Palaeontological heritage specialist assessment: desktop study

PROPOSED BOTSWANA-SOUTH AFRICA (BOSA) TRANSMISSION INTERCONNECTION PROJECT: SOUTH AFRICAN SECTOR, NORTH WEST PROVINCE

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EXECUTIVE SUMMARY

The *c.*150 km-long South African sector of the proposed Botswana-South Africa (BOSA) Transmission Interconnection Project between the Isang substation near Gaberone, Botswana and the proposed Mahikeng substation near Mahikeng, RSA traverses outcrops of a wide range of geological units in the North West Province. These comprise (1) very ancient Precambrian basement rocks of igneous origin (*e.g.* Ventersdorp Supergroup lavas, Gaborone Complex granites), (2) younger Precambrian sediments and lavas of the Transvaal Supergroup that mainly crop out along the Southern and Northern Bankenveld regions along the margins of the western Transvaal Basin, and (3) Caenozoic superficial sediments of the Kalahari Group including aeolian sands, calcretes and river deposits, among others. The fossil heritage of this region is poorly known. This is probably because of the lack of palaeontological field studies and often low levels of bedrock exposure due to extensive cover by superficial sediments in topographically subdued regions. Important occurrences of Precambrian stromatolites (fossil microbial columns, domes *etc*) are reported from several carbonate subunits of the Chuniespoort and Pretoria Groups of the Transvaal Supergroup, including in the Mafikeng 1: 250 000 sheet area. The underlying igneous basement rocks are completely unfossiliferous while the Caenozoic superficial sediments (including the Kalahari Group) are generally poorly fossiliferous. Rich Caenozoic vertebrate fossil assemblages may be associated, however, with older alluvium, pans, springs as well as calc-tufa, cave and fissure infills in regions featuring karstified limestone or dolomite (*e.g.* Transvaal Supergroup, Kalahari calcretes).

It is concluded that most of the BOSA transmission line project area is generally of low palaeontological sensitivity. However, several sectors of the line underlain by carbonate bedrocks of the Transvaal Supergroup or by consolidated superficial deposits may contain scientifically important occurrences of fossils, such as stromatolites or mammalian remains, that may be threatened by surface clearance or excavations during the construction phase of the transmission line. These sectors are assigned a medium to high palaeosensitivity (SAHRIS website, Groenewald & Groenewald 2014) and as a precautionary measure, especially in view of the general lack of palaeontological field data in the region, it is therefore recommended that once the

powerline footprint is finalised, and *before* construction commences, a specialist palaeontological walk-down of the BOSA transmission line corridor should be conducted by a suitably qualified palaeontologist. The focus of the walk-down would be on potentially-fossiliferous Precambrian carbonate bedrocks (see red dotted sectors highlighted in Figs. 11 to 14), karstified areas (caves and fissure infills), thick calcretes, tufa deposits and ancient, consolidated or semi-consolidated alluvium along major drainage lines. Following the walk-down the specialist should submit a full report to SAHRA documenting any fossil occurrences and making recommendations for further mitigation or monitoring measures for the pre-construction or construction phases of the transmission line. These recommendations must be incorporated into the Environmental Management Programme for the development. 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 published by SAHRA (2013).

The following mitigation measures to safeguard fossils exposed as chance finds on site during the construction phase of the development are recommended (Please also see the tabulated Chance Fossil Finds Procedure appended to this report). The ECO and / or the Site Engineer responsible for the development must remain aware that all sedimentary deposits have the potential to contain fossils and he / she should thus monitor all substantial excavations into sedimentary bedrock for fossil remains on an ongoing basis. If any substantial fossil remains (*e.g.* stromatolites, vertebrate bones, teeth, horn cores) are found during construction SAHRA should be notified immediately (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). This is so that appropriate mitigation (*i.e.* recording, sampling or collection) by a palaeontological specialist can be considered and implemented, at the developer's expense.

Provided that the mitigation measures outlined above are adhered to, the residual impact significance of any construction phase impacts on local palaeontological resources are anticipated to be low.

1. INTRODUCTION

1.1. Project outline and brief

The proposed Botswana-South Africa (BOSA) Transmission Interconnection Project involves the construction of a new 400 kV transmission powerline of *c*. 210 km length between the existing Isang Substation near Gaberone in Botswana and the proposed Watershed B substation (also referred to as the Mahikeng Substation) near Mahikeng in South Africa (Fig. 1). Approximately 150 km of the new transmission line will be situated within the North West Province of the Republic of South Africa (Ramotshere Moiloa and Mahikeng Local Municipalities, Ngala Modiri Molema District Municipality). The application for environmental authorisation for this development is for a 1 km-wide corridor within which the transmission lines will be located.

The project area for the BOSA transmission line is underlain by potentially-fossiliferous sedimentary rocks of Precambrian and Late Caenozoic age (Sections 2 and 3). The construction phase of the development may entail substantial surface clearance as well as excavations into bedrocks or superficial sediments (*e.g.* for pylon footings and new access roads). All these developments may adversely affect legally-protected 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. All palaeontological heritage resources in the Republic of South Africa are protected by the National Heritage Resources Act (Act 25 of 1999) (See Section 1.2 below). Heritage resource management in the North West Province is the responsibility of the South African Heritage Resources Agency or SAHRA (Contact details: SAHRA, 111 Harrington Street, Cape Town. PO Box 4637, Cape Town 8000, South Africa. Phone: +27 (0)21 462 4502. Fax: +27 (0)21 462 4509. Web: www.sahra.org.za).

The Environmental and Social Impact Assessment Report (ESIA) compiled for the BOSA transmission line development (DEA REF: 14/12/16/3/3/2/1025) by Aurecon South Africa (Pty) Ltd (Aurecon, March 2018) was conducted in terms of the Environmental Impact Assessment (EIA) Regulations (Government Notices R983 to 985 of 2014, as amended) promulgated in terms of the National Environmental Management Act (No. 107 of 1998) (NEMA) in South Africa and the Environmental Assessment Regulations (2012) promulgated in terms of the Environmental Assessment Act (No. 10 of 2011), Schedule 1 (Regulation 3) in Botswana. Very brief reference to palaeontological heritage resources, largely at desktop level, is made in the supporting Heritage Impact Assessment for the BOSA project by Gaigher (2017) who concluded that the palaeontological heritage impact was probably low but recommended a heritage walk-down survey of final pylon positions before construction. The associated cultural heritage & archaeological management plan (Appendix 9) does not make specific recommendations regarding palaeontological heritage.

In response to submission of a Draft Scoping report for the BOSA project, SAHRA issued an Interim Comment stating that: *A desktop palaeontological must be conducted by a qualified palaeontologist for the proposed project. The desktop study must comply with the 2012 Minimum Standards: Palaeontological Component for Heritage Impact Assessments* (SAHRA Case ID: 11363; letter dated Feb. 19, 2018). Before a desktop study was submitted for comment by SAHRA, the Department of Environmental Affairs granted Environmental Authorisation for the BOSA transmission line in July 2018 with no conditions specifically relating to palaeontological heritage. This decision has since (26 July 2018) been appealed by SAHRA.

The present desktop palaeontological heritage assessment for the South African sector of the BOSA transmission line project which had been commissioned by Aurecon South Africa (Pty) Ltd (Contact details: Ms Diane Erasmus. Aurecon South Africa (Pty) Ltd. Address: Aurecon Centre, Lynnwood Bridge Office Park 4, Daventry Street, Lynnwood Manor 0081.Tel: +27 44 805 5428; Fax: +27 44 805 5454; E-mail: diane.erasmus@aurecongroup.com) has since been completed. The present desktop assessment refers only to the *c*. 150 km sector of the BOSA transmission line within the North West Province of the RSA. The proposed new Mahikeng Substation will be the subject of a separate assessment process (*cf* Durand 2018).

1.2. Legislative context for palaeontological assessment studies

The various categories of heritage resources recognised as part of the National Estate in Section 3 of the National Heritage Resources Act (Act 25 of 1999) include, among others:

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

1.3. Approach to the desktop palaeontological heritage study

The approach to this desktop palaeontological heritage study is briefly as follows. Fossil bearing rock units occurring within the broader study area are determined from geological maps and satellite images. Known fossil heritage in each rock unit is inventoried from scientific literature, previous assessments of the broader study region, and the author's field experience and palaeontological database (See Table 1). 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 and recommendations for any necessary further studies or mitigation are made.

In preparing a palaeontological **desktop** study (as is the case in this report) 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 a development (Provisional tabulations of palaeontological sensitivity of all formations in the North West Province have already been compiled by J. Almond and colleagues; *cf* Groenewald & Groenewald 2014).

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 North West Province). It should be emphasized that, *provided that 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 BOSA project area in the Ngala Modiri Molema District Municipality, North West Province, a major limitation for fossil heritage studies is the low level of surface exposure of many potentially fossiliferous bedrocks (*e.g.* readily-weathered carbonate sediments), as well as the paucity of previous field-based specialist palaeontological studies in the North West Province as a whole.

1.5. Information sources

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

1. Project outlines and maps abstracted from the Environmental and Social Impact Assessment Report (ESIA) compiled for the BOSA development by Aurecon South Africa (Pty) Ltd (Aurecon, March 2018) as well as the Heritage Impact Assessment report by Gaigher (2017);

2. A review of the relevant scientific literature, including published geological maps and accompanying sheet explanations (*e.g.* Walraven 1981, Michaluk & Moen 1991, Groenewald & Groenewald 2014) as well as a few desktop and field-based palaeontological assessment studies in the broader region of the North West Province : *e.g.* Almond 2017, Rossouw 2017, Durand 2018);

