PALAEONTOLOGICAL HERITAGE REPORT: DESKTOP STUDY

Prospecting Application for Portions 2 and 3 of the Farm Bishop 671 near Kathu, Kuruman District, Northern Cape

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1. EXECUTIVE SUMMARY

Nuberry Enterprises (PTY) Ltd, North Riding, is proposing to undertake exploration phase activities for iron and manganese ores employing percussion drilling and bulk sampling on Portions 2 and 3 of the Farm Bishop 671, situated approximately 30 km southwest of Kathu, Kuruman District, Northern Cape. The main targets for mineral exploration are high grade iron and manganese ores within highly modified Precambrian sediments of the Ghaap Group and Elim Group (Manganore / Gamagara Formations) that are not in themselves of palaeontological heritage significance. The presence of potentially-stromatolitic carbonates of the Campbellrand Subgroup (and perhaps even the Koegas Subgroup) within the exploration project area is ambiguous; outcrop areas are small, at most, and significant palaeontological impacts on these Ghaap Group rock units are considered unlikely. The Postmasberg Group is represented here by unfossiliferous Ongeluk Formation volcanics as well as a small outcrop area of the glacially-related Makganyene Formation. Equivocal stromatolites have been recorded from this last unit but not within platform facies of the Ghaap-Plateau Subbasin which are represented here. Quaternary to Recent superficial sediments of the Kalahari Group – mainly Gordonia Formation aeolian sands – are generally of low palaeontological sensitivity. It is concluded that the proposed invasive exploration activities on Portions 2 and 3 of Farm Sishop 671 do not pose a significant threat to local fossil heritage and there are no objections on palaeontological grounds to their approval.

The ECO responsible for the mineral exploration project should be aware of the potential for important fossil stromatolite finds within Precambrian carbonate bedrocks and the necessity to conserve them for possible professional mitigation. A Chance Fossil Finds Procedure for this development is outlined in tabular form at the end of this report. Recommended mitigation of chance fossil finds during the proposed exploration phase activities involves safeguarding of the fossils (preferably *in situ*) by the responsible ECO and reporting of all significant finds to the South African Heritage Resources Agency, SAHRA (Contact details: SAHRA, 111 Harrington Street, Cape Town. PO Box 4637, Cape Town 8000, South Africa. Phone: +27 (0)21 462 4502. Fax: +27 (0)21 462 4509. Web: www.sahra.org.za). Where appropriate, judicious sampling and recording of fossil material and associated geological data by a qualified palaeontologist, appointed by the developer, may be required by the relevant heritage regulatory authorities. Any fossil material collected should be curated within an approved repository (museum / university fossil collection). These recommendations should be included within the Environmental Management Programme (EMPr) for the proposed mining project.

2. INTRODUCTION & BRIEF

The company Nuberry Enterprises (PTY) Ltd, North Riding, is proposing to undertake exploration phase activities for iron and manganese ores employing percussion drilling and bulk sampling on Portions 2 and 3 of the Farm Bishop 671, situated approximately 30 km southwest of Kathu, Kuruman District, Northern Cape (Figs. 1 to 4).

Invasive prospecting / exploration activities (Figs. 3 & 4) will involve:

- **50 boreholes** constructed using percussion drilling, with a 10m x 10m surface disturbance and depth of around 50 m. The position of the boreholes is dependent on the results of the review of historical activities, geological mapping, desktop study and a geophysical survey. The collar position of all boreholes will be surveyed. The sizes of the boreholes drilled will be determined by such factors as cost, proposed sampling, availability of drilling machines and the volume of sample required, among others. All drilling will be short term and undertaken by a contractor using truck-mounted equipment.

- **Bulk sampling** of a total volume of 47 500 m^3 of ore. For exploration purposes 23 750 m^3 of iron ore will be bulk sampled and 23 750 m^3 of manganese ore will be bulk sampled. The excavation process will be initiated by drilling of blast holes. These holes will then be blasted, after which the ore will be loaded from the open excavations and hauled to the processing plant. Bulk sampling will be conducted during phase 4 of the prospecting operation for a period of 19 months.

The following **infrastructure** will be established on site during the exploration phase:

- Ablution facilities (chemical toilets)
- Diesel tank
- Generator
- Offices (mobile containers)
- Processing Plant for iron ore
- Processing Plant for manganese ore
- Roads (access & haul) - Although it is recommended that the operation utilize existing roads as far as possible, it is anticipated that the operation will create 500 m of roads, with a width of 10 m each and more than one lane of traffic in both directions. The footprint of these roads will be determined by the geology of the area (excavation areas) and the locality of the infrastructure.
- Salvage yard (fenced)
- Security access point
- Stockpile area
- Storage facilities (mobile containers)
- Washbay
- Water tanks (drinking water)
- Weighbridge
- Weighbridge control room (mobile container)
- Workshops (mobile containers)

The exploration project area is underlain in part by potentially-fossiliferous sedimentary rocks of the Precambrian Transvaal and Kheis Supergroups and the Late Caenozoic Kalahari Group. A palaeontological heritage assessment of the project has therefore been requested by SAHRA (South African Heritage Resources Agency) in accordance with the requirements of the National Heritage Resources Act, 1999. The various categories of heritage resources recognised as part of the National Estate in Section 3 of the Heritage Resources Act include, among others:

- geological sites of scientific or cultural importance
- palaeontological sites
- palaeontological objects and material, meteorites and rare geological specimens

The present palaeontological heritage study has accordingly been commissioned on behalf of the proponent by M&S Consulting (Contact details: Ms Tanja Jooste, M&S Consulting, 36 William Street, Kestellhof, Kimberley, 8301. Postal Address: P.O. Box 2473, Kimberley, 8300. Tel: 053 861 1765; Fax: 086 636 0731; E-mail: ms.consulting@vodamail.co.za).

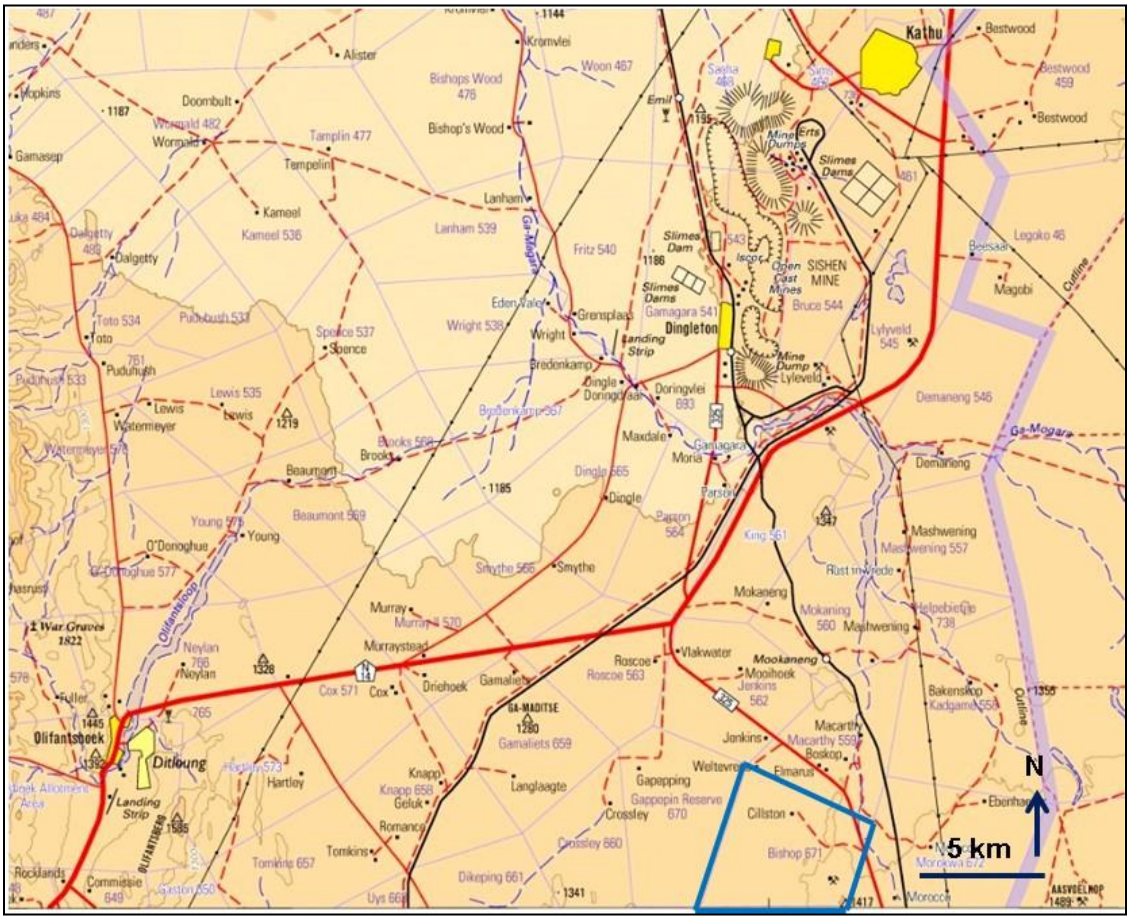

Figure 1: Extract from 1: 250 000 topographical map 2722 Kuruman (Courtesy of the Chief Directorate: National Geo-spatial Information, Mowbray) showing the *approximate* location of the Farm Bishop 671 (blue polygon) located *c.* 30 km southwest of Kathu, Kuruman Magisterial District, Northern Cape (Note that the exploration project area is situated only on Portions 2 and 3 of the farm – see following three figures).

