PALAEONTOLOGICAL ASSESSMENT: COMBINED DESKTOP & SITE VISIT REPORT

PROPOSED MELETSE IRON ORE PROJECT ON REMAINING EXTENT OF THE FARMS DONKERPOORT 448KQ AND RANDSTEPHANE 455KQ NEAR THABAZIMBI, WATERBERG DISTRICT, LIMPOPO PROVINCE

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1. SUMMARY

The **Meletse Iron Ore Project** study area, situated *c*. 25-30 km east of Thabazimbi in Limpopo Province, is largely underlain by Precambrian marine sediments of the Transvaal Supergroup (Malmani Subgroup dolomites, Penge Formation ironstones) and also by continental red-beds of the younger Waterberg Group in the northeast. Bushveld Complex granites crop out in the eastern sector. These Precambrian bedrocks are extensively mantled with colluvial (slope) deposits and soil on low palaeontological sensitivity. Apart from microbial mats, fossils are unknown from the Waterberg Group, while granites are invariably unfossiliferous. The Penge Formation ironstones that are targeted for opencast iron ore mining are not known to contain macroscopic fossil remains, although microbial fossils are probably present. The Malmani Subgroup dolomites and associated sediments are well-known elsewhere for their stromatolite biotas (reef-like microbial mounds), and also contain a range of microfossils. However, these recessive-weathering carbonate rocks are generally poorly exposed in the study area and the stromatolites are of widespread occurrence. It is concluded that the Meletse Iron Ore project area is of low palaeontological sensitivity.

This assessment applies to all **six optional layouts** for the opencast iron ore mine pit, waste dump and associated infrastructure within the study area which are all of LOW palaeontological impact significance. Options 4 to 6 are slightly preferred over Options 1 to 3, however, due to higher impact of the latter on potentially fossiliferous Malmani dolomites. Where practicable, dolomite rock exposures showing well-developed stromatolites should be safeguarded from damage during prospecting and mining activity and related infrastructure developments. Good examples of stromatolites should be reported to SAHRA for recording by a professional palaeontologist.

The **Gatkop Cave site** on farm Randstephane 455 KQ lies *outside* the current Meletse Iron Ore Project area. Several dolomitic breccia units of various ages, degrees of cementation and sedimentary facies are exposed within the cave. They include horizons with a component of extraneous (*i.e.* extra-cave) material such as ferruginous cave earth, gravel or soil. However, no occurrences of bone-bearing breccia were identified during a recent site visit (Almond 2012). Dolomitic host rocks of the Malmani Subgroup show here fine lamination but no well-developed stromatolitic domes or columns. It is concluded that the palaeontological sensitivity of the Gatkop Cave site is probably LOW. The site is situated some four kilometres SSW of the main iron ore prospecting area and over 600 m lower in elevation. Any unrecorded palaeontological heritage resources here are therefore unlikely to be directly or indirectly affected by prospecting or any subsequent mining activity. Protection of the cave site on archaeological and cultural heritage grounds, as recommended by the cultural heritage assessment practitioner (Miller 2011), should in turn safeguard any fossil remains in the area. No special measures to protect fossil heritage are therefore warranted here.

The two alternative **ore transportation routes** from the Meletse Iron Ore Project under consideration follow existing roads. Upgrading of several sections from unpaved to tar roads as well as upgrading of several culverts and bridges is envisioned here, but not major new excavations of potentially fossiliferous bedrock. **Route 1** running to the west of the Meletse Iron Ore project traverses the outcrop areas of a wide range of geological units, the majority of which are of low palaeontological sensitivity (*e.g.* Malmani dolomites, Bushveld igneous rocks, Late Caenozoic superficial deposits). Significant impacts on possible stromatolite-bearing formations within the Pretoria Group to the south of Thabazimbi (R511, R510) as well as in the gorge just east of Sandrivierpoort (D928) are not anticipated here. **Route 2** running from the Meletse Iron Ore Project to Modimolle *via* Alma is almost entirely underlain by Precambrian fluvial sandstones and conglomerates of the lowermost Waterberg Group (Nylstroom Subgroup) that are of low palaeontological sensitivity. It is concluded that there is no preference on palaeontological heritage grounds between the two alternative routes which are both of LOW palaeontological impact significance.

Recent (unauthorised) prospecting activities at the Meletse iron ore mine have involved the construction of ± 32.89 km of roads entailing ±33 ha disturbance and also twelve blasting operations. The impacts of these prospecting activities as well as the proposed mining project on local palaeontological heritage resources are briefly assessed the Appendix. Given the LOW PALAEONTOLOGICAL SENSITIVITY of the bedrocks and superficial deposits represented within the development footprint, the probability of *significant* palaeontological impacts is anticipated to be LOW (UNLIKELY)). Any impacts are likely to be of LIMITED EXTENT (restricted to development footprint) and volume, but they are generally IRREVERSIBLE. Impact magnitudes are therefore assessed as LOW. It is concluded that palaeontological impacts relating to the Meletse Iron Ore Project are of LOW SIGNIFICANCE.

Given the small scale of the mining developments with regard to the total outcrop area of the comparatively unfossiliferous rock units concerned, cumulative impacts are rated as LOW.

This assessment applies to past activities (*e.g.* construction of prospecting roads and other prospecting activities) as well as to future mining and related activities, including upgrading of haulage routes.

Pending the discovery of substantial new fossil remains during development, no further specialist palaeontological studies or mitigation for this project are considered necessary.

- The ECO responsible for the mining and road developments should be aware of the possibility of important fossils being present or unearthed on site and should monitor all substantial excavations into fresh (*i.e.* unweathered) sedimentary bedrock for fossil remains;

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

- These recommendations should be incorporated into the EMP for the Meletse Iron Ore Project 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).

2. INTRODUCTION & BRIEF

2.1. Project description

The company Aquila Steel (S Africa) (Proprietary) Limited (Aquila) is proposing to develop an opencast iron ore mine, known as the Meletse Iron Ore project, on the remainder of the farms Donkerpoort 448KQ (*c.* 838 ha) and Randstephne 455KQ (*c*. 1301 ha), situated some 25-30 km to the east of Thabazimbi, Thabazimbi Local Municipal Area of the Waterberg District, Limpopo Province (Figure 1).

The following brief project description for the proposed Meletse Iron Ore Project that will exploit high grade haematite iron ore has been abstracted from data kindly provided by Shangoni Management Services (Pty) Ltd:

> An open pit iron ore mine is proposed. The open pit will be mined through conventional truck and shovel mining techniques. The topsoil (seed bearing soil) will be stripped prior to mining and placed on a separate dump to be used during rehabilitation. The overburden and waste rock material will be stripped and dumped on the waste rock dump that will be established on the contour of 1620 m amsl on the south-eastern side of the open pit. During the final years of the open pit, an in-pit waste rock dump will be established in the north-eastern section of the open pit. Six optional layouts of the Meletse open cast iron ore mine pit, waste dump and associated infrastructure are under consideration and are shown in Figures. 5a and 5b below.
>
> The mining sequence in the open pit environment will be as follows:
> - Creating initial free faces by making a boxcut;
> - Drilling and blasting of overburden;
> - Loading and hauling of overburden to waste dumps or backfilling after iron ore extraction;
> - Drilling and blasting of waste rock;
> - Loading and hauling of waste rock to waste dumps or backfilling after iron ore extraction.

It is anticipated that the mine will have a lifetime of at least 18 years, but this may well be extended as a result on on-going exploration.

Two alternative routes for transporting the iron ore to a railhead are also under consideration, as shown in Figure. 2. Alternative ore transportation Route 1 runs westwards from the Meletse Iron Ore Project for *c*. 60 km and ends at Chromedale Siding close to the R510 some 20 km SSW of Thabazimbi. Alternative ore transportation Route 2 runs for some 45 km to the ENE of Meletse Iron Ore Project to Alma and a further 45 km SE to Modimolle (Nylstroom). Both routes follow existing tar and unpaved dust roads. Upgrading of unpaved sections of road to tar road will be necessary as well as various improvements to bridges and culverts.

The following details of the two ore transportation routes and the necessary upgrading required in each case have been abstracted from the Traffic Impact Assessment report by Corli Havenga Transportation Engineers (March 2014):

Route 1 to Chromedale Siding: The existing gravel road is followed from the mine along Road P240/1 to the intersection with Road D928, then along Road D928 to the intersection with Road D1031 and then along Road D1031 to the intersection with Road R511/P110/1. At this intersection the R511/P110/1 becomes a surfaced road up to the intersection with Road R510 and then along the R510 to the Chromedale siding. This route is approximately 60.9 km long.

The following sections of road need to be upgraded from gravel to a surfaced road:

- New access on P240/1;

- Road P240/1 from the mine’s access to the intersection with Road D928 (± 6 km);
- Road D928 from Road P240/1 to the intersection with Road D1031 (± 7 km); and
- Road D1031 from D928 to R510 (±2 4,5km).

The existing culvert on Road D1031 needs to be widened to accommodate two-way traffic. The minimum road width should be 3, 7 m lanes with 0, 5 m surfaced shoulders. The structural capacity of Road R510 and R511 should be evaluated to determine if the road can carry the additional heavy vehicles to the Chromedale siding; if not, it should be upgraded.

Route 2 to Alma Route: The existing gravel road from the mine along Road P240/1 is followed all the way to Alma. In Alma the section of P24-/1 is a surfaced road. This route was indicated as a possible route for product to the Alma railway station. This route is ± 45km long.

This will require the upgrading of the following roads from gravel roads to surfaced roads:

- New access on P240/1;
- Road P240/1 from the access to the mine to the intersection with Road D927 (± 6 km);
- Road D928 from Road P240/1 to Road D1485 (± 16,2 km); and
- P240/1 from the mine’s access to Alma (± 45km section).

The bridge near Alma needs to be upgraded from a single lane to double lanes. The roads in Alma up to the siding should be upgraded. The minimum road width should be 3, 7 m lanes with 0, 5 m surfaced shoulders. Road D928 from the intersection with Road P240/1 to Rooiberg should be upgraded and a maintenance plan implemented to keep the road in a good condition. This section is approximately 30, 7 km long.

From Alma Route 2 follows the P240/1 tar road to Modimolle (Nylstroom). Details for this second sector of the route are not provided in the Traffic Impact Assessment report.

2.2. Current brief

A Phase 1 Cultural Heritage Resources Assay of the Meletse Iron Ore Project prospecting area has been conducted by Sidney Miller of African Heritage Consultants cc, Magalieskruin (Miller 2011). This survey identified Gatkop Cave on the farm Randstephne 455 KQ as a site of high cultural heritage significance as well as having potentially high palaeontological heritage significance.

To quote from Miller’s report (*ibid*., p. 6):

Secondly it is a dolomitic cave, opening to daylight, and from the outside appears to be of significant size. It therefore may contain breccia similar to that found at the Mokopaan Cave known as the Cave of Hearths. It is advised that a palaeontologist be asked to investigate this cave’s potential.

The interior of the cave - which is dark and apparently infested with histoplasmosis (cave disease) - does not appear to have been investigated by Miller. However, it should be noted that this is a site of considerable cultural, historical and archaeological significance, as recognised in the study of Iron Age archaeology of the Rooiberg region, Limpopo, by Hall (1981). Gatkop Cave probably played a role as a refuge site from Mzilikazi’s Ndebele impis during the early nineteenth century Mfecane, and perhaps also later following the arrival of the European trekboers. It is apparent that the archaeological resources within the cave – such as the wooden kraals and abundant pottery recorded by Hall in the large entrance chamber - have since been considerably degraded. Surface scatters of archaeological material are still evident in front of the mouth of the cave. These include ostrich eggshell beads, abundant shards of Iron Age pottery assignable to the Late Iron Age (Hall’s

1981 Rooiberg Unit 3, approximately dated to the Fifteenth Century) as well as Middle Stone Age flakes of ferruginous quartzite (Amanda Esterhuysen, Madelon Tusenius, pers. comm., 2011).

Following Miller's (2011) recommendation, a palaeontological assessment of Gatkop Cave was commissioned by PGS Heritage & Grave Relocation Consultants, 906 Bergarend Street, Waverley, Pretoria (Almond 2012). The site visit was carried out on 12 December 2011 by the author, accompanied by two experienced field archaeologists: Dr Amanda Esterhuysen (Department of Archaeology, Wits) who has worked extensively at various cave sites in the Makapansgat Valley and elsewhere in the Cradle of Humankind World Heritage Site, and Madelon Tusenius (MA in Archaeology, University of Stellenbosch).

It should be noted that this earlier palaeontological heritage report does *not* represent a comprehensive palaeontological heritage assessment of the entire Aquila Resources prospecting area. However, general remarks are made on the fossil record of the main bedrock units represented inside the prospecting area. Given their low overall palaeontological sensitivity, a more detailed palaeontological field assessment of the prospecting area was not regarded as warranted.

A desktop palaeontological heritage assessment of the proposed Meletse opencast iron ore mine on the farms Donkerpoort 448KQ and Randstephne 455KQ, including the two alternative ore transportation routes, has subsequently been commissioned by PGS Heritage, Pretoria (Contact details: 906 Bergarend Street, Waverley, Pretoria, 0186. PO Box 32542, Totiusdal, 0134. Tel: (012) 332 5305 Fax: (012) 332 2625. Email: wouter@gravesolutionas.co.za). Given the generally low palaeontological sensitivity of the study area, it was considered by the author that a further field assessment was not warranted for this project. It is noted that the Gatkop Cave site now lies *outside* the study area for the Meletse Mine (Figures. 1 & 3). Field data from the earlier report on this site by Almond (2012) is also incorporated here.

