Palaeontological specialist assessment: combined desktop and field-based study

PROPOSED 16 MTPA EXPANSION OF TRANSNET'S EXISTING MANGANESE ORE EXPORT RAILWAY LINE & ASSOCIATED INFRASTRUCTURE BETWEEN HOTAZEL AND THE PORT OF NGQURA, NORTHERN & EASTERN CAPE.

Part 1: Hotazel to Kimberley, Northern Cape

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November 2013

EXECUTIVE SUMMARY

Transnet SOC Limited is planning to expand the capacity of the existing manganese ore export railway line between Hotazel (Northern Cape) and the Port of Ngqura (Coega IDZ, Eastern Cape) from the originally envisaged 12 Mtpa to 16 Mtpa. In the Northern Cape an additional eight rail loops that were not part of the previous EIA will be extended and two new loops will be constructed, one at Witloop and another close to Sishen. The present combined desktop and field-based palaeontological heritage report forms part of the Basic Assessment process for (1) the ten railway loop developments along the manganese ore railway line between Hotazel and Kimberley in the Northern Cape, as well as (2) thirteen associated borrow pit sites. The 16 Mtpa expansion will require a new rail compilation yard located at Mamathwane, Northern Cape, which is the subject of a separate palaeontological assessment report.

The construction phase of the proposed new and extended railway loops as well as of borrow pits along the Transnet Hotazel to Kimberley manganese ore railway will entail substantial excavations into the superficial sediment cover as well as locally into the underlying bedrock. These excavations may disturb, damage or destroy scientifically valuable fossil heritage exposed at the surface or buried below ground. Other infrastructure components (*e.g.* laydown areas) may seal-in buried fossil heritage. However, with the exception of several (but not all) of the borrow pits, most of the direct impacts will occur within the existing railway reserve, which is already highly disturbed, while palaeontologically sensitive rock units along the route, such as the lower Ecca Group, will be directly affected by the construction programme only to a very marginal extent (*e.g.* Fieldsview borrow pit). The operational and decommissioning phases of the 16 Mtpa railway project are very unlikely to involve significant adverse impacts on palaeontological heritage.

Fieldwork shows that most of the loop study sites are mantled with superficial sediments of the Kalahari Group – predominantly thick calcrete ("surface limestone") hardpans, aeolian sands and surface gravels – that are mainly of Late Caenozoic (Pliocene / Quaternary – Holocene) age and at most very sparsely fossiliferous (Table 1). The very limited fossil remains recorded here – principally isolated blocks of stromatolitic dolostone and chert at Trewil and Tsantabane as well as low-diversity trace fossil assemblages at Witloop – are of low palaeontological significance and special mitigation measures are not considered warranted in these three cases.

At the Fieldsview loop extension site unfossiliferous lavas of the Ventersdorp Supergroup (Precambrian) are locally overlain by thin outliers of Dwyka Group tillite and mantled with quartz-rich gravels (possibly diamondiferous) as well as Hutton sands. The Gong Gong loop extension study site is also largely underlain by Ventersdorp lavas but in the southern part of the area a thick calcrete hardpan overlies Ecca Group mudrocks locally. The latter are too deeply weathered to be fossiliferous, however. Thick calcrete hardpans are also developed at the Ulco loop extension site, here replacing alluvial deposits of the Harts River, and at Trewil loop extension site where they overlie Campbell Rand Supergroup dolostones (Precambrian Ghaap Group). Occasional displaced or reworked blocks of dolostone and chert at Trewil contain fossil stromatolites (microbial mounds) but these are widely represented within the surrounding bedrocks and no exceptionally well-preserved examples were observed. The thick calcrete development at Tsantsabane loop extension site features impressive calcretised fluvial conglomerates overlain by downwasted gravels. At Postmasburg loop extension site surface gravels are dominated by locally derived chert and iron ore clasts, in places cemented to form ferricrete, overlying karstified Campbell Rand carbonate bedrocks that probably contain stromatolites. Deeply-weathered Campbell Rand siltstones at Glosam loop extension site are mantled by conglomerates largely composed of iron ore pebbles and cobbles that also infill deep karstic solution hollows in tectonically disturbed dolostones. The very thick Kalahari calcrete at the Sishen new loop site is karstified at the top and contains sizeable pipe-like solution hollows that are partially infilled with calcrete gravel breccia (apparently unfossiliferous). Well-developed calcrete hardpans and calcrete rubble are also present at Wincanton loop extension site. A complex calcrete succession at Witloop new loop site is associated with the largely abandoned Witloopleegte drainage system (a tributary of the Ga-Mogara River). The older calcretes here are partially silicified and overlain by calcretised river channel gravels. The upper calcrete beds are extensively bioturbated by dense branching burrow systems (possibly of insects), plant root impressions and the moulds of narrow reed-like plants that were probably associated with damp vlei settings within a largely abandoned river channel.

The geology and fossils at each of the thirteen borrow pit sites examined between Kimberley and Hotazel is summarized in Table 3 of this report. Most of the proposed borrow pits will be excavated into Kalahari Group sediments (calcretes, gravels, sands) of low palaeontological sensitivity. Karoo Supergroup marine mudrocks of the Dwyka and Ecca Groups represented in borrow pits at Fieldsview and Gong Gong are apparently unfossiliferous and / or deeply weathered.

The only fossil remains recorded during field assessment include (1) isolated blocks of Precambrian dolostone and chert of the Campbell Rand Subgroup containing small to medium-sized domical stromatolites (microbial domes) at both Trewil borrow pit sites and Tsantsabane and (2) low-diversity trace fossil assemblages within vlei-associated calcretes at the two Witloop borrow pit sites. Such fossils are of widespread occurrence so impacts on fossil heritage here are likely to be of low significance and special mitigation measures are not considered warranted.

Due to the low palaeontological sensitivity of the bedrocks as well as superficial sediments along the Kimberley to Hotazel sector of the 16 Mtpa manganese ore export railway line at the ten proposed railway loop sites and the thirteen proposed borrow pit sites, the proposed developments are rated as of LOW palaeontological heritage significance. It is concluded that they are unlikely to constitute a significant threat to fossil heritage within the study area. There are therefore no objections on palaeontological heritage grounds to the proposed developments and, pending the discovery of significant new fossils during the construction phase, no further specialist studies are recommended here.

It is recommended that:

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

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

- These recommendations should be incorporated into the Environmental Management Plan (EMP) for the 16 Mtpa manganese ore export railway line project.

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

1. INTRODUCTION AND BRIEF

Manganese ore mined in the Hotazel area near Kuruman (Kalahari Manganese Field) in the Northern Cape is transported by rail to a bulk minerals handling terminal at Port Elizabeth, where it is unloaded and placed on stockpiles before being loaded onto ships for export. Transnet SOC Limited is planning to expand the capacity of the existing manganese ore export railway line between Hotazel (Northern Cape) and the Port of Ngqura (Coega IDZ, Eastern Cape) from the originally envisaged 12 Mtpa to 16 Mtpa. Twelve project areas were originally assessed when the 12 Mtpa Environmental Impact Assessment was completed in 2009. In the Northern Cape an additional eight rail loops that were not part of the previous EIA will be extended (Fieldsview, Gong Gong, Ulco, Trewil, Tsantsabane, Postmasburg, Glosam, Wincanton). Two new loops will also be constructed, one at Witloop and another close to Sishen (Table 1 and map Fig. 1). Thirteen associated borrow pit developments have also been proposed close to the railway line between Kimberley and Hotazel; most of these lie within the existing railway reserve and close to the loop development sites (Table 3). All these proposed loop and borrow pit developments are covered by the present combined desktop and field-based palaeontological heritage assessment. The 16 Mtpa expansion will in addition require a new rail compilation yard located at Mamathwane near Hotazel in the Northern Cape which is the subject of a separate palaeontological assessment.

1.1. Legislative context for palaeontological assessment studies

ERM Southern Africa (Pty) Ltd (Block A, Silverwood House, Silverwood Close, Steenberg Office Park, Cape Town 7945, South Africa; tel: +27 21 702 9100) has been appointed as the Independent Environmental Assessment Practitioners to undertake a Basic Assessment of an additional fourteen railway loops between Hotazel and Ngqura and the associated borrow pit developments.

The present combined desktop and field-based study forms part of the Basic Assessment of the proposed loop and borrow pit developments located between Hotazel and Kimberley in the Northern Cape. A list of the loops under consideration is given in Table 1 and these are also shown on the map in Fig. 1 (kindly provided by ERM). The borrow pit sites are listed in Table 3. The present palaeontological heritage report also falls under Section 38 (Heritage Resources Management) of the South African Heritage Resources Act (Act No. 25 of 1999), and it will also inform the Environmental Management Plan for this project.

The proposed railway line developments are located in areas that are underlain by potentially fossil-rich sedimentary rocks of Precambrian and younger, Tertiary or Quaternary age (Sections 2 and 3). The construction phase of the loop and borrow pit developments will entail substantial excavations into the superficial sediment cover as well as locally into the underlying bedrock. In addition, sizeable areas of bedrock may be sealed-in or sterilized by railway infrastructure, lay-down areas as well as new gravel roads. All these developments may adversely affect potential fossil heritage at or beneath the surface of the ground within the study area by destroying, disturbing or permanently sealing-in fossils that are then no longer available for scientific research or other public good. Once constructed, the operational and decommissioning phases of the railway developments are unlikely to involve further adverse impacts on palaeontological heritage, however.

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 recently been published by SAHRA (1913).

1.2. Scope of this palaeontological heritage study

This combined desktop and field-based palaeontological specialist report provides an assessment of the observed or inferred palaeontological heritage within the ten proposed loop study areas and thirteen associated borrow pit study areas within the Northern Cape between Hotazel and Kimberley (Fig. 1, Table 1, Table 3), with recommendations for further specialist palaeontological studies and / or mitigation where this is considered necessary.

The report has been commissioned by ERM Southern Africa (Pty) Ltd (Block A, Silverwood House, Silverwood Close, Steenberg Office Park, Cape Town 7945, South Africa; tel: +27 21 702 9100). It contributes to the Basic Assessment for the proposed 16 Mtpa railway expansion and it will also inform the Environmental Management Plan for the project. The scope of work for this desktop study, as defined by ERM, is as follows:

> The Contractor's role involves generating a Paleontological Baseline Report and a Paleontological Assessment Report. The findings will be based on one extended field trip (10 days) covering both the Northern Cape and Eastern Cape.

1.3. Approach to the palaeontological heritage Basic Assessment study

The approach to this palaeontological heritage Basic Assessment study is briefly as follows. Fossil bearing rock units occurring within the broader study area are determined from geological maps and satellite images (Figs. 3 to 8). 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 (Table 2). 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 (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 (Provisional tabulations of palaeontological sensitivity of all formations in the Western, Eastern and Northern Cape have already been compiled by J. Almond and colleagues; *e.g.* Almond & Pether 2008). 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 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 (*e.g.* SAHRA for the Northern Cape). 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.

1.4. 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 present case, site visits to the various loop and borrow pit study areas in some cases considerably modified our understanding of the rock units (and hence potential fossil heritage) represented there.

In the case of the Transnet 16 Mtpa study areas a major limitation for fossil heritage studies is the low level of exposure of potentially fossiliferous bedrocks such as the Karoo Supergroup, as well as the paucity of previous specialist palaeontological studies in the Northern Cape region as a whole.

1.5. Information sources

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

1. A short project outline provided by ERM;

2. A review of the relevant scientific literature, including published geological maps and accompanying sheet explanations as well as several desktop and field-based palaeontological assessment studies in the broader Hotazel to Kimberley region by the author (*e.g.* Almond 2010a, 2010b, 2011a, 2011b, 2012a, 2012b, among others) (See also previous desktop study of the Northern Cape railway loop developments by Almond 2012d).

3. The author's previous field experience with the formations concerned and their palaeontological heritage (See also review of Northern Cape fossil heritage by Almond & Pether 2008).

4. A seven-day field assessment of the relevant loop and borrow pit study areas in October 2013.

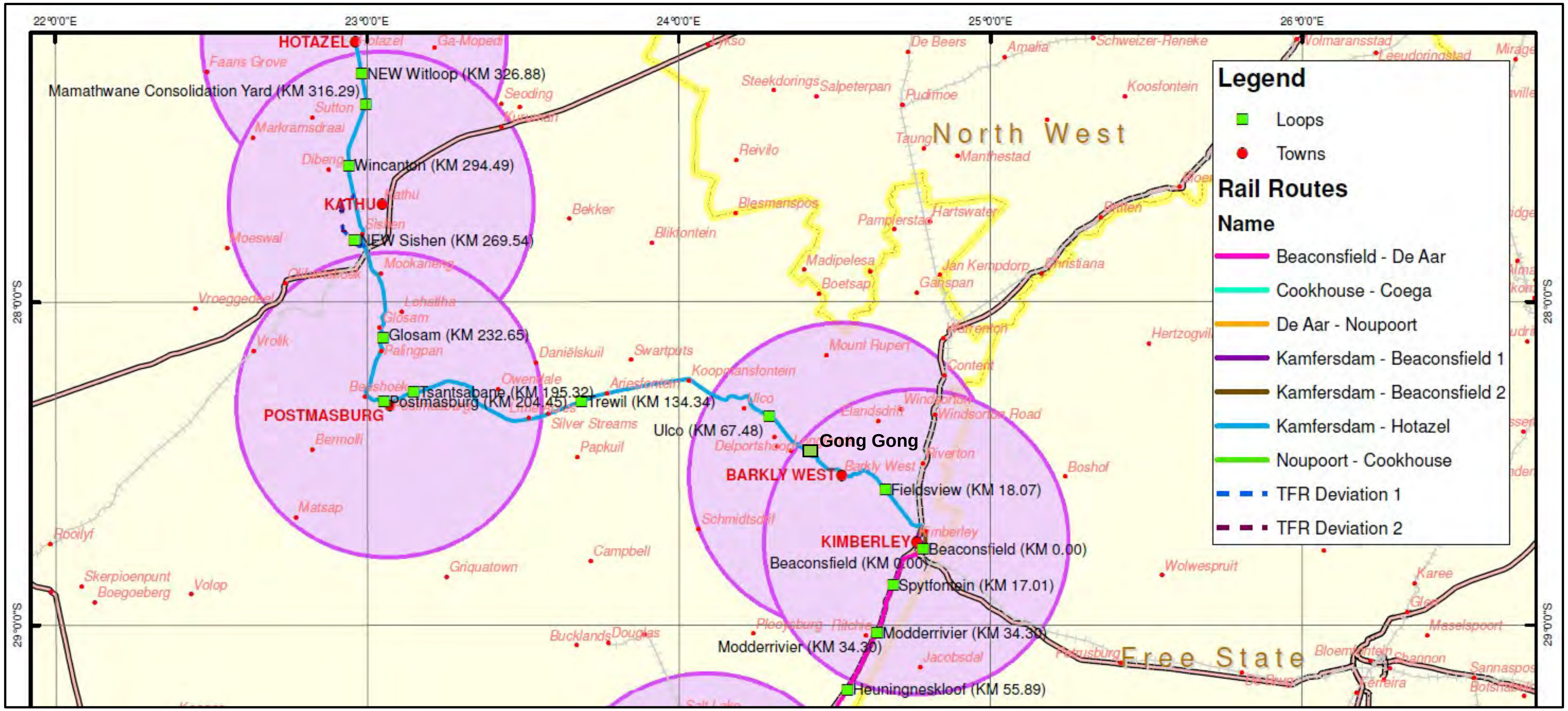

Fig. 1. Map of the Hotazel to Kimberley sector of the Transnet manganese ore export railway line, Northern Cape, showing the ten railway loop sites between Hotazel and Kimberley covered by the present desktop Basic Assessment report (green squares) as well as the location of the proposed Mamathwane Compilation Yard (Map modified from image kindly provided by ERM).

Table 1. Summary of geology, palaeontological sensitivity and recommended action regarding fossil heritage resources at the 10 railway loop study sites between Hotazel and Kimberley, based on published data and current fieldwork.

LOOP	APPROXIMATE LOCATION	PROJECT	GEOLOGY	PALAEONTOLOGICAL HERITAGE SENSITIVITY	RECOMMENDATION
1. WITLOOP	27º 17' 54.4" S 23º 00' 59.05" E	New loop	Thick, complex calcrete succession, including silicified calcretes, calcretised fluvial gravels and bioturbated vlei deposits (Kalahari Group)	MEDIUM TO LOW	No further palaeontological specialist input required, pending discovery of significant new fossil remains during development. ECO should be alerted to possible important fossil finds during the construction phase. Significant fossil remains exposed during development (*e.g.* vertebrate bones, shell concentrations, plant remains) should be safeguarded and reported by the ECO to SAHRA for professional recording and mitigation.
2. WINCANTON	27º 34' 48.1" S 22º 56' 27.02" E	Loop extension	Thick calcrete hardpan mantled by calcrete surface rubble, Gordonia Formation aeolian sands (Kalahari Group)	LOW	
3. SISHEN	27º 48' 31.52" S 22º 57' 26.9" E	New loop	Very thick calcrete succession, karstified at surface and with solution hollows, mantled by Gordonia Formation aeolian sands and sparse surface gravels (Kalahari Group)	LOW	
4. GLOSAM	28º 06' 40.09" S 23º 02' 58.22" E	Loop extension	Highly deformed siltstones, karstified dolostones and minor quartzites of the Campbell Rand Subgroup with mantle of surface gravels, locally dominated by iron ore pebbles	LOW	
5. POSTMASBURG	28º 18' 26.63" S 23º 03' 08.92" E	Loop extension	Thick colluvial to alluvial surface gravels (cherts, iron ore *etc*), locally ferricretised, overlying karstified Campbell Rand Subgroup dolostones / calcareous grits	LOW	

LOOP	APPROXIMATE LOCATION	PROJECT	GEOLOGY	PALAEONTOLOGICAL HERITAGE SENSITIVITY	RECOMMENDATION
6. TSANTSABANE	**28º 16' 45.12" S** **23º 08' 51.78" E**	**Loop extension**	**Polymict colluvial and alluvial surface gravels (chert, BIF *etc*) overlying thick calcretes with calcretised bouldery river channel gravels. Campbell Rand Subgroup dolomitedolostones at depth.**	**LOW**	**No further palaeontological specialist input required, pending discovery of significant new fossil remains during development.** **ECO should be alerted to possible important fossil finds during the construction phase.** **Significant fossil remains exposed during development (*e.g.* vertebrate bones, shell concentrations, plant remains) should be safeguarded and reported by the ECO to SAHRA for professional recording and mitigation.**
7. TREWIL	**28º 18' 25.01" S** **23º 41' 10.45" E**	**Loop extension**	**Thick calcretes and cherty surface gravels overlying stromatolitic Campbell Rand Subgroup dolostones at depth.**	**LOW**	
8. ULCO	**28º 21' 15.12" S** **24º 17' 20.11" E**	**Loop extension**	**Thick, complex calcrete succession, in part replacing alluvium of Harts River.**	**LOW**	
9. GONG GONG	**28º 28' 27.99" S** **24º 25' 31.61" E**	**Loop extension**	**Thick calcrete hardpan, bouldery surface gravels locally overlying deeply-weathered Ecca Group mudrocks, lavas of the Allanridge Formation (Ventersdorp Supergroup).**	**LOW**	
10. FIELDSVIEW	**28º 34' 48.76" S** **24º 39' 40.98" E**	**Loop extension**	**Gordonia Formation aeolian sands and gravel lenticles overlying thin alluvial to colluvial gravels (Kalahari Group) and weathered Allanridge Formation lavas (Ventersdorp Supergroup) with thin relicts of Dwyka Group tillite in basement lows.**	**LOW**	

2. GEOLOGICAL OUTLINE OF THE STUDY AREA

The existing Transnet manganese ore export railway line between Hotazel and Kimberley, Northern Cape, crosses several different physiographic regions of the RSA (Visser *et al.* 1989, their Fig. 2.1.). The northernmost stretch between Hotazel southwards to Dingleton traverses flat-lying, sandy semi-desert terrain at *c*. 1100-1200 m amsl of the southern Kalahari Region lying between the Korannaberg in the west and the Kurumanheuwels in the East. This region is drained by the Ga-Mogara River (a southern tributary of the Kuruman River) and its tributaries, and bedrock exposure is extremely limited due to the thick Kalahari Group cover. Between Dingleton, Postmasburg and east to Lime Acres the line runs through the slightly higher-lying (1300-1400m amsl), more rocky terrain of the Griqua Fold Belt Region on the western side of the Ghaap Plateau. This region is characterised by north-south trending rocky ridges and megafolds of Precambrian bedrocks, including the Maremane Anticline in the west and the Asbesberge to the east. From Lime Acres (south of Daniëlskuil) east to Ulco the railway crosses the southern part of the extensive, flat-lying Ghaap Plateau Region (*c*. 1200-1400m amsl) that is underlain by great thicknesses of Precambrian carbonate sediments (limestones, dolostones). The railway line then descends from the eastern edge of the Ghaap Plateau into the western portion of the Upper Karoo Region drained by the Harts and Vaal Rivers. This lower-lying region (*c*. 1100-1200m amsl) includes the sector all the way to Barclay West and Kimberley, situated between the Vaal and Orange Rivers.

