Palaeontological heritage: combined desktop and field-based assessment

PROPOSED UPGRADING OF THE 66 KV NETWORK TO A 132 KV NETWORK BETWEEN HOTAZEL, KURUMAN AND KATHU, NORTHERN CAPE

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February 2019

EXECUTIVE SUMMARY

Eskom Holdings SOC Limited are currently engaged in the upgrading to a 132 kV network of the existing 66 kV distribution line network between the towns of Hotazel, Kuruman and Kathu in the Northern Cape Province. The project area for the authorised new 132 kV transmission line and associated electrical substations is largely underlain by sedimentary bedrocks of Precambrian (Late Archaean – Early Proterozoic) age that are assigned to the Ghaap Group (Transvaal Supergroup). These sediments were laid down in shallow inshore to deep offshore marine settings on the margins of the ancient Kaapvaal Craton some 2.5 to 2.4 Ga (= billion years ago). Excellent hillslope exposures of limestones and dolomites of the Campbell Rand Subgroup crop out at Kurumankop (*c.* 1-2 km west and southwest of the Gamohaan Substation site) and at several other points along the eastern flanks of the Kurumanberge (*e.g.* on Alphen 442 some 12 km south of Kuruman). These Precambrian carbonate bedrock exposures are of considerable geoscientific significance and also contain well-preserved biosedimentary structures, including a range of different types of stromatolites (fossil microbial mounds). However, they lie just *outside* the project footprint and will not be impacted by the proposed development. Other Precambrian bedrocks within the project area include banded ironstones (BIF) of the Asbestos Hills Subgroup and igneous rocks of the Ongeluk Formation (Postmasburg Group), neither of which are fossiliferous.

Stromatolite-rich Campbell Rand Subgroup carbonates lie at or near-surface within several sectors of the distribution line corridor, notably close to Moffat Substation on the outskirts of Kuruman. However, in these lower-lying areas of the Ghaap Plateau the bedrocks are usually karstified - *i.e.* have been subjected to extensive solution weathering – so well-preserved stromatolite beds are uncommon. The carbonate bedrocks are locally capped by tough siliceous breccias of Precambrian age and extensively mantled by thin to thick (up to several meters) superficial deposits. These Late Caenozoic deposits – variously comprising ferruginised gravels of reworked chert and banded ironstone, coarse to sandy alluvium (highly calcretised along major water courses such as the Kuruman River and its tributaries) and reworked Kalahari sands – are generally unfossiliferous. The gravels contain numerous reworked clasts of silicificied stromatolitic chert, while occasional blocks of calcretised alluvium containing Late Caenozoic (probably Quaternary) microbial structures are recorded along the Kuruman River.

The existing powerline servitude and substation areas are generally highly disturbed at surface, especially in the vicinity of towns and townships. Although occasional float blocks of richly-stromatolitic carbonate are recorded here, for example near Moffat Substation, many of these have been damaged by vehicle or other construction activity. It is noted that fossil stromatolites are difficult to discern within freshly-broken limestone and dolomite, as exposed in quarries, burrow pits

and smaller artificial excavations, compared with naturally-weathered hillslope exposures. Pockets of high palaeosensitivity – for example assemblages micromammal and other vertebrate remains embedded within karstic fissure-infill and tufa deposits – *might* occur here, by analogy with Precambrian carbonate outcrops elsewhere in southern Africa (*e.g.* Namibia), but are impossible to predict. Excavations for the 132 kV monopole footings and any new access roads are small in volume and will mainly impact unfossiliferous Late Caenozoic superficial sediments. It is concluded that (1) the study areas for the 132 kV transmission line corridor and associated substations are generally of low palaeontological sensitivity and consequently (2) the impact significance of the proposed development in terms of palaeontological heritage is low. None of the sparse fossil stromatolite occurrences recorded within the development footprint is considered to be especially conservation worthy, and no specialist palaeontological monitoring or mitigation is recommended for this electrical infrastructure project.

Should substantial fossil remains – such as well-preserved stromatolitic beds, mammalian bones and teeth - be encountered at surface or exposed during the construction phase, the ECO should safeguard these, preferably *in situ*. They should then alert the South African Heritage Resources Agency as soon as possible (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 to ensure that appropriate action (*i.e.* recording, sampling or collection of fossils, recording of relevant geological data) can be taken by a professional palaeontologist at the proponent’s expense. A Chance Fossil Finds Procedure is tabulated in Appendix 2. These recommendations must be incorporated in the Environmental Management Programme for the 132 kV electrical infrastructure project.

1. PROJECT OUTLINE & BRIEF

Eskom Holdings SOC Limited are currently engaged in the upgrading to a 132 kV network of the existing 66 kV distribution line network between the towns of Hotazel, Kuruman and Kathu. The electrical infrastructure project is situated along the existing powerline servitude within the Ga-Segonyana, Joe Morolong and Gamagara Local Municipalities, John Taolo Gaetsewe District Municipality, Northern Cape Province (Fig. 1). A preferred alignment of the new 132 kV distribution line (chosen from up to 4 alternative options) has already been selected and authorized (2015); some sectors have already been constructed. In addition to the 314 new monopole metal electricity pylons, spaced some 200-300 apart, new infrastructure includes access roads, fencing and gates. The upgrading project also involves the development of two new electrical substations (Mothibastat SS andGamohaan SS) as well as the extension or upgrading of a further five substations (Hotazel SS, Eldoret SS, Riries SS, Moffat SS and Valley SS). A new switching station, the Sekgame Switching Station, will be constructed where the powerline upgrade ends just south of the town of Kathu. The application for Environmental Authorization for this switching station has been undertaken independently from the assessment of the above-mentioned substations.

Following commencement of the construction phase of the project, a Phase 1 palaeontological impact assessment report for the Hotazel - Kuruman - Kathu electrical infrastructure project was commissioned by Zitholele Consulting, Midrand, and submitted by Fourie (2018a), supplemented by a second report by the same author (Fourie 2018b). No fossils were recorded during the field study. The following recommendations regarding palaeontological heritage have been abstracted verbatim from these two reports:

> *Concerns/threats to be added to the EMPr:*

> *1. The overburden and inter-burden must always be surveyed for fossils. Special care must be taken during the digging, drilling, blasting and excavating of foundations, trenches, channels and footings and removal of overburden not to intrude fossiliferous layers.*
> *2. Threats are earth moving equipment/machinery (front end loaders, excavators, graders, dozers) during construction, the sealing-in, disturbance, damage or destruction of the fossils by development, vehicle traffic and human disturbance.*
>
> *The recommendations are:*
>
> *1. Mitigation is needed if fossils are found, permission needed from SAHRA.*
> *2. No consultation with parties was necessary.*
> *3. The development may go ahead with caution, but the ECO must survey for fossils before or after blasting or excavating in line with the legally binding Environmental Management Programme (EMPr) this must be updated to include the involvement of a palaeontologist/ archaeozoologist when necessary.*
> *4. The EMPr already covers the conservation of heritage and palaeontological artefacts that may be exposed during construction activities. The protocol is to immediately cease all construction activities if a fossil is unearthed, a buffer of 30 m must be established, and contact SAHRA for further investigation. It is recommended that the EMPr be updated to include the involvement of a palaeontologist / archaeozoologist (pre-construction training of ECO) and during the digging and excavation phase of the development the ECO must visit the site bi-weekly for monitoring and to keep a photographic record. A palaeontologist / archaeozoologist does not need to monitor the excavations.*
> *5. Care must be taken during the Dolomite Risk Assessment according to SANS 1936-1 (2012) as stromatolites may be present.*
> *6. Authorisation has already been granted in 2015 and construction has begun.*

Following submission of the two palaeontological heritage reports by Fourie (2018a, 2018b), SAHRA issued an Interim Comment (Case ID: 11967, letter of 7 September 2018) as follows:

> *The SAHRA Archaeology, Palaeontology and Meteorites (APM) Unit accepts the submitted report and awaits the monitoring reports (from either the ECO or appointed palaeontologist) of the areas that require monitoring as per the map on page 2 (red lines) and on page 5 of the report (i.e. SS footprint monitoring required highlighted in pink, and servitude monitoring required highlighted in yellow)* [See Figure 15 in the present report]. *These areas must be surveyed prior to construction.*

Natura Viva cc, Cape Town was then commissioned by Zitholele Consulting, Midrand (Contact details: Dr Mathys Vosloo, Zitholele Consulting. Building 1, Maxwell Office Park, Waterfall City, Midrand, 1682. Tel: 011 207 2060. E-mail: mathysv@zitholele.co.za) to undertake a detailed palaeontological site survey, on-site training and monitoring as and when required for the 132 kV powerline construction project between Hotazel, Kuruman and Kathu in the Northern Cape.

The scope of work, as defined by Zitholele Consulting, was as follows:

1. Palaeontologist to do the survey of identified sensitive areas as per the attached google earth file (kml), prior to construction. The palaeontologist must:
    a. Visit any areas of interest (i.e. rocky outcrops), the substation footprint areas and tower locations

  - b. Take detailed photographs of the areas surveyed
  - c. Set out a representative track to follow during the surveys, i.e. plan upfront how the areas will be walked/covered to ensure the survey is representative to successfully identify sensitive areas
  - d. Provide the track logs as evidence of the survey and area covered.
  - e. Show the tracklogs and findings on a clearly labelled map

2. The appointed palaeontologist must then provide on-site training to the ECO, contractor's and environmental officers in terms of monitoring. The training must cover:
   - a. How to identify and monitor a construction suite successfully;
   - b. Images/pictures/examples of what fossils could be expected to be found. A presentation with all this info should preferably be given;
   - c. The protocol/procedure to follow in the event fossils are identified, with relevant contact numbers and persons on the presentation;
   - d. A training attendance register must be signed by all parties, copies to be sent to Eskom and kept in the site file. Evidence of this must be submitted with the final monitoring report.
   - e. Copies of the training material/presentation must be given to Eskom and kept in the site file. Evidence of this must be submitted with the final monitoring report.

A 3-day palaeontological survey was conducted by the author and one assistant over the period 29 November to 1 December 2018. A palaeontological heritage workshop for Eskom environmental officers was presented at Kuruman on 4 December 2018.

1.1. Legislative context of this palaeontological study

The development footprint is situated in an area that is underlain by potentially fossiliferous sedimentary rocks of Palaeozoic to Caenozoic age (Sections 2 and 3). The construction phase of the 132 kV distribution line and associated substations entails surface clearance and small to substantial excavations into the superficial sediment cover and perhaps locally into the underlying bedrock as well (*e.g.* for pylon footings, access roads, substation foundations). All these developments may adversely affect fossil heritage preserved 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.

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

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

According to Section 35 of the National Heritage Resources Act, dealing with archaeology, palaeontology and meteorites:
(1) The protection of archaeological and palaeontological sites and material and meteorites is the responsibility of a provincial heritage resources authority.
(2) All archaeological objects, palaeontological material and meteorites are the property of the State.

(3) Any person who discovers archaeological or palaeontological objects or material or a meteorite in the course of development or agricultural activity must immediately report the find to the responsible heritage resources authority, or to the nearest local authority offices or museum, which must immediately notify such heritage resources authority.
(4) No person may, without a permit issued by the responsible heritage resources authority—
(a) destroy, damage, excavate, alter, deface or otherwise disturb any archaeological or palaeontological site or any meteorite;
(b) destroy, damage, excavate, remove from its original position, collect or own any archaeological or palaeontological material or object or any meteorite;
(c) trade in, sell for private gain, export or attempt to export from the Republic any category of archaeological or palaeontological material or object, or any meteorite; or
(d) bring onto or use at an archaeological or palaeontological site any excavation equipment or any equipment which assist in the detection or recovery of metals or archaeological and palaeontological material or objects, or use such equipment for the recovery of meteorites.
(5) When the responsible heritage resources authority has reasonable cause to believe that any activity or development which will destroy, damage or alter any archaeological or palaeontological site is under way, and where no application for a permit has been submitted and no heritage resources management procedure in terms of section 38 has been followed, it may—
(a) serve on the owner or occupier of the site or on the person undertaking such development an order for the development to cease immediately for such period as is specified in the order;
(b) carry out an investigation for the purpose of obtaining information on whether or not an archaeological or palaeontological site exists and whether mitigation is necessary;
(c) if mitigation is deemed by the heritage resources authority to be necessary, assist the person on whom the order has been served under paragraph *(a)* to apply for a permit as required in subsection (4); and
(d) recover the costs of such investigation from the owner or occupier of the land on which it is believed an archaeological or palaeontological site is located or from the person proposing to undertake the development if no application for a permit is received within two weeks of the order being served.

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

1.2. General approach to the palaeontological heritage assessment

In preparing an initial palaeontological desktop study the potentially fossiliferous rock units (groups, formations *etc*) represented within the study area are determined from geological maps and satellite images. The known fossil heritage within each rock unit is inventoried from the published scientific literature, previous palaeontological impact studies (PIAs) in the same region, and the author's field experience (Consultation with professional colleagues as well as examination of institutional fossil collections may play a role here, or later following field assessment during the compilation of the final report). This data is then used to assess the palaeontological sensitivity of each rock unit to development. Provisional tabulations of palaeontological sensitivity of all formations in Northern Cape have already been compiled by Almond and Pether (2008). The potential impact of the proposed development on local fossil heritage is then determined on the basis of (1) the palaeontological sensitivity of the rock units concerned and (2) the nature and scale of the development itself, most significantly (3) the extent of fresh bedrock excavation envisaged. When rock units of moderate to high palaeontological sensitivity are present within the development footprint, a Phase 1 field assessment study by a professional palaeontologist is usually warranted to identify any palaeontological hotspots and make specific recommendations for any mitigation required before or during the construction phase of the development.

On the basis of the desktop and Phase 1 field assessment studies, the likely impact of the proposed development on local fossil heritage and any need for specialist mitigation are then determined. Adverse palaeontological impacts normally occur during the construction rather than the operational or decommissioning phase. Phase 2 mitigation by a professional palaeontologist – normally involving the recording and sampling of fossil material and associated geological information (*e.g.* sedimentological data) may be required (a) in the pre-construction phase where important fossils are already exposed at or near the land surface and / or (b) during the construction phase when fresh fossiliferous bedrock has been exposed by excavations. To carry out mitigation, the palaeontologist involved will need to apply for a palaeontological collection permit from the relevant heritage management authority, *i.e.* the South African Heritage Resources Agency, SAHRA. It should be emphasized that, *providing appropriate mitigation is carried out*, the majority of developments involving bedrock excavation can make a *positive* contribution to our understanding of local palaeontological heritage.

1.3. Information sources for this study

The information used in this combined desktop and field-based palaeontological heritage study was based on the following:

1. Preceding palaeontological heritage studies for the 132 kV powerline project submitted by Fourie (2018a, 2018b) as well as additional background information and kmz files provided by Zitholele Consulting, Midrand;

2. A review of the relevant scientific literature, including published geological maps and accompanying sheet explanations, as well as previous palaeontological assessment reports for the broader Kuruman region (*e.g.* 2014b, 2015a, 2015b, 2018a, 2018b, 2018c, 2018d);

3. The author's database on the geological formations concerned and their palaeontological heritage (See Almond & Pether 2008).

4. A three-day palaeontological field survey of the northern sector of the distribution line study area as well as relevant rock exposures in the vicinity that was carried out by the present author *plus* an experienced field assistant on 29 November – 1 December 2018 (See areas outlined in green, red and blue in satellite map Fig. 2 as well as locality site maps in Figures 66 to 68). As agreed in advance with the EAP, the southern sector of the study area (area outlined in orange in Fig. 2) does *not* require field surveying at this stage. This stretch of the powerline servitude was the subject of a recent combined field-based and desktop palaeontological heritage assessment in connection with the proposed Kuruman Wind Energy Facility and its grid connection (Almond 2018d), the results of which are included in the present report.

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.

To the author's knowledge (*cf* SAHRIS website), there have been very few field-based specialist palaeontological field studies in this part of the Southern Kalahari region. Bedrock exposure levels along the majority of the distribution line corridor are low due to pervasive cover by Late Caenozoic superficial deposits (*e.g.* Kalahari Group sands, calcretes as well as colluvium, alluvium and downwasted surface gravels). Confidence levels for this palaeontological assessment are therefore only MODERATE.

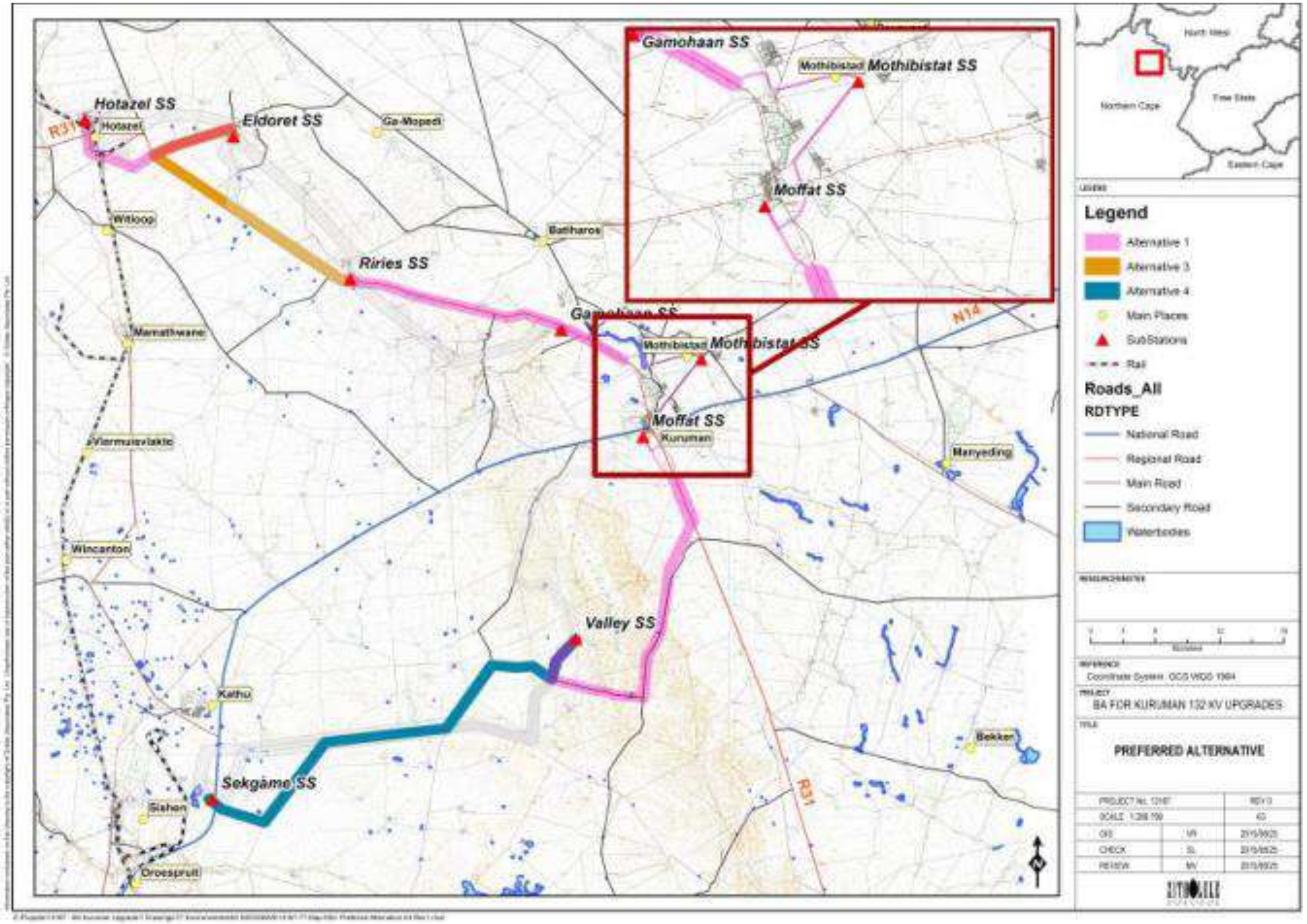


Figure 1. Map showing the authorised alignments for the upgraded 132 kV distribution line network between Hotazel, Kuruman and Kathu as well as the associated existing and new substations (SS) (Map produced by Zitholele Consulting, Midrand). The new distribution line largely follows existing servitudes. The Hotazel – Riries distribution line sector has already been constructed. The 132 kV line will terminate at the proposed new Sekgame Switching Station near Sishen.

