PALAEONTOLOGICAL HERITAGE REPORT: COMBINED DESKTOP & FIELD STUDY

Proposed Mining Right Application for the Farm Magoloring 668 (Japies Rus) near Postmasburg, ZF Mgcawu District, Tsantsabane Municipality, Northern Cape

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1. EXECUTIVE SUMMARY

Japies Rus Minerale (Pty) Ltd is submitting a Mining Right Application to mine for iron and managenese ore on Portion 1 and Portion 6 (a portion of Portion 2) of the Farm Magoloring 668 located near Postmasburg in the Northern Cape Province. The targets for open-cast mining are high grade iron and manganese ores within Precambrian sediments of the Ghaap Group and Elim Group (Manganore / Gamagara / Roinekke Formations) that are not in themselves of palaeontological heritage significance. The proposed footprint of associated mine infrastructure (processing plant, stockpile area *etc*) overlies Precambrian glacially-related sediments of the Makganyene Formation (Postmasburg Group) as well as Quaternary to Recent superficial sediments of the Kalahari Group. Important occurrences of stromatolites (fossil microbial reefs) are reported from carbonate lenses within the Early Proterozoic Koegas Subgroup (upper Ghaap Group) and Makganyene Formation in the Griqualand West Basin, Northern Cape. Although isolated patches of Precambrian carbonate bedrocks of uncertain stratigraphic position were noted on Magoloring 668, no fossil stromatolites were recorded here during the one-day site visit. The Late Caenozoic superficial sediments - *viz.* Kalahari Group sands, colluvial rock rubble, downwasted surface gravels, calcretes – are likewise very sparsely fossiliferous, at most. It is concluded that the proposed mining development does not pose a significant threat to local fossil heritage and there are no objections on palaeontological grounds to the current Mining Rights Application.

The ECO responsible for the mining 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 construction and operational phases of the proposed mine 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. 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 Japies Rus Minerale (Pty) Ltd is submitting a Mining Right Application to mine for iron and managenese ore on Portion 1 and Portion 6 (a portion of Portion 2) of the Farm Magoloring 668 located near Postmasburg in the Northern Cape Province. The Japies Rus project area is situated approximately 30 km southeast of the town of Olifantshoek and approximately 25 km northwest of Postmasburg within the ZF Mgcawu District and Tsantsabane Municipality (Figs. 1 & 2).

The following outline of the proposed mining project has been abstracted from the Phase 1 Heritage Impact Assessment prepared by GA Heritage (Gaigher 2017):

> Mining is done by the conventional opencast mining method. It is designed based on the nature of the ore--bodies on the mine, which proposes that each resource be treated as a separate pit (selective mining). Where present, vegetated soil overlying the planned mining area is stripped prior to mining and stockpiled on a dedicated (temporary) dump to be used for rehabilitation purposes at a later stage. A haul road network provides access to the opencast mining areas, to the dry (modular) crushing and screening plants (Fe & Mn) and to the wet (modular) scrubber / DMS plants (Fe). The mining process is initiated by drilling, then blasting and is then followed by loading and hauling both ore and waste to their respective destination on the mine site. The mine will be operational 24 hours a day, 7 days a week to achieve the targeted production.
>
> The main infrastructure to be established at the mine comprises the following elements (Fig. 3):
>
> - Ablution facilities (chemical toilets to be upgraded to brick buildings with septic tanks)
> - Diesel tanks
> - Explosive magazine
> - Generators
> - Laboratory (mobile container to be upgraded to brick building)
> - Offices (mobile containers to be upgraded to brick buildings)
> - Parking bay
> - Processing plant
> - Recycling dam
> - Salvage yard
> - Security access point
> - Stockpile area
> - Storage facilities (mobile containers)
> - Washbay
> - Waste disposal sites (concrete floor with bud walls)
> - Water dams (clean water)
> - Water tanks (drinking water)
> - Weighbridge and control room (mobile container)
> - Workshops (mobile containers to be upgraded to brick buildings)

The mining right area is underlain in part by by potentially fossiliferous sedimentary rocks of the Precambrian Transvaal and Keis 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 developer by M&S Consulting (Contact details: Ms Tanja Jooste, M&S Consulting. 17 Carters Road, Kestelhof 8300, RSA. Tel:053 861 1765; Fax:086 636 0731; E-mail: joostetanja@gmail.com).