The geology of the study area between Hotazel and Kimberley is covered by three adjacent 1: 250 000 scale geological maps, 2722 Kuruman (brief sheet explanation printed on map), 2822 Postmasburg (brief sheet explanation printed on map) and 2824 Kimberley (sheet explanation by Bosch 1993). Relevant extracts from these sheets are provided in Figs. 3 to 8 below. A more regional geological map at 1: 1 000 000 scale is also available (sheet explanation by Visser *et al.* 1989) but differs in several respects from the more detailed 1: 250 000 maps that form the preferred basis for the present desktop study (*e.g.* regarding the outcrop area of the Dwyka Group).

All major rock units mapped along the railway line between Hotazel and Kimberley are listed in Table 2, together with a brief summary of their geology, age, known fossil heritage and inferred palaeontological sensitivity (largely based on Almond & Pether 2008). The location of these rock units within the stratigraphic column for South Africa is shown in Fig. 2. They include a wide range of sedimentary and igneous rocks ranging in age from Late Archaean (2.7 Ga = billion years old) to Recent. The igneous rocks (*e.g.* lavas, dolerite intrusions) are entirely unfossiliferous and a high proportion of the sedimentary rocks are of low palaeontological sensitivity. The main exceptions are fossiliferous marine shelf carbonates of the Ghaap Group (Vryburg Formation, Campbell Rand Subgroup), interglacial to post-glacial sediments of the Dwyka and Ecca Groups (Karoo Supergroup) and Late Tertiary (Neogene) to Pleistocene alluvial gravels along the Vaal River.

For the purposes of the present Basic Assessment of the proposed new railway loops and loop extensions only those rock units that are mapped within the development footprint (as shown on 1: 250 000 geological maps, Figs. 3 to 8) or identified during fieldwork will be considered further here. Asdepicted on the relevant 1: 250 000 geological maps, the Gong Gong study area is underlain by Late Archaean lavas of the **Allanridge Formation** (**Ventersdorp Subgroup**), the Glosam, Postmasburg, Tsantsabane and Trewil sites by Late Archaean shelf carbonates of the **Campbell Rand Subgroup** (**Transvaal Supergroup**), the Wincanton, Sishen and Ulco sites by Late Caenozoic (probably Plio-Pleistocene) **calcretes** or pedogenic limestones, while the Witloop and Fieldsview sites overlie Pleistocene to Recent aeolian sands of the **Gordonia Formation** (**Kalahari Group**). A more complex geological setting for several of the loop sites was revealed during the site visits, as described in Section 4 of the report. A short review of the geology of the rock units concerned is given below, while details of their known fossil heritage are given in Section 3.

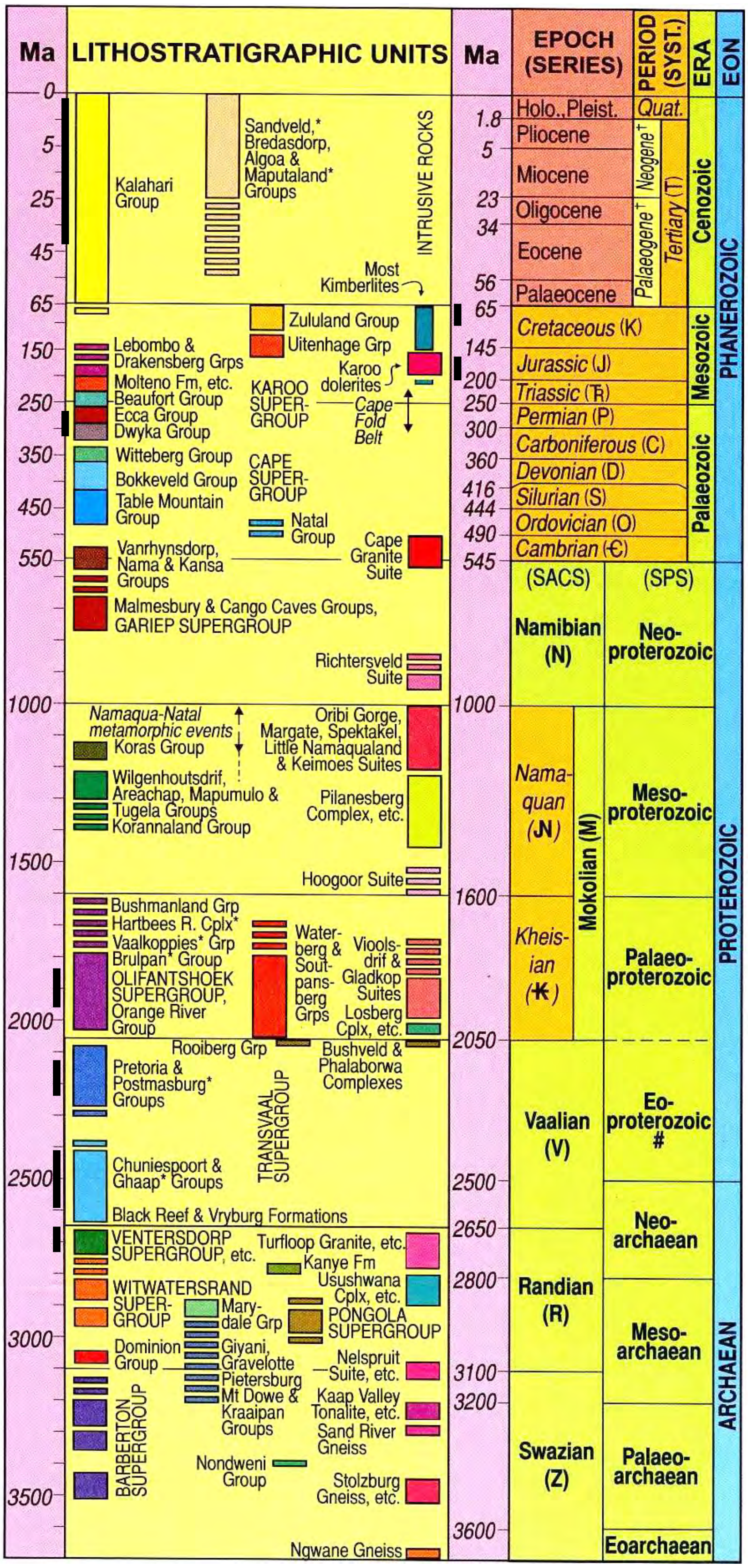

Fig. 2. Stratigraphic column for southern Africa showing the main rock units represented along the manganese ore export line railway between Hotazel and Kimberley, Northern Cape (thick vertical black lines) (See also Table 2).

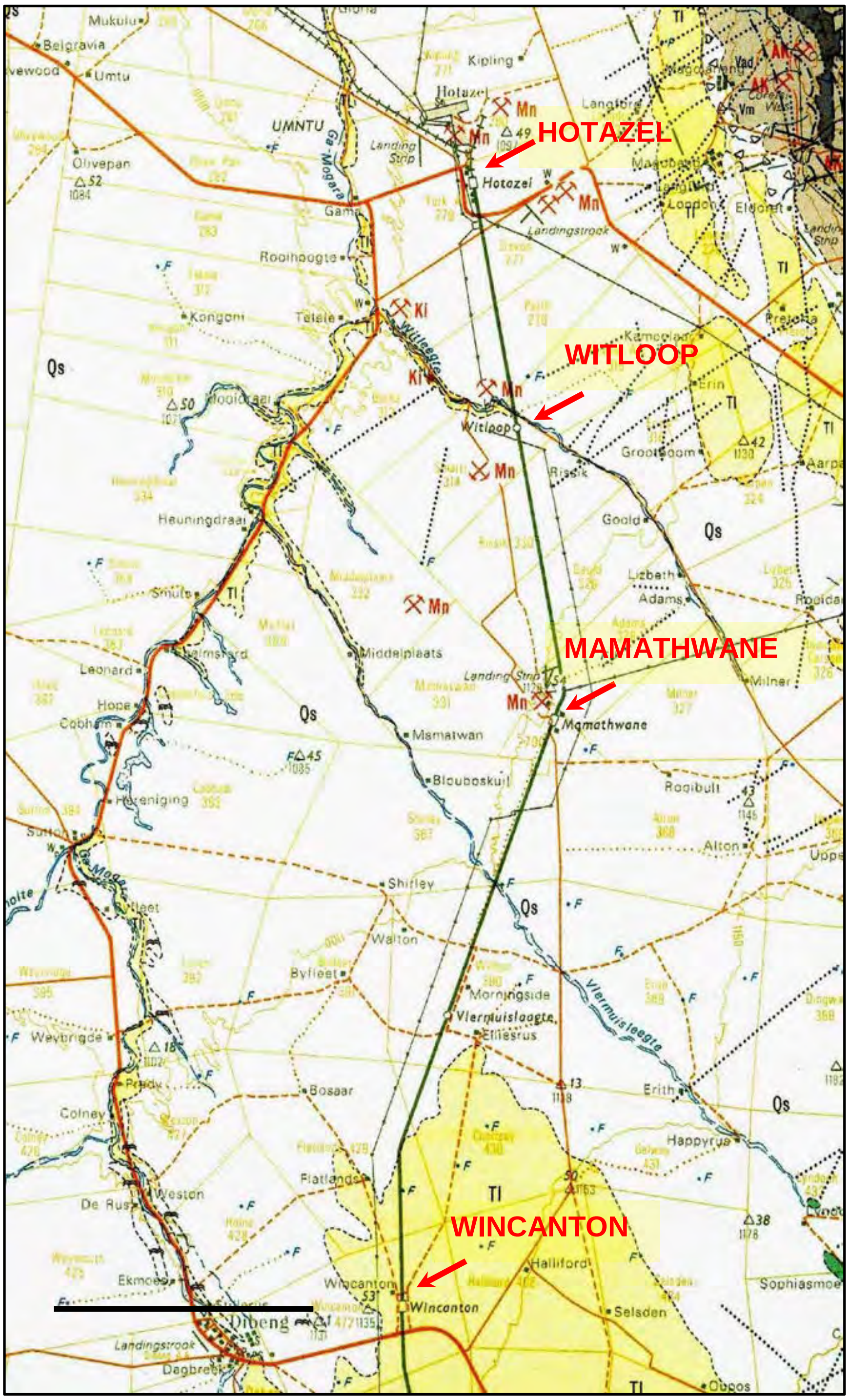

Fig. 3. Extract from 1: 250 000 geology map 2722 Kuruman (Council for Geoscience, Pretoria) showing location of the proposed new rail loop at Witloop (underlain by aeolian sands of the Gordonia Formation, Qs) and the loop extension at Wincanton (underlain by surface calcrete, Tl). Note also the position of the proposed new compilation yard at Mamathwane that is underlain by Gordinia Formation aeolian sands. See Table 2 for summary of geology and fossils within rock units along the Transnet manganese ore export railway line. Scale bar here = *c*. 10 km.

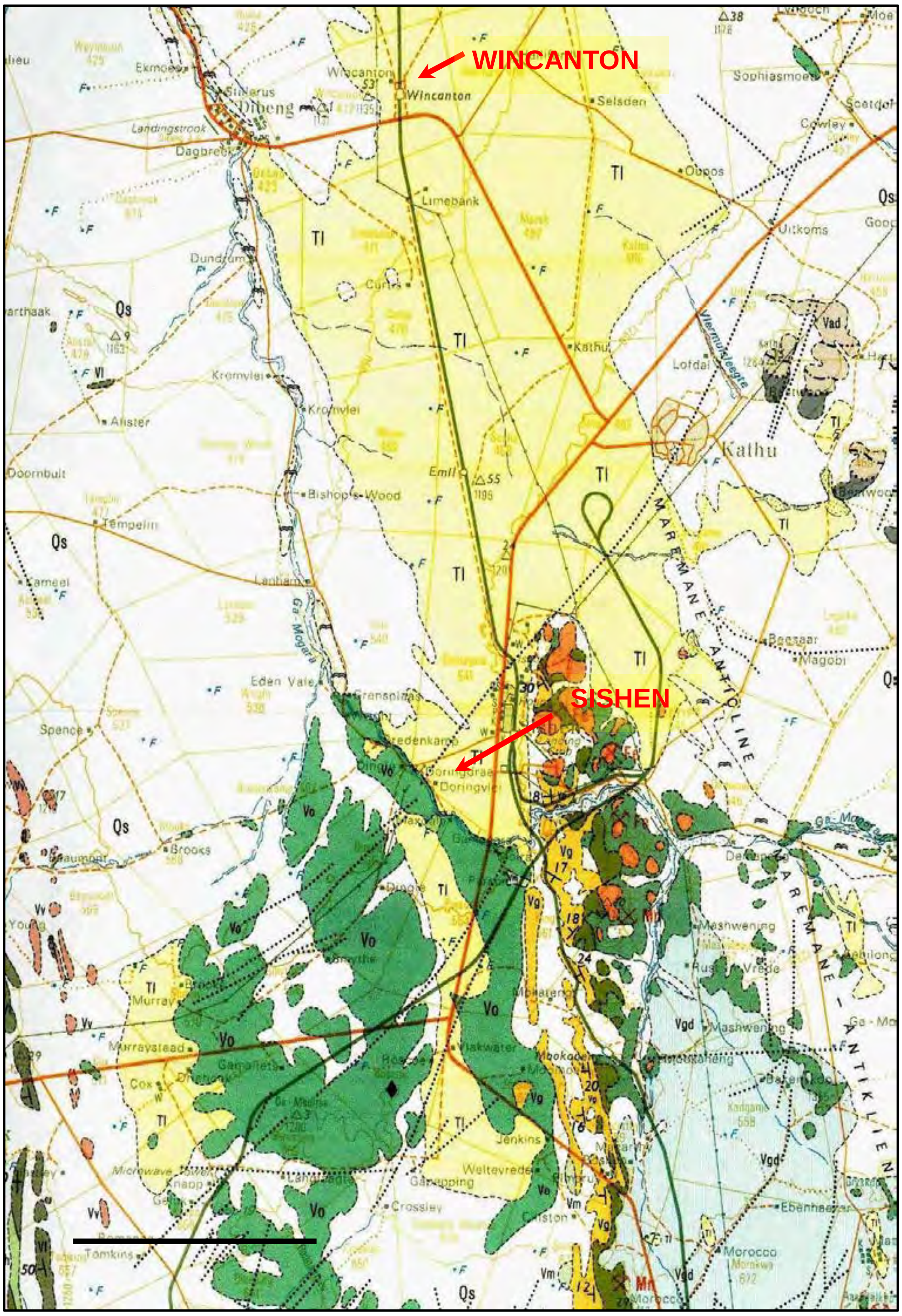

Fig. 4. Extract from 1: 250 000 geology map 2722 Kuruman (Council for Geoscience, Pretoria) showing location of the proposed new loop extensions at Wincanton and new loop at Sishen (both underlain by surface calcrete, Tl). See Table 2 for summary of geology and fossils within rock units along the Transnet manganese ore export railway line. Scale bar here = *c*. 10 km.