3. Examination of relevant 1: 250 000 topographical maps and Google Earth© satellite images;

4. The author's previous field experience with the formations concerned and their palaeontological heritage.

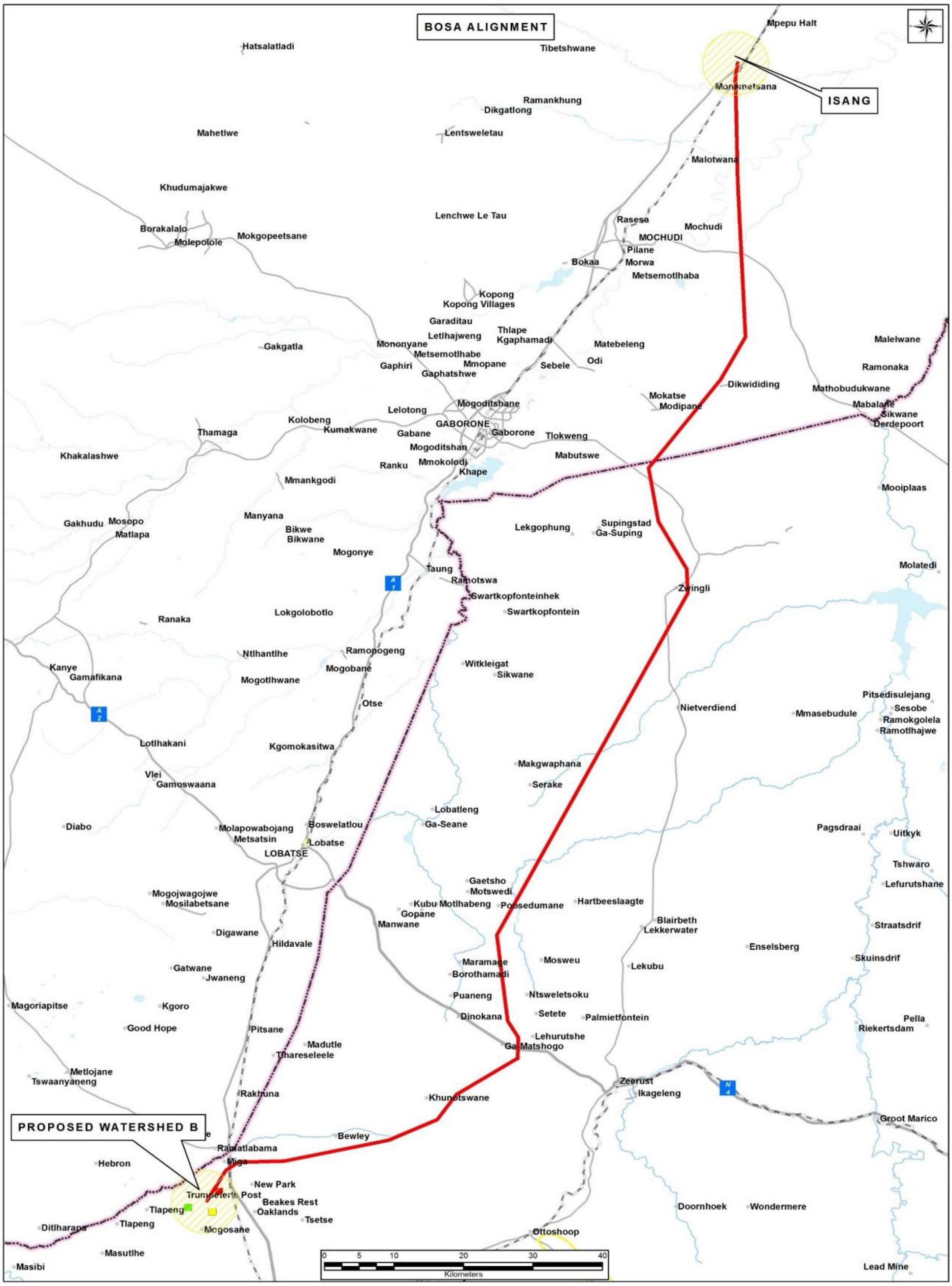

Figure 1. Map showing the route (red line) of the proposed Botswana-South Africa (BOSA) 400kV Transmission Interconnection between the existing Isang substation near Gaberone in Botswana and the proposed new Watershed B substation (referred to as Mahikeng substation) near Mahikeng in South Africa. The Mahikeng Substation will be located at one of the three sites under consideration within the yellow circle. The present desktop assessment refers to the *c*. 150 km sector of the BOSA transmission line within the North West Province of the RSA.

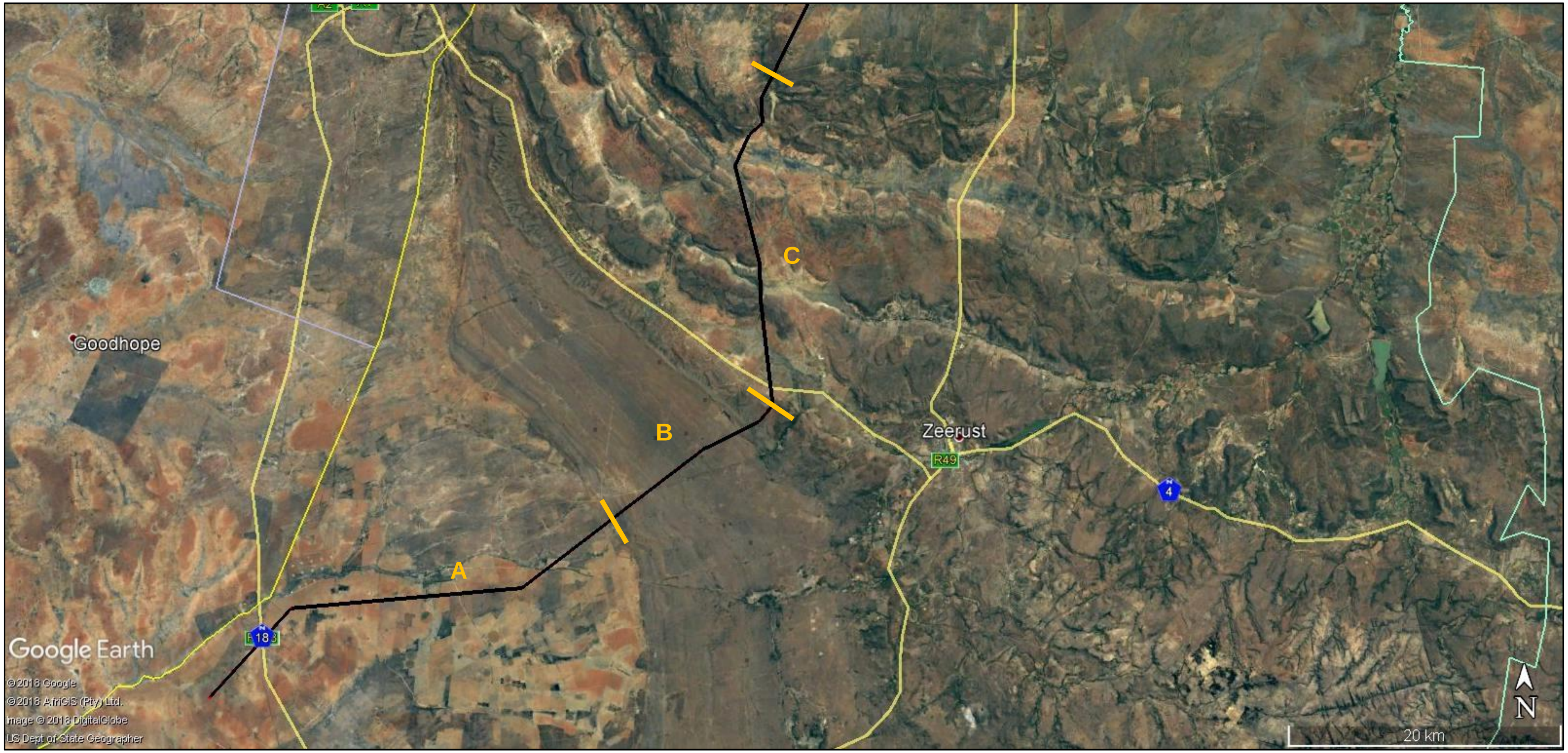

Figure 2. Google earth© satellite image of BOSA 400 kV transmission line geological Sectors A, B and C, North West Province, South Africa. Dark yellow line = RSA / Botswana Border. Black line = BOSA transmission line corridor.

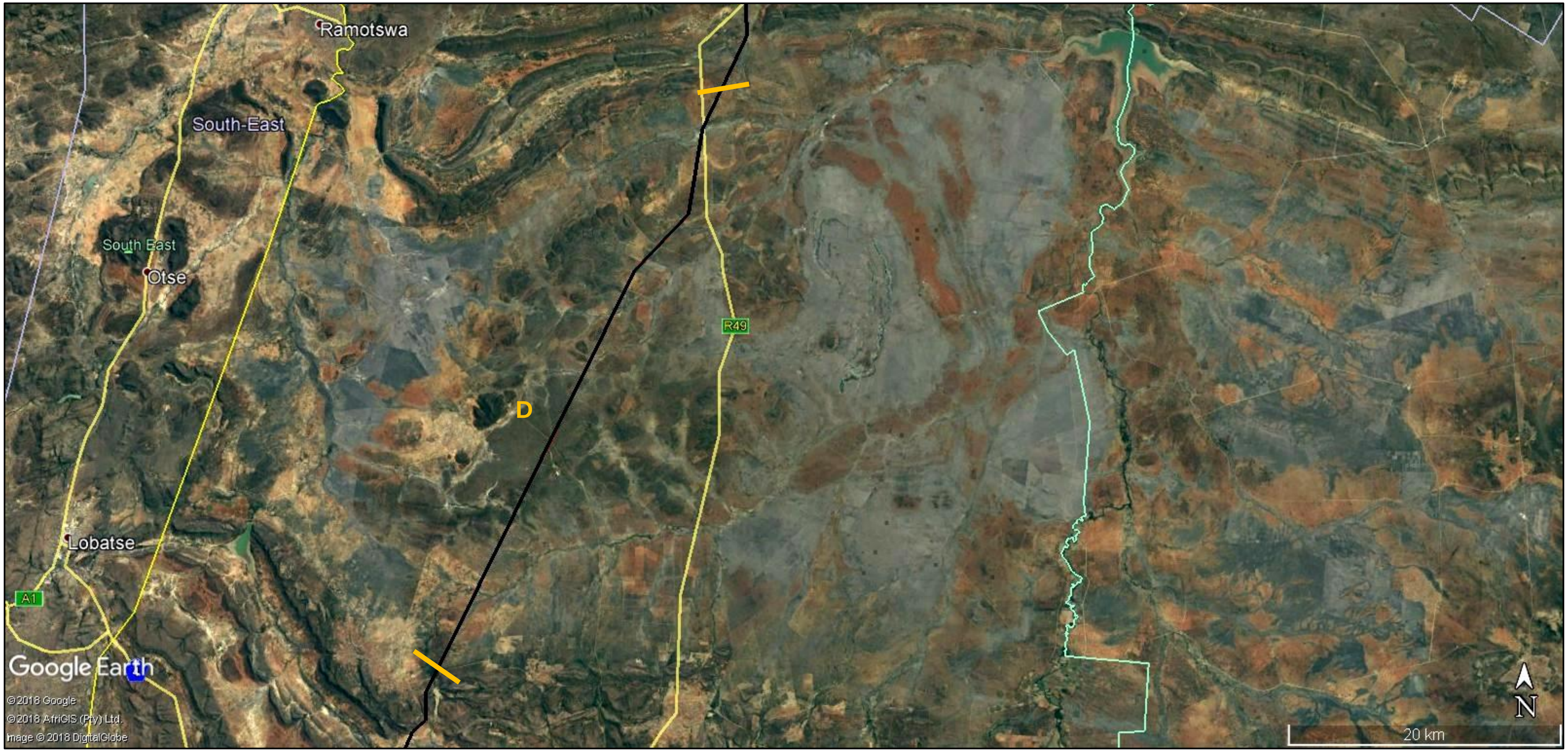

Figure 3. Google earth© satellite image of BOSA 400 kV transmission line geological Sector D, North West Province, South Africa. Dark yellow line = RSA / Botswana Border. Black line = BOSA transmission line corridor.