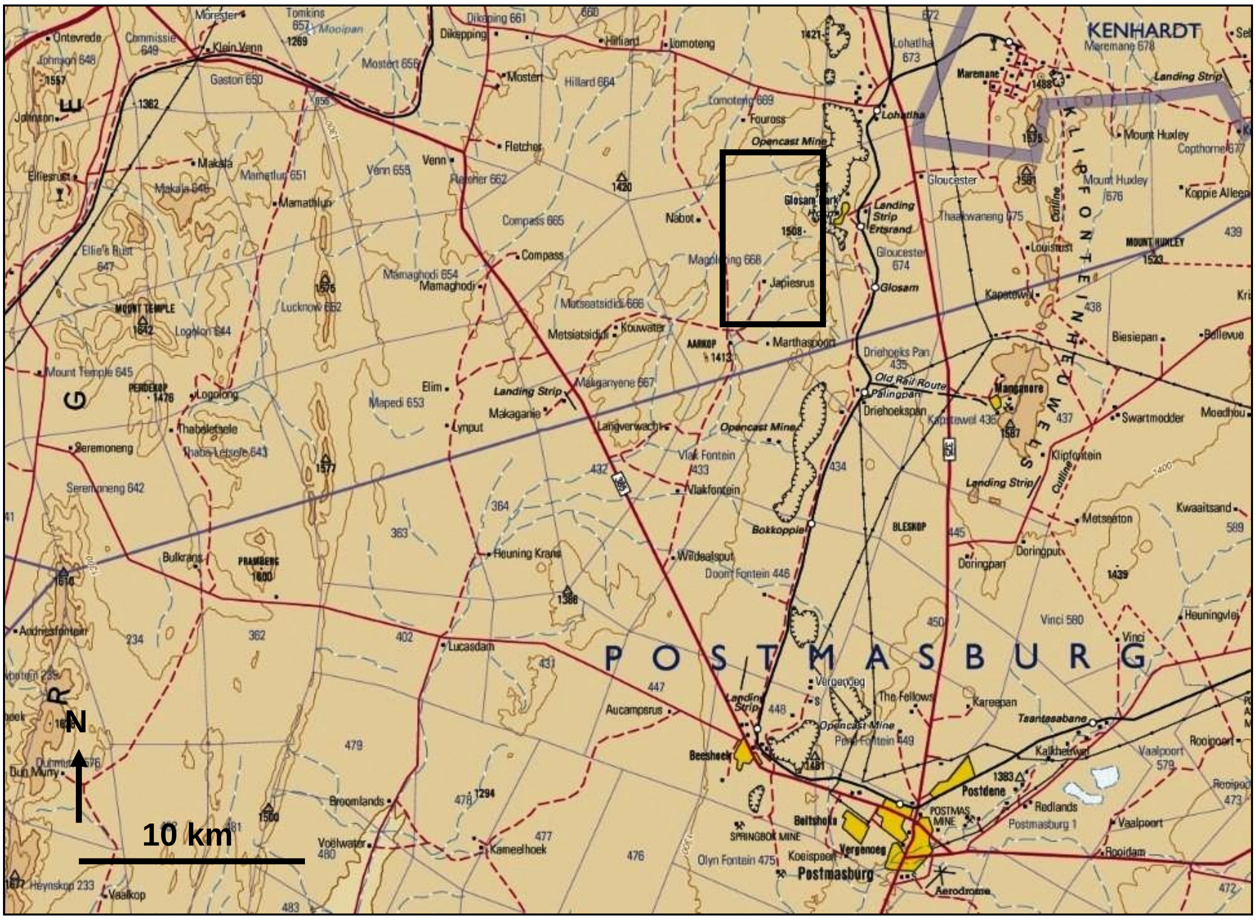

Fig. 1. Extract from 1: 250 000 topographical map 2822 Postmasburg (Courtesy of the Chief Directorate: National Geo-spatial Information, Mowbray) showing the *approximate* location of the mining rights study area on Farm Mokgoloring 668 (Japies Rus) located *c.* 30 km southeast of Olifantshoek and *c.* 25 km northwest of Postmasburg, Northern Cape.