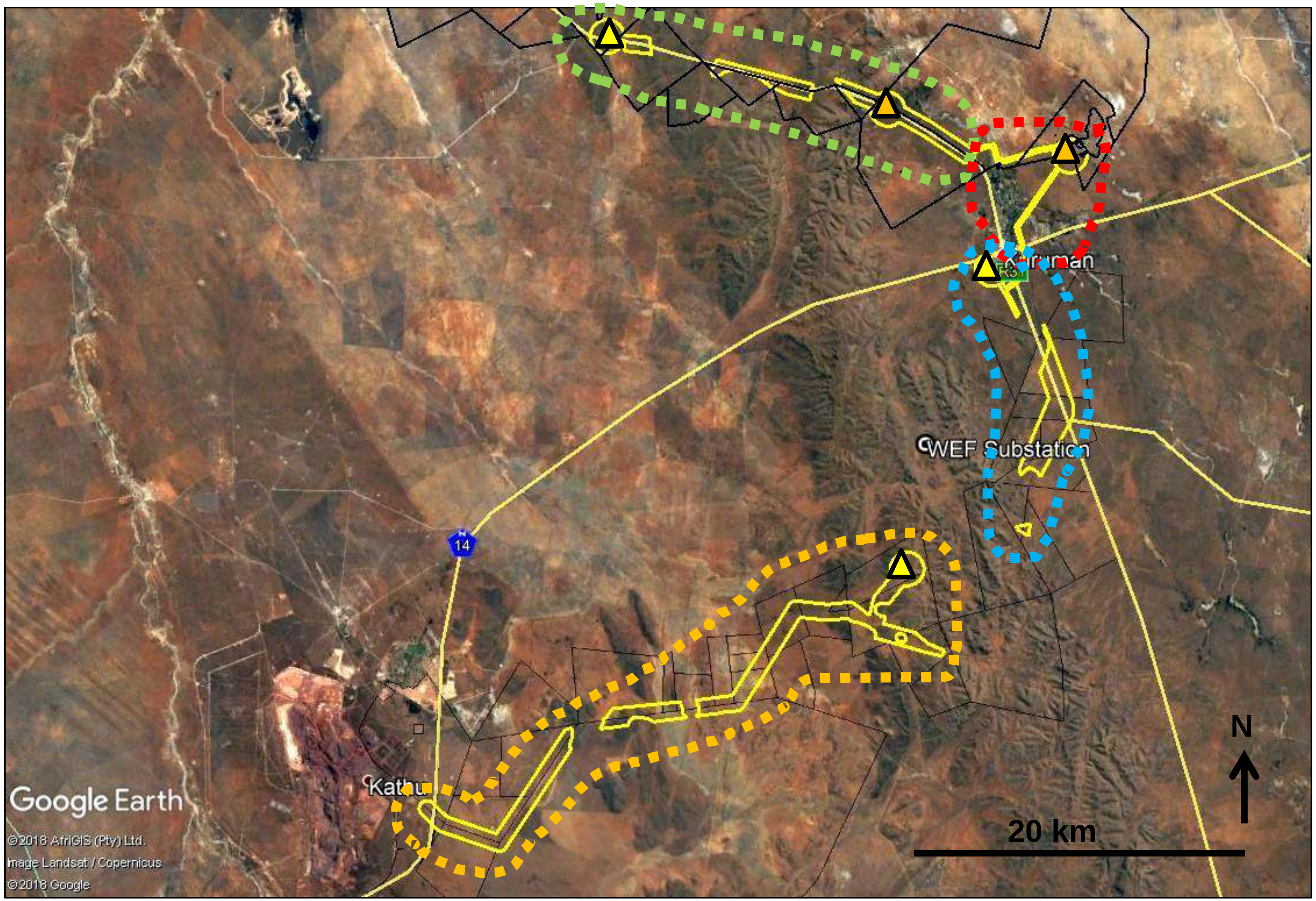


Figure 2. Google Earth© satellite image of the Kuruman – Kurumanheuwels – Kathu region of the Northern Cape showing the distribution line sectors (yellow polygons) that are the subject of the present PIA study. The green, red and blue outlined areas were examined in the field while the orange outlined area has already been covered by a previous field-based PIA relating to the proposed Kuruman Wind Energy Facility (Almond 2018d). Yellow triangles = existing substations; orange triangles = new substations; red triangle = new switching station.

2. GEOLOGICAL CONTEXT

The project area for the new Hotazel – Kuruman – Kathu 132 kV distribution line network is situated in the semi-arid Southern Kalahari Physiographic Region of the Northern Cape (Partridge *et al.* 2010). Figures 3 to 11 illustrate the range of terrain encountered in this area. Much of the existing distribution line servitude is already disturbed at surface, especially in the vicinity of large townships and towns. The field study areas that are the primary focus of this report (outlined in green, red and blue in Fig. 2) for the most part traverse flat to gently hilly, sandy and gravelly terrain at *c.* 1200-1400 m amsl. flanking the Kurumanberg Range which lies towards the western edge of the Ghaap Plateau. The main Kurumanberge comprise a NNW-SSE trending series of low, flat-crested hills which range in elevation from *c*. 1500-1770 m amsl. (Fig. 2). These are erosional relicts of an elongate, low, dome-shaped upland area that has become highly dissected by numerous small water courses draining towards the Ghaap Plateau and Kuruman River in the northeast and to the west into the Lohatla Plains of the southern Kalahari. The Riries – Gamohaan – Mothibastat sector of the 132 kV distribution line network traverses the lower-lying northern extension of the Kurumanberge, passing closely to the iconic peaks of Kurumankop (*c*. 1500 m) and crossing the wide, dry bed of the Kuruman River just north of the Moffat Mission Station (*N.B.* In this region much of the drainage flows underground through karstified carbonate bedrocks of the Ghaap Plateau, occasionally emerging at springs such as the famous Eye of Kuruman). From Mothibistat the distribution line servitude heads in a broadly N-S direction across gravely, disturbed terrain through the outskirts of Kuruman and then towards the low, rocky hills along the eastern flank of the Kurumanberge. The south-western sector of the distribution line between Valley and Sekgame Substations (area outlined in orange in Fig. 2) crosses the low-lying, gently hilly - and often sandy - terrain of the Lohatlha plains on the western flank of the Kurumanberge. This sector of the project is drained by non-perennial tributaries of the Ga-Mogara drainage system and is covered by the recent field-based palaeontological report by Almond (2018d).

Figure 3. Typical flat, sandy terrain of the southern Kalahari mantled by Quaternary orange-hued aeolian sands of the Gordonia Formation (Kalahari Group), seen here along the 132 kV distribution line servitude south of Maheane (Loc. 278).

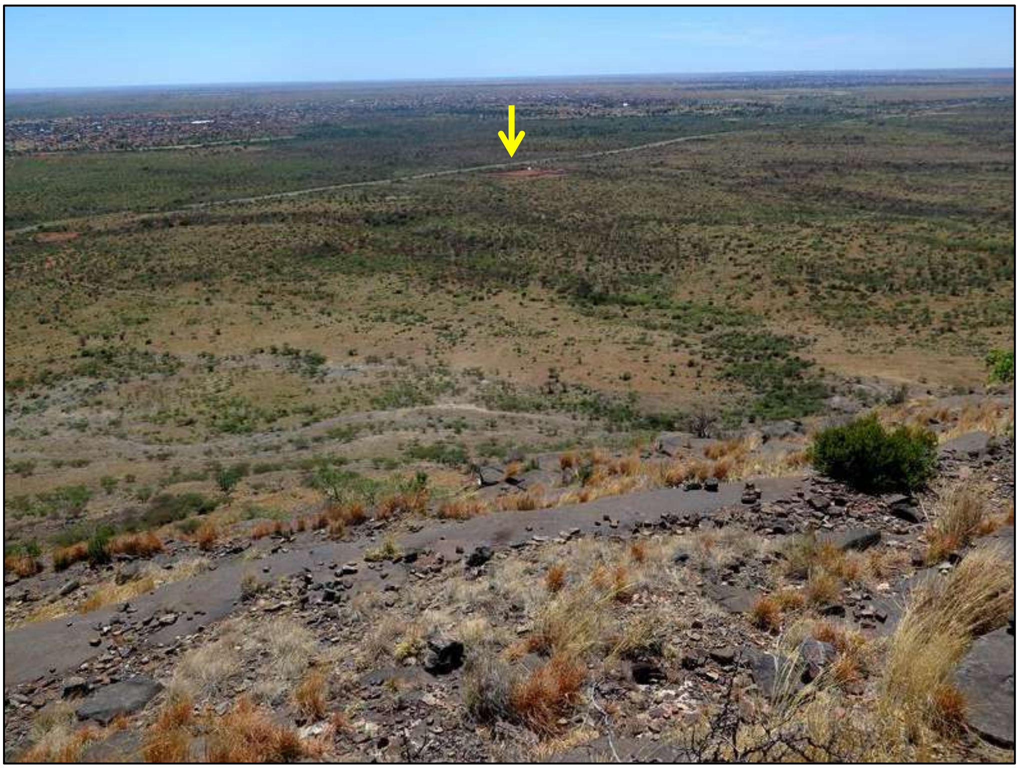


Figure 4. View towards the Gamohaan Substation construction site on the southern side of the R31 near Maruping (arrowed), seen from Kurumankop to the SW. The 132 kV powerline servitude here is largely by a several m-thick blanket of ferruginised BIF gravels.

Figure 5. Kurumankop, situated *c*. 1.5 km SW of Gamohaan Substation, is a key geosite featuring excellent exposures of the uppermost Precambrian platform carbonates of the Campbell Rand Subgroup, some of which contain outstanding examples of stromatolites (fossil microbial mounds) and other biosedimentary structures.

Figure 6. The broad, shallow bed of the Kuruman River just N of Moffat Mission Station showing the lack of good bedrock exposure here (Loc. 249). Coarse alluvial gravels include reworked blocks of pale calcrete, some of which contain subfossil biosedimentary structures (See Fig. 61) (Hammer = 30 cm).

Figure 7. Thick ferruginised alluvial sands and gravels on the outskirts of Mothibastat, *c*. 600 m NW of the new substation site, have been extensively excavated by *zama zamas* (informal miners) (Loc. 241). The resulting densely pock-marked terrain is clearly seen on satellite images of the region.

Figure 8. Karstified Campbell Rand carbonate bedrocks lie at or close to the surface along many sectors of the 132 kV powerline servitude (seen here on the eastern outskirts of Kuruman) where they are partially mantled by thin Kalahari sands and surface gravels (Loc. 236).

Figure 9. Shrubby Kalahari thornveld on the southern outskirts of Kuruman, viewed from the rocky slopes of Oogkop (1400 m amsl) (Loc. 218). The eastern flanks of the Kurumanberge are seen in the distance.

Figure 10. Low hills of Campbell Rand carbonate bedrocks and BIF gravels on the eastern margin of the Kurumanberge merging into gravelly *vlaktes* near Alphen and Spitsberg homesteads.

Figure 11. Good exposures of gently-dipping, greyish Campbell Rand Group carbonates (Kogelbeen and Gamohaan Formations) in the eastern foothills of the Kurumanberge, *c.* 2 km NW of Spitskop homestead (Loc. 225). These exposures are rich in fossil stromatolites but lie outside the project footprint.

The geology of the Hotazel – Kuruman – Kathu region is shown on the 1: 250 000 sheet map 2722 Kuruman (Council for Geoscience, Pretoria), for which a full explanation has yet to be published; this map is now outdated in several respects (Figs. 12 to 14). The 1: 1 000 000 scale geological map used in Figure 15 and by Fourie (2018a, 2018b) is inaccurate in several respects. Excellent simplified geological maps and sections of the region are provided in the Kalahari Manganese Field volume by Cairncross & Beukes (2013) (Figs. 16 & 17). The silicicastic and carbonate bedrocks here are assigned to the Precambrian (Late Archaean to Early Proterozoic) **Transvaal Supergroup** (Griqualand West Basin) on the western margins of the ancient Kaapvaal Craton (McCarthy & Rubidge 2005, Eriksson *et al.* 2006). They lie within the Ghaap Plateau Subbasin of the Transvaal succession, situated to the NE of the Griquatown Fault Zone. The Transvaal Supergroup bedrocks here have been folded into a major NNW-SSE trending mega-syncline, known as the Dimoten Syncline, and are cut by several broadly N-S trending faults. Within the distribution line project area the bedrocks of the **Ghaap Group** – comprising shallow water carbonates of the **Campbell Rand Subgroup** overlain by deeper water banded iron formation (BIF) of the **Asbestos Hills Subgroup** - lie for the most part on the eastern flank of the syncline, dipping gently and becoming younger towards the WSW. The youngest bedrocks in the Dimoten Syncline, assigned to the Proterozoic **Postmasberg Group**, are glacial sediments of the **Makganyene Formation** and the overlying **Ongeluk Formation** lavas. These younger rocks, unconformably overlying the Ghaap Group, crop out in the core of the Dimoten Syncline to the west of the Kurumanberge Range. Throughout the study area a large portion of the Precambrian outcrop area is mantled by various, mostly unconsolidated **superficial deposits** of Late Caenozoic age. These younger deposits include thick mantles of BIF colluvial gravels on the slopes and foothills of the Kurumanberge, downwasted cherty surface rubble, calcrete pedocretes, orange-hued aeolian (wind-blown) Kalahari sands, as well as sandy to gravelly alluvial sediments (often calcretised) along stream and river valley floors.

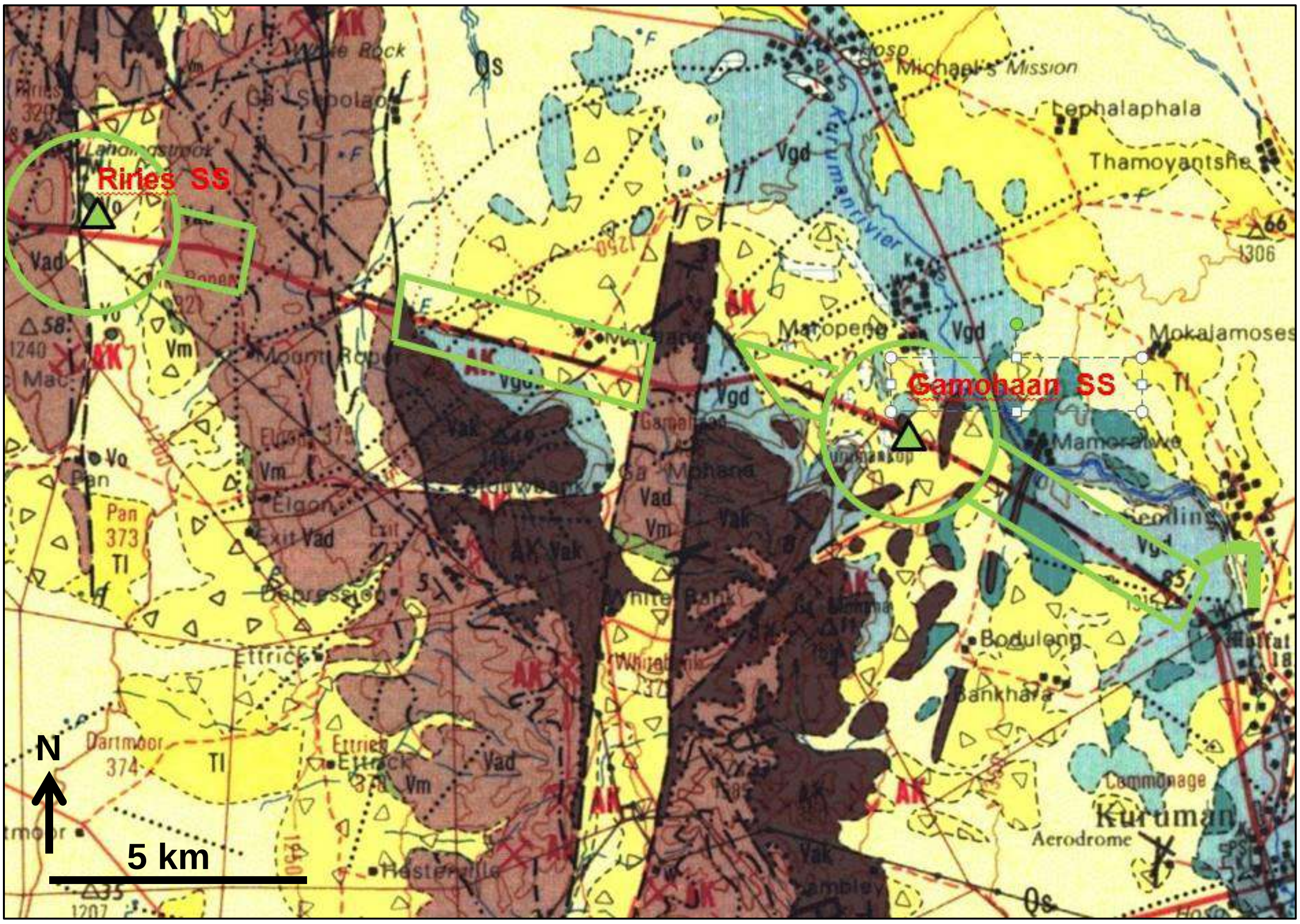


Figure 12. Extract from 1: 250 000 geology sheet 2722 Kuruman (Council for Geoscience, Pretoria) showing in green the study areas for the northern sector of the new 132 kV distribution line between Hotazel and Kuruman. The main rock units mapped here are:

GHAAP GROUP

Campbell Rand Subgroup:

"Ghaap Plateau" dolomites, limestones and secondary cherts (Vgd, pale blue), *plus* overlying chert breccias (Vgd, dark blue)

Asbestos Hills Subgroup:

Kuruman Formation banded iron formation (Vak, dark purple)
Daniëlskuil Formation (Vad, pale purple)