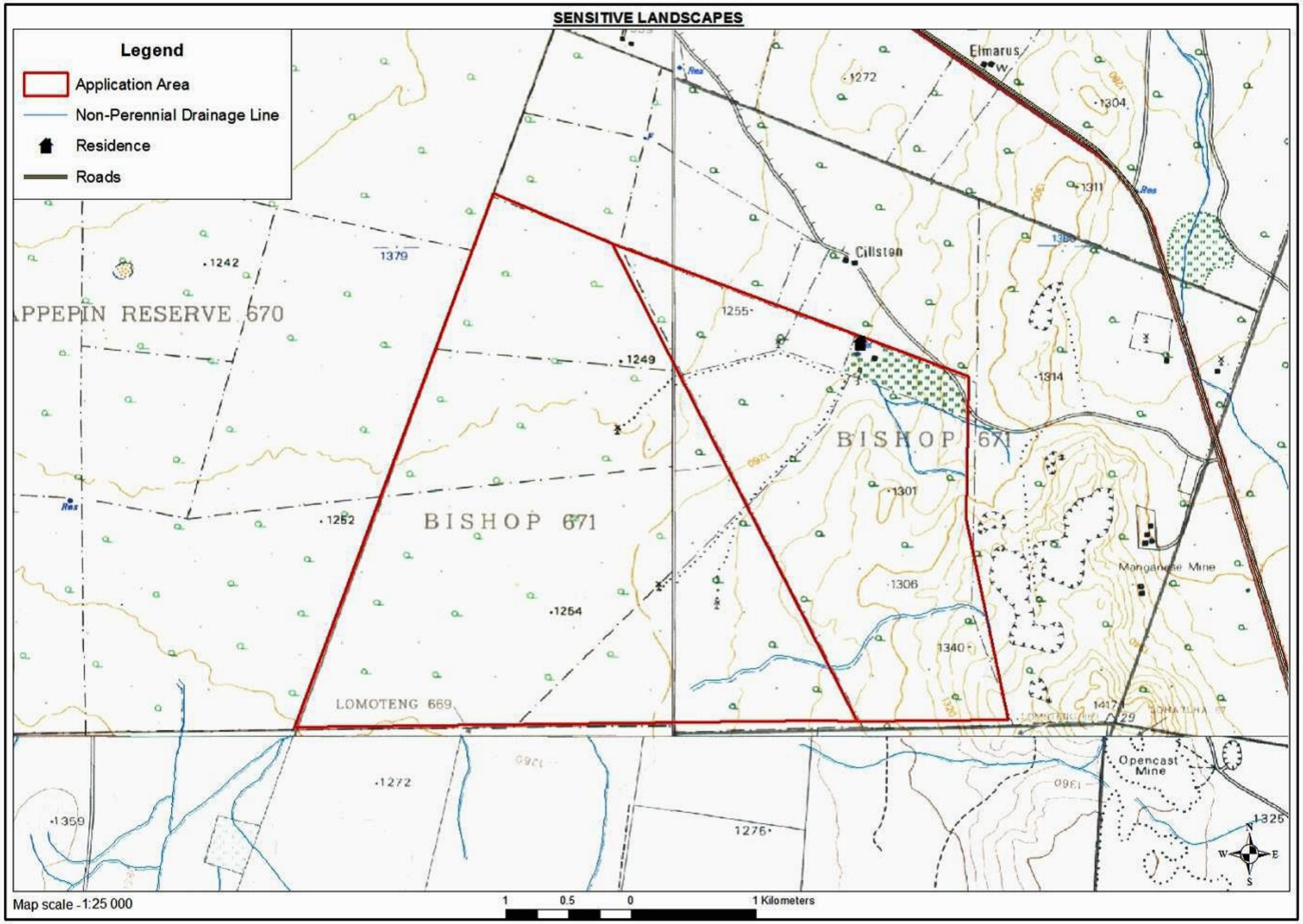

Figure 2: Extract from relevant 1: 50 000 topographic sheets showing the study area for the mineral prospecting on Portions 2 and 3 of the Farm Bishop 671 (red polygon) (Map extracted from the EIA and EMPR report by Jooste 2019). Note existing opencast mines on Farm Bishop 671 just the east of the present study area.