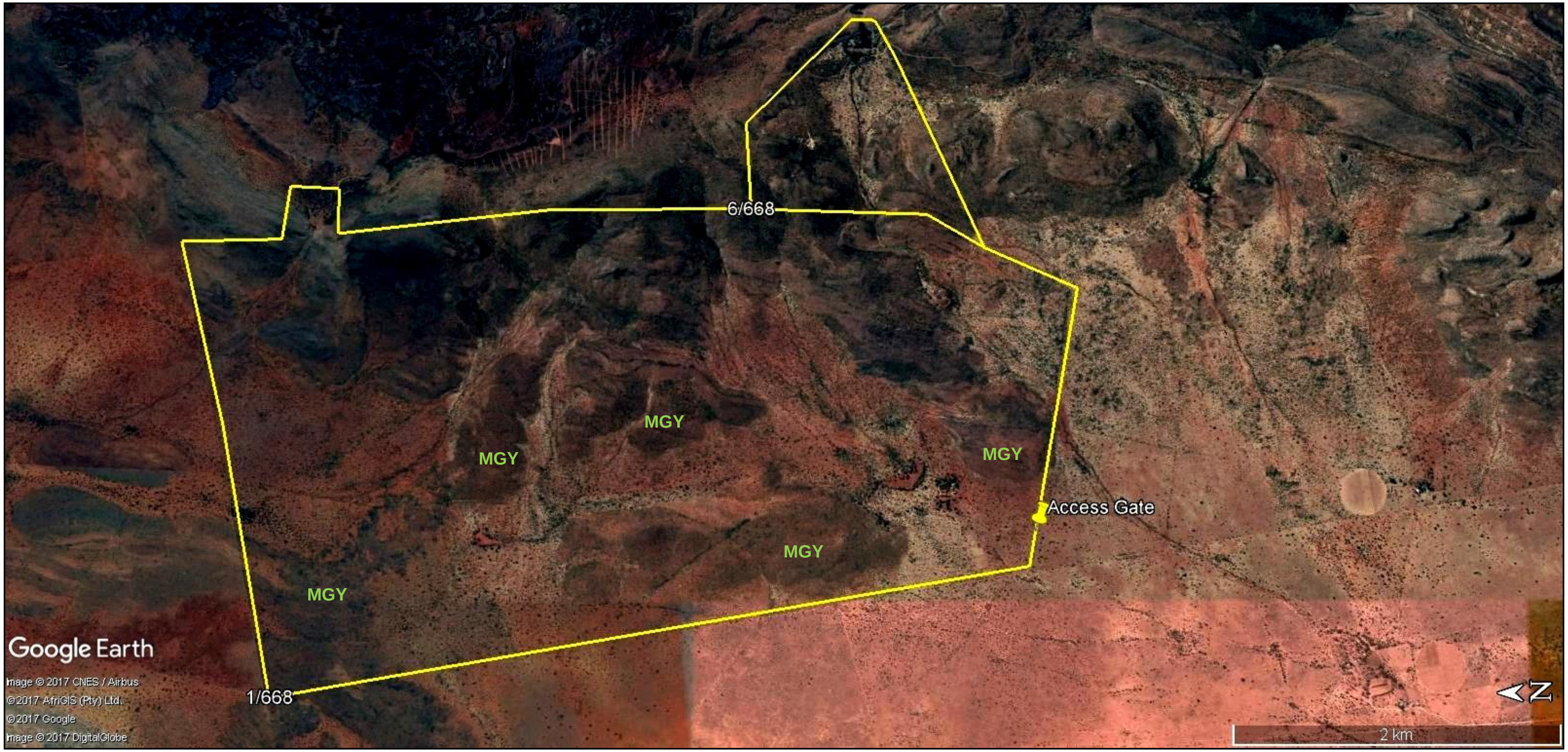

Fig. 2. Google Earth© satellite image of the mining rights study area on Portion 1 and Portion 6 (a portion of Portion 2) of the Farm Magoloring 668 located near Postmasburg in the Northern Cape Province (Note N is towards the LHS). The main *mapped* outcrop areas of the Makganyene Formation are indicated by MGY (See also geological map Fig. **) but some of these areas may in fact belong to the unconformably underlying, folded Koegas Subgroup.

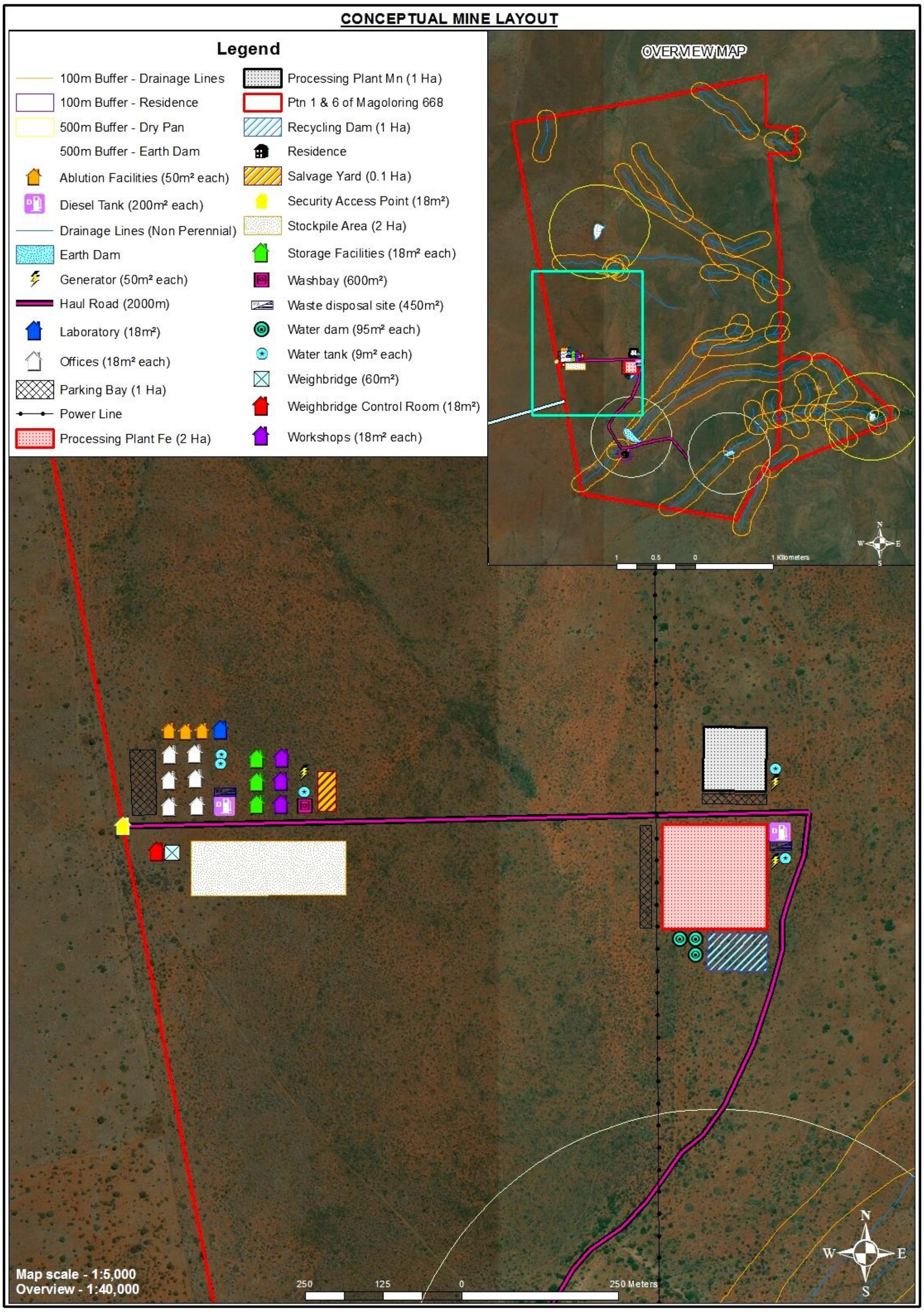

Fig. 3. Proposed Mine Layout Plan for the iron and manganese ore mine on Farm Magoloring 668 located near Postmasburg in the Northern Cape Province (Image provided by M&S Consulting).

2. APPROACH TO THE PALAEONTOLOGICAL HERITAGE STUDY

In the case of the Magoloring 668 Mining Right application study area, the main potentially fossiliferous rock units present include:

- possible stromatolitic carbonate horizons or lenses within the **Koegas Subgroup** and **Makganyene Formation** (Postmasburg Group), both subunits 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 as well as field examination of representative exposures of all major sedimentary rock units present, 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 HIA report by Stephan Gaigher of G&A Heritage (Gaigher 2017) and the geological field report by Mienie (2017);

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 Postmasburg region elsewhere (*e.g.* Almond 2010a, 2012b, 2013, 2014).