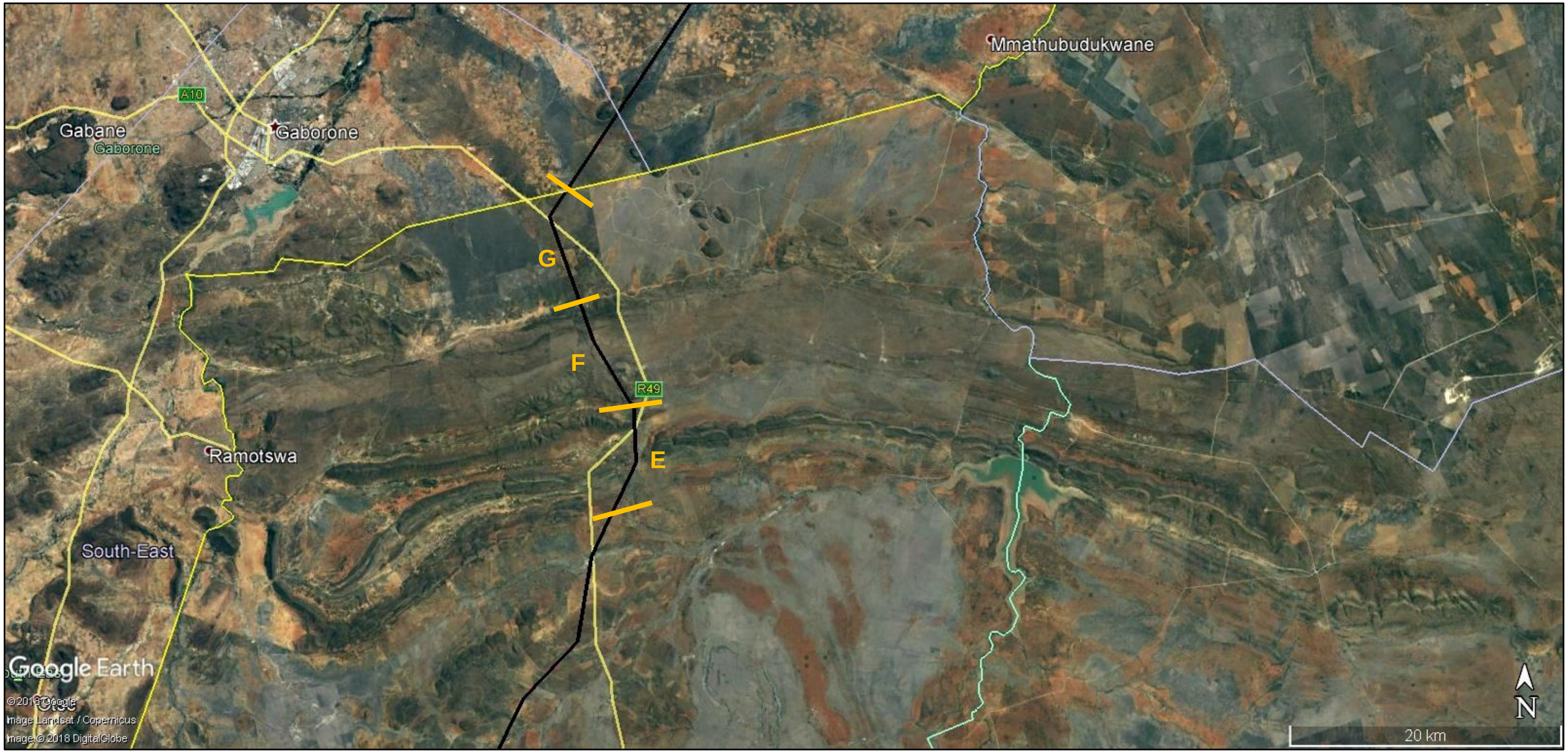

Figure 4. Google earth© satellite image of BOSA 400 kV transmission line geological Sectors E, F and G, North West Province, South Africa. Dark yellow line = RSA / Botswana Border. Black line = BOSA transmission line corridor.

2. GEOLOGICAL OUTLINE OF THE PROJECT AREA

The BOSA transmission line project area in North West Province, RSA, lies in semi-arid terrain towards the south-eastern margins of the Kalahari Basin of southern Africa (Partridge *et al.* 2006). The transmission line crosses several adjoining geomorphic provinces as defined by Partridge *et al.* (2010), namely the Kalahari Geomorphic Province drained by Molopo and Phepane Rivers, the NW Highveld Geomorphic Province drained by the Harts River, the Southern Bankenveld Geomorphic Province, the Western Transvaal Basin drained by the Madikwane River, the Northern Bankenveld Geomorphic Province drained by the Madikwane River, and the Western Limpopo Flats Geomorphic Province drained by the Marico River (Fig. 5).

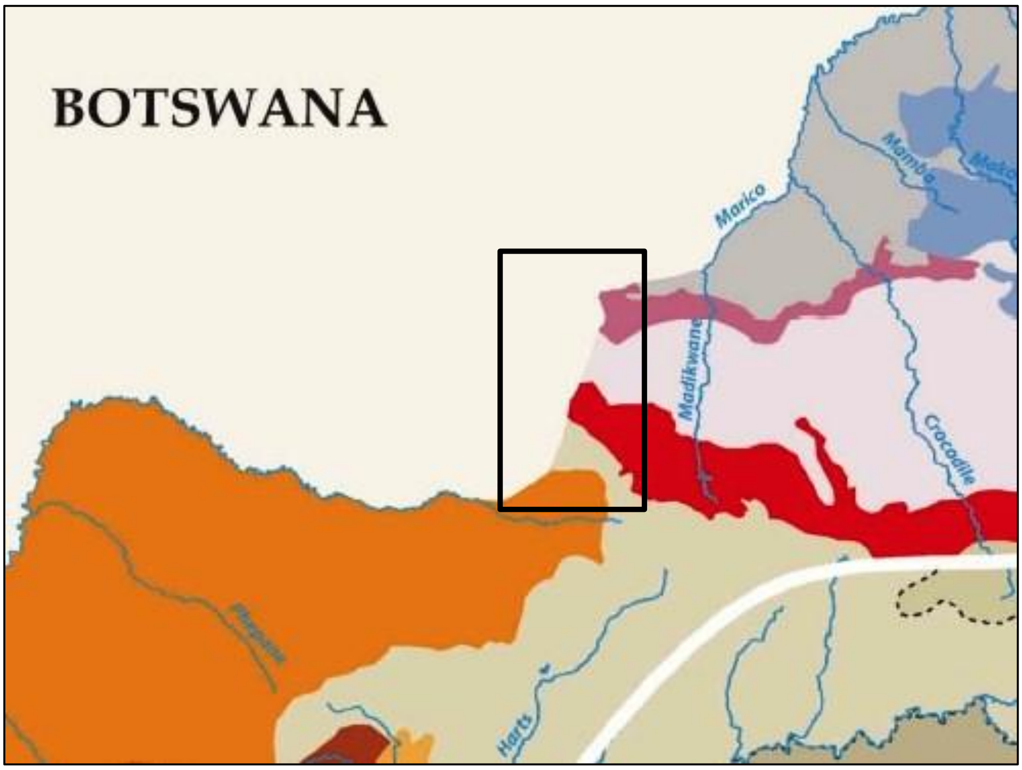

Figure 5. Geomorphic provinces represented within the BOSA transmission line study region (black rectangle) in the North West Province, RSA (extract from Partridge *et al.* 2010, their Map 1): Kalahari Geomorphic Province (orange), NW Highveld (pale grey), Southern Bankenveld (red), Western Transvaal Basin (pink), Northern Bankenveld G (purple), Western Limpopo Flats (grey).

The geology of the BOSA transmission line study region is shown on three adjoining 1: 250 000 geological sheets, *viz*. sheet 2524 Mafikeng, sheet 2526 Rustenburg and sheet 2426 Thabazimbi (Council for Geoscience, Pretoria) (See overview map in Fig. 6 herein). Short explanations to the first two sheets have been published by Michaluk and Moen (1991) and Walraven (1981) respectively, while only a very brief, and somewhat outdated, explanation to the Thabazimbi sheet is published on the geological map itself.

In the BOSA transmission line project area the bedrock geology beneath the Kalahari cover rocks is dominated by ancient Precambrian (Late Archaean – Early Proterozoic) sediments, metasediments (metamorphosed sediments) and lavas of the Transvaal Supergroup (Eriksson *et al.* 2006). The transmission line corridor traverses the western portion of the Transvaal Basin (Fig. 7). The stratigraphy of the Transvaal Supergroup succession is outlined in Figures 8 and 9. The oldest **Transvaal Supergroup** beds - proto-basinal rocks of the **Black Reef Formation** and **Tschwene-Tshwene Belt** followed by carbonates of the **Chuniespoort Group** - build the Southern and Northern Bankenveld on the margins of the basin. The younger **Pretoria Group** sedimentary and volcanic succession – locally intruded by younger igneous rocks of the **Bushveld Complex** - crops out towards the basin centre. Outside the Transvaal Basin, even older - but predominantly igneous - bedrocks beneath the northern and southwestern sectors of the powerline are assigned to the Archaean **Ventersdorp Supergroup** (volcanics with subordinate sediments) (Van der Westhuizen *et al.* 2006) and associated major intrusions such as the **Gaborone Granite Complex**. Considerable stretches of the Precambrian bedrocks within the BOSA transmission line corridor are mantled by a broad spectrum of thin to thick cover sediments broadly assigned to the Cretaceous to Recent **Kalahari Group** (Partridge *et al.* 2006) which may be up to 70 m thick in the Mafikeng 1: 250 000 sheet area (Michaluk & Moen 1991) (Fig. 10). These include, most notably, aeolian sands of the Pleistocene to Recent **Gordonia Formation** as well as alluvial deposits along drainage lines, colluvial sediments such as scree, pedocretes (*e.g.* calcrete), surface gravels and soils. Any cave, spring and pan sediments, although small in volume and unmapped at 1: 250 000 scale , may be of considerable palaeontological interest.

