DECOMMISSIONING OF TRANSNET PIPELINES DURBAN – JOHANNESBURG

PALAEONTOLOGICAL DESKTOP STUDY

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For:

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1. Executive Summary

The decommissioning of the Transnet pipeline from Durban to Klerksdorp to Pretoria will occur in an area that is largely underlain by geological formations that are regarded as having a Very High Palaeontological Sensitivity.

The impact on the surrounding geological formations will probably be low due to the nature of the project. However, it is inevitable that fossiliferous rocks will be exposed during the decommissioning process when the overburden and infills are removed to expose the pipeline and valves. The fact that there will be equipment, trucks and people in palaeontologically sensitive areas should also not be overlooked.

Stromatolite formations may be encountered along the pipeline sections in Gauteng and Northwest. When the soil and underlying eroded rock stratum are removed, it is possible that stromatolite formations could be exposed in places along the study site. When significant stromatolite formations are uncovered during excavations a palaeontologist must be appointed to assist in the evaluation of the importance and with the conservation of these structures.

The sedimentary rocks of the Karoo Supergroup occur along the largest part of the study site. These strata are not ubiquitously exposed and are mostly covered with soil. This is especially the case in the Free State where exposures are usually limited to dongas, river beds and road cuttings. Large sections of rocky strata are exposed in the mountainous areas, hillsides and along rivers in KwaZulu-Natal from Pietermaritzburg, through the Midlands and up to Van Reenen's Pass however.

All new sites that are discovered in the Ecca Group deposits during operations must be recorded by the ECO. If a significant plant fossil site is uncovered a palaeontologist must be appointed to assist in the evaluation of the importance of the site and the documentation thereof so that the information will be available for future palaeontological studies.

The fossils of the Beaufort Group and the Elliot Formation are the most vulnerable to development in areas where the bedrock is exposed or in areas where the soil cover is shallow. These geological units contain scarce but scientifically important fossil skeletons of synapsids, thecodonts and dinosaurs. These fossils are extremely fragile and if significant, need to be salvaged if possible following the Chance Find Procedures.

It is advised that a palaeontologist should be appointed to inspect the decommissioning procedures at intervals in the KwaZulu-Natal area between Estcourt and Van Reenen because of the high probability that highly sensitive fossiliferous strata will be compromised during the decommissioning process. The decommissioning procedures will involve more than mere pumping of cement into the pipes at intersections because the equipment, trucks and workers must operate from somewhere outside the ditch itself and it is inevitable that exposed fossils may inadvertently be damaged in the process.

The success of the conservation and management of the palaeontological aspect of this project depends on the ECO's commitment to following the Chance Find Procedures, especially along sections where the geology is obscured by soil and overburden.

2. Introduction

The Heritage Act of South Africa stipulates that fossils and fossil sites may not be altered or destroyed. The purpose of this document is to detail the probability of finding fossils in the study area that may be impacted by the proposed development.

The palaeontological heritage of South Africa is unsurpassed and can only be described in superlatives. The South African palaeontological record gives us insight in inter alia the origin of dinosaurs, mammals and humans. Fossils are also used to identify rock strata and determine the geological context of the subregion with other continents and played a crucial role in the discovery of Gondwanaland and the formulation of the theory of plate tectonics. Fossils are also used to study evolutionary relationships, sedimentary processes and palaeoenvironments.

South Africa has the longest record of palaeontological endeavour in Africa. South Africa was even one of the first countries in the world in which museums displayed fossils and palaeontologists studied earth history. South African palaeontological institutions and their vast fossil collections are world-renowned and befittingly the South African Heritage Act is one of the most sophisticated and best considered in the world.

Fossils and palaeontological sites are protected by law in South Africa. Development and operations in fossiliferous areas may be mitigated in exceptional cases but there is a protocol to be followed.

This is a Palaeontological Desktop Study that was prepared in line with Regulation 28 of the National Environmental Management Act (No. 107 of 1998) Regulations on Environmental Impact Assessment. This involved an evaluation of the nature of the geology and potential palaeontology of the study site and an overview of the literature on the palaeontology and associated geology of the area.

3. Terms of reference for the report

According to the South African Heritage Resources Act (Act 25 of 1999) (Republic of South Africa, 1999), certain clauses are relevant to palaeontological aspects for a terrain suitability assessment.

- **Subsection 35(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 with the detection or recovery of metals or archaeological material or objects, or use such equipment for the recovery of meteorites.
- **Subsection 35(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 procedures 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 form 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.

South Africa's unique and non-renewable palaeontological heritage is protected in terms of the NHRA. According to this act, heritage resources may not be excavated, damaged, destroyed or otherwise impacted by any development without prior assessment and without a permit from the relevant heritage resources authority.

As areas are developed and landscapes are modified, heritage resources, including palaeontological resources, are threatened. As such, both the environmental and heritage legislation require that development activities must be preceded by an assessment of the impact undertaken by qualified professionals. Palaeontological Impact Assessments (PIAs) are specialist reports that form part of the wider heritage component of:

- Heritage Impact Assessments (HIAs) called for in terms of Section 38 of the National Heritage Resources Act, Act No. 25, 1999 by a heritage resources authority.
- Environmental Impact Assessment process as required in terms of other legislation listed in s. 38(8) of NHRA;
- Environmental Management Plans (EMPs) required by the Department of Mineral Resources.

HIAs are intended to ensure that all heritage resources are protected, and where it is not possible to preserve them in situ, appropriate mitigation measures are applied. An HIA is a comprehensive study that comprises a palaeontological, archaeological, built environment, living heritage, etc specialist studies. Palaeontologists must acknowledge this and ensure that they collaborate with other heritage practitioners. Where palaeontologists are engaged for the entire HIA, they must refer heritage components for which they do not have expertise on to appropriate specialists. Where they are engaged specifically for the palaeontology, they must draw the attention of environmental consultants and developers to the need for assessment of other aspects of heritage. In this sense, Palaeontological Impact Assessments that are part of Heritage Impact Assessments are similar to specialist reports that form part of the EIA reports.
The standards and procedures discussed here are therefore meant to guide the conduct of PIAs and specialists undertaking such studies must adhere to them.
The process of assessment for the palaeontological (PIA) specialist components of heritage impact assessments, involves:

Scoping stage in line with regulation 28 of the National Environmental Management Act (No. 107 of 1998) Regulations on Environmental Impact Assessment. This involves an **initial assessment** where the specialist evaluates the scope of the project (based, for example, on NID/BIDs) and advises on the form and extent of the assessment process. At this stage the palaeontologist may also decide to compile a **Letter of Recommendation for Exemption from further Palaeontological Studies**. This letter will state that there is little or no likelihood that any significant fossil resources will be impacted by the development. This letter should present a reasoned case for exemption, supported by consultation of the relevant geological maps and key literature.

A **Palaeontological Desktop Study** – the palaeontologist will investigate available resources (geological maps, scientific literature, previous impact assessment reports, institutional fossil collections, satellite images or aerial photos , etc) to inform an assessment of fossil heritage and/or exposure of potentially fossiliferous rocks within the study area. A Desktop studies will conclude whether a further field assessment is warranted or not. Where further studies are required, the desktop study would normally be an integral part of a field assessment of relevant palaeontological resources.

A **Phase 1 Palaeontological Impact Assessment** is generally warranted where rock units of high palaeontological sensitivity are concerned, levels of bedrock exposure within the study area are adequate; large-scale projects with high potential heritage impact are planned; and where the distribution and nature of fossil remains in the proposed project area is unknown. In the recommendations of Phase 1, the specialist will inform whether further monitoring and mitigation are necessary. The Phase 1 should identify the rock

units and significant fossil heritage resources present, or by inference likely to be present, within the study area, assess the palaeontological significance of these rock units, fossil sites or other fossil heritage, comment on the impact of the development on palaeontological heritage resources and make recommendations for their mitigation or conservation, or for any further specialist studies that are required in order to adequately assess the nature, distribution and conservation value of palaeontological resources within the study area.

A **Phase 2 Palaeontological Mitigation** involves planning the protection of significant fossil sites, rock units or other palaeontological resources and/or the recording and sampling of fossil heritage that might be lost during development, together with pertinent geological data. The mitigation may take place before and / or during the construction phase of development. The specialist will require a Phase 2 mitigation permit from the relevant Heritage Resources Authority before Phase 2 may be implemented.

A **'Phase 3' Palaeontological Site Conservation and Management Plan** may be required in cases where the site is so important that development will not be allowed, or where development is to co-exist with the resource. Developers may be required to enhance the value of the sites retained on their properties with appropriate interpretive material or displays as a way of promoting access of such resources to the public.

The assessment reports will be assessed by the relevant heritage resources authority, and depending on which piece of legislation triggered the study, a response will be given in the form of a Review Comment or Record of Decision (ROD). In the case of PIAs that are part of EIAs or EMPs, the heritage resources authority will issue a comment or a record of decision that may be forwarded to the consultant or developer, relevant government department or heritage practitioner and where feasible to all three.

4. Details of study area and the type of assessment

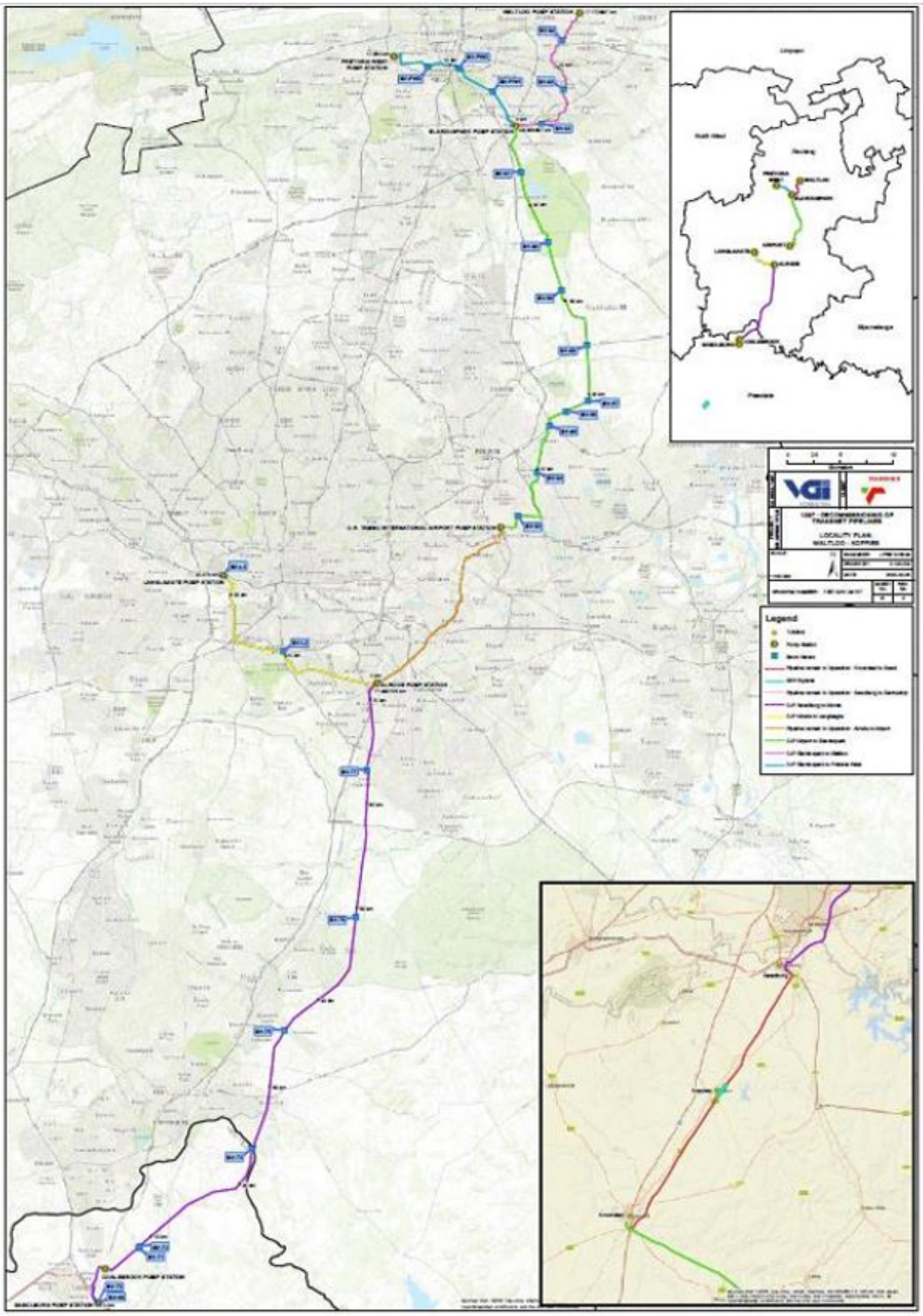


Figure 1: Map showing the northern part of the study area

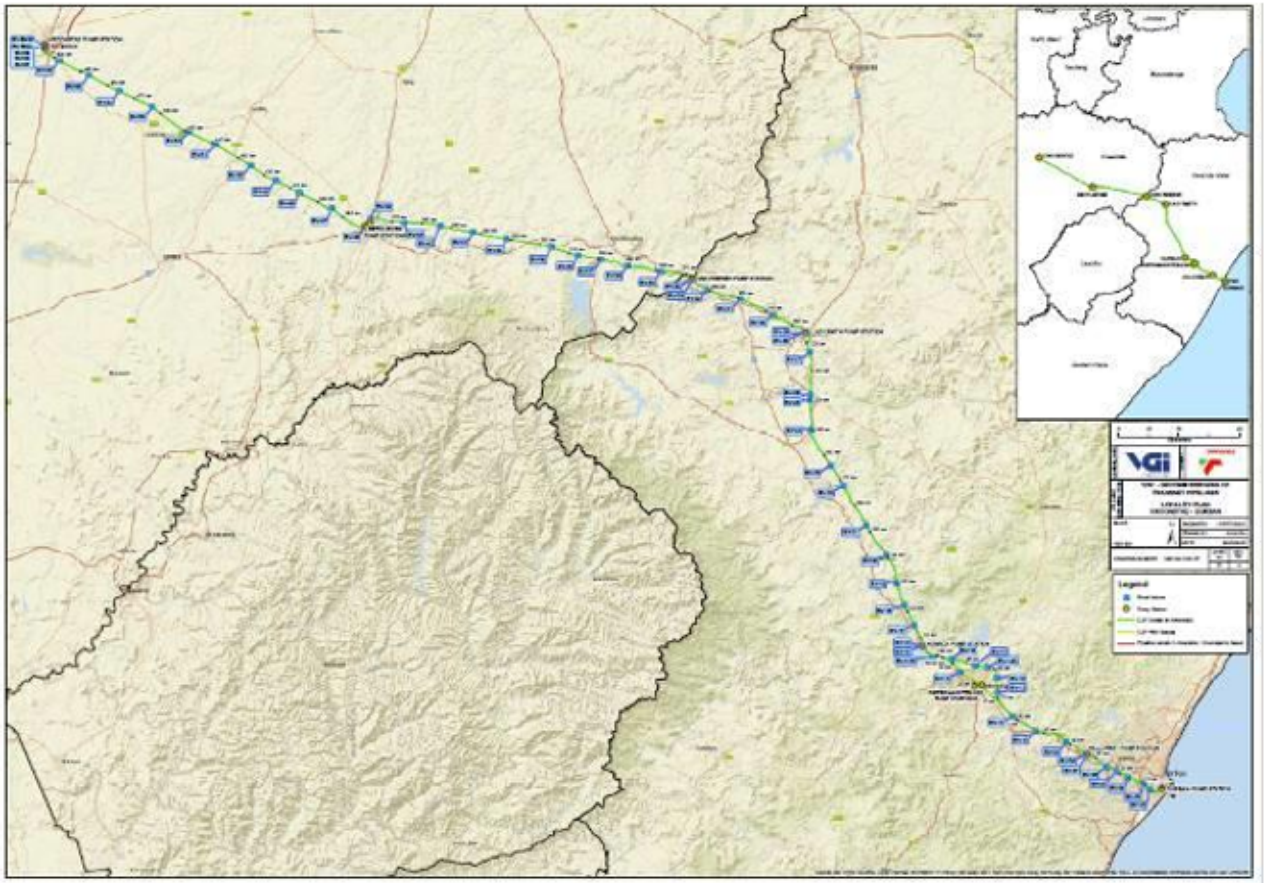


Figure 2: Map showing southern part of study area

The study site runs from Durban in the south to Pretoria in the north and Klerksdorp in the northwest and runs through four provinces: KwaZulu-Natal, Free State, Gauteng and Northwest.