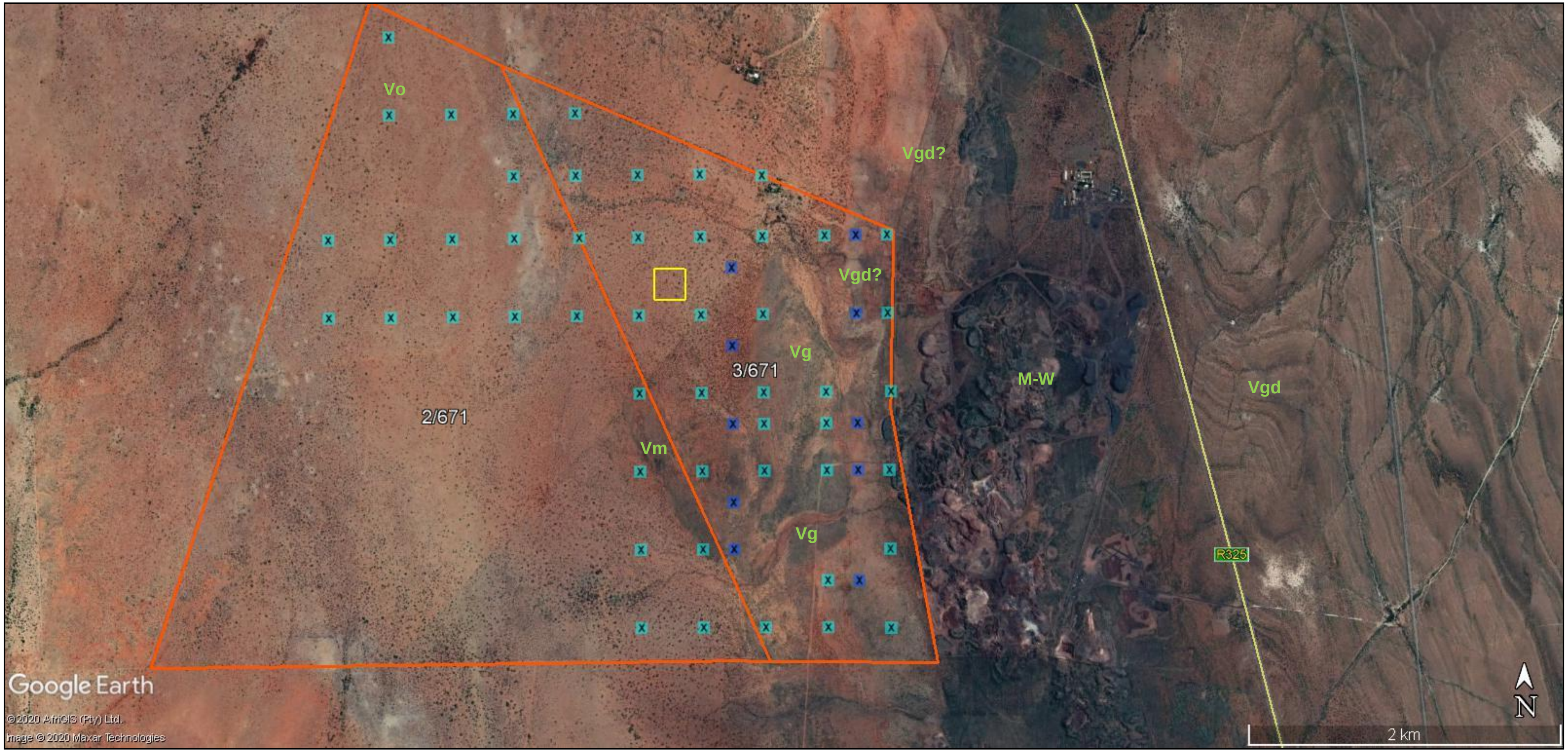

Figure 3: Google Earth© satellite image of the prospecting study area on Portions 2 and 3 of the Farm Bishop 671 (orange polygon). Also shown here are the provisional locations of the proposed boreholes (pale blue squares), trenches (dark blue squares) and infrastructure area (yellow square). Mapping of bedrock units in this area is ambiguous. The main *mapped* outcrop area of the potentially-fossiliferous Makganyene Formation is indicated by Vm (See also geological map Fig. 5). Vg indicates the mapped Gamagara Formation and probable Doornfontein Member conglomerates; Koegas Subgroup beds might also be represented here. Dark purple-brown areas with opencast mining on the more eastern portion of Bishop 671 indicate the Manganore Formation and Wolhaarkop Breccia (M-W). Clearly stratified carbonates of the Cambellrand succession (Vgd) are seen building the Maremane Dome further to the east and *may* extend marginally into the project area as well (*cf* Fig. 5). The Ongeluk Formation volcanics (Vo) are mapped in the NW corner of the project area, most of which is mantled by Pleistocene to Recent Kalahari Group sands.

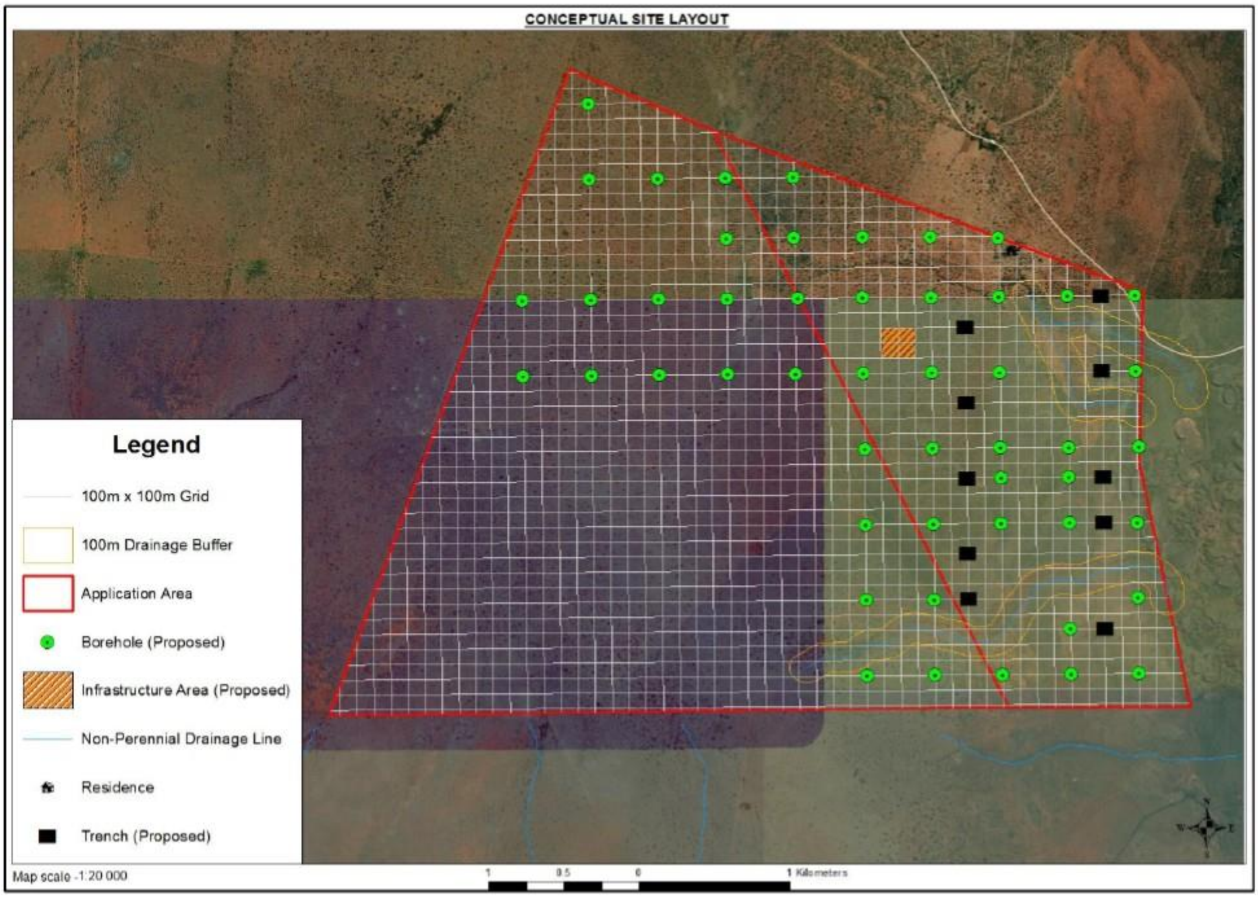

Figure 4: Conceptual site layout for the mineral prospecting activities on Portions 2 and 3 of the Farm Bishop 671 (Image provided by M&S Consulting, Kimberley). Note shallow drainage lines indicated in the eastern sector of the Application Area.

2. APPROACH TO THE PALAEONTOLOGICAL HERITAGE STUDY

In the case of the Farm Bishop 671 mineral exploration study area, the main potentially fossiliferous rock units present include:

- possible stromatolitic carbonate horizons or lenses within the **Makganyene Formation** (Postmasburg Group), a subunit of the Transvaal Supergroup and of Early Proterozoic age;
- **Kalahari Group** sands, calcretes.

The approach to this palaeontological heritage study is briefly as follows. Fossil bearing rock units occurring within the broader study area are determined from geological maps and satellite images. Known fossil heritage in each rock unit is inventoried from scientific literature, previous assessments of the broader study region, and the author's field experience and palaeontological database. Based on this data, the impact significance of the proposed development is assessed with recommendations for any further studies or mitigation.

In preparing a palaeontological desktop study the potentially fossiliferous rock units (groups, formations *etc*) represented within the study area are determined from geological maps and satellite images. The known fossil heritage within each rock unit is inventoried from the published scientific literature, previous palaeontological impact studies in the same region, and the author's field experience (Almond & Pether 2008). 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 likely impact of the proposed development on local fossil heritage is then determined on the basis of (1) the palaeontological sensitivity of the rock units concerned and (2) the nature and scale of the development itself, most significantly the extent of fresh bedrock excavation envisaged. When rock units of moderate to high palaeontological sensitivity are present within the development footprint, a Phase 1 field assessment study by a professional palaeontologist is usually warranted to identify any palaeontological hotspots and make specific recommendations for any monitoring or 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 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 palaeontological collection permits from the relevant heritage management authorities, *i.e.* the South African Heritage Resources Agency, SAHRA (Contact details: SAHRA, 111 Harrington Street, Cape Town. PO Box 4637, Cape Town 8000, South Africa. Phone: +27 (0)21 462 4502. Fax: +27 (0)21 462 4509. Web: www.sahra.org.za). 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. Information sources

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

1. Project descriptions, maps, kmz files and supporting documents provided by M&S Consulting, including the Environmental Impact Assessment Report and Environmental Management Programme Report by Jooste (2019);

2. A review of the relevant satellite images, topographical maps and scientific literature, including published geological maps and accompanying sheet explanations, as well as a previous desktop and field-based palaeontological assessment studies featuring comparable bedrocks in the Kathu - Postmasburg region elsewhere (*e.g.* Almond 2010a, 2012b, 2013, 2014, 2017, 2019a, 2019b);

3. The author's previous field experience with the formations concerned and their palaeontological heritage (Almond & Pether 2008);

2.2. 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 study area near Kathu in the Northern Cape levels of natural bedrock exposure are often good but access to them may be limited in some areas by dense swarthaak bushy vegetation. Comparatively few academic palaeontological studies or field-based fossil heritage impact studies have been carried out in the region, so any new data from field-based impact studies here are of scientific interest.