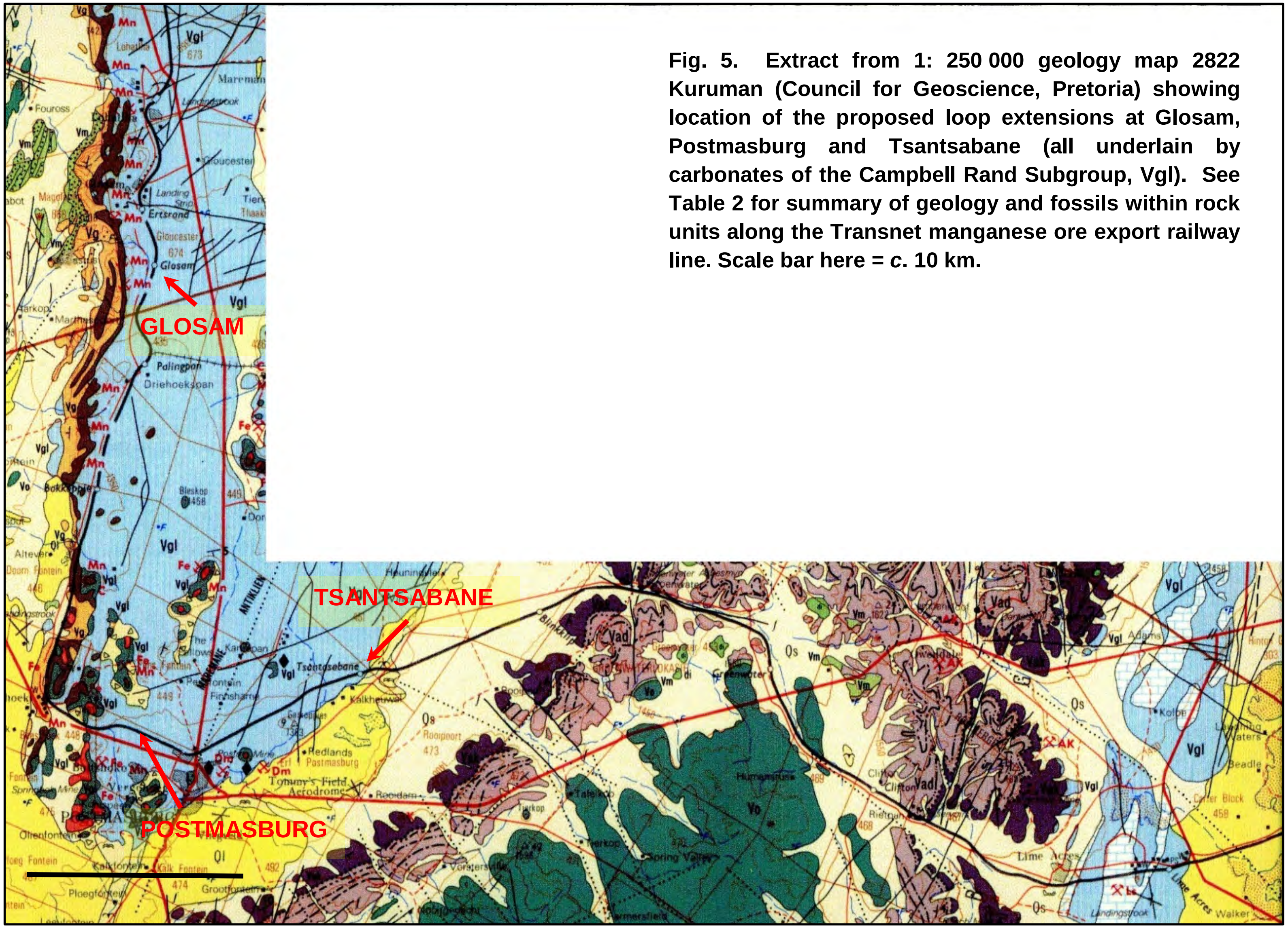

Fig. 5. Extract from 1: 250 000 geology map 2822 Kuruman (Council for Geoscience, Pretoria) showing location of the proposed loop extensions at Glosam, Postmasburg and Tsantsabane (all underlain by carbonates of the Campbell Rand Subgroup, Vgl). See Table 2 for summary of geology and fossils within rock units along the Transnet manganese ore export railway line. Scale bar here = *c*. 10 km.

Fig. 6. Extract from 1: 250 000 geology map 2822 Kuruman (Council for Geoscience, Pretoria) showing location of the proposed loop extension at Trewil (underlain by carbonates of the Campbell Rand Subgroup, Vgl). See Table 2 for summary of geology and fossils within rock units along the Transnet manganese ore export railway line. Scale bar here = *c*. 10 km.

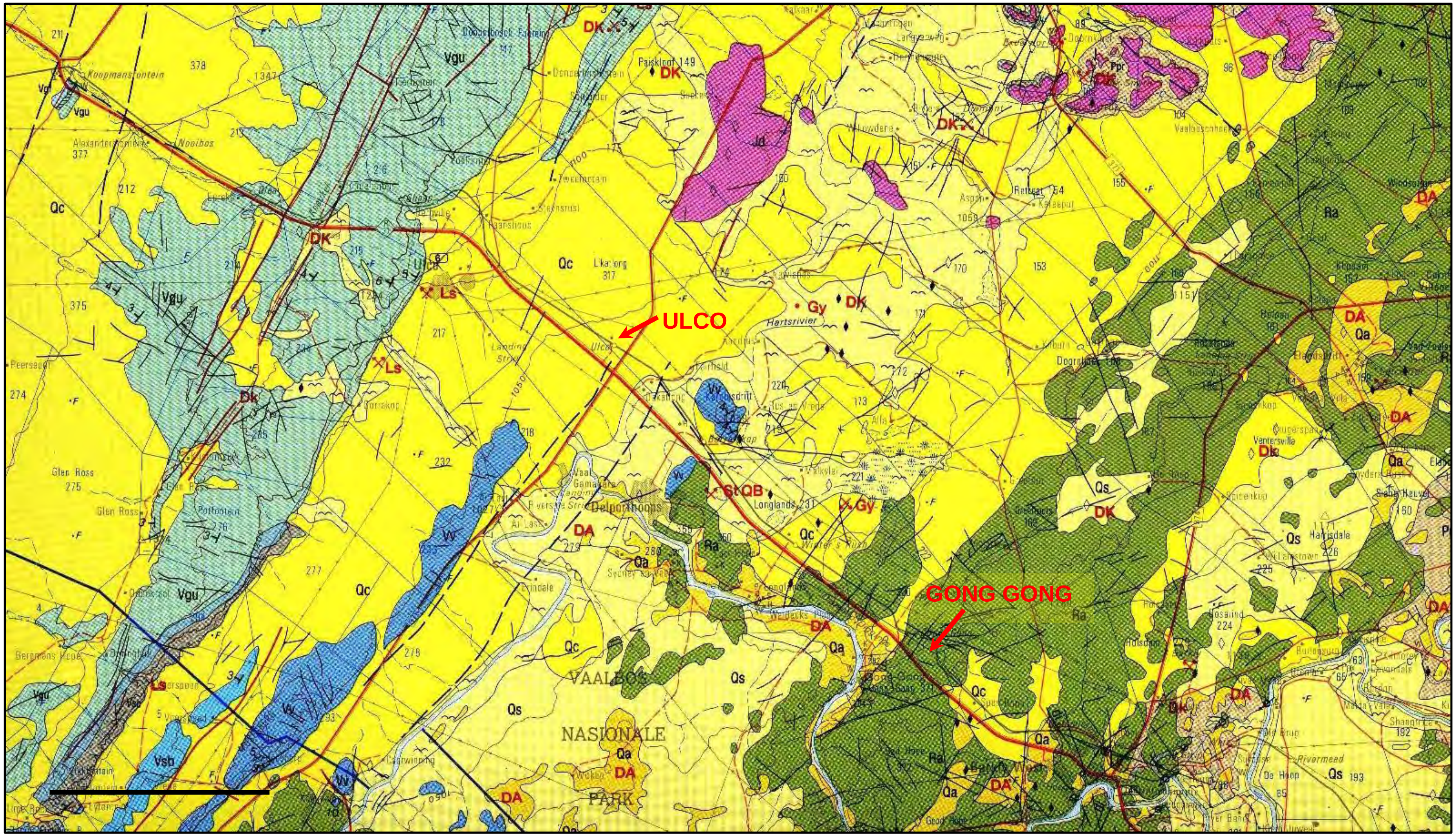

Fig. 7. Extract from 1: 250 000 geology map 2824 Kimberley (Council for Geoscience, Pretoria) showing location of the proposed loop extensions at Ulco (underlain by surface calcrete, Qc) and Gong Gong (underlain by Allanridge Formation lavas, Ra). See Table 2 for summary of geology and fossils within rock units along the Transnet manganese ore export railway line. Scale bar here = *c*. 10 km.

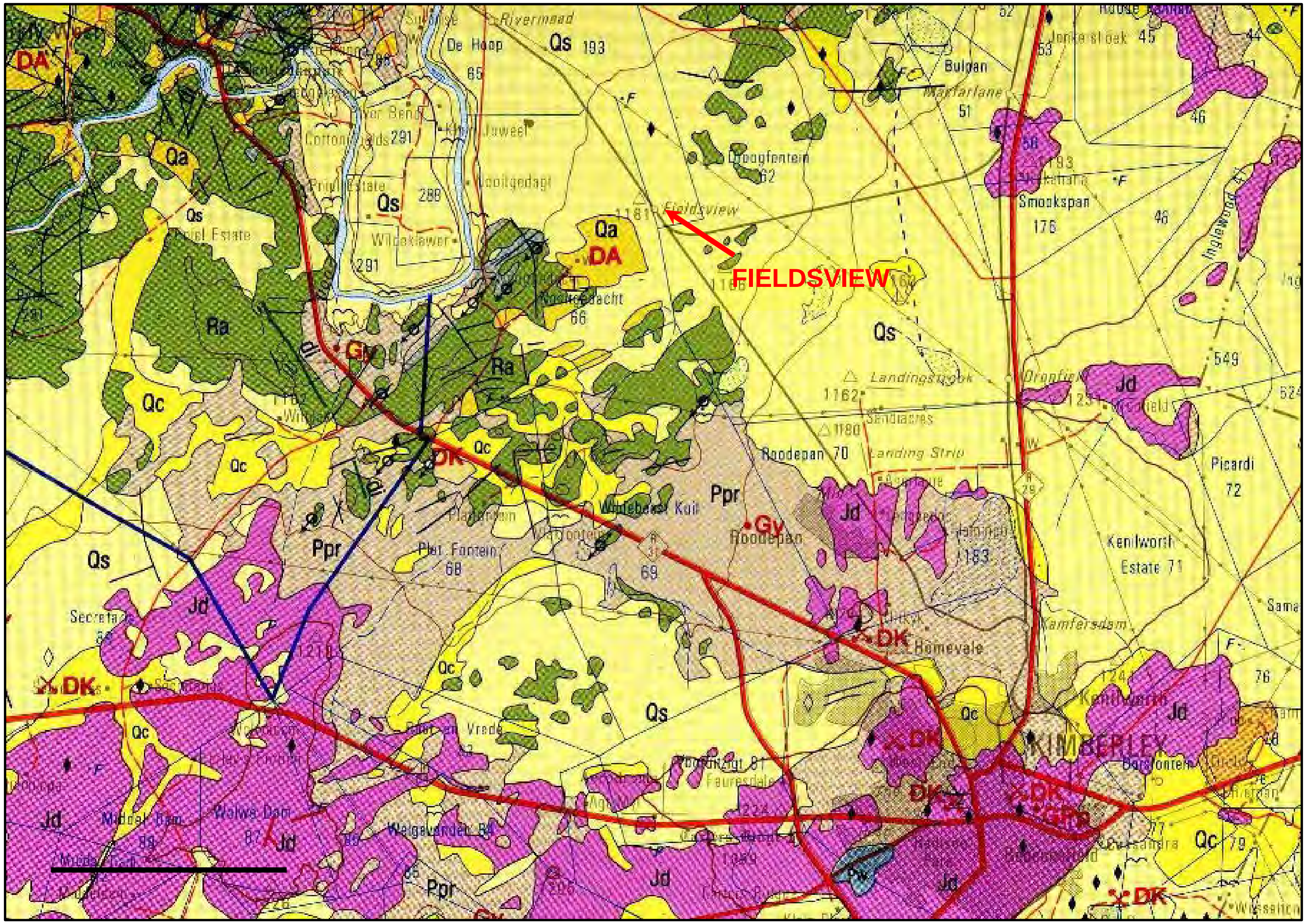

Fig. 8. Extract from 1: 250 000 geology map 2824 Kimberley (Council for Geoscience, Pretoria) showing location of the proposed loop extension at Fieldsview (underlain by Gordonia Formation aeolian sands, Qs). See Table 2 for summary of geology and fossils within rock units along the Transnet manganese ore export railway line. Scale bar here = *c*. 10 km.

2.1. Allanridge Formation (Ventersdorp Supergroup)

The **Ventersdorp Supergroup** represents a major episode of igneous extrusion (LIP = Large Igneous Province) that is associated with fracturing of the Kaapvaal Craton some 2.7 Ga (billion years) ago. The basal lava pile termed the Klipriviersberg Group - mainly basaltic lavas welling up in fissure eruptions, totalling up to two kilometres thick and 100 000 km^2 in extent - accumulated over a comparatively short period of some six million years (McCarthy & Rubidge 2005). The overlying Platberg Group comprises a range of felsic to mafic volcanic rocks, including lavas and pyroclastics, such as the porphyritic felsites and pyroclastic flows of the Makwassie Formation near Kimberley (Bosch 1993, Van der Westhuizen *et al.* 2006). These igneous rocks are associated with rift-related sediments, including colluvial, alluvial fan and lacustrine deposits, and are overlain by fluvial polymict conglomerates and quartzites of the Bothaville Formation. At the top of the Ventersdorp succession are the greyish-green amydaloidal and porphyritic lavas - mainly basaltic andesites - of the **Allanridge Formation**. Here can be recognised lava flows up to 14 m thick with vesicular tops, pipe-like structures due to lava degassing, and pillow structures formed during subaqueous eruptions (Bosch 1993). Gas vesicles within the amygdaloidal lavas are infilled with a range of secondary minerals including reddish chalcedony, quartz, calcite, chlorite and epidote. A thin lenticular succession of conglomerate and cross-bedded quartzites occurs locally just above the base of the succession.

A broad NE-SW trending outcrop area of resistant-weathering Allanridge Formation lavas is mapped to the northwest of Kimberley, including the Gong Gong loop extension study area (Fig. 7) as well as beneath Kalahari cover rocks at Fieldsview. A rusty-brown to metallic (desert varnish) surface weathering patina has developed on many surface boulders; this patina has been exploited locally by Later Stone Age rock engravers (*e.g.* Wildebeest Kuil rock art centre near Kimberley). A number of glacial pavements - glacially-striated and eroded bedrocks - of Dwyka age (*i.e.* Permo-Carboniferous, *c*. 300 Ma) are mapped within the Allanridge Formation outcrop area in the same region, for example at Nooigedacht 66. These features, which here indicate consistent ice transport directions to the southwest, are of geological conservation significance (Bosch 1993, Almond 2012c).

2.2. Campbell Rand Subgroup (Ghaap Group, Transvaal Supergroup)

According to the 1: 250 000 geology maps (Figs. 5 to 7) the majority of the manganese ore railway line between Sishen to just east of Ulco is underlain by Early Precambrian (Late Archaean to Early Proterozoic) marine sediments of the **Transvaal Supergroup**, and in particular by the **Ghaap Group** of the Griqualand West Basin, Ghaap Plateau Subbasin. Useful reviews of the stratigraphy and sedimentology of these Transvaal Supergroup rocks have been given by Moore *et al.* (2001), Eriksson and Altermann (1998) as well as Eriksson *et al.* (1993, 1995, 2006). The Ghaap Group represents some 200 Ma of chemical sedimentation - notably iron and manganese ores, cherts, carbonates and minor siliciclastics - within the Griqualand West Basin that was situated towards the western edge of the Kaapvaal Craton (See also fig. 4.19 in McCarthy & Rubidge 2005).

The **Campbell Rand Subgroup** (previously included within the Ghaapplato Formation) of the Ghaap Group is a very thick (1.6-2.5 km) carbonate platform succession of dolostones, dolomitic limestones and cherts with minor tuffs and siliciclastic rocks that was deposited on the shallow submerged shelf of the Kaapvaal Craton roughly 2.6 to 2.5 Ga (billion years ago; see the readable general account by McCarthy & Rubidge, pp. 112-118 and Fig. 4.10 therein). A range of shallow water facies, often forming depositional cycles reflecting sea level changes, are represented here, including stromatolitic limestones and dolostones, oolites, oncolites, laminated calcilutites, cherts and marls, with subordinate siliclastics (shales, siltstones) and minor tuffs (Eriksson *et al.* 2006). Due to their solubility and low resistence to weathering, exposure levels of these rocks are often very low. The outcrop area of chert-rich subunits is often largely covered in downwasted, siliceous rock rubble (*e.g.* Postmasburg sheet area).

Carbonates (*i.e.* limestones, dolostones) of the "Ghaapplato Formation" underlie the loop study areas at Glosam, Postmasburg, Tsantsabane and Trewil (Figs. 5 & 6). Note that since the 1: 250 000 geological maps were produced, the Campbell Rand succession has been subdivided into a series of formations, some of which were previously included within the older Schmidtsdrift Formation or Subgroup (Beukes 1980, 1986, Eriksson *et al.* 2006). It is unclear exactly which of these newer carbonate-dominated units are represented in the Transnet railway study areas. However, this level of stratigraphic resolution is not critical for the current baseline report.

2.3. Permo-Carboniferous Dwyka Group

The Late Carboniferous to Early Permian sediments of the Elandsvlei Formation (Dwyka Group, C-Pd) were deposited as glacial tillites and interglacial mudrocks in a shallow epicontinental sea on the margins of Gondwana. The geology of the Dwyka Group has been summarized by Visser (1989, 2003), Visser *et al.* (1990) and Johnson *et al.* (2006), among others. A brief account of the Dwyka rocks in the Kimberley sheet area is given by Bosch (1993). The Dwyka succession consists largely of massive, blue-grey to grey-green glacial diamictites with subordinate well-bedded sandstones and shales. North of Kimberley thin relict Dwyka succesions infill basement depressions interpreted as glacial valleys while several excellent examples of planed-off, polished and striated glacial pavements on Ventersdorp Group bedrocks are known in the area, for example on the farm Nooigedacht 66. Potentially fossiliferous interglacial mudrock successions, including dropstone laminites, are also present here between the massive diamictites but are often obscured by drift cover, including Quaternary alluvium as well as downwasted polymict gravels.

2.4. Prince Albert Formation (Ecca Group)

The post-glacial basinal mudrocks of the Prince Albert Formation (Ppr) form the lowermost subunit of the Ecca Group. This thin-bedded to laminated mudrock-dominated succession of Early Permian (Asselian / Artinskian) age was previously known as "Upper Dwyka Shales". Key geological accounts of this formation are given by Visser (1992) and Cole (2005). The Prince Albert succession consists mainly of tabular-bedded mudrocks of blue-grey, olive-grey to reddish-brown colour with occasional thin (dm) buff sandstones and even thinner (few cm), soft-weathering layers of yellowish water-lain tuff (*i.e.* volcanic ash layers). Extensive diagenetic modification of these sediments has led to the formation of thin cherty beds, pearly- blue phosphatic nodules, rusty iron carbonate nodules, as well as beds and elongate ellipitical concretions impregnated with iron and manganese minerals. The brittle rocks are well-jointed and often display a well-developed tectonic cleavage that results in sharp, elongate cleavage flakes ("pencil cleavage"). Extensive bedding planes are therefore rarely encountered in the southern outcrop area close to the Cape Fold Belt while Northern Cape outcrops are much less deformed.

The Prince Albert Formation (Ppr, Ppw) in the Kimberley sheet area consists predominantly of dark, well-laminated basinal mudrocks (shales, siltstones) with minor thin-bedded fine-grained sandstone and siltstone lenses. The mudrocks are sometimes micaceous, carbonaceous or pyritic and typically contain a variety of diagenetic concretions enriched in iron and carbonate minerals (Visser *et al.* 1977, Zawada 1992, Bosch 1993). Some of these carbonate concretions are richly fossilferous (See Section 3.4 below).

The Prince Albert Formation crops out intermittently along the railway line between Kimberley and the Vaal River (Ppr in Fig. 8) and appears to also occur north of the Vaal beneath the Kalahari Group cover rocks. Much of the Ecca shale outcrop area has been modified by extensive near-surface calcretization as well as baking by Karoo dolerite intrusions.