2.3. 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).

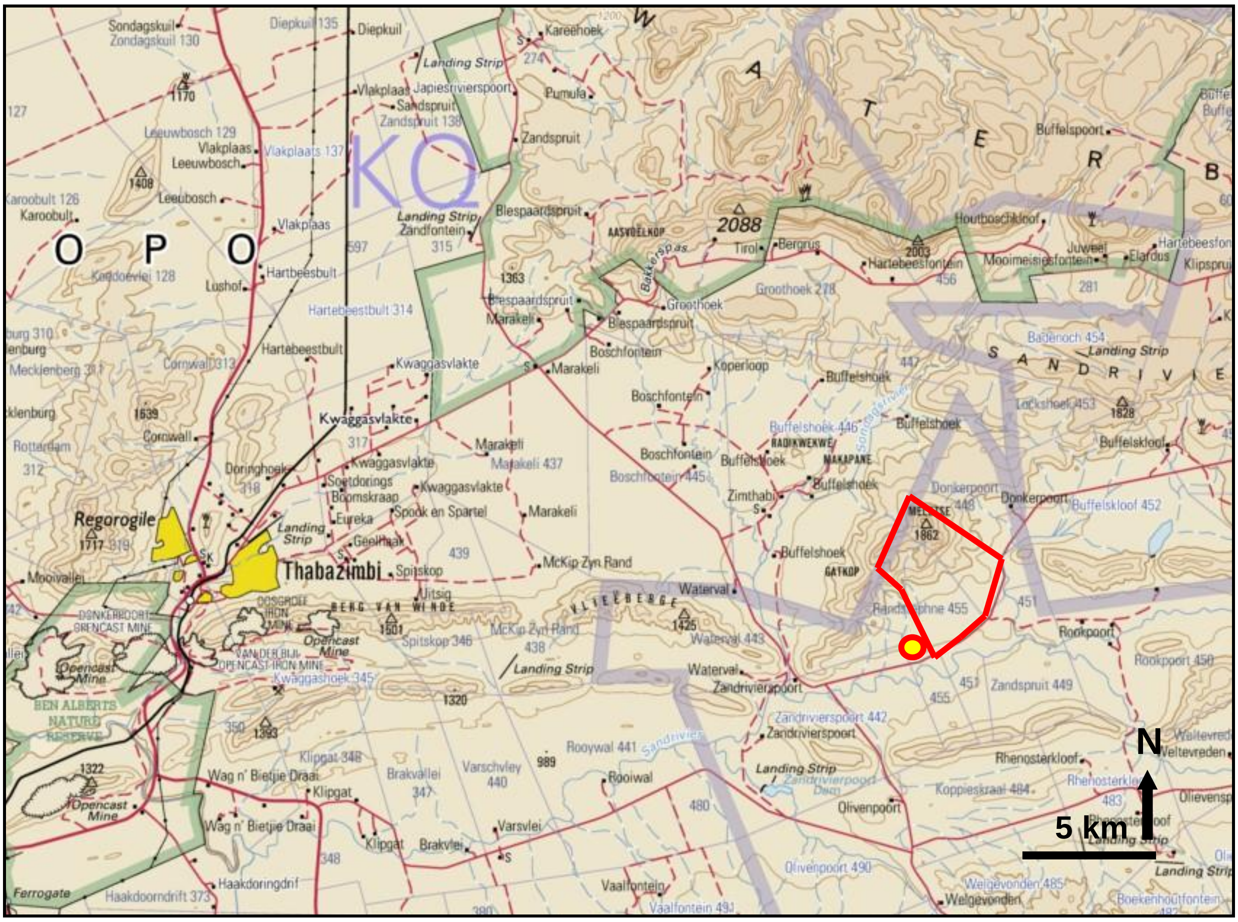


Figure 1. Extract from 1: 250 000 topographical map 2426 Thabazimbi showing approximate location of the Meletse Iron Ore Project study area on the remaining extent of the farms Donkerpoort 448 KQ, Randstephane 455 KQ and Waterval 443 some 25-30 km to the east of Thabazimbi (red polygon). The location of Gatkop Cave on Randstephane 455, just outside the present study area, is indicated by the yellow dot. Original map courtesy of the Chief Directorate: National Geo-spatial Information, Mowbray.

Figure 2. The two ore transportation route options under consideration for the Meletse iron ore mine: the southern Route 1 (blue, black) to Chromedale Siding in the west and the northern Route 2 (red) to Modimolle / Nylstroom in the east.

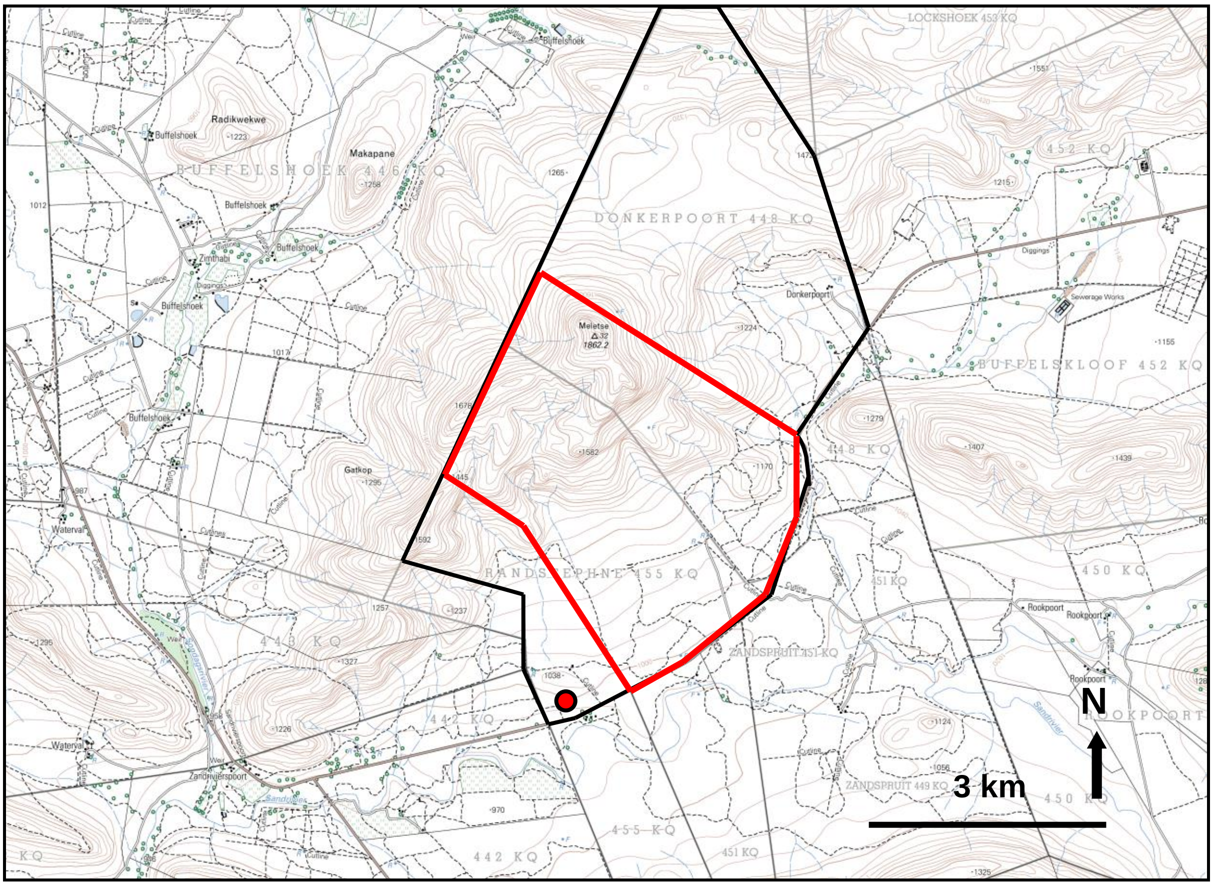


Figure 3. Extract from 1: 50 000 topographical sheet 2427 DA Sandrivierspoort (Courtesy of the Chief Directorate: National Geo-spatial Information, Mowbray) showing the outline of the Farms Donkerpoort No. 448 KQ and Randstephane No. 455 KQ (black polygon) as well as the present study area for the Meletse iron ore mine (red polygon). The red dot shows the location of Gatkop Cave on farm Randstephane 455 KQ, north of the Zandrivierpoort to Donkerpoort dust road (24º 37' 05.2" S, 27º 39' 08.4" E), which lies outside the study area for the proposed Meletse iron ore mine.

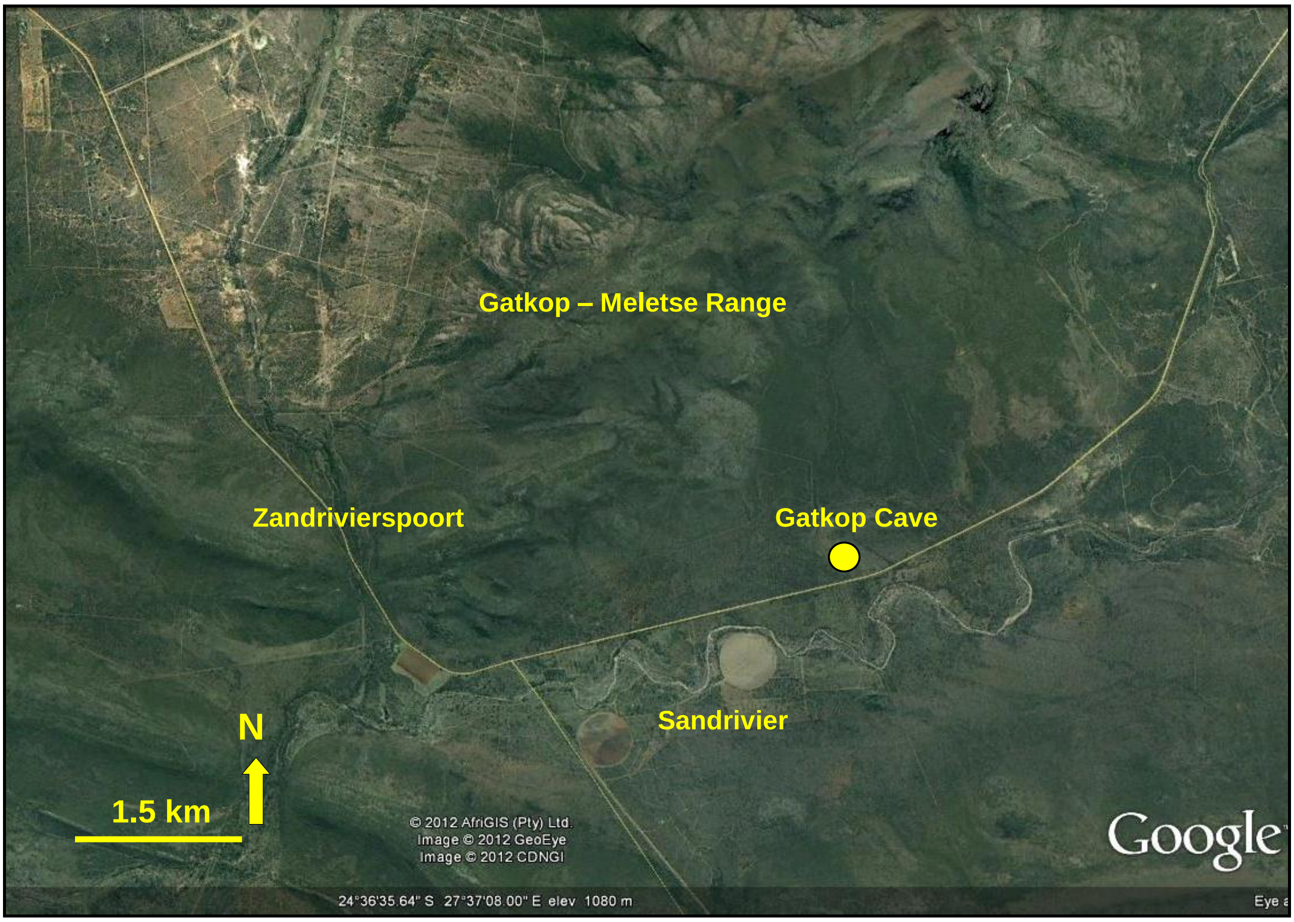


Figure 4. Google Earth© satellite image of the study area *c.* 25-30 km east of Thabazimbi showing the location and setting of Gatkop Cave on the low, southern foothills of the Gatkop – Meletse mountain range, just north of the Sandrivier.