The geomorphology and associated topography are the most relevant physical aspects to this study. The southern part of the pipeline rises at an incline from close to sea level to the escarp while the northern part runs from there over a relatively horizontal position over the Highveld. This difference in topography is also reflected in the soil cover versus exposed geology of the different sections.

The relevant literature and geological maps for the region in which the development is proposed to take place, have been studied for a Palaeontological Desktop Study.

5. Geological setting

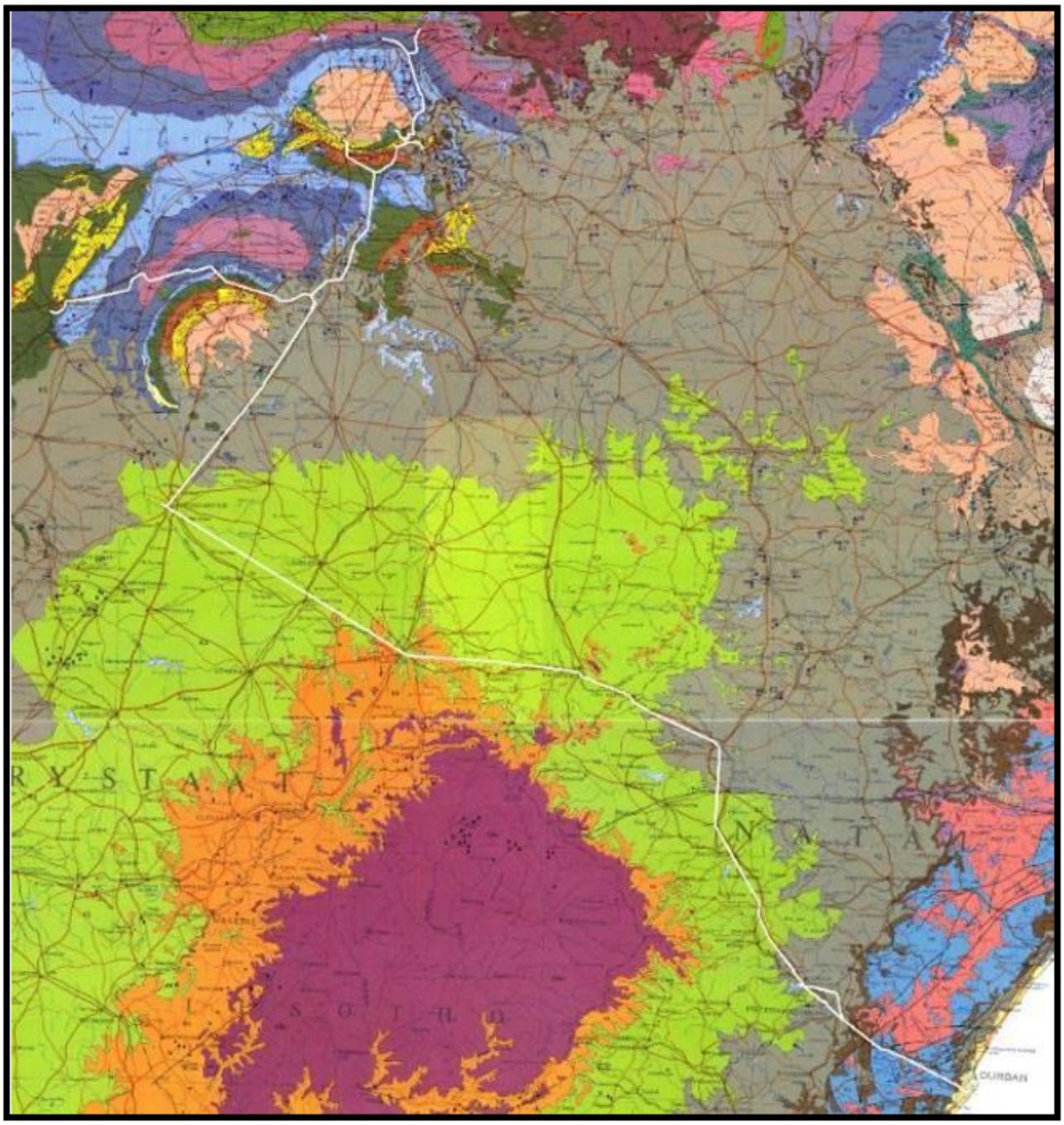
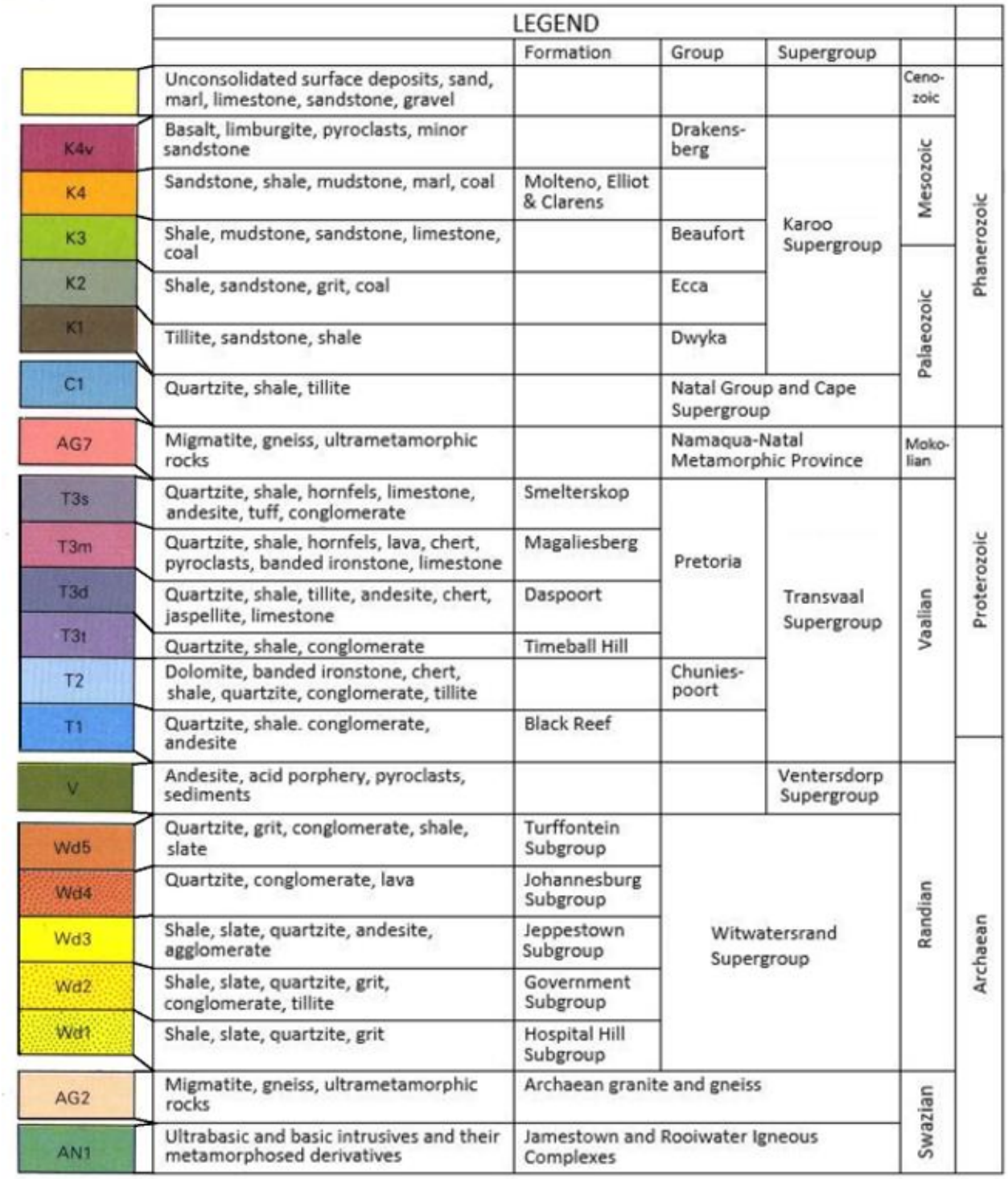


Figure 3: Geology map of the study site (white line) (adapted from the 1: 1 000 000 Geology Map, Geological Survey, 1970)



The geology impacted by the development involves sedimentary rocks of the Witwatersrand, Ventersdorp, Transvaal, Witwatersrand and Karoo Supergroups and Natal Group. Of these, the Karoo Supergroup and the Transvaal Supergroup are the most fossiliferous and vulnerable, containing geological units that are classified as being of Very High Palaeontological Sensitivity.

Dolerite intrusions and igneous rocks of the Archaean basement and Jamestown Igneous Complexes and the metamorphic rocks of the Namaqua-Natal metamorphic province are also encountered along the study site but they will fall outside the main focus of this report because they are non-fossiliferous and therefore not of palaeontological importance.

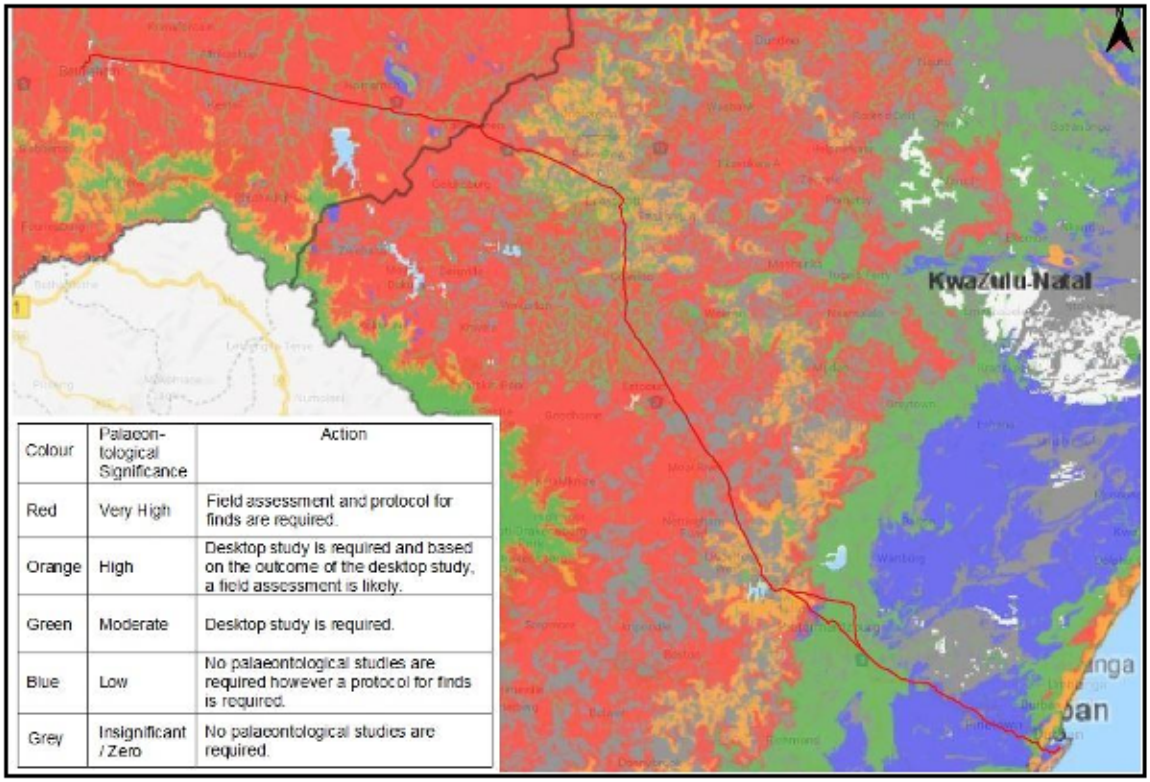
Transvaal Supergroup

The Transvaal Supergroup is one of the world's earliest and most extensive carbonate platform successions. It is characterised by extensive and well-preserved stromatolite formations that are of palaeontological importance. Different types of stromatolites were identified and range from flat stromatolite mats from supratidal zones, to intertidal columnar stromatolites, to giant stromatolitic domes that existed in subtidal zones. Other fossils from this sequence include fossils of bacteria documenting the rise and diversification of early life on earth and algae mats (Erikkson *et al*., 2009; Erikkson *et al*., 2012).

