebied Kimberley. Explanation to 1: 250 000 geology Sheet 2824 Kimberley, 60 pp. Council for Geoscience, Pretoria.

CLOUD, P.E. & LICARI, G.R. 1968. Microbiotas of the banded iron formations. Proceedings of the National Academy of Science USA 61, 779-786.

COETZEE, L.L., BEUKES, N.J. & GUTZMER, J. 2006. Links of organic carbon cycling and burial to depositional depth gradients and establishment of a snowball Earth at 2.3 Ga. Evidence from the

Timeball Hill Formation, Transvaal Supergroup, South Africa. South African Journal of geology 109, 109-122.

DINGLE, R.V., SIESSER, W.G. & NEWTON, A.R. 1983. Mesozoic and Tertiary geology of southern Africa. viii + 375 pp. Balkema, Rotterdam.

DU TOIT, A. 1954. The geology of South Africa. xii + 611pp, 41 pls. Oliver & Boyd, Edinburgh.

ERIKSSON, P.G. & TRUSWELL, J.F. 1974. Tidal flat associations from a Lower Proterozoic carbonate sequence in South Africa. Sedimentology 21: 293-309.

ERIKSSON, P.G. & ALTERMANN, W. 1998. An overview of the geology of the Transvaal Supergroup dolomites (South Africa). Environmental Geology 36, 179-188.

ERIKSSON, P.G., ALTERMANN, W. & HARTZER, F.J. 2006. The Transvaal Supergroup and its precursors. In: Johnson, M.R., Anhaeusser, C.R. & Thomas, R.J. (Eds.) The geology of South Africa, pp. 237-260. Geological Society of South Africa, Marshalltown.

EVANS, D.A., BEUKES, N.J. & KITSCHVINK, J.L. 1997. Low-latitude glaciation in the Palaeoproterozoic Era. Nature 386, 262-266.

FOCKEMA, P.D. 1967. Crocidolite and associated rocks of the Kuruman area in the Northern Cape Province. Unpublished PhD thesis, University of Witwatersrand, Johannesburg.

HADDON, I.G. 2000. Kalahari Group sediments. In: Partridge, T.C. & Maud, R.R. (Eds.) The Cenozoic of southern Africa, pp. 173-181. Oxford University Press, Oxford.

HAENTZSCHEL, W. 1975. Treatise on invertebrate paleontology. Part W. Miscellanea. Supplement 1. Trace fossils and problematica, 269 pp. Geological Society of America, Boulder, and University of Kansas Press, Lawrence.

HAUGHTON, S.H. 1963. Two problematic fossils from the Transvaal System. Annals of the Geological Survey of South Africa 1, 257-260.

HAUGHTON, S.H. 1969. Geological history of southern Africa, 535 pp, Johannesburg. The Geological Society of South Africa.

KLEIN, C., BEUKES, N.J. & SCHOPF, J.W. 1987. Filamentous microfossils in the early Proterozoic Transvaal Supergroup: their morphology, significance, and palaeoenvironmental setting. Precambrian Research 36, 81-94.

KLEIN, C. & BEUKES, N.J. 1989. Geochemistry and sedimentology of a facies transition from limestone to iron formation deposition in the early Proterozoic Transvaal Supergroup, South Africa. Economic Geology 84, 1733-1774.

KLEMM, D.D. 1979. A biogenetic model of the formation of the Banded Iron Formation in the Transvaal Supergroup / South Africa. Mineralia Deposita Berlin) 14, 381-385.

KOPP, R.E., KIRSCHVINK, J.L., HILBURN, I.A. & NASH, C.Z. 2005. The Paleoproterozoic snowball Earth: a climate diasater triggered by the evolution of oxygenic photosynthesis. Proceedings of the National Academy of Sciences 102, 11 131-11 136.

LA BERGE, G.L. 1973. Possible biological origin of Precambrian iron-formations. Economic Geology 68, 1098-1109.
MACRAE , C. 1999. Life etched in stone. Fossils of South Africa. 305 pp. The Geological Society of South Africa, Johannesburg.

MCCARTHY, T. & RUBIDGE, B. 2005. The story of Earth and life: a southern African perspective on a 4.6-billion-year journey. 334pp. Struik, Cape Town.

MOORE, J.M., TSIKOS, H. & POLTEAU, S. 2001. Deconstructing the Transvaal Supergroup, South Africa: implications for Palaeoproterozoic palaeoclimate models. African Earth Sciences 33, 437-444.