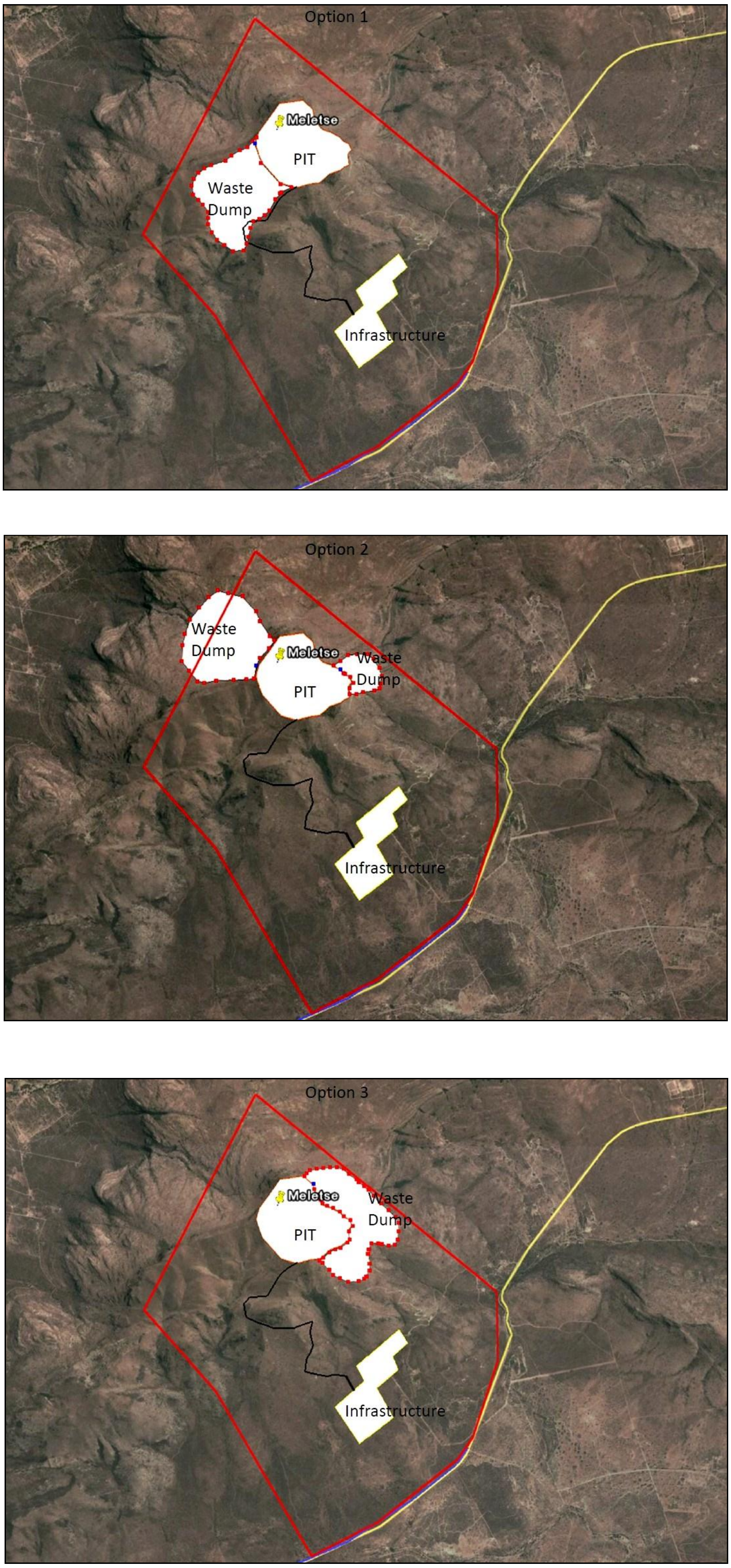
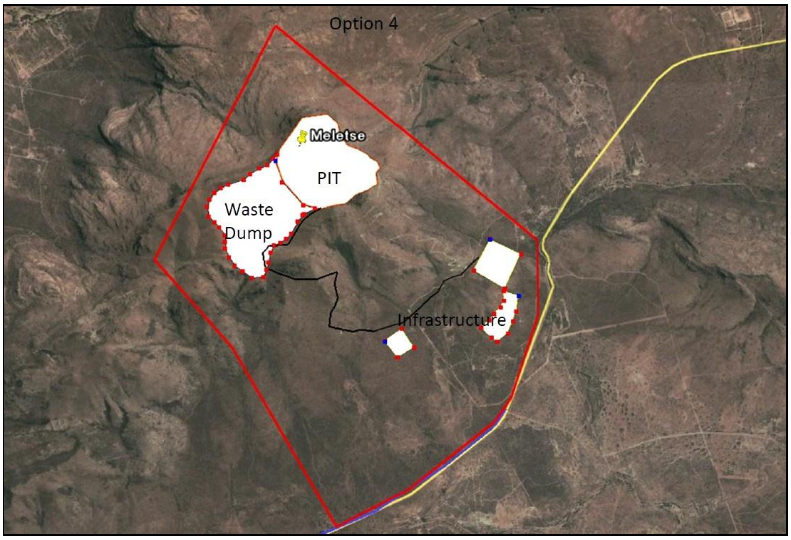
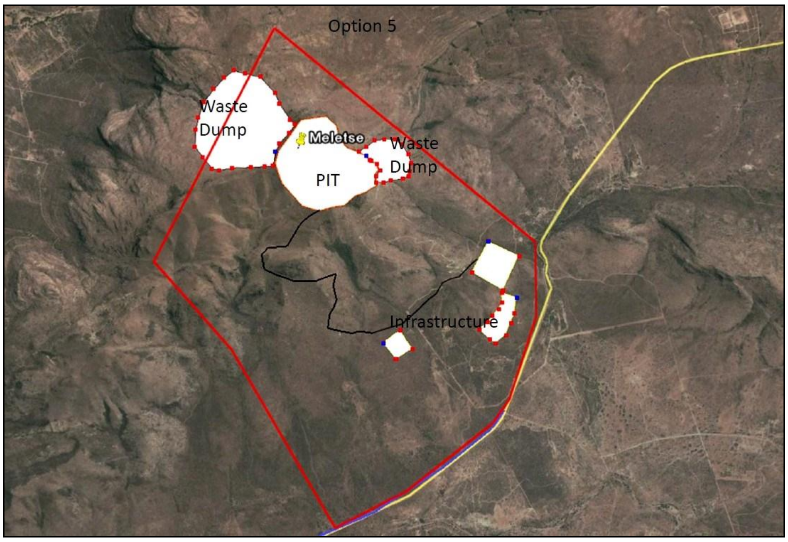


Figure 5a. Proposed layout of the Meletse Iron Ore Project pit, waste dump and associated infrastructure (Options 1 to 3, from top to bottom respectively).





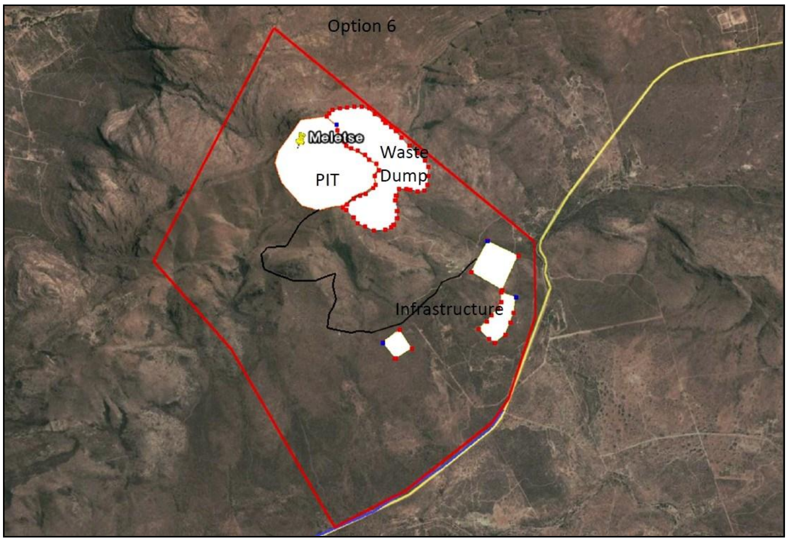


Figure 5b. Proposed layout of the Meletse Iron Ore Project pit, waste dump and associated infrastructure (Options 4 to 6, from top to bottom respectively).

3. APPROACH TO THE PALAEONTOLOGICAL HERITAGE ASSESSMENT

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

1. A short project outline abstracted from the Heritage Impact Assessment for the prospecting phase of the project by Miller (2011), the Traffic Impact Assessment by Corli Havenga Transportation Engineers (2014), an outline of the Meletse mining project as well as various maps and additional data kindly provided by Lidwala Consulting Engineers, Shangoni Management Services (Pty) Ltd as well as by PGS Heritage;

2. A review of the relevant scientific literature, including published geological maps, satellite images and previous palaeontological heritage reports (*e.g.* Durand 2013, Almond 2012);

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 development projects in the Thabazimbi – Modimolle study region the major limitation for fossil heritage assessments is the paucity of previous specialist palaeontological field studies in this area. Detailed geological explanations for the relevant 1: 250 000 sheets have not yet been published and the short explanations printed on the map itself include almost no palaeontological data.

4. GEOLOGICAL BACKGROUND

The geology of the Meletse Iron Ore Project study area as well as the associated alternative ore transportation routes are shown on the adjoining 1: 250 000 geological maps 2426 Thabazimbi and 2428 Nylstroom / Modimolle (Council for Geoscience, Pretoria) (Figs. 6, 8a and 8b). In both cases only a very brief sheet explanation is printed on the map itself. The Gatkop – Meletse mountain range and its southern foothills, where Gatkop Cave is situated, are built of Precambrian dolomites and associated marine sedimentary rocks that are assigned to the **Malmani Subgroup** (**Chuniespoort Group**) within the **Transvaal Supergroup**. The Transvaal Supergroup rocks here lie on the southern, east-west trending limb of a roughly L-shaped outcrop area centred on Thabazimbi, forming part of the north-western margin of the huge Transvaal Basin (Eriksson *et al.* 2006). The 2 km-thick Malmani Subgroup succession consists of a series of formations of stromatolitic and oolitic carbonates (limestones and dolomites), cherts and black carbonaceous shales. These marine sediments were laid down in a range of supratidal, intertidal and subtidal settings over a major epicontinental carbonate platform in Late Archaean to Early Proterozoic times, roughly 2.55 to 2.50 Ga (billion years ago). The individual Malmani formations are not mapped at 1: 250 000 scale, so the rock units represented within the Meletse Iron Ore Project study area have not been identified at that level here. Key references among a very extensive literature on the "Transvaal Dolomites" include papers by Button (1973, 1986), Eriksson *et al.* (1993), Eriksson *et al.* (1995), Eriksson & Altermann (1998), Catuneanu & Eriksson (1999), Moore *et al.* (2001), Eriksson *et al.* (2006), as well as Sumner & Beukes (2006).

Surface and subsurface dissolution of the relatively soluble Malmani carbonate rocks has generated a wide range of karstic weathering features at varying scales such as elephant skin weathered surfaces, pavements, potholes, sinkholes or dolines, shafts or avens and caves (Marker 1988, Buttrick *et al.* 1993). A good example is the Gatkop Cave site on farm Randstephane 455 KQ, some 25 km ESE of Thabazimbi, Limpopo Province (See Section 4.3). The formation of caves within the Transvaal dolomite outcrop area and of their notoriously complex sedimentary infills has been studied in some detail, not least because of their considerable palaeontological and palaeoclimatological significance (*e.g.* Turner 1980, Maguire *et al.* 1980, Latham 1999, Partridge 2000, Latham *et al.* 2003, Partridge *et al.* 2006, and extensive references in these articles). Notable examples include the Plio-Pleistocene hominin-bearing cave infills within the Cradle of Humankind World Heritage Site. These fossiliferous caves are mainly situated in Gauteng and Northwest Province but also include several important sites in the Makapansgat Valley in Limpopo (Hilton-Barber & Berger 2004, Bonner *et al.* (eds) 2007). A highly schematic outline of cave formation, infilling and erosion is presented in Fig. 9 (from Hilton-Barber & Berger 2004).

The Malmani Subgroup carbonates are overlain by banded ironstones (BIF) and cherty shales of the **Penge Formation** of the Chuniespoort Group, dated approximately 2.5 Ga (Eriksson *et al.* 2006). These are the target rocks for the proposed mining of high grade haematite iron ore in the Meletse Iron Ore Project study area by Aquila. They outcrop along the crest of the Gatkop – Meletse range, well above the Gatkop Cave site in both stratigraphic and topographic terms. The contact between the Penge ironstones and underlying Malmani carbonates was extensively karstified in Precambrian times. The genesis of the Thabazimbi iron ores has been discussed by Van Deventer *et al.* (1986).

To the south of the Gatkop – Meletse range and the Zandrivierspoort – Donkerpoort dust road, as well as south of Thabazimbi, a more complete, broadly west-east trending, southwards-younging succession of Transvaal Supergroup sediments crops out. This includes the Malmani Subgroup and Penge Formation (BIF) of the Chuniespoort Group as well as several formations of the overlying **Pretoria Group**. The lithostratigraphy shown on the 1: 250 000 sheet Thabazimbi has not been aligned with the currently accepted scheme outlined, for example, by Eriksson *et al.* (2006). However, it is clear that at least the **Timeball Hill Formation** through the **Daspoort** and **Magaliesberg Formations** are represented here, especially in area south of Thabazimbi, and a complete Pretoria Group succession may in fact be present. The Early Proterozoic Pretoria Group succession consists of a wide range of rock types, including mudrocks, quarztites and andesites with subordinate diamictites, conglomerates, carbonates and iron formation. In contrast to the underlying Chuniespoort Group, the sediments are predominantly clastic rather than chemical in nature. Depositional environments included alluvial fans and floodplains, delta complexes, coastal settings as well as deep marine basins (Eriksson *et al.* 1991, 1993, 1995, 1999, 2006). The degree to which the depository was a closed, lacustrine system *versus* an epicontinental sea, or a combination of both, remains unresolved. In the Thabazimbi area the Pretoria Group rocks are extensively intruded, and locally metamorphosed, by laterally persistent sills of **diabase** (di, green in Figs. 6 & 8) of ill-defined age.