Karoo Supergroup

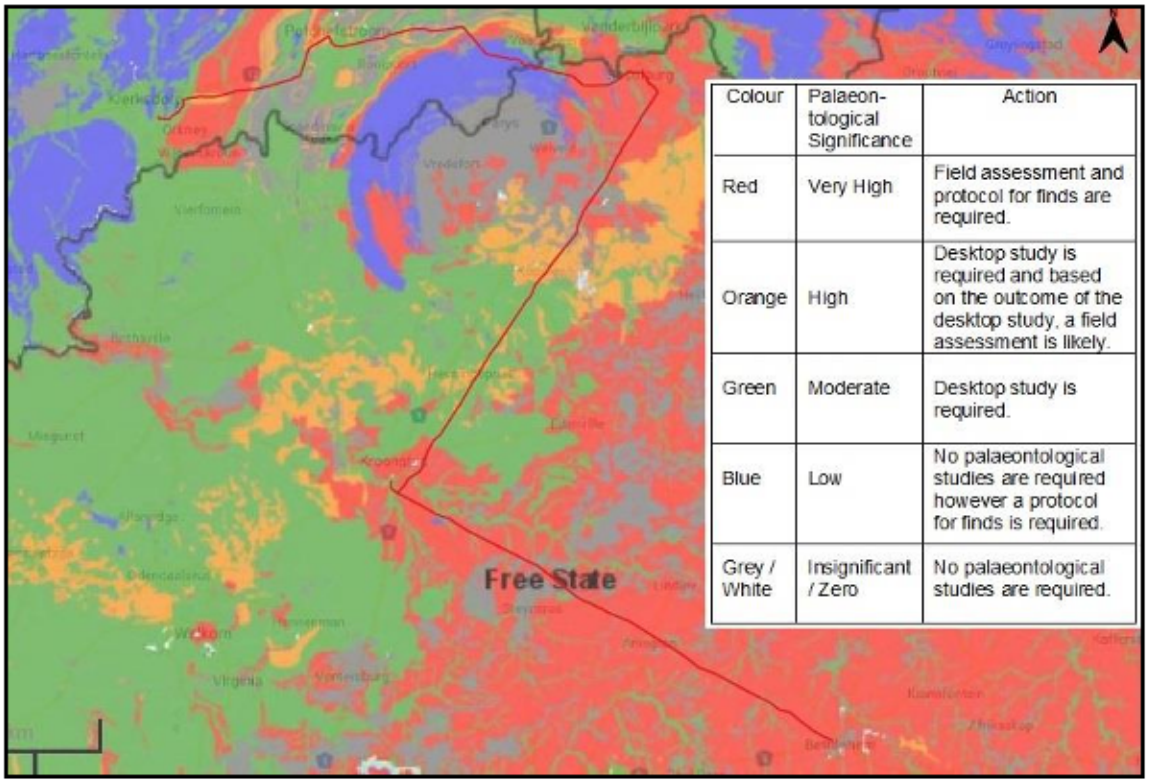
The Karoo Supergroup is the largest geological feature in South Africa and covers about 60% of the surface area of South Africa. It is just a remnant of a geological feature that, before the break-up of Gondwana and the subsequent erosion around the new continental margins, covered not only South Africa, but a major part of Gondwanaland. Karoo-aged rocks extend further north into countries to the north of South Africa and several southern landmasses including South America, Antarctica, Australia, Madagascar and India have Karoo-age deposits. It is the most extensive sequence of terrestrial and lacustrine sedimentary deposits in the world, spanning a period from the Late Carboniferous to the Middle Jurassic which attains a cumulative thickness of approximately 12 km in the southwestern part of the Main Karoo Basin and which contains an unsurpassed fossil record of terrestrial life of that period (Johnson *et al*., 2009).

6. Palaeontological potential of the study area



Colour	Palaeon-tological Significance	Action
Red	Very High	Field assessment and protocol for finds are required.
Orange	High	Desktop study is required and based on the outcome of the desktop study, a field assessment is likely.
Green	Moderate	Desktop study is required.
Blue	Low	No palaeontological studies are required however a protocol for finds is required.
Grey	Insignificant / Zero	No palaeontological studies are required.

Figure 4: Palaeontological sensitivity of section Durban – Estcourt - Bethlehem



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Green	Moderate	Desktop study is required.
Blue	Low	No palaeontological studies are required however a protocol for finds is required.
Grey / White	Insignificant / Zero	No palaeontological studies are required.

Figure 5: Palaeontological sensitivity for section Bethlehem – Kroonstad – Sasolburg – Klerksdorp

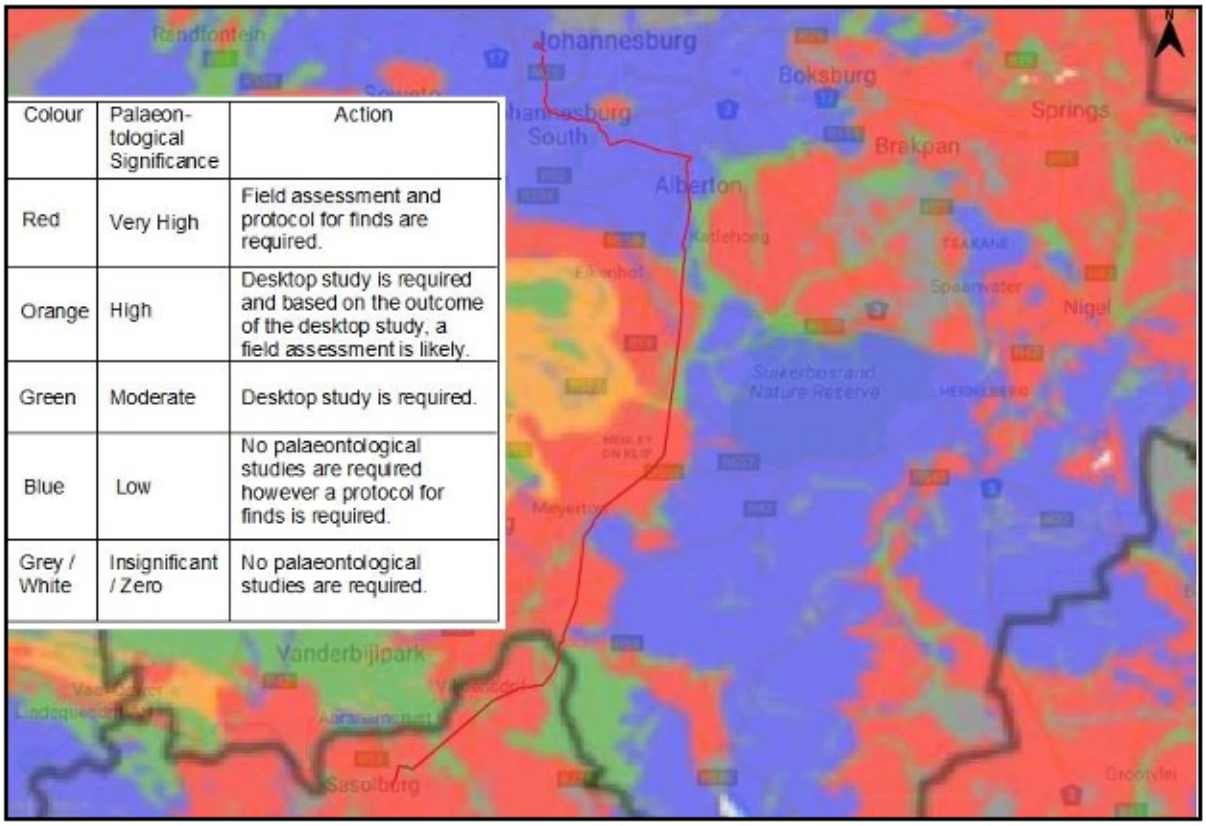


Figure 6: Palaeontological sensitivity for section Sasolburg - Johannesburg

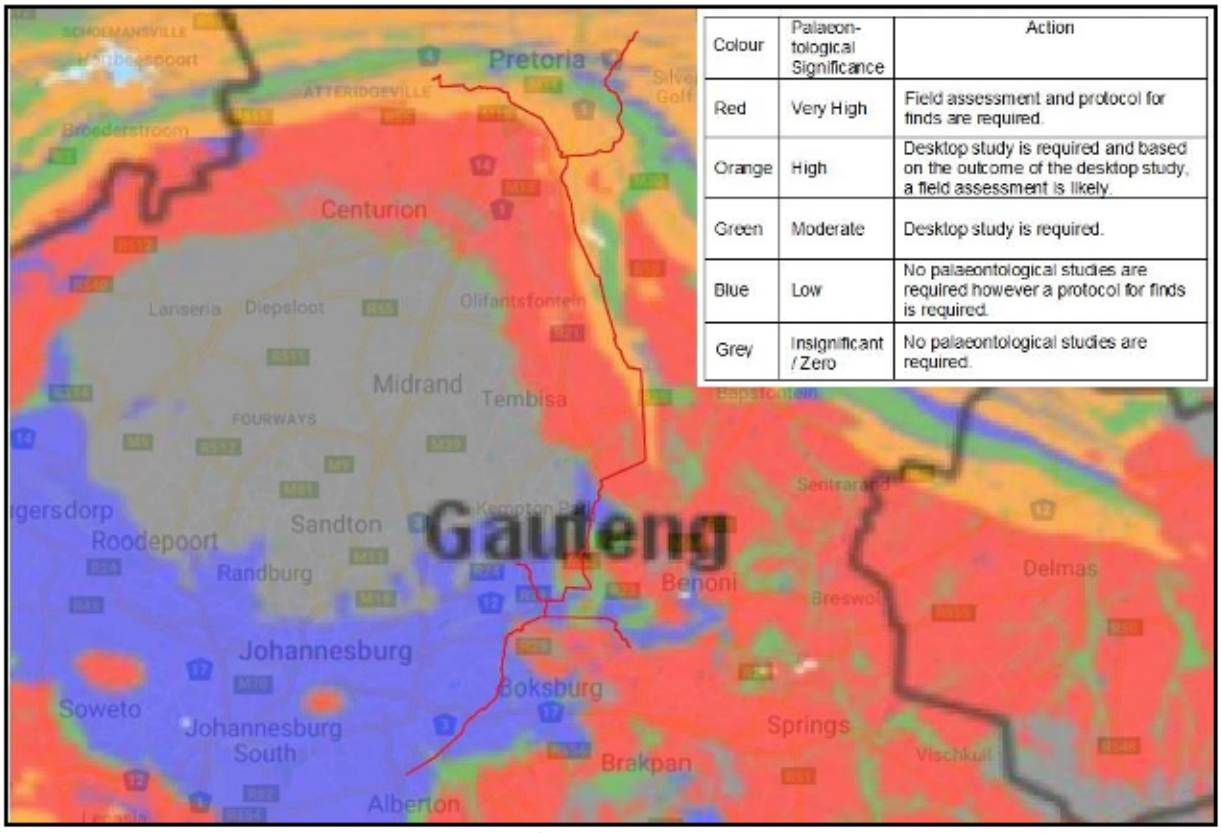


Figure 7: Palaeontological sensitivity for section Alberton – Pretoria

Due to the scale of the project, the study site has been split up into different sections for review: Sections A: Durban to Pietermaritzburg, B: Pietermaritzburg to Estcourt, C: Estcourt to Ladysmith, D: Ladysmith to Bethlehem, E: Bethlehem to Kroonstad F: Kroonstad to Sasolburg, G: Sasolburg to Klerksdorp, H: Sasolburg to Johannesburg and I: Alberton to Pretoria.

Section A: Durban to Pietermaritzburg

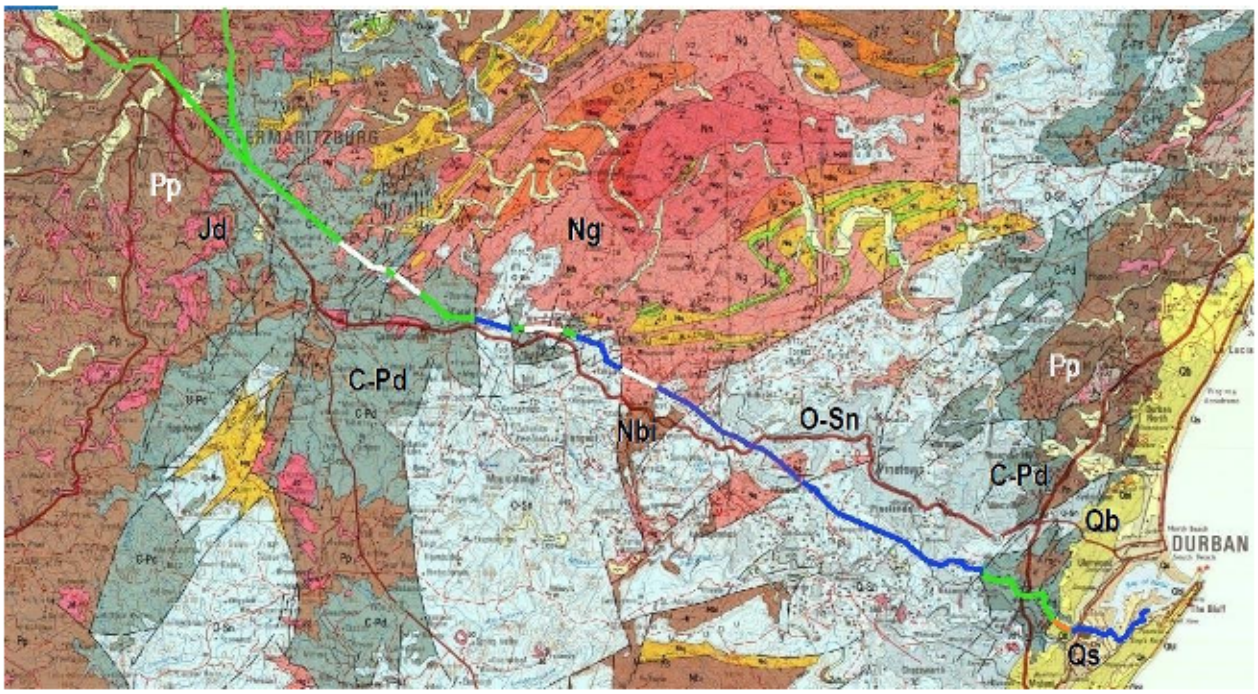


Figure 8: Section A - Durban to Pietermaritzburg, based on the 1: 250 000 2030 DURBAN geology map (Geological Survey, 1988). The different colours along the route indicate the relative palaeontological sensitivity of this section (white indicates non-fossiliferous areas)

The geological units encountered along this section of the route are:

Quaternary-aged yellowish red, grey and white dune sands from extensive reworking of the Kosi Bay Formation that have a Low Palaeontological Sensitivity (Figs. 4 & 8). Localized pockets of peat, up to 4 m thick occur in this formation (Groenewald, 2012).

Berea Formation that includes the rocky shoreline, basal aeolianites, truncated by calcified beach and dune deposits of the last Interglacial age. Oyster beds are present in karst potholes in places and isolated bone fossils have been found in this formation (Groenewald, 2012) which is considered to be of High Palaeontological Sensitivity (Figs. 4 & 8).