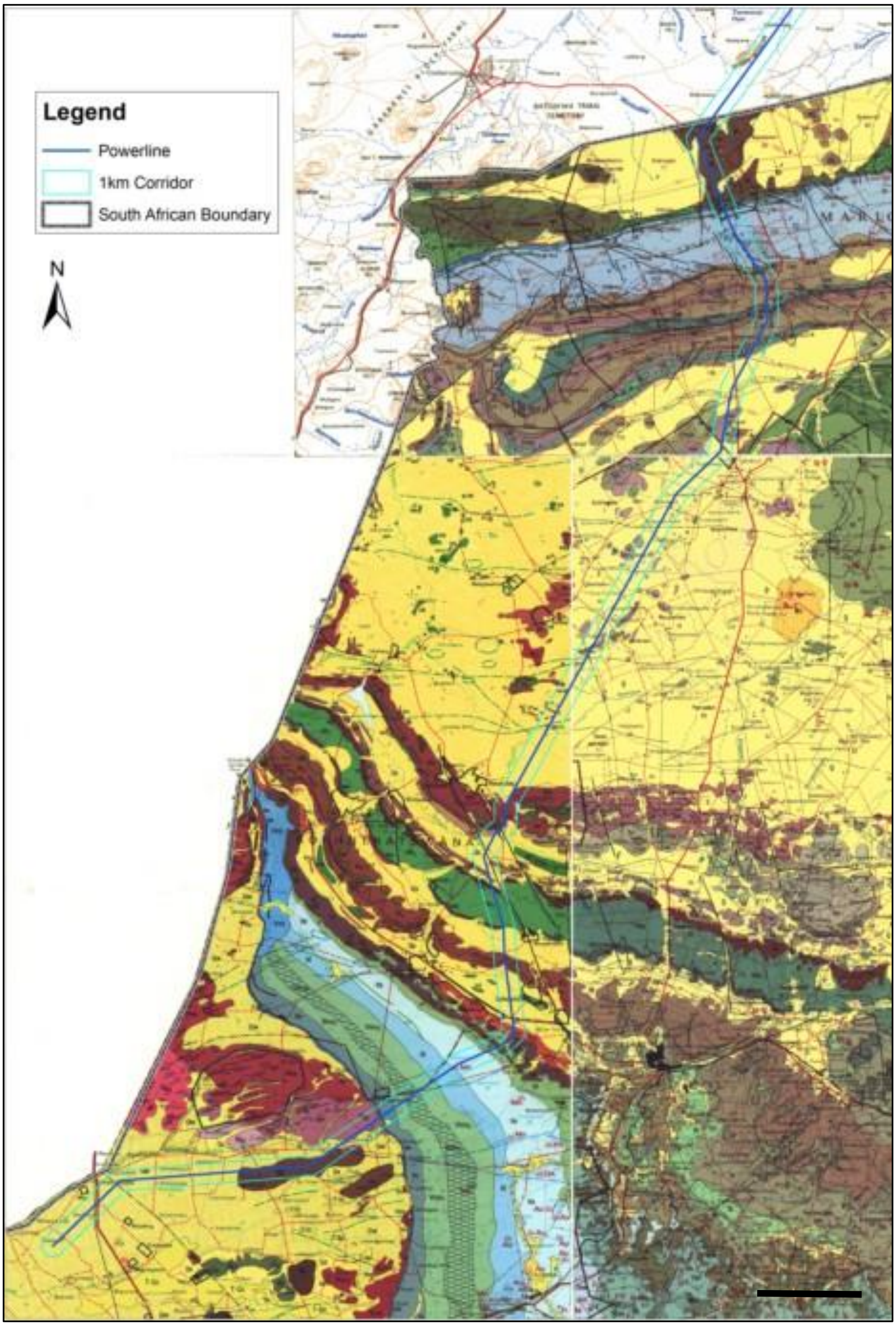

Figure 6. Composite geological map of the BOSA transmission line study region compiled from extracts from adjoining 1: 250 000 sheets 2524 Mafikeng, 2526 Rustenburg and 2426 Thabazimbi (Council for Geoscience, Pretoria). The 400 kV transmission line corridor is indicated by the dark blue line. Scala bar = 10 km. N towards the top of the image. Please see also the series of detailed maps presented in Figs. 11 to 14 below.

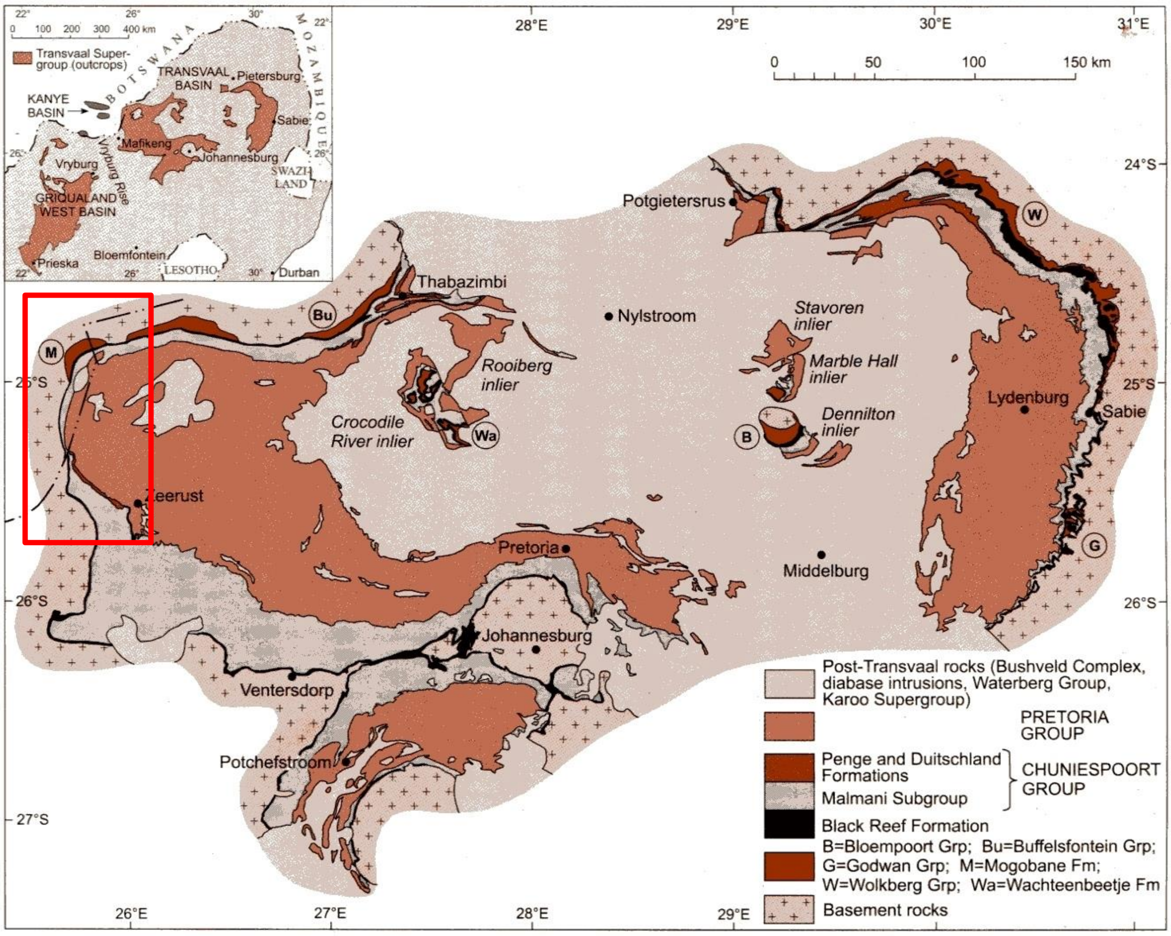

Figure 7. Geological map of the Transvaal Basin in the north-eastern RSA and Botswana showing the main Precambrian Transvaal Supergroup successions represented within the BOSA transmission line study region (red rectangle) (Figure abstracted from Eriksson *et al.* 2006).

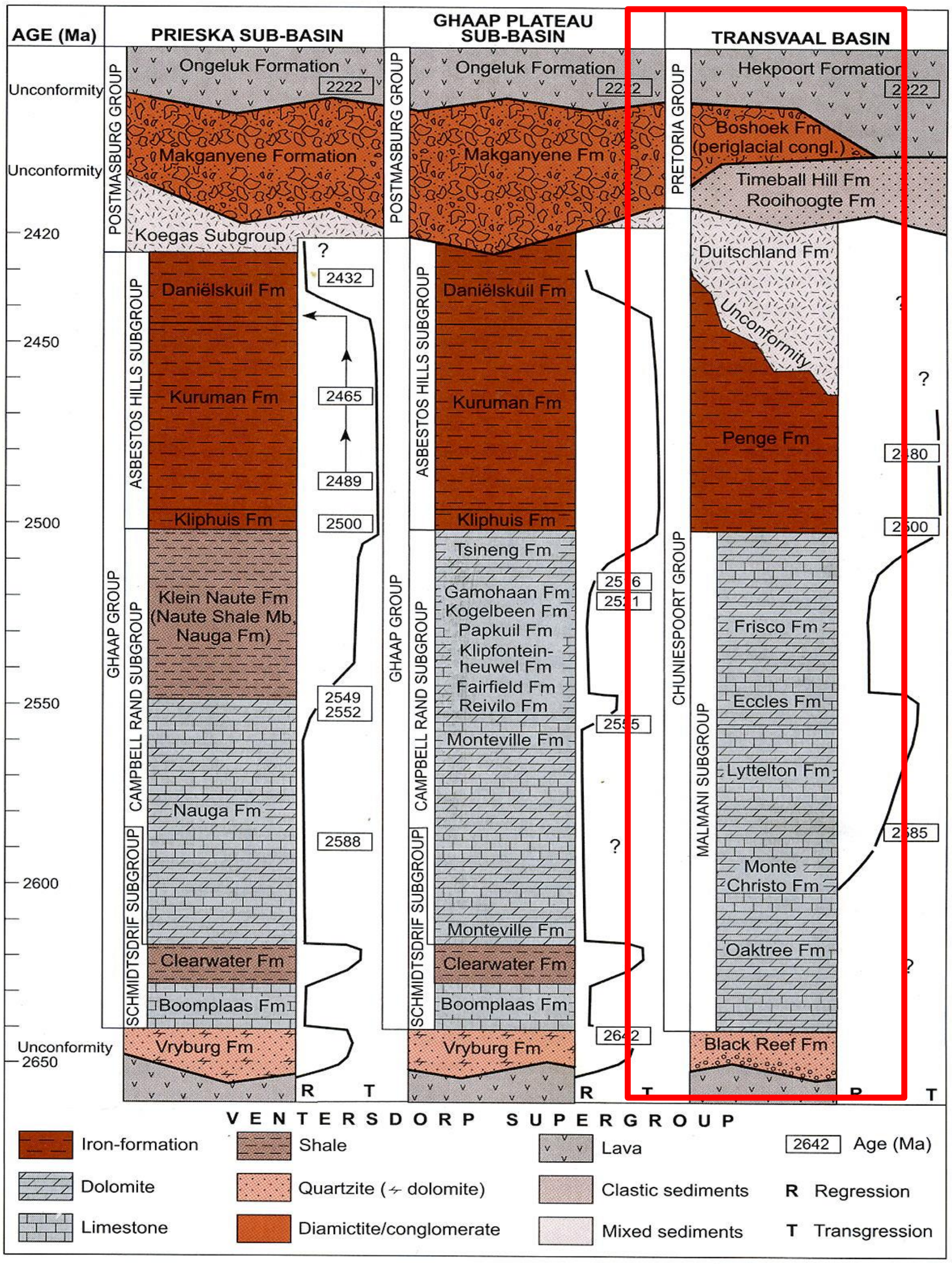

Figure 8. Stratigraphy of the lower part of the Transvaal Supergroup in the Transvaal Basin showing the main rock units represented within the BOSA transmission line project area (red rectangle) (Figure abstracted from Eriksson *et al.* 2006).