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

4. A short, one-day palaeontological field assessment in November 2017 by the author.

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 Postmasburg in the Northern Cape levels of natural bedrock exposure are often good but access to them is limited in some areas by dense swarthaak bushy vegetation. However, sufficient exposures of the key rock units were examined during the course of this study to allow the broader palaeontological heritage sensitivity of the study area to be assessed and confidence levels for this assessment are therefore moderately good. Comparatively few academic palaeontological studies or field-based fossil heritage impact studies have been carried out in the region, so any new data from 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 Magoloring 668 Mining Rights Application study area 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, between the R385 dust road between Postmasburg and Olifantshoek and the Sishen railway line. The low rounded, rocky hills of the Gamagara Ridge reach elevations of 1500 m amsl in this area, descending to *c*. 1300 m amsl on the sandy Kalahari thornveld plains to the west. The region is drained by several SW-flowing intermittent streams. Several large open-cast manganese mines (Gloucester, Glosam, Lohatlha) are situated along the Gamagara Ridge on the western edge of the Maremane Dome, just to the east of the study area.

The geology of the study area to the northwest of Postmasburg is shown on 1: 250 000 geology sheet 2822 Postmasburg (Council for Geoscience, Pretoria, 1977) (Figs. 4 and 5). However, this map, 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. 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). The concise and well-illustrated geological report for Magoloring 668 by Mienie (2017) is also very relevant, and includes a detailed facies map, but focuses more on economic geology rather than stratigraphic context.

As shown in the recently published maps (Figs. 6 & 7), the Magoloring 668 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 - *viz.* Campbell Rand carbonates, Asbesheuwels BIF and Koegas quartzites and iron formation. This 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 are overlain by several thick, upward-coarsening shale to quartzite packages of the Lucknow Formation. The Elim beds are tectonically overlain by wedges of older Palaeoproterozoic sediments assigned to the Koegas Subgroup and the unconformably overlying **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). The Koegas Subgroup is represented here by several thin, upward-shoaling marine packages within which offshore ferruginous muds pass up into pale shoreface quartzites. The Koegas succession 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).

The upper contact of the Koegas beds with the overlying Postmasburg Group is marked by a regional 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. 31 & 32). 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 just to the west of the study area (*e.g.* Aarkop).

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).

Representative exposures of the main rock units mapped beneath the proposed mine footprint were examined during the one-day site visit and are illustrated in Figs. 8 to 30. Brief notes, together with gps data for all numbered localities, relating to the various sites examined are provided in the Appendix to this report.