POSTMASBURG GROUP

Makganyene Formation tillites (Vm, pale green)
Ongeluk Formation lavas (Vo, blue-green)

LATE CAENOZOIC SUPERFICIAL SEDIMENTS

Surface rubble (middle yellow with triangle ornament)
Calcrete (Tl, dark yellow)
Gordonia Formation aeolian sands (Qs, pale yellow)

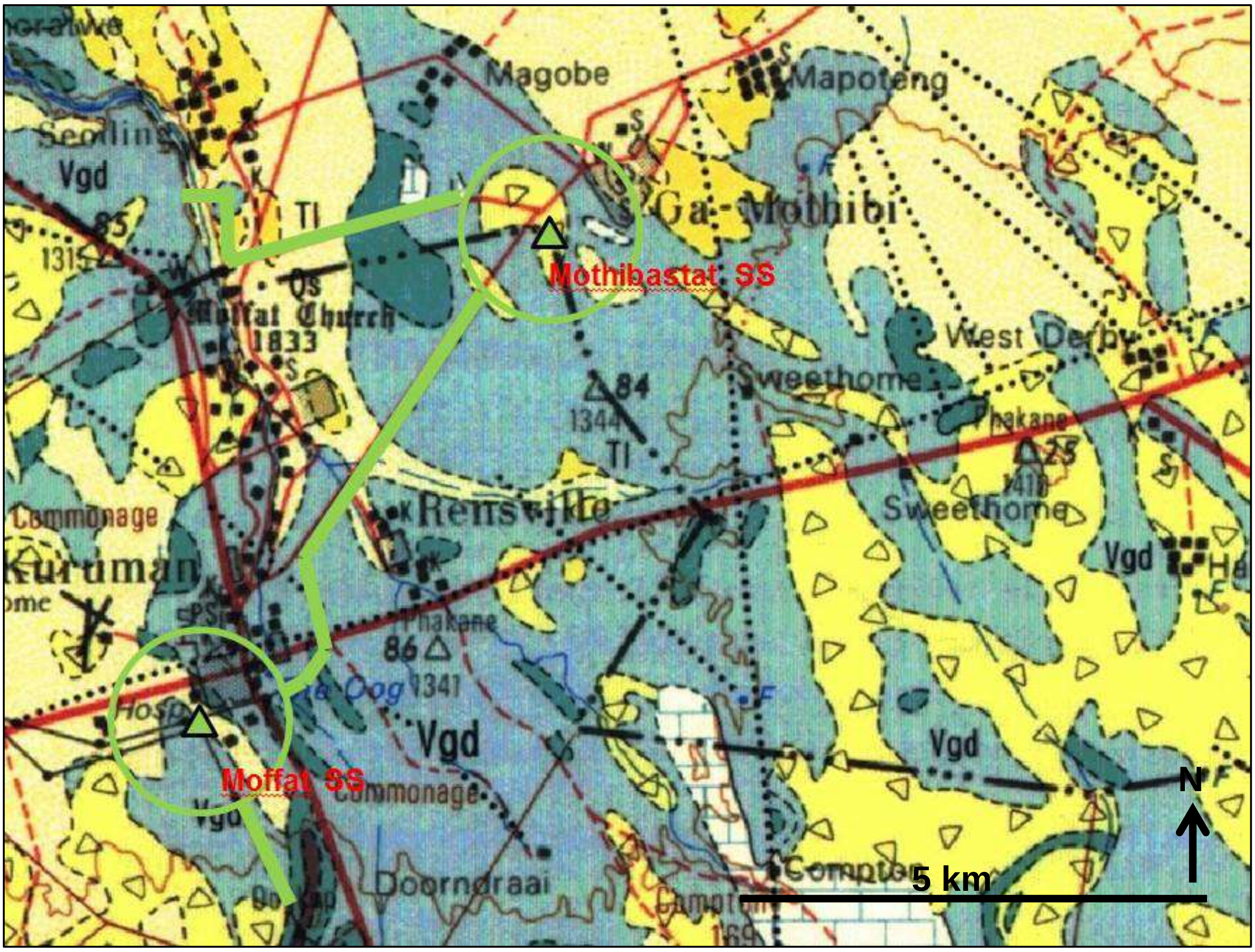


Figure 13. Extract from 1: 250 000 geology sheet 2722 Kuruman (Council for Geoscience, Pretoria) showing in green the study areas for the central sector of the new 132 kV distribution line near Kuruman. See legend to Figure 12 for key to the main rock units mapped here.

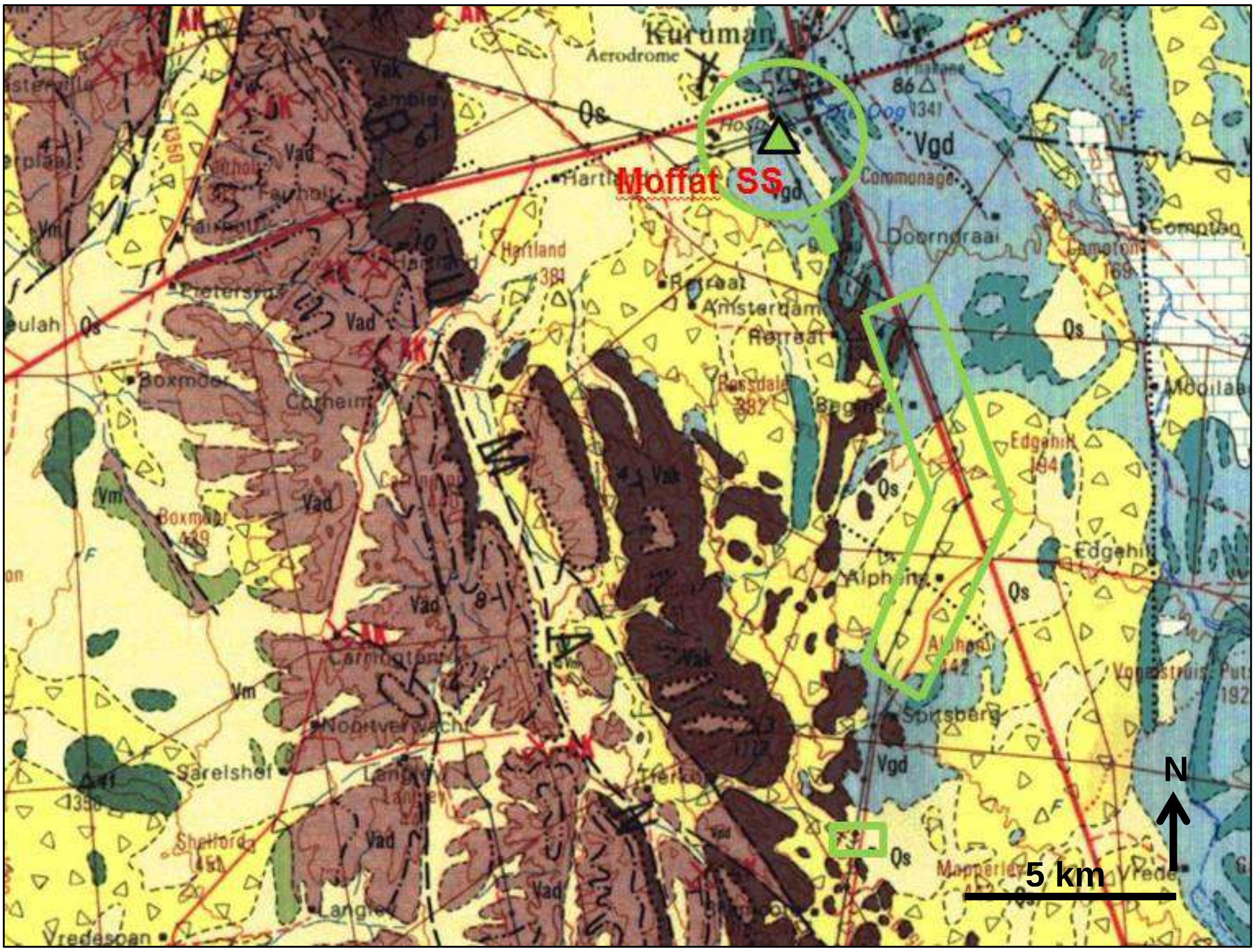
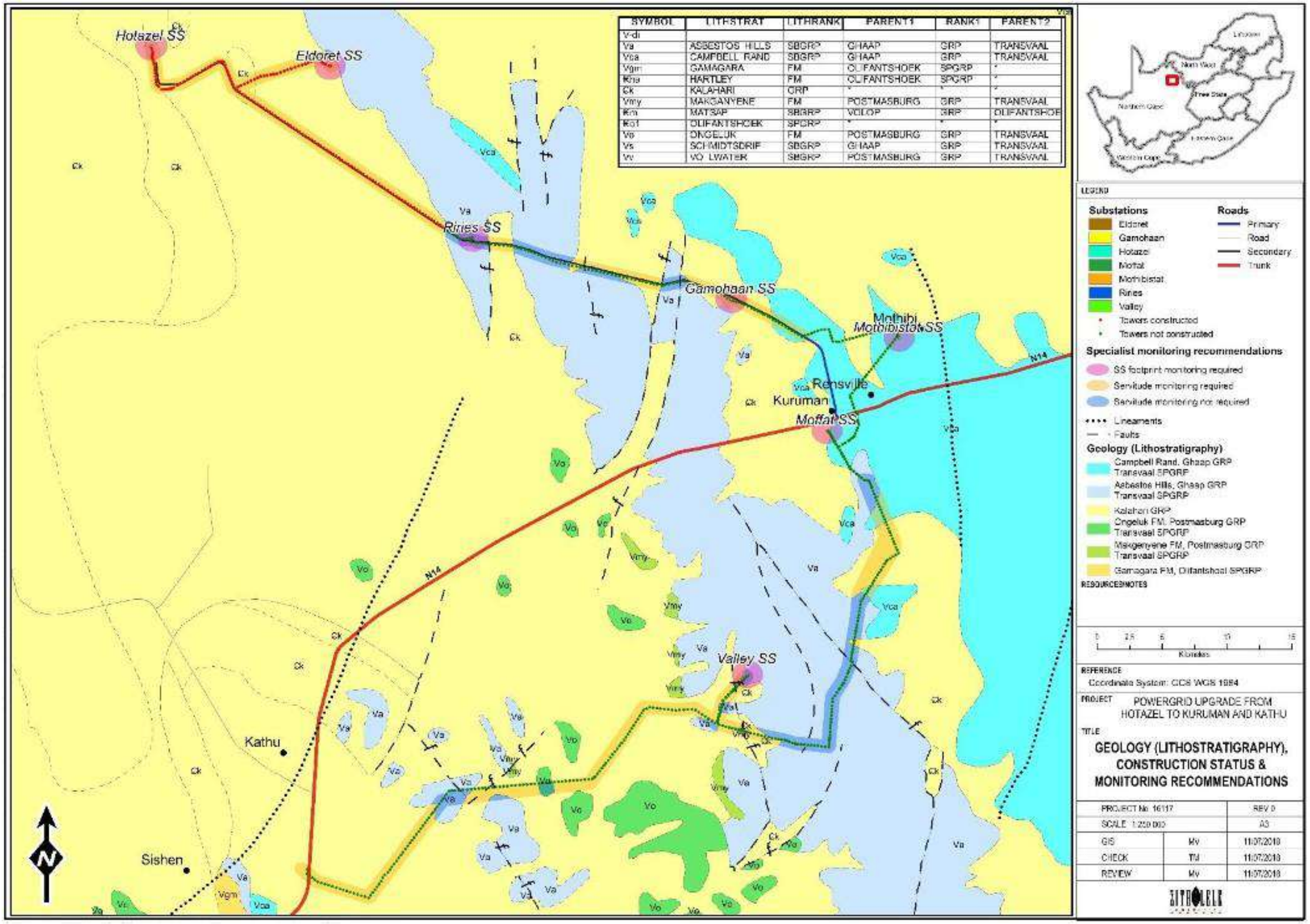


Figure 14. Extract from 1: 250 000 geology sheet 2722 Kuruman (Council for Geoscience, Pretoria) showing in green the study areas for the south-eastern sector of the new 132 kV distribution line south of Kuruman. See legend to Figure 12 for key to the main rock units mapped here.



SYMBOL	LITHSTRAT	LITHRANK	PARENT1	RANK1	PARENT2
V-di					
Va	ASBESTOS HILLS	SBGRP	GHAAP	GRP	TRANSVAAL
Vca	CAMPBELL RAND	SBGRP	GHAAP	GRP	TRANSVAAL
Vgm	GAMAGARA	FM	OLIFANTSHOEK	SPGRP	*
Rha	HARTLEY	FM	OLIFANTSHOEK	SPGRP	*
Ck	KALAHARI	GRP	*	*	*
Vmy	MAKGANYENE	FM	POSTMASBURG	GRP	TRANSVAAL
Rm	MATSAP	SBGRP	VOLOP	GRP	OLIFANTSHOE
Ro1	OLIFANTSHOEK	SPGRP	*	*	*
Vo	ONGELUK	FM	POSTMASBURG	GRP	TRANSVAAL
Vs	SCHMIDTSDRIF	SBGRP	GHAAP	GRP	TRANSVAAL
Vv	VOELWATER	SBGRP	POSTMASBURG	GRP	TRANSVAAL

Figure 15. The proposed Hotazel – Kuruman – Kathu 132 kV distribution line corridor superimposed on a 1: 1 000 000 scale geological map of the Northern Cape (Map produced by Zitholele Consulting). Palaeontological monitoring in the substation areas (pink) as well as along the sectors marked in yellow was recommended by Fourie (2018a, 2018b).

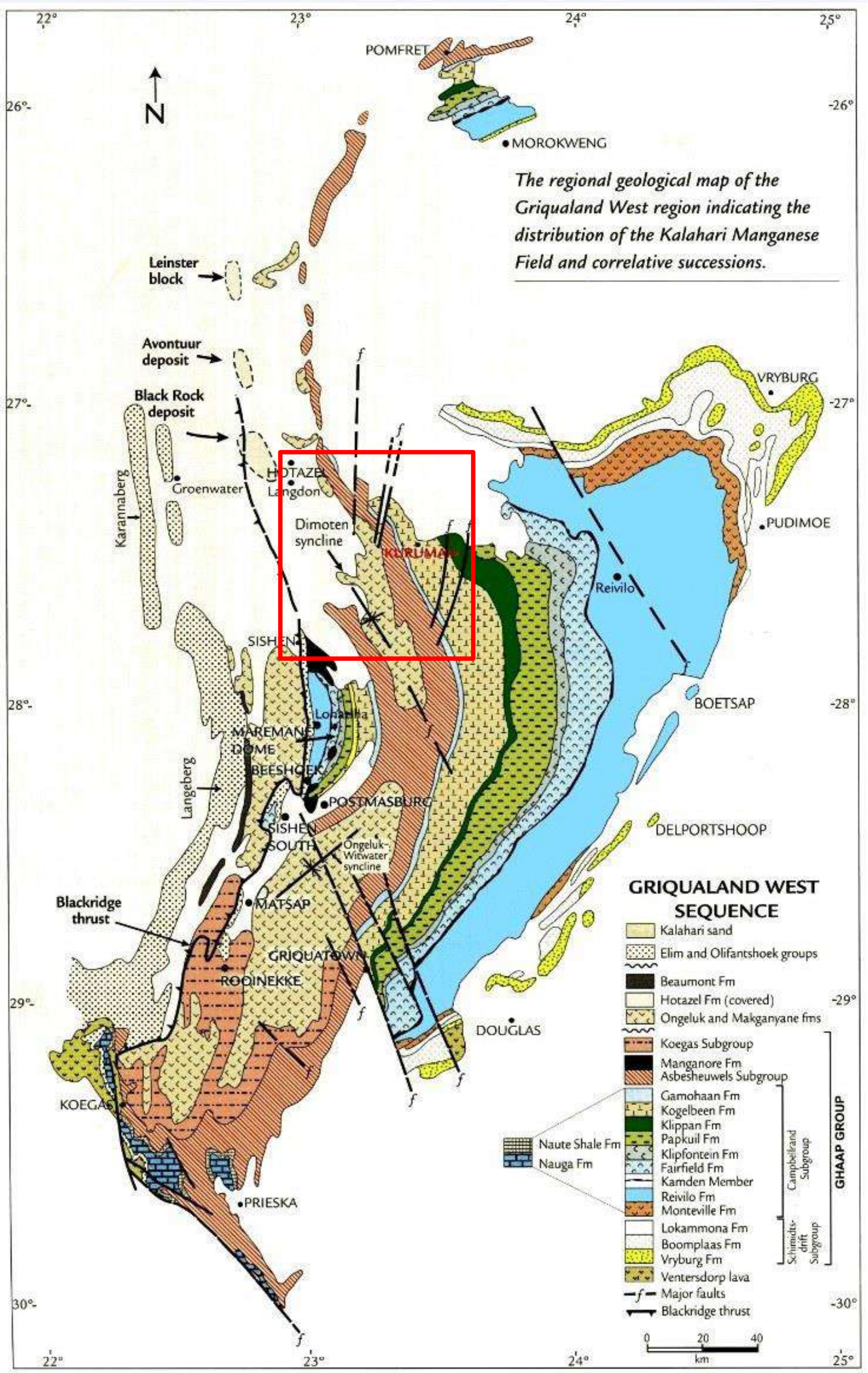


Figure 16. Schematic geological map of the Griqualand West region of the Northern Cape showing the *approximate* position of the project area for the new 132 kV distribution line network between Hotazel – Kuruman – Kathu (red rectangle) (From Cairncross & Beukes 2012). This overlies the NNW-SSE Dimoten mega-syncline with bedrocks of the Campbell Rand and Asbestos Hills Subgroups on the flanks and younger rocks of the Postmasburg Group (Ongeluk and Makganyene Formations) in the core. Note several N-trending major faults in the region.