FORMATIONS		WESTERN AREA	CENTRAL AREA	EASTERN AREA	SOUTHERN AREA	Inferred palaeoenvironments
Houtenbek	Mudrock (tuffaceous in places), sandstone, limestone	Rayton/Woodlands Formation in far west (mudrock, sandstone) ≤200 m	Rayton Formation (mudrock, sandstone, minor andesite and dolomite) ~1200 m	150–200 m	Absent	Fan, fan-delta, delta, shallow lacustrine
Steenkampsberg	Sandstone			450–600 m		
Nederhorst	Sandstone (arkosic in places) Mudrock (tuffaceous in places)			200–800 m		
Lakenvalei	Sandstone			200–350 m		
Vermont	Mudrock (tuffaceous in places)			500–700 m		
Magaliesberg	Sandstone with mudrock lenses and interbeds	150–430 m, significant mudrock, sandstones thicken westwards and eastwards	260–340 m, subordinate mudrocks thicken westwards	~225–550 m, subordinate mudrock	≤340 m, mostly eroded	Regressive sandy shoreline, braid-delta, high-energy tidal flat
Silverton	Carbonate rocks Lydenburg Shale Member (commonly tuffaceous) Machadodorp Volcanic Member (pyroclastic rocks, basalt) Boven Shale Member	~500–1328 m, reworked tuffs common, thins westwards, uppermost carbonates ~117–167 m thick, Machado-dorp Member absent, basal shale generally thin	~450–850 m, Machadodorp Member 1–2 m thick, upper shales thin	~1040–2230 m, lower shales generally thin, Machadodorp Member ~57–517 m thick	≤1365 m, Machadodorp Member thin (≤6 m), mostly eroded	Relatively deep-water, transgressive epeiric sea; volcanic activity, mainly in the east
Daspoort	Sandstone, mudrock	~65–120 m, sandstone pebbly in far west	~40–110 m, pebbly sandstone common	~10–120 m, sandstone pebbly, thicker in north, ironstones in northeast	~45–80 m, sandstone pebbly	Distal fan, fluvial braid-plain, braid-delta; transgressive epeiric sea in the east
Strubenkop	Mudrock, subordinate sandstone	~50–360 m, minor sandstone	~100–150 m, significant sandstone, minor tuff	~30–145 m, thickens to north and south	~80–185 m, thickens southwards	Transgressive lacustrine
Dwaalheuwel	Sandstone, conglomerate, subordinate mudrock	~15–70 m, basal conglo-merate in north	≤3–4 m, lenticular, absent in places	~40–110 m, minor conglomerates in north	Absent	Alluvial fan, fan-delta
Hekpoort	Basaltic andesite, pyroclastic rocks	~190–890 m, thins northwards	~340–630 m, air-fall and reworked pyroclastics relatively common	~90–500 m, thins northwards, pyroclastics common	~430–1140, significant tuffs (200–300 m thick), thickens southwards	Volcanic
Boshoek	Sandstone, conglomerate, diamictite	~35–70 m, significant conglomerates	≤2 m, mostly absent	~20–80 m, large channels	~30–60 m, localised diamictite	Alluvial fan, slump deposits
Timeball Hill	Upper mudrock unit Diamictite/conglomerate/arkose lens	Mudrock 200–430 m, thickens westwards	Mudrock 130–350 m, thick lens of diamictite/ conglomerate	Mudrock ~225–750 m, thickens northwards, thick arkose/diamictite lenses in north and northeast	Mudrock ~130–300 m	Relatively deep lacustrine (with suspension sedimentation and turbidity currents), distal fluvio-deltaic, basal volcanism in south and southwest
	Klapperkop Quartzite Member	Quartzite ~90–620 m, thickens westwards	Quartzite ~40	Quartzite ~70–230 m, thins southwards	Quartzite ~40–100 m, thins southwards	
	Lower mudrock unit	Mudrock 160–460 m, thickens westwards	Mudrock ~220–350 m	Mudrock ~300–580 m, thins to south, thin tuff bed	Mudrock ~80–540 m, thickens southwards	
	Bushy Bend Lava Member	Minor basal lavas			Bushy Bend Member ≤90 m	
Rooihoogte	Polo Ground Quartzite Member Mudrock, subordinate carbonate rocks Bevets Conglomerate/Breccia Member	~17–232 m, basal conglo-merate thick in north, shale thick in south	~10–50 m, breccia and conglomerate lenticular, Polo Ground Member thin	≤~2–140 m, thickest in Dennilton and Marble Hall fragments	~14–150 m, thick breccia	Karst-fill, alluvial fan, lacustrine
Chuniespoort Group	Iron-formation, dolomite		Palaeokarst topography			

Figure 9. Stratigraphy of the Early Proterozoic Pretoria Group in the western part of the Transvaal Basin showing the rock units represented within the BOSA transmission line project area (red rectangle) (Figure abstracted from Eriksson *et al.* 2006).

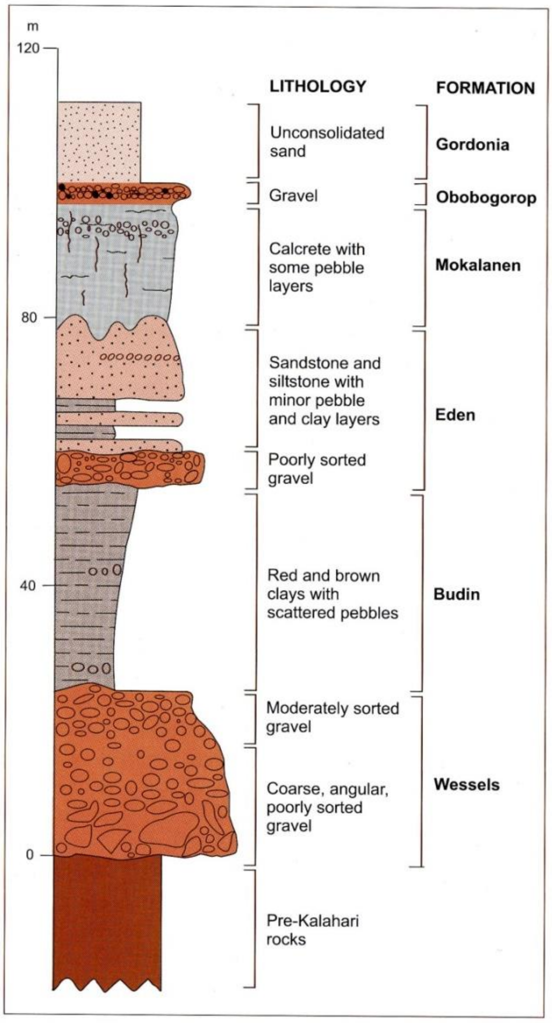

Figure 10 Generalised stratigraphy of the Late Cretaceous to Recent Kalahari Group (From Partridge *et al.* 2006). Apart from Gordonia aeolian sands and underlying calcretes it is unclear from the available 1: 250 000 geological maps exactly which of these units are represented at or below the surface within the BOSA transmission line project area.

For the purposes of the present desktop palaeontological desktop study, the South African (North West Province) portion of the BOSA powerline route can be subdivided, from south to north, into the following seven unequal sectors (A to F) on the basis of the underlying geology (Please refer to satellite images Figs. 2-4 and geological maps Figs. 11 - 14)

- **Sector A**

This sector at the south-western end of the BOSA transmission line traverses flat (*c*. 1250-1450 m amsl), extensively cultivated terrain of the Malopo and Marico regions due north of Mahikeng. It is *c*. 34 km long. Most of the sector is mantled by Late Caenozoic superficial sediments of the Kalahari Group, including aeolian sands of the Gordonia Formation and calcrete hardpans *plus* alluvium along major water courses such as the Ramatlabama River, a tributary of the Molopo the runs westward to RSA / Botswana border near Ramatlabama. Small inliers of predominantly igneous, Early Precambrian (Randian) basement rocks are assigned to the Ventersdorp Supergroup (Klipriviersberg Group lavas) and granitic intrusions.

- **Sector B**

This sector (*c*. 15 km long), largely located to the southwest of the Makadima Range (Southern Bankenveld) some 16 km due west of Zeerust, traverses flattish terrain at *c*. 1450 m amsl. for the most part and is underlain by Late Archaean subunits forming the lower part of the Transvaal Supergroup. These include proto-basinal sediments of the Black Reef Formation and thick, carbonate-dominated successions of the Malmani Subgroup (Chuniespoort Group) represented by five mapped formations (Fig. 8). Along the NW-SE trending Makadima Range at the northern end of the sector the Malmani carbonates are overlain by banded ironstones of the Early Proterozoic Penge Formation.

- **Sector C**

This sector of c. 25 km crosses highly-dissected, rugged hilly terrain of the Southern Bankenveld situated between Zeerust and Lobatse. It traverses almost the entire succession of the Early Proterozoic Pretoria Group (Transvaal Supergroup), younging towards the north (See Fig. 9 for stratigraphic subdivisions). The beds here dip to the NNE with SSW-facing scarps of more resistant-weathering rock units such as quartzites and conglomerates (Rooihoogte, Boshoek, Dwaalheuwel, Daspoort and Magaliesberg Formations). On satellite images the Hekpoort Formation lavas appear rusty-brown while the thick, recessive-weathering, mudrock-dominated Silverton Formation underlies a strike-parallel valley (*e.g.* Ngotwane River Valley). The upper Pretoria Group units are extensively intruded by dolerite (*e.g.* in the Mogologadikwe Range). Bands of Late Caenozoic Superficial Deposits mantle the lowlands between subparallel ridges of the Bankenveld.

- **Sector D**

This long sector (*c*. 48 km) of the BOSA transmission line heads roughly SSW-NNE across topographically subdued terrain between the Southern and Northern Bankenveld ranges, the latter represented here by the Dwarsberge due east of Ramotswa. This low-lying region is largely mantled by Late Caenozoic superficial deposits, including alluvium of the Sandsloot and Brakfonteinspruit systems which drain towards the NE (Molatedi Dam). Projecting through the superficial cover sediments are numerous small inliers of upper Pretoria Group bedrocks (*e.g.* Rayton Formation) intruded by dolerite. An outlier of Magaliesberg and Silverton Formation bedrocks near Sandbult, forming a ridge running subparallel to and largely west of the BOSA corridor, is intruded by gabbros of the Bushveld Complex.

- **Sector E**

A short powerline sector (*c*. 9 km) crosses the Northern Bankeveld, here represented by the W-E trending Dwarsberge Range (1200-1300 m amsl.). In stratigraphic terms this is a mirror image of the Pretoria Group succession of the Southern Bankenveld, from the basal Rooihoogte in the north passing up *via* the Hekpoort lavas to the Magaliesberg quartzites (extensively intruded by dolerite) in the south near the top of the succession. Here, however, the Pretoria beds dip and young towards the south, with resistant-weathering formations building steep, N-facing scarps and gentle S-sloping dip slopes. Superficial sediments mantle the lowlands but are not mapped as such on the Thabazimbi 1: 250 000 sheet.