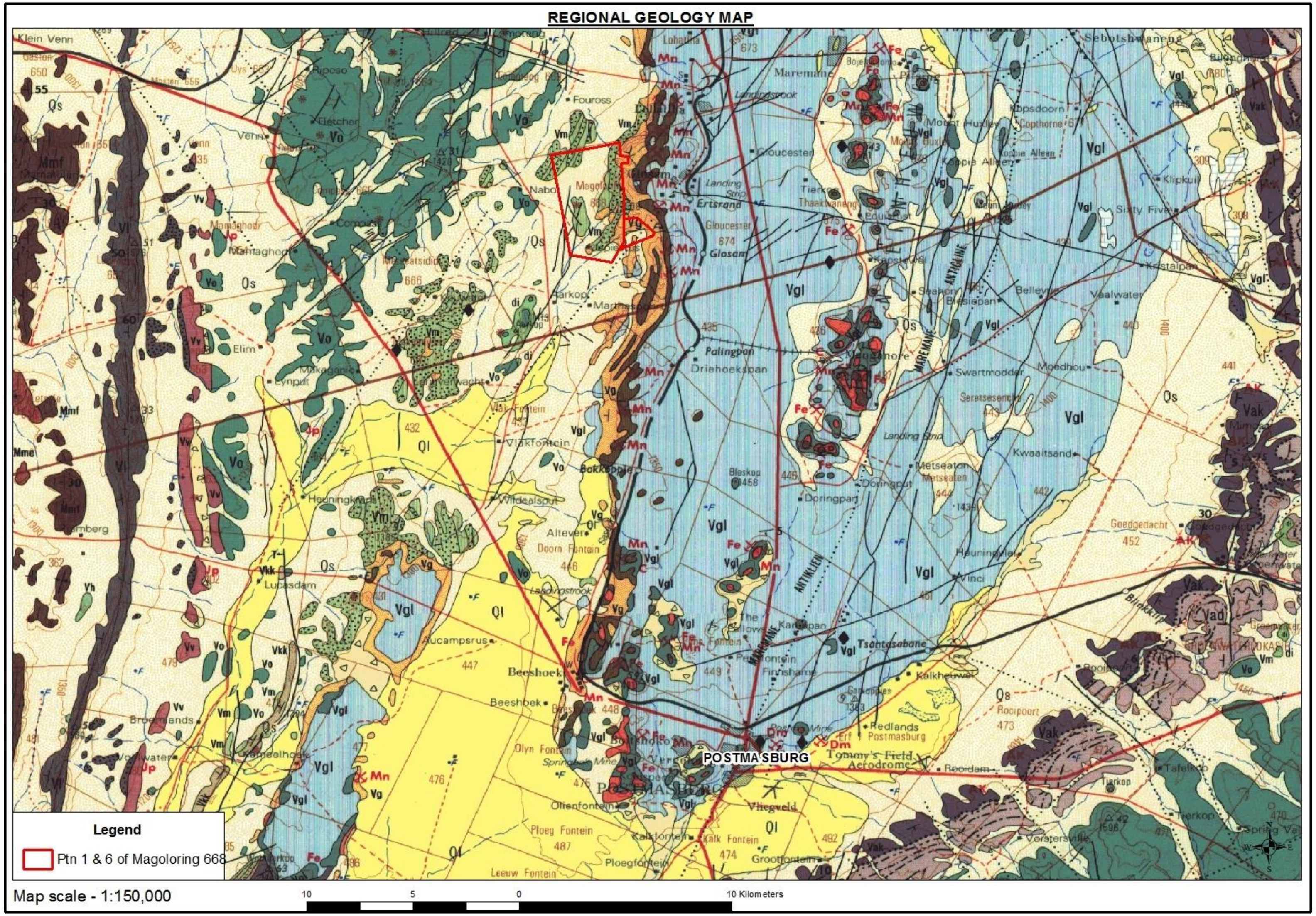

Fig. 4. Extract from 1: 250 000 geology sheet 2822 Postmasburg (Council for Geoscience, Pretoria) showing the location of the Mining Rights Application study area on Farm Magoloring 668 near Postmasburg, Northern Cape (red polygon). See following figure for legend. *N.B.* This map is now outdated in several respects.

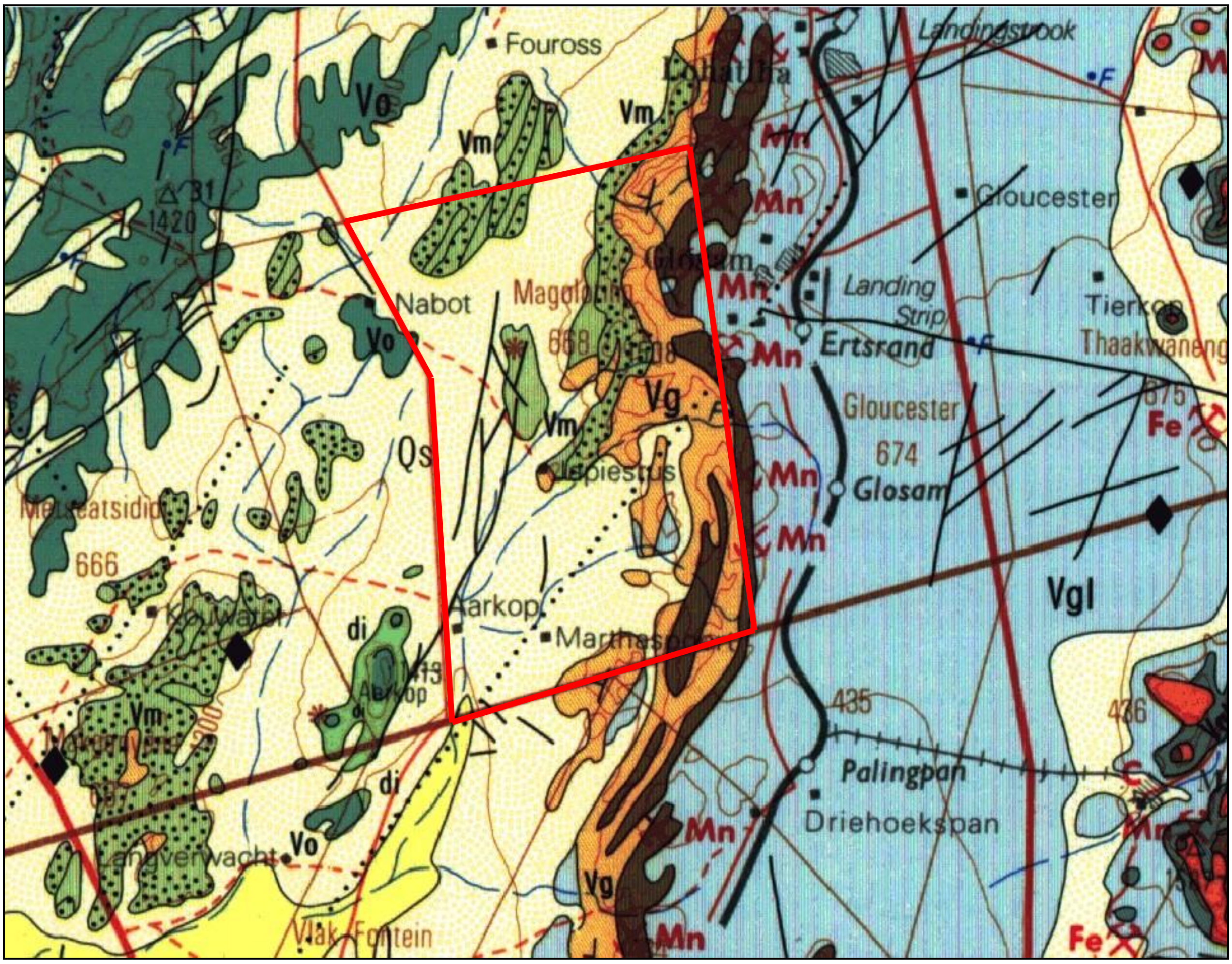

Fig. 5. Detail of the 1: 250 000 geological map shown above to show the main rock units mapped in the broader region on Farm Magoloring 668 (*N.B.* This extends beyond the Mining Rights Application Area). The mapping and lithostratigraphy shown here are now out-of-date. Main rock units: Vgl (pale blue) = Campbell Rand Subgroup; dark grey = Wolhaarkop chert breccia; red = Manganore Formation (Blinkklip breccia); Vg (orange) = Gamagara Formation with basal Doornfontein conglomerate (dark brown); Vm (green with and without stipple) = Makganyene Formation; Vo (blue-grey) = Ongeluk Formation; Qs (pale yellow) = red Kalahari Group sands (Gordonia Formation).