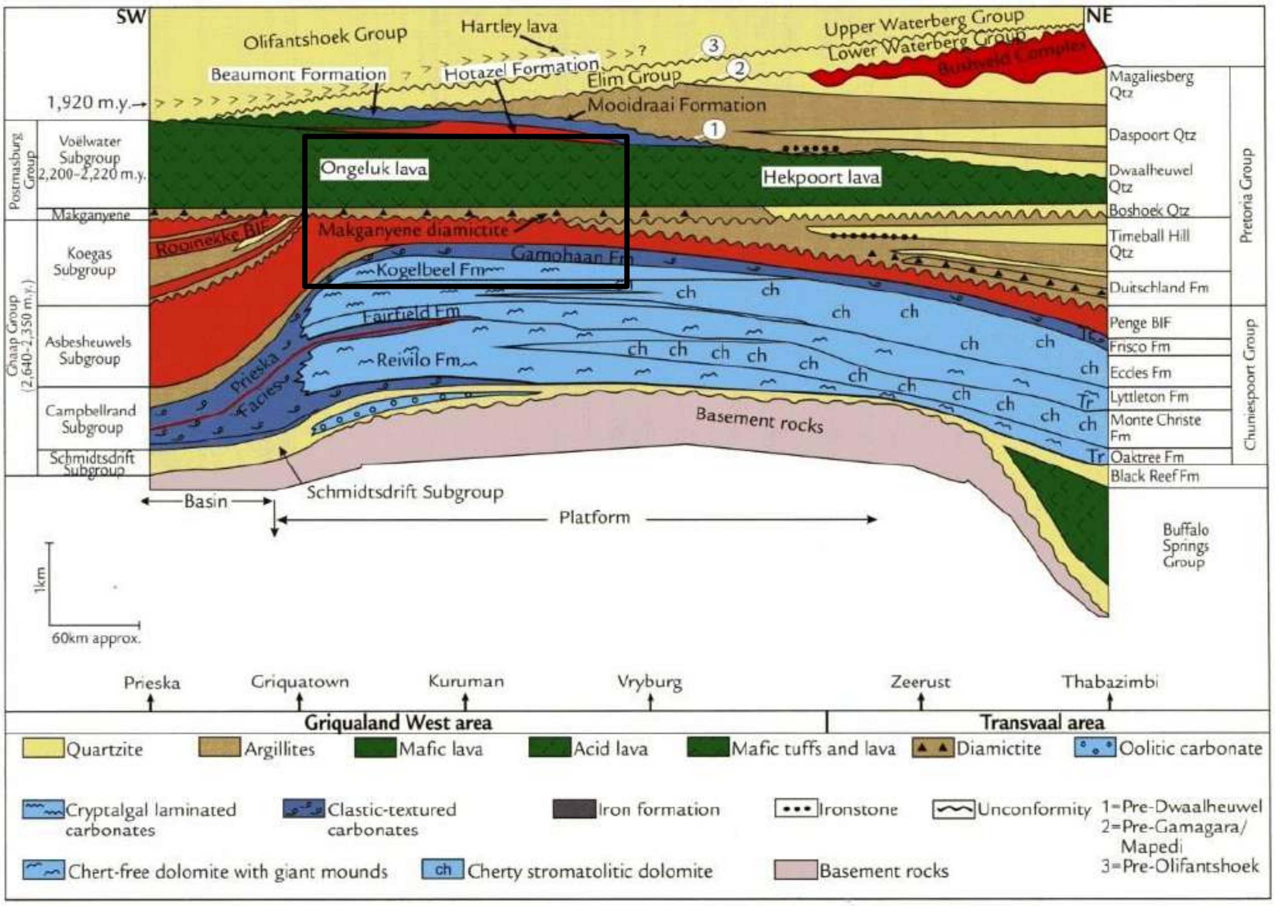


Figure 17. Stratigraphy of the Transvaal Supergroup showing the bedrock units of the Ghaap Group and unconformably overlying Postmasburg Group within the Griqualand West Basin that are represented in the Hotazel – Kuruman – Kathu 132 kV distribution line network project area (black rectangle).

2.1. Campbell Rand Subgroup

The **Campbell Rand Subgroup** (Vgd in Figs. 12 to 14) of the Ghaap Group - previously included within the “Ghaapplato Formation” in older literature - is a very thick (1.6 - 2.5 km) carbonate platform succession of dolostones, dolomitic limestones and cherts with minor tuffs and siliciclastic rocks. It was deposited on the shallow submerged shelf of the Kaapvaal Craton roughly 2.6 to 2.5 Ga (billion years ago) (See the readable general account by McCarthy & Rubidge, pp. 112-118 and Fig. 4.10 therein). A range of shallow water facies, often forming depositional cycles reflecting sea level changes, are represented here, including stromatolitic limestones and dolostones, oolites, oncolites, laminated calcilutites, cherts and marls, with subordinate siliclastics (shales, siltstones) and minor tuffs (Beukes 1980, Beukes 1986, Sumner 2002, Eriksson *et al.* 2006, Sumner & Beukes 2006).

Since the current 1: 250 000 geological maps were produced, the Campbell Rand succession has been subdivided into a series of formations, some of which were previously included within the older Schmidtsdrift Formation or Subgroup (Beukes 1980, 1986, Eriksson *et al.* 2006). Formations represented within the 132 kV distribution line study area near Kuruman, but not fully differentiated on the geological map, include the **Kogelbeen Formation** (with the **Lime Acres Member** at the top), the **Gamohaan Formation** and the **Tsineng Formation** (See stratigraphic columns, Figs. 18

& 19). Short descriptions of these rock units are given by Altermann and Wotherspoon (1995) as well as by Eriksson *et al.* (2006) and are summarized as follows:

- **Kogelbeen Formation** (*c*. 450 m thick) – varied succession of dolomite, limestone and chert, with important horizons of stromatolites and microbial laminites; secondary chert replacement common.
- **Gamohaan Formation** (< 100 m thick) – microbial laminites (crinkly "algal mats") and stromatolites with minor dolarenite, tuff (volcanic ash horizon).
- **Tsineng Formation** (*c*. 30 m thick) – microbial laminites with abundant cherts, showing a transitional contact with the overlying deeper-water banded iron formations of the Asbestos Hills Subgroup.

An important age constraint on these rocks is provided by a tuff in the upper part of the Gamohaan Formation that is dated to 2.52 Ga, *i.e.* terminal Archaean (Ga = billion years) (Altermann & Nelson 1998, Sumner & Bowring 1996, Sumner 2002).

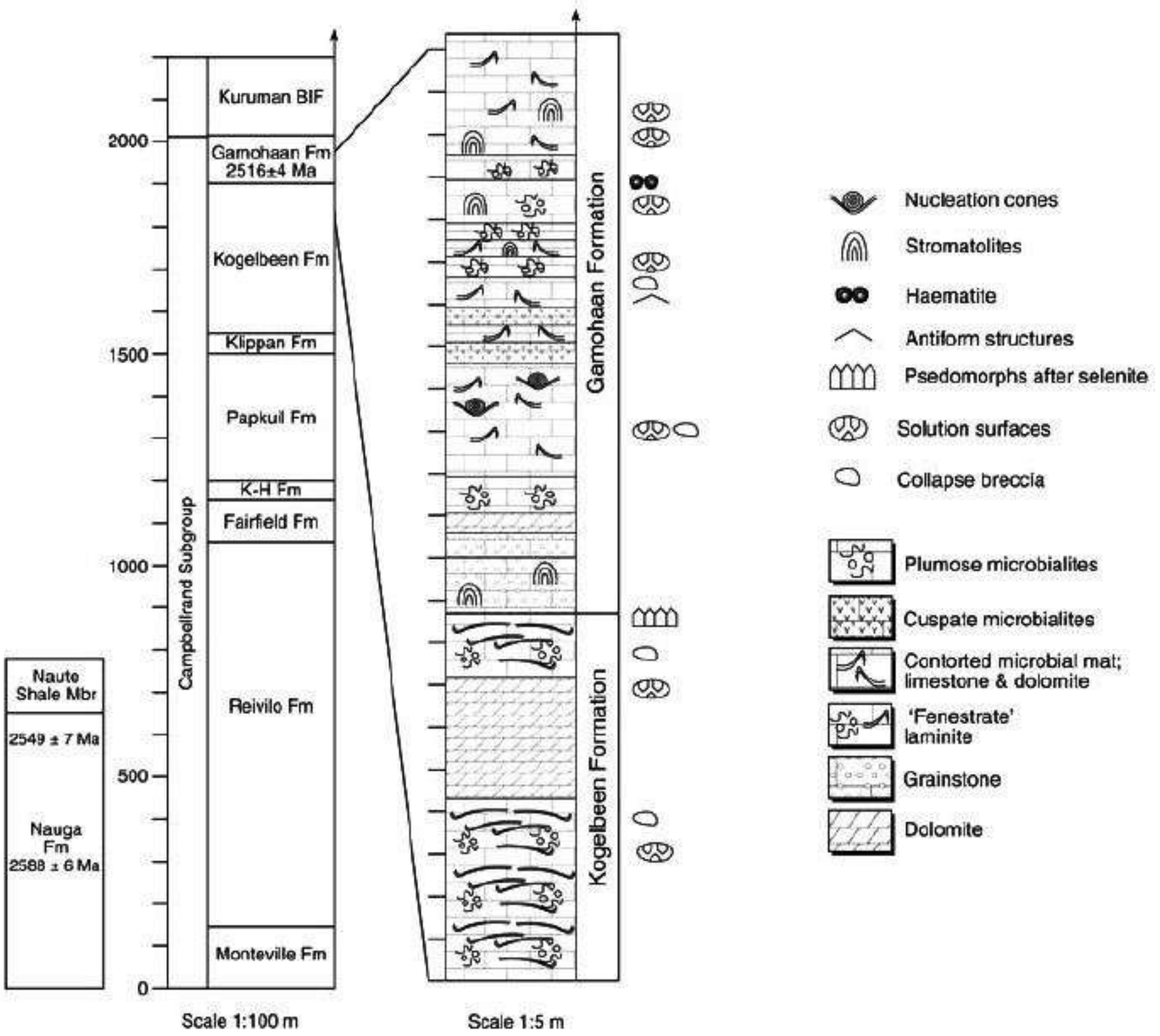


Figure 18. Stratigraphy and sedimentology of the Campbell Rand carbonate succession at Kurumankop – a key locality for diverse Precambrian stromatolites and other biosedimentary structures (From Gandin & Wright 2007).

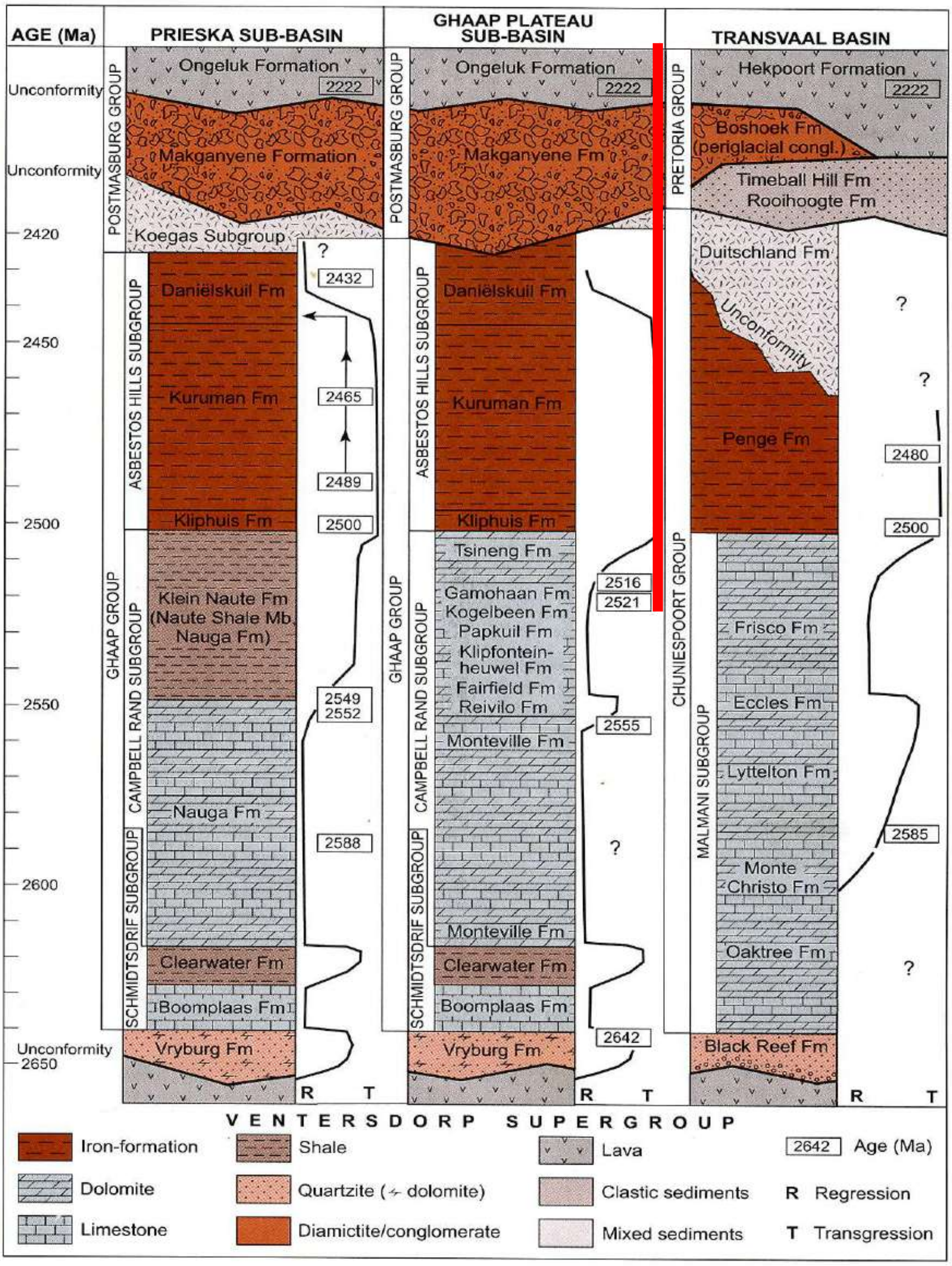


Figure 19. Stratigraphy of the Transvaal Supergroup of the Ghaap Plateau Sub-basin (central column) showing Precambrian bedrock units represented in the 132 kV distribution line network project area (thick red line) (Modified from Eriksson *et al.* 2006). Figures in boxes indicate radiometric ages in millions of years (Ma).

Due to their solubility and low resistance to weathering, exposure levels of the Campbell Rand carbonate sediments are often very low. Many flatter-lying areas are mantled with thick Caenozoic calcrete hardpans, where pans are seen on satellite images (*cf* Almond 2013a). The outcrop area of chert-rich subunits is often locally covered in downwasted, siliceous rock rubble (*ibid.*). In the foothills of the Kurumanberge and adjoining *vlaktes* the carbonate bedrocks are often mantled by a thick blanket (up to several meters) of poorly-consolidated, ferruginised BIF and chert gravels (Figs. 41 & 42). The gravels may infill steep-sided solution hollows within the extensively karstified upper surface of the Ghaap Plateau (Fig. 30). Several disconnected exposures of uppermost Campbell Rand Subgroup carbonates occur along the lower slopes and foot of the east-facing Kurumanberge escarpment (*e.g.* on Alphen 442 south of Kuruman) as well as - most notably - on Kurumankop, situated on the southern side of the R31 some 12 km NW of Kuruman (Figs. 5 & 11). The Kurumankop hillslope exposures are of considerable geological as well as palaeontological interest since they include excellent sections through the upper Kogelbeen, Gamohaan as well as Tsineng Formations that are otherwise generally poorly-exposed due to denudation and superficial sediment cover (*cf* Sumner 2002 and her subsequent papers listed in the References, Gandin & Wright 2007) (Figs. 20 to 25). The upper Campbell Rand succession reflects an overall deepening of the depositional basin up into the offshore BIF facies of the overlying Asbestos Hills Subgroup. The carbonates are markedly tabular-bedded, thin- to medium-bedded and grey to brownish–weathering, and often stylolitic due to post-depositional solution. Their striking lateral continuity and the high proportion of chemically-precipitated (as opposed to biogenic) carbonate have been remarked upon by Sumner (2002).

Several of the interesting geological and palaeontological features of the Late Archaean to Early Proterozoic Campbell Rand carbonates observed on Kurumankop, just over one kilometre due SE of the Gamohaan Substation construction site, as well as in low hillslope exposures of the same carbonate succession on Alphen 442 west of Spitsberg homestead on the eastern margins of the Kurumanheuwels, are illustrated here in Figs. 20 to 26. They include a wide range of microbialite features such as several types of stromatolite (giant elongate domes over 10 m wide *plus* smaller-scale columnar, obconical and domal stromatolites) (Figs. 49 to 58), fenestrate microbialites, plumose and diapiric structures, herringbone calcite, and thin volcanic ash beds or tuffs (See also Section 2). Diagenetic secondary silicification of the carbonate bedrocks often preferentially affected the more stromatolitic horizons; consequently cherty gravels derived from weathering of these bedrocks often contain stromatolitic clasts (Fig. 60). It is notable that many of these carbonate sedimentological and palaeontological phenomena are much more readily observed in naturally-weathered hillslope exposures than in artificial exposures in quarries (Fig. 27), road cuttings and small excavations related to recent construction (Fig. 63).

Downwasting of secondary chert from within the carbonate succession in Precambrian times led to the development of a distinctive, highly-resistant, blocky-weathering siliceous breccia that caps the carbonate bedrocks in many areas (darker blue areas on geological maps Figs. 12 to 14). This silcrete-like breccia contains angular clasts of laminated silicified carbonate and chert but no BIF, indicating that it formed during a major erosive episode preceding transgression and deposition of the Asbestos Hills deep marine succession. Good examples of these ancient Precambrian breccias are seen near the Gamohaan Substation site as well as on the eastern and southern outskirts of Kuruman (Figs. 28 & 29).

In low-lying areas of the Ghaap Plateau around Kuruman the upper surface of the carbonate bedrocks has been extensively karstified in Caenozoic times, with widespread steep-sided solution hollows - often infilled with ferruginised surface gravels of chert and BIF - together with the development of an underground drainage network (*cf* the Eye of Kuruman, cave systems with stalactites on Kurumankop) (Fig. 30).

Figure 20. Outstanding exposures of the upper Campbell Rand Group carbonate succession (Kogelbeen and Gamohaan Formations) on the northern face of Kurumankop, *c*. 1.25 km west of the Gamohaan Substation construction site (Loc. 250).

Figure 21. Interbedded thin- to medium-bedded, tabular grey carbonates and darker secondary cherts of the Kogelbeen Formation, Kurumankop (Loc. 257).

Figure 22. Thin-bedded carbonates of the Gamohaan Formation showing multiple horizons of "fenestrate microbialites" – possibly reflecting calcite replacement of evaporite minerals, Kurumankop (Loc. 262).

Figure 23. Close-up of mutile successive horizons of fenestrate microbialites within the Gamohaan Formation (Scale is 15 cm long) (Loc. 262).

Figure 24. Carbonate package within the Gamohaan Formation containing several tabular cherty layers, greenish when fresh, that probably represent airfall tuffs (volcanic ashes), Kurumankop (Loc. 269) (Hammer = 30 cm). A comparable laterally extensive tuff horizon has been dated to 2.52 Ga (billion years old).

Figure 25. Laterally-persistent horizon of large plumose structures within the Gamohaan Formation on Alphen 442 due west of Spitsberg homestead (Loc. 227) (Hammer = 30 cm). These peculiar structures are probably related to secondary replacement of evaporite deposits by calcite.

Figure 26. Close-up of plumose structure marker horizon illustrated previously showing subvertical diapiric features disrupting the overlying laminated carbonates (Loc. 227) (Hammer = 30 cm).

Figure 27. Cut face through Campbell Rand carbonates in a large quarry due south of Maheane (Loc. 279). Key stratigraphic marker beds of the Gamohaan Formation can be recognised here, but in general the sedimentology and palaeontology of these rocks is better seen in naturally-weathered exposures.

Figure 28. Extensive surface exposure of silcrete-like siliceous breccia overlying the Campbell Rand carbonates on the south-eastern outskirts of Kuruman (Loc. 234). These tough breccias probably formed in Precambrian times following erosive downwasting of chert-rich carbonate bedrocks.