2.3. Legislative context for palaeontological assessment studies

The proposed alternative energy project is located in an area that is underlain by potentially fossiliferous sedimentary rocks of Precambrian and younger, Late Tertiary or Quaternary, age (Sections 3 and 4). The proposed mining development will entail voluminous excavations into the superficial sediment cover and the underlying bedrock as well. Potentially this development might adversely affect potential fossil heritage within the study area by destroying, disturbing or permanently sealing-in fossils at or beneath the surface of the ground that are then no longer available for scientific research or other public good. The decommissioning phase of the mine is unlikely to involve further adverse impacts on local palaeontological heritage.

The present combined desktop and field-based palaeontological heritage study falls under the South African Heritage Resources Act (Act No. 25 of 1999). It will also inform the Environmental Management Programme (EMPr) for this mining project.

The various categories of heritage resources recognised as part of the National Estate in Section 3 of the National Heritage Resources Act include, among others:

- geological sites of scientific or cultural importance;
- palaeontological sites;
- palaeontological objects and material, meteorites and rare geological specimens.

According to Section 35 of the National Heritage Resources Act, dealing with archaeology, palaeontology and meteorites:

(1) The protection of archaeological and palaeontological sites and material and meteorites is the responsibility of a provincial heritage resources authority.

(2) All archaeological objects, palaeontological material and meteorites are the property of the State.

(3) Any person who discovers archaeological or palaeontological objects or material or a meteorite in the course of development or agricultural activity must immediately report the find to the responsible heritage resources authority, or to the nearest local authority offices or museum, which must immediately notify such heritage resources authority.

(4) No person may, without a permit issued by the responsible heritage resources authority—

(a) destroy, damage, excavate, alter, deface or otherwise disturb any archaeological or palaeontological site or any meteorite;

(b) destroy, damage, excavate, remove from its original position, collect or own any archaeological or palaeontological material or object or any meteorite;

(c) trade in, sell for private gain, export or attempt to export from the Republic any category of archaeological or palaeontological material or object, or any meteorite; or

(d) bring onto or use at an archaeological or palaeontological site any excavation equipment or any equipment which assist in the detection or recovery of metals or archaeological and palaeontological material or objects, or use such equipment for the recovery of meteorites.

(5) When the responsible heritage resources authority has reasonable cause to believe that any activity or development which will destroy, damage or alter any archaeological or palaeontological site is under way, and where no application for a permit has been submitted and no heritage resources management procedure in terms of section 38 has been followed, it may—

(a) serve on the owner or occupier of the site or on the person undertaking such development an order for the development to cease immediately for such period as is specified in the order;

(b) carry out an investigation for the purpose of obtaining information on whether or not an archaeological or palaeontological site exists and whether mitigation is necessary;

(c) if mitigation is deemed by the heritage resources authority to be necessary, assist the person on whom the order has been served under paragraph *(a)* to apply for a permit as required in subsection (4); and

(d) recover the costs of such investigation from the owner or occupier of the land on which it is believed an archaeological or palaeontological site is located or from the person proposing to undertake the development if no application for a permit is received within two weeks of the order being served.

Minimum standards for the palaeontological component of heritage impact assessment reports (PIAs) have been published by SAHRA (2013).

3. GEOLOGICAL BACKGROUND

The mineral exploration study area on Portions 2 and 3 of Farm Bishop 671 is situated within the semi-arid Southern Kalahari Geomorphic Province (Partridge *et al.* 2010) on the western side of the N-S trending Gamagara Ridge, some 4 km west of the R385 dust road between Postmasburg and Olifantshoek (Figs. 1 to 4). The low rounded, rocky hills of the Gamagara Ridge reach elevations of 1300-1340 m amsl in this area, descending to *c*. 1250 m amsl on the sandy Kalahari thornveld plains to the west. The region to the south is drained by several SW-flowing intermittent streams while a couple of minor water courses run E-W across the western footslopes of the Gamagara Ridge in the eastern sector of the study area. Several large open-cast mines (*e.g.* Bishop) are situated along the Gamagara Ridge on the western edge of the Maremane Dome, just to the east of the study area (Figs. 2 & 3).

The geology of the study area to the southwest of Kathu is shown on 1: 250 000 geology sheet 2722 Kuruman (Council for Geoscience, Pretoria, 1977) (Figs. 5) and has been outlined in a previous field-based palaeontological assessment report by the author (Almond 2017) from which most of the following information has been abstracted. It is noted the 1: 250 000 Kuruman geological sheet, for which no sheet explanation has been published, is now very out-of-date, while the stratigraphy of the Precambrian rock units represented in the study region has been radically revised in recent years (*ibid*.). For the purposes of the present palaeontological study, with its main focus on potentially-fossiliferous Precambrian carbonate rock units, considerable reliance has been placed on the recently published schematic maps of the Griqualand West area published by Cairncross and Beukes (2013) and Smith and Beukes (2016) (Figs. 6 & 7).

As shown in the recently published maps (Figs. 6 & 7), the Bishop 671 study area lies on the western side of a major N-S trending anticline within the Early Proterozoic bedrocks of the **Ghaap Group** (**Transvaal Supergroup**) known as the Maremane Dome. A major unconformity at the base of the Palaeoproterozoic **Elim Group** (basal **Keis Supergroup**), dated at approximately 2.2 Ga, truncates the gently folded Ghaap Group succession on the western side of the Maremane Dome. In this area the Ghaap Group is represented by Campbell Rand carbonates with overlying quartzites and iron formation of the **Koegas Subgroup** mapped further to the south (*N.B.* Koegas Subgroup bedrocks may also be represented in the subsurface within the present study area). The basal Elim (or pre-Gamagara) regional unconformity is associated with the major development of iron and manganese ores that are extensively exploited in the Sishen – Postmasburg region of Griqualand West. The metallic ores are associated with (1) the palaeokarst-related **Manganore Formation** overlying Campbell Rand Subgroup carbonates of the Maremane Dome as well as (2) the **Gamagara Formation** at the base of the Elim Group (Van Niekerk 2006, Da Silva 2011, Cairncross & Beukes 2013, Smith & Beukes 2016).

The Gamagara Formation unconformably overlies Late Archaean to Early Proterozoic Campbell Rand dolomites in the eastern part of the study region where basal haematite pebble conglomerates (**Doornfontein Member**) are followed firstly by thin shales and quartzites. These beds may be overlain by several thick, upward-coarsening shale to quartzite packages of the **Lucknow Formation** (Not separately mapped in Fig. 5). The Elim beds in the project area are tectonically overlain by wedges of older Palaeoproterozoic sediments assigned here to the **Postmasburg Group**. These upper Transvaal Supergroup successions have been displaced eastwards onto the western flank of the Maremane Dome along multiple thrust planes constituting the Blackridge Thrust (*cf* Moen 2006, his Fig. 3, and Mienie 2017). Less than 10 km to the south (Farm Magoloring 668 Japies Rus *cf* Almond 2017), the thrust sheets also include components of the **Koegas Subgroup** (uppermost Ghaap Group) which is represented there by several thin, upward-shoaling marine packages within which offshore ferruginous muds pass up into pale shoreface quartzites. The Koegas succession in this more southerly area is capped by banded ironstones of the **Roinekke Formation** which is typically 20-45 m thick and has been dated to *c.* 2.4 Ga (Schröder *et al.* 2011).

Regionally, the upper contact of the Koegas beds with the overlying Postmasburg Group is marked by a major erosional unconformity at the base of the 50 to 100 m – thick diamictites of the **Makganyene Formation** which reaches a thickness of 500 m near Postmasburg. According to some authors these diamictites reflect a 250 million year glacial episode 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 as a catastrophic global "Snowball Earth" event 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). Makganyene sedimentary facies include massive to coarsely-bedded diamictites, sandstones, shales, BIF and even manganese-rich carbonates with stromatolitic bioherms (reefs) (Figs 8 & 9). Most of the diamictite clasts are derived from the older Transvaal Supergroup succession (*e.g.* BIF, carbonates, cherts). Abundant striated clasts within the more proximal Makganyene facies support a glacial origin or provenance for the diamictites (tillites and / or debrites). Basaltic to andesitic lavas of the **Ongeluk Formation** overlying the Makganyene diamictites are dated to 2.2 Ga and crop out in the north-western sector of the study area.