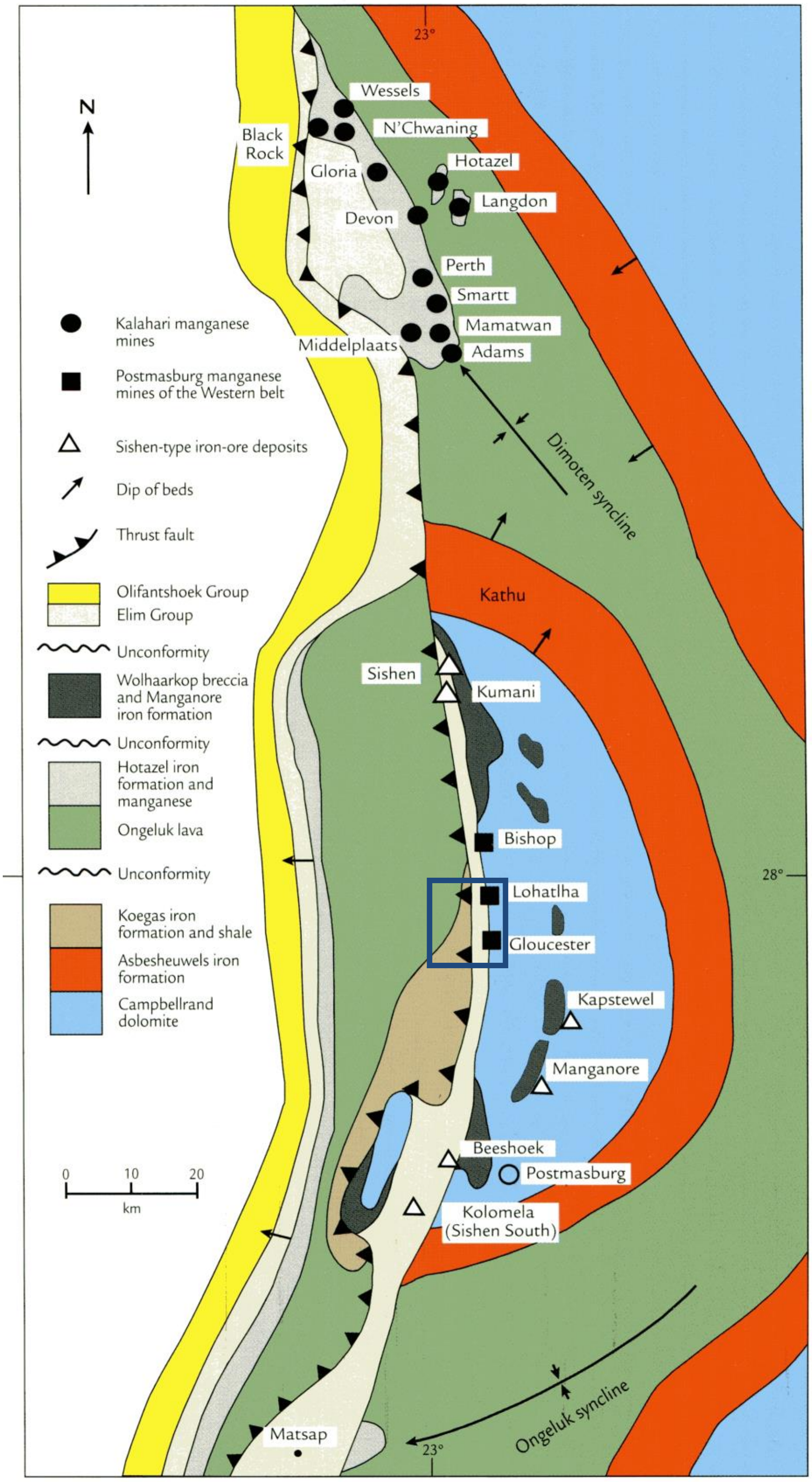

Fig. 6. Schemtic geological map of the Griqualand West region, Northern Cape, showing the revised stratigraphic interpretation of the rock units represented in the Magoloring 668 study region (dark blue square) (Map abstracted from Cairncross & Beukes 2013). The Ongeluk lava outcrop area (grey-green) also includes the Makganyene Formation diamictites.