Figure 29. Close-up of highly-siliceous breccias with angular clasts of chert and silicified laminated carbonate exposed near Alphen homestead (Scale = 15 cm) (Loc. 222).

Figure 30. Deeply-karstified Campbell Rand carbonates exposed in a trench along the existing distribution line servitude south of Moffat Substation (Loc. 215). The steep-sided hollows between relict carbonate pillars are infilled with secondarily ferruginised, rusty-brown gravels of chert and BIF.

2.2. Asbestos Hills Subgroup

The Campbell Rand carbonates are overlain by the thick Early Proterozoic banded iron formations (BIF) of the **Asbestos Hills Subgroup** (Ghaap Group) (*c.* 2.5 – 2.43 Ga). The gradational contact between these two Ghaap group successions can be seen, for example, on Kurumankop (Fig. 31). The resistant-weathering, cherty, iron-rich BIF sediments build the low-lying, highly-dissected and locally faulted hills of the Kurumanberge range. They also underlie short sectors of the 132 kV distribution line corridor NW and S of Kuruman (*e.g.* Oogkop, Fig. 32) as well as building low hills in the Lohatlha plains area. The lithostratigraphic subdivisions shown on the 1: 250 000 geological map (Figs. 12 to 14) and used by Eriksson *et al.* (2006) (Fig. **) are also employed here, while it is noted that more refined stratigraphy has been presented by Beukes (1984: Kuruman and Griquatown Formations, with several members). The Asbestos Hills Group rocks are for the most part poorly exposed in the Kurumanberge region due to extensive colluvial gravel cover. Prominent-weathering, rusty-brown chert-rich packages at the tops of BIF sedimentary cycles build narrow scarps or *kranzes* imparting a stepped profile to many otherwise gentle hillslopes as seen, for example, on Kurumankop (Fig. 31).

The **Kliphuis Formation** that crops out across the Griqualand West Basin at the base of the Asbestos Hills Subgroup comprises a thin (< 15 m) package of interbedded ferruginous shales and cherts sandwiched between the Campbell Rand carbonates and the overlying BIF. However, it was not encountered in the present study area, probably due to BIF scree cover.

The **Kuruman Formation** (Vak in Figs. **) of the Asbestos Hills Subgroup consists predominantly of banded iron formations (BIF). These distinctive BIF rocks – exposed, for example, on Oogkop south of Kuruman as well as in the vicinity of the Gamohaan Substation site - consist of rhythmically bedded, thinly composition- and colour-banded cycles of fine-grained mudrock, chert and iron minerals (siderite, magnetite, haematite) that were deposited in an offshore, intermittently anoxic basin. In the Ghaap Plateau Sub-basin to the north of the Griquatown Fault Zone the Kuruman BIF reaches thicknesses of up to 250 m (Eriksson *et al.* 2006). BIF deposition characterizes the Late Archaean – Early Proterozoic interval (2.6 to 2.4 Ga) before the onset of well-oxygenated atmosphere and seas. Hillslope exposures of prominent-weathering Kuruman Formation beds comprise alternating cherty and ferruginous-laminated units (dm scale) within *c*. 10 m-thick packages or cycles. The dominant facies is laminated to thin-bedded (2 cm), buff to ferruginous or metallic BIF with flat, dimpled, pustulose to undulose bedding planes (not rippled). The beds and laminae are typically very laterally-persistent, tabular and monotonous. Occasional float blocks show convolute soft-sediment deformation (possibly slumping) with crumpled, disrupted lamination and small-scale unconformities.

The overlying iron–rich succession of the **Daniëlskuil Formation** (Vad in Figs. 12 to 14), up to 200 m-thick, is interpreted as a current- or wave-reworked banded iron formation, as suggested by the abundance of BIF intraclasts and sedimentary structures (Beukes 1983, Klein & Beukes 1989, Beukes & Klein 1990). The base of the Daniëlskuil Formation has been radiometrically dated to 2.43-2.49 Ga, *i.e.* Early Proterozoic (Eriksson *et al.* 2006). The Daniëlskuil Formation BIFs tend to be more prominent weathering than the underlying finer-grained Kuruman BIF rocks. The fine-grained siliciclastics are brown to ochreous weathering, very tabular in geometry, laminated to thin-bedded (to *c*. 10-20 cm), cherty (*e.g.* showing conchoidal fracture) with bands of iron minerals (reddish haematite, dark magnetite *etc*). Jointing is typically well developed. Road cuttings along the R31 in the north-western part of the 132 kV distribution line project area are built of thin- to medium-bedded, tan to reddish-brown cherty mudrocks (Fig. 33). They are typically thicker-bedded, less tabular and with comparatively fewer metallic ore laminae compared with underlying Kuruman Formation. Cherty layers show blocky to conchoidal fracture. Sedimentary structures include occasional wave ripples, cross-lamination, cut-and-fill structures and other erosional discontinuities suggesting a higher-energy, shallower depositional setting to that prevailing during Kuruman Formation times. Extensive road cuttings showing good sections through various contrasting subfacies of the Daniëlskuil Formation are seen along the N14 west of Kuruman (Almond 2018b). Sedimentary structures seen here include thin-bedded to laminated BIF, tabular bedded or showing small-scale soft-sediment deformation, thin platy breccia or blocky diamictite horizons, erosive cut-and-fill structures, possible boudinaged and loaded cherty layers, and isolated convex-up domes with a finger-like substructure. These rocks have probably suffered high levels of diagenetic (post-depositional) modification.

2.3. Postmasberg Group

As shown in the stratigraphic columns for the Ghaap Plateau Subbasin in Figures 17 and 19, the Koegas Subgroup is not represented within the Kurumanberge study area, having been entirely denuded by erosion along the basal-Postmasburg Group unconformity. Palaeoproterozoic glacial-related diamictites (“tillites”) of the **Makganyene Formation** (*c*. 2.2-2.3 Ga) which unconformably overlie the Asbestos Hills BIF in the Kuruman region are mapped close to, but not within, the southern sector of the project area in the western foothills of the Kurumanberge (Almond 2018d). They and the overlying **Ongeluk Formation** volcanics occur here along the core of the Dimoten Syncline, while small downfaulted outliers of Ongeluk volcanics (and perhaps related intrusive facies) are encountered between the Gamohaan and Riries Substations in the north (Figs. 34 & 35). No stromatolites or other fossils were recorded within these small outcrop areas and the poorly-exposed Postmasburg Group succession is therefore not treated further in this report.

Figure 31. Transition zone between pinkish-hued carbonates of the Tsineng Formation (uppermost Campbell Rand Subgroup) in the foreground and overlying banded ironstones of the Asbestos Hills Subgroup building the steeper hillslopes in the background, Kurumankop (Loc. 271).

Figure 32. Steeply-dipping, thinly-bedded banded ironstones of the Kuruman Formation (Asbestos Hills Subgroup) in a tight syncline on Oogkop, *c*. 2 km south of Kuruman (Loc. 218).

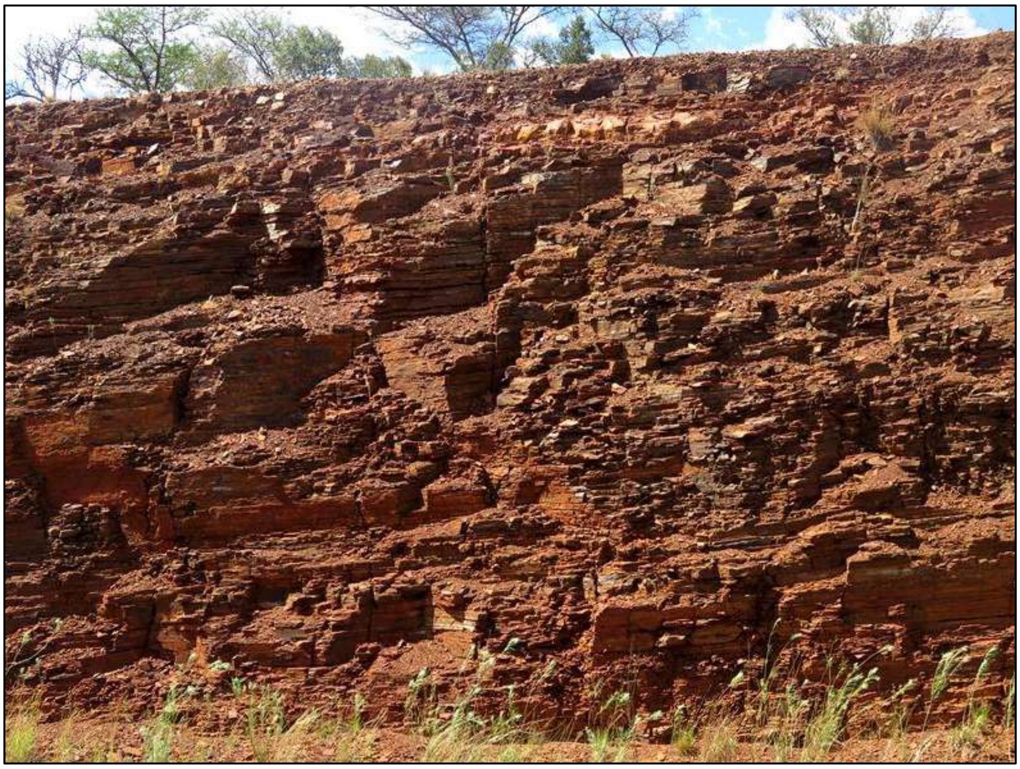


Figure 33. Road cutting exposure of thinly-bedded, tabular ironstones of the Daniëlskuil Formation (Asbestos Hills Subgroup) along the R31 between the Gamohaan and Riries Substation sites (Loc. 277).

Figure 34. Quarry exposure of highly-weathered and partially-calcretised, greenish, speckled, igneous rock apparently intruding Campbell Rand country rocks – possibly a coarse-grained hypabyssal intrusion (*e.g.* feeder dyke) related to the Ongeluk Formation volcanics (Hammer = 30 cm) (Loc. 276).

Figure 35. Pale greenish-grey, massive, blocky-weathering lavas of the Ongeluk Formation (Postmasburg Group) exposed in a borrow pit just east of Riries Substation (Loc. 281) (Hammer = 30 cm).

2.4. Late Caenozoic superficial deposits

Most of the Precambrian bedrock outcrop in the 132 kV distribution line and associated substation project area is mantled by a range of – mostly unconsolidated – superficial deposits of ill-defined Late Caenozoic age. The low, rounded hills of the Kurumanberge reflect protracted post-Gondwana denudation involving extensive dissection of the eastern flank of the Dimoten Syncline. Extensive flattish hillcrests at *c*. 1500-1600 m amsl. featuring sparse rounded (water-worn) pebble and cobble clasts suggest a possible ancient pediment surface here, perhaps of Late Cretaceous or Tertiary age and subsequently dissected following Tertiary uplift.

Most of the hill crests and slopes in the Kurumanberge are covered by a thin to several meter-thick mantle of angular, gravelly colluvium (downwasted surface gravels and scree) composed of blocky chert and BIF (occasionally flaked) with occasional clasts of ferricrete and vein quartz. Where the hilly foot slopes of the Kurumanberge level out towards the monotonous flatlands of the Ghaap Plateau and the Lohatlha Plains the landscape is incised by shallow water courses choked with platy to blocky BIF debris and minor carbonate clasts. Here the bedrocks are mantled with ferruginous cherty gravels, locally up to several meters thick, and orange-brown sandy soils. Borrow pit exposures on Mapperley 443 south of Kuruman as well as excavations at the Gamohaan Substation site and elsewhere show good sections through several meters of semi-consolidated, angular pebbly to cobbly gravels, locally with evidence of debris flow deposition towards the base (Figs. 41 & 42). The gravels are composed of well-rounded to angular clasts of chert, BIF together with occasional angular float blocks of black carbonate and silicified stromatolitic carbonate. Some clasts show a well-developed dark grey ferro-manganese patina and are cemented by ferricrete.

Carbonate-cemented breccia lenses and flowstones (calc-tufa) are associated with Campbell Rand Subgroup exposures along the eastern edge of the Kurumanberge as well as on Kurumankop. Relict stalactites and stalagmites as well as spectacular tufa cones related to exhumed underground drainage systems can be seen here (Fig. 37). The calcretised breccias - and, to a lesser degree, the flowstones - contain angular or occasionally water-worn, poorly-sorted clasts of carbonate, chert, BIF as well as sparse embedded MSA tools (Fig. 38). Cones and veins of calc tufa on cliff faces are associated with solution hollows, gullies and overhangs pointing to a long history of Late Caenozoic karstic weathering of carbonate bedrocks in the Ghaap Plateau region. Steep-sided, shallow to deep solution hollows within karstified Campbell Rand carbonates in the vicinity of Kuruman are usually infilled with ferruginised gravels of secondary chert and BIF (Fig. 30).

A range of Late Caenozoic alluvial deposits are associated with major drainage lines, such as the Kuruman River and its (usually dry) tributaries. They include heavily calcretised to locally ferruginised, oligomict alluvial gravels and semi-consolidated orange-brown sands (Figs. 36, 43 to 46, 48). Possible relict High Level Gravels composed of well-rounded boulders of Precambrian silicified breccia and porphyritic lava are recorded south of Kuruman (Fig. 47). Surface gravels in areas underlain by carbonate bedrocks typically contain common downwasted clasts of chert and silicified stromatolitic carbonate (Figs. 39 & 40) while platy clasts of BIF predominate in gravels overlying the Asbestos Hills Subgroup outcrop areas as well as broad colluvial aprons margining the Asbestosberge uplands. Soils in lower-lying areas are predominantly orange-brown sands, some of which may represent reworked aeolian (wind-blown) sands that may be provisionally assigned to the Pleistocene Gordinia Formation of the Kalahari Group) (Fig. 3).

Figure 36. Intensely-calcretised weathering profile (possibly originally alluvial) overlying Campbell Rand carbonate bedrocks in a quarry north of the R31 (Loc. 276) (Hammer = 30 cm).

Figure 37. Extensive development of calc-tufa flowstone associated with karstified Campbell Rand carbonates on the eastern face of Kurumankop (Loc. 273). Relict stalagmites and stalactites are seen in this area.

Figure 38. Lens of coarse, angular carbonate breccia cemented by calcrete - possibly a fissure infill – exposed on the slopes of Kurumankop (Hammer = 30 cm) (Loc. 262).

Figure 39. Ferruginised, rubbly breccias of silicified carbonate and secondary chert overlying karstified and secondarily mineralised carbonate bedrocks in a quarry cut face east of the R31 and SSE of Kuruman (Loc. 220).

Figure 40. Karstified grey Campbell Rand carbonates exposed on hillslopes north of Bodulang showing pale grey secondary chert bands as well as concentration of pale yellowish chert clasts in the overlying downwasted surface gravels (Hammer = 30 cm) (Loc. 245).

Figure 41. Thin, upward-coarsening debris flow deposits of ferruginous sand and BIF gravels exposed in a borrow pit near Mapperley homestead (Hammer = 30 cm) (Loc. 233).

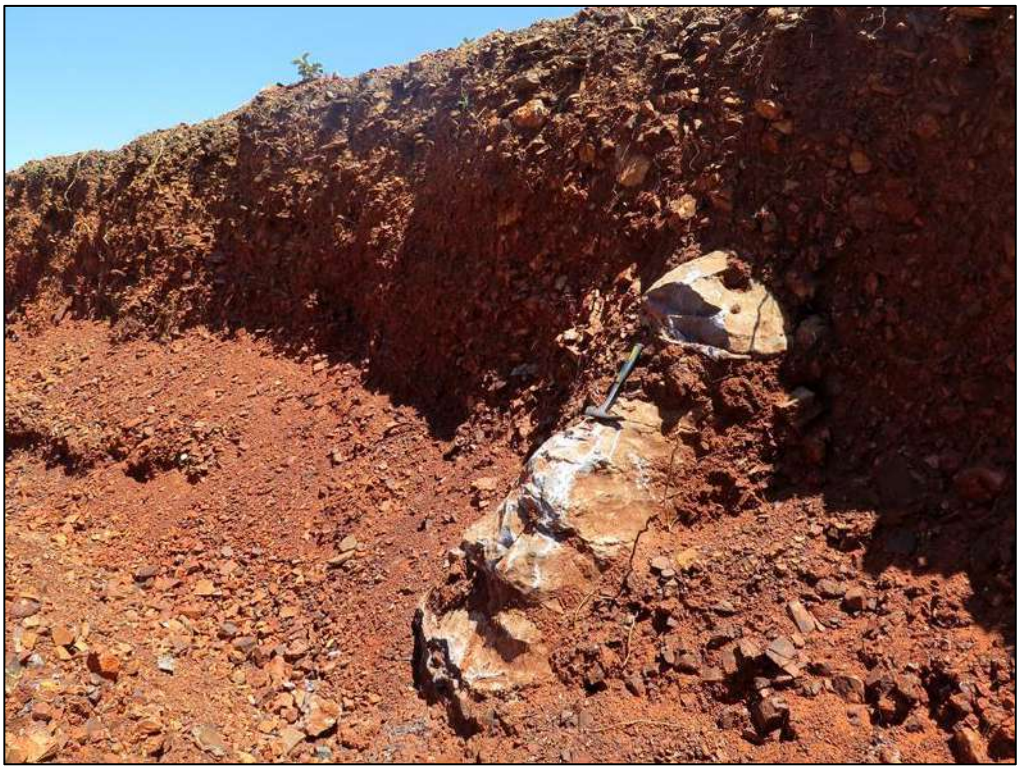


Figure 42. Thick, poorly-sorted, ferruginised BIF gravels mantling a relict karst pillar of Campbell Rand carbonate bedrocks exposed by excavations for the Gamohaan Substation (Loc. 243) (Hammer = 30 cm).

Figure 43. Concentrated platy BIF gravels of probable alluvial origin on the flat floodplain of the Kuruman River (Loc. 247).

Figure 44. Several-m thick section through ferruginised, poorly-sorted, angular to subrounded alluvial gravels associated with a left bank tributary of the Kuruman River, borrow pit near Wrenchville (Loc. 240).

Figure 45. Rusty-brown alluvial sands with dispersed fine gravels exposed in a borrow pit near Wrenchville (Hammer = 30 cm) (Loc. 240).

Figure 46. Thick, highly-calcretised, coarse, oligomict, matrix-supported alluvial gravels associated with a tributary of the Kuruman River, road cutting near Wrenchville (Loc. 237) (Hammer = 30 cm).

Figure 47. Rounded boulders of silicified breccia and porphyritic lava – possible alluvial High Level Gravels exposed SSE of Kuruman (Loc. 221) (Scale = 15 cm).

Figure 48. Poorly-sorted, cherty alluvial gravels and overlying semi-consolidated rusty-brown sands exposed in the walls of an informal excavation near Mothibastat (Loc. 241).

2.5. 132 kV grid connection from Valley Substation to Ferrum Substation near Kathu

The geology and palaeontology of the southern sector of the proposed new 132 kV distribution line, between the Valley Substation on the western flank of the Kurumanberge and Ferrum Substation near Kathu (area outlined in orange in Fig. 2), has been covered by a recent, extensively-illustrated palaeontological heritage assessment report by Almond (2018d) from which the following, slightly modified, account is extracted.