As shown on the geological maps, the Transvaal Supergroup rocks south and east of Thabazimbi show a general southerly dip and have been tectonically repeated by a couple of north-verging thrust faults. Gatkop Cave lies along the line of one of these major thrust faults and probably owes its genesis to high levels of bedrock fracturing and consequently enhanced groundwater movement along the fault plane. The Transvaal dolomites have been thrust northwards by Waterberg-age tectonism over younger intrusive and extrusive igneous rocks of the **Bushveld Complex** (3G1, **Lebowa Granite Suite**, 3Lf **felsitic igneous rocks**) as well as over still younger continental sediments of the Mid Proterozoic Waterberg Group (considered below).

Intrusion of the Early Proterozoic (Late Vaalian / Early Proterozoic, 2.06 Ga) Bushveld Complex followed by isostatic compensation and much later Tertiary crustal depression led to the basining of the Transvaal Supergroup and younger Waterberg Group rocks. Differential erosion of the upturned edge of the Transvaal Supergroup outcrop has generated a distinctive topographic pattern characterised by inward-dipping ridges and valleys surrounding the Bushveld Complex (King 1963, Moon 1988). This pattern is known as *Bankenveld* topography and is well seen to the east of Thabazimbi in the area between the Waterberg in the north and the Boshoffsberge of the Bushveld Igneous Complex in the south as well as in the area of Modimolle (Fig. 8b).

The eastern part of the study area, between Meletse Iron Ore Project and Modimolle, is almost entirely underlain by continental “red beds” of the Early to Mid Proterozoic **Waterberg Group** (Mokolian, > 1.9/1.8-1.7 Ga). These red beds were laid down in a spectrum of continental settings, predominantly by sandy to gravelly braided streams but also on beaches, tidal flats, sand dunes and in lakes, with a possible shallow marine shelf component as well. They are of special geological interest as evidence for the development of oxygenated atmospheres on Earth after 2 Ga (billion years ago) (McCarthy & Rubidge 2005). Key references to the Waterberg Group rocks in this area include Jansen (1982), Callaghan *et al.* (1991), Callaghan and Brandl (1991), Callaghan (1993) and Barker *et al.* (2006).

Younger fluvial sandstones of the thick Waterberg succession build the spectacular massif of the Waterberg to the north of the present study area. The lowermost Waterberg Group sediments cropping out in the study area itself form the southern edge of the Main Waterberg Basin as well as the subsidiary Nylstroom Basin and have been recently summarized by Barker *et al.* (2006). They are assigned to the basal **Swaershoek Formation** (W1s or Ms in Fig. 8) and the overlying **Alma Formation** (W1a or Mag in Fig. 8) that together make up the **Nylstroom Subgroup**, a broadly upward-fining *c*. 4 km-thick sequence. The Swaershoek Formation comprises up to 1000 m of sheared and jointed arenitic and ruditic sediments, with mudrock interbeds towards the top. The succession also includes several lava units and a quartz porphyry. Deposition occurred primarily within fan-deltas with minor reworking on beaches and tidal flats. The conformably to unconformably overlying Alma Formation consists of a range of medium- to coarse-grained feldspathic to lithic arenites, locally trough cross-bedded, with few mudrock interbeds but common conglomeratic intervals, including boulder beds in the southern part of the outcrop area, east of Thabazimbi (Figure 7). Palaeocurrents were directed due NE in the western outcrop area. Deposition occurred within a series of alluvial fans that built out from the edge of an uplifted block located on the southern side of the Murchison Fault Zone. The Waterberg rocks are extensively intruded by **diabase** units (sills, dykes) of ill-defined age (di / d, green in Figure 8), for example south of the Sandriviersberge and around Modimolle.

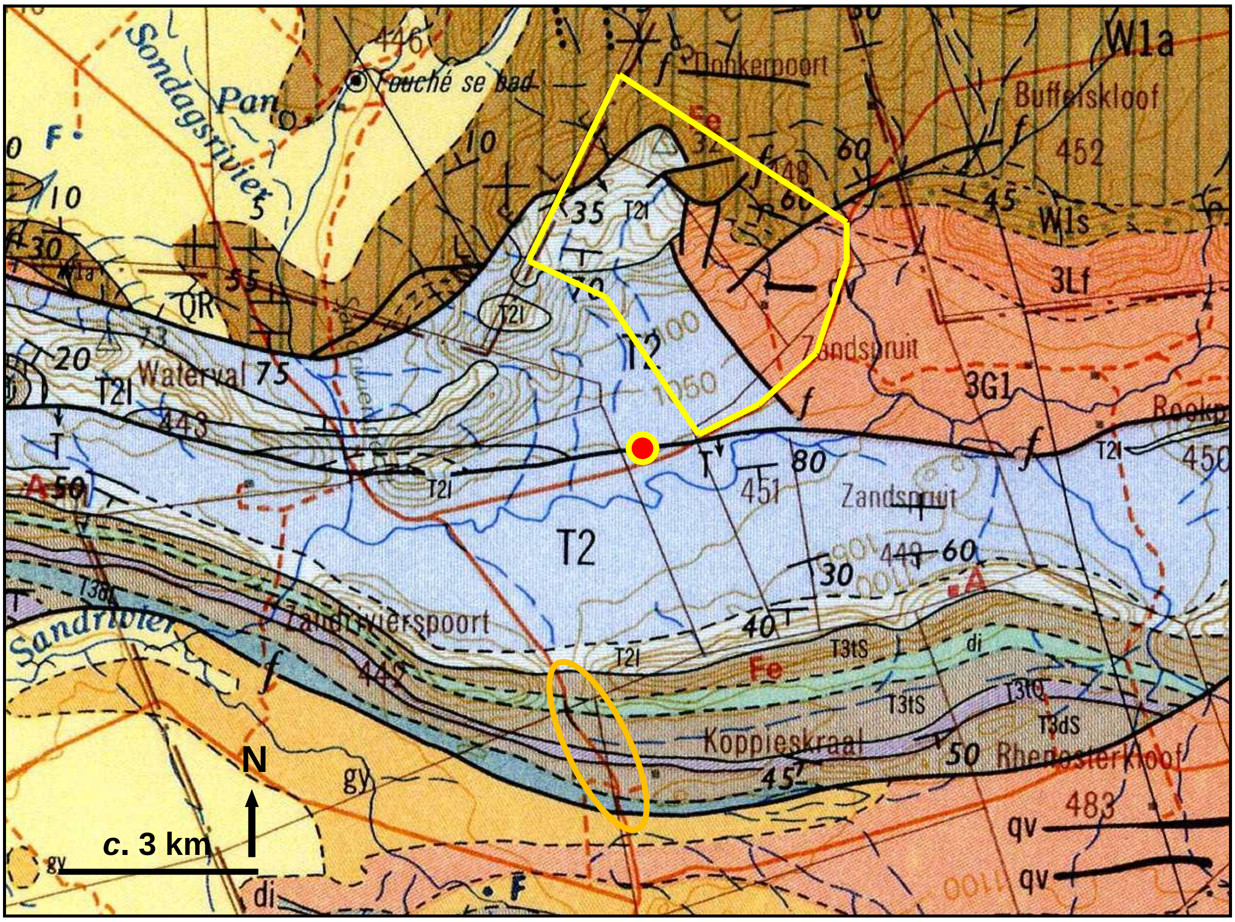


Figure 6. Extract from 1: 250 000 geology map 2426 Thabazimbi (Council for Geoscience, Pretoria) showing the approximate outline of the Meletse iron ore mine study area (yellow polygon). The location of Gatkop Cave along a major east-west trending thrust fault (thick black line) is shown by the red dot. The major rock units mapped within the study area include: T2 (medium blue) = Transvaal dolomites of the Malmani Subgroup (Chuniespoort Group, Transvaal Supergroup); T2l (pale blue) = banded ironstones of the Penge Formation (Chuniespoort Group). The orange ellipse to the east of Sandrivierspoort emphasises a series of formations making up the Pretoria Group, some of which may contain stromatolites. 3G1 (pale red) = granites of the Lebowa Granite Suite of the Bushveld Complex. 3Lf (pale red) = felsitic igneous rocks of the Bushveld Complex. W1a, W1s (brown) = continental sediments of the Waterberg Group (Swaershoek and Alma Formations of the Nylstroom Subgroup). Note several major thrust faults in this region.

4.1. Geology of Meletse Iron Ore Project study area

The Meletse Iron Ore Project study area, *c*. 25-30 km east of Thabazimbi in Limpopo Province, is largely situated in mountainous terrain towards the eastern end of the Meletse – Gatkop range that reaches elevations of 1862 mamsl and lies due south of the more extensive Sandriviersberge (Figures 1 & 4). The surrounding lowlands are largely utilised for agricultural purposes.

As shown on the geological map in Fig. 6 the gentler lower slopes of the Meletse mountain in the west are built of Transvaal dolomites (Malmani Subgroup) with banded ironstones of the Penge Formation – the target for iron ore mining - capping the mountain (reddish-brown on satellite images). The Transvaal Supergroup rocks are thrust northwards over granites of the Bushveld Complex (Lebowa Granite Suite) and unconformably overlying sediments of the Waterberg Group (Nylstroom Subgroup). The latter appear as rugged, well-stratified outcrop areas on satellite images. These younger rock units underlie much of the eastern portion of the study area. General levels of bedrock exposure over much of the study area are low due to extensive mantle of rocky colluvium, soil and vegetation (Figure 12).

4.2. Geology of the alternative ore transportation routes

Route 1 heading west from Meletse Iron Ore Project (Figures 4 & 8a) initially traverses Transvaal dolomites along the P240/1 dust road on northern side of the Sandrivier, crossing a major W-E trending thrust fault. The NNW-SSE sector along the D928 travels through a narrow gorge just to the east of Sandrivierpoort. Here the road transects the outcrop of a succession of south-dipping formations making up the Pretoria Group, with another major thrust fault along its southern margin (see orange oval Fig. 6). South of the fault the route briefly crosses the outcrop of Bushveld igneous rocks (granites and granophyres). Most of the following westerly route along the D1031 overlies various undifferentiated Late Caenozoic superficial sediments on the floodplain of the Sandrivier (probably mainly alluvium *plus* pedocretes), with a short sector of Bushveld granite. The westernmost sector of the D1031 as well as the tarred route stretches along the R511 and R510 as far as Chromedale Siding overlie a thick succession of Pretoria Group sedimentary rocks with occasional diabase sills.

Route 2 heading east of Meletse Iron Ore Project (Figures 4, 8a & 8b) traverses the lower part of the Waterberg Group succession (Nylstroom Subgroup) throughout almost its entire course. Most of the route overlies the outcrop area of the Alma Formation but the underlying, more conglomeratic Swaershoek Formation is traversed to the northwest of Modimolle. Minor diabase intrusions are crossed to the south of the Sandriviersberge as well as west of Alma and on the outskirts of Modimolle.

Figure 7. Typical reddish-brown braided fluvial sandstones with lenticular conglomeratic interbeds of the lower Waterberg Group (Alma Formation) to the east of Meletse (Hammer = 30 cm).