- **Sector F**

This short (*c*. 7 km) powerline sector crosses the lower units of the Transvaal Supergroup along the NW margins of Transvaal Basin. The terrain is mainly flat at 1000-1200 m amsl with higher ground along the Rant van Tweede Poort. Proto-basinal rocks are represented here by lavas and coarse clastic sediments of the Tschwene-Tshwene Belt (Eriksson *et al.* 2006, Fig. 4) while Malmani Subgroup carbonates, *plus* dolerite towards the base, build low-lying terrain further south (but also Abaterskop at 1377 m amsl). Banded ironstones are not mapped separately in the upper Chuniespoort Group here.

- **Sector G**

North of the Bankenveld, and outside the Transvaal Basin, the last 10 km of the BOSA transmission line traverses Randian basement rocks - mainly comprising andesitic to acid lavas *plus* quartzites of the Ventersdorp Supergroup as well as granites of the Gabarone Complex (*cf* Section A). The ancient bedrocks underlie flat terrain at *c*. 1000-1150 m amsl. with an extensive mantle of Late Caenozoic Kalahari Group cover sediments.

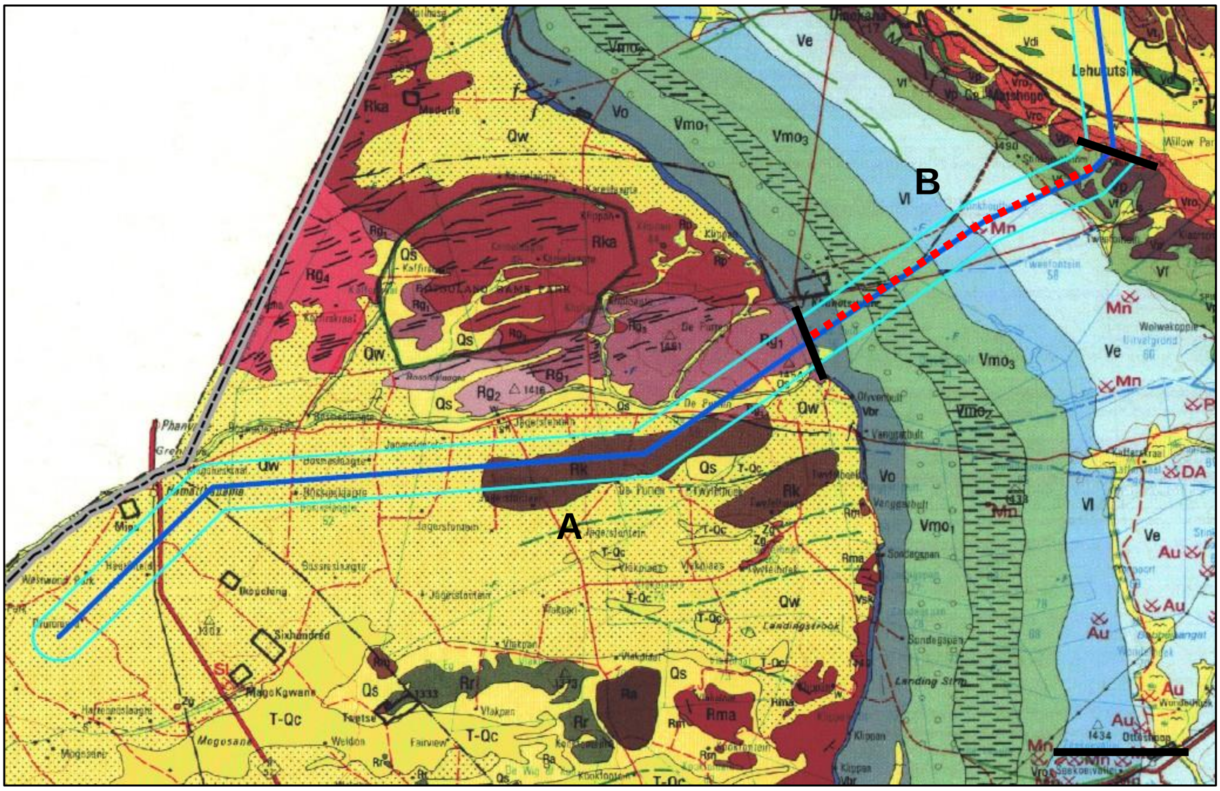

Figure 11. Detailed geological map of Sectors A & B of the BOSA transmission line (Extract from 1: 250 000 sheet 2524 Mafikeng, Council for Geoscience. Pretoria). Scale bar = 5 km. N towards top of the image. Red dotted sectors are of medium to high palaeosensitivity and should be subject to a specialist palaeontological walk-down in the pre-construction phase of the transmission line project.

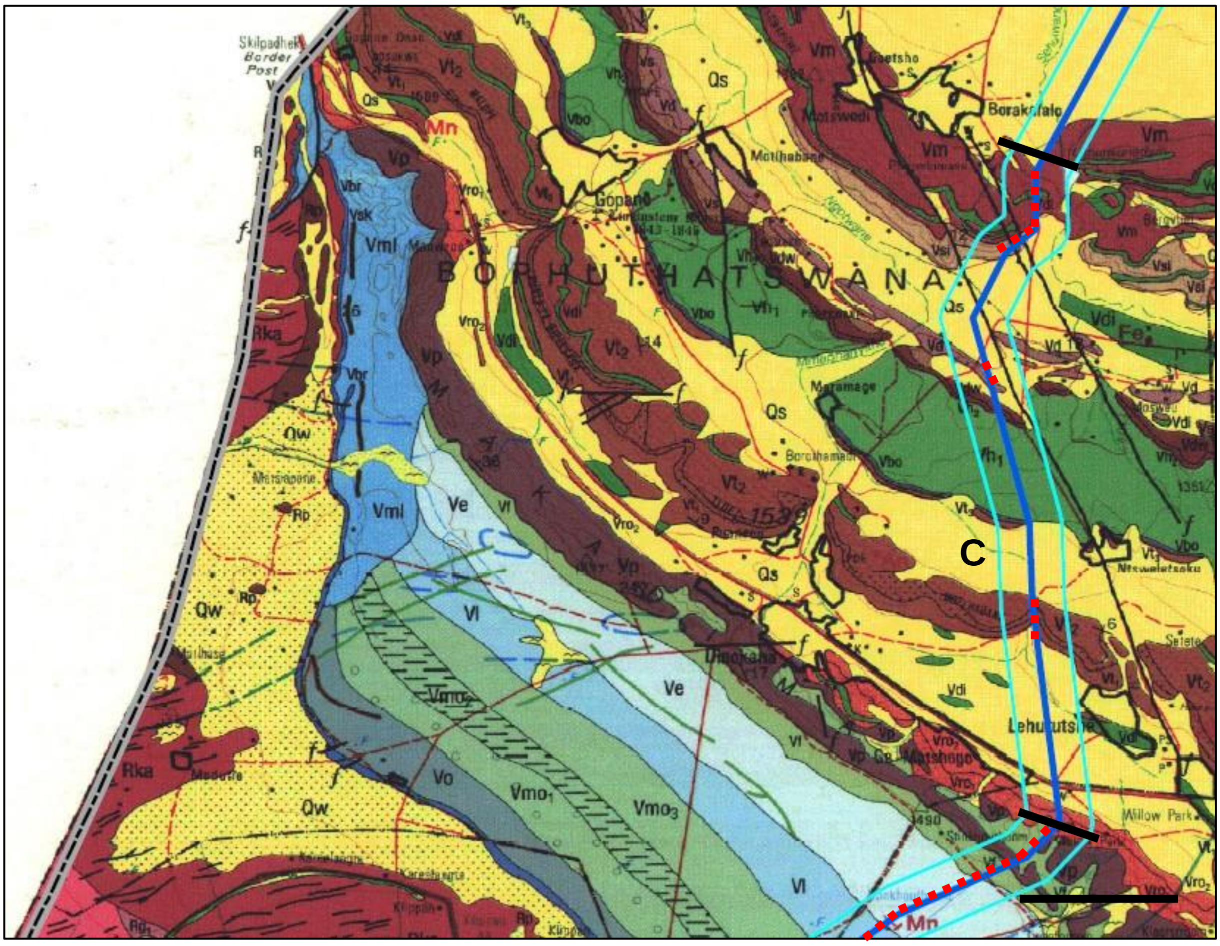

Figure 12. Detailed geological map of Sector C of the BOSA transmission line (Extract from 1: 250 000 sheet 2524 Mafikeng, Council for Geoscience. Pretoria). Scale bar = 5 km. N towards top of the image. Red dotted sectors are of medium to high palaeosensitivity and should be subject to a specialist palaeontological walk-down in the pre-construction phase of the transmission line project.

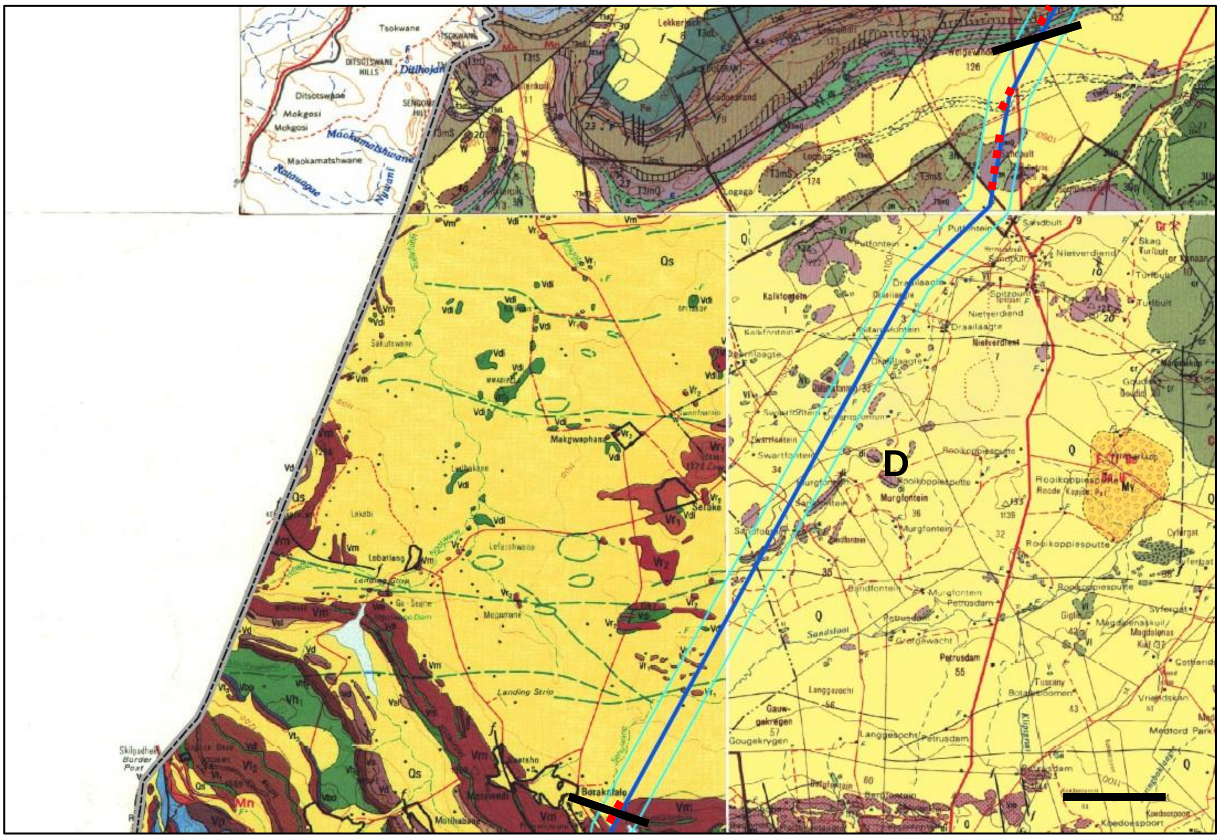

Figure 13. Detailed geological map of Sector D of the BOSA transmission line (Extracts from adjoining 1: 250 000 sheets 2524 Mafikeng, 2526 Rustenburg and 2426 Thabazimbi, Council for Geoscience. Pretoria). Scale bar = 5 km. N towards top of the image. Red dotted sectors are of medium to high palaeosensitivity and should be subject to a specialist palaeontological walk-down in the pre-construction phase of the transmission line project.