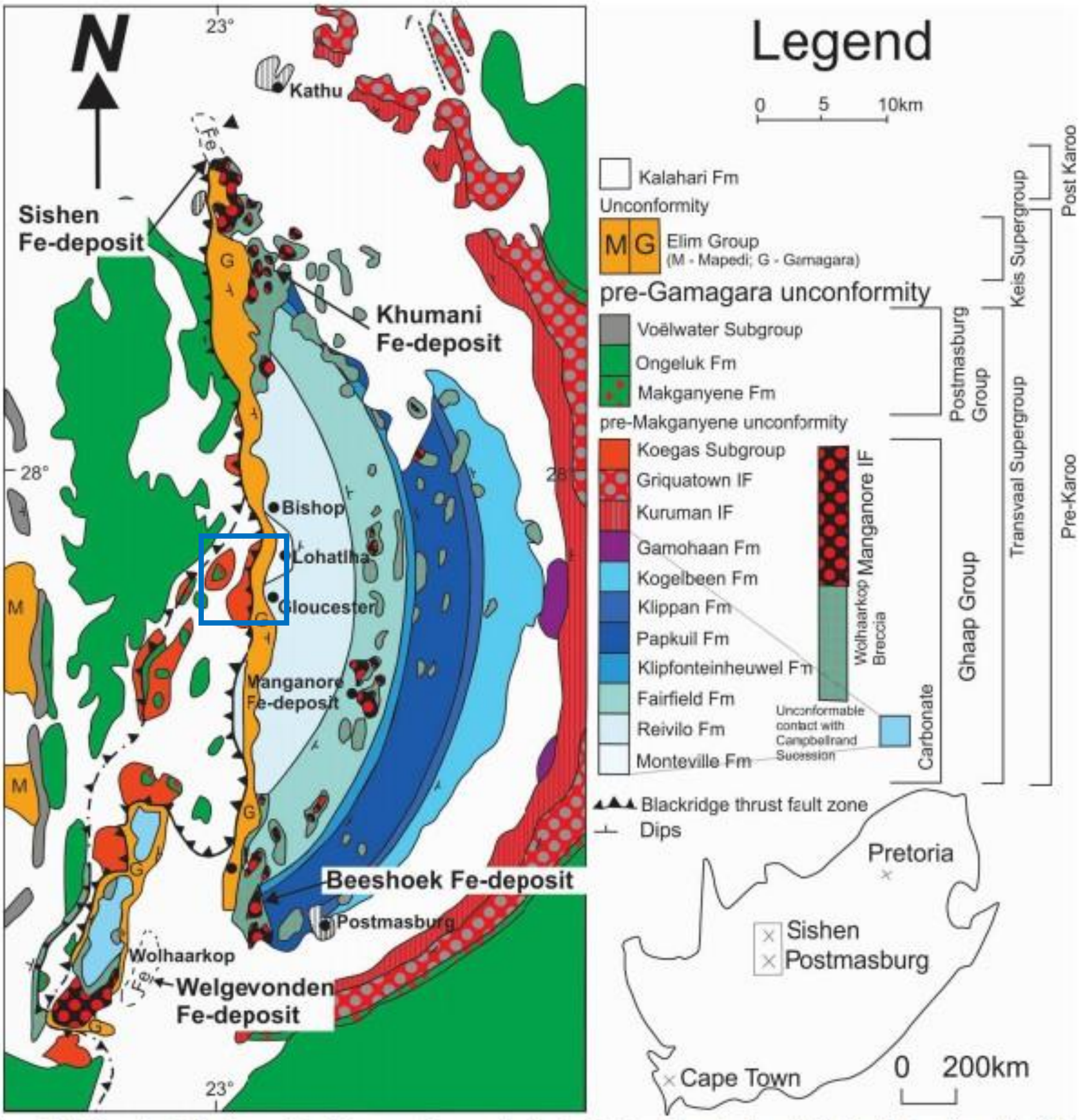

Figure 2: Regional geological map of the Maremane Dome region in the Northern Cape Province indicating the location of the Sishen, Khumani, Beeshoek and Sishen South iron ore deposits (modified after Van Schalkwyk and Beukes, 1986).

Fig. 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. The Makganyene Formation outcrop area is shown in red with green spots (contrary to the legend).

Fig. 8. View westwards from the ironstone ridge just east of Japies Rus homestead showing low relief terrain with Kalahari thornveld in the western portion of Magoloring 668 (Loc. 004).

Fig. 9. Small exposure of grey dolomites with calcretised joints on the valley floor *c*. 2.4 km east of Japies Rus homestead – probably Campbell Rand carbonates below the pre-Gamagara unconformity, but possibly part of the Lucknow Formation (Elim Group) (Hammer = 30 cm) (Loc. 027).

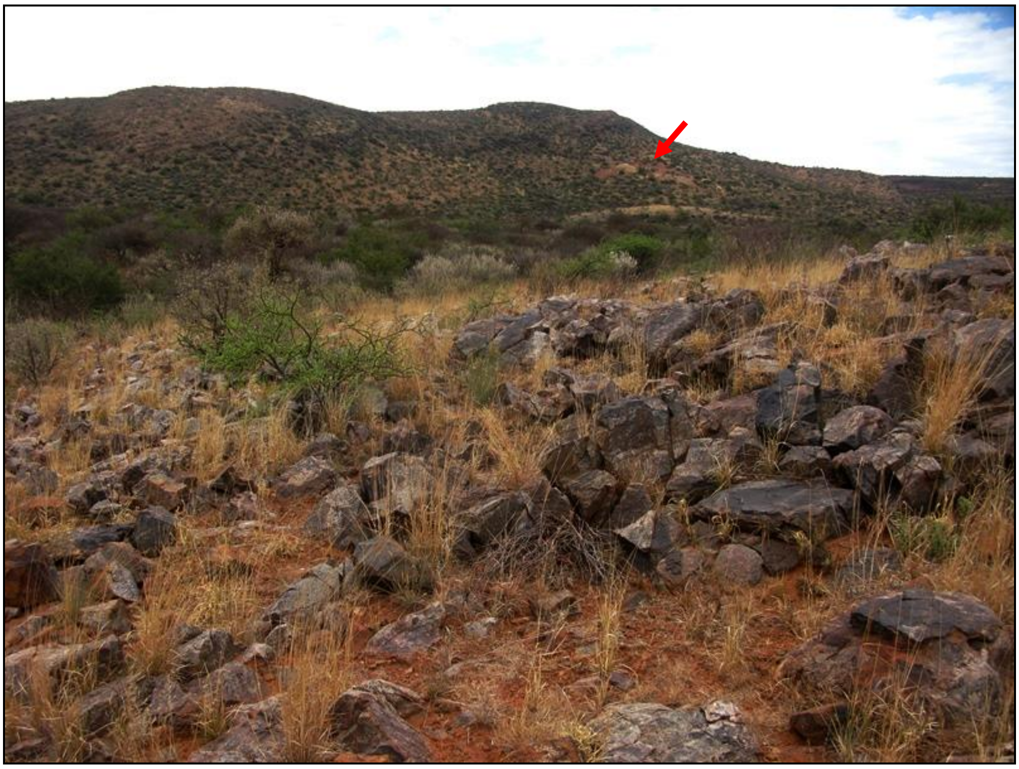

Fig. 10a. Low hills to the east of Japies Rus homestead showing prominent-weathering, westward-dipping, greyish quartzites of the Elim Group (possibly Lucknow Formation) (Taken from Loc. 026). Arrow = small abandoned mine shown in following figure.