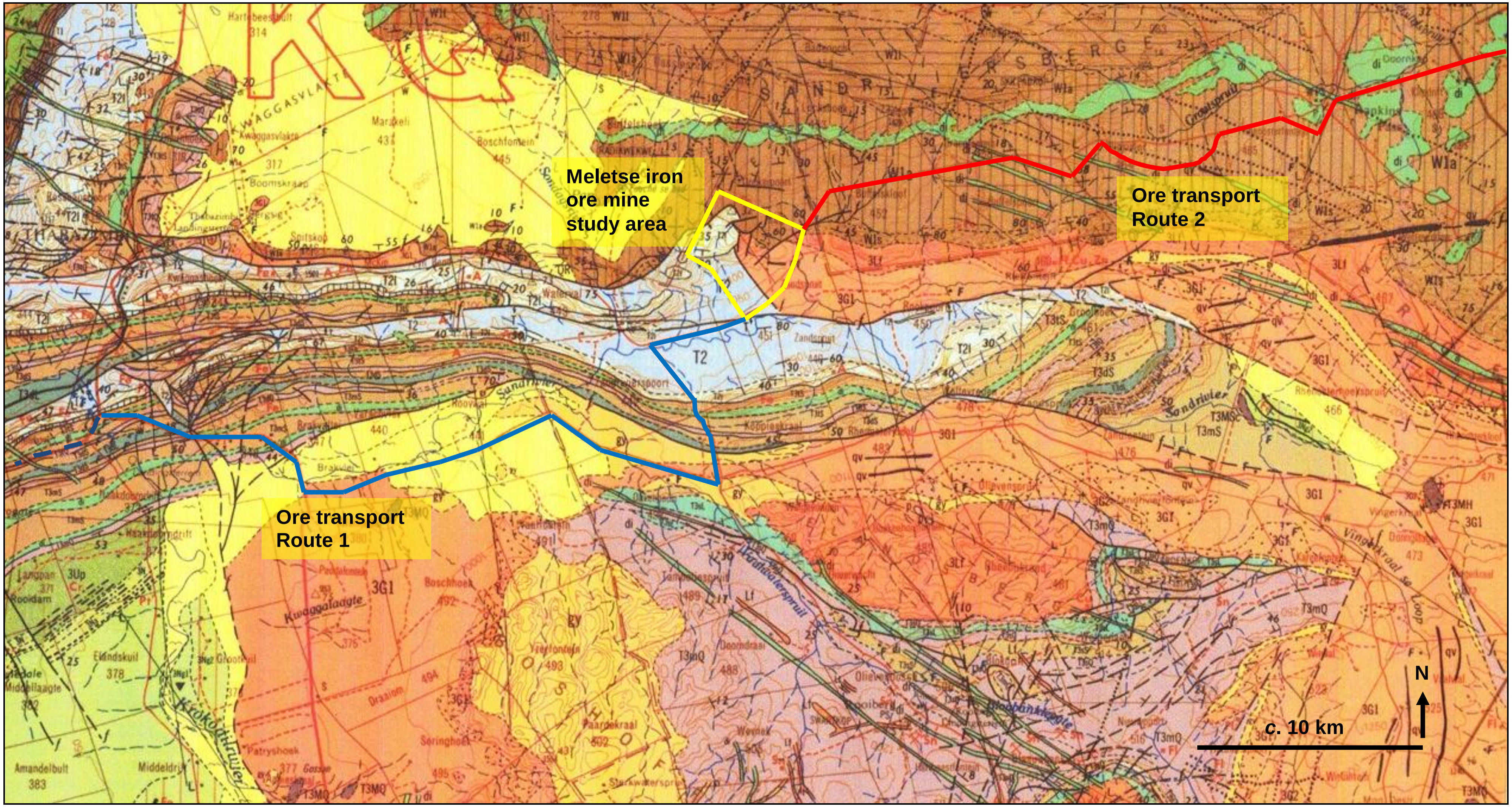


Figure 8a. Extract from 1: 250 000 geology map 2426 Thabazimbi (Council for Geoscience, Pretoria) showing the approximate outline of the Meletse iron ore mine study area (yellow polygon), ore transportation route Option 1 (blue line) and the western portion of ore transportation route Option 2 (red line). See legend to Figure 6 for key to the main rock units.

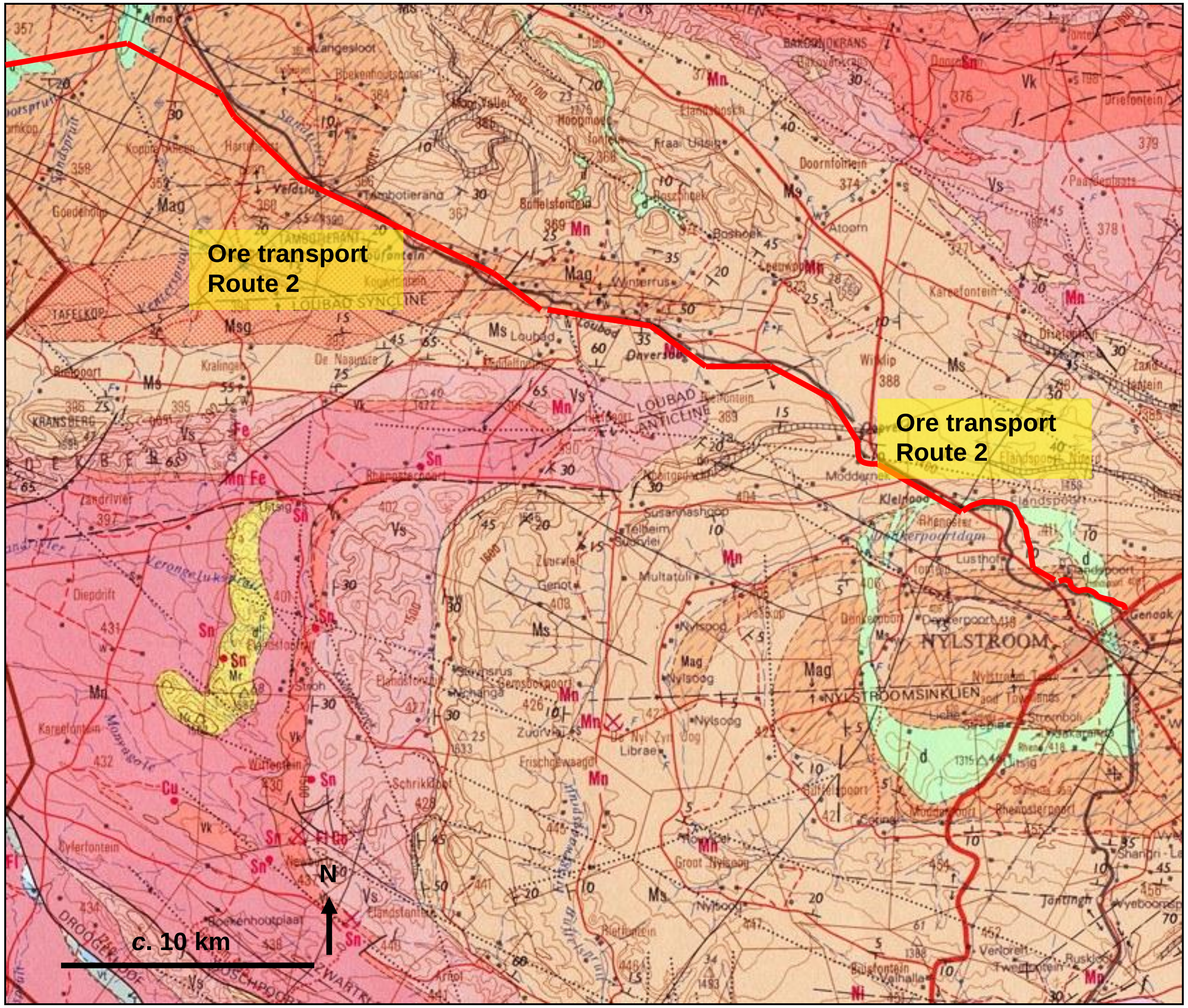


Figure 8b. Extract from 1: 250 000 geology map 2428 Nylstroom / Modimolle (Council for Geoscience, Pretoria) showing the eastern portion of ore transportation route Option 2 (red line) from Alma to Nylstroom. See legend to Fig. 6 for key to the main rock units.

4.3. Geology of the Gatkop Cave site

Gatkop Cave (24º 37' 05.2" S, 27º 39' 08.4" E) is a sizeable dolomitic cavern set in gently sloping, semi-arid thornveld terrain on the southern foothills of the Gatkop – Meletse mountain range, Limpopo Province (Fig. 12). The site is situated some 25.5 km ESE of Thabazimbi and just north of the Zandrivierspoort – Donkerpoort dust road (Figs. 1, 3 & 4). The winding Sandrivier, a tributary of the Crocodile, flows 0.4 km to the south. The mouth of the cave emerges through dolomite crags at *c*. 1000m amsl and is well shaded by sizeable trees (Fig. 13).

A detailed description of Gatkop Cave lies outside the brief for the present study; only a short, illustrated account of some of the geological features observed during the site visit is presented here. The various types of caves and cave openings found in the Transvaal dolomites are illustrated by Brain (1958) (Fig. 10). Gatkop Cave, situated on the gentle lower slopes of the Sandrivier Valley with a short, fairly wide and moderately sloping side entrance, is intermediate between Brain's types D and E. The approximate phase of development seen in Gatkop Cave is shown very schematically in Fig. 11 (From Brain and Watson 1992).

The regional dip of the Transvaal Supergroup rocks in the study region is towards the south (Fig. 6). However, well-exposed medium-bedded Malmani dolomites at the cave entrance show a moderately steep local dip to the northeast (Fig. 13). The south-facing entrance is littered with large, angular blocks of dolomite, some of which show well-developed elephant-skin weathering suggesting protracted exposure to the elements. The coarse rubble of fallen blocks with interstitial soil and hillwash continues down into a large main or entrance chamber, descending gently to the NE. The long axis of the chamber probably extends more-or-less NW-SE, parallel to the regional strike of the bedrocks (This orientation is assumed for the purposes of the present description). The main chamber of the cave is still largely open, with only a relatively limited sheet or cone of coarse blocky debris extending into it from the short but fairly wide side entrance (Fig. 14). The cave therefore does not appear to have been open to the exterior over a very long time interval in contrast with, for example, the cave systems in the Makapansgat Valley and at Swartkrans. Above a steeply sloping pile of large fallen blocks (collapse breccia) at the NW end of the main chamber there is a higher-lying subchamber that hosts a sizeable colony of bats and is floored with a soft carpet of bat guano. One or more small, open shafts that might possibly lead to lower-lying chambers are present in the NW part of the main cave.

The Malmani Subgroup host rocks consist of medium- to thin-bedded, pale grey to buff dolomites, dipping to the northeast, with numerous bands, lenticles and clots of yellowish to grey secondary chert and occasional thin grey mudrocks (Fig.15). Bedding is generally tabular, but often obscured by high levels of tectonic brecciation related to the major thrust fault zone along which Gatkop Cave developed (Fig. 16). Around the cave walls, especially on south-western side, the dolomite bedrock is obscured by a variety of cream to rusty-brown speleothems built of calc tufa or dripstone (sometimes termed travertine; *cf* Fig. 11). These speleothems include dense arrays of small stalactites on the roof and ridged to rippled flowstones on the walls and floor (Fig. 16). Sheets and irregular layers of flowstone locally overlie massive to bedded gravels and reddish finer sediments on the cave floor (Fig. 22). These fine ferruginous sediments are sometimes referred to as "cave earth". They probably consist of a mixture of allochthonous soil or hillwash *plus* aeolian dust together with autochthonous chert debris and terra rossa (*i.e.* iron-rich, insoluble residuum from dolomite dissolution). Thinly-laminated flowstone interbedded with reddish gravelly "cave earth" can be seen near the main entrance (Fig. 20).

Good, water-worn sections through dolomite breccias are preserved against the south-western face of the main chamber, with recent reddish-brown, fine-grained silty "cave earth" deposits banked up against them (Fig. 19). The dolomite clasts are variously subrounded to angular with a brownish matrix. These well-cemented breccias, either clast- or matrix-supported, clearly belong to an early phase of cave infilling. A meter-thick band of highly ferruginised and / or cave earth - rich breccia occurs within a downward-projecting roof buttress on the north-eastern wall of the main cave (Fig. 21). It is unclear whether any extraneous clasts, such as gravels of banded ironstone, are present within this zone. Lenticles of rubbly, vuggy dolomite breccias with pebble- to cobble-sized clasts, some apparently rounded, are exposed in the same area.

The most substantial breccias observed in Gatkop Cave are found on the steep walls of the north-western "upper" or bat-infested subchamber in the NW. The exposures are heavily draped in cobwebs (Figs. 17, 18). Some of the breccia bodies are plastered against the well-bedded Malmani dolomite bedrock. Other lenticles or bands of well-cemented breccia appear to be conformable and interbedded with the dolomitic bedrocks, but they probable infill bedding-parallel erosional cavities. The breccia clasts – exclusively composed of dolomite and chert - are poorly size-sorted, chaotically organised and often subrounded, implying a degree of water transport. These breccia exposures are ancient and water-worn. They are capped and cemented locally by pale, laminated flowstone (Fig. 18).

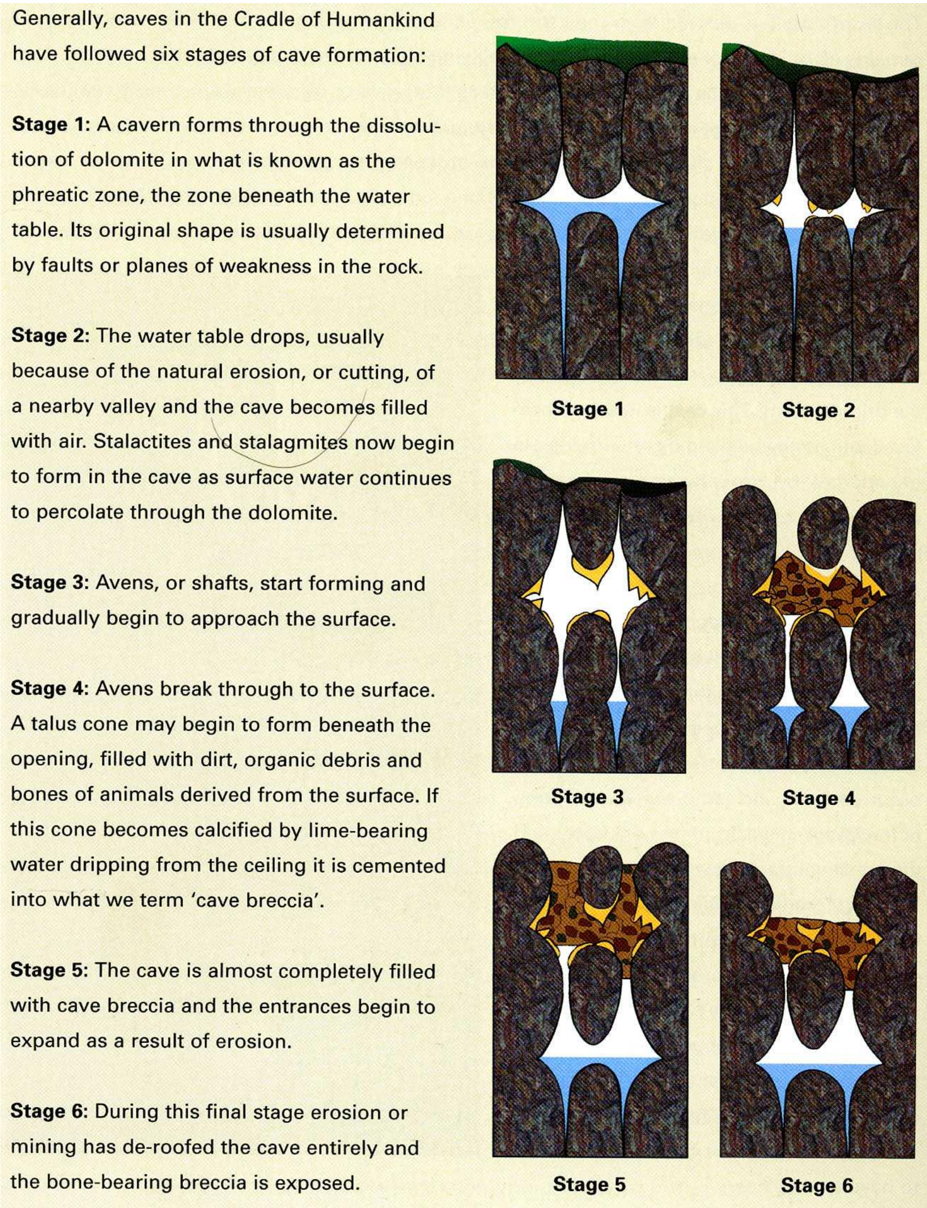


Figure 9. Simplified scheme to explain the successive stages of cave formation, infilling and eventual exposure of cave sediments by erosion in dolomitic terrain (From Hilton-Barber & Berger 2004).