The regional Pre-Gamagara erosional unconformity dated to ± 2.2 - 2 Ga (pre-dating eastward thrusting) cuts across the gently-dipping outcrops of the Campbell Rand, Asbesheuwels, Koegas and Postmasburg successions on the western flank of the Maremane Dome. Supergene (secondarily-enriched) iron ores (*e.g.* Doornfontein Member) are developed at the contact with BIF facies of the Asbesheuwels Subgroup and Koegas Subgroup (*e.g.* Rooinekke Formation).

The lithostratigraphy and mapping of pre-Kalahari bedrock units on Bishop 671 as depicted on the published 1: 250 000 Kuruman sheet (Fig. 5) is outdated, as indicated by the more recent, schematic regional maps shown in Figures 6 and 7. On the eastern margins of the study area the basal Elim Group (Gamagara Formation) overlies the Campbell Rand carbonates building the western edge of the Maremane Dome along a strong regional erosional unconformity that is characterised by the ferruginous Doornfontein Member conglomerates (Figs. 5 & 7). It is noted that the Doornfontein Member in Fig. 5 (dark brown) is mapped in direct contact with the Campbell Rand carbonates (pale blue) on Farm Bishop 671, suggesting erosional denudation of iron-rich Koegas (or Manganore / Wolhaarkop) bedrocks here. The revised but somewhat schematic geological map in Fig. 6 indicates that extensive ore bodies on the western flank of the Maremane Dome near Bishop include representatives of the Wolhaarkop breccia and Manganore Formation as well as (probably) the basal Elim Group. Small outcrop areas of the Makganyene and Ongeluk Formation of the Postmasburg Group in the central and north-western sectors of the project area have been thrust eastwards over the younger Elim Group rocks. Much of the central and south-western sectors of the area are mantled by **Kalahari Group** aeolian and alluvial sands (**Gordinia Formation**) of Pleistocene to Recent age (Partridge *et al.* 2006).

The following useful account of iron and manganese mineralisation in the broader study region is abstracted from Jooste (2019):

> The Postmasburg iron & manganese field is situated on the Maremane Anticline dome, which is located within the Kaapvaal Craton, although close to its western margin. The country rocks are Palaeoproterozoic metasediments of the Transvaal Supergroup. Two arcuate belts of deposits extend from Postmasburg in the south to Sishen in the north. Two major ore types are present. The ferruginous type of ore is composed mainly of braunite, partidgeite and bixbyite and occurs along the centre of the Gamagara Ridge, or Western Belt. The siliceous type of ore consists of braunite, quartz and minor partidgeite and occurs in deposits along the Klipfontein Hills (or Eastern Belt) and the northern and southern extremities of the Gamagara Ridge. Dolomites of the Campbellrand Group form the basement rock for these deposits and are overlain by the Manganore Iron-Formation and the Gamagara Formation. The dolomite palaeosurface is karsted, leading to collapse structures where iron and manganese formation has fallen into karst cavities to form the well-known Wolhaarkop Breccia body.
>
> Geological and geochemical evidence suggest that the manganese ores represent weakly metamorphosed wad deposits that accumulated in karst depressions during a period of lateritic weathering and karstification in a supergene, terrestrial environment during the Late Paleoproterozoic period. The dolomites of the Campellrand Group of the Transvaal Supergroup are host and source for the wad accumulations. The ore at Bishop originated as pods and lenses of wad in chert breccia that accumulated in a karst cave system capped by the hematitized Manganore iron-formation of the Transvaal Supergroup. The cave system finally collapsed and the hematitized iron-formation slumped into the sinkhole structures. The manganese ore were affected by diagenesis and lower greenschist facies metamorphism. Evidence for renewed subaerial exposure of the ore and their host rocks can be seen in the secondary karstification and supergene weathering.

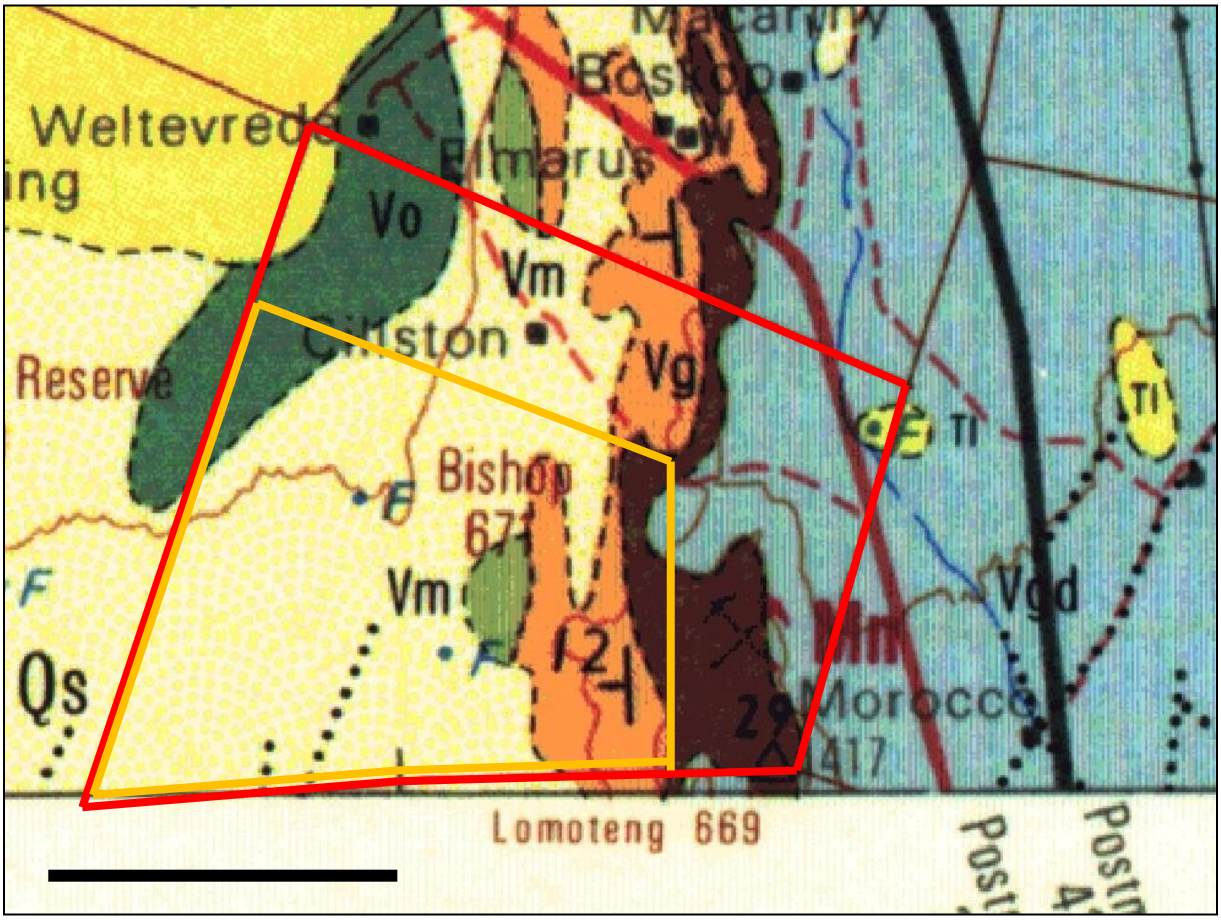

Figure 5: Extract from 1: 250 000 geology sheet 2722 Kuruman (Council for Geoscience, Pretoria) showing the main rock units mapped on Farm Bishop 671 (Farm boundary indicated by the red polygon; orange polygon approximately outlines the present mineral exploration study area on Portions 2 and 3) *N.B.* The mapping and lithostratigraphy shown here are now out-of-date (See text and following two map figures). Main rock units: Vgd (pale blue) = Campbell Rand Subgroup; Vg (orange) = Gamagara Formation with basal Doornfontein Member conglomerates (dark brown); Vm (pale green) = Makganyene Formation; Vo (dark green) = Ongeluk Formation; Tl (dark yellow) = Caenozoic calcrete; Qs (pale yellow) = red Kalahari Group aeolian sands (Gordonia Formation). Scale bar = 3 km. N towards the top of the map.