Fig. 10b. Small opencast mine excavated into brecciated, weathered and veined mudrocks towards the base of a shoaling cycle, Elim Subgroup (possibly Lucknow Formation) (Loc. 030).

Fig. 11. Undulating sandy terrain mantled in orange-hued Kalahari sands (Gordonia Formation) in the western sector of Magoloring 668.

Fig. 12. View westwards through the upper part of the Koegas Subgroup succession with dark, shiny iron formation in the foreground and a succession of pale quartzite ridges capped by iron formation in the background (Taken from Loc. 007).

Fig. 13. Well-jointed dark, shiny iron formation with multiple slickenside surfaces within the the Koegas Subgroup succession. Stratigraphically lower ironstone horizons beneath the main Koegas quartzite sequences *might* correlate with the Doradale Formation (Loc. 023).

Fig. 14. Reddish-brown conglomeratic facies within the upper part of the Koegas Subgroup (Hammer = 30 cm). The clasts are mainly subrounded chert pebbles (Loc. 008).

Fig. 15. Package of tabular pale shallow marine quartzites within the upper part of the Koegas Subgroup (probably Heynskop Formation) (Hammer = 30 cm) (Loc. 010).

Fig. 16. Thin-bedded iron formation of the Rooinekke Formation overlying quartzite cycles within the upper Koegas Subgroup (Hammer = 30 cm) (Loc. 012).

Fig. 17. Thin-bedded, west-dipping iron formation in the northern sector of Magoloring 668 – probably the Rooinekke Formation (Koegas Subgroup) (Loc. 037).

Fig. 18. High-grade iron ore with dark metallic patina along crest of ironstone ridge (Rooinekke Formation) (Hammer = 30 cm) (Loc. 013).

Fig. 19. Brecciated iron ore of the Doornfontein Member (Gamagara Formation, basal Elim Group) overlying the Roinekke iron formation (Hammer = 30 cm) (Loc. 003).

Fig. 20. Close-up of the Doornfontein breccia showing occasional angular clasts of pale quartzite (Scale in cm) (Loc. 003).

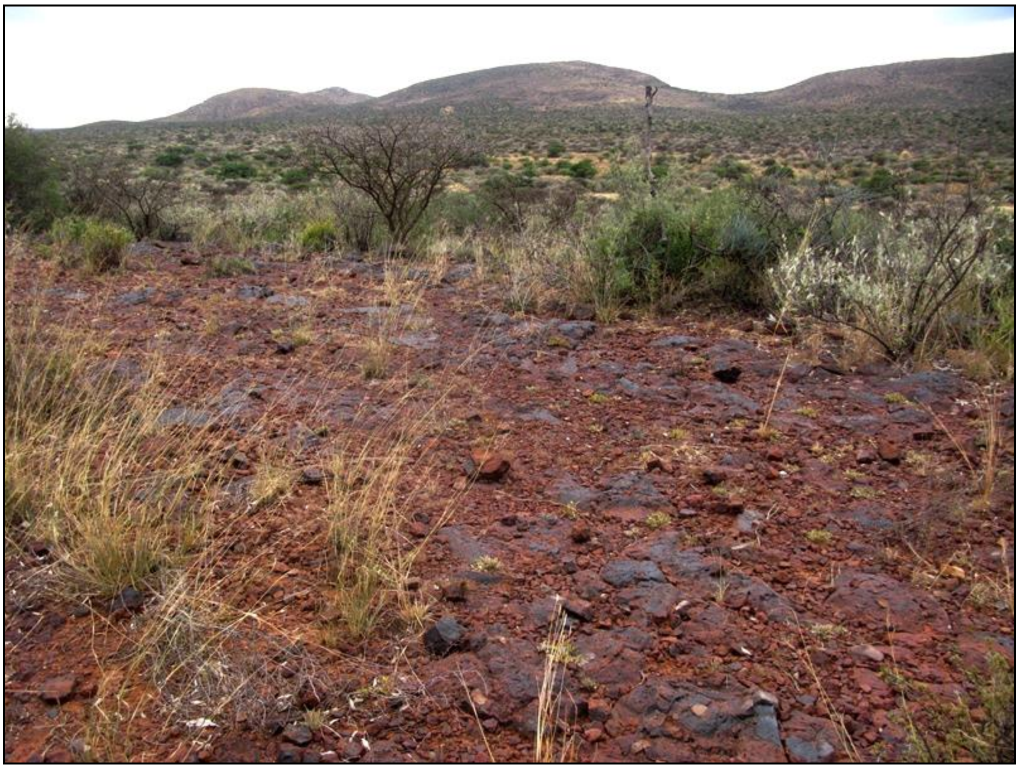

Fig. 21. Fairly extensive, rubbly exposure of rusty-brown, manganese-patinated Makganyene Formation diamictite along a low hill crest (Loc. 034).

Fig. 22. Typical massive, reddish-brown to ochreous appearance of the massive, weathered, jointed Makganyene diamictite with dispersed pebble-sized clasts (Hammer = 30 cm) (Loc. 034).

Fig. 23. Close-up of moderately well-rounded, pebble-sized chert erratics embedded within the weathered Makganyene diamictite (Scale in cm and mm) (Loc. 034).

Fig. 24. Freshly-excavated block (15 cm long) of unweathered, dark grey Makganyene diamictite with dispersed, poorly-sorted angular to subrounded clasts (Loc. 031).