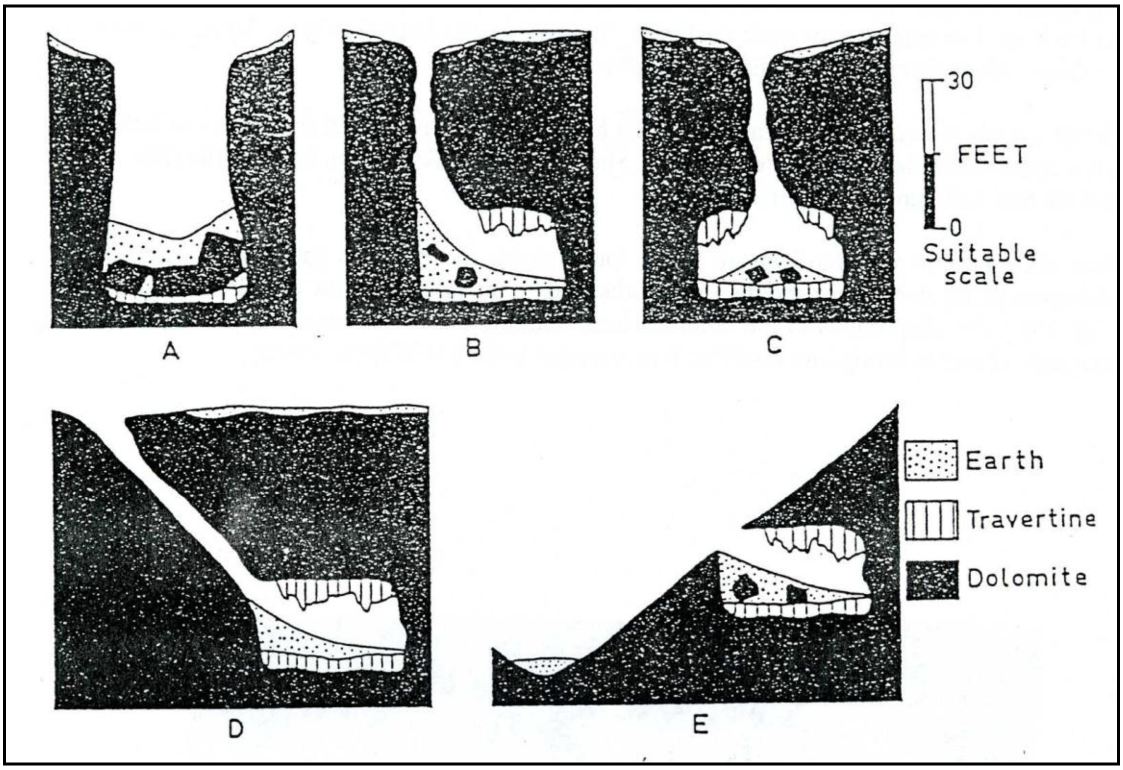


Figure 10. A range of different cave openings recognised in the Transvaal dolomites by Brain (1958). Gatkop Cave situated at a shallow depth below the gently sloping land surface is intermediate in form between types D and E.

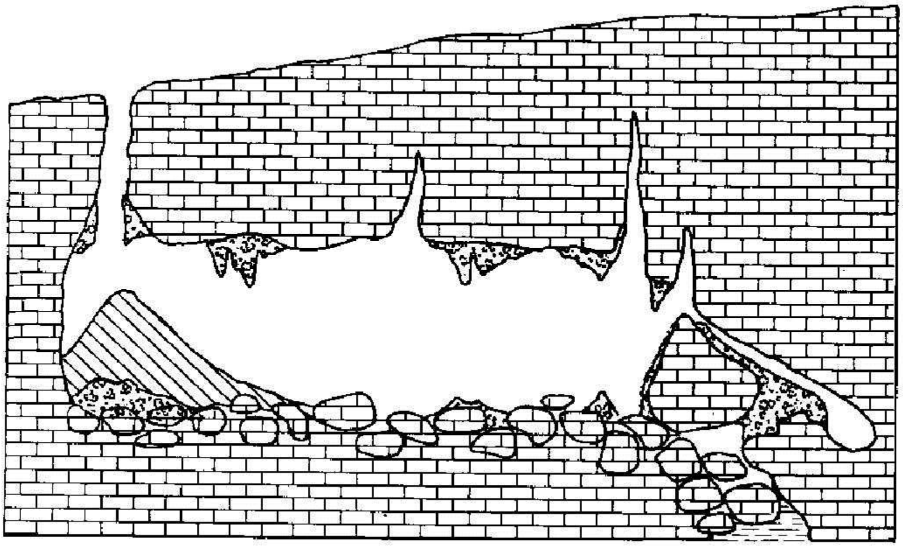


Figure 11. Schematic section through a dolomite cave at a similar early level of development to Gatkop Cave (From Brain & Watson 1992). As yet only a small portion of the main chamber has been infilled with sediment. The floor of the main chamber is carpeted with large dolomite blocks and residual chert inherited from the initial phase of cave formation by solution within the phreatic zone as well as subsequent roof collapse after the cave became air-filled. A relatively small debris cone composed of angular dolomitic rubble as well as soil, gravel, animal and plant remains and other material washed in from the exterior extends across the chamber floor from the single entrance to one side. Parts of the floor, side walls and roof of the original cave are lined with calc tufa, deposited from solution, including sheet-like flowstones as well as tapering stalactites and stalagmites. Vertical shafts or avens enlarged by solution along joints or other fractures extend up towards the surface. Some of these will eventually break through to create secondary entrances to the cave.

Figure 12. View of thornveld vegetation surrounding Gatkop Cave site, looking NNE towards Meletse peak. The mountains here are capped by banded ironstones of the Penge Formation while the slopes and foothills are built of Malmani dolomites and Bushveld granites.

Figure 13. South-facing entrance to Gatkop Cave showing rubble of fallen blocks extending into the cave interior and NE-dipping Malmani dolomites which host the cave system. The rusty old sign warns visitors of the danger of cave disease (histoplasmosis).

Figure 14. Main chamber of Gatkop Cave showing talus or scree of large, angular dolomite blocks extending from the entrance situated in the southwest. Petite archaeologist for scale.

Figure 15. Grey, thin-bedded, horizontally-laminated Malmani dolomites with slightly projecting, irregular lenticles and blobs of less soluble secondary chert (Scale = 16 cm).

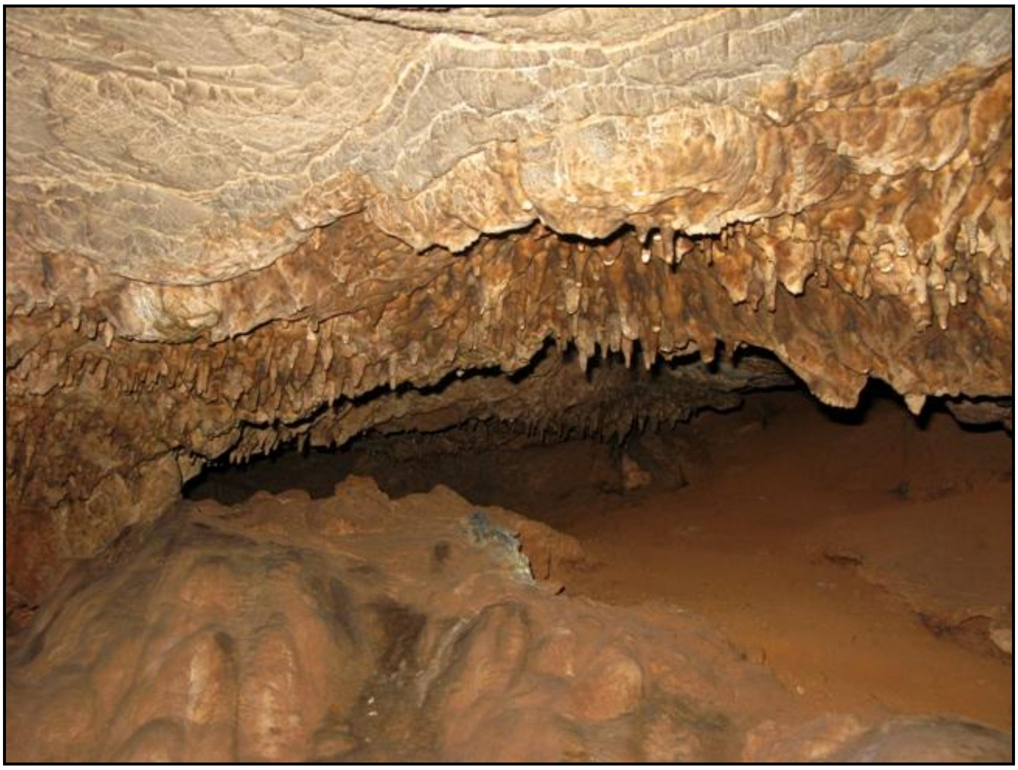


Figure 16. South-western margin of the main chamber showing roof of grey, brecciated dolomite covered with dense arrays of small stalactites (mostly broken). The floor of the cave here is mantled with reddish-brown cave earth overlying smooth to rippled flowstone.

Figure 17. Side wall of upper chamber in NE showing thick (*c*. 1m) horizon of well-cemented early dolomite breccia that is apparently sandwiched between thin-bedded, steeply-dipping dolomite beds.

Figure 18. Detail of breccia horizon in previous figure showing chaotic, clast-supported fabric, with poorly- sorted but moderately well-rounded dolomite and chert clasts. The pale banded rock above is carbonate flowstone that locally caps and cements together the underlying breccia.

Figure 19. Reddish-brown cave earth abutting against poorly-sorted, well-cemented dolomite breccia in the SW wall of the main chamber (Hammer = 30 cm). Dolomite clasts here are angular to subrounded and clast- to matrix-supported (possible debris flow origin).

Figure 20. Thin lenticle of pale, well-laminated flowstone and reddish-brown, well-cemented, gravelly cave earth intercalated between thick-bedded grey dolomite near the main cave entrance.

Figure 21. Horizon (*c*. 1m thick) of highly ferruginised breccia and reddish-brown material (possibly cave earth) overlying well-bedded Malmani dolomites, NE margin of main chamber (Scale = 16 cm).

Figure 22. Horizon of dolomite gravels overlain by interbedded reddish cave earth and pale flowstone layers, NE end of the main chamber The succession is capped by a thicker, dirty flowstone horizon (Hammer = 30 cm).

5. PALAEONTOLOGICAL HERITAGE

In this section of the report the fossil heritage reported from the main sedimentary rock units that are represented within the study area is briefly reviewed. Igneous rock units such as the Bushveld Complex and various diabase intrusions do not contain any fossils and are therefore not considered further here.

5.1. Fossils in the Malmani Subgroup

The Malmani Subgroup platform carbonates of the Transvaal Basin host a variety of stromatolites (microbial laminites), ranging from supratidal mats to intertidal columns and large subtidal domes. These biogenic structures are of biostratigraphic as well as palaeoecological interest; for example, the successive Malmani dolomite formations are in part differentiated by their stromatolite biotas (Eriksson *et al.* 2006). There is an extensive literature dealing with the Malmani stromatolites, including articles by Button (1973), Truswell and Eriksson (1972, 1973, and 1975), Eriksson and MacGregor (1981), Eriksson and Altermann (1998), Sumner (2000), Schopf (2006), among others. Microbial filaments and unicells have been reported from stromatolites of the Transvaal Supergroup (Eriksson & MacGregor 1981, MacGregor 2002 and refs. therein). Short accounts of stromatolites associated with Transvaal dolomite exposures in the Cradle of Humankind World Heritage Site, including the Makapansgat Valley, Limpopo, have been given by MacGregor (2002) and Maguire (1998). Finely-laminated Malmani dolomites are exposed both within and in the immediate vicinity of Gatkop Cave. The lamination may well be of microbial origin. No examples of domical or columnar stromatolites were observed here. In general, exposure levels of Malmani dolomites within the Meletse Iron Ore Project study area appear to be low due to extensive colluvial, soil and vegetation cover. There remains a possibility that well-preserved stromatolites are represented here, at or near-surface, but this can only be determined through fieldwork and excavation.