Dolerite from the Jurassic Period is non-fossiliferous.

Pietermaritzburg Formation of the Ecca Group of the Karoo Supergroup consists of dark grey shale, siltstone and subordinate sandstone that may contain trace fossils (Groenewald, 2012). This formation is considered to be of Moderate Palaeontological Sensitivity (Figs. 4 & 8).

Dwyka Group rocks consist of tillite and diamictite. No fossils have been discovered in this unit in KwaZulu-Natal so far. It is considered to have a Low Palaeontological Sensitivity (Figs. 4 & 8).

The Natal Group rocks consist of red-brown coarse-grained sandstone, quartz arenite, micaceous sandstone and small pebble conglomerate that are non-fossiliferous. No fossils have been found in this unit that is considered to have a Low Palaeontological Sensitivity (Figs 4 & 8).

The igneous and metamorphic rocks of the Natal Metamorphic Province in the study area consist of biotite gneiss, biotite-hornblende gneiss, calc-silicate rocks and granulite. megacrystic biotite and granite. This unit is non-fossilferous.

	Formation	**Group**	**Geology**	**Palaeontology**	**Sensitivity**
Qs			Dune sand	Peat deposits of up to 4 m thick	Low
Qb	Berea		Red sand, basal conglomerate, rocky shoreline, dune deposits	Oyster beds preserved in karst potholes	High
Jd			Dolerite	Non-fossiliferous	None
Pp	Pieter-maritzburg	Ecca	Dark-grey shale, siltstone, subordinate sandstone	Trace fossils	Moderate
C-Pd		Dwyka	Tillite, diamictite	None recorded from this province	Moderate
O Sn		Natal	Red-brown coarse-grained sandstone, quartz arenite, micaceous sandstone, small pebble conglomerate	No fossils are known from this unit	Low
Ng		Natal Meta-morphic Province	Megacrystic biotite granite	Non-fossiliferous	None
Nbi			Biotite gneiss, biotite-hornblende gneiss, calc-silicate rocks and granulite		
Information based on Groenewald, 2012 and the latest Palaeosensitivity Map, SAHRA					

Section A of the study site is of the least palaeontological concern and it ranges from having no palaeontological sensitivity to having a high palaeontological sensitivity.

No field assessment would be necessary for Section A.

Section B: Pietermaritzburg to Estcourt

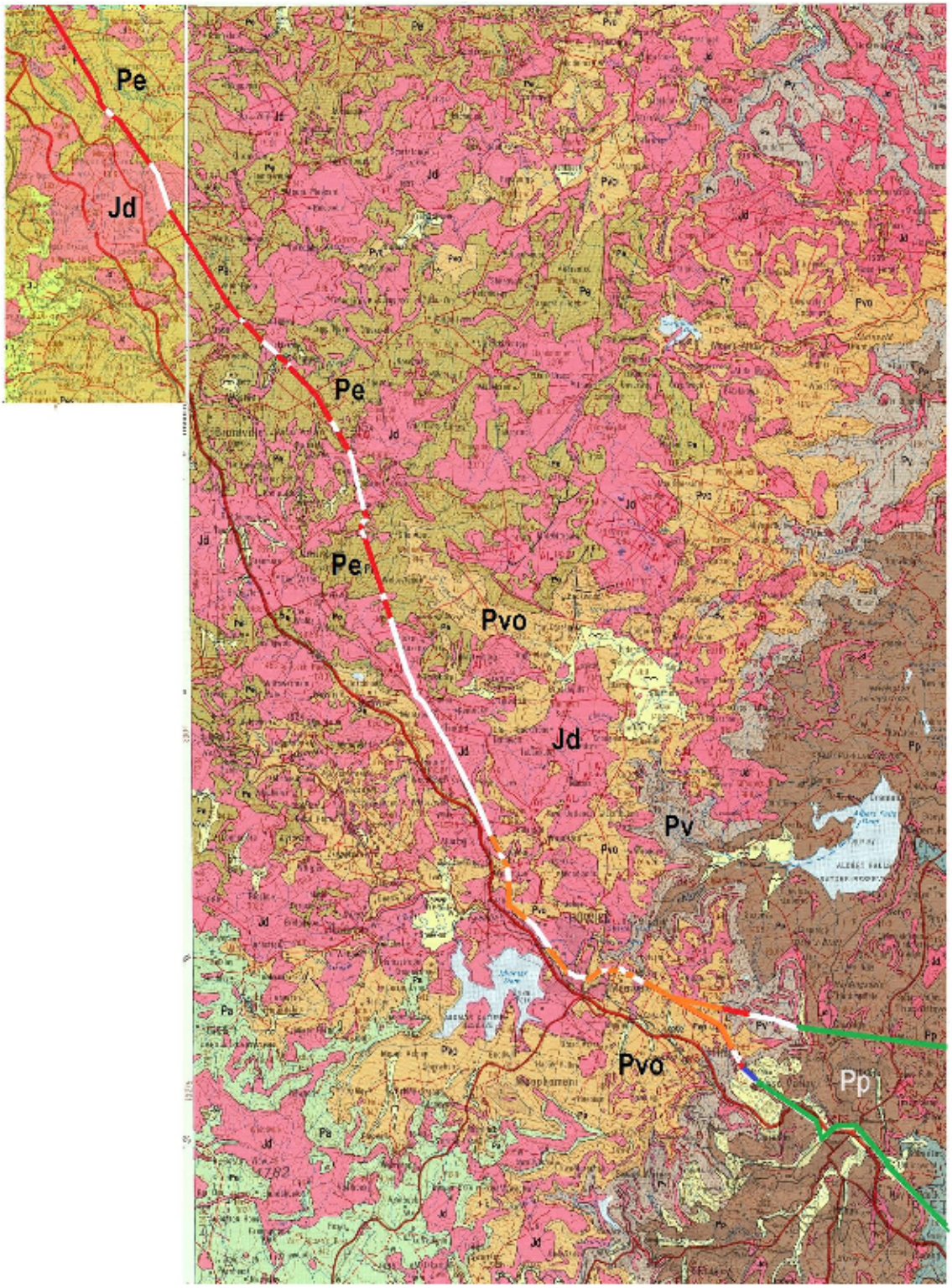


Figure 9: Section B - Pietermaritzburg to Estcourt adapted from the 1:250 000 2030 DURBAN geology map (Geological Survey, 1988) and the left upper corner is adapted from the 1:250 000 2928 DRAKENSBERG geology map (Geological Survey, 1981). The different colours along the route indicate the relative palaeontological sensitivity of that section (white indicates non-fossiliferous areas)

The palaeontologically significant geological units that will be impacted along this section are the Dwyka Group (C-Pd) and the Pietermaritzburg (Pp), Vryheid (Pv), Volksrust (Pvo) and Estcourt (Pe) Formations.

Dwyka Group rocks consist of tillite and diamictite. No fossils have been discovered in this unit in KwaZulu-Natal so far. It is considered to have a Low Palaeontological Sensitivity (Groenewald, 2012) (Figs. 4 & 9).

Pietermaritzburg Formation of the Ecca Group of the Karoo Supergroup consists of dark grey shale, siltstone and subordinate sandstone that may contain trace fossils (Groenewald, 2012). This formation is considered to be of Moderate Palaeontological Sensitivity (Figs. 4 & 9).

Vryheid Formation of the Ecca Group of the Karoo Supergroup consists of light grey medium to coarse- grained sandstone and siltstone. Dark-coloured carbonaceous siltstone and coal beds are common. It is considered to have a Very High Palaeontological Sensitivity due to the fact that trace fossils and abundant plant fossils – mainly of *Glossopteris* occur in these beds (Groenewald, 2012) (Figs. 4 & 9).

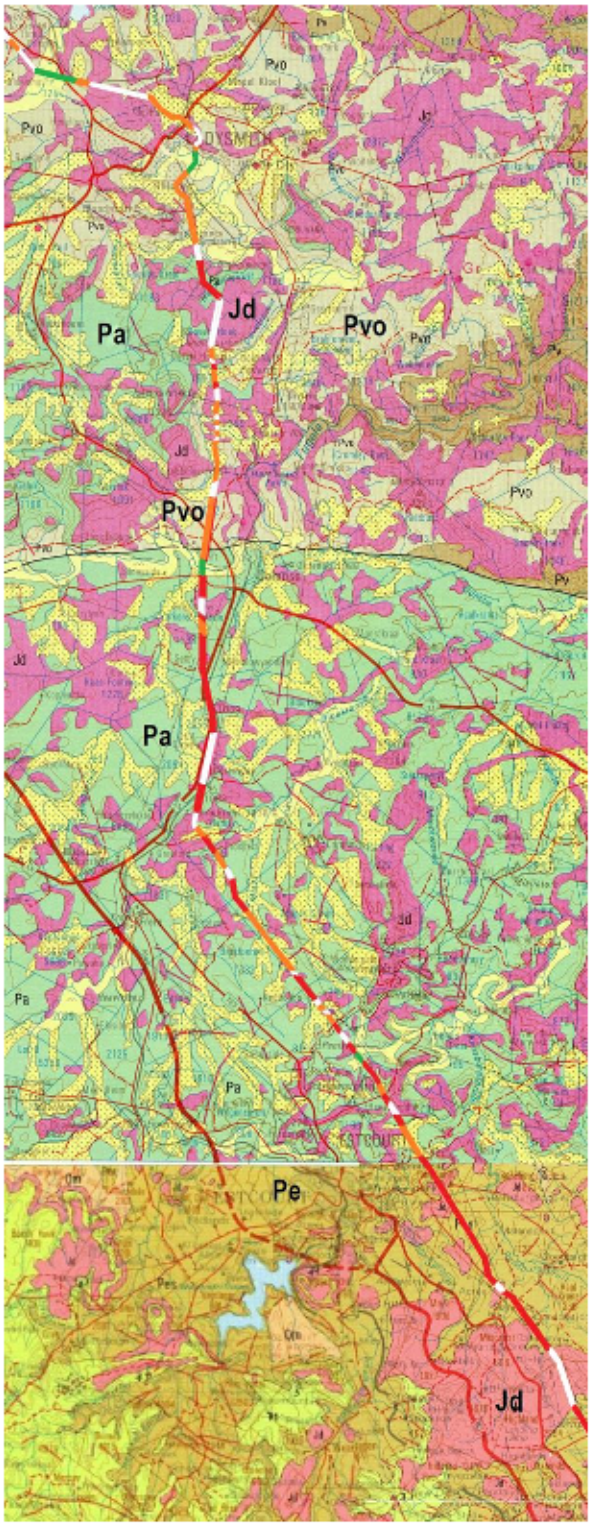
The Volksrust Formation of the Ecca Group of the Karoo Supergroup consist of dark grey shale and contains trace fossils. It is considered to be of High Palaeontological Sensitivity (Groenewald, 2012) (Figs. 4 & 9).

The Estcourt Formation of the Beaufort Subgroup of the Karoo Supergroup consists of deltaic coarse-grained sandstone and shale. It contains trace fossils and abundant plant fossils, mainly *Glossopteris* leaf imprints. This formation is considered to have a Very High Palaeontological Sensitivity (Groenewald, 2012) (Figs. 4 & 9).

Dolerite from the Jurassic Period is non-fossiliferous.

	Formation	**Group**	**Geology**	**Palaeontology**	**Sensitivity**
Jd			Dolerite	Non-fossiliferous	None
Pe	Estcourt	Ecca	Deltaic coarse-grained sandstone and shale	Trace fossils, *Glossopteris*	Very High
Pvo	Volksrust		Dark grey Shale	Trace fossils	High
Pv	Vryheid		Light grey medium to coarse-grained sandstone and siltstone. Carbonaceous siltstone and coal beds	Trace fossils and abundant plant fossils – mainly *Glossopteris*	Very High
Pp	Pieter-maritzburg		Dark-grey shale, siltstone, subordinate sandstone	Trace fossils	Moderate
C-Pd		Dwyka	Tillite, diamictite	None recorded from this province	Moderate
Information based on Groenewald, 2012 and the latest Palaeosensitivity Map, SAHRA					

Section C: Estcourt to Ladysmith



This section is the one of the two most sensitive sections of the study site because of the exposure of bedrock in this area and because of the fossiliferous nature of these particular geological units.

The Adelaide Subgroup and the Estcourt Formation of the Beaufort Group of the Karoo Supergroup which occur along this section are renowned for its synapsid fossil content.

Large parts of the study site are underlain by dolerite sills that are devoid of fossils but there are sections in between indicated in red along the route that need special attention.

The geological units that will be impacted along this section are:

The Volksrust Formation (Pvo), the Adelaide Subgroup (Pa), the Estcourt Formation (Pe) of the Karoo Supergroup and unconsolidated Quaternary sediments.

The Volksrust Formation (Pvo) rocks are considered to be of High Palaeontological Sensitivity.

The parts that cross over Adelaide Subgroup (Pa) and Estcourt Formation (Pe) rocks are considered to be of Very High Palaeontological Sensitivity.

The unconsolidated sediments of the Masocheni Formation are considered to be of Moderate Palaeontological Sensitivity.

Figure 10: Section C - Estcourt to Ladysmith. Lower section adapted from the 1:250 000 2928 DRAKENSBERG geology map (Geological Survey, 1981) and the upper section adapted from the 1:250 000 2828 HARRISMITH geology map (Geological Survey, 1998). The different colours along the route indicate the relative palaeontological sensitivity of that section (white indicates non-fossiliferous areas)

	Formation	Group	Geology	Palaeontology	Sensitivity
Jd			Dolerite	Non-fossiliferous	None
Pa	Adelaide Subgroup	Beaufort	Deltaic and fluvial sequences of sandstone and green-grey mudstone	*Dicynodon* and *Lystrosaurus* Assemblage zones. Fossils of fish, amphibians, reptiles, and burrows	Very High
Pe	Estcourt	Ecca	Deltaic coarse-grained sandstone and shale	Trace fossils, *Glossopteris*	Very High
Pvo	Volksrust		Dark grey Shale	Trace fossils	High
Pv	Vryheid		Light grey medium to coarse-grained sandstone and siltstone. Carbonaceous siltstone and coal beds	Trace fossils and abundant plant fossils – mainly *Glossopteris*	Very High
Pp	Pieter-maritzburg		Dark-grey shale, siltstone, subordinate sandstone	Trace fossils	Moderate
Information based on Groenewald, 2012 and the latest Palaeosensitivity Map, SAHRA					

Section D: Ladysmith to Bethlehem

Figure 11: Section D – Ladysmith to Bethlehem. Lower section adapted from the 1 1:250 000 2828 HARRISMITH geology map (Geological Survey, 1998). The different colours indicate the relative palaeontological sensitivity of that section (white indicates non-fossiliferous areas)

This section is one of the two most vulnerable areas of the study site.