MOORE, J.M., POLTEAU, S., ARMSTRONG, R.A., CORFU, F. & TSIKOS, H. 2012. The age and correlation of the Postmasburg Group, southern Africa: constraints from detrital zircons. Journal of African Earth Sciences 64, 9-19.

PARTRIDGE, T.C., BOTHA, G.A. & HADDON, I.G. 2006. Cenozoic deposits of the interior. In: Johnson, M.R., Anhaeusser, C.R. & Thomas, R.J. (Eds.) The geology of South Africa, pp. 585-604. Geological Society of South Africa, Marshalltown.

POLTEAU, S. 2000. Stratigraphy and geochemistry of the Makganyene Formation, Transvaal Supergroup, South Africa. Unpublished MSc thesis, Rhodes University, Grahamstown, 146 pp.

POLTEAU, S. 2005. The Early Proterozoic Makganyene glacial event in South Africa: its implication in sequence stratigraphy interpretation, paleoenvironmental conditions, and iron and manganese ore deposition. Unpublished PhD thesis, Rhodes University, Grahamstown, South Africa, 215 pp.

POLTEAU, S., MOORE, J.M. & TSIKOS, H. 2006. The geology and geochemistry of the Palaeoproterozoic Makganyene diamictite. Precambrian Research 148, 257-274.

SAHRA 2013. Minimum standards: palaeontological component of heritage impact assessment reports, 15 pp. South African Heritage Resources Agency, Cape Town.

SCHOPF, J.W. 2006. Fossil evidence of Archaean life. Philosophical Transactions of the Royal Society of London B 361, 869-885.

SUMNER, D.Y. 2002. Neoarchaean carbonates – clues to early life and early ocean chemistry. Excursion A6, 1-6 July 2002, 24 pp. 16th International Sedimentological Congress, International Association of Sedimentologists. Rand Afrikaans University, Johannesburg,

SUMNER, D.Y. & BEUKES, N.J. 2006. Sequence stratigraphic development of the Neoarchaean Transvaal carbonate platform, Kaapvaal Craton, South Africa. South African Journal of Geology 109, 11-22.

TANKARD, A.J., JACKSON, M.P.A., ERIKSSON, K.A., HOBDAY, D.K., HUNTER, D.R. & MINTER, W.E.L. 1982. Crustal evolution of southern Africa – 3.8 billion years of earth history, xv + 523pp. Springer Verlag, New York.

THOMAS, M.J. 1981. The geology of the Kalahari in the Northern Cape Province (Areas 2620 and 2720). Unpublished MSc thesis, University of the Orange Free State, Bloemfontein, 138 pp.

THOMAS, D.S.G. & SHAW, P.A. 1991. The Kalahari environment, 284 pp. Cambridge University Press.

TRUTER, F.C., WASSERSTEIN, B., BOTHA, P.R., VISSER, D.L.J., BOARDMAN, L.G. & PAVER, G.L. 1938. The geology and mineral deposits of the Olifants Hoek area, Cape Province. Explanation of 1: 125 000 geology sheet 173 Olifants Hoek, 144 pp. Council for Geoscience, Pretoria.

VISSER, D.L.J. 1958. The geology and mineral deposits of the Griquatown area, Cape Province. Explanation to 1: 125 000 geology sheet 175 Griquatown, 72 pp. Council for Geoscience, Pretoria.

YOUNG, R.B. 1932. The occurrence of stromatolitic or algal limestones in the Campbell Rand Series, Griqualand West. Transactions of the Geological Society of South Africa 53: 29-36.

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

Declaration of Independence

I, John E. Almond, declare that I am an independent consultant and have no business, financial, personal or other interest in the proposed mining 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
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APPENDIX: Stromatolites from the Ghaap Group (Transvaal Supergroup) in the Postmasburg region, Northern Cape

Here are illustrated examples of typical *stromatolites* – *i.e.* reef-like fossil microbial mounds – from the Transvaal Supergroup (Ghaap Group, Campbell Rand Subgroup) carbonate succession near Postmasberg, Northern Cape, as seen in surface outcrop. The hammer for scale is *c*. 30 cm long.

Fig. A1. Large domical stromatolites from the Kogelbeen Formation near Lime Acres.

Fig. A2. Marker bed of close-packed columnar stromatolites from the Kogelbeen Formation near Lime Acres.

Fig. A3. Detail of columnar stromatolites seen within the marker bed shown in previous figure. The individual columns are *c.* 5 to 25 cm wide and are separated by laminated carbonate sediment.