2.5. Late Caenozoic superficial sediments (calcretes, aeolian sands)

Large sections of the Transnet manganese ore export railway line study area are mantled by a range of **superficial sediments** of probable Late Caenozoic (*i.e.* Late Tertiary or Neogene to Recent) age, most of which are assigned to the **Kalahari Group**. The geology of the Late Cretaceous to Recent Kalahari Group is reviewed by Thomas (1981), Dingle *et al.* (1983), Thomas & Shaw 1991, Haddon (2000) and Partridge *et al.* (2006). Other superficial sediments whose outcrop areas are often not indicated on geological maps include colluvial or slope deposits (scree, hillwash, debris flows *etc*), sandy, gravelly and bouldery river alluvium, surface gravels of various origins, as well as spring and pan sediments. The colluvial and alluvial deposits may be extensively calcretised (*i.e.* cemented with pedogenic limestone), especially in the neighbourhood of dolerite intrusions or overlying Ghaap Group carbonate rocks.

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

Large areas of unconsolidated, reddish-brown to grey aeolian (*i.e.* wind-blown) sands of the Quaternary **Gordonia Formation** (**Kalahari Group**; **Qs** in Figs. 3 to 8) are mapped in the Transnet manganese ore railway study region, including the Witloop and Fieldsview loop study areas. According to Bosch (1993) the Gordonia sands in the Kimberley area reach thicknesses of up to eight meters and consist of up to 85% quartz associated with minor feldspar, mica and a range of heavy minerals. The Gordonia dune sands are considered to range in age from the Late Pliocene / Early Pleistocene to Recent, dated in part from enclosed Middle to Later Stone Age stone tools (Dingle *et al*., 1983, p. 291). Note that the recent extension of the Pliocene - Pleistocene boundary from 1.8 Ma back to 2.588 Ma would place the Gordonia Formation almost entirely within the Pleistocene Epoch. Reworked and diagenetically altered sands of probable aeolian origin in the Kimberley area are often referred to as Hutton Sands.

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3. PALAEONTOLOGICAL HERITAGE WITHIN THE STUDY AREA

Fossil biotas recorded from each of the main rock units mapped along the Transnet manganese ore export railway line are briefly reviewed in Table 2 (Based largely on Almond & Pether 2008 and references therein), where an indication of the palaeontological sensitivity of each rock unit is also given. Pervasive calcretisation and chemical weathering of many near-surface bedrocks in the Northern Cape has further compromised their original fossil heritage in many areas (*e.g.* Ecca Group outcrop). The fossil record of the rock units underlying the proposed railway loop and borrow pit developments between Hotazel and Kimberly are outlined in more detail below.

3.1. Fossils within the Ventersdorp Supergroup

Domical stromatolites are recorded from shallow water lacustrine calcarenites within the volcano-sedimentary succession of the Rietgat Formation at the top of the Platberg Group (Schopf 2006, Van der Westhuizen *et al.* 2006). The overlying predominantly siliciclastic Bothaville Formation contains conical stromatolites (Schopf 2006). Carbonate sediments are not reported in association with the Allanridge Formation lavas at the top of the Ventersdorp Supergroup, however.

3.2. Fossils within the Campbell Rand Subgroup

The shallow shelf and intertidal sediments of the carbonate-dominated lower part of the **Ghaap Group** (*i.e.* **Schmidtsdrif** and **Campbell Rand Subgroups**) are well known for their rich fossil biota of *stromatolites* or microbially-generated, finely-laminated sheets, mounds, columns and branching structures. Some stromatolite occurrences on the Ghaap Plateau of the Northern Cape are spectacularly well-preserved (*e.g.* Boetsap locality northeast of Daniëlskuil figured by McCarthy & Rubidge 2005, Eriksson *et al.* 2006). Detailed studies of these 2.6-2.5 Ga carbonate sediments and their stromatolitic biotas have been presented by Young (1932), Beukes (1980, 1983), Eriksson & Truswell (1974), Eriksson & Altermann (1998), Eriksson *et al* (2006), Altermann and Herbig (1991), and Altermann and Wotherspoon (1995). Some of the oldest known (2.6 Ga) fossil microbial assemblages with filaments and coccoids have been recorded from stromatolitic cherty limestones of the Lime Acres Member, Kogelbeen Formation at Lime Acres (Altermann & Schopf 1995). The oldest, Archaean stromatolite occurrences from the Ghaap Group have been reviewed by Schopf (2006, with full references therein). The Tsineng Formation at the top of the Campbell Rand carbonate succession has yielded both stromatolites (previously assigned to the Tsineng Member of the Gamohaan Formation) as well as filamentous microfossils named *Siphonophycus* (Klein *et al.* 1987, Altermann & Schopf 1995).

3.3. Fossils in the Elandsvlei Formation (Dwyka Group)

The fossil record of the Permo-carboniferous Dwyka Group is generally poor, as expected for a glacial sedimentary succession (McLachlan & Anderson 1973, Anderson & McLachlan 1976, Visser 1989, Visser *et al*., 1990, MacRae 1999, Visser 2003, Almond 2008a, 2008b). Sparse, low diversity trace fossil biotas from the Elandsvlei Formation along the southern basin margin mainly consist of delicate arthropod trackways (probably crustacean) and fish swimming trails associated with recessive-weathering dropstone laminites (Savage 1970, 1971, Anderson 1974, 1975, 1976, 1981). Sporadic vascular plant remains (drifted wood and leaves of the *Glossopteris* Flora) are also recorded (Anderson & Anderson 1985, Bamford 2000, 2004), while palynomorphs (organic-walled microfossils) are likely to be present within finer-grained mudrock facies. Glacial diamictites (tillites or “boulder mudstones”) are normally unfossiliferous but do occasionally contain fragmentary transported plant material as well as palynomorphs in the fine-grained matrix (Plumstead 1969). There are biogeographically interesting records of limestone glacial erratics from tillites along the southern margins of the Great Karoo that contain Cambrian eodiscid trilobites as well as diverse assemblages of archaeocyathid sponges. Such derived fossils provide important data for reconstructing the movement of Gondwana ice sheets (Cooper & Oosthuizen 1974, Stone & Thompson 2005).

3.4. Fossils within the Prince Albert Formation (Ecca Group)

The fossil biota of the post-Dwyka mudrocks of the **Prince Albert Formation** is usefully summarized by Cole (2005). The typical *Umfolozia / Undichna* – dominated trace fossil assemblages of the non-marine *Mermia* Ichnofacies commonly found in basinal mudrock facies of the Prince Albert Formation throughout the Ecca Basin have been briefly reviewed by Almond (2008a, b). Low diversity Prince Albert trace fossil assemblages within the Kimberley sheet area are briefly mentioned by Bosch (1993). Diagenetic nodules containing the remains of palaeoniscoids (primitive bony fish), sharks, spiral bromalites (coprolites *etc*) and wood have been found in the Ceres Karoo and rare shark remains (*Dwykaselachus*) near Prince Albert on the southern margin of the Great Karoo (Oelofsen 1986). Microfossil remains in this formation include sponge spicules, foraminiferal and radiolarian protozoans, acritarchs and miospores.

The most diverse as well as biostratigraphically, palaeobiogeographically and palaeoecologically interesting fossil biota from the Prince Albert Formation is that described from calcareous concretions exposed along the Vaal River in the Douglas area of the Northern Cape (McLachlan and Anderson 1973, Visser *et al.,* 1977-78). The important Douglas biota contains petrified wood (including large tree trunks), palynomorphs (miospores), orthocone nautiloids, nuculid bivalves, articulate brachiopods, spiral and other "coprolites" (probably of fish, possibly including sharks) and fairly abundant, well-articulated remains of palaeoniscoid fish. Most of the fish have been assigned to the palaeoniscoid genus *Namaichthys* but additional taxa, including a possible acrolepid, may also be present here (Evans 2005). The invertebrates are mainly preserved as moulds.

3.5. Fossils within the Kalahari Group

The fossil record of the **Kalahari Group** is generally sparse and low in diversity. The **Gordonia Formation** dune sands were mainly active during cold, drier intervals of the Pleistocene Epoch that were inimical to most forms of life, apart from hardy, desert-adapted species. Porous dune sands are not generally conducive to fossil preservation. However, mummification of soft tissues may play a role here and migrating lime-rich groundwaters derived from the underlying bedrocks (including, for example, dolerite) may lead to the rapid calcretisation of organic structures such as burrows and root casts. Occasional terrestrial fossil remains that might be expected within this unit include calcretized rhizoliths (root casts) and termitaria (*e.g. Hodotermes*, the harvester termite), ostrich egg shells (*Struthio*) and shells of land snails (*e.g. Trigonephrus*) (Almond 2008, Almond & Pether 2008). Other fossil groups such as freshwater bivalves and gastropods (*e.g. Corbula, Unio*) and snails, ostracods (seed shrimps), charophytes (stonewort algae), diatoms (microscopic algae within siliceous shells) and stromatolites (laminated microbial limestones) are associated with local watercourses and pans. Microfossils such as diatoms may be blown by wind into nearby dune sands (Du Toit 1954, Dingle *et al*., 1983). These Kalahari fossils (or subfossils) can be expected to occur sporadically but widely, and the overall palaeontological sensitivity of the Gordonia Formation is therefore considered to be low. Underlying calcretes of the **Mokolanen Formation** might also contain trace fossils such as rhizoliths, termite and other insect burrows, or even mammalian trackways. Mammalian bones, teeth and horn cores (also tortoise remains, and fish, amphibian or even crocodiles in wetter depositional settings such as pans) may be expected occasionally expected within Kalahari Group sediments and calcretes, notably those associated with ancient, Plio-Pleistocene alluvial gravels.

Table 2. Fossil heritage of rock units cropping out along the Hotazel to Kimberley sector of the Transnet manganese ore export railway line

GEOLOGICAL UNIT	ROCK TYPES & AGE	FOSSIL HERITAGE	PALAEONT-OLOGICAL SENSITIVITY	RECOMMENDED MITIGATION
OTHER LATE CAENOZOIC TERRESTRIAL DEPOSITS OF THE INTERIOR (Most too small to be indicated on 1: 250 000 geological maps)	Fluvial, pan, lake and terrestrial sediments, including diatomite (diatom deposits), pedocretes, spring tufa / travertine, cave deposits, peats, colluvium, soils, surface gravels including downwasted rubble MOSTLY QUATERNARY TO HOLOCENE (Possible peak formation 2.6-2.5 Ma)	Bones and teeth of wide range of mammals (*e.g.* mastodont proboscideans, rhinos, bovids, horses, micromammals), reptiles (crocodiles, tortoises), ostrich egg shells, fish, freshwater and terrestrial molluscs (unionid bivalves, gastropods), crabs, trace fossils (*e.g.* termitaria, horizontal invertebrate burrows, stone artefacts), petrified wood, leaves, rhizoliths, diatom floras, peats and palynomorphs. calcareous tufas at edge of Ghaap Escarpment might be highly fossiliferous (*cf* Taung in NW Province – abundant Makapanian Mammal Age vertebrate remains, including australopithecines)	LOW Scattered records, many poorly studied and of uncertain age	Any substantial fossil finds to be reported by ECO to SAHRA
Gordonia Formation (Qs) KALAHARI GROUP *plus* SURFACE CALCRETES (Tl / Qc)	Mainly aeolian sands *plus* minor fluvial gravels, freshwater pan deposits, calcretes PLEISTOCENE to RECENT	Calcretised rhizoliths & termitaria, ostrich egg shells, land snail shells, rare mammalian and reptile (*e.g.* tortoise) bones, teeth freshwater units associated with diatoms, molluscs, stromatolites *etc*	LOW	Any substantial fossil finds to be reported by ECO to SAHRA
Windsorton & Rietputs Formations HIGH LEVEL ALLUVIAL GRAVELS (Qa) Miocene to Pleistocene	Ancient alluvial gravels, locally diamondiferous and calcretised	Sparse Tertiary vertebrates in older gravels. Rich Pleistocene mammalian fauna (bones, teeth) in younger gravels (*e.g.* equids, elephants, hippo) associated with Acheulian stone artefacts	HIGH	Pre-construction field assessment by professional palaeontologist
KIMBERLITE INTRUSIONS (diamond symbol)	Kimberlite / olivine melilitite / carbonatite volcanic pipes and related intrusions (fissure fills), sometime diamondiferous. JURASSIC, CRETACEOUS TO PALAEOCENE *c.* 200-60 Ma	Rare fossiliferous xenoliths of country rocks (*e.g.* Beaufort Group sediments with fossil fish). Bryophytes, vascular plants (leaves, wood, fruit), fish, pipid frogs (adults, tadpoles), reptiles (tortoises, lizards), rare dinosaurs, birds (ratites), insects, ostracods, palynomorphs (bryophytes, ferns, gymnosperms, angiosperms) within crater lake sediments	LOW	none

GEOLOGICAL UNIT	ROCK TYPES & AGE	FOSSIL HERITAGE	PALAEONT-OLOGICAL SENSITIVITY	RECOMMENDED MITIGATION
KAROO DOLERITE SUITE **(Jd)**	**Intrusive dolerites (dykes, sills), associated diatremes** **EARLY JURASSIC** **(182-183 Ma)**	**No fossils recorded**	**ZERO** (also cause baking of adjacent fossiliferous sediments)	**None**
Prince Albert Formation **(Ppr; locally mapped within C-Pd)** **ECCA GROUP**	**Basinal mudrocks with calcareous concretions** **EARLY PERMIAN**	**Marine invertebrates (esp. molluscs, brachiopods), coprolites, palaeoniscoid fish & sharks, trace fossils, various microfossils, petrified wood**	**HIGH** **IN KIMBERLEY - DOUGLAS REGION**	**Pre-construction field assessment by professional palaeontologist**
Mbizane & Elandsvlei Formations **(C-Pd)** **DWYKA GROUP**	**Tillites, interglacial mudrocks, deltaic & turbiditic sandstones, minor thin limestones** **LATE CARBONIFER-OUS – EARLY PERMIAN**	**Sparse petrified wood & other plant remains, palynomorphs, trace fossils (*e.g.* arthropod trackways, fish trails,** **U-burrows)** **Possible stromatolites in limestones**	**LOW TO MODERATE** **(*N.B.* stratotype section in the Douglas area)**	**Pre-construction field assessment by professional palaeontologist**
Gamagara Formation (Vga / Vg) **OLIFANTSHOEK SUPERGROUP**	**Continental red beds (shales, sandstones, conglomerates), lateritic palaeosols** **EARLY PROTEROZOIC** **(1.9 Ga or older)**	**Lateritic palaeosols reflect terrestrial biomass**	**LOW**	**None recommended**
Ongeluk Formation (Vo) **Makganyene Formation (Vm)** **POSTMASBURG GROUP**	**Lavas** **Glacial diamictites *plus* carbonates** **EARLY PROTEROZOIC** **(2.2-2.3 Ga)**	**None** **Stromatolitic domes within carbonate facies**	**LOW TO MODERATE**	**Recording & sampling of any newly exposed stromatolites by palaeontologist**
Daniëlskuil Formation (Vad) **Kuruman Formation (Vak)** **Asbestos Hills Subgroup (Va)** **GHAAP GROUP**	**BIF (banded iron formations) with cherty bands** **EARLY PROTEROZOIC** **(*c.* 2.5-2.4 Ga)**	**Important early microfossil biotas.** **Spurious"medusoid" fossil *Gakarusia*.**	**LOW**	**None recommended**

GEOLOGICAL UNIT	ROCK TYPES & AGE	FOSSIL HERITAGE	PALAEONT-OLOGICAL SENSITIVITY	RECOMMENDED MITIGATION
Campbell Rand Subgroup (Vca / Vgl, Vgu, Vgd *etc*) GHAAP GROUP	Shallow marine to intertidal limestones / dolostones, siliceous breccias ("Manganese Marker") LATE ARCHAEAN (*c*. 2.6-2.5 Ga)	Rich stromatolite assemblages (stratiform, domical, columnar), important early microfossil biotas	MODERATE TO HIGH	Recording & sampling of any newly exposed stromatolites in development footprint
Vryburg Formation (Vv) GHAAP GROUP	Lavas, siliciclastics, carbonates Late archaean 2.64 ga	Stromatolites in carbonates	Moderate	Recording & sampling of any newly exposed stromatolites in development footprint
Allanridge Formation (Ra / Ral) VENTERSDORP SUPERGROUP	Lavas and volcaniclastic sediments LATE ARCHAEAN 2.7 Ga	No fossils recorded	LOW	None recommended Any substantial fossil finds to be reported by ECO to SAHRA

4. SUMMARY OF GEOLOGICAL AND PALAEONTOLOGICAL FIELD OBSERVATIONS

4.1. Loop extension sites

A short, illustrated account of the most informative geological and palaeontological sites examined during the course of fieldwork at the ten proposed new railway loop development sites along the 16 Mtpa manganese railway line between Kimberley and Hotazel is given in this section of the report. The geographic positions of these sites are shown in Figure 1 and they are also indicated on the geological maps in Figures 3 to 8. Fieldwork focused on areas of good bedrock exposure in railway cuttings and existing borrow pits within or in the vicinity of the proposed loop sites. In some railway sectors useful natural or artificial rock exposures are not available so paleontological sensitivity here needs to be inferred from exposures in the broader study region. Only very sparse fossil material (almost exclusively stromatolites and trace fossils) was noted during the present palaeontological heritage survey along the railway line. Recognition of fossil material and sedimentary structures was sometimes compromised by the pervasive rusty patina covering rock surfaces adjacent to the railway line. GPS locality data for all numbered sites mentioned in the text are provided in an appendix. The hammer used as scale in most of the field photographs is *c*. 30 cm long.

4.1.1. Fieldsview loop extension

The proposed Fieldsview loop extension site is situated at *c*.1140-1180 m amsl on flat to slightly undulating sandy, grassy terrain with scattered thorn trees some 3 to 5.5 km east of a pronounced southward loop of the Vaal River and about 10-15 km ESE of Barclay West. The relevant 1: 250 000 geological map shows this area as blanked by Quaternary aeolian sands (Qs, Fig. 8). These sands are often no more than a few meters thick here and extensive railway cuttings at Fieldsview expose a more complex subsurface stratigraphy (Figs. 9 to 13). The main features seen include:

1. An irregular, pre-Dwyka surface of Ventersdorp Supergroup bedrocks, comprising low *koppies* or *bulte* of grey-green, blocky-jointed, amygdaloidal andesitic lava with a relief of at least several meters. This is weathered *in situ* to crumbly, pale buff to orange saprolite with rounded corestones towards the upper surface and locally contains *in situ* banded quartz veins.

2. A mantle of semi-consolidated regolith largely composed of weathered, downwasted, clast-supported Ventersdorp lava rubble, corestones and residual quartz-rich gravels, with a concentration of angular fragments of quartz vein material (some banded like agate) as well as large, more rounded agates weathered out of the Ventersdorp amygdaloidal lavas.