The chosen 132 kV distribution line corridor traverses the majority of the NNW-SSE trending Dimoten Syncline (See geological map Fig. 15). Several minor drainage lines are crossed, but no major water courses. The easternmost sectors of the corridor (both branches) follow dry valleys transecting the Kurumanberge which are floored by thick alluvial sands and BIF basal gravels. The western hills of the Kurumanberge here are built of west-dipping BIF of the **Asbestos Hills Subgroup** (**Kuruman** and **Daniëlskuil Formations**). The Proterozoic bedrocks are widely mantled with thin gravelly colluvium here, within only intermittent thin *kranzes* or cliffs of prominent-weathering cherty BIF, while along the western flanks of the hills colluvial fans of ferruginised BIF gravels are locally seen.

In the core of the Dimoten Syncline around Lohatlha the Ghaap Group bedrocks are unconformably overlain by Proterozoic glacially-related sediments and lavas of the **Postmasburg Group** (Makganyene and Ongeluk Formations). According to the 1: 250 000 geological map no outcrop areas of Makganyene Formation glacial diamictites are traversed by the new powerline corridor, although these are present in the subsurface. In the Rooikop region the powerline corridor passes close to low hills capped by resistant-weathering **Ongeluk Formation** grey-green lava. These ancient lavas are well-jointed, massive (no amygdales seen) and may show the development of columnar jointing within thicker lava flows. The igneous bedrocks here are mantled by lava rubble and surface gravels, including vein quartz. On the western flank of the Dimoten Syncline the corridor traverses BIF bedrocks once again (east-dipping in this case) but exposures are very poor and rusty-weathered on the gentle, BIF rubble-strewn hillslopes here. Over the greater part of the low-lying Lohatlha Plains region west of the Kurumanberge as far as Kathu the Proterozoic bedrocks are covered by thick orange-brown aeolian sands of the **Gordonia Formation**, locally reworked and semi-consolidated at depth, as well as underlying well-developed calcrete hardpans (both assigned to **Kalahari Group**). The calcretes are rarely exposed, except along shallow drainage lines where they are seen to be polyphase and locally karstified. Shallow drainage lines are associated with pans or *vleis* featuring oligomict alluvial gravels of finely-banded chalcedony (weathered-out amydales from the Ongeluk lavas), cherts, quartz and possible tuffs. Some of the gravels clasts show anthropogenic flaking.

3. PALAEONTOLOGICAL HERITAGE

A summary of the potential fossil groups associated with the principal rock units that are represented in the Kuruman distribution line project area is given in Table 1. GPS locality data together with brief descriptive notes for all sites of geological or palaeontological interest visited during the recent field assessment are provided in Appendix 1. The numbered sites are shown with reference to the study area outline on a satellite map in Figures 66 to 68.

3.1. Fossils within the Campbell Rand Subgroup

The shallow shelf and intertidal sediments of the carbonate-dominated lower part of the **Ghaap Group** (*i.e.* **Schmidtsdrif** and **Campbell Rand Subgroups**) are well known for their rich fossil biota of *stromatolites* or microbially-generated, finely-laminated sheets, mounds, domes, columns and branching structures. Some stromatolite occurrences on the Ghaap Plateau of the Northern Cape are spectacularly well-preserved (*e.g.* Boetsap locality northeast of Daniëlskuil figured by McCarthy & Rubidge 2005, Eriksson *et al.* 2006). Detailed studies of these 2.6-2.5 Ga carbonate sediments and their stromatolitic biotas have been presented by Young (1932 and several subsequent papers), Beukes (1980, 1983), Eriksson & Truswell (1974), Eriksson & Altermann (1998), Eriksson *et al* (2006), Altermann and Herbig (1991), Altermann and Wotherspoon (1995), and Sumner (2002). The oldest, Archaean stromatolite occurrences from the Ghaap Group have been reviewed by Schopf (2006, with full references therein).

Horizons of microbial mats as well as domal and columnar stromatolites on various scales are reported from the **Kogelbeen Formation**. Some of the oldest known (2.6 Ga) fossil microbial assemblages with filaments and coccoids have been recorded from stromatolitic cherty limestones of the **Lime Acres Member** (Kogelbeen Formation) at Lime Acres near Kuruman (Altermann & Schopf 1995, Altermann & Wotherspoon 1995). The **Gamohaan Formation** also features well-developed horizons of microbial mats as well as domal and columnar stromatolites (Eriksson *et al.* 2006). The **Tsineng Formation** at the top of the Campbell Rand carbonate succession has yielded stromatolites (previously assigned to the Tsineng Member of the Gamohaan Formation), microbial mats as well as filamentous microfossils named *Siphonophycus* that are thought to have developed in shallow waters of the photic zone that were no more than a few tens of meters deep (Klein *et al.* 1987, Altermann & Schopf 1995, Eriksson *et al*. 2006).

Complex fabrics forming tabular to conical structures within carbonates of the Kogelbeen and Gamohaan Formations that are composed of thin, filmy dark laminae draped around calcite-infilled voids (*e.g.* fenestrate microbialites, plumose structures) have been interpreted as being of microbial origin and generated in deep subtidal settings by some workers (*cf* Sumner 1997, 2002, Sumner & Grotzinger 2004, Sumner & Beukes 2006, Riding 2008, 2011). Other sedimentologists have plausibly attributed many of these strange structures to diagenetically-replaced “vanished” evaporites (Gandin *et al.* 2005, Gandin & Wright 2015).

Small, isolated cliff and hillslope exposures of Campbell Rand carbonates exposed along the eastern margins of the Kurumanberge (*cf* Almond 2018b, 2018c) – for example on Alphen 442 south of Kuruman - are of considerable palaeontological interest – and conservation value - for the wealth of stromatolites and other microbially-generated biosedimentary structures seen here. Classic examples of Late Archaean stromatolites and other biosedimentary structures have been recorded from the Kurumankop locality – close to Gamohaan Substation - by Sumner (2002) and later authors. Lagoonal, shallow water carbonates of the upper **Kogelbeen Formation** seen at these sites feature abundant laminated microbialites including “giant” elongate stromatolites containing subdued to well-developed, elongate stromatolitic micro-columns (mini-stromatolites) (Figs. 51 to 54). Large-scale elongate stromatolites (2-10 m wide x 5 m to > 45 m long) are better known at the famous Boetsap locality on the eastern edge of the Ghaap Plateau and interpreted as being shallow subtidal in origin (Sumner 2002). The simple to branched stromatolitic micro-columns (1-5 cm across) probably have a composite precipitated *plus* trapped-and-bound origin.

Cliff-forming, darker brownish- and grey-weathering, deep-subtidal carbonates of overlying the **Gamohaan Formation** are characterised by abundant fenestrate microbialites (often interbedded with brownish ferruginous carbonate beds), laterally-persistent horizons of conical plumose structures, herringbone calcite as well as intact and reworked microbial mat material and upwardly penetrating, stromatolite-like diapirs (Figs. 22, 23, 25 to 26). A varied spectrum of well-preserved small-, medium- and large-scale domal and columnar to conical stromatolites are found in these beds on Kurumankop and elsewhere, some of which display strongly asymmetrical, current-influenced growth patterns (Figs. 55 to 58). Abundant chemically-precipitated calcite in both the Kogelbeen and Gamohaan beds includes occasional horizons featuring spaced domal pseudostromatolites with markedly isopachous internal lamination (Fig. 59).

The **Tsineng Formation** at the top of the Campbell Rand carbonate succession is generally more recessive-weathering than underlying cliff-forming Gamohaan Formation (Fig. 31). It is thin- to medium-bedded, pale grey to slightly lilac-hued or greenish-khaki, with several thin to 20 cm-thick horizons of black, finely-laminated chert. Abundant concentrically-laminated soft sediment deformation features (and / or Liesegang rings) give the superficial appearance of stromatolites while true domical stromatolites may occur occasionally (but were not seen in this study). The well-developed cherts probably contain organic-walled microfossils (see refs. above).

It is noted that stromatolites, even where abundantly present, are generally not readily visible within freshly-excavated carbonate bedrock, especially where this is scratched and soil-covered, as readily seen in various small-scale and large quarry excavations in the study region (Figs. 63 to 65). These fossil complex bio-sedimentary structures are best seen on naturally-weathered surfaces (Figs. 49 & 50). Here slow etching by slightly acidic rain picks out the delicate stromatolitic lamination, especially where this has been secondarily replaced by resistant-weathering chert.

3.2. Fossils within the Asbestos Hills Subgroup

The deep water BIF facies of the Asbestos Hills Subgroup (**Kuruman** and **Daniëlskuil Formations**) have not yielded stromatolites which are normally restricted to the shallow water photic zone (< 200 m) since they are constructed primarily by photosynthetic microbes. No convincing trace fossils, attributable to sizeable metazoans (multi-cellular animals), have been reported from BIF facies. However, there are several reports of microfossils from cherty sediments within the Kuruman Formation according to MacRae (1999) and Tankard *et al.* (1982 – see refs. therein by Fockema 1967, Cloud & Licari 1968, La Berge 1973). (*N.B.* the stratigraphic position of these older records may require confirmation). The supposed fossil medusoid or jellyfish *Gakarusia* reported from the Asbestos Hills Subgroup by Haughton (1963) (“Griquatown Beds” at Gakarusa, between Daniels Kuil and Kuruman) is almost certainly a pseudofossil (*cf* Haughton 1969, Haentzschel 1975).

No macrofossils, including trace fossils, were observed in well-exposed sections through the Kuruman and Daniëlskuil Formations within the broader 132 kV distribution line project area.

Dendrites – fossil moss- or fern-like pseudofossils composed of the manganense ore pyrolusite - are locally developed on BIF bedding planes.

3.3. Fossils within Late Caenozoic superficial sediments

Most of the Late Caenozoic superficial sediments within the 132 kV distribution line project area are of low palaeontological sensitivity, preserving few, if any, scientifically-valuable fossil remains. Calcretes associated with the Campbell Rand carbonates on the Ghaap Plateau to the east of the Kurumanberge might contain trace fossils such as rhizoliths, termite and other insect burrows, or even mammalian trackways. Reworked blocks of calcretised fine-grained alluvium encountered in the bed of the Kuruman River contain subfossil, stromatolite-like laminations generated by fresh- or brackish-water microbial communities (Fig. 61).

Mammalian bones, teeth and horn cores (also tortoise remains, and fish, amphibian or even crocodiles in wetter depositional settings) may be expected occasionally expected within Kalahari Group sediments and calcretes, notably those associated with ancient alluvial sands and gravels. Unconsolidated surface gravels and colluvium are for the most entirely unfossiliferous. However, sporadic reworked cherty carbonate blocks within ferruginous colluvial gravels do contain small silicified stromatolitic domes (Fig. 60); stromatolitic horizons were preferentially silicified during diagenesis, and are therefore preferentially represented within surface gravels that concentrate resistant-weathering rock rubble. Occurrences of calc-tufa, flowstone and fissure-infill breccias in the karstified Campbell Rand outcrop area – as recorded, for example, along the eastern edge of the Kurumanberge and Kurumankop (Figs. 37 & 38) – might possibly be associated with micromammal remains as well as the bones and teeth of larger mammals (including hominins), reptiles and birds, plant fossils *etc*, as well-seen, for example, in karstified Precambrian carbonate successions in Namibia. No bones, teeth or other fossil remains were seen in this context during the present field study, while occasional embedded cherty stone artefacts – including probable MSA – imply a Pleistocene or younger age (Almond 2018b, 2018c).

Table 1: Potential fossil heritage in the Hotazel – Kuruman – Kathu 132 kV distribution line study area

GEOLOGICAL UNIT	ROCK TYPES & AGE	FOSSIL HERITAGE	PALAEONTOLOGICAL SENSITIVITY	RECOMMENDED SPECIALIST MITIGATION
Gordonia Formation **KALAHARI GROUP** ***plus*** **SURFACE CALCRETE, CALC TUFA**	Mainly aeolian sands *plus* minor fluvial gravels, freshwater pan deposits, calcretes, calc tufa / flow stone, karstic fissure infill breccias PLIO-PLEISTOCENE to RECENT	calcretised rhizoliths & termitaria, ostrich egg shells, land snail shells, rare mammalian and reptile (*e.g.* tortoise, micromammal) bones, teeth, plant remains freshwater units associated with diatoms, molluscs, stromatolites *etc*	GENERALLY LOW with exception of rare pockets of fossiliferous fissure infill, karst breccia (HIGH sensitivity)	None recommended Any substantial fossil finds to be reported by ECO to SAHRA
Makganyene & Ongeluk Fms **POSTMASBURG GROUP**	Glacial diamictites (tillites), volcanic lavas, dolomites, ironstones EARLY PROTEROZOIC (*c*. 2.2 Ga)	Stromatolites associated with glacial deposits within the Makganyene Formation (Prieska Sub-basin)	GENERALLY LOW with exception of stromatolitic units	Reporting and documentation of ancient stromatolites in surface exposures of Makganyene Fm
Asbestos Hills Subgroup (Kuruman & Daniëlskuil Fms) **GHAAP GROUP**	BIF (banded iron formations) with cherty bands EARLY PROTEROZOIC (*c*. 2.5-2.4 Ga)	Important early microfossil biotas No macrofossils reported to date	LOW	None recommended
Campbell Rand Subgroup (Kogelbeen, Gamohaan & Tsineng Fms) **GHAAP GROUP**	Limestones, dolomites, subordinate cherts & tuffs LATE ARCHAEAN – EARLY PROTEROZOIC (*c*. 2.6-2.5 Ga)	Range of microbialites including various forms of stromatolite, organic-walled microfossils within cherts	HIGH	Stromatolite-rich exposures to be protected as No-Go areas. Specialist recording and mitigation of Chance Fossil Finds.

Figure 49. Secondarily-silicified, low-relief, medium-scale stromatolitic domes etched out by solution weathering of karstified Carmpbell Rand carbonates in the vicinity of Moffat Substation (Loc. 206) (Hammer = 30 cm).

Figure 50. Vertical section through well-preserved columnar stromatolites with rounded to squared-off internal lamination (upward accretion towards the left) exposed in a float block near Moffat Substation (Scale in cm and mm) (Loc. 209).

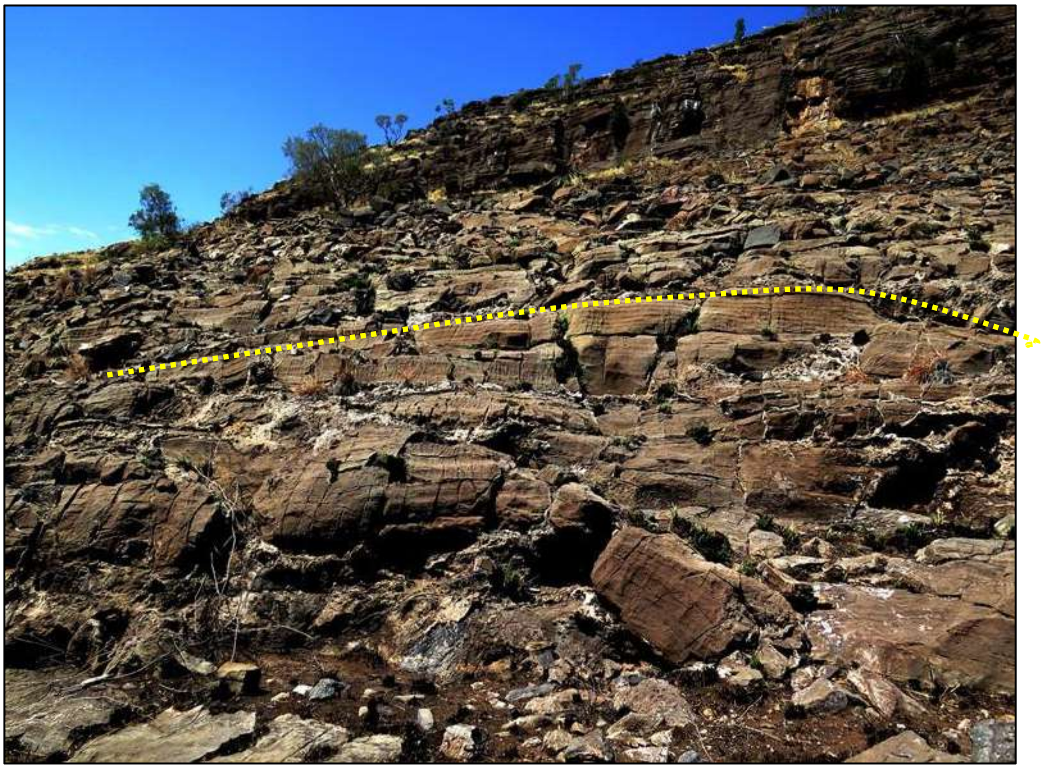


Figure 51. Superimposed, overlapping giant elongate stromatolitic domes (upper surface of one example indicated by yellow dotted line) within brownish-weathering carbonates of the upper Kogelbeen Formation, Kurumankop (Loc. 260).

Figure 52. Close-up of thin-bedded, brownish carbonates building the giant stromatolites seen above showing internal construction by small-scale stromatolitic columns (some leaning, or expanding-upwards) (Scale in cm) (Loc. 260).

Figure 53. Closely-packed, small-scale micro-stromatolites within the upper Kogelbeen Formation on farm Alphen 442 (Scale is 25 cm long) (Loc. 223).

Figure 54. Vertical section through small-scale stromatolitic bodies building the brown carbonate facies seen in the previous figure (*qv* for scale). Most of the bodies show vertical accretionary growth but some may represent loose structures with a more concentric growth pattern (*cf* oncolites) (Loc. 223).

Figure 55. Medium-scale, secondarily-silicified, domical stromatolites in the Gamohaan Formation on Kurumankop showing pronounced lateral accretion (towards the right) that is probably related to prevailing currents (Scale in cm) (Loc. 259).

Figure 56. Large-scale, adjoining stromatolitic domes showing high levels of inheritance and preferential replacement of laminae by dark diagenetic silica, Gamohaan Formation, Kurumankop (Loc. 259).

Figure 58. Stromatolitic horizon within the Gamohaan Formation, Kurumankop, showing closely-spaced, medium-scale (*c*. 15-20 cm wide) columns separated by grey interstitial carbonate sediment (Hammer = 30 cm). In some cases the internal lamination is subconical (*cf Conophyton*) (Loc. 266).

Figure 59. Stromatolite-like domal structures within the Kogelbeen Formation constructed by concentric layers of isopachous carbonate cement. The domes are *c*. 5 to 20 cm across (Loc. 254).

Figure 59. Stromatilite-like microbialites preserved within a transported block of Quaternary calcrete in the bed of the Kuruman River (Loc. 249) (Scale in cm).

Figure 61. Block of reworked silicified stromatolitic carbonate within downwasted cherty gravels on the SE outskirts of Kuruman (Loc. 234) (Scale in cm and mm).