The palaeontologically sensitive geological units that will be impacted along this section are: The Vryheid Formation (Pvo), the Adelaide Subgroup (Pa), the Tarkastad Formation (TRt), Molteno Formation (TRm) and Elliot Formation (Tre) of the Karoo Supergroup.

	Formation	Group	Geology	Palaeontology	Sensitivity
Jd			Dolerite	Non-fossiliferous	None
TRe	Elliot		Red mudstone with interbedded yellow brown sandstone lenses	Fossils of fish and reptiles including thecodonts, crocodiles and dinosaurs such as *Massospondylus*.	Very High
TRm	Molteno		Coarse-grained, glittering sandstone. Interbedded khaki coloured mudstone	Most diverse plant and insect assemblages in the Gondwana. Seed ferns such as *Dicroidium* dominate the vegetation.	Very High
TRt	Tarkastad	Beaufort	Fluvial sandstone and red mudstone.	*Lystrosaurus* and *Cynognathus* Assemblage zones. Fossils of fish, amphibians, reptiles (including synapsids) and trace fossils.	Very High
Pa	Adelaide Subgroup		Deltaic and fluvial sequences of sandstone and green-grey mudstone	*Dicynodon* and *Lystrosaurus* Assemblage zones. Fossils of fish, amphibians, reptiles (including synapsids), and burrows	Very High
Pvo	Volksrust	Ecca	Dark grey Shale	Trace fossils	High
Information based on Groenewald & Groenewald, 2014a and the latest Palaeosensitivity Map, SAHRA					

The Volksrust Formation of the Ecca Group of the Karoo Supergroup consist of dark grey shale and contains trace fossils. It is considered to be of High Palaeontological Sensitivity (Groenewald, 2012) (Figs. 4 & 11).

The Estcourt Formation of the Beaufort Subgroup of the Karoo Supergroup consists of deltaic coarse-grained sandstone and shale. It contains trace fossils and abundant plant fossils, mainly *Glossopteris* leaf imprints. This formation is considered to have a Very High Palaeontological Sensitivity (Groenewald, 2012) (Figs. 4 & 11).

The Adelaide Subgroup of the Beaufort Group of the Karoo Supergroup consists of deltaic and fluvial sequences of sandstone and characteristic green-grey mudstones. This unit is subdivided into *Dicynodon* and *Lystrosaurus* Assemblage zones on the basis of the unique fossil assemblages that occur in these layers. Fossils of fish, amphibians, reptiles, including those of synapsids (mammal-like reptiles) and burrows occur in these layers (Kitching, 1977; Rubidge *et al*., 1995). This formation is considered to have a Very High Palaeontological Sensitivity (Groenewald, 2012) (Figs. 4 & 11).

The Tarkastad Subgroup of the Beaufort Group of the Karoo Supergroup consists of alluvial sandstone and red mudstones. It is subdivided into the *Lystrosaurus* and *Cynognathus* Assemblage zones on the basis of the unique fossil assemblages that occur in these layers. Fossils of fish, amphibians, reptiles (including those of synapsids) and trace fossils occur in these layers (Kitching, 1977; Rubidge *et al*., 1995). This formation is considered to have a Very High Palaeontological Sensitivity (Groenewald, 2012) (Figs. 4 & 11).

The Molteno Formation of the Karoo Supergroup consist of coarse-grained, glittering sandstone. Interbedded khaki coloured mudstone. It contains the most diverse plant and insect assemblages in the Gondwana. Seed ferns such as *Dicroidium* dominate the palaeontological deposits in these layers. This formation is considered to have a Very High Palaeontological Sensitivity (Groenewald, 2012) (Figs. 4 & 11).

The Elliot Formation of the Karoo Supergroup consist of red mudstone with interbedded yellow brown sandstone lenses. It contains a variety of bony fossils including those of fish and reptiles including thecodonts, crocodiles and dinosaurs such as *Massospondylus*. This formation is considered to have a Very High Palaeontological Sensitivity (Groenewald, 2012) (Figs. 4 & 11).

Section E: Bethlehem to Kroonstad

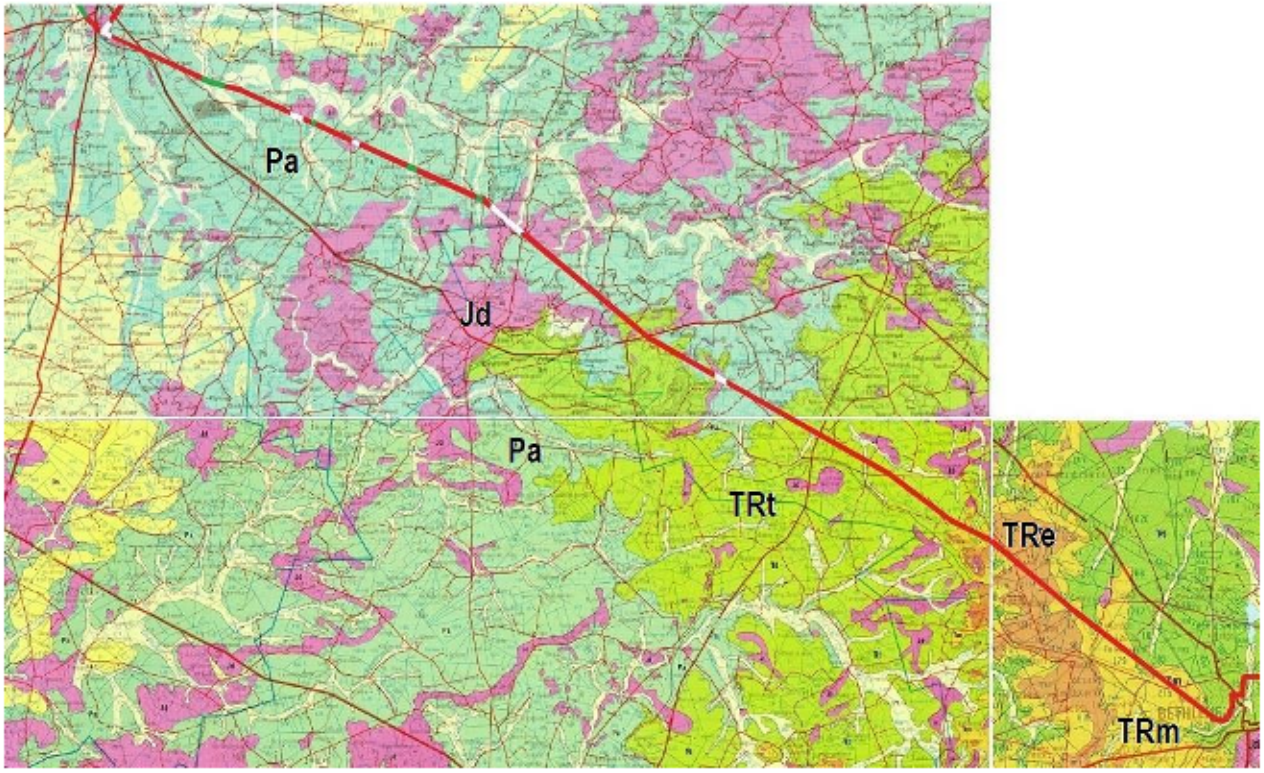


Figure 12: Section E – Bethlehem to Kroonstad. Right bottom section adapted from the 1 1:250 000 2828 HARRISMITH geology map (Geological Survey, 1998), left bottom section adapted from the 1:250 000 2826 WINBURG geology map (Council for Geoscience, 1998), central section adapted from the 1 1:250 000 2826 KROONSTAD geology map (Council for Geoscience, 2000), top section adapted from the 1 1:250 000 2626 WEST RAND geology map (Geological Survey, 1986). The different colours indicate the relative palaeontological sensitivity of that section (white indicates non-fossiliferous areas)

The palaeontologically sensitive geological units that will be impacted along this section are: the Adelaide Subgroup (Pa), the Tarkastad Formation (TRt), Molteno Formation (TRm) and Elliot Formation (Tre) of the Karoo Supergroup.

The Adelaide Subgroup of the Beaufort Group of the Karoo Supergroup consists of deltaic and fluvial sequences of sandstone and characteristic green-grey mudstones. This unit is subdivided into *Dicynodon* and *Lystrosaurus* Assemblage zones on the basis of the unique fossil assemblages that occur in these layers. Fossils of fish, amphibians, reptiles, including those of synapsids (mammal-like reptiles) and burrows occur in these layers (Kitching, 1977; Rubidge *et al*., 1995). This formation is considered to have a Very High Palaeontological Sensitivity (Groenewald & Groenewald, 2014a) (Figs. 5 & 12).

The Tarkastad Subgroup of the Beaufort Group of the Karoo Supergroup consists of alluvial sandstone and red mudstones. It is subdivided into the *Lystrosaurus* and *Cynognathus* Assemblage zones on the basis of the unique fossil assemblages that occur in these layers. Fossils of fish, amphibians, reptiles (including those of synapsids)

and trace fossils occur in these layers (Kitching, 1977; Rubidge *et al*., 1995). This formation is considered to have a Very High Palaeontological Sensitivity (Groenewald & Groenewald, 2014a) (Figs. 5 & 12).

The Molteno Formation of the Karoo Supergroup consist of coarse-grained, glittering sandstone. Interbedded khaki coloured mudstone. It contains the most diverse plant and insect assemblages in the Gondwana (Anderson & Anderson, 1985). Seed ferns such as *Dicroidium* dominate the palaeontological deposits in these layers. This formation is considered to have a Very High Palaeontological Sensitivity (Groenewald & Groenewald, 2014a) (Figs. 5 & 12).

The Elliot Formation of the Karoo Supergroup consist of red mudstone with interbedded yellow brown sandstone lenses. It contains a variety of bony fossils including those of fish and reptiles including thecodonts, crocodiles and dinosaurs such as *Massospondylus*. This formation is considered to have a Very High Palaeontological Sensitivity (Groenewald & Groenewald, 2014a) (Figs. 5 & 12).

Dolerite from the Jurassic Period is non-fossiliferous.

	Formation	**Group**	**Geology**	**Palaeontology**	**Sensitivity**
Jd			Dolerite	Non-fossiliferous	None
TRe	Elliot		Red mudstone with interbedded yellow brown sandstone lenses	Fossils of fish and reptiles including thecodonts and crocodiles and dinosaurs such as *Massospondylus*.	Very High
TRm	Molteno		Coarse-grained, glittering sandstone. Interbedded khaki coloured mudstone	Most diverse plant and insect assemblages in the Gondwana. Seed ferns such as *Dicroidium* dominate the vegetation.	Very High
TRt	Tarkastad	Beaufort	Fluvial sandstone and red mudstone.	*Lystrosaurus* and *Cynognathus* Assemblage zones. Fossils of fish, amphibians, reptiles (including synapsids) and trace fossils.	Very High
Pa	Adelaide Subgroup		Deltaic and fluvial sequences of sandstone and green-grey mudstone	*Dicynodon* and *Lystrosaurus* Assemblage zones. Fossils of fish, amphibians, reptiles, and burrows	Very High
Information based on Groenewald & Groenewald, 2014a and the latest Palaeosensitivity Map, SAHRA					

Section F: Kroonstad to Sasolburg

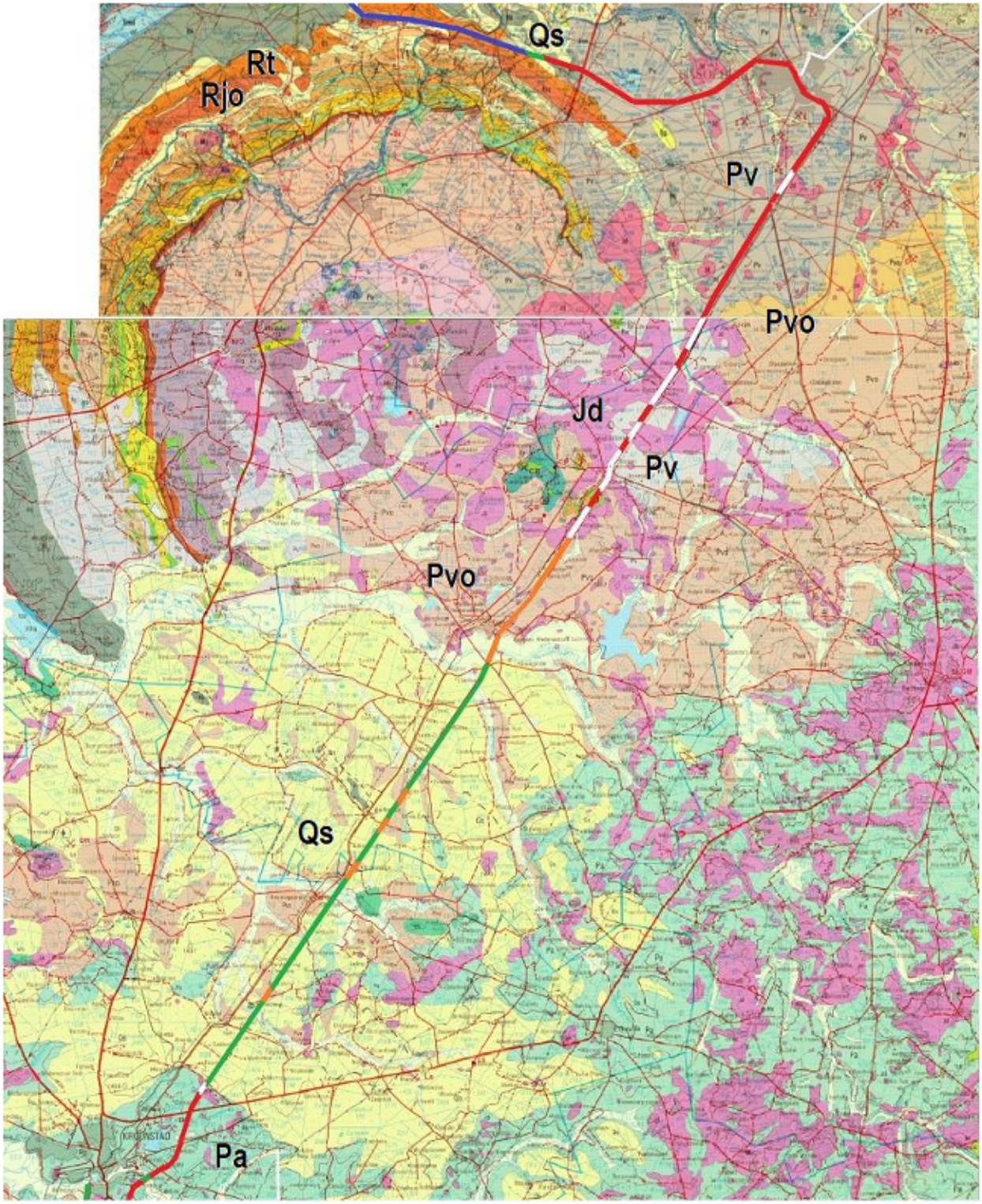


Figure 13: Section F – Kroonstad to Sasolburg. Bottom section adapted from the 1:250 000 2826 KROONSTAD geology map (Council for Geoscience, 2000), top section adapted from the 1 1:250 000 2626 WEST RAND geology map (Geological Survey, 1986). The different colours indicate the relative palaeontological sensitivity of that section (white indicates non-fossiliferous areas)

The palaeontologically sensitive geological units that will be impacted along this section are: the Volksrust Formation (Pvo), the Vryheid Formation (Pvo) and the Adelaide Subgroup (Pa).