3. Relict lenses (several dm thick) of Dwyka Group tillite preserved in basement lows. The tillites contain poorly-sorted, polymict, pebble- to boulder-sized erratics (granite, reddish Makwassie Fm porphyries, quartzite, mudrocks *etc*) in a grey-green, gritty to muddy matrix. Some larger clasts are clearly facetted and striated. Narrow, NE-SW trending strips of Dwyka Group rocks are mapped on the southern side of the Vaal River just to the west (Fig. 8) and polished, striated glacial pavements of Ventersdorp lava are recorded on the farm Nooigedacht 66 (Bosch 1993, his fig. 6.2).

4. A zone (few dm) of mixed angular colluvial material and better rounded, water-worn alluvial gravels, dominated by resistant clasts of vein quartz, amygdales, Ventersdorp andesitic lavas, quartzite with minor possible dolerite. Occasional *in situ* anthropogenically flaked grey quartzite clasts indicate a Quaternary or younger age for these sediments (Fig. 12). The gravels infill shallow channels between and gullies into the basement *bulte*.

5. Unconsolidated to poorly-consolidated, orange-brown aeolian sands of the Gordonia Formation (“Hutton sands”) with occasional lenses of poorly-sorted stream gravels. A thin zone (*c*. 30 cm) of better-consolidated brownish sands with an irregular base occurs at or near the top of the sandy succession in some areas. The Hutton sands are no more than a few meters (< 5 m) thick in this area. A surface concentration of sparse downwasted gravels is seen locally. Nearby road cuttings showing well-defined bands of interbedded gravels and sands may well represent material that has been disturbed by railway construction.

It is noted that economically important diamondiferous gravels of probable Late Tertiary age (Nooigedacht gravels) are mapped on farm Nooitgedacht 66 within two kilometres to the west of the railway loop study area (Qa in Fig. 8). The geological setting for these diamondiferous gravels, associated with an irregular Ventersdorp basement surface buried beneath Hutton sands, is similar to that observed at the Fieldsview railway study site, although the former probably occur at a slightly higher elevation above present day river level (*cf* De Wit 2004). The possibility that diamond-bearing gravels may be intersected by the proposed loop development at Fieldsview should be borne in mind, however.

No fossil remains were recorded during fieldwork within the Fieldsview loop extension study area.

Fig. 9. Basement highs of blocky-jointed Ventersdorp Group andesites flanking a shallow gully infilled with mixed colluvial and alluvial gravels (note rounded corestones), the whole blanked beneath orange-brown Hutton sands, Fieldsview railway cutting

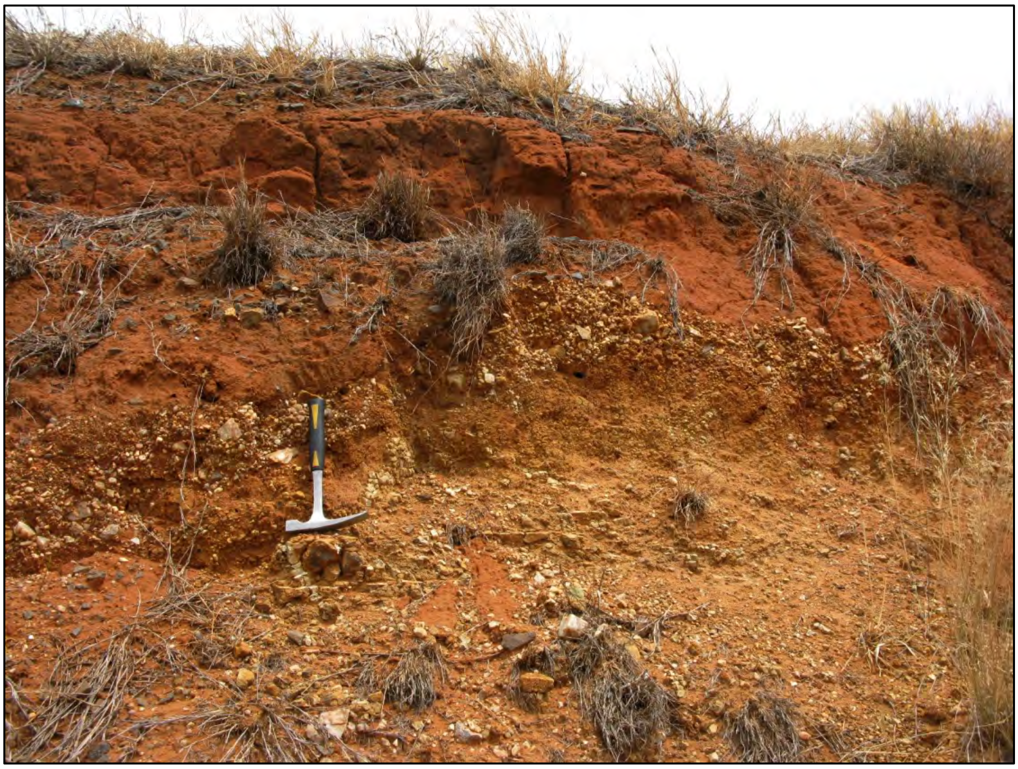

Fig. 10. Deeply-weathered Venterdorp Group lava saprolite mantled by residual gravels and orange-brown Hutton sands, Fieldsview railway cutting (Hammer = *c*. 30 cm).

Fig. 11. Detail of poorly-sorted residual gravels mantling basement rocks, dominated by angular vein quartz, chert, amgdaloidal agates (arrow) and rounded to angular clasts of Ventersdorp lava, Fieldsview railway cutting (Scale in cm). These gravels are potentially diamondiferous.

Fig. 12. Anthropogenically flaked quartzite clast (arrowed) within the residual gravels, Fieldsview railway cutting. Flaked clast is *c*. 6 cm long.

Fig. 13. Pebbly to bouldery lens of Dwyka Group tillite preserved within a basement low, Fieldsview railway cutting (Hammer = *c*. 30 cm). Note angular granitic erratic boulder (yellow arrow). The rounded cobble to the right of the hammer head is facetted and striated.

4.1.2. Gong Gong loop extension

The Gong Gong loop extension study area lies in fairly flat, rubbly-surfaced terrain some 11 km northwest of Barclay West and within two kilometres of the Vaal River. According to the 1: 250 000 geology map, the area is underlain by andesitic lavas of the Ventersdorp Group (Allanridge Formation, Ra) and Quaternary calcretes (Qc) (Fig. 7). Diamondiferous gravels of Late Tertiary age (Qa) are mapped on the inside bend of the Vaal River just to the west.

Extensive railway cuttings in the southern portion of the Gong Gong study area expose several meters of cream, grey to buff calcrete, variably soft and powdery, nodular, rubbly with numerous vugs (cavities), gravelly or forming a dense hard pan capping the succession (Figs. 14 – 15). The surface pan is locally overlain by reworked calcrete rubble that may infill local channels. Relict patches of thinly-bedded greyish mudrocks and more resistant-weathering, pale brown, ovoid to lenticular diagenetic nodules indicate that the calcretes here have developed at least in part through replacement of Karoo Supergroup sediments (Fig. 16). These parent rocks were probably basinal mudrocks of the Prince Albert Formation (Ecca Group), such as are mapped on the 1: 250 000 Kimberley sheet some 14 km to the ESE of Gong Gong but not at Gong Gong itself.

Railway cuttings in the northern sector of the Gong Gong study area show good sections through massive, blocky (locally columnar) jointed, pale buff- to brown-weathering andesites of the Precambrian Allanridge Formation (Ventersdorp Group) (Fig. 17). These resistant lavas crop out extensively in the Barclay West area and give rise to highly rubbly terrain here. The Venterdorp outcrop area has been extensively planed-off by the Dwyka ice sheets (Bosch 1993). Weathering with the uppermost jointed andesites has generated a regolith of rounded corestones separated by reddish-brown, lateritic gravelly soils. Concentrations of well-rounded andesite cobbles and boulders may indicate stream reworking of locally-derived corestones within shallow channels, though much of this material may be essentially colluvial in origin. A borrow pit near Gong Gong station (Loc. 388) contains good exposures of well-rounded andesitic boulders or corestones within a deep reddish-brown sandy to gravelly matrix overlying deeply weathered Ventersdorp lava bedrock. Finer interstitial gravels are dominated by quartz vein material weathered out from the Archaean lavas and might also be diamondiferous (Figs. 18 to 19).

No fossil remains were recorded during fieldwork within the Gong Gong loop extension study area.

Fig. 14. Thick calcrete hardpan with rubbly top and occasional relict diagenetic nodule of the Ecca Group parent rocks (arrow), railway cutting at Gong Gong (Hammer = *c*. 30 cm).

Fig. 15. Dense calcrete hardpan capping showing vuggy character and karstic surface weathering, Gong Gong railway cutting (Hammer = *c*. 30 cm).

Fig. 16. Relict bedding (folded) and diagenetic nodules of deeply-weathered parent Ecca Group succession beneath crumbly to rubbly calcrete capping, Gong Gong railway cutting (Hammer = *c*. 30 cm).

Fig. 17. Massive, blocky-jointed andesites of the Allanridge Formation (Ventersdorp Subgroup), railway cutting in northern sector of Gong Gong study area.

Fig. 18. Deeply-weathered Ventersdorp lava saprolite overlain by poorly sorted, bouldery gravels of rounded andesite corestones, with a possible element of stream reworking. Borrow pit near Gong Gong siding.

Fig. 19. Detail of the subsurface bouldery gravels seen in the previous figure showing the reddish-brown sandy matrix and patches of interstitial quartz gravels (Hammer = *c*. 30 cm).

4.1.3. Ulco Loop Extension

The proposed Ulco Loop Extension study area is located on flat to undulating terrain at *c*. 1010 to 1060 m amsl on the northern side of the Harts River, close to the intersection of the R31 and R370 roads and some 6 km north of Delpoortshoop. This area is underlain by an extensive calcrete hardpan that overlies, and in part replaces, alluvium along the banks of the Harts River. Extensively calcretised silty alluvium with a calcrete hardpan capping can be seen from the R31 bridge across the river 1.25 km southwest of the loop extension site (Fig. 20). These low-elevation silts are probably equivalent to the Quaternary to Holocene Riverton Formation recognised along the Vaal River (*cf* Partridge *et al.* 2006). Precambrian bedrocks - siliciclastic sediments of the Vryburg Formation (quartzites, conglomerates *etc*) - crop out just to the south of the Harts River but are not mapped in the study area (Vv in Fig. 7).

Extensive railway cuttings expose the well-developed, thick (2 m to > 5 m) calcrete succession that mantles the entire Ulco study area (Figs. 21-23). Various calcrete facies are represented here and the succession is almost certainly composite. In places a lower, brownish-weathering, sparsely gravelly, well-consolidated unit may be distinguished beneath a softer-weathering, pale calcrete that is in turn overlain by a more indurated hardpan and surface calcrete rubble. Towards the Harts River the calcretes have developed within, and largely replaced, silty to sandy (locally gritty) alluvial sediments, relict patches of which are still preserved within the lower part of the calcrete succession. Away from the river, possible relict bedding - usually obscure, often deformed (folded, faulted) and brecciated - of the parent rocks may be seen. The parent rock unit concerned is unclear; it may be related to the Precambrian Vryburg succession or perhaps the much younger Karoo Supergroup.

No fossil remains were observed during fieldwork within the Ulco Loop Extension study area.

Fig. 20. View of the north-western banks of the Harts River from the R31 road bridge near Ulco Siding showing extensively calcretised, greyish alluvium.

Fig. 21. Thick, composite calcrete hardpan exposed in railway cutting at Ulco Siding (Hammer = *c*. 30 cm). Relict patches of silty alluvium are preserved within the lower part of the succession.

Fig. 22. Contrast between the lower, well-consolidated, brownish weathering (possibly manganese-stained) lower calcrete unit and the upper, crumbly calcrete with a hard hardpan capping, Ulco railway cutting (Hammer = *c*. 30 cm).

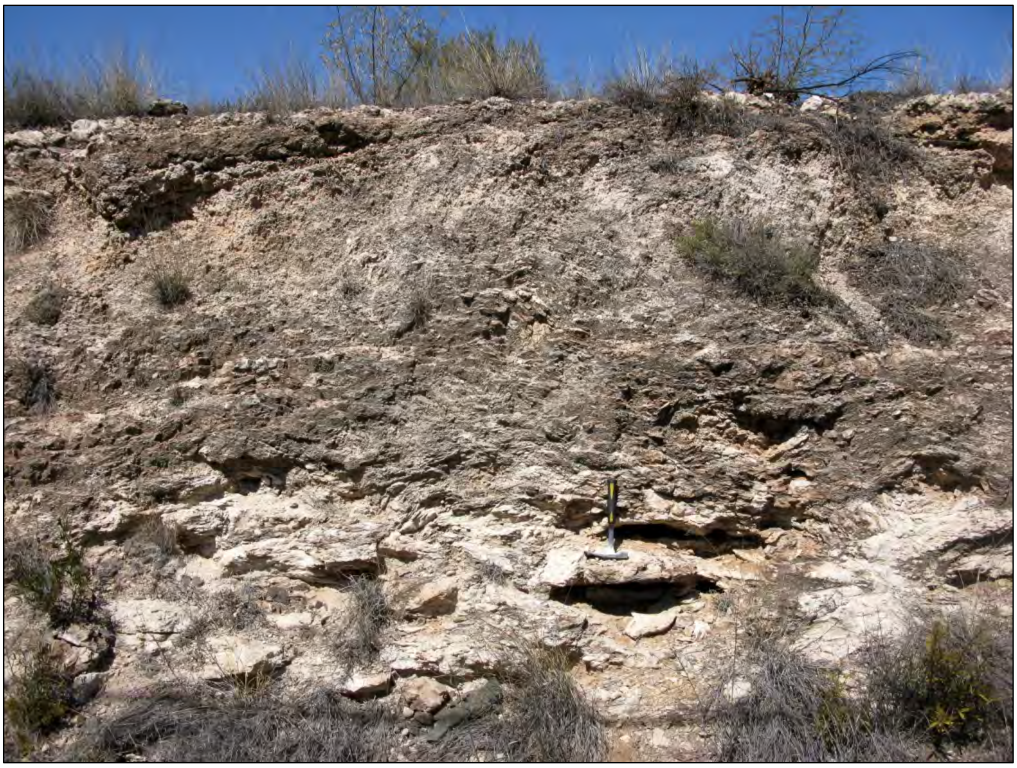

Fig. 23. Probable deformed and disrupted relict bedding of the sedimentary parent rock preserved within the lower part of the thick calcrete hardpan at Ulco (Hammer = *c.* 30 cm).

4.1.4. Trewil Loop Extension

The study area for the Trewil Loop Extension is situated at *c.* 1450 m amsl on the extensive, flat-lying Ghaap Plateau, some 20 km southeast of Daniëlskuil and 7.5 km south of the R31 tar road between Kimberley and Postmasburg. The carbonate bedrocks here are assigned to the Lime Acres Member of the Kogelbeen Formation (Campbell Rand Subgroup, Ghaap Group). This richly stromatolitic carbonate (limestone / dolostone) succession with occasional cherty interbeds has been described in the nearby Lime Acres mining area by Altermann and Wotherspoon (1995). Large areas of the Campbell Rand carbonates are covered by a thick mantle of calcrete hardpan of various ages, including Quaternary (Ql in Fig. 6). To the east of Trewil extensive bedrock areas overlain by downwasted siliceous “rubble” are also mapped separately (*e.g.* near Arriesfontein; pale buff areas with triangle ornament in Fig. 6). Large pans such as the Great Pan and Rooipan are located a few kilometres to the west of the Trewil study area.

Surface calcretes of various facies are exposed in several existing shallow, elongate borrow pits along the southern side of the railway line at Trewil (See also notes for the Trewil Borrow Pit 1 study site, Section 4.2.4.) (Fig. 24). Calcrete in the pit floor displays a distinctive, finely net-veined or honeycomb, vuggy fabric with relict patches of yellowish to buff coarse sandy sediment, possibly derived from older units within the Kalahari Group such as the Eden Formation (Fig. 26). Calcretes exposed in the pit walls include greyish to cream, crumbly nodular, rubbly and dense hardpan varieties, capped by surface calcrete rubble, brown, slightly ferruginous sandy soils and sparse gravels (mainly cherts) (Fig. 25). Occasional blocks and layers show a porous, bioturbated fabric with dense networks of tubular hollows that may be attributed to insect burrowing, probably termites (Fig. 27). Downwasted and reworked blocks of black to dark grey Campbell Rand cherts and grey karst-weathered dolostone / limestone frequently contain small-scale domical stromatolites (Figs. 60 and 61).

Apart from blocks of Precambrian stromatolitic dolostone and chert as well as low diversity trace fossil assemblages within the Kalahari calcretes, neither of which is high palaeontological significance, no other fossil remains were observed during fieldwork within the Ulco Loop Extension study area.

Fig. 24. Elongate shallow borrow pit into surface calcrete along the southern side of the railway line at Trewil, looking towards the ENE (Trewil Borrow Pit 1 study area).

Fig. 25. Rubbly calcrete hardpan overlain by brown sandy soils, Trewil Loop Extension site (Hammer = *c*. 30 cm).

Fig. 26. Distinctive network or honeycomb texture of calcretised sandy sediments on the floor of borrow pit at Trewil Siding, close to Borrow Pit 1 study site (Hammer = *c*. 30 cm).

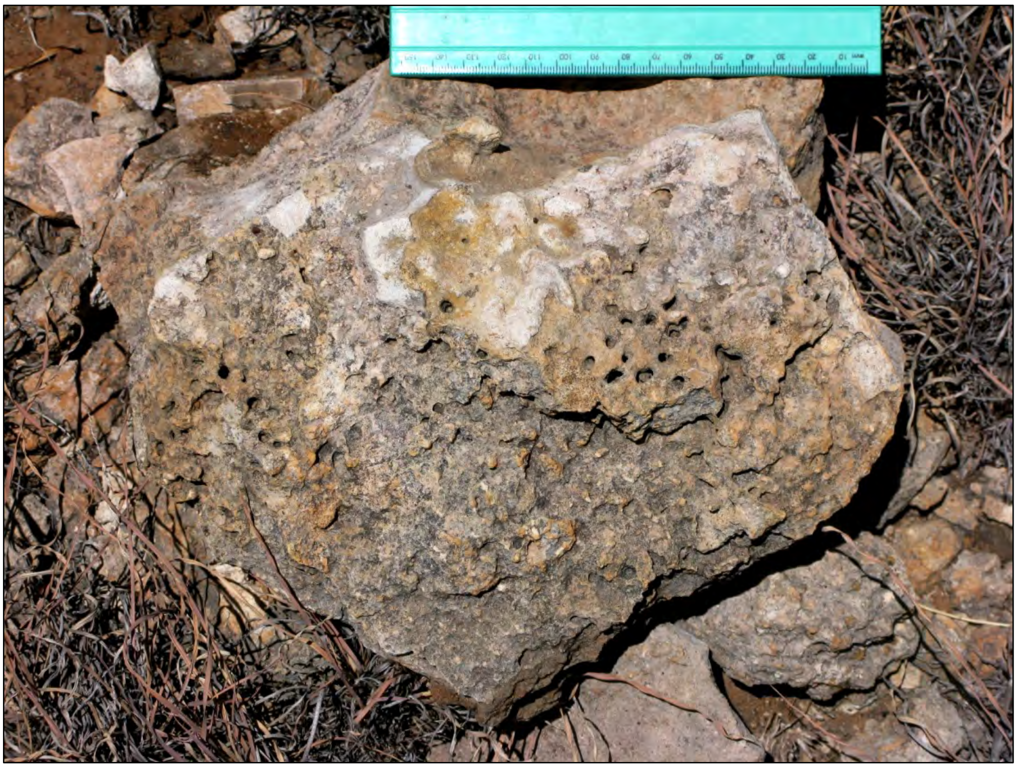

Fig. 27. Bioturbated, burrowed texture seen in some calcrete horizons at Trewil Siding, probably attributable to termites or other invertebrates (Scale in cm and mm).