5.2. Fossils in the Penge Formation

Macrofossils have not been reported from banded ironstones of the Penge Formation such as outcrops along the crest of the Gatkop – Meletse range and that are the target of current ore prospecting activities there. It is of note that biological mediation of banded ironstone deposition has been proposed by some authors. Possible fossilised microbes, including tantalizing "siliceous nano-cucumber structures", have been reported from BIF facies in the Transvaal Supergroup of the Northern Cape and elsewhere (Klemm 1979, Hälbich *et al.* 1993).

5.3. Fossils in the Pretoria Group

Stromatolites have been recorded from several subunits within the Pretoria Group including lacustrine facies of the Timeball Hill Formation, marine facies in the Daspoort Formation (especially in the eastern outcrop area) and Silverton Formation, as well as the mudrock-dominated Vermont Formation (Button 1971, Catuneanu & Eriksson 2002, Eriksson *et al.* 2006). Pretoria Group subunits with stromatolites probably also contain organic-walled microfossils. This may well also apply to carbonaceous mudrocks. Microbial mat structures (desiccated mats sometimes resemble trace fossils) are known from paralic sandstones of the Magaliesberg Formation. Significant impacts on fossiliferous Pretoria Group rocks are not anticipated as a consequence of the Meletse Iron Ore Project.

5.4. Fossils in the Waterberg Group

The Early Proterozoic Waterberg Group and Soutpansberg Group "red bed" successions of southern Africa are of considerable palaeobiological and palaeoenvironmental significance in that they provide key evidence for the development of an oxygenated atmosphere on Earth after *c*. 2 billion years ago. Some of the earliest known (1.8 Ga) terrestrial cyanobacterial mats have been recorded from playa lake deposits of the Makgabeng Formation within the Waterberg Group outcrop area on the Makgabeng Plateau, west of Soutpansberg, Limpopo Province (Eriksson *et al.* 2000, Eriksson *et al.* 2008). The Makgabeng Formation does not occur within the present study area and the palaeontological sensitivity of the Waterberg braided fluvial rocks seen here is rated as low.

5.5. Fossil in the Late Caenozoic superficial sediments

The fossil record of most **Late Caenozoic superficial sediments** or "drift" deposits in the subcontinental interior have been comparatively neglected in palaeontological terms. The palaeontological sensitivity of these geologically youthful deposits is generally low. However, they may occasionally contain important fossil biotas, notably the bones, teeth and horn cores of mammals as well as remains of reptiles like tortoises. Good examples are the Pleistocene mammal faunas from alluvial and pan sediments in the Free State and elsewhere (Wells & Cooke 1942, Cooke 1974, Skead 1980, Klein 1984, Brink, J.S. 1987, Bousman *et al.* 1988, Bender & Brink 1992, Brink *et al*. 1995, MacRae 1999, Meadows & Watkeys 1999, Churchill *et al*. 2000, Partridge & Scott 2000, Brink & Rossouw 2000, Rossouw 2006). Other late Caenozoic fossil biotas from these superficial deposits include non-marine molluscs (bivalves, gastropods), ostrich egg shells, tortoise remains, trace fossils (*e.g.* calcretised termitaria, coprolites, invertebrate burrows), and plant material such as peats or palynomorphs (pollens) in organic-rich alluvial horizons (Scott 2000) and diatoms in pan sediments. In Quaternary deposits, fossil remains may be associated with human artefacts such as stone tools and are also of archaeological interest.

Significant impacts on fossiliferous Late Caenozoic superficial sediments are not anticipated as a consequence of the Meletse Iron Ore Project.

5.6. Fossils in Late Caenozoic cave deposits

In accordance with the brief for the earlier palaeontological site visit to Gatkop Cave, attention focused mainly, but not exclusively, on breccias within the cave infill (Almond 2012). Some of these deposits, by analogy with breccias in dolomite caves in the Cradle of Humankind and Makapansgat Valley for example, might be bone-bearing and thus of considerable palaeontological interest. Within the fossiliferous breccias the bone clasts may appear variously white, or secondarily reddened by ferric compounds, or even stained black by manganese minerals. The biostratigraphy and taxonomy of the rich Late Pliocene to Pleistocene mammalian faunas, including micromammal and hominin remains, that have been recorded from dolomite cave infills in the South African interior have been reviewed by authors such as Brain (1981), Klein (1984), McKee *et al.* (1995), Maguire (1998), Partridge (2000), Tobias (2000), and Avery (2000). Accessible, well-illustrated accounts of these fossil assemblages are provided by MacRae (1999) as well as Hilton-Barber and Berger (2004). Caves such as Sterkfontein have in addition yielded well-preserved fossil plant remains, including petrified (calcified) woods, pollens and spores (Bamford *in* Bonner *et al.* 2007, pp. 91-101).

Very useful accounts of the accumulation of fossiliferous cave breccias and cave taphonomy within a southern African context have been provided by Brain (1981), Maguire *et al.* (1980) and Partridge (2000), among others. These authors emphasize the important role played by carnivores, such as hyaenas, leopards and owls, in mammal bone accumulation within caves. Passive introduction of skeletal remains into caves through open shafts acting as fossil traps as well as the redistribution of bones within the cave system by gravity and water flow also played important roles.

It should be noted that not all breccias associated with dolomite caves are fossiliferous. Breccias may owe their origins variously to (1) energetic sedimentary processes in the original depositional basin (*e.g.* debris flows), (2) episodes of palaeokarst formation during Precambrian times, (3) fracturing of host rocks along major fault planes (as seen, for example, at Gatkop), as well as (4) deposition during the early to late phases of cave formation and subsequent cave infilling (*e.g.* roof-fall or collapse breccias, talus and debris cone breccias, or breccias formed by secondary reworking of debris cone material). Fossil-bearing breccias often contain extraneous (*i.e.* extra-cave) material such as soil, cave earth and gravels in addition to dolomitic and chert debris. In the present case, this extraneous material might include occasional gravel clasts of banded ironstone and reddish, ferruginous soils that typify the area. During the author's 2011 site visit, attention therefore focused on breccia horizons or lenses that do not consist exclusively of dolomitic and cherty debris. None of the breccia bodies inspected, including those containing an extraneous component such as reddish-hued cave earth, appear to contain recognisable macrofossil remains, however (Almond 2012).

6. CONCLUSIONS & RECOMMENDATIONS

The **Meletse Iron Ore Project** area, situated *c.* 25-30 km east of Thabazimbi in Limpopo Province, is largely underlain by Precambrian marine sediments of the Transvaal Supergroup (Malmani Subgroup dolomites, Penge Formation ironstones) and also by continental red-beds of the younger Waterberg Group in the northeast. Bushveld Complex granites crop out in the eastern sector. These Precambrian bedrocks are extensively mantled with colluvial (slope) deposits and soil on low palaeontological sensitivity. Apart from microbial mats, fossils are unknown from the Waterberg Group, while granites are invariably unfossiliferous. The Penge Formation ironstones that are targeted for opencast iron ore mining are not known to contain macroscopic fossil remains, although microbial fossils are probably present. The Malmani Subgroup dolomites and associated sediments are well-known elsewhere for their stromatolite biotas (reef-like microbial mounds), and also contain a range of microfossils. However, these recessive-weathering carbonate rocks are generally poorly exposed in the study area and the stromatolites are of widespread occurrence. It is concluded that the Meletse Iron Ore project area is of low palaeontological sensitivity.

This assessment applies to all **six optional layouts** for the opencast iron ore mine pit, waste dump and associated infrastructure within the study area which are all of LOW palaeontological impact significance. Options 4 to 6 are slightly preferred over Options 1 to 3, however, due to higher impact of the latter on potentially fossiliferous Malmani dolomites. Where practicable, dolomite rock exposures showing well-developed stromatolites should be safeguarded from damage during prospecting and mining activity and related infrastructure developments. Good examples of stromatolites should be reported to SAHRA for recording by a professional palaeontologist.

The **Gatkop Cave site** on farm Randstephane 455 KQ lies *outside* the current Meletse Iron Ore Project study area. Several dolomitic breccia units of various ages, degrees of cementation and sedimentary facies are exposed within the cave. They include horizons with a component of extraneous (*i.e.* extra-cave) material such as ferruginous cave earth, gravel or soil. However, no occurrences of bone-bearing breccia were identified during a recent site visit (Almond 2012). Dolomitic host rocks of the Malmani Subgroup show here fine lamination but no well-developed stromatolitic domes or columns. It is concluded that the palaeontological sensitivity of the Gatkop Cave site is probably LOW. The site is situated some four kilometres SSW of the main iron ore prospecting area and over 600 m lower in elevation. Any unrecorded palaeontological heritage resources here are therefore unlikely to be directly or indirectly affected by prospecting or any subsequent mining activity. Protection of the cave site on archaeological and cultural heritage grounds, as recommended by the cultural heritage assessment practitioner (Miller 2011), should in turn safeguard any fossil remains in the area. No special measures to protect fossil heritage are therefore warranted here

The two alternative **ore transportation routes** from the Meletse Iron Ore Project under consideration follow existing roads. Upgrading of several sections from unpaved to tar roads as well as upgrading of several culverts and bridges is envisioned here, bit not major new excavations of potentially fossiliferous bedrock. **Route 1** running to the west of the Meletse Iron Ore Project traverses the outcrop areas of a wide range of geological units, the majority of which are of low palaeontological sensitivity (*e.g.* Malmani dolomites, Bushveld igneous rocks, Late Caenozoic superficial deposits). Significant impacts on possible stromatolite-bearing formations within the Pretoria Group to the south of Thabazimbi (R511, R510) as well as in the gorge just east of Sandrivierpoort (D928) are not anticipated here. **Route 2** running from the Meletse Iron Ore Project to Modimolle *via* Alma is almost entirely underlain by Precambrian fluvial sandstones and conglomerates of the lowermost Waterberg Group (Nylstroom Subgroup) that are of low palaeontological sensitivity. It is concluded that there is no preference on palaeontological heritage grounds between the two alternative routes which are both of LOW palaeontological impact significance.

Recent (unauthorised) prospecting activities at the Meletse iron ore mine have involved the construction of ± 32.89 km of roads entailing ±33 ha disturbance and also twelve blasting operations. The overall impact significance of the proposed Meletse opencast iron ore mining project, including upgrading of the associated ore transport routes as well as recent prospecting activities, is considered to be LOW. Pending the discovery of substantial new fossil remains during development, no further specialist palaeontological studies or mitigation for this project are considered necessary.

- The ECO responsible for the mining and road developments should be aware of the possibility of important fossils being present or unearthed on site and should monitor all substantial excavations into fresh (*i.e.* unweathered) sedimentary bedrock for fossil remains;

- In the case of any significant fossil finds (*e.g.* vertebrate teeth, bones, stromatolites) during construction, these should be safeguarded - preferably *in situ* - and reported by the ECO as soon as possible to the relevant heritage management authority (South African Heritage Resources Agency. Contact details: SAHRA, 111 Harrington Street, Cape Town. PO Box 4637, Cape Town 8000, South Africa. Phone: +27 (0)21 462 4502. Fax: +27 (0)21 462

4509. Web: www.sahra.org.za) so that any appropriate mitigation by a palaeontological specialist can be considered and implemented, at the developer's expense;

- These recommendations should be incorporated into the EMP for the Meletse Iron Ore 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).

7. ACKNOWLEDGEMENTS

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APPENDIX: ASSESSMENT OF IMPACTS ON FOSSIL HERITAGE OF PAST AND FUTURE ACTIVITIES ASSOCIATED WITH THE MELETSE IRON ORE PROJECT

Updated maps showing the layout of the Meletse Iron Ore mine near Thabazibi, Limpopo, including on-site road infrastructure, are given in Figures. A1 to A3 below.

In Table A1 the estimated or anticipated impacts on local fossil heritage resources are assessed with regard to (a) activities previous to completion of the combined desktop and field-based given above (prospecting activities, including construction of prospecting roads), and (b) proposed mining and related activities (including upgrading of haulage roads).

The NATURE OF THE IMPACT of relevance here is*: disturbance, damage or destruction of fossil heritage resources on or beneath the surface of the ground during the construction or operational phase of the mine.*

Given the LOW PALAEONTOLOGICAL SENSITIVITY of the bedrocks and superficial deposits represented within the development footprint, the probability of *significant* palaeontological impacts is anticipated to be LOW (UNLIKELY)). Any impacts are likely to be of LIMITED EXTENT (restricted to development footprint) and volume, but they are generally IRREVERSIBLE. Impact magnitudes are therefore assessed as LOW.

It is concluded that palaeontological impacts relating to the Meletse Iron Ore Project are of LOW SIGNIFICANCE.

Pending the discovery of substantial new fossil remains during development, NO FURTHER SPECIALIST PALAEONTOLOGICAL STUDIES OR MITIGATION for this project are considered necessary.

Given the small scale of the mining developments with regard to the total outcrop area of the comparatively unfossiliferous rock units concerned, cumulative impacts are rated as LOW.

This assessment applies to past activities (*e.g.* construction of prospecting roads and other prospecting activities) as well as to future mining and related activities.