	Formation	Group	Geology	Palaeontology	Sensitivity
Qs			Soil cover		Moderate
Jd			Dolerite	Non-fossiliferous	None
Pa	Adelaide Subgroup	Beaufort	Deltaic and fluvial sequences of sandstone and green-grey mudstone	*Dicynodon* and *Lystrosaurus* assemblage zones. Fossils of fish, amphibians, reptiles, and burrows	Very High
Pv	Vryheid	Ecca	Light grey medium to coarse- grained sandstone and siltstone. Carbonaceous siltstone and coal beds	Trace fossils and abundant plant fossils – mainly *Glossopteris*	Very High
Pvo	Volksrust	Ecca	Dark grey shale	Trace fossils	High
Rt	Turffontein	Central Rand	Quartzite, shale, conglomerate	No fossils on record	Low
Rjo	Johannes-burg		Quartzite, conglomerate	No fossils on record	Low
Information based on Groenewald & Groenewald, 2014a and the latest Palaeosensitivity Map, SAHRA					

The Vryheid Formation of the Ecca Group of the Karoo Supergroup consists of light grey medium to coarse- grained sandstone and siltstone. Dark-coloured carbonaceous siltstone and coal beds are common. It is considered to have a Very High Palaeontological Sensitivity due to the fact that trace fossils and abundant plant fossils – mainly of *Glossopteris* occur in these beds (Groenewald & Groenewald, 2014a) (Figs. 5 & 13).

The Volksrust Formation of the Ecca Group of the Karoo Supergroup consist of dark grey shale and contains trace fossils. It is considered to be of High Palaeontological Sensitivity (Groenewald & Groenewald, 2014a) (Figs. 5 & 13).

The Adelaide Subgroup of the Beaufort Group of the Karoo Supergroup consists of deltaic and fluvial sequences of sandstone and characteristic green-grey mudstones. This unit is subdivided into *Dicynodon* and *Lystrosaurus* Assemblage zones on the basis of the unique fossil assemblages that occur in these layers. Fossils of fish, amphibians, reptiles, including those of synapsids (mammal-like reptiles) and burrows occur in these layers (Kitching, 1977; Rubidge et al., 1995). This formation is considered to have a Very High Palaeontological Sensitivity (Groenewald & Groenewald, 2014a) (Figs. 5 & 13).

The Quaternary-aged surface deposits may contain bones, ostrich shells, tortoise shells and the shells of terrestrial molluscs (Partridge *et al*., 2009). It is considered to be of moderate palaeontological sensitivity (Figs. 5 & 13).

Section G: Sasolburg to Klerksdorp

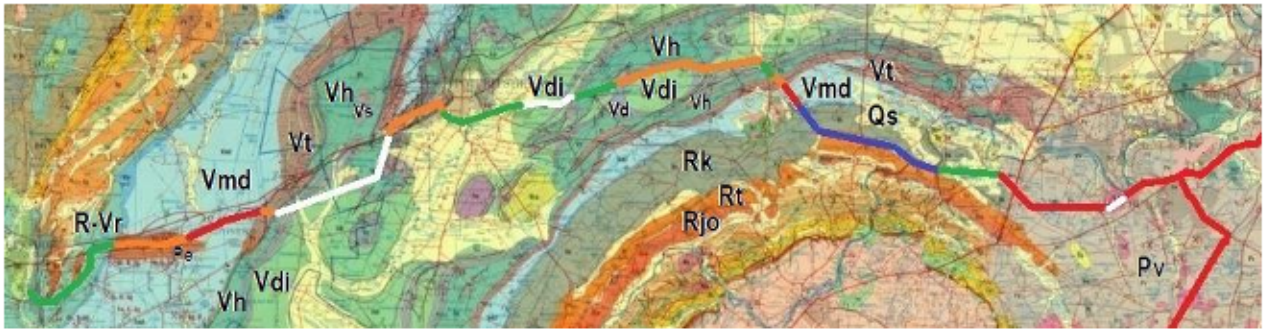


Figure 14: Section G – Sasolburg to Klerksdorp adapted from the 1:250 000 2626 WEST RAND geology map (Geological Survey, 1986). The different colours indicate the relative palaeontological sensitivity of that section (white indicates non-fossiliferous areas)

The potentially fossiliferous geological units that will be impacted along this section are rocks of the Ecca Group (Pe, Pv), the Pretoria Group (Vs, Vh, Vt) and the Malmani Subgroup of the Chuniespoort Group (Vmd), the Platberg Group (R-Vr) and Quarternary deposits (Qs) and alluvial deposits next to rivers. The rest of the geological units are either igneous or metamorphic rocks that are non-fossiliferous.

	Formation / Subgroup	**Group**	**Geology**	**Palaeontology**	**Sensitivity**
Qs			Soil cover	Diversity of bones, mollusc shells, ostrich shells.	Moderate
Pe		Ecca	Shale, sandstone, coal	Plant fossils abundant, mainly *Glossopteris* leaf imprints but also tree trunks, roots, pollen, insects and trace fossils.	High
Pv	Vryheid		Deltaic sandstones, shales and coals, with minor conglomerates	Abundant plant fossils – mainly *Glossopteris* leaf imprints but also wood and roots, trace fossils, insect fossils and pollen	Very High
Pvo	Volksrust		Shale, subordinate sandstone	Trace fossils	High
Vdi			Diabase	Non-fossiliferous	None
Vs	Strubenkop	Pretoria	Ferruginous shale, quartzite	No fossils on record	Low
Vh	Hekpoort		Andesite, agglomerate, tuff	No fossils on record	Low
Vt	Timeball Hill		Ferruginous shale, hornfels, quartzite	Some stromatolites in lower strata	Moderate
Vmd	Malmani Subgroup	Chunies-poort	Dolomite, chert, chert breccia	Stromatolites	Very High
R-Vr	Rietgat	Platberg	Amygdaloidal lava, agglomerate, tuff	Some stromatolites	Moderate
Rk	Kliprivierberg Subgroup		Basaltic lava, agglomerate, tuff	No fossils on record	Low
Rt	Turffontein	Central Rand	Quartzite, shale, conglomerate	No fossils on record	Low
Rjo	Johannes-burg		Quartzite, conglomerate	No fossils on record	Low
Information based on Groenewald & Groenewald, 2014b and the current Palaeosensitivity Map, SAHRA					

Ecca deposits (Pe) consisting of shale, sandstone and coal seams may potentially have plant fossils (mainly Glossopteris), petrified wood, roots, palynomorphs, rare insects, conchostracans and trace fossils. It is considered to be of High Palaeontological Sensitivity (Groenewald & Groenewald, 2014b) (Figs. 5 & 14).

Vryheid Formation of the Ecca Group of the Karoo Supergroup consists of light grey medium to coarse- grained sandstone and siltstone. Dark-coloured carbonaceous siltstone and coal beds are common. It is considered to have a Very High Palaeontological Sensitivity because of the trace fossils and abundant plant fossils – (mainly *Glossopteris*) that it contains (Groenewald & Groenewald, 2014b) (Figs. 5 & 14).

The Volksrust Formation of the Ecca Group of the Karoo Supergroup consist of dark grey shale and contains trace fossils. It is considered to be of High Palaeontological Sensitivity (Groenewald & Groenewald, 2014b) (Figs. 5 & 14).

Timeball Hill Formation of the Pretoria Group consists of lacustrine and fluvio-deltaic mudrocks with diamictite, conglomerates, quartzite and minor lavas. It is considered to have a very High Palaeontological Sensitivity due its stromatolite content in its lower strata (Groenewald & Groenewald, 2014b, Figs. 5 & 14).

Malmani Subgroup of the Chuniespoort Group consists of stromatolitic carbonates (limestones / dolomites), minor secondary cherts and mudrocks including carbonaceous shales. It is considered to have a Very High Palaeontological Sensitivity due to the extensive stromatolitic formations and microfossils that occur in this subgroup (Groenewald & Groenewald, 2014b, Figs. 5 & 14).

The Rietgat Formation of the Platberg Group of the Ventersdorp Supergroup consists predominantly of lavas with minor metasediments (fluvial and lacustrine conglomerates, breccias, minor shales, stromatolitic carbonates and cherts. It contains lacustrine stromatolites reported in the carbonates and possible organic-walled microfossils in thecherts and is considered to be of Moderate Palaeontological Sensitivity (Groenewald & Groenewald, 2014b, Figs. 5 & 14).

Section H: Sasolburg to Johannesburg

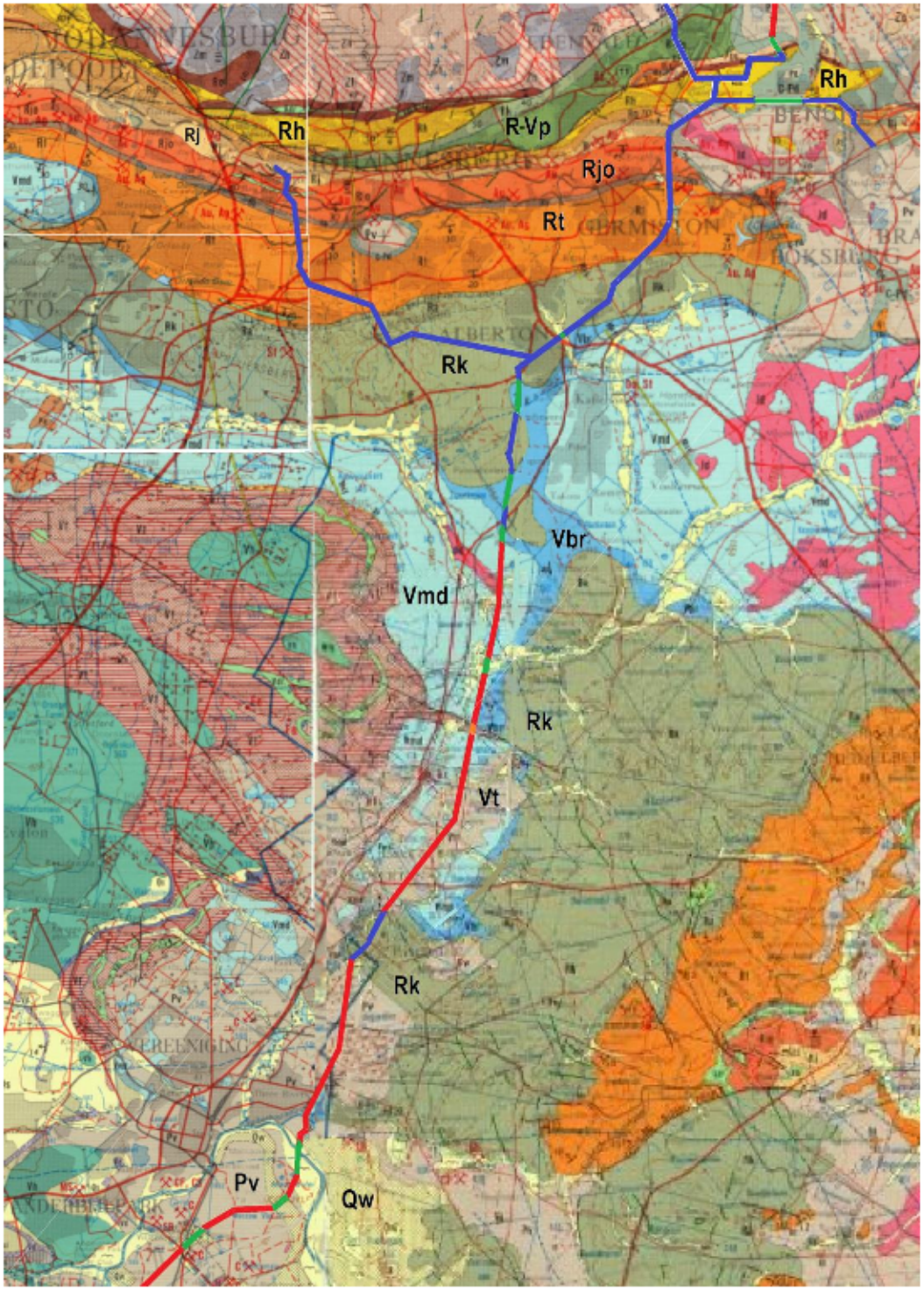


Figure 15: Section H – Sasolburg to Johannesburg. Left section adapted from the 1:250 000 2626 WEST RAND geology map (Geological Survey, 1986) and the right section adapted from the 1:250 000 2628 EAST RAND geology map (Geological Survey, 1986) (white indicates non-fossiliferous areas)

The potentially fossiliferous geological units that will be impacted along this section are rocks of the Vryheid Formation of the Ecca Group (Pv), the Timeball Hill Formation of the

Pretoria Group (Vt) and the Malmani Subgroup of the Chuniespoort Group (Vmd), the Black Reef Formation (Vbr) and Quaternary deposits (Qw) and alluvium next to rivers. The rest of the geological units are either igneous or metamorphic rocks that have a low palaeontological sensitivity or are non-fossiliferous.