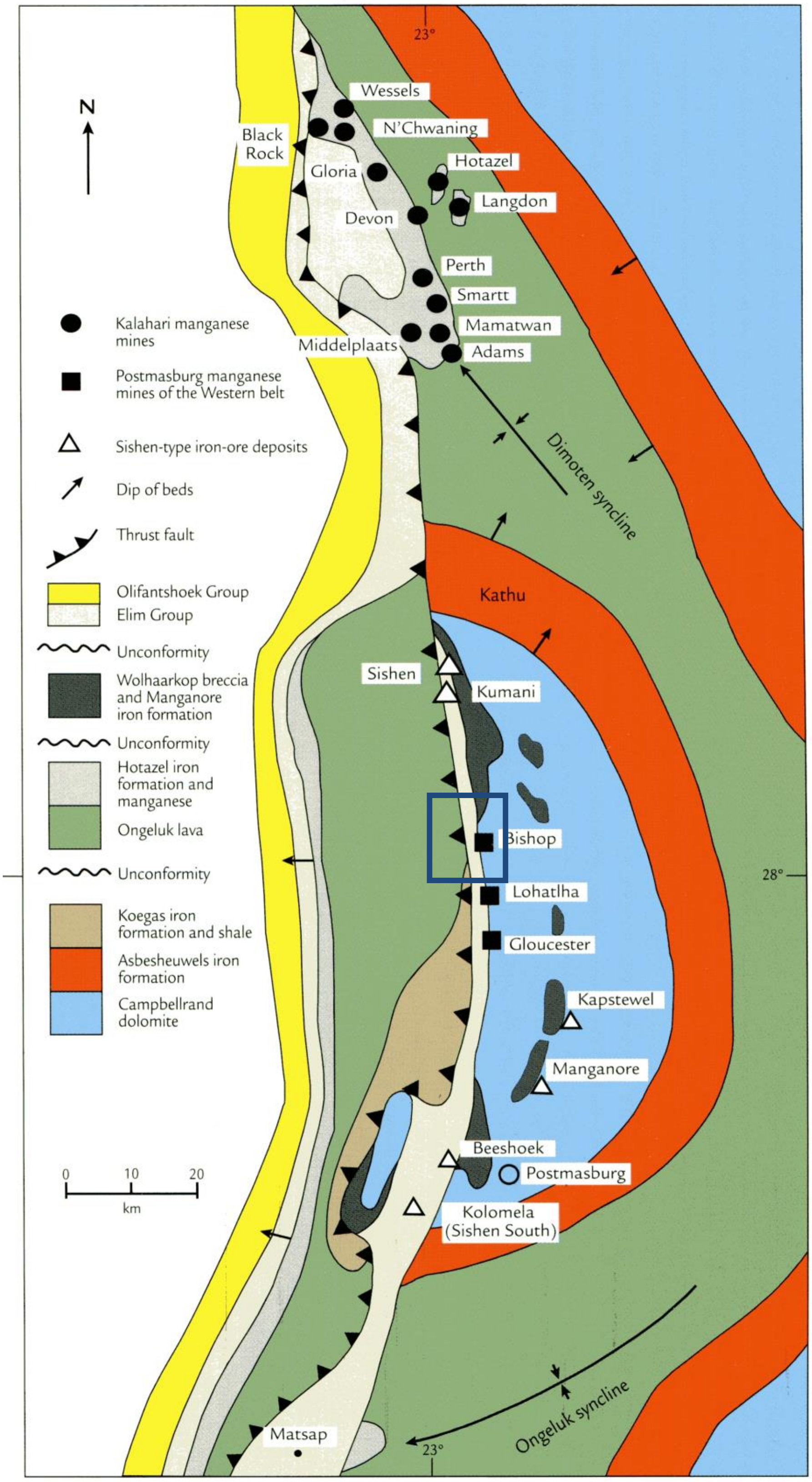

Figure 6: Schematic geological map of the Griqualand West region, Northern Cape, showing the revised stratigraphic interpretation of the rock units represented in the Farm Bishop 671 study region (dark blue square) (Map abstracted from Cairncross & Beukes 2013). The Ongeluk lava outcrop area (grey-green) also includes the Makganyene Formation diamictites (both within the Postmasburg Group). The basal Elim Group includes the Gamagara Formation. Iron / manganese ores on the western flanks of the dome near Bishop are assigned to the Manganore Formation / Wolhaarkop breccia here.

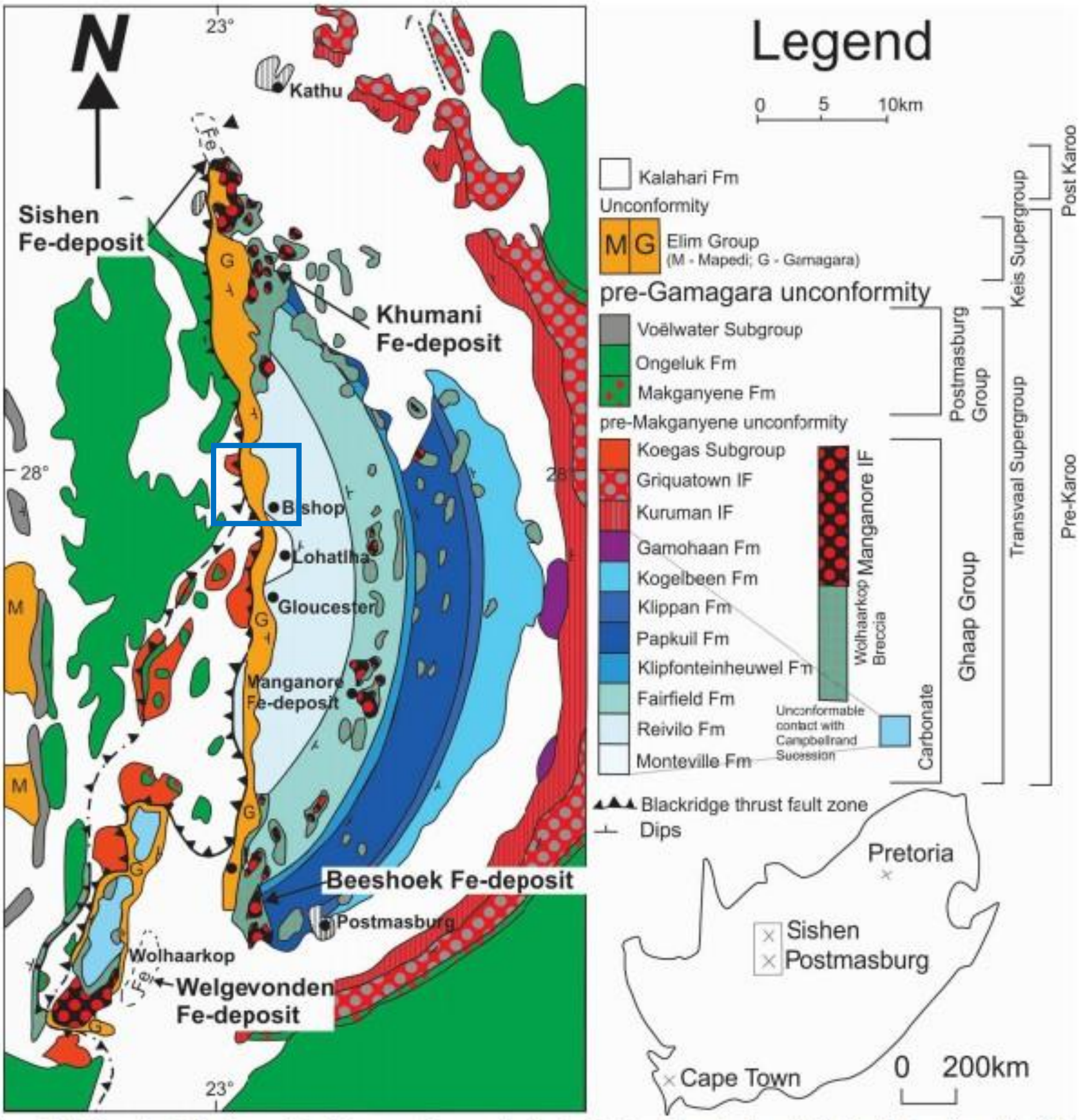

Figure 2: Regional geological map of the Maremane Dome region in the Northern Cape Province indicating the location of the Sishen, Khumani, Beeshoek and Sishen South iron ore deposits (modified after Van Schalkwyk and Beukes, 1986).

Figure 7: Revised geological map and lithostratigraphy of the Maremane Dome area of Griequaland West (from Smith & Beukes 2016). The present study area lies within the blue square. Iron / manganese ores on the western flanks of the dome near Bishop are assigned to the Gamagara Formation here. The Makganyene Formation outcrop area is shown in red with green spots (contrary to the legend).