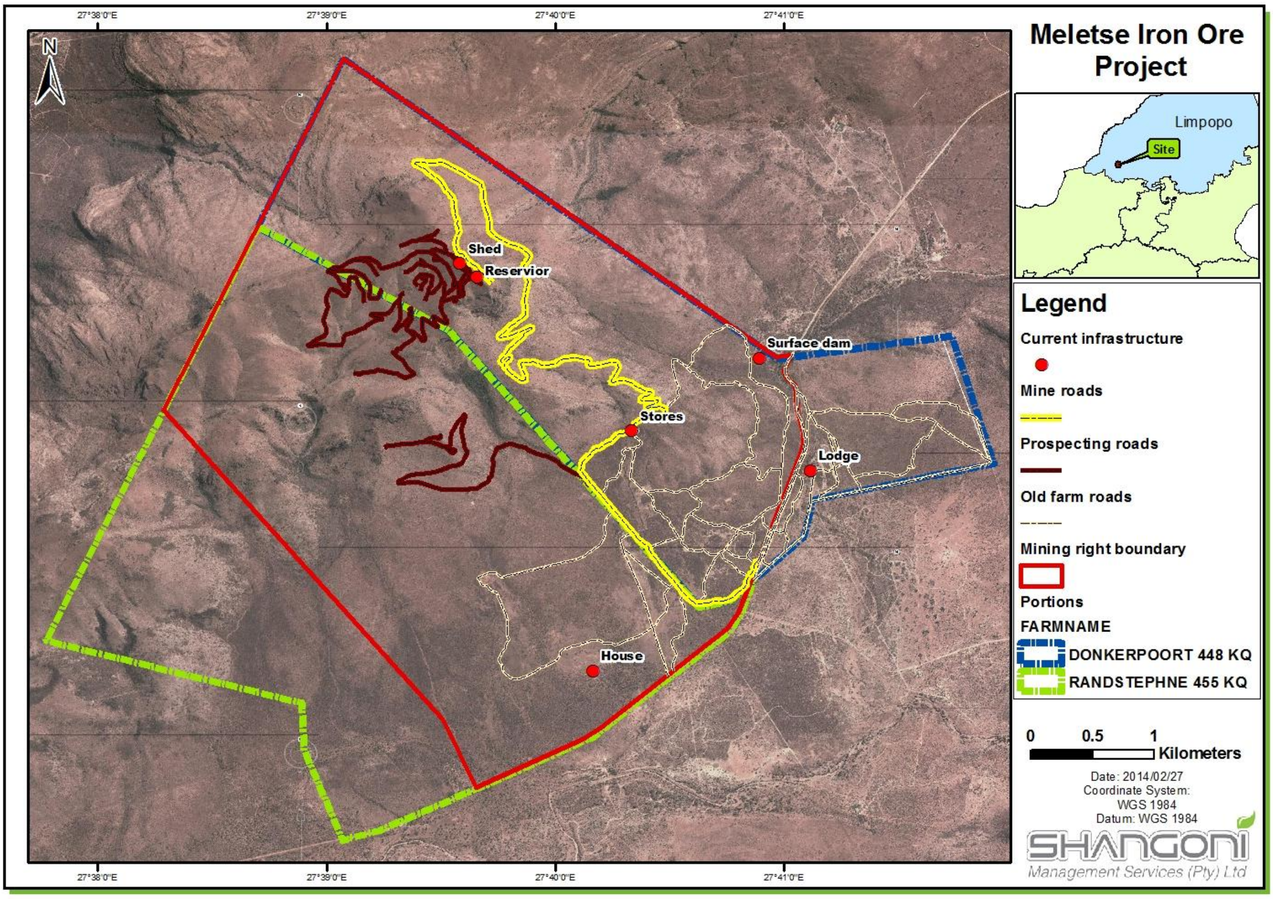

Figure A1. Summary map showing land parcels and infrastructure related to the proposed Meletse Iron Ore Project (Image kindly supplied by Shangoni Management Services (Pty) Ltd).

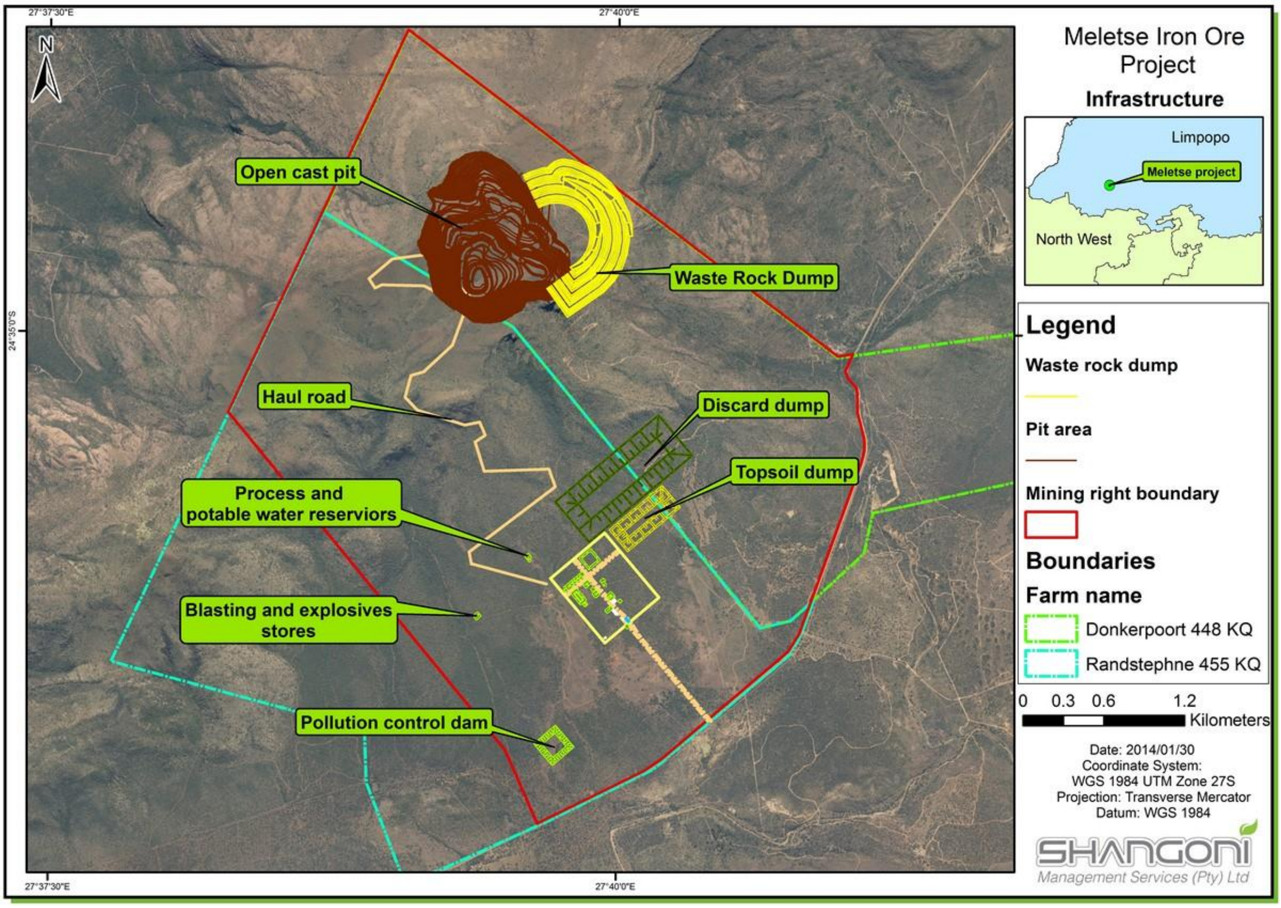

Figure A2. Map showing planned infrastructure related to the proposed Meletse Iron Ore Project (Image kindly supplied by Shangoni Management Services (Pty) Ltd).

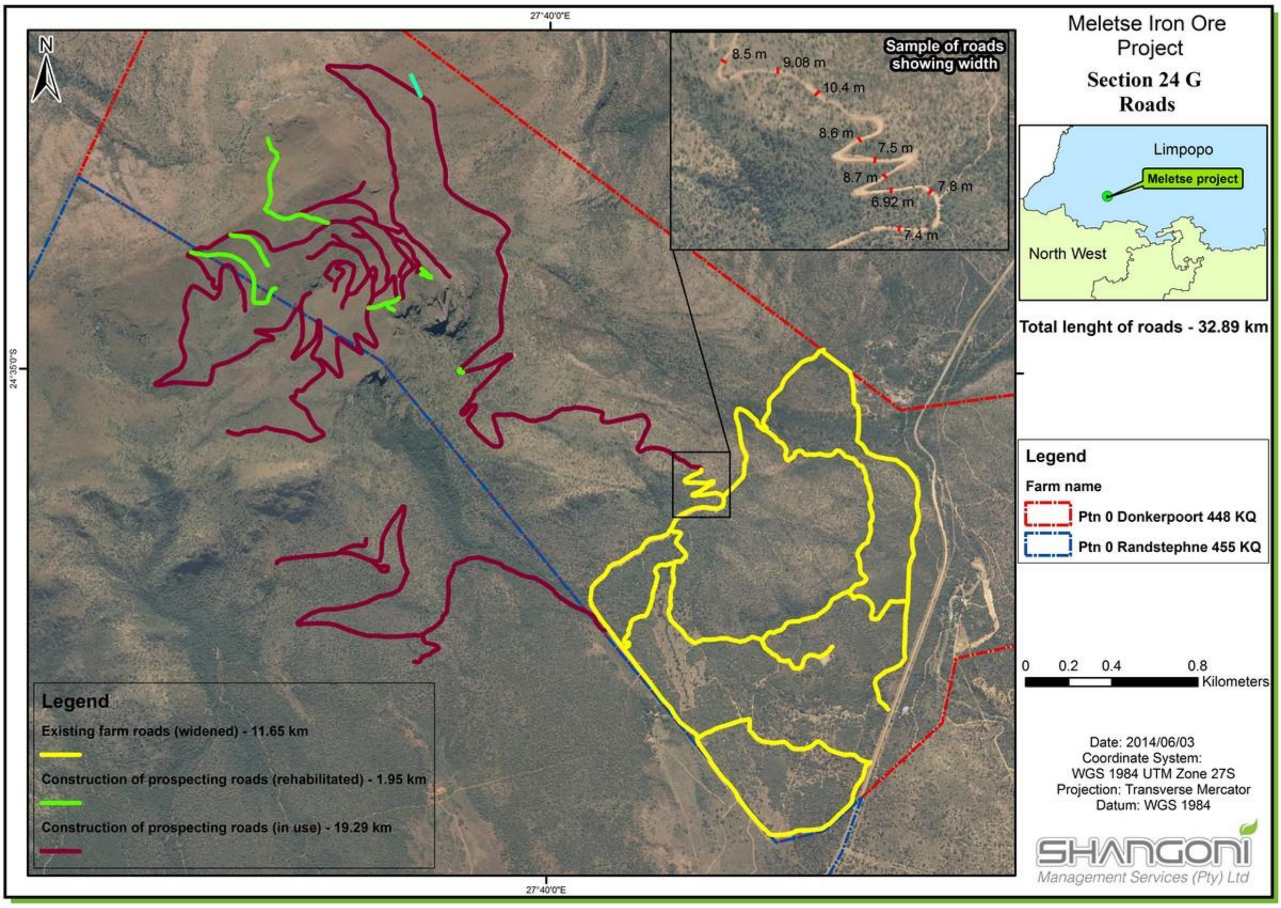

Figure A3. Map showing original and new road infrastructure related to the proposed Meletse Iron Ore Project (Image kindly supplied by Shangoni Management Services (Pty) Ltd).

Table A1: Assessment of actual or potential impacts on local palaeontological heritage resources associated with the Meletse Iron Ore Project near Thabazimbi

Nature of impact: disturbance, damage or destruction of fossil heritage resources on or beneath the surface of the ground during the construction or operational phase of the mine

Activities	***Significance of impact***	***Degree to which impact can be reversed***	***Degree to which impact may cause irreplaceable loss***	***Cumulative Impact***	***Mitigation possibility***
Previous activity as undertaken prior to specialist site visit: *Prospecting (± 32.89km roads constructed (±33ha disturbance) for prospecting activities, also 12x blasting done during the same period).* *See Figure A3 herein*	*Given the low probability (unlikely) and limited extent (restricted to development footprint) of substantial impacts to fossil heritage, their significance is rated as LOW*	*Impacts to fossil heritage are normally irreversible*	*Any losses of local fossil heritage are irreplaceable*	*Cumulative impacts are LOW, given the small scale of the developments with regard to the total outcrop area of the comparatively unfossiliferous rock units concerned*	*No mitigation measures are recommended*

Proposed activity: *Mining and related activities, including upgrading of proposed ore haulage routes* *See Figures 2, A1 and A2 herein.*	*Given the low probability (unlikely) and limited extent (restricted to development footprint) of substantial impacts to fossil heritage, their significance is rated as LOW*	*Impacts to fossil heritage are normally irreversible*	*Any losses of local fossil heritage are irreplaceable*	*Cumulative impacts are LOW, given the small scale of the developments with regard to the total outcrop area of the fossiliferous rock units concerned*	*No mitigation measures are recommended*

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 project, application or appeal in respect of which I was appointed other than fair remuneration for work performed in connection with the activity, application or appeal. There are no circumstances that compromise the objectivity of my performing such work.

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