4. CONCLUSIONS & RECOMMENDATIONS

The project area for the authorised new 132 kV distribution line and associated electrical substations between Kathu, Kuruman and Hotazel is largely underlain by sedimentary bedrocks of Precambrian (Late Archaean – Early Proterozoic) age that are assigned to the Ghaap Group (Transvaal Supergroup). These sediments were laid down in shallow inshore to deep offshore marine settings on the margins of the ancient Kaapvaal Craton some 2.5 to 2.4 Ga (= billion years ago). Excellent hillslope exposures of limestones and dolomites of the Campbell Rand Subgroup crop out at Kurumankop (*c.* 1-2 km west and southwest of the Gamohaan Substation site) and at several other points along the eastern flanks of the Kurumanberge (*e.g.* on Alphen 442 some 12 km south of Kuruman). These Precambrian carbonate bedrock exposures are of considerable geoscientific significance and also contain well-preserved biosedimentary structures, including a range of different types of stromatolites (fossil microbial mounds). However, they lie just *outside* the project footprint and will not be impacted by the proposed development. Other Precambrian bedrocks within the project area include banded ironstones (BIF) of the Asbestos Hills Subgroup and igneous rocks of the Ongeluk Formation (Postmasburg Group), neither of which are fossiliferous.

Stromatolite-rich Campbell Rand Subgroup carbonates lie at or near-surface within several sectors of the distribution line corridor, notably close to Moffat Substation on the outskirts of Kuruman. However, in these lower-lying areas of the Ghaap Plateau the bedrocks are usually karstified - *i.e.* have been subjected to extensive solution weathering – so well-preserved stromatolite beds are uncommon. The carbonate bedrocks are locally capped by tough siliceous breccias of Precambrian age and extensively mantled by thin to thick (up to several meters) superficial deposits. These Late Caenozoic deposits – variously comprising ferruginised gravels of reworked chert and banded ironstone, coarse to sandy alluvium (highly calcretised along major water courses such as the Kuruman River and its tributaries) and reworked Kalahari sands – are generally unfossiliferous. The gravels contain numerous reworked clasts of silicificied stromatolitic chert, while occasional blocks of calcretised alluvium containing Late Caenozoic (probably Quaternary) microbial structures are recorded along the Kuruman River.

4.1. Recommended monitoring & mitigation

The existing powerline servitude and substation areas are generally highly disturbed at surface, especially in the vicinity of towns and townships. Although occasional float blocks of richly-stromatolitic carbonate are recorded here, for example near Moffat Substation, many of these have been damaged by vehicle or other construction activity. It is noted that fossil stromatolites are difficult to discern within freshly-broken limestone and dolomite, as exposed in quarries, borrow pits and smaller artificial excavations, compared with naturally-weathered hillslope exposures. Pockets of high palaeosensitivity – for example assemblages micromammal and other vertebrate remains embedded within karstic fissure-infill and tufa deposits – *might* occur here, by analogy with Precambrian carbonate outcrops elsewhere in southern Africa (*e.g.* Namibia), but are impossible to predict. Excavations for the 132 kV monopole footings and any new access roads are small in volume (Fig. 62) and will mainly impact unfossiliferous superficial sediments. It is concluded that (1) the study areas for the 132 kV distribution line corridor and associated substations are generally of low palaeontological sensitivity and consequently (2) the impact significance of the proposed development in terms of palaeontological heritage is low. None of the sparse fossil stromatolite occurrences recorded within the development footprint is considered to be especially conservation worthy, and no specialist palaeontological monitoring or mitigation is recommended for this electrical infrastructure project.

Should substantial fossil remains – such as well-preserved stromatolitic beds, mammalian bones and teeth - be encountered at surface or exposed during the construction phase, the ECO should safeguard these, preferably *in situ*. They should then alert the South African Heritage Resources Agency as soon as possible (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 to ensure that appropriate action (*i.e.* recording, sampling or collection of fossils, recording of relevant geological data) can be taken by a professional palaeontologist at the proponent’s expense. A Chance Fossil Finds Procedure is tabulated in Appendix 2. These recommendations must be incorporated in the Environmental Management Programme for the 132 kV electrical infrastructure project.

5. ACKNOWLEDGEMENTS

Dr Mathys Vosloo of Zitholele Consulting, Midrand, is thanked for commissioning this study and for providing the necessary background information. Mnr Frederik Ludeke of Eskom Holdings SOC Ltd, Kimberley, kindly accompanied us for a morning in the field and also facilitated the palaeontological heritage workshop in Kuruman. Both are further thanked for editorial input to this report. I am very grateful to Ms Madelon Tusenius for logistical support and assistance in the field.

Figure 62. Example of an aluminium 132 kV distribution line monopole showing the small scale of excavation required for the pylon footing. In this region such excavations would only penetrate geologically young superficial deposits of low palaeontological heritage sensitivity (Loc. 242).

Figure 63. Freshly-excavated blocks of grey Campbell Rand carbonate bedrocks in the vicinity of Moffat Substation (Hammer = 30 cm) (Loc. 211a). Although fossil stromatolites are present in some blocks, these are very difficult to pick out in freshly broken and soil-covered rock surfaces.

Figure 64. Excavated block of calcite-veined Campbell Rand carbonate containing darker-hued microbialites. Well-defined stromatolites are hard to pick-out on freshly-broken, unweathered surfaces such as seen here (Scale is 15 cm long) (Loc. 211b).

Figure 65. Block of Campbell Rand carbonate containing well-preserved fossil stromatolites that have been extensively damaged during transport and / or vehicle activity (Scale is 15 cm long) (Loc. 211b)

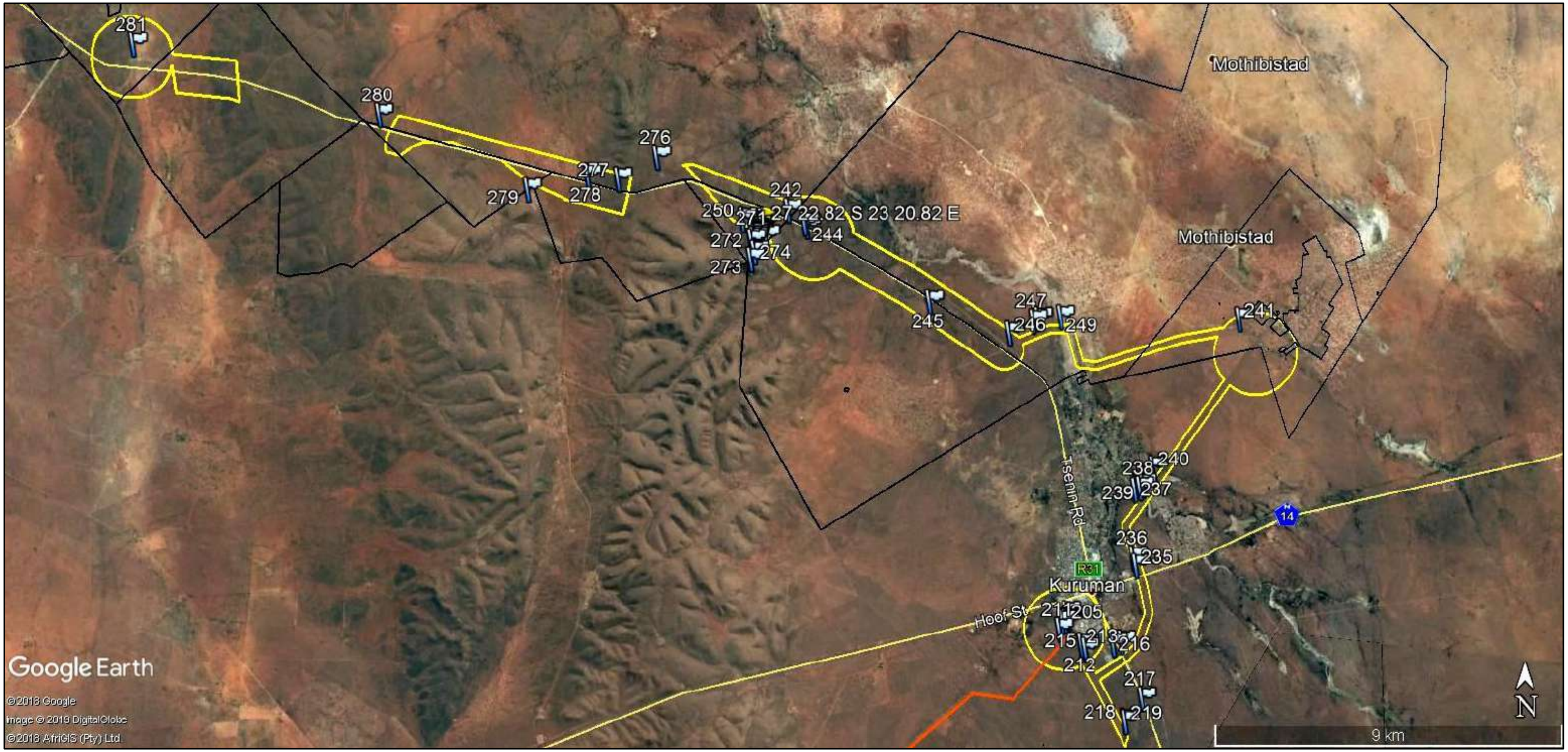


Figure 66. Google Earth© satellite image of the northern sector of the 132 kV distribution line network between Riries, Mothibastat and Moffat Substations. The numbered geological and palaeontological sites are briefly described with GPS data in Appendix 2. None of the fossil sites recorded within the distribution corridor and substation study areas (outlined in yellow) warrants specialist palaeontological mitigation. A Chance Finds Fossil Procedure (Appendix 2) should be implemented during the Construction Phase of the electrical infrastructure project.

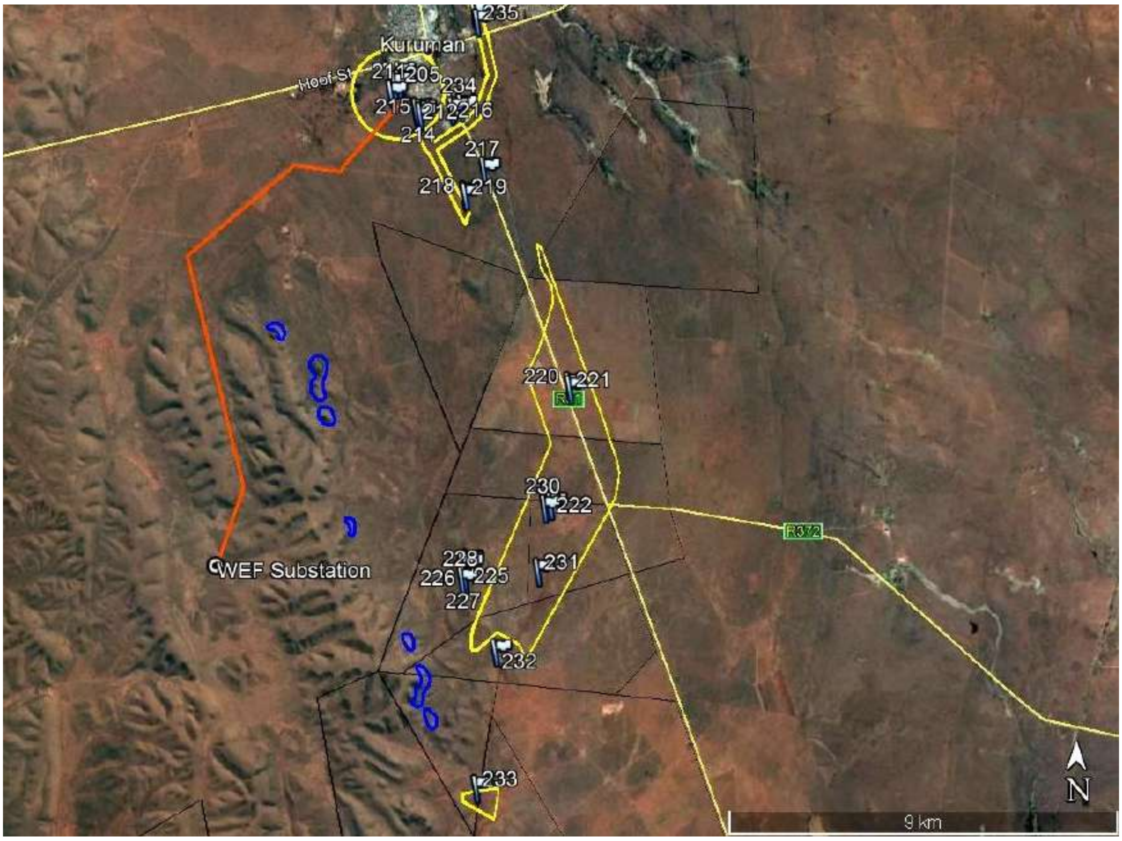


Figure 67. Google Earth© satellite image of the eastern sector of the 132 kV distribution line route. None of the fossil sites within the study areas outlined in yellow warrant specialist palaeontological mitigation. Small blue areas = small outcrops of Campbell Rand carbonates.

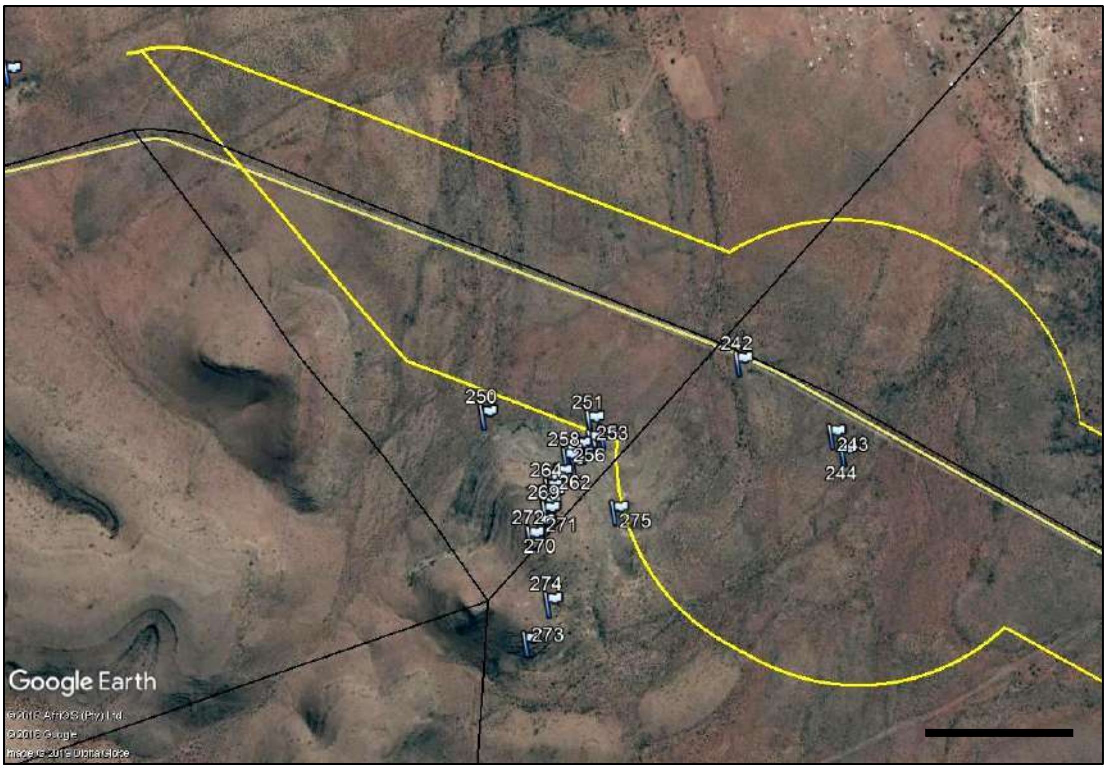


Figure 68. Google Earth© satellite image of 132 kV distribution line and Gamohaan Substation study areas. Numerous palaeontologically significant sites located on Kurumankop lie *outside* the study area and will not be impacted by the proposed development. Scale bar = 1 km

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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, Northwest, Gauteng, KwaZulu-Natal and the Free State under the aegis of his Cape Town-based company *Natura Viva* cc. He has served as 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.

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APPENDIX 1: geological and palaeontological field data

All GPS readings were taken in the field using a hand-held Garmin GPSmap 62sc instrument. The datum used is WGS 84.

Proposed field ratings for fossil occurrences are those recommended in the most recent Minimum Standards for Heritage Specialist Studies document circulated (but not yet approved) by SAHRA (2017).

N.B. This data is not for publication (e.g. on the Internet) to avoid compromising the security of scientifically and culturally valuable geological and fossil sites.

Loc	GPS data	Comments
204	S27° 28' 17.7" E23° 25' 42.9"	Flat, disturbed ground in vicinity of existing Moffat Substation on western outskirts of Kuruman. Sporadic low exposures of grey, karstified Kogelbeen Fm carbonates, locally silicified, mantled by sandy Kalahari soils.
205	S27° 28' 24.5" E23° 25' 42.8"	Low Kogelbeen carbonate exposures near track, *c*. 160 m SE of Moffat Substation. Silicified stromatolitic horizons. Proposed Field Rating IIIC Local Resource.
206	S27° 28' 25.3" E23° 25' 39.0"	Low Kogelbeen carbonate exposures in savannah veld *c*. 180 m SW of Moffat Substation. Dark / blackish silicified domical to irregular stromatolite horizons. Proposed Field Rating IIIC Local Resource.
207	S27° 28' 24.7" E23° 25' 41.8"	Low Kogelbeen carbonate exposures in veld *c*. 160 m S of Moffat Substation. Good horizontal and vertical sections through medium-sized domical stromatolites. Proposed Field Rating IIIC Local Resource.
208	S27° 28' 23.0" E23° 25' 42.6"	Open area along access track to Moffat Substation with low exposures of grey stromatolitic carbonate bedrock. Proposed Field Rating IIIC Local Resource.
209	S27° 28' 23.8" E23° 25' 43.1"	Substantial float block of Kogelbeen carbonate showing columnar to upwardly-expanding growth of vertically-sectioned elongate stromatolites (*c*. 10 cm wide) with rounded to flattened crests. Proposed Field Rating IIIB Local Resource.
210	S27° 28' 23.4" E23° 25' 44.2"	Low exposures of stromatolitic Kogelbeen carbonate adjacent to track showing recent extensive vehicle damage to the fossils. Proposed Field Rating IIIC Local Resource.
211a	S27° 28' 32.0" E23° 25' 36.1"	Construction site *c*. 400 SSW of Moffat Substation with series of rectangular excavations into sandy soils, rubbly surface gravels (ferruginised stromatolitic carbonate, chert) up to c. 1 m thick overlying karstified subsurface Campbell Rand carbonate bedrocks. Stromatolites probably present (indicated by alternating pale and dark lamination) but not clear within excavated rubbly bedrock. Proposed Field Rating IIIC Local Resource.
211b	S27° 28' 41.6" E23° 25' 57.7"	Heaps of excavated grey carbonate bedrock along track on outskirts of Kuruman, several containing well-preserved medium-scale columnar stromatolites showing damage by vehicles or during transport. Some blocks display fresh sections through carbonate breccia and other carbonate facies. Proposed Field Rating IIIC Local Resource.
212	S27° 28' 45.4" E23° 25' 57.4"	Existing trench parallel to NW-SE powerline servitude cut through rusty-brown surface gravels to reveal strongly karstified, dark grey, sugary-textured, laminated Kogelbeen carbonate bedrocks beneath.
213	S27° 28' 44.8" E23° 25' 57.0"	Deep (2-3 m.), steep-sided karst solution hollow within grey-brown subsurface Kogelbeen carbonates, infilled with rusty-brown, rubbly unconsolidated gravels (ferruginised, cherty).
214	S27° 28' 46.2" E23° 26' 00.7"	Large excavated blocks of grey, thin-bedded to laminated Kogelbeen carbonate showing development of secondary blackish chert associated with possible load structures, isopachous cement and domical stromatolites. Proposed Field Rating IIIC Local Resource.
215	S27° 28' 48.6" E23° 26' 00.7"	Row of karstic solution hollows in laminated Kogelbeen Fm bedrocks infilled with rusty-brown ferruginous gravels and Kalahari sands.
216	S27° 28' 44.4" E23° 26' 27.3"	Gravel borrow pit exposure of karstified Kogelbeen Fm carbonates on SE outskirts of Kuruman. Relict pillar karst of laminated brown-weathering carbonate bedrocks with gritty / finely-gravelly calcretised surface mantled with rusty-brown ferruginous gravels and Kalahari sands.