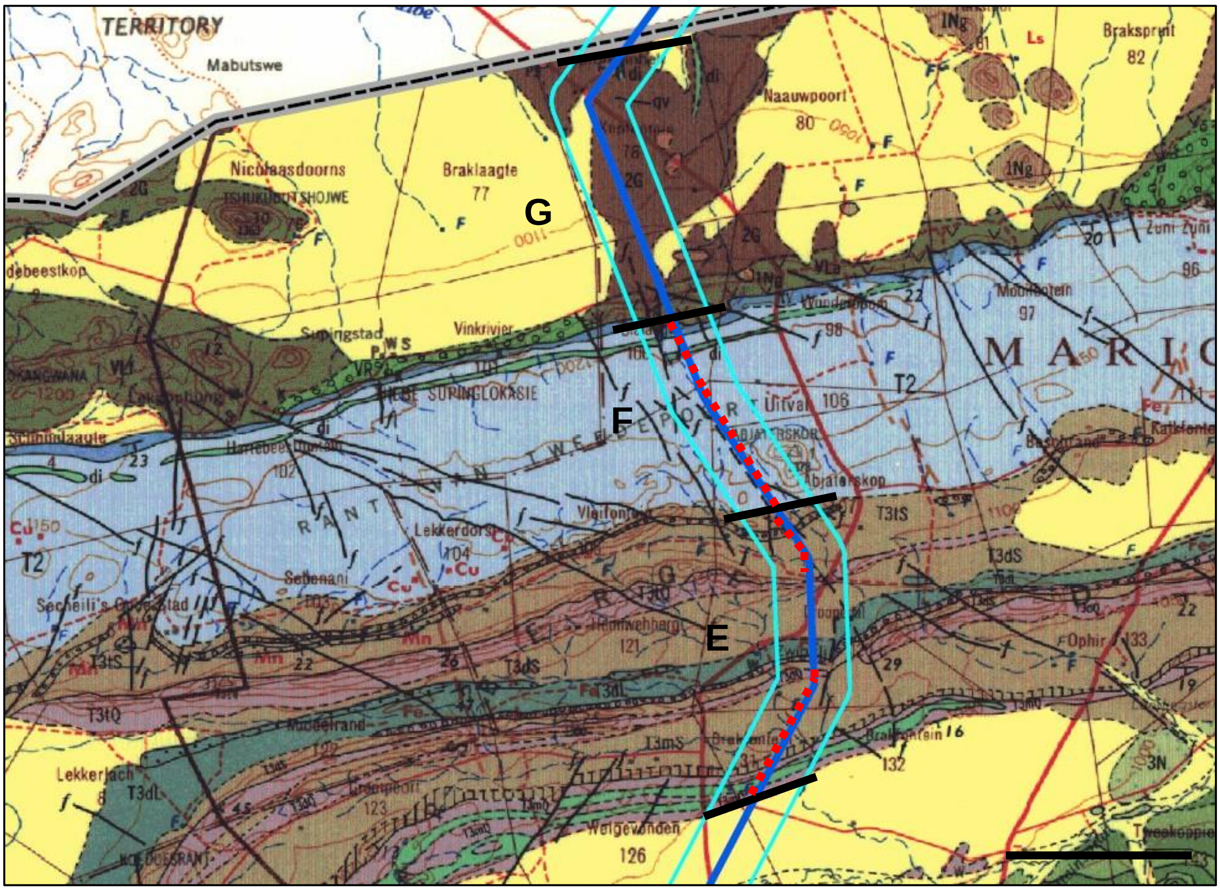

Figure 14. Detailed geological map of Sectors E, F and G of the BOSA transmission line (Extracts from 1: 250 000 sheet 2426 Thabazimbi, Council for Geoscience. Pretoria). Scale bar = 5 km. N towards top of the image. Red dotted sectors are of medium to high palaeosensitivity and should be subject to a specialist palaeontological walk-down in the pre-construction phase of the transmission line project.

3. POTENTIAL PALAEONTOLOGICAL HERITAGE WITHIN THE STUDY AREA

Fossil biotas recorded from each of the main rock units mapped at or near surface within the BOSA transmission line corridor are briefly reviewed in Table 1 where an approximate indication of the overall palaeontological sensitivity of each rock unit is also given (See also Groenewald & Groenewald 2014). Very little fossil data is provided in the relevant 1: 250 000 sheet explanations (Michaluk & Moen, 1991 and Walraven 1981) and the region appears to have been comparatively neglected in palaeontological terms. It is noted that tectonic deformation (cleavage, folding, fracturing), calcretisation and chemical weathering of near-surface bedrocks may have compromised their original fossil heritage in many areas.

- **Ventersdorp Supergroup**

Various Archaean stromatolite occurrences have been recorded from sedimentary intervals within the upper part of the Ventersdorp Supergroup (Platberg Group) but not from the older **Klipriviersberg Group** succession represented within the BOSA project area (Schopf 2006, Van der Westhuizen *et al.* 2006).

- **Proto-basinal rocks and Chuniespoort Group**

Fossils have not so far been recorded from Transvaal Basin proto-basinal successions within the BOSA transmission line study area but stromatolites are known from possibly equivalent rocks (Buffelsfontein Group) near Thabazimbi, North West Province

The overlying **Chuniespoort Group** (Malmani Subgroup) platform carbonates host a variety of stromatolites (microbial laminites), ranging from supratidal mats to intertidal columns and large subtidal domes (*cf* Michaluk & Moen, 1991 for stromatolites in the Mafikeng sheet area, for example). These biosedimentary structures are of considerable biostratigraphic as well as palaeoecological interest. For example, the successive Malmani dolomite formations are in part differentiated by their stromatolite biotas (*e.g.* Truswell and Eriksson 1972, 1973, and 1975, Schopf 2006 and Eriksson *et al.* 1993, 2006, among others). Microbial filaments and unicells have been reported from stromatolites of the Transvaal Supergroup and may also occur within banded ironstone facies of the Penge Formation.

- **Pretoria Group**

To the author's knowledge, no fossil remains have been recorded hitherto from the non-marine **Rooihoogte Formation** succession. Minor carbonate as well as shale facies might yield lacustrine stromatolites and organic-walled microfossils respectively. Stromatolites (microbial mounds) have been recorded from several younger subunits within the Pretoria Group including lacustrine facies of the **Timeball Hill Formation**, marine facies in the **Daspoort Formation** (especially in the eastern outcrop area) and **Silverton Formation**, as well as the mudrock-dominated **Vermont Formation** (Button 1971, Catuneanu & Eriksson 2002, Eriksson *et al.* 2006). Pretoria Group subunits with stromatolites probably also contain organic-walled microfossils. This may well also apply to carbonaceous mudrocks. Microbial mat structures (desiccated mats sometimes resemble trace fossils) are known from paralic sandstones of the **Magaliesberg Formation**. The stromatolites recorded from the Timeball Hill Formation are associated with thin carbonate interbeds within turbidite successions in the lower part of the formation ("lower mudstones"), implying deposition within the photic zone (Catuneanu & Eriksson 2002).

- **Intrusive igneous rocks**

The Randian granitoids of the **Gaborone Complex**, the **dolerite / diabase** units intruding the Transvaal Supergroup as well as the major intrusive sequences of the **Bushveld Complex** are igneous rocks without any fossil remains. They may have compromised fossil preservation in the adjacent country rocks through thermal metamorphism.

- **Late Caenozoic superficial sediments**

The Late Caenozoic superficial sediments (soils, rock rubble *etc*) in the Kalahari study region are generally of very low palaeontological sensitivity but pockets of high to very high sensitivity may also occur here (*e.g.* within Pleistocene alluvium). The fossil record of the **Kalahari Group** is 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, pans and solution cavity infills.

It is noted that fissure infills and cave deposits as well as calc-tufa and flowstones in **karstified carbonate bedrock terrain** underlain by the Transvaal Supergroup may be associated with important Late Caenozoic fossil assemblages including mammalian bones and teeth or fossil plants (*cf* occurrences at Taung and Makapansgat in North West and Limpopo).