4. PALAEONTOLOGICAL HERITAGE

Among the Palaeoproterozoic Transvaal Supergroup bedrock units of the Griqualand Basin mapped within the present study area, the highly altered and mineralised Manganore Formation, Gamagara Formation (including Doornfontein Member) and Ongeluk Formation are all unfossiliferous. Fossil stromatolites *i.e.* laminated microbial reefs preserved within carbonate sediments (sometimes secondarily silicified) have been reported from the Campbellrand Subgroup and Koegas Subgroup (Ghaap Group) of the Griqualand Basin (*cf* Almond 2017). Based on the available geological maps, the presence of outcrops of potentially-stromatolitic carbonates of the Campbellrand and Koegas Subgroups (Ghaap Group) is very ambiguous within the project area; if present, they are likely to be small and marginal, and so will not be considered further here. While beds of the Lucknow Formation (upper Elim Group) may be present overlying the mapped Gamagara Formation (*e.g.* in the subsurface), this unit is not known to be fossiliferous (Almond 2019b).

4.1. Stromatolitic bioherms within the Makganyene Formation

Supposed stromatolitic bioherms or reefs made up of manganese-rich laminated carbonates have been reported within glacially-related diamictites of the Early Proterozoic Makganyene Formation (Postmasburg Group) in the more distal sector of the Griqualand Basin (*i.e.* Prieska Subbasin) (Kopp *et al.* 2005, Polteau 2000, 2005, Polteau *et al*. 2006) (Figs. 8 and 9). The purported bioherms are up to 5 m long and 3 m thick and are apparently associated with a period of regression (lowered sea levels) within the basin, bringing the sea floor back up into the photic zone. The direct association of "warm water" reefal carbonates with cold water glacial sediments - the latter completely enclosing the former - is somewhat unexpected (although cold water stromatolites are recorded from the modern Antarctic), as is the claimed occurrence of bioherms containing embedded glacial erratics; the consistency of living stromatolites was probably rather firm. A diagenetic (abiotic) origin for these lenticular carbonate bodies also needs to be considered, involving enclosure of erratic megaclasts by precipitation of secondary manganese-rich carbonate within diamictite facies. It is noted that striking examples of Liesegang rings related to diagenetic (post-depositional) iron / manganese mineralisation can be seen within massive, jointed Makganyene Formation exposures near Postmasburg and might conceivably be mistaken for stromatolitic lamination (*cf* Almond 2012b). An alternative view is that these Early Proterozoic "stromatolites" actually developed within low palaeolatitude *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).

Fossil bioherms have not yet been reported from the shallow platform facies of the Makganyene Formation in the Griqualand Basin (Ghaap Plateau Sub-basin). Any fossil occurrences of indubitable Makganyene stromatolites in association with glacial rocks found here would therefore be of special research and conservation significance. No carbonate bodies or stromatolites were recorded from the limited exposures of Makganyene Formation diamictites examined on Magoloring 668 some 10 km south of the present study area (Almond 2017).

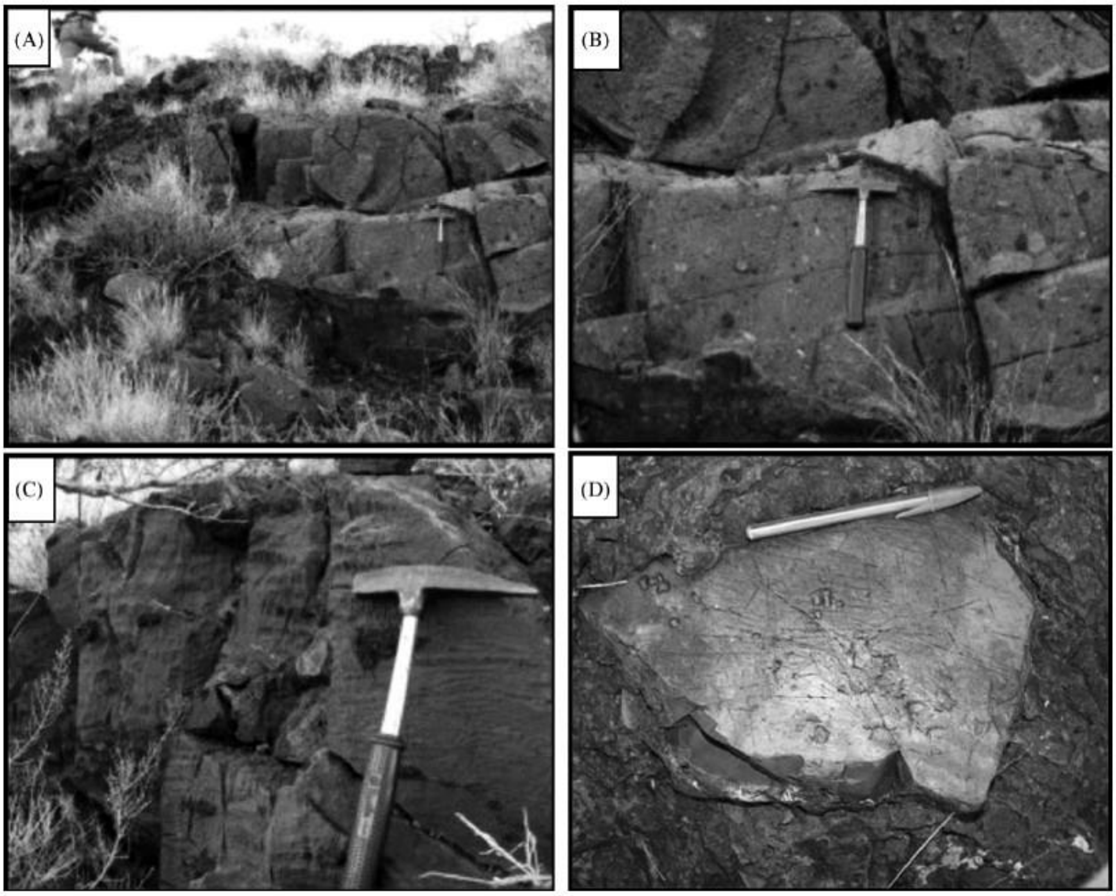

Fig. 4. (A and B) Clast bearing stromatilitic bioherms within the Makganyene diamictites. (C) Clast-free stromatolitic bioherm within the Makganyene diamictites. (D) Large striated pebble from the Makganyene Formation at the Griquatown hinge zone.

Figure 8: Purported stromatolitic bioherms, some containing megaclasts interpreted as ice-rafted debris (dropstones), apparently in direct association with glacial tillites of the Makganyene Formation (Illustration abstracted from Polteau *et al.* 2006). The true stromatolitic nature of these carbonate bodies warrants further investigation.

4.2. 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, including calcretes, notably those associated with ancient alluvial gravels. Younger (Quaternary to Recent) surface gravels and colluvium are probably unfossiliferous.