217	S27° 29' 29.8" E23° 26' 54.5"	R31 road cutting adjacent to Oogkop just SE of Kuruman incised through thick (15-20 m) banks of semi-consolidated BIF colluvial gravels (subangular to angular, pebble- to cobble-sized black to rusty-brown BIF clasts).
218	S27° 29' 48.0" E23° 26' 37.8"	Western slopes of Oogkop, gently dipping, tabular, thin--bedded BIF of the Kuruman Formation. Local development of small-scale folds, undulose and kinked bedding (brittle deformation, quartz veining are probably tectonic > synsedimentary, related to tight N-S syncline in Asbestos Hills beds here), thin sedimentary breccias
219	S27° 29' 49.0" E23° 26' 38.7"	Oogkop. Local development of small-scale folds, undulose and kinked bedding (brittle deformation, quartz veining are probably tectonic > synsedimentary, related to tight N-S syncline in Asbestos Hills beds here), thin sedimentary breccias
220	S27° 32' 10.9" E23° 28' 05.8"	Edgehill 194. Small quarry just E of R31 excavated into thick, rubbly, poorly-sorted, rusty-brown to black (Mn-ore patinated) BIF gravels overlying greyish to pale karstified Campbell Rand carbonates. Latter possibly secondarily silicified beneath unconformity. Quarry cut face exposes poorly-sorted, vuggy oligomict breccias of pale, angular silicified limestone blocks (some with small-scale stromatolitic lamination) embedded in gritty ferruginous matrix. Proposed Field Rating IIIC Local Resource.
221	S27° 32' 13.6" E23° 28' 06.6"	Edgehill 194. Land surface above and west of quarry near existing powerline with patches or zones of coarse, well-rounded, bouldery surface gravels of probable alluvial origin (“High Level Gravels”). Boulders with dark desert varnish patina, possible impact crescents, composed of BIF, porphyritic lava, chert, silicified Campbell Rand carbonates.
222	S27° 33' 40.2" E23° 27' 50.3"	Alphen farmstead, SW outskirts. Surface exposures of cherty breccias showing conchoidal fracture, clasts of reworked silicified laminated carbonate. Unclear if these tough-weathering rocks predate BIF and relate to Precambrian palaeokarst episode (as suggested by lack of BIF clasts, high degree of cementation) or rather represent silcretised Late Caenozic surface gravels.
223	S27° 34' 23.4" E23° 26' 39.5"	Alphen 442. Eastern foothills of Kurumanheuwels showing good NE-facing hillslope exposures of upper Campbellrand Group and overlying BIF. Basal stream gulley exposure of karstified grey Kogelbeen Fm carbonates containing horizons of small-scale, irregular microstromatolites (1-2 cm scale) showing vertical as well as lateral accretion (some possibly detached, oncolitic). Bedding parallel and oblique sections suggest variable, tightly-packed, finger-like to anastomosing ridge-like morphology. Proposed Field Rating IIIA Local Resource – 50 m buffer zone recommended for future developments.
224	S27° 34' 24.6" E23° 26' 39.7"	Alphen 442. Lower part of Kogelbeen Fm exposure showing large scale (deca-m) giant low elongate domal stromatolites composed of slightly brownish-grey, thin-bedded, laminated to microstromatolitic carbonate (irregular microcolumns, *c.* 2-3 cm wide). Thin-bedded cyclical carbonate facies with stylolitic bedding contacts. Possible wavy-laminated calcarenites. Local lenses and pods of pebbly, calcrete-cemented cherty limestone breccia. Horizon with medium-scale (several dm diam.) domical stromatolites with thick lamination. Proposed Field Rating IIIA Local Resource – 50 m buffer zone recommended for future developments.
225	S27° 34' 26.1" E23° 26' 40.0"	Alphen 442. Possible upper Koggelbeen Fm or Gamohaan Fm with horizons of fenestrate microbialites. Overlying succession poorly-exposed, pinkish, thin-bedded with rounded, prominent-weathering bodies of possible diagenetic / concretionary origin (*cf* Tsineng Fm). Proposed Field Rating IIIA Local Resource – 50 m buffer zone recommended for future developments.
226	S27° 34' 34.7" E23° 26' 38.3"	Alphen 442. Grey Gamohaan carbonates with abundant horizons of fenestrate microbialites, diapirs structures – probably related to previous evaporite deposits. Proposed Field Rating IIIA Local Resource – 50 m buffer zone recommended for future developments.
227	S27° 34' 35.5" E23° 26' 37.8"	Alphen 442. Gamohaan Fm. Up to *c*. 50 cm-thick horizons of plumose structures associated with secondary pyrite, diapiric structures (probably marker horizon of Saylor 2002). Horizons of chocolate-brown ferruginous carbonate. Proposed Field Rating IIIA Local Resource – 50 m buffer zone recommended for future developments.
228	S27° 34' 36.6" E23° 26' 35.5"	Alphen 442. BIF capping Campbellrand carbonates. No clear exposure of Tsineng Fm carbonates here (probably mantled by BIF gravels).
229	S27° 34' 25.0"	Alphen 442. Medium-scale (10-20 cm diam.) domical stromatolites within

	E23° 26' 35.7"	Kogelbeen Fm, low exposures in sandy veld. Proposed Field Rating IIIC Local Resource.
230	S27° 33' 42.6" E23° 27' 45.3"	Alphen 442. Bouldery silicified surface gravels, including clasts of ferruginous cherty stromatolitic carbonate, surrounded by orange-brown gravelly to sandy Kalahari soils. Proposed Field Rating IIIC Local Resource.
231	S27° 34' 30.0" E23° 27' 39.7"	View from road near Spitsberg farmstead westwards towards carbonate hills in foothills of Kurumanheuwels across BIF gravel-strewn vlaktes.
232	S27° 35' 29.9" E23° 27' 03.7"	Thin bedded BIF and BIF gravels gravels in road cuttings near Spitsberg homestead, Alphen 442.
233	S27° 37' 11.7" E23° 26' 47.4"	Deep, elongate borrow pit excavated into thick (> 10m), crudely-bedded, orange-brown BIF gravels building apron along margins of Kurumanheuwels. Lower-lying gravels well-consolidated, megaclasts suspended in ferruginous gritty matrix with chaotic fabric – probably successive, meter-scale, upward-coarsening debris flow deposits. Upper parts of cycles and succession clast-supported.
234	S27° 28' 42.4" E23° 26' 35.1"	E side of R31 / Voortrekker Road. Extensive exposure of tough, blocky-weathering, purple-brown silicified breccia showing conchoidal fracture. Clasts and blocks of pale greyish-yellow and grey as well as black silicified stromatolitic carbonate within surface rubble. Proposed Field Rating IIIC Local Resource.
235	S27° 27' 38.3" E23° 26' 48.8"	S side of N14 on E outskirts of Kuruman. Low exposures of karstified Campbell Rand carbonates with small-scale domical stromatolites (5-10 cm diam.). Orange-brown Kalahari sands mantle Precambrian bedrocks. Proposed Field Rating IIIC Local Resource.
236	S27° 27' 31.9" E23° 26' 46.2"	N side of N14 on E outskirts of Kuruman. Low exposures of grey Campbell Rand carbonates (probably Kogelbeen Fm) showing undulose karstified surface, elephant skin weathering. Carbonates mostly massive but some stromatolitic horizons with small scale (< 5 cm diam.) present (often silicified), locally showing vehicle damage. Proposed Field Rating IIIC Local Resource.
237	S27° 26' 34.6" E23° 26' 48.0"	Road cutting through thick (*c*. 10 m) calcretised alluvial deposits related to Kuruman River drainage system. Dispersed subangular to subrounded cobbles and boulders of BIF, chert, carbonate, quartzite within pale greyish-brown, calcretised finer sandy alluvium. Capped by unconsolidated BIF gravels.
238	S27° 26' 33.2" E23° 26' 52.5"	Thick calcretised alluvium overlying Campbell Rand massive grey carbonate bedrocks. Downwasted and alluvially-reworked calcrete rubble.
239	S27° 26' 30.7" E23° 26' 55.0"	Dry, wide, shallow tributary valley of Kuruman River. Bank exposures of thick grey-brown, calcretised sandy alluvium overlain by unconsolidated BIF gravels.
240	S27° 26' 16.1" E23° 27' 04.8"	Borrow pit excavated into BIF gravels on SE side of N14 just N of Wrenchville. Several m thick orange-brown gravels (platy BIF, some subrounded pebbles and cobbles of chert, carbonate, quartzite, calcrete) infilling solution hollows within karstified surface of underlying Campbell Rand carbonate bedrock. Lenses of ferruginised BIF gravels at surface. Vertical cut face through rusty-brown, gravelly alluvial sands incised by younger channel gravels.
241	S27° 24' 11.4" E23° 28' 26.3"	Southern outskirts of Mothibastad & Magobe townships – extensive area of informal diggings by informal miners or "*zama zamas*" (well seen on satellite images). Exacavations only a few m deep into rusty-brown surface alluvial sands with thin gravel lenses overlying black to ochreous, semi-consolidated cherty gravels with minor BIF clasts, locally crudely bedded. Succession probably overlies karstified Campbell Rand carbonate (not seen).
242	S27° 22' 40.4" E23° 21' 19.8"	Subvertical, thin beds of greyish BIF (Kuruman Fm) exposed on low hill shortly NW of Gamohaan Substation site. Surface mantled by BIF gravels. Good views of Kurumankop.
243	S27° 22' 51.4" E23° 21' 35.5"	Extensive excavations at Gamohaan Substation site into thick (several m) blanket of massive, rusty-brown, angular, clast-supported, poorly-sorted BIF gravels with isolated relict karst pillars of underlying Campbell Rand carbonate.
244	S27° 22' 54.1" E23° 21' 37.4"	Cherty breccias at surface south of Gamohaan Subststion site. Clasts of silicified laminated carbonate, not BIF – probably predate BIF deposition. Do not reflect composition of local surface gravels (*i.e.* probably not Caenozoic silcretes).
245	S27° 23' 57.0" E23° 23' 33.5"	Low karstified carbonate *koppies* N of Bodulong township. Surface gravels with abundant downwasted cherty silicified stromatolitic carbonate weathered out of bedrocks. Large quartz veins. Silicification of stromatolitic bands may be related to palaeokarst formation on Campbell Rand carbonate platform before BIF deposition. Black and pale yellow certified carbonate may have different ages.

		Proposed Field Rating IIIC Local Resource.
246	S27° 24' 23.4" E23° 24' 49.1"	Borrow pit into subrounded, subequant (rather than platy) BIF and cherty gravels (probably alluvial) as well as alluvial sands with gravel and gritty lenses, situated between R31 and the Kuruman River. Larger gravel clasts concentrated at surface by downwasting, winnowing. Possible flaked BIF artefacts.
247	S27° 24' 13.2" E23° 25' 11.5"	Kuruman River floodplain mantled in platy BIF alluvial gravels.
249	S27° 24' 09.7" E23° 25' 37.4"	Wide dry bed of Kuruman River just N of Moffat Mission; no good bank sections. Probable extensive underground drainage within carbonate bedrocks in this region (*cf* Eye of Kuruman). Pale sandy to silty alluvium, gravels of calcrete and dark brown ferro-managenese enriched carbonate blocks (some brecciated, possibly fault-related). Some reworked calcrete blocks with possible Caenozoic laminated microbialites. Proposed Field Rating IIIC Local Resource.
250	S27° 22' 48.2" E23° 20' 36.9"	Kurumankop, view of Campbell Rand carbonate succession on N slopes. These important bedrock exposures should be protected from development (conservation-worthy geosite).
251	S27° 22' 49.1" E23° 20' 54.8"	Kurumankop. Base of classic Campbell Rand Subgroup carbonate succession (Kogelbeen – Gamohaan – Tsineng Fms). Kogelbeen succession appears greyish cf Gamohaan beds sl. brownish. Thick beds of greyish laminated Kogelbeen carbonates, speckled, imperistent stringers of white sparite.
252	S27° 22' 51.2" E23° 20' 56.9"	Lenses of carbonate-cemented, rubbly cherty breccia (Late Caenozoic).
253	S27° 22' 52.0" E23° 20' 55.1"	Thick horizon of secondary black chertification, brown ferruginous carbonate within Kogelbeen laminated carbonates. Capped by medium-scale domal stromatolites (< 20 cm diam.) picked-out by secondary silicification. Proposed Field Rating IIIA Local Resource – 50 m buffer zone recommended for future developments.
254	S27° 22' 53.2" E23° 20' 53.8"	Thin zone of small-scale (5-10 cm diam.) pseudostromatolites composed of isopachous cement draped over irregular (karstified?) surface.
255	S27° 22' 52.9" E23° 20' 52.8"	Medium-scale domal stromatolites (*c*. 10-20 cm) showing strong preferential sideways growth towards south in plan view. Proposed Field Rating IIIA Local Resource – 50 m buffer zone recommended for future developments.
256	S27° 22' 54.0" E23° 20' 51.3"	Undulose bedding / lamination within carbonates, probably reflecting laterally coalescent stromatolitic domes. Possible microstromatolitic substructure in core and cortex. Proposed Field Rating IIIA Local Resource – 50 m buffer zone recommended for future developments.
257	S27° 22' 54.4" E23° 20' 51.6"	Banded, thin-bedded, tabular succession of pale grey carbonate and dark secondary chert horizons. Columnar and domical stromatolites preferentially silicified. Proposed Field Rating IIIA Local Resource – 50 m buffer zone recommended for future developments.
258	S27° 22' 54.6" E23° 20' 51.0"	Well-developed zone of secondarily silicified medium to large (> 1m) stromatolitic domes (small button stromatolites on surface), with occasional fenestrate microbialites. Proposed Field Rating IIIA Local Resource – 50 m buffer zone recommended for future developments.
259	S27° 22' 55.5" E23° 20' 52.3"	Good section through large stromatolitic domes (same horizon as above). Thin-bedded, intensely silicified carbonate package – possibly reflects position below sequence boundary within upper Kogelbeen Fm (silicification possibly related to shallowing and subaerial exposure of carbonate platform, karstification). Pronounced preferential southwards accretion of small-scale stromatolitic domes (suggests current influence in shallow water).Cherty and limestone breccias along sequence boundary with possible penetration of brownish upper Kogelbeen carbonate into fissures within karstified Kogelbeen platform carbonates. Proposed Field Rating IIIA Local Resource – 50 m buffer zone recommended for future developments.
260	S27° 22' 57.0" E23° 20' 49.7"	Pale brownish-weathering (dolomitised calcarenites?) giant elongate stromatolite zone within upper Kogelbeen Fm, above sequence boundary, with fewer secondary cherty horizons than seen below. Overlapping giant stromatolites several m thick and *c.* 20 m or more across. Curved whale-back outer layers with microripple-like texture containing small-scale (few cm diam.) columnar mini-stromatolite “fingers” and upwardly-expanding, often obliquely-orientated conical stromatolites. Also some large domal stramatolites with black certified cortex showing small stromatolitic buttons. Proposed Field Rating IIIA

		Local Resource – 50 m buffer zone recommended for future developments.
261	S27° 22' 58.2" E23° 20' 48.6"	Cliff-forming package of thin-bedded tabular carbonates (lower Gamohaan Fm) with several horizons of fenestrate microbialites. Soft-sediment deformation of dolomite layers. Calc-tufa at base of cliff.
262	S27° 22' 59.3" E23° 20' 48.9"	Cliff-forming package of thin-bedded tabular carbonates (lower Gamohaan Fm) with several horizons of fenestrate microbialites.
263	S27° 23' 00.1" E23° 20' 48.4"	Marker bed (35-65 cm thick) of giant plumose structures (*cf* Sumner 2002) capped by herringbone calcite.
264	S27° 22' 59.2" E23° 20' 48.1"	Marker bed (35-65 cm thick) of giant plumose structures (*cf* Sumner 2002) capped by herringbone calcite.
265	S27° 23' 00.4" E23° 20' 47.5"	Dispersed to close-packed medium-scale (10-20 cm diam.) domical to columnar stromatolites with vuggy, white, calcite-infilled cortical layers. Proposed Field Rating IIIA Local Resource – 50 m buffer zone recommended for future developments.
266	S27° 23' 00.2" E23° 20' 47.2"	As above. Good vertical sections and cross-sections of stromatolitic columns with *Conophyton*-like internal lamination. Outer lamination irregular, vuggy. Some upwardly-expanding cones. Proposed Field Rating IIIA Local Resource – 50 m buffer zone recommended for future developments.
267	S27° 23' 01.5" E23° 20' 47.8"	Stromatolitic capping of plumose structure bed showing pyrite pseudomorphs on stromatolitic peaks / cores. Abundant possible diapiric structures – possible confusion with stromatolites (or stromatolites may nucleate on diapirs). Proposed Field Rating IIIA Local Resource – 50 m buffer zone recommended for future developments.
268	S27° 23' 02.5" E23° 20' 47.9"	Pale-weathering, thin-bedded zone – possibly tuff-related. Diagenetic carbonate blobs. Stone artefacts of greenish tuffaceous chert.
269	S27° 23' 02.5" E23° 20' 47.7"	Multiple (at least 4) tabular, greenish chert horizons up to 20 cm thick – volcanic tuffs (*cf* 2.52 Ga tuff of Saylor 2002) – within thin- to medium-bedded brownish laminated carbonate. Possible secondary silicification of some carbonate beds. Cliff exposure of brown laminated carbonate above. Occasional cherty stone artefacts, blocks of greenish cherty raw material.
270	S27° 23' 04.4" E23° 20' 47.1"	Tabular, thin-bedded to laminated, wavy-laminated carbonates with slightly pinkish to rusty-brown hue. Small blobs of secondary chert abundant. Possible Tsineng Fm. Abundant white calcite vug infills. Desert-varnished flaked stone artefacts common.
271	S27° 23' 04.2" E23° 20' 46.8"	Pinkish-hued carbonates of Tsineng Fm underlying BIF building upper