	Formation / Subgroup	**Group**	**Geology**	**Palaeontology**	**Sensitivity**
Qw			Aeolian sand	Diversity of bones, mollusc shells, ostrich shells.	Moderate
Pv	Vryheid	Ecca	Deltaic sandstones, shales and coals, with minor conglomerates	Abundant plant fossils – mainly *Glossopteris* leaf imprints but also wood and roots, trace fossils, insect fossils and pollen	Very High
Vt	Timeball Hill	Pretoria	Ferruginous shale, hornfels, quartzite	Some stromatolites in lower strata	Very High
Vmd	Malmani Subgroup	Chunies -poort	Stromatolitic carbonates (limestones / dolomites), minor secondary cherts, mudrocks including carbonaceous shales	Shallow marine to intertidal stromatolites (domes, columns etc), organic-walled microfossils	Very High
Vbr	Black Reef		Quartzite, conglomerate, shale	Stromatolitic carbonates	Moderate
Rk		Kliprivier-berg	Basaltic lava, agglomerate, tuff	No fossils on record	Low
Rt	Turffontein	Central Rand	Quartzite, shale, conglomerate	No fossils on record	Low
Rjo	Johannes-burg		Quartzite, conglomerate	No fossils on record	Low
Rh	Hospital Hill	West Rand	Partly ferruginous shale, quartzite, banded ironstone	Kerogen, but no fossils on record	None
Information based on Groenewald & Groenewald, 2014c and the current Palaeosensitivity Map, SAHRA					

Vryheid Formation of the Ecca Group of the Karoo Supergroup consists of light grey medium to coarse- grained sandstone and siltstone. Dark-coloured carbonaceous siltstone and coal beds are common. It is considered to have a Very High Palaeontological Sensitivity because of the trace fossils and abundant plant fossils – (mainly *Glossopteris*) that it contains (Groenewald & Groenewald, 2014c) (Figs. 7 & 15).

Timeball Hill Formation of the Pretoria Group consists of lacustrine and fluvio-deltaic mudrocks with diamictite, conglomerates, quartzite and minor lavas. It is considered to have a very High Palaeontological Sensitivity due its stromatolite content in its lower strata (Groenewald & Groenewald, 2014c, Figs. 7 & 15).

Malmani Subgroup of the Chuniespoort Group consists of stromatolitic carbonates (limestones / dolomites), minor secondary cherts and mudrocks including carbonaceous shales. It is considered to have a Very High Palaeontological Sensitivity due to the extensive stromatolitic formations and microfossils that occur in this subgroup (Groenewald & Groenewald, 2014c, Figs. 7 & 15).

Black Reef Formation consists of mature sandstones plus minor mudrocks and conglomerates). It may contain stromatolites in places and is considered to be of Moderate Palaeontological Sensitivity(Groenewald & Groenewald, 2014c, Figs. 7 & 15).

Section I: Alberton to Pretoria

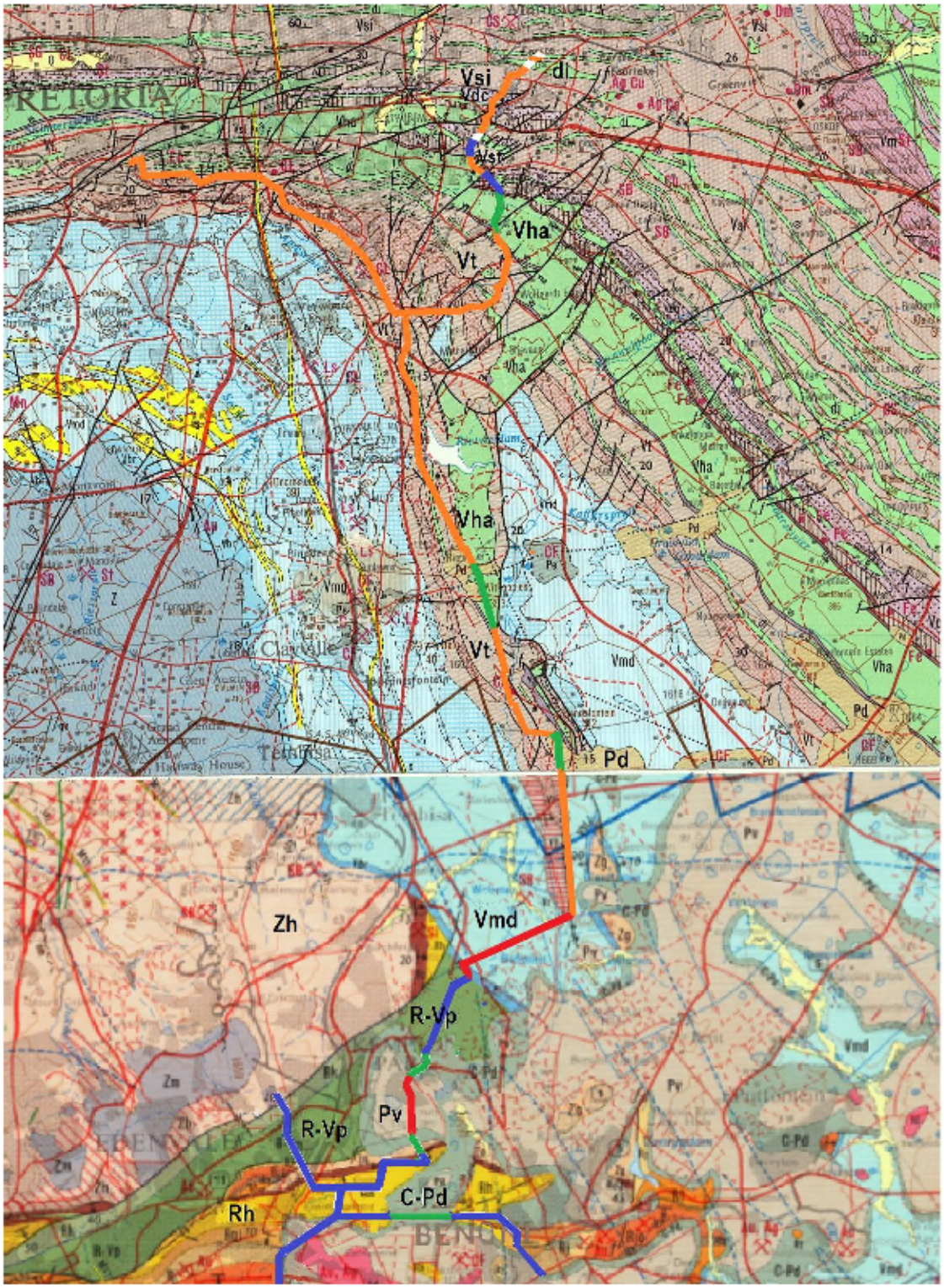


Figure 16: Section I – Alberton to Pretoria top section adapted from the 1:250 000 2528 PRETORIA geology map (Geological Survey, 1978), bottom left section adapted from the 1:250 000 2626 WEST RAND geology map (Geological Survey, 1986) (white indicates non-fossiliferous areas)

The potentially fossiliferous geological units that will be impacted along this section are rocks of the Dwyka (C-Pd) and Ecca Groups (Pv) of the Karoo Supergroup, the Pretoria Group (Vsi, Vha, Vt) and Chuniespoort Subgroup (Vmd) of the Chuniespoort Group of the Transvaal Supergroup and the Platberg Group (R-Vp). The rest of the geological units are either igneous or metamorphic rocks that are non-fossiliferous.

	Formation / Subgroup	Group	Geology	Palaeontology	Sensitivity
Pv	Vryheid	Ecca	Light grey medium to coarse-grained sandstone and siltstone. Carbonaceous siltstone and coal beds	Trace fossils and abundant plant fossils – mainly *Glossopteris*	Very High
C-Pd Pd		Dwyka	Tillite, diamictite	None recorded from this province	Moderate
Vsi	Silverton	Pretoria	Marine mudrocks with minor carbonates, volcanic rocks	Stromatolites	High
Vha	Hekpoort		Andesite, agglomerate, tuff	No fossils on record	Low
Vt	Timeball Hill		Shale, siltstone, conglomerate in places, quartzite	Some stromatolites in lower strata	High
Vmd	Malmani Subgroup	Chunies-poort	Dolomite, chert, chert breccia	Stromatolites	Very High
R-Vp	Rietgat	Platberg	Breccia, conglomerate, greywacke	Stromatolites	Moderate
Rh	Hospital Hill	West Rand	Partly ferruginous shale, quartzite, banded ironstone	Kerogen, but no fossils on record	None
Zh	Halfway House Granite		Granodioriet	Non-fossiliferous	None
Information based on Groenewald & Groenewald, 2014c and the current Palaeosensitivity Map, SAHRA					

Vryheid Formation of the Ecca Group of the Karoo Supergroup consists of light grey medium to coarse- grained sandstone and siltstone. Dark-coloured carbonaceous siltstone and coal beds are common. It is considered to have a Very High Palaeontological Sensitivity because of the trace fossils and abundant plant fossils – (mainly *Glossopteris*) that it contains (Groenewald & Groenewald, 2014c) (Figs. 7 & 16).

Dwyka Group rocks consist of tillite and diamictite. No fossils have been discovered in this unit in Gauteng so far. It is considered to have a Low Palaeontological Sensitivity (Groenewald & Groenewald, 2014c) (Figs. 7 & 16).

Silverton Formation consists of marine mudrocks with minor carbonates and volcanic rocks. It contains stromatolites and remnants of algae mats and is considered to have a High Palaeontological Sensitivity (Groenewald & Groenewald, 2014c) (Figs. 7 & 16).

Timeball Hill Formation of the Pretoria Group consists of lacustrine and fluvio-deltaic mudrocks with diamictite, conglomerates, quartzite and minor lavas. It is considered to have a very High Palaeontological Sensitivity due its stromatolite content in its lower strata (Groenewald & Groenewald, 2014c, Figs. 7 & 16).

Malmani Subgroup of the Chuniespoort Group consists of stromatolitic carbonates (limestones / dolomites), minor secondary cherts and mudrocks including carbonaceous shales. It is considered to have a Very High Palaeontological Sensitivity due to the

extensive stromatolitic formations and microfossils that occur in this subgroup (Groenewald & Groenewald, 2014c, Figs. 7 & 18).

The Rietgat Formation of the Platberg Group of the Ventersdorp Supergroup consists predominantly of lavas with minor metasediments (fluvial and lacustrine conglomerates, breccias, minor shales, stromatolitic carbonates and cherts. It contains lacustrine stromatolites reported in the carbonates and possible organic-walled microfossils in thecherts and is considered to be of Moderate Palaeontological Sensitivity (Groenewald & Groenewald, 2014c, Figs. 7 & 18).

7. Discussion

The palaeontological aspect of the study site is dominated by the fossiliferous nature of the rocks of mainly the Transvaal Supergroup and the Karoo Supergroup.

Palaeontology of the Transvaal Supergroup

Stromatolites (Figs. 17-19) are very important from an evolutionary, environmental, ecological and geological perspective. Stromatolites were formed approximately 2.2 Ga ago when mats of cyanobacteria covered the sea floor up to a certain depth which allowed them to photosynthesize. The slimy surface caused fine grained mud and precipitates to adhere to them after which cyanobacterial strands consisting of chains of bacterial cells would continue to extend by means through the sediment in order to get enough light to photosynthesize. Very thin layers of sediments were set down during this process. In time these sedimentary layers were petrified and turned into columns of rock. Some of these columns which are stacked closely together are as thin as pencils, while others are formed mushroom-like scallops and others formed bigger domes and even megadomes which are meters across.

Figure 17: Example of stromatolites at Sterkfontein Caves

Cyanobacteria were the first photosynthesizing organisms and it is thought that the chloroplast found in plants has evolved from a cyanobacterial ancestor. Cyanobacteria released oxygen as a by-product of photosynthesis in such quantities that it irrevocably changed the atmosphere from a reducing to an oxidizing atmosphere which had a devastating effect to most bacteria which were and still are anoxic. This event was also responsible for the oxidization and precipitation of huge amounts of iron from solution that formed the Banded Ironstone Formations for which this region is known. Higher organisms such as fungi, plants and animals would not have been able to exist without

the oxygen in the atmosphere and would therefore not have evolved if it were not for cyanobacteria.

Figure 18: Polished vertical section through stromatolites
(from: https://www.google.co.za/imgres?imgurl=http%3A%2F%2Fwww.therockgallery.co.uk%2Fekmps%2Fshops%2Ftherockgallery%2Fimages%2Fstromatolite-large-polished-slice-100-million-years-old-andes-mountains-bolivia-%5B4%5D-1997-p.jpg&imgrefurl=http%3A%2F%2Fwww.therockgallery.co.uk%2Fstromatolite-large- polished-slice---100-million-years-old-----andes-mountains-bolivia-1997p.asp&docid=2vFkg_vqTH0I5M&tbnid=FQcixxQGdtBUFM%3A&vet=10ahUKEwinl8rfwqjcAhUGsKQKHf8wBy0QMwgsKAYwBg..i&w=500&h=500&bih=918&biw=1280&q=stromatolites&ved=0ahUKEwinl8rfwqjcAhUGsKQKHf8wBy0QMwgsKAYwBg&iact=mrc&uact=8)

Figure 19: Domal structures of stromatolites seen from above
(from: https://www.google.co.za/imgres?imgurl=http%3A%2F%2Fwww.kidsdiscover.com%2Fwp-content%2Fuploads%2F2015%2F04%2FBacteria_2.jpg&imgrefurl=http%3A%2F%2Fwww.kidsdiscover.com%2Fspotlight%2Fbacteria%2F%3Fmc_cid%3D97b6810d71%26mc_eid%3Df31cca173c&docid=jpZALMrhml6d1M&tbnid=6zCWRFeJArwpQM%3A&vet=10ahUKEwioiMq6z6jcAhWisqQKHTkzCSoQMwhCKAMwAw..i&w=1000&h=683&bih=344&biw=553&q=Bacteria_2%20stromatolites&ved=0ahUKEwioiMq6z6jcAhWisqQKHTkzCSoQMwhCKAMwAw&iact=mrc&uact=8)

In addition to stromatolites, enigmatic structures of probably organic origin were discovered in sedimentary rocks of the Pretoria Group. It is postulated that these rolled up structures that are found between ripple marks are indeed the remnants of algal mats that grew on the sea floor (Eriksson *et al*., 2012)

Palaeontology of the Karoo Supergroup

The pipeline runs for the largest part of its extent through the Ecca and Beaufort Groups of the Karoo Supergroup from KwaZulu Natal, through the length of the Fee State and into Gauteng (see Figs. 3, 8-16).

The Karoo Supergroup is the largest terrestrial deposit in the world and preserves an unsurpassed record of terrestrial life from the Late Carboniferous to the Middle Jurassic. Reptiles diversified during this period and the South African fossil record bears witness to some of the most important evolutionary events including the evolution and radiation of the synapsids from which mammals originated and the origin and radiation of early dinosaurs. Basal tetrapods and many reptile groups, besides the synapsids, including a variety of anapsids and diapsids are represented in the Karoo Supergroup.