Table 1: Fossil heritage of rock units represented in the BOSA transmission line study region, North West Province

GEOLOGICAL UNIT	ROCK TYPES & AGE	FOSSIL HERITAGE	COMMENTS
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, fissure and 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)	**Palaeosensitivity of these sediments is generally low but may be locally VERY HIGH (e.g. older alluvial, pan, calc-tufa, karstic fissure infill and cave deposits)**
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 (e.g. doline infills) freshwater units associated with diatoms, molluscs, stromatolites	

BUSHVELD COMPLEX			Intrusive igneous rocks Late Vaalian / Early Proterozoic 2.06 Ga Mafic intrusives of Rustenberg Layered Suite Intrusive granites & granophyres	NO FOSSILS	Bushveld Complex has been described as "One of the great geological wonders of the world" – the largest layered igneous complex in the world with the richest reserves of platinum group metals known anywhere. Intruded between Magaliesberg Fm quartzites (Pretoria Group) and the Rooiberg Group volcanics.
TRANSVAAL SUPERGROUP **Late Archaean – Early Proterozoic (= Vaalian) <2.7 to 2.1 Ga**	**PRETORIA GROUP**	**Rayton Formation (Vr1, Vr2)**	Mudrocks and sandstones	No fossils recorded	
		Magaliesberg Fm (Vmg, Vlm)	Coastal sandstones with mudrocks	Microbial mat structures (Desiccated mats sometimes resemble trace fossils)	
		Silverton Fm (Vsi)	Marine mudrocks with minor carbonates, volcanic rocks (= Machadodorp Member) [Green areas are younger basic igneous intrusions (Vdi)]	Stromatolites	
		Daspoort Fm (Vda, Vhd)	Alluvial, fluvial and deltaic sandstones and mudrocks, marine sediments in east	Stromatolites	
		Strubenkop Fm (Vs, Vhd)	Lacustrine mudrocks with minor sandstone	No fossils recorded	
		Dwaalheuwel Fm (Vdw, Vhd)	Alluvial sandstones, conglomerates and mudrocks	No fossils recorded	Pretoria Group subunits with stromatolites probably also contain microfossils. This may
		Hekpoort Fm (Vh, Vhd)	Volcanics (basalts, pyroclastics) with minor lacustrine shales	No fossils recorded	

		Boshoek Fm (Vh)	Sandstones, conglomerates, diamictite (alluvial fans, slumps)	No fossils recorded	well also apply to carbonaceous mudrocks. **ALERT FOR POTENTIALLY FOSSILIFEROUS LATE CAENOZOIC CAVE BRECCIAS, CLA-TUFAS WITHIN OUTCROP AREA OF CARBONATE SUBUNITS – *i.e.* LIMESTONES & DOLOMITES (breccia bodies are usually small and not individually mapped)**
		Timeball Hill Formation (Vt)	Lacustrine and fluvio-deltaic mudrocks with diamictite, conglomerates, quartzite, minor lavas	Stromatolites	
		Rooihoogte Formation (Vt)	Basal breccio-conglomerates, quartzites, mudrocks, carbonates (alluvial fan, lakes, karst infill)	No fossils recorded	
		Penge Formation (Vp)	**Banded iron formation (BIF) with iron ores (siderite, haematite, magnetite), cherts, ferruginous mudrocks deposited within quiet water basinal settings**	Possible microfossils	
TRANSVAAL SUPERGROUP **Late Archaean – Early Proterozoic (= Vaalian) <2.7 to 2.1 Ga**	**CHUNIESPOORT GP**	**MALMANI SUBGROUP (Vm)** **(Series of 5 formations:** **Oaktree Vo, Monte Christo Vmo1-2, Lyttelton, Vl, Eccles Ve, & Frisco Fms Vf)**	Stromatolitic carbonates (limestones / dolomites), minor secondary cherts, mudrocks incl. carbonaceous shales	Range of stromatolites (domes, columns *etc*), organic-walled microfossils	**ALERT FOR POTENTIALLY FOSSILIFEROUS LATE CAENOZOIC CAVE BRECCIAS WITHIN "TRANSVAAL DOLOMITE" OUTCROP AREA** **(breccia bodies are usually small and not individually mapped)**

	Proto-basinal rocks	**Tshwene-Tshwene Belt**	Mafic lavas and coarse fluvial or mass-flow sediments	No fossils recorded	Stromatolites recorded from possibly related Buffelsfontein Group near Thabazimbi
		Black Reef Formation (Vb)	Siliciclastic sediments (mature sandstones *plus* minor mudrocks, conglomerates) deposited during a fluvial to shallow marine transition	No fossils recorded	Records flooding of Kaapvaal Craton by shallow epicontinental seas Possible equivalent of Black Reef Fm in N. Cape (Vryburg Formation) contains stromatolitic carbonates.
VENTERSDORP SUPERGROUP **Rk – Klipriviersberg Group**			Predominantly basic lavas with minor metamorphosed sediments (breccias, conglomerates, quartzites) at base of succession Late Archaean (Randian) *c.* 2.7-2.5 Ga	Lacustrine stromatolites are recorded within the upper Ventersdorp Supergroup (Platberg Group) in the Free State	
ARCHAEAN GRANITE-GNEISS BASEMENT **e.g. Gaborone Granite Complex**			Intrusive granitoids, gneisses, migmatites and other high grade metamorphic rocks Early to Late Archaean 3.6 –2.4 (Swazian / Randian)	NO FOSSILS	These ancient basement rocks build one of the oldest surviving blocks of continental crust (Kaapvaal Craton)

N.B. **FONT COLOUR REFLECTS PALAEOSENSITIVITY OF ROCK UNITS:**

Black – zero to negligible **Blue – low** **Red – moderate to high**

4. CONCLUSIONS AND RECOMMENDATIONS

The *c.*150 km-long South African sector of the proposed Botswana-South Africa (BOSA) Transmission Interconnection Project in the North West Province traverses outcrops of a wide range of geological units. These comprise (1) very ancient Precambrian basement rocks of igneous origin (*e.g.* Ventersdorp Supergroup lavas, Gaborone Complex granites), (2) younger Precambrian sediments and lavas of the Transvaal Supergroup that mainly crop out along the Southern and Northern Bankenveld regions along the margins of the western Transvaal Basin, and (3) Caenozoic superficial sediments of the Kalahari Group including aeolian sands, calcretes and river deposits, among others. The fossil heritage of this region is poorly known. This is probably because of the lack of palaeontological field studies and often low levels of bedrock exposure due to extensive cover by superficial sediments in topographically subdued regions. Important occurrences of Precambrian stromatolites (fossil microbial columns, domes *etc*) are reported from several carbonate subunits of the Chuniespoort and Pretoria Groups of the Transvaal Supergroup, including in the Mafikeng 1: 250 000 sheet area. The underlying igneous basement rocks are completely unfossiliferous while the Caenozoic superficial sediments (including the Kalahari Group) are generally poorly fossiliferous. Rich Caenozoic vertebrate fossil assemblages may be associated, however, with older alluvium, pans, springs as well as calc-tufa, cave and fissure infills in regions featuring karstified limestone or dolomite (*e.g.* Transvaal Supergroup, Kalahari calcretes).

It is concluded that most of the BOSA transmission line project area is generally of low palaeontological sensitivity. However, several sectors of the line underlain by carbonate bedrocks of the Transvaal Supergroup or by consolidated superficial deposits may contain scientifically important occurrences of fossils, such as stromatolites or mammalian remains, that may be threatened by surface clearance or excavations during the construction phase of the transmission line. These sectors are assigned a medium to high palaeosensitivity (SAHRIS website, Groenewald & Groenewald 2014) and as a precautionary measure, especially in view of the general lack of palaeontological field data in the region, it is therefore recommended that once the powerline footprint is finalised, and *before* construction commences, a specialist palaeontological walk-down of the BOSA transmission line corridor should be conducted by a suitably qualified palaeontologist. The focus of the walk-down would be on potentially-fossiliferous Precambrian carbonate bedrocks (see red dotted sectors highlighted in Figs. 11 to 14), karstified areas (caves and fissure infills), thick calcretes, tufa deposits and ancient, consolidated or semi-consolidated alluvium along major drainage lines. Following the walk-down the specialist should submit a full report to SAHRA documenting any fossil occurrences and making recommendations for further mitigation or monitoring measures for the pre-construction or construction phases of the transmission line. These recommendations must be incorporated into the Environmental Management Programme for the development. 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 published by SAHRA (2013).

The following mitigation measures to safeguard fossils exposed as chance finds on site during the construction phase of the development are recommended (Please also see the tabulated Chance Fossil Finds Procedure appended to this report). The ECO and / or the Site Engineer responsible for the development must remain aware that all sedimentary deposits have the potential to contain fossils and he / she should thus monitor all substantial excavations into sedimentary bedrock for fossil remains on an ongoing basis. If any substantial fossil remains (*e.g.* stromatolites, vertebrate bones, teeth, horn cores) are found during construction SAHRA should be notified immediately (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). This is so that appropriate mitigation (*i.e.* recording, sampling or collection) by a palaeontological specialist can be considered and implemented, at the developer's expense.

Provided that the mitigation measures outlined above are adhered to, the residual impact significance of any construction phase impacts on local palaeontological resources are anticipated to be low.

5. ACKNOWLEDGEMENTS

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

Declaration of Independence

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

<table>
<tr><td colspan="3">APPENDIX: CHANCE FOSSIL FINDS PROCEDURE: BOSA 400 kV transmission line</td></tr>
<tr><td>Province & region:</td><td colspan="2">NORTH WEST PROVINCE, Ngala Modiri Molema District Municipality</td></tr>
<tr><td>Responsible Heritage Resources Authority</td><td colspan="2">SAHRA (Contact details: Dr Ragna Redelstorff, SAHRA, P.O. Box 4637, Cape Town 8000. Tel: 021 202 8651. Email: rredelstorff@sahra.org.za or Ms Natasha Higgitt. Tel: 021 462 4502. Email: nhiggitt@sahra.org.za)</td></tr>
<tr><td>Rock unit(s)</td><td colspan="2">Precambrian dolomites / limestones, Late Caenozoic alluvium, karstic cave and fissure deposits, calc-tufa, pan sediments, calcretes</td></tr>
<tr><td>Potential fossils</td><td colspan="2">Stromatolites, vertebrate bones, teeth and horn cores, mollusc and crustacean remains, trace fossils or plant material</td></tr>
<tr><td rowspan="5">ECO protocol</td><td colspan="2">1. Once alerted to fossil occurrence(s): alert site foreman, stop work in area immediately (N.B. safety first!), safeguard site with security tape / fence / sand bags if necessary.</td></tr>
<tr><td colspan="2">2. Record key data while fossil remains are still in situ:
• Accurate geographic location – describe and mark on site map / 1: 50 000 map / satellite image / aerial photo
• Context – describe position of fossils within stratigraphy (rock layering), depth below surface
• Photograph fossil(s) in situ with scale, from different angles, including images showing context (e.g. rock layering)</td></tr>
<tr><td>3. If feasible to leave fossils in situ:
• Alert Heritage Resources Authority and project palaeontologist (if any) who will advise on any necessary mitigation
• Ensure fossil site remains safeguarded until clearance is given by the Heritage Resources Authority for work to resume</td><td>3. If not feasible to leave fossils in situ (emergency procedure only):
• Carefully remove fossils, as far as possible still enclosed within the original sedimentary matrix (e.g. entire block of fossiliferous rock)
• Photograph fossils against a plain, level background, with scale
• Carefully wrap fossils in several layers of newspaper / tissue paper / plastic bags
• Safeguard fossils together with locality and collection data (including collector and date) in a box in a safe place for examination by a palaeontologist
• Alert Heritage Resources Authority and project palaeontologist (if any) who will advise on any necessary mitigation</td></tr>
<tr><td colspan="2">4. If required by Heritage Resources Authority, ensure that a suitably-qualified specialist palaeontologist is appointed as soon as possible by the developer.</td></tr>
<tr><td colspan="2">5. Implement any further mitigation measures proposed by the palaeontologist and Heritage Resources Authority</td></tr>
<tr><td>Specialist palaeontologist</td><td colspan="2">Record, describe and judiciously sample fossil remains together with relevant contextual data (stratigraphy / sedimentology / taphonomy). Ensure that fossils are curated in an approved repository (e.g. museum / university / Council for Geoscience collection) together with full collection data. Submit Palaeontological Mitigation report to Heritage Resources Authority. Adhere to best international practice for palaeontological fieldwork and Heritage Resources Authority minimum standards.</td></tr>
</table>