4.1.5. Tsantabane Loop Extension

The proposed Tsantasbane Loop Extension study area is situated some 8.8 km northeast of Postmasburg and 6 km north of the R385 Kimberley to Postmasburg tar road. In terms of its geological setting the site lies at *c*. 1340 – 1360 m amsl on the south-eastern flank of the Maremane Dome, a major anticlinal feature built of Precambrian carbonate sediments of the Ghaap Group (Fig. 5). The carbonate basement rocks are largely mantled with Late Caenozoic superficial sediments - notably Quaternary calcretes, colluvium and alluvium - at this site, which traverses a south-west flowing tributary of the Groenwaterspruit drainage system. Small outliers of highly enriched iron ores developed within palaeokarst depressions within the Maremane Dome are preserved in the neighbourhood of the study site, including the archaeologically important specularite mine site at Blinkkklipkop (Tsantsabane) only some 2.7 km to the southwest (Thackeray & Thackeray 1983).

Bedrock exposure of Ghaap Group dolostones is not seen at the study site. A several meter thick succession of calcretised polymict alluvial gravels of the Groenwaterspruit dranage system is well exposed in railway cuttings within the eastern sector of the area (Figs. 28 to 31). The gravels are poorly-sorted, clast-to matrix-supported with a calcretised sandy to gravelly matrix, and contain pebble to boulder-sized clasts of dark grey to black Campbell Rand dolostone (occasionally stromatolitic), ferruginous limestone, banded iron formation, jasper, quartzite, calcrete, specularite, "Blinkklip breccia" iron ore, grey-green sandstone or lava *etc*. The larger clasts are well-rounded but smaller ones may be angular to subangular. Platy clasts locally show well-developed current imbrication. Two or more generations of calcretised alluvial deposits are apparent here, contrasting in the abundance of coarse gravels and the degree of consolidation by calcrete. Contacts between lenticular sedimentary units is often sharp; some may represent cut-and-fill channel bodies. In general, the older sediments are much more compact and consolidated. The calcretised sediments are overlain by downwasted gravels containing abundant resistent-weathering cherts and BIF. Apart from occasional reworked blocks and clasts of Precambrian stromatolitic dolostone within the calcretised fluvial gravels, no fossil remains were recorded during fieldwork at the Tsantsabane Loop Extension study site.

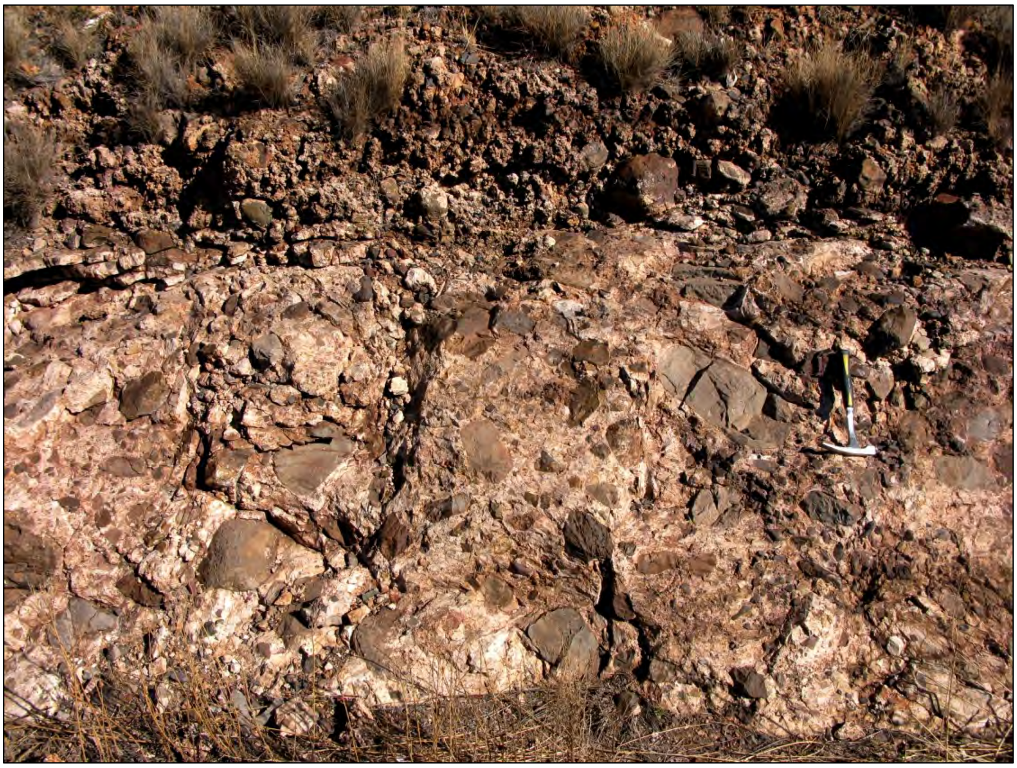

Fig. 28. Poorly-sorted, matrix-supported, polymict calcretised alluvial gravels exposed in a railway cutting at Tsantsabane (Hammer = *c*. 30 cm).

Fig. 29. Sharp contact between well-consolidated, matrix-supported older gravels and rubbly, clast-supported younger gravels, Tsantsabane railway cutting (Hammer = *c*. 30 cm).

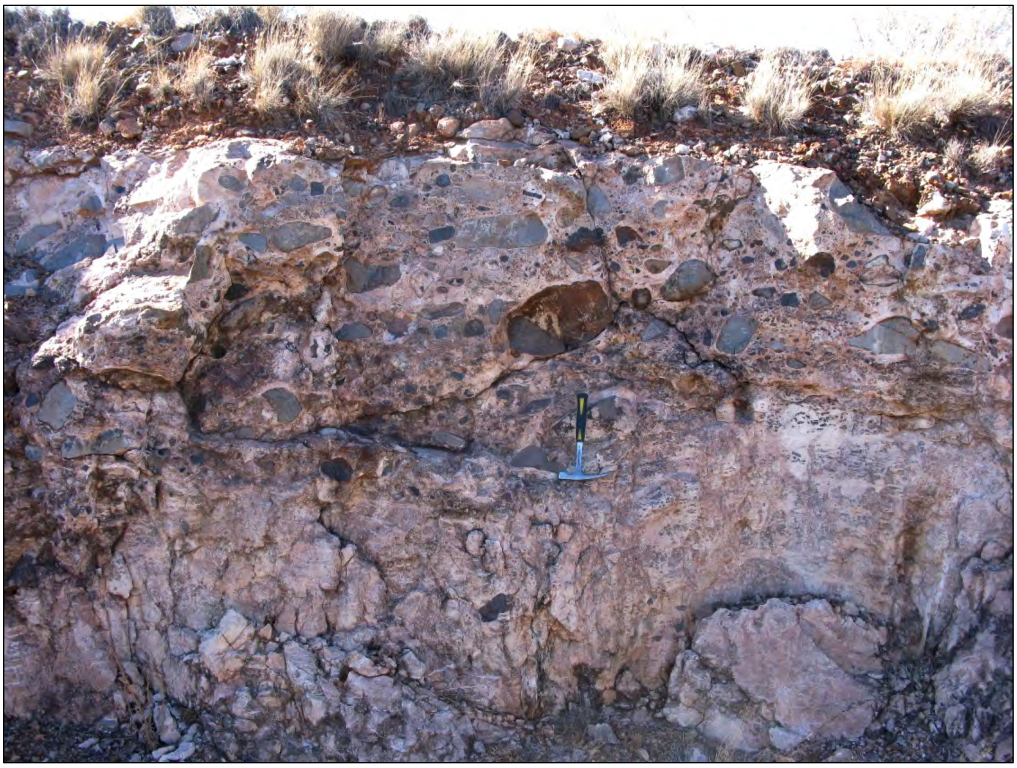

Fig. 30. Calcretised coarse alluvial channel infill incising underlying calcretised, clast-poor alluvium, Tsantsabane railway cutting (Hammer = *c*. 30 cm).

Fig. 31. Detail of well-consolidated older alluvial gravels showing preferential alignment of more platy clasts suggesting current imbrication (Hammer = *c.* 30 cm).

4.1.6. Postmasburg Loop Extension

The proposed Postmasburg Loop Extension study site is situated in flat terrain at *c*. 1340 m amsl to the west of the extensive railway development on the north-eastern outskirts of Postmasburg, just north of the R385 tar road to Olifantshoek. The study site is mostly underlain at depth by Precambrian carbonates (limestone / dolostone) of the Campbell Rand Subgroup. In the west the railway line bends round the southern edge of the low, north-south trending Gamagara Hills. Here, at Beeshoek, mining exploits major deposits of high-grade iron ores of the haematitic Manganore Formation (a highly mineralised, oxidised correlate of the Kuruman and Griquatown Formations of the Asbestos Hills Subgroup, Transvaal Supergroup) as well as overlying ferruginous conglomerates at the base of the Gamagara Formation (Olifantshoek Supergroup) (Gutzmer 1996).

Small, low karstified exposures of grey Campbell Rand dolostones occur north of the railway line where the bedrocks are largely mantled with unconsolidated, poorly-sorted surface gravels composed of resistant lithologies such as chert, BIF and iron ore (Fig. 32). The gravel clasts vary from angular to subrounded and are probably of mixed alluvial and colluvial origin. A prominent-weathering bank (*c*. 2 m) of rusty-brown weathering breccio-conglomerates may represent older ferricretised surface gravels (Fig. 33). The poorly-sorted sediment comprises dispersed, clast- to matrix-supported, rounded to subangular clasts of chert and BIF with a coarse, vuggy matrix of iron minerals and quartz. It is overlain by downwasted surface gravels.

Displaced blocks of Campbell Rand dolostone and horizontally-laminated, grey-green calcareous grits display stromatolitic lamination (Fig. 35) but no well-formed stromatolitic domes or columns were observed here. Towards the east, away from the Gamagara Hills, the surface gravels thin out and the bedrock dolostones are mantled with reddish-brown lateritic soils with sparse downwasted dolostone blocks.

Apart from occasional displaced blocks of Precambrian stromatolitic dolostone, no fossil remains were recorded during fieldwork at the Postmasburg Loop Extension study site.

Fig. 32. Karst-weathered dolostone bedrocks of the Campbell Rand Subgroup emerging from beneath unconsolidated surface gravels, Postmasburg study area (Hammer = *c*. 30 cm).

Fig. 33. Resistent-weathering bank of ferricretised surface gravels north of the railway line in the Postmasburg study area (Hammer = *c*. 30 cm).

Fig 34. Close-up of ferricretised breccio-conglomerates seen in the previous figure showing dispersed subrounded clasts of chert and BIF as well as the vuggy, gritty ferruginous matrix (Scale in cm).

Fig. 35. Displaced blocks of laminated calcareous grits and elephant-skin weathered dolostone north of the railway line, Postmasburg study area.

4.1.7. Glosam Loop Extension

The proposed Glosam Loop Extension study area is situated at *c*. 1410-1430 m amsl on the eastern flank of the north-south trending Gamagara Hills, some 24 km NNW of Postmasburg and 2.5 km west of the R325 Sishen tar road. The Glosam mine exploiting ferruginous manganese ores lies just to the west. The bedrock stratigraphy in this area is complex. The manganese ores formed in Late Proterozoic times within highly irregular palaeokarstic systems developed within carbonates of the Campbell Rand Subgroup and are associated here with ferruginous haematite pebble conglomerates (Doornfontein Member) of the basal Gamagara Formation (Olifantshoek Supergroup) that mantle a major erosional unconformity surface (Gutzmer 1996). Tectonic deformation in the region is related to westward thrusting of upper Transvaal Supergroup rocks over the Gamagara succession to the west of the Gamagara Ridge.

Bedrock exposure within the largely flat-lying study area is very limited due to the pervasive cover by superficial gravels. These are locally calcretised near-surface and are dominated variously by haematite pebbles downwasting from the ore bodies to the west and / or platy to blocky clasts of pinkish, buff and grey weathered mudrocks (Fig. 39). A window into the geological complexity of the area is provided by an extensive borrow pit at the southernmost end of the study area (Figs. 36 to 38). Here a series of highly-deformed, deeply-weathered, grey, pinkish, ochreous to orange-brown shales with subordinate grits and calcrete veining abuts against, or is interbedded with, steeply-dipping, disrupted beds of greyish to ferruginous brown dolostone. An uneven mantle of poorly-consolidated colluvial conglomerates of metallic grey haematite ore pebbles, possibly derived from the Gamagara Formation, covers the shaly bedrock. Deep, irregular palaeokarst hollows within the carbonate beds are infilled with similar haematite ore conglomerate. The stratigraphic position of the shales and limestones is unclear. They probably belong low down within the Campbell Rand succession close to the core of the Maremane Dome - perhaps even within the Monteville Formation which contains significant mudrock intervals (Eriksson *et al.* 2006, p. 247).

No fossil remains were recorded during fieldwork at the Glosam Loop Extension study site.

Fig. 36. Intensely folded, weathered and ferruginised siltstones, probably belonging to the lower Campbell Rand Subgroup, overlain by pebbly conglomerates of haematite pebbles, borrow pit at southern end of Glosam study area (Hammer = *c*. 30 cm).

Fig. 37. Close-up of folded shales within the borrow pit at Glosam (Hammer = *c*. 30 cm).

Fig. 38. Haematite pebble conglomerate infilling solution hollows within palaeokarst-weathered carbonate rocks of the Campbell Rand Subgroup, Glosam study area (Hammer = *c*. 30 cm).

Fig. 39. Flat-lying terrain within the Glosam study area that is probably largely underlain by Campbell Rand Subgroup carbonates, mantled here with iron ore-rich gravels.

4.1.8. Sishen New Loop

The study area for the Sishen New Loop lies in flat terrain at *c*. 1180-1200 m amsl on the north-eastern side of the Ga-Mogara River, due west of the main opencast mine at Sishen and *c*. 8.6 km southwest of Kathu. The area is sparsely vegetated by Kalahari thornveld and is already extensively modified by on-going development (*e.g.* road construction, stormwater trenches). There is no Precambrian bedrock exposure here since the entire area is mantled with thick calcrete and other superficial deposits. These younger sediments overlie rocks of the Postmasburg Subgroup (*e.g.* Ongeluk lavas) and the Olifantshoek Supergroup (*e.g.* Gamagara basal conglomerates) at depth. Haddon (2005) reports a thickness of *about* 80 m of Kalahari Group sediments overlying the Precambrian bedrocks in the Sishen Iron Ore Mine located just east of the present study area. These beds are assigned to the Wessels Formation (basal gravels) and Budin Formation (calcareous clays). The uppermost 15 m of the Kalahari sediments comprises well-indurated calcretised siltstones, pebbly horizons and clays with the development of solution hollows along joint surfaces within 10 m of the surface. Close to the surface calcretised silcretes showing *in situ* brecciation are also recognised.

A pale pinkish, karstified calcrete hardpan is exposed at surface in the Sishen New Loop study area, partially mantled with a thin layer of downwasted surfaced gravels (*e.g.* calcrete rubble) and orange-brown Kalahari sands (Fig. 40). Numerous reworked blocks of the dense, pale grey to buff or cream surface hardpan are available along the margins of several deep stormwater drainage trenches (Fig. 41). Various calcrete facies are represented, including gravelly, pelleted, brecciated, silicified and honeycomb types (Fig. 42). Several blocks contain well-defined, tubular to irregular solution pipes lined with pale brown calcareous silt. Consolidated, poorly-sorted calcrete gravel breccia and reddish-brown sands partially infill some of these solution hollows, but no associated fossil bones or teeth were observed within them (Figs. 43 & 44).

No fossil remains were recorded during fieldwork at the Sishen New Loop study site.

Fig. 40. Karst-weathered surface of pinkish calcrete and overlying Kalahari sands in the Sishen New Loop study area (Hammer = *c*. 30 cm).

Fig. 41. Recently-excavated trench through thick surface calcretes in the Sishen loop study area.

Fig. 42. Dense calcrete breccia, possibly formed by partial replacement and *in situ* brecciation of a silcrete horizon, Sishen loop study area (Scale in cm).

Fig. 43. Excavated block of surface calcrete showing large, subvertical silt-lined solution hollow, Sishen loop study area (Hammer = *c*. 30 cm).

Fig. 44. Interior of exhumed solution cavity (*c*. 30 cm wide) within calcrete hardpan showing partial infill with cemented gravelly calcrete breccia and orange-brown sand, Sishen loop study area. Trapped vertebrate remains (bones, teeth) and molluscs (*e.g.* snails) might be encountered in such settings.

4.1.9. Wincanton Loop Extension

The Wincanton Loop Extension study site extends either side of the R380 Kathu to Deben (Dibeng) road around 6 km east of Deben. The terrain here is flat-lying (*c*. 1140-1150 m amsl.) fairly featureless Kalahari thornveld; scattered rounded pans or dolines (solution hollows) can be seen in the vicinity on satellite images. The region is underlain by an extensive calcrete hardpan of probable Quaternary or older age (Kalahari Group). This is mantled variously by thin, orange-brown Kalahari aeolian sands (Gordonia Formation) or pale brown calcareous soils, in all cases with a scatter of angular calcrete rubble blocks (Fig. 46). Bedrocks are nowhere exposed, and the Kalahari succession is probably several tens of meters thick. A vertical section through the upper part of the calcrete hardpan in the Wincanton region is seen in a rectangular excavation in the siding area. Several meters of crudely bedded to nodular, well-consolidated, pinkish to cream calcretes are seen here (Fig. 45).

No fossil remains were recorded during fieldwork at the Wincanton Loop Extension study site.

Fig. 45. Thick, pseudobedded surface calcretes exposed in an artificial excavation in the Wincanton siding area. The section seen here is about 2 m thick.

Fig. 46. Thin mantle of Kalahari sands and downwasted calcrete rubble in the Wincanton study area.

4.1.10. Witloop New Loop

The study area for the proposed Witloop New Loop is situated in flat-lying Kalahari terrain at *c*. 1070 – 1080 m amsl, just to the east of the R380 Postamasburg to Hotazel road and about 11.5 km south of Hotazel itself. The site lies astride the Witloopleegte, a largely defunct east bank tributary of the Go-Magara River system whose SW – NE orientation, parallel to adjacent tributaries, is probably controlled by bedrock structure. The pre-Kalahari bedrocks in the region are blanketed by several tens of meters of Kalahari Group sediments that are heavily calcretised near-surface. Good exposures of the uppermost Kalahari sediments are available in existing borrow pits on either side of the R380; it is proposed to extend these pits as part of the Transnet 16 mtpa project (Section 4.2.7). Most of the remainder of the study area is mantled in Kalahari sands.

The best stratigraphic sections are seen in the eastern (Borrow Pit 2) study site, with the upper part of the succession exposed in a low dry waterfall at the eastern end of the pit and the lower succession on the pit floor. The very dense, pinkish to pale brown calcrete hardpan with a sharp, undulose (possibly karst-weathered) upper surface that is exposed on the pit floor contains reworked calcrete clasts / pellets and angular greenish-grey basement gravels towards the base. It has been extensively silicified; sphaeroidal to irregular-shaped, cobble- to boulder-sized, pale yellowish, grey to creamy, cherty siliceous nodules occur extensively within this horizon (Figs. 49 to 50). Secondary silcretisation of calcretes in wetter settings such as pans is widely recorded in the Kalahari region (*e.g.* Nash & Shaw 1998). The cherty calcretes are overlain by two to four meters of poorly-sorted, polymict, angular to subrounded gravels of quartzite, lava, jaspilite, lavas and other lithologies that probably represent an ancient fluvial channel fill along the Witloopleegte. The gravels are matrix supported (gritty sand) and heavily calcretised. They are overlain by a thin (few dm), pale cream, rubbly calcrete followed by an uppermost, highly-bioturbated, greyish sandy calcrete forming a near-surface hardpan with a slightly undulose upper surface (Figs. 47 & 48). This last unit (*c*. 2 m thick) is riddled with vertical as well as horizontal and oblique, interconnected, branching open tubes of *c*. 1 cm diameter or less lined with dense calcrete that probably represent fossilised invertebrate (*e.g.* insect) burrows (Fig. 71).

The stratigraphy in Borrow Pit 1 on the western side of the R380 is broadly comparable but not so clearly developed. Small exposures of blocky-weathering, grey-green bedrocks are seen locally but their identity is unclear (probably lavas). Displaced blocks of calcrete hardpan contain sizeable subvertical, branching hollows - possibly root casts (rhizoliths) or invertebrate burrows (Fig. 72). Towards the top of the succession is a 30-40 cm thick zone of greyish, impure silty to gritty calcrete that is permeated by numerous closely-spaced, narrow (few mm) parallel tubes, imparting a distinctive light, porous character to the rock. Locally very fine calcrete tubules can be seen weathering out of the profile (Figs. 73 to 75). These are interpreted as the moulds of reedy stems growing in a swampy vlei area within the largely abandoned Witloopleegte (*cf* Nash & McLaren 2003). No traces of freshwater molluscs were found. Also characteristic of this zone are sparse, dispersed cm-sized sharp-edged flakes of vein quartz; they may represent stone artefacts imported from elsewhere. The uppermost few meters of the calcrete succession in the western pit, above the bioturbated vlei calcrete zone, is weathered, crumbly with a rubble calcrete mantle on top and a calcrete breccia zone below.

The low diversity fossil assemblages recorded at the Witloop New Loop study site are probably of widespread occurrence within the Kalahari Group and are not regarded as of high palaeontological significance.

Fig. 47. Greyish, bioturbated calcrete hardpan overlying calcretised channel gravels, eastern end of Borrow Pit 2 study area at Witloop.

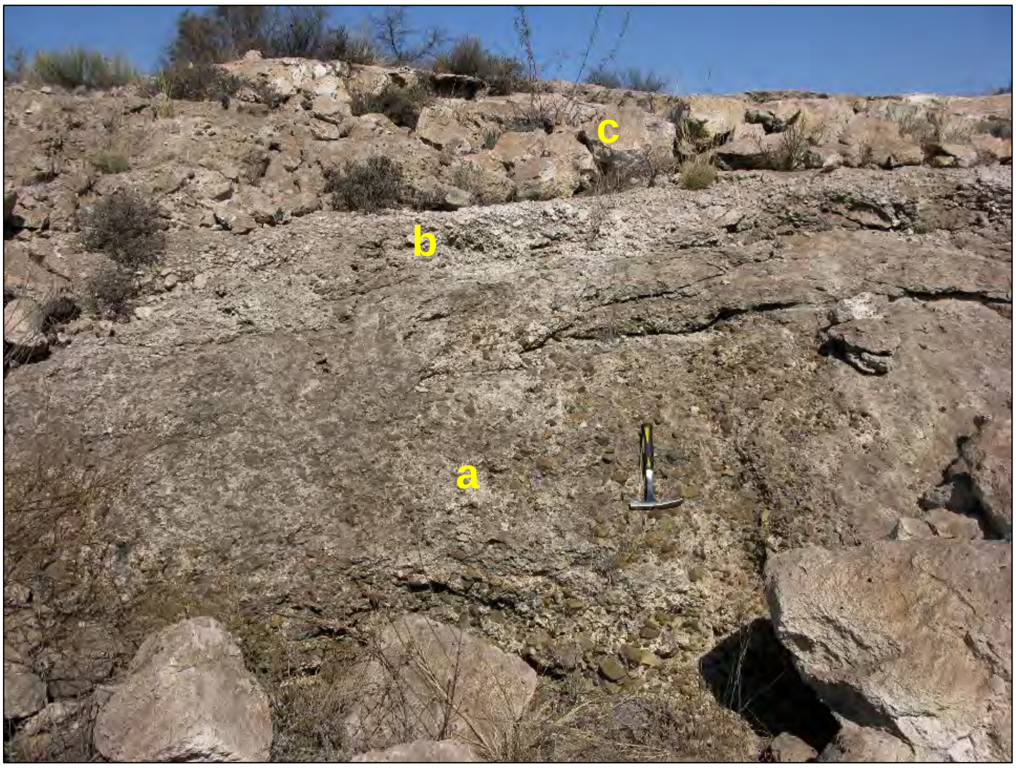

Fig. 48. **Same locality as in previous figure, showing (a) poorly-sorted calcretised gravels infilling a palaeochannel; (b) thin horizon of rubbly calcrete; and (c) bioturbated calcrete hardpan (Hammer = *c*. 30 cm).**

Fig. 49. Basal silicified calcrete in Borrow Pit 2 site showing irregular cherty concretions (Hammer = *c*. 30 cm).

Fig. 50. Elongate, cobble-sized cherty concretion weathered out from the basal silicified calcrete zone (Scale in cm).

4.2. Borrow pit sites

A short account of geological and palaeontological observations made at each of the thirteen proposed borrow pit sites along or close to the 16 Mtpa railway line between Kimberley and Hotazel is given here. Key data, with recommendations for any further action regarding palaeontological heritage management, is also summarised below in Table 3 below.

4.2.1. Fieldsview borrow pit

The proposed Fieldsview borrow pit study area lies at *c*. 1100 m amsl on farm Nooitgedacht 66, just to the north of a large existing shallow pit (28º 33' 50.9" S, 24º 36' 30.1" E) and some 200-300 m east of the Vaal River. The existing pit is largely excavated into dark grey to grey-green silty mudrocks of the uppermost Dwyka Group, close to the contact with the Ecca Group. Occasional thin (several dm) interbeds of buff, horizontally-laminated, tabular-bedded, fine sandstone are exposed *in situ* along the eastern edge of the pit (Figs. 51 & 52). These contain dispersed, well-rounded erratics of weathered granite and other lithologies towards the base and are interpreted as upward-fining event beds such as turbidites reworking poorly-sorted glacial material into an offshore basin. The grey mudrocks contain scattered concretions of rusty-brown ferruginous carbonate and pale grey, possible phosphatic or cherty material.

The Dwyka bedrocks are overlain by two meters or less of pale buff alluvial silts and orange-brown Hutton sands (Fig. 53). The low-elevation, fine-grained alluvial deposits of the Vaal River thicken towards the west, where they contain locally-reworked platy Dwyka sandstone gravels. They have been provisionally assigned to the Riverton Formation. This unit has been dated to the Middle Pleistocene / Holocene interval based on enclosed MSA & LSA stone artefacts (Partridge *et al.* 2006, Helgren 1979).

No fossils were observed within the Dwyka mudrocks and associated concretions, the alluvial silts or the overlying Hutton sands at the Fieldsview borrow pit site. It is noted that mudrocks of the stratigraphically slightly higher-lying Prince Albert Formation in the Kimberley – Douglas region may contain fossiliferous concretions with petrified woods, fish remains and marine invertebrates (McLachlan & Anderson 1973).

Fig. 51. Grey Dwyka Group mudrocks with occasional tabular interbeds of horizontally-laminated sandstone, Fieldsview borrow pit on Nooigedacht 66 (Loc. 409) (Hammer = *c*. 30 cm). The Karoo bedrocks are overlain here by buff alluvial silts and orange-brown Hutton sands.

Fig. 52. Close-up of tabular sandstone interbeds within the Dwyka Group at Fieldsview showing dispersed pebbly erratics at the base (Hammer = *c*. 30 cm).

Fig. 53. Pale buff alluvial silts of the Vaal River overlying Karoo mudrocks (bottom RHS) and overlain in turn by orange-brown Hutton sands, western side of Fieldsview borrow pit (Hammer = *c*. 30 cm).

4.2.2. Gong Gong borrow pit

The proposed Gong Gong pit study area (28º 28’ 31.25” S, 24º 25’ 33.68” E) features several existing deep borrow pits at *c*. 1180 m amsl along the southern side of the railway access road. These pits have been excavated through the surface calcrete hardpan into deeply weathered, calcretised, greyish, thin-bedded silty mudrocks that are probably assignable to the Prince Albert Formation (Ecca Group) (Figs. 54 & 55). This unit is not mapped at Gong Gong because it is normally mantled by superficial sediments here (Map Fig. 7). Occasional prominent-weathering, lenticular to ovoid diagenetic ferruginous nodules and tabular beds of sandstone are exposed in the pit walls. Small scale folding of the Ecca beds is probably a consequence of extensive secondary calcrete development (calcrete tectonics), as indicated by the numerous calcrete veins extending downwards into the Karoo bedrocks from the surface hardpan. Ventersdorp Supergroup lavas are not exposed in this area.

No fossil remains were recorded during fieldwork at the Gong Gong borrow pit study site.

Fig. 54. One of several existing deep borrow pits in the Gong Gong study area showing deeply-weathered, calcrete-veined Ecca Group bedrocks overlain by pale brown calcrete hardpan.

Fig. 55. Same locality as the previous figure showing a close up of relict bedding within the Ecca Group bedrocks that are contorted due to calcrete tectonism.

4.2.3. Ulco borrow pits

The Ulco Borrow Pit 1 site (28º 22’ 01.8” S, 24º 18’ 19.8” E) located some 300 m southwest of the railway line in flat-lying thornveld at *c*. 1040 m amsl is characterised by a near-surface calcrete hardpan mantled locally by pale brownish sandy soils, calcrete rubble and sparse gravels. There is little exposure of the calcrete succession in depth. The surface hardpan locally shows evidence of reworking and karstic weathering (Fig. 56).

The Ulco Borrow Pit 2 site is situated at *c*. 1020 m amsl in flat agricultural lands on the northeast side of the railway line just southeast of a shallow existing pit at 28º 22’ 11.05” S, 24º 18’ 47.62” E (Fig. 57). The several meter – thick composite calcrete succession exposed in the existing pit closely resembles better exposures in nearby railway cuttings described earlier (Section 4.1.3).

No fossil remains were observed during fieldwork at either of the two Ulco borrow pit study sites.

Fig. 56. Karst-weathered, brecciated calcrete hardpan exposed at surface in the Ulco Borrow Pit 1 study area (Hammer = *c*. 30 cm).

Fig. 57. View southwards across the existing calcrete borrow pit adjoining the northern edge of the Ulco Borrow Pit 2 study area.

4.2.4. Trewil borrow pits

The Trewil Borrow Pit 1 study site (28º 18' 26.8" S, 23º 41' 09.0" E) is associated with an existing shallow borrow pit at *c*. 1450 m amsl on the south side of the railway line within the Trewil Loop Extension study area and has already been covered in Section 4.1.4. The only fossil material observed here comprises small-scale stromatolitic domes within blocks of downwasted or reworked dark chert and grey dolostone / limestone of the Kogelbeen Formation (Campbell Rand Subgroup) as well as displace blocks of bioturbated calcrete (Fig. 27).

The Trewil Borrow Pit 2 study area (28º 16' 54.91" S, 23º 46' 03.61" E) is located close to Arriesfontein Siding some 8.45 km ENE of the Trewil Siding study site. The proposed pit lies within an existing shallow calcrete excavation at *c*. 1430 m amsl on the southern side of the railway line. A range of calcrete facies are exposed in the pit area, with evidence for karstic weathering and brecciation of the uppermost hardpan (Fig. 58). Karst hollows are infilled with well-cemented, gravelly to sandy sediment which is locally ferruginised (Fig. 59). Rounded gravel clasts indicate a degree of water transport. Sandy parent material with dispersed, fine gravel clasts may be of alluvial origin. Fairly abundant downwasted (surface gravel) or reworked blocks of dark grey to black Campbell Rand cherts and grey dolostone / limestone contain well-preserved stromatolitic lamination, mainly from small domal bioherms (Figs. 60 & 61).

Apart from blocks of Precambrian stromatolitic dolostone and chert as well as low diversity trace fossil assemblages within the Kalahari calcretes, neither of which is high palaeontological significance, no other fossil remains were observed during fieldwork within the two Ulco borrow pit study areas.

Fig. 58. Well-consolidated, reworked calcrete rubble within a pale brown, finely-gravelly matrix, Trewil Borrow Pit 2 study area (Hammer = *c*. 30 cm).

Fig. 59. Displaced block of karstified calcrete hardpan with solution hollows infilled by calcretised gravelly sediment, Trewil Borrow Pit 2 study area (Hammer = *c*. 30 cm).

Fig. 60. Downwasted block of dark grey chert from the Campbellrand Subgroup showing small-scale domical stromatolite, Trewil Borrow Pit 1 study area (Scale in cm).

Fig. 61. Disturbed block of Campbellrand Subgroup dolostone / limestone showing extensive development of stromatolitic limestone, typical of the Kogelbeen Formation, Trewil Borrow Pit 1 study area (Hammer = *c*. 30 cm).

4.2.4. Tsantsabane borrow pit

The proposed Tsantsabane borrow pit site (28º 16 50'.03" S, 23º 08' 38.60" E) lies south of the railway line at *c*. 1350 m in an area that has already been extensively disturbed by calcrete mining and railway development. The Campbell Rand Subgroup carbonate bedrocks here are covered by several meters of well-consolidated calcretised gravels, as well exposed in nearby railway cuttings (Section 4.1.5) and in several heaps of large, excavated blocks (Fig. 62). The gravels are polymict (grey and ferruginous dolostone, BIF, Blinkklip ironstone breccia, chert, calcrete *etc*) and matrix-supported, with prominent-weathering blocks of tougher lithologies. *In situ* calcrete surfaces show potholing due to karst weathering with lenticles of finer gravels exposed at various levels (Fig. 63). A thin mantle of rubbly, polymict downwasted gravels and pale silty sands covers the ground surface. The gravels are enriched in resistant rock types such as BIF, chert, jasper and Blinkklip iron ore breccia, many clasts of which are well-rounded, as well as reworked local calcrete and occasional blocks of dense, metallic-grey specularite (Figs. 64 & 65). Several large blocks of Campbell Rand dolostone show well-developed stromatolitic lamination (Fig. 66).

Apart from occasional reworked blocks and clasts of Precambrian stromatolitic dolostone within the calcretised fluvial gravels, no fossil remains were recorded during fieldwork at the Tsantsabane borrow pit study site.

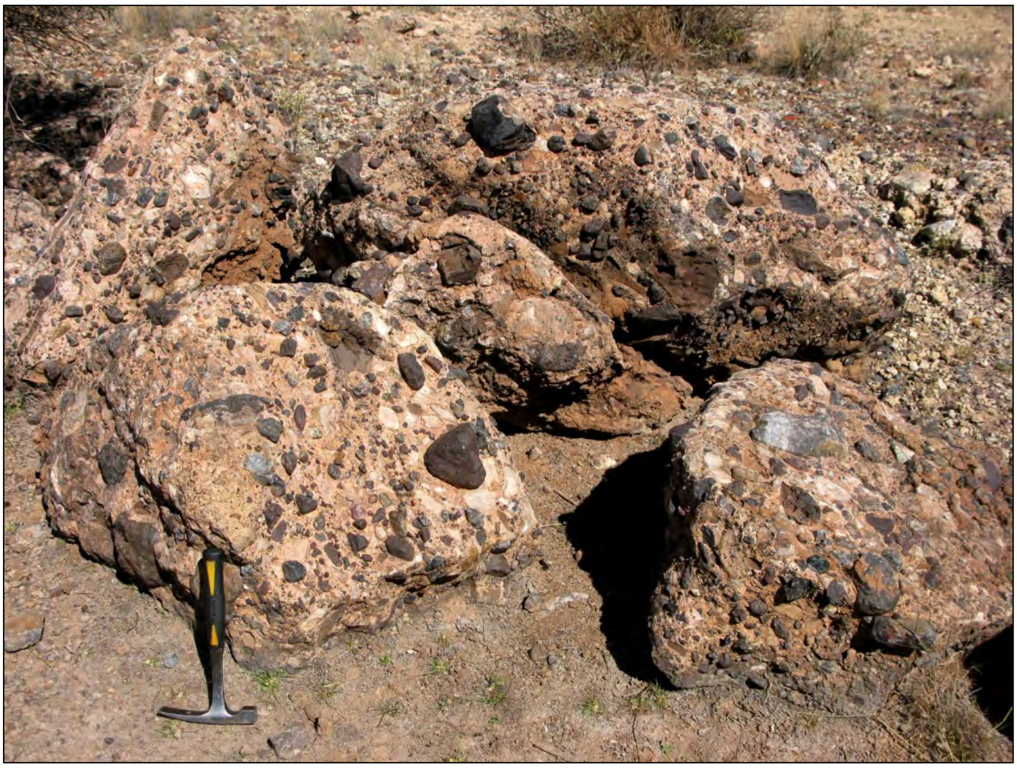

Fig. 62. Displaced blocks of calcretised, poorly-sorted coarse alluvium showing wide range of clast composition, size and rounding, Tsantsabane (Hammer = *c*. 30 cm).

Fig. 63. Karstified upper surface of calcrete hardpan showing embedded lenticles of fine gravels, Tsantsabane (Hammer = *c.* 30 cm).

Fig. 64. Thin polymict surface gravels at Tsantsabane composed of resistant-weathering chert, jasper, iron ore *etc* as well as reworked calcrete (Hammer = *c*. 30 cm).

Fig. 65. Well-rounded boulder of Blinkklip ferruginous cherty breccia within surface gravels, Tsantsabane (Scale in cm).

Fig. 66. Reworked block of Campbell Rand carbonate showing small domical stromatolites, Tsantsabane (Hammer = *c*. 30 cm).

4.2.5. Postmasburg borrow pits

The two proposed borrow pit sites at Postmasburg (Pit 1 at 28º 18' 08.31" S, 23º 01' 37.98" E and Pit 2 at 28º 18' 07.25" S, 23º 02' 02.62" E) are both situated at *c*. 1340 m amsl on the southern side of the railway line about 5 km to the northwest of Postmasburg. The flat to gently sloping terrain is either disturbed or covered in Kalahari thornveld with grasses (Fig. 67). The borrow pit sites are underlain by Campbell Rand Subgroup dolostones at depth but at surface are mantled by poorly-sorted, brown to reddish-brown, pebbly to cobbly, angular to subrounded surface gravels dominated by resistant-weathering clasts of chert, milky quartz, BIF and iron / manganese ore (*e.g.* Blinkklip breccia, metallic grey specularite) together with calcrete and ferruginous sandy soils (Figs. 67 to 69). A degree of fluvial reworking is suggested by the roundedness of some clasts.

No fossil remains were recorded during fieldwork at the two Postmasburg borrow pit study sites.

Fig. 67. View northwards across the Postmasburg borrow study area showing surface gravels in test pit area and low Gamagara Hills of iron ore (Beeshoek mine) in background.

Fig. 68. Polymict mixed alluvial and colluvial surface gravels, test pit in Postmasburg Borrow Pit 2 study area (Hammer = *c*. 30 cm).

Fig. 69. Better rounded surface gravels and reddish sandy soils observed locally in Borrow Pit 1 study area, Postmasburg (Hammer = *c*. 30 cm).

4.2.6. Wincanton borrow pits

The two proposed new borrow pits at Wincanton are located either side of the railway line within areas already disturbed by railway development. Borrow Pit 1, west of the railway line (27º 34' 47.93", 22º 56' 22.53" E), is situated just south of a shallow existing pit that exposes crudely-bedded, rubbly calcrete in its walls (Fig. 70). Thick calcretes also underlie the Borrow Pit 2 area east of the railway line (27º 34' 50.70" S, 22º 56' 26.89" E), as shown by artificial excavations here (Fig. 45).

No fossil remains were observed at surface or within excavations into surface calcretes in the two Wincanton borrow pit study areas.

Fig. 70. Crudely bedded, rubbly surface calcrete exposed in an existing borrow pit just north of the proposed Borrow Pit 1 study area at Wincanton (Hammer = *c*. 30 cm).

4.2.7. Witloop borrow pits

The two proposed borrow pit sites at Witloop – Borrow Pit 1 (27º 17' 43.95 S, 22º 58' 53.05" E) and Borrow Pit 2 (27º 17' 50.73" S, 22º 59' 01.65" E) - are located within or adjacent to existing sizeable pits located at *c*. 1070-1080 m amsl either side of the R380 tar road. The geology and palaeontology of the calcretised Kalahari Group sediments at these two pit sites has already been described in Section 4.1.10. The low diversity trace fossil assemblages recorded here are illustrated below. They probably represent invertebrate faunas (*e.g.* insects such as termites) (Fig. 71), plant root moulds (rhizoliths) (Fig. 72) as well as the densely-packed stems of reedy vegetation associated with damp, vlei-like areas in the almost-abandoned course of the Witloopleegte in Late Pleistocene or Holocene times (*cf.* Nash & McLaren 2003) (Figs. 73 to 75). Similar trace fossil assemblages are probably of widespread occurrence within the Kalahari Group (*cf* Nash & McLaren 2003) and these examples at Witloop are therefore not regarded as of high palaeontological significance.

Fig. 71. Substantial hollow, branching burrow systems with a discrete lining preserved within the near-surface calcrete hardpan in Witloop Borrow Pit 2 study area (Scale in cm and mm).

Fig. 72. Displaced block of dense hardpan calcrete showing irregular, subvertical silt-lined hollows – possibly root moulds, Witloop Borrow Pit 1 study area (Hammer = *c*. 30 cm).

Fig. 73. Displaced block of impure, greyish sandy calcrete within the upper Kalahari succession at Witloop (Borrow Pit 1 study area) that is permeated by numerous narrow hollow tubes.

Fig. 74. *In situ* impure calcrete horizon riddled with fine calcrete tubules, seen weathering out from the profile here, Witloop Borrow Pit 1 study area (Hammer = c. 30 cm).

Fig. 75. Close-up of calcretised tubules – possible moulds formed round reedy plant stems - shown in previous figure. The tubules are *c.* 2-4 mm in diameter.

Table 3. Summary of geology and fossils at the thirteen proposed borrow pit sites related to the 16 Mtpa manganese railway infrastructure project between Kimberley and Hotazel, with recommended action regarding palaeontological heritage management.

<table>
<tr><th>BORROW PIT</th><th colspan="2">LOCATION</th><th>MAIN ROCK UNITS</th><th>FOSSILS RECORDED</th><th>RECOMMENDED ACTION</th></tr>
<tr><td>Witloop 1</td><td>S27 17 43.95</td><td>E22 58 53.05</td><td>Thick, composite calcrete succession, cherty towards base and containing fluvial channel gravels as well as calcretised vlei deposits</td><td>Probable plant root moulds, calcretised moulds of reedy vlei vegetation, invertebrate (probably insect) burrow networks</td><td rowspan="6">No specialist mitigation recommended unless significant new fossil finds (e.g. bones, teeth, shells) are exposed during excavation.

Such finds should to be reported by ECO to SAHRA for recording / sampling by a qualified palaeontologist.</td></tr>
<tr><td>Witloop 2</td><td>S27 17 50.73</td><td>E22 59 01.65</td><td>Thick, composite calcrete succession, cherty towards base and containing fluvial channel gravels as well as calcretised vlei deposits</td><td>Probable plant root moulds, calcretised moulds of reedy vlei vegetation, invertebrate (probably insect) burrow networks</td></tr>
<tr><td>Wincanton 1</td><td>S27 34 47.93</td><td>E22 56 22.53</td><td>Thick calcrete hardpan, surface calcrete rubble and aeolian sands</td><td>None recorded</td></tr>
<tr><td>Wincanton 2</td><td>S27 34 50.70</td><td>E22 56 26.89</td><td>Thick calcrete hardpan, surface calcrete rubble and aeolian sands</td><td>None recorded</td></tr>
<tr><td>Postmasburg 1</td><td>S28 18 08.86</td><td>E23 01 36.68</td><td>Chert- and iron ore-rich colluvial to fluvial surface gravels overlying Campbell Rand dolostones, grits</td><td>None recorded</td></tr>
<tr><td>Postmasburg 2</td><td>S28 18 07.33</td><td>E23 02 02.83</td><td>Chert- and iron ore-rich colluvial to fluvial surface gravels overlying Campbell Rand dolostones, grits</td><td>None recorded</td></tr>
</table>

BORROW PIT	LOCATION		MAIN ROCK UNITS	FOSSILS RECORDED	RECOMMENDED ACTION
Tsantsabane	S28 16 50.03	E23 08 38.60	Karst-weathered, gravelly calcrete hardpan with downwasted surface gravels	Domical stromatolites within occasional displaced or reworked blocks of Campbell Rand dolostone	**No specialist mitigation recommended *unless* significant new fossil finds (*e.g.* bones, teeth, shells) are exposed during excavation.** **Such finds should to be reported by ECO to SAHRA for recording / sampling by a qualified palaeontologist.**
Trewil 1	S28 18 25.14	E23 41 09.74	Thick calcrete hardpan overlying Campbell Rand dolostone	Domical stromatolites within occasional displaced blocks of Campbell Rand dolostone, chertified limestone	
Trewil 2	S28 16 54.91	E23 46 03.61	Thick calcrete hardpan overlying Campbell Rand dolostone; downwasted chert surface gravels	Domical stromatolites within occasional displaced blocks of Campbell Rand dolostone, chertified limestone	
Ulco 1	S28 22 00.38	E24 18 22.50	Thick calcrete hardpan, calcrete surface rubble	None recorded	
Ulco 2	S28 22 10.89	E24 18 48.73	Thick calcrete hardpan, calcrete surface rubble	None recorded	
Gong Gong	S28 28 31.25	E24 25 33.68	Prince Albert Formation (Ecca Group) mudrocks overlain by calcrete hardpan	None recorded	
Fieldsview	S28 33 50.77	E24 36 28.87	Dwyka Group mudrocks and thin sandstones overlain by silty alluvium (Riverton Formation), Hutton sands	None recorded	

5. CONCLUSIONS AND RECOMMENDATIONS

Fieldwork along the Kimberley to De Aar sector of the 16 Mtpa manganese ore railway line, Northern Cape, shows that most of the loop study sites are mantled with superficial sediments of the Kalahari Group – predominantly thick calcrete ("surface limestone") hardpans, aeolian sands and surface gravels – that are mainly of Late Caenozoic (Pliocene / Quaternary – Holocene) age and at most very sparsely fossiliferous (Table 1). The sparse fossil remains recorded here – principally isolated blocks of stromatolitic dolostone and chert at Trewil and Tsantabane as well as low-diversity trace fossil assemblages at Witloop – are of low palaeontological significance and special mitigation measures are not considered warranted in these two cases.

At the Fieldsview loop extension site unfossiliferous lavas of the Ventersdorp Supergroup (Precambrian) are locally overlain by thin outliers of Dwyka Group tillite and mantled with quartz-rich gravels (possibly diamondiferous) as well as Hutton sands. The Gong Gong loop extension study site is also largely underlain by Ventersdorp lavas but in the southern part of the area a thick calcrete hardpan overlies Ecca Group mudrocks locally. The latter are too deeply weathered to be fossiliferous, however. Thick calcrete hardpans are also developed at the Ulco loop extension site, here replacing alluvial deposits of the Harts River, and at Trewil loop extension site where they overlie Campbell Rand Supergroup dolostones (Precambrian Ghaap Group). Occasional displaced or reworked blocks of dolostone and chert at Trewil contain fossil stromatolites (microbial mounds) but these are widely represented within the surrounding bedrocks and no exceptionally well-preserved examples were observed. The thick calcrete development at Tsantsabane loop extension site features impressive calcretised fluvial conglomerates overlain by downwasted gravels. At Postmasburg loop extension site surface gravels are dominated by locally derived chert and iron ore clasts, in places cemented to form ferricrete, overlying karstified Campbell Rand carbonate bedrocks that probably contain stromatolites. Deeply-weathered Campbell Rand siltstones at Glosam loop extension site are mantled by conglomerates largely composed of iron ore pebbles and cobbles that also infill deep karst solution hollows in tectonically disturbed dolostones. The very thick Kalahari calcrete at the Sishen new loop site is karstified at the top and contains sizeable pipe-like solution hollows that are partially infilled with calcrete gravel breccia (apparently unfossiliferous). Well-developed calcrete hardpans and calcrete rubble are also present at Wincanton loop extension site. A complex calcrete succession at Witloop new loop site is associated with the largely abandoned Witloopleegte drainage system (a tributary of the Ga-Mogara River). The older calcretes here are partially silicified and overlain by calcretised river channel gravels. The upper calcrete beds are extensively bioturbated by dense branching burrow systems (possibly of insects), plant root impressions and the moulds of narrow reed-like plants that were probably associated with damp vlei settings within a largely abandoned river channel.

The geology and fossils at each of the thirteen borrow pit sites examined between Kimberley and Hotazel is summarized in Table 3 of this report. Most of the proposed borrow pits will be excavated into Kalahari Group sediments (calcretes, gravels, sands) of low palaeontological sensitivity. Karoo Supergroup marine mudrocks of the Dwyka and Ecca Groups represented in borrow pits at Fieldsview and Gong Gong are apparently unfossiliferous and / or deeply weathered.

The only fossil remains recorded during field assessment include (1) isolated blocks of Precambrian dolostone and chert of the Campbell Rand Subgroup containing small to medium-sized domical stromatolites (microbial domes) at both Trewil borrow pit sites and Tsantsabane plus (2) low-diversity trace fossil assemblages within vlei-associated calcretes at the two Witloop borrow pit sites. Such fossils are of widespread occurrence so impacts on fossil heritage here are likely to be of low significance and special mitigation measures are not considered warranted.

Due to the low palaeontological sensitivity of the bedrocks as well as superficial sediments along the Kimberley to Hotazel sector of the 16 Mtpa manganese ore export railway line at the ten proposed railway loop sites and the thirteen proposed borrow pit sites, the proposed developments are rated as of LOW palaeontological heritage significance. It is concluded that they are unlikely to constitute a significant threat to fossil heritage within the study area. There are therefore no objections on palaeontological heritage grounds to the proposed developments and, pending the discovery of significant new fossils during the construction phase, no further specialist studies are recommended here.

It is recommended that:

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

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

- These recommendations should be incorporated into the Environmental Management Plan (EMP) for the 16 Mtpa manganese ore export railway line 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).

6. ACKNOWLEDGEMENTS

Mr Junaid Moosajee and Ms Tania Swanepoel of ERM, Cape Town, are both thanked for commissioning this study, for providing the relevant background information, and for facilitating the necessary fieldwork. I am also grateful to Ms Elize Becker, Environmental Services Group, HATCH, Johannesburg for extensive discussions concerning heritage related issues relating to the Transnet 16 Mtpa project. Mr Clement Moncho and Mr Lesiba Ramatlodi of Transnet, Kimberley, are thanked for assisting with safety issues and access to the railway sites during fieldwork. The logistical support and company of Ms Madelon Tusenius in the field is, as always, deeply appreciated.

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8. QUALIFICATIONS & EXPERIENCE OF THE AUTHOR

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

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

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

APPENDIX: GPS LOCALITY DATA FOR NUMBERED LOCALITIES

All GPS readings were taken in the field using a hand-held Garmin GPSmap 60CSx instrument. The datum used is WGS 84.

Locality Number	Co-ordinates	Comments
374	S28 34 59.4 E24 39 50.5	Fieldsview railway cutting Gordonia sands overlying stream and surface gravels, Ventersdorp lava basement
375	S28 34 56.1 E24 39 48.0	Fieldsview railway cutting Poorly-sorted boulder alluvial channel and / or surface gravels beneath Gordonia sands
376a	S28 34 52.0 E24 39 44.3	Fieldsview railway cutting. Regolith of Ventersdorp lava clasts and angular quartz vein gravels, agates.
376b	S28 34 48.2 E24 39 41.3	Fieldsview railway cutting. Stream gravels overlying basement contain occasional flaked quartzite stone artefacts.
377	S28 34 46.4 E24 39 39.9	Relict lenses of Dwyka tillite overlying Ventersdorp basement
378	S28 34 46.3 E24 39 39.8	Relict lenses of Dwyka tillite overlying Ventersdorp basement
379	S28 34 46.1 E24 39 39.0	Road cutting through probable artificially reworked Kalahari sands and gravels
380	S28 28 28.5 E24 25 33.1	Gong Gong S railway cutting. Thick calcrete hardpan, relict nodules.
381	S28 28 31.0 E24 25 36.4	Gong Gong S railway cutting. Rubbly reworked calcrete forming composite hardpan.
382	S28 28 33.2 E24 25 40.	Gong Gong S pit study area. Existing borrow pit into Ecca mudrocks.
383	S28 28 31.6 E24 25 33.4	Gong Gong S pit study area. Existing borrow pit into Ecca mudrocks. Calcrete tectonics (small scale folding).
384	S28 27 29.6 E24 24 32.3	Gong Gong N railway cutting. Jointed andesitic lavas of Ventersdorp Group.
385	S28 28 37.6 E24 26 00.5	Gong Gong N, borrow pit near siding, boldery surface gravels of lava (corestones / alluvium)
386	S28 18 08.3 E23 45 16.0	Cherty surface rubble (some cherts with stromatolitic domes) between Arbeidsloon and Ariesfontein, south of Transnet railway line
387	S28 18 05.9 E23 45 15.6	Cherty surface rubble (some cherts with stromatolitic domes) between Arbeidsloon and Ariesfontein, south of Transnet railway line
388	S28 16 57.0 E23 46 03.6	Trewil Borrow Pit 2 area near Ariesfontein, stromatolitic dolostones and cherts, surface calcrete
389	S28 18 29.5 E23 41 01.3	Trewil Borrow Pit 1 area, calcrete with invertebrate burrows, reworked blocks of stromatolitic dolostone, chert
390	S28 18 24.5 E23 41 16.1	Trewil Borrow Pit 1 area, calcrete with invertebrate burrows, reworked blocks of stromatolitic dolostone, chert
391	S28 18 23.0 E23 41 19.9	Trewil Borrow Pit 1 area, reworked blocks of stromatolitic dolostone
392	S28 16 04.3 E23 31 49.0	Roadcutting along Kimberley – Postmasburg tar road nr Danielskul exposing Campbell Rand dolostones with small domical stromatolites
393	S28 16 52.9 E23 08 29.6	Tsantsabane loop extension site,displaced calcretised polymict bouldery alluvial conglomerates, cherty surface gravels
394	S28 16 42.7 E23 09 01.6	Tsantsabane loop extension site, railway cutting through calcretised polymict bouldery alluvial conglomerates
394a	S28 18 07.9 E23 01 35.5	Postmasburg Borrow Pit 1 area, quartz- and iron ore-rich surface gravels
394b	S28 18 07.0 E23 01 58.9	Postmasburg Borrow Pit 2 area, quartz- and iron ore-rich surface gravels
394c	S28 18 09.0 E23 02 28.9	Postmasburg loop study area, ferricretised cherty gravels
395	S28 18 11.4 E23 02 31.3	Postmasburg loop study area, displaced blcosk of stromatolitic dolostone, calcareous grits
396a	S27 34 42.3 E22 56 26.5	Wincanton loop study area, existing shallow pit into crudely bedded calcrete
396b	S27 34 43.8 E22 56 23.3	Wincanton loop study area, deep trench through surface calcretes
401	S27 17 54.0 E22 59 06.2	Witloop Borrow Pit 2 study area, waterfall section through composite calcrete succession

402	S27 17 44.5 E22 58 53.7	Witloop Borrow Pit 1 study area, composite calcrete succession with moulds of reedy vlei vegetation
403	S27 48 47.0 E22 57 31.0	Sishen New Loop study area, karstified surface calcretes with solution pipes, this surface gravels
404	S28 07 37.0 E23 02 29.9	Glosam Loop study area, quarry into weathered siltstones and karstified dolostones, Campbell Rand Subgroup
408a	S28 22 01.8 E24 18 19.8	Ulco Borrow Pit 1 study area, karstified surface calcrete
408b	S28 22 11.05 E24 18 47.62	Ulco Borrow Pit 2 study area, thick calcretised alluvium
409	S28 33 50.9 E24 36 30.1	Fieldsview borrow pit. Cobbly-based sandstone event beds within Dwyka mudrocks