Ecca Group

The pipeline crosses over the Pietermaritzburg, Vryheid and Volksrust Formations of the Ecca Group. Whereas the fossil record of the Pietermaritzburg Formation is limited to trace fossils and the Volksrust Formation is mostly limited to trace fossils and rare basal tetrapod and invertebrate fossils, the Vryheid Formation is renowned for its vast quantities of fossils of a variety of plants that dominated southern Gondwanaland during the Permian. These Permian fossils are mostly leaf and stem imprints of *Glossopteris* (see Fig. 20), lycopods, ferns, horsetails, cordaitaleans, conifers and ginkgoaleans. Rare fossils of silicified and coalified wood, insects, bivalves, conchostrachans and fish scales have also been found in the shales and sandstones of the Vryheid Formation (Groenewald & Groenewald, 2014). The fossils of this unit with its chronostratigraphic equivalents in other landmasses such as South America, Antarctica, Australia and India, proved the existence of Gondwana. The pipeline crosses over the Vryheid Formation along Sections B - C and F – I.

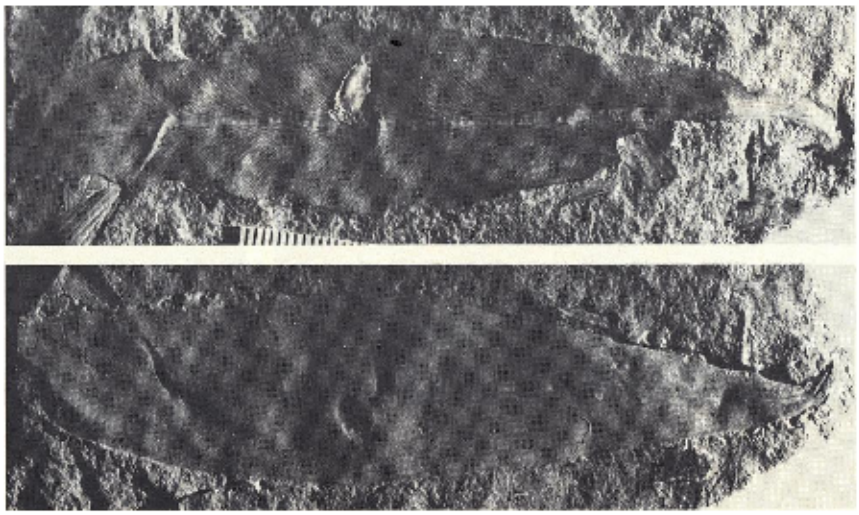


Figure 20: *Glossopteris* leaf imprint (from Kovács-Endrödy, 1976)

Beaufort Group

The Late Permian to early Triassic sediments that constitute the Beaufort Group is subdivided into a lower Adelaide Subgroup and upper Tarkastad Subgroup. The Adelaide Subgroup consists of a sequence of sediments ranging from Permian aged lower deltaic environments through meandering fluvial environments to early Triassic lacustrine deposits (Groenewald & Groenewald, 2014a).

A wide diversity of animal and plant fossils has been discovered in this geological unit including palaeoniscoid fish, basal tetrapods, anapsids, diapsids (including thecodonts) and synapsids, insects, freshwater bivalves, trace fossils (including trackways, coprolites and burrow-infills) and plants including *Glossopteris* leaf imprints and petrified logs.

Figure 21: *Dicynodon* skull

The synapsids or mammal-like reptiles (see Figs. 21 & 22) were the dominant terrestrial vertebrates during the Permian and early Triassic before the rise of the dinosaurs. Approximately 70% of synapsids on earth are found in the Beaufort Group of the Karoo Supergroup (Durand, 2005). Synapsids are of particular importance because they gave rise to mammals of which some of the oldest fossils occur in the Clarence Formation of the Karoo Supergroup. Other bony fossils that occur in the Beaufort Group are fish, anapsid and diapsid fossils. One of the diapsid fossil groups that is of particular importance are the thecodonts that were ancestral to the first dinosaurs (Durand, 2005).

The fossils of the Beaufort Group, like that of the Elliot Formation, are very sensitive due to their scarcity, evolutionary importance and fragility. The pipeline crosses over the Beaufort Group in Sections C-F. The geology is mostly obscured in Sections E and F, but is commonly exposed or near the surface along Sections C and D.

Figure 22: *Cynognathus* skull

Molteno Formation

Figure 23: Dicroidium zuberi

The Molteno Formation contains the most diverse plant and insect assemblages in Gondwana and provides an unsurpassed record of life during the late Triassic. This layer provides a record of forests dominated by seed ferns (see Fig. 23) at the end of the Triassic (Anderson & Anderson, 1985). The fossil flora includes seedferns, ferns, horsetails, gymnosperms, ginkgophytes and cycads. Most of the fossils consist of leaf imprints but silicified woods and palynormphs are also common (MacRae, 1999). This formation contains the largest assemblage of insect fossils in South Africa. Rare fish, conchostracan and bivalves fossils occur in this formation as well as invertebrate trace fossils and dinosaur tracks (MacRae, 1999; Groenewald & Groenewald, 2014a). The pipeline crosses over the Molteno Formation in Sections D-E.

Elliot Formation

Figure 24: *Massospondylus*

The Elliot Formation consists of red mudstones and subordinate sandstones that indicate that these sediments were deposited in an arid environment in which braided rivers and playa lakes occurred. This formation is one of the most important sources of prosauropod fossils such as *Massospondylus* (see Fig, 24) in the world and has yielded hundreds of bone fossils and even eggs. Other fossils from this formation include ornithischians, theropods and crocodilomorphs, amphibians, turtles, fish, advanced mammal-like reptiles (cynodonts) and early mammals, wood, conchostacans, insects, tetrapod trackways, root casts and possible termitaria (MacRae, 1999; Durand, 2005; Groenewald & Groenewald, 2014a). The pipeline crosses over the Molteno Formation in Sections D & E.

References:

Anderson, J.M. & Anderson, H.M. (1985). Palaeoflora of southern Africa. Prodromus of South African megafloras, Devonian to Lower Cretaceous, 423 pp. Botanical Research Institute, Pretoria.

Council for Geoscience (2000). 2826 KROONSTAD 1: 250 000 Geology Map, Council for Geoscience, Pretoria.

Durand, J.F. (2005) Major African contributions to Palaeozoic and Mesozoic vertebrate palaeontology, Journal for African Earth Sciences, 43(1-3):53-82.

Erikkson, P.G; Altermann, W. & Hartzer, F.J. (2009). The Transvaal Supergroup and its precursors. In: Johnson, M. R., Anhaeusser, C. R. and Thomas, R. J. (eds.), *The Geology of South Africa*. Geological Society of South Africa, Johannesburg / Council for Geoscience, Pretoria, pp. 237-260.

Eriksson, P.G.; Bartman, R.; Catuneanu, O.; Mazumder, R. & Lenhardt, N., (2012). A case study of microbial mats-related features in coastal epeiric sandstones from the Palaeoproterzoic Pretoria Group, Transvaal Supergroup, Kaapvaal craton, South Africa); the effect of preservation (reflecting sequence stratigraphic models) on the relationship between mat features and inferred palaeoenvironment. Sedimentary Geology 263:67-75.

Geological Survey (1970). SOUTH AFRICA 1:1000 000 geology map, Geological Survey, Pretoria.

Geological Survey (1978). 2528 PRETORIA 1:250 000 geology map, Geological Survey, Pretoria.

Geological Survey (1981). 2928 DRAKENSBERG 1:250 000 geology map, Geological Survey, Pretoria.

Geological Survey (1986). EAST RAND 1:250 000 geology map, Geological Survey, Pretoria.

Geological Survey (1986). 2626 WEST RAND 1:250 000 geology map, Geological Survey, Pretoria.

Geological Survey (1988). 2030 DURBAN 1:250 000 geology map, Geological Survey, Pretoria.

Groenewald, G. (2012). Palaeontological Technical Report for KwaZulu-Natal. South African Heritage Resources Agency.

Groenewald, G. & Groenewald, D. (2014a) SAHRA Palaeotechnical Report - Palaeontological Heritage of the Free State, South African Heritage Resources Agency.

Groenewald, G. & Groenewald, D. (2014b) SAHRA Palaeotechnical Report - Palaeontological Heritage of North West, South African Heritage Resources Agency.

Groenewald, G. & Groenewald, D. (2014c) SAHRA Palaeotechnical Report - Palaeontological Heritage of Gauteng, South African Heritage Resources Agency.

Johnson, M.R.; Van Vuuren, C.J.; Visser, J.N.J.; Cole, D.I.; Wickens, H. De V.; Christie, A.D.M.; Roberts, D.L. & Brandl, G. (2009). Sedimentary rocks of the Karoo Supergroup, pp. 461-499. *In*: Johnson. M.R., Anhaeusser, C.R. & Thomas, R.J. (eds.) *The geology of South Africa*. Geological Society of South Africa, Johannesburg & the Council for Geoscience, Pretoria.

Kitching, J.W. (1977). The distribution of the Karoo vertebrate fauna. *Memoir 1*, Bernard Price Institute for Palaeontological Research, University of the Witwatersrand.

Kovács-Endrödy, E. (1976). Notes on some *Glossopteris* species from Hammanskraal (Transvaal). *Palaeontologia africana* 19:67-95.

MacRae, C. (1999). *Life Etched in Stone*. Fossils of South Africa. The Geological Society of South Africa, Johannesburg.

Partridge, T.C., Botha, G.A. & Haddon, I.G. 2009. Cenozoic Deposits of the Interior. In: Johnson, M. R., Anhaeusser, C. R. and Thomas, R. J. (eds.), The Geology of South Africa. Geological Society of South Africa, Johannesburg / Council for Geoscience, Pretoria. 585-604.

Rubidge, B.S. (e*d.*) (1995). Biostratigraphy of the Beaufort Group (Karoo Supergroup), *Biostratigraphic Series* no.1, South African Committee for Stratigraphy, Council for Geoscience.

8. Conclusion and recommendations:

Stromatolite formations may be encountered along the pipeline sections in Gauteng and Northwest. The impact on these will probably be low because of the nature of the development that will take place. When the soil and underlying eroded rock stratum are removed, it is possible that stromatolite formations could be exposed in places in the study site. When significant stromatolite formations are uncovered during excavations a palaeontologist must be appointed to assist in the evaluation of the importance of the conservation of these structures before decommissioning continues, following the Chance Find Procedures.

The sedimentary rocks of the Karoo Supergroup occur along the largest part of the study site. These strata are not ubiquitously exposed and are mostly covered with soil. This is especially the case in the Free State where exposures are usually limited to dongas, river beds and road cuttings. Large sections of rocky strata are exposed in the mountainous areas, hillsides and along rivers in KwaZulu-Natal up to Van Reenen's Pass however.

Although substantial collections of fossils from the Ecca and Beaufort Groups are housed at the National Museum in Bloemfontein, the South African Museum in Cape Town, the Bernard Price Institute for Palaeontology at the University of the Witwatersrand, Ditsong Museum in Pretoria and the Council for Geoscience collections, there is always the possibility that new species or new fossil sites may be found during excavations and construction.

The most valuable contribution will be that all fossil sites in the Ecca Group that are discovered during the decommissioning process are recorded by the ECO following the Chance Find Procedures so that the information is available for potential palaeontological studies in future.

The Beaufort Group and the Elliot Formation are the most vulnerable to development in areas where the bedrock is exposed or in areas where the soil cover is shallow. These geological units contain scarce but scientifically very important fossil skeletons of synapsids, thecodonts and dinosaurs. These fossils are extremely fragile and if significant, need to be salvaged if possible following the Chance Find Procedures.

No palaeontological impact study was done when the pipeline was originally constructed and it is possible that fossils could have been exposed during the original digging of the ditch in areas where the soil cover was too thin to accommodate the pipeline. The potentially fossiliferous rocks will be exposed when the pipeline and valves are opened up during the decommissioning of the pipeline.

It is advised that a palaeontologist should be appointed to inspect the decommissioning procedures at intervals in the KwaZulu-Natal area between Estcourt and Van Reenen because of the high probability that highly sensitive fossiliferous strata will be compromised during the decommissioning procedures. The decommissioning procedures will involve more than mere pumping of cement into the pipes at intersections because the equipment, trucks and workers must operate from somewhere outside the ditch itself.

In the light of the impracticality of having a palaeontologist on site at all localities for the duration of construction, the responsibility of the recording of fossil localities and the collection of samples of trace fossils, plant and invertebrate fossil material will fall upon the ECO following the Chance Find Procedures, especially along sections where the geology is obscured by soil and overburden.

In the event of a substantial fossil find during the decommissioning operations, the ECO should take the responsibility of marking the site and take a GPS reading of the locality. No attempt must be made to excavate fossils before they have been assessed by a palaeontologist. Photographs of the fossil site and fossils should be taken. The advice of a qualified palaeontologist should be called in and if necessary, a rescue collection could be undertaken by the palaeontologist (after obtaining a SAHRA permit) to remove the fossils from the building site.

PROCEDURE FOR CHANCE PALAEONTOLOGICAL FINDS

Extracted and adapted from the National Heritage Resources Act, 1999 Regulations Reg No. 6820, GN: 548.

The following procedure must be considered in the event that previously unknown fossils or fossil sites are exposed or found during the life of the project:

1. Surface excavations should continuously be monitored by the ECO and any fossil material be unearthed the excavation must be halted.

2. If fossiliferous material has been disturbed during the excavation process it should be put aside to prevent it from being destroyed.

3. The ECO then has to take a GPS reading of the site and take digital pictures of the fossil material and the site from which it came.

4. The ECO then should contact a palaeontologist and supply the palaeontologist with the information (locality and pictures) so that the palaeontologist can assess the importance of the find and make recommendations.

5. If the palaeontologist is convinced that this is a major find an inspection of the site must be scheduled as soon as possible in order to minimise delays to the development.

From the photographs and/or the site visit the palaeontologist will make one of the following recommendations:

a. The material is of no value so development can proceed, or:

b. Fossil material is of some interest and a representative sample should be collected and put aside for further study and to be incorporated into a recognised fossil repository after a permit was obtained from SAHRA for the removal of the fossils, after which the development may proceed, or:

c. The fossils are scientifically important and the palaeontologist must obtain a SAHRA permit to excavate the fossils and take them to a recognised fossil repository, after which the development may proceed.

7. If any fossils are found then a schedule of monitoring will be set up between the developer and palaeontologist in case of further discoveries.

9. Declaration of Independence:

I, Jacobus Francois Durand declare that I am an independent consultant and have no business, financial, personal or other interest in the proposed development, application or appeal in respect of which I was appointed other than fair remuneration for work performed in connection with the activity, application or appeal. There are no circumstances that compromise the objectivity of my performing such work.

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