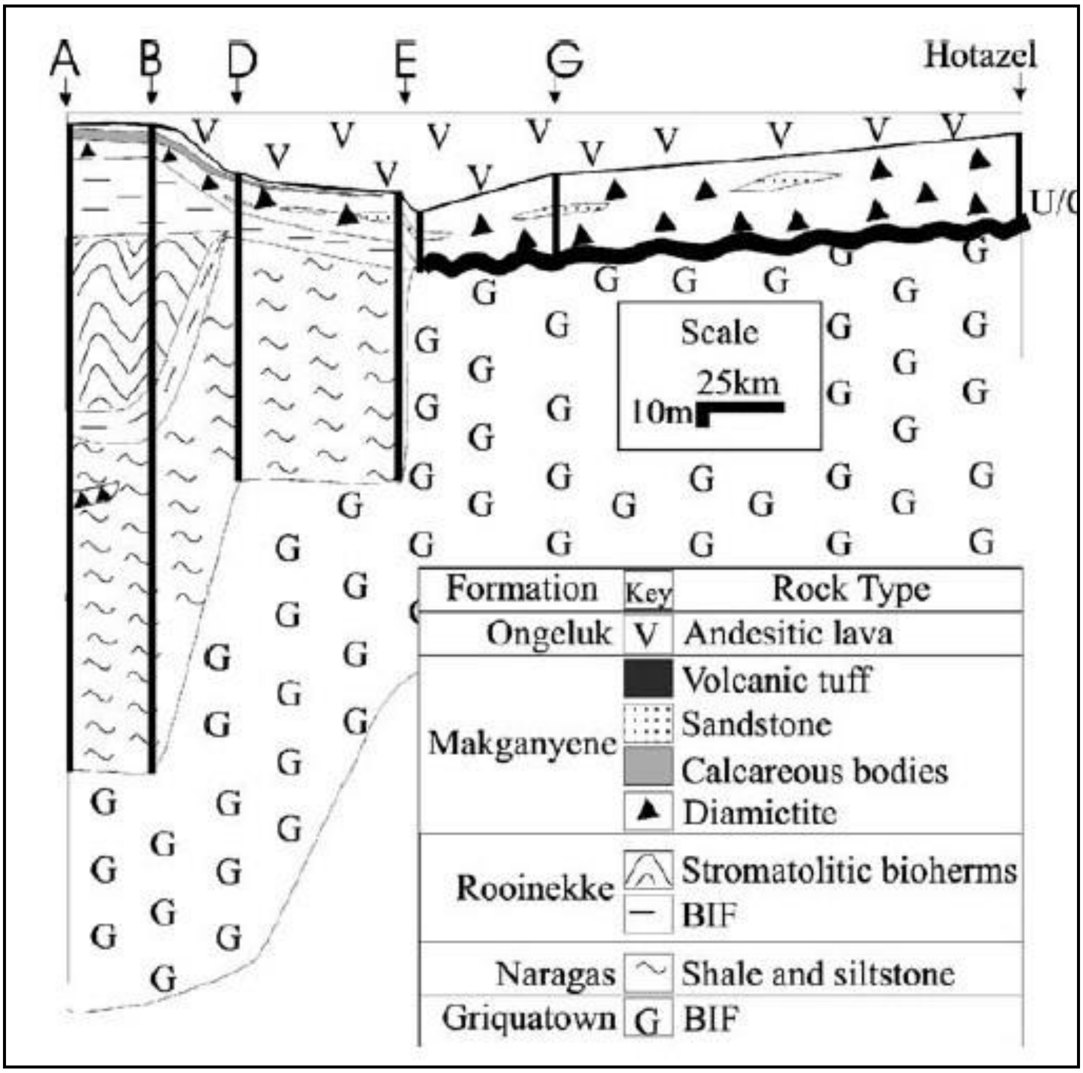

Figure 9: Series of profiles through the Makganyene Formation, roughly from SW to NE across the Griqualand Basin, Northern Province (From Polteau *et al.* 2006). On the platform area to the NE of the major Griquatown Fault Zone (Ghaap Plateau Sub-basin), the Makganyene glacial diamictites contain lenticular sandstone bodies but no carbonate lenticles with stromatolitic bioherms. These last are apparently confined to the more offshore parts of the basin preserved further to the southwest (= Prieska Sub-basin).

5. SUMMARY & RECOMMENDATIONS

The targets for open-cast mining on Portions 2 and 3 Farm 671 are high grade iron and manganese ores within highly modified Precambrian sediments of the Ghaap Group and Elim Group (Manganore / Gamagara Formations) that are not in themselves of palaeontological heritage significance. The presence of potentially-stromatolitic carbonates of the Campbellrand Subgroup (and perhaps even the Koegas Subgroup) within the exploration project area is ambiguous; outcrop areas are small and significant palaeontological impacts on these Ghaap Group rock units are considered unlikely. The Postmasberg Group is represented here by unfossiliferous Ongeluk Formation volcanics as well as a small outcrop area of the glacially-related Makganyene Formation. Equivocal stromatolites have been recorded from this last unit but not within platform facies of the Ghaap-Plateau Subbasin which are represented here. Quaternary to Recent superficial sediments of the Kalahari Group – mainly Gordonia Formation aeolian sands – are generally of low palaeontological sensitivity. It is concluded that the proposed invasive exploration activities on Portions 2 and 3 of Farm Sishop 671 do not pose a significant threat to local fossil heritage and there are no objections on palaeontological grounds to their approval.

The ECO responsible for the mineral exploration project should be aware of the potential for important fossil stromatolite finds within Precambrian carbonate bedrocks and the necessity to conserve them for possible professional mitigation. A Chance Fossil Finds Procedure for this development is outlined in tabular form at the end of this report. Recommended mitigation of chance fossil finds during the proposed exploration phase activities involves safeguarding of the fossils (preferably *in situ*) by the responsible ECO and reporting of all significant finds to the South African Heritage Resources Agency, SAHRA (Contact details: SAHRA, 111 Harrington Street, Cape Town. PO Box 4637, Cape Town 8000, South Africa. Phone: +27 (0)21 462 4502. Fax: +27 (0)21 462 4509. Web: www.sahra.org.za). Where appropriate, judicious sampling and recording of fossil material and associated geological data by a qualified palaeontologist, appointed by the developer, may be required by the relevant heritage regulatory authorities. Any fossil material collected should be curated within an approved repository (museum / university fossil collection).

These recommendations should be included within the Environmental Management Programme (EMPr) for the proposed mining project.

6. ACKNOWLEDGEMENTS

Ms Tanja Jooste of M&S Consulting, Kestelhof, is thanked for commissioning this study and for providing the relevant background information.

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

Declaration of Independence

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

John E. Almond

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

<table>
<tr><td colspan="3">CHANCE FOSSIL FINDS PROCEDURE: Mineral exploration on Portions 2 and 3 of Farm Bishop 671 near Kathu</td></tr>
<tr><td>Province & region:</td><td colspan="2">NORTHERN CAPE, Kuruman Magisterial District</td></tr>
<tr><td>Responsible Heritage Resources Authority</td><td colspan="2">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</td></tr>
<tr><td>Rock unit(s)</td><td colspan="2">Possible carbonate lenses within the Campbellrand Subgroup, Koegas Subgroup, Makganyene Formation, plus Late Caenozoic alluvium, calcretes of Kalahari Group</td></tr>
<tr><td>• Potential fossils</td><td colspan="2">• Stromatolites (laminated microbial reefs) within Precambrian carbonate bedrocks; bones, teeth, horn cores of mammals as well as calcretised burrows (e.g. termite nests) within Kalahari Group sands and alluvial deposits.</td></tr>
<tr><td rowspan="5">• ECO protocol</td><td colspan="2">• 1. Once alerted to fossil occurrence(s): alert site foreman, stop work in area immediately (N.B. safety first!), safeguard site with security tape / fence / sand bags if necessary.</td></tr>
<tr><td colspan="2">• 2. Record key data while fossil remains are still in situ:
• Accurate geographic location – describe and mark on site map / 1: 50 000 map / satellite image / aerial photo
• Context – describe position of fossils within stratigraphy (rock layering), depth below surface
• Photograph fossil(s) in situ with scale, from different angles, including images showing context (e.g. rock layering)</td></tr>
<tr><td>• 3. If feasible to leave fossils in situ:
• Alert Heritage Resources Authority and project palaeontologist (if any) who will advise on any necessary mitigation
• Ensure fossil site remains safeguarded until clearance is given by the Heritage Resources Authority for work to resume</td><td>• 3. If not feasible to leave fossils in situ (emergency procedure only):
• Carefully remove fossils, as far as possible still enclosed within the original sedimentary matrix (e.g. entire block of fossiliferous rock)
• Photograph fossils against a plain, level background, with scale
• Carefully wrap fossils in several layers of newspaper / tissue paper / plastic bags
• Safeguard fossils together with locality and collection data (including collector and date) in a box in a safe place for examination by a palaeontologist
• Alert Heritage Resources Authority and project palaeontologist (if any) who will advise on any necessary mitigation</td></tr>
<tr><td colspan="2">• 4. If required by Heritage Resources Authority, ensure that a suitably-qualified specialist palaeontologist is appointed as soon as possible by the developer.</td></tr>
<tr><td colspan="2">• 5. Implement any further mitigation measures proposed by the palaeontologist and Heritage Resources Authority</td></tr>
<tr><td>• Specialist palaeontologist</td><td colspan="2">• Record, describe and judiciously sample fossil remains together with relevant contextual data (stratigraphy / sedimentology / taphonomy). Ensure that fossils are curated in an approved repository (e.g. museum / university / Council for Geoscience collection) together with full collection data. Submit Palaeontological Mitigation report to Heritage Resources Authority. Adhere to best international practice for palaeontological fieldwork and Heritage Resources Authority minimum standards.</td></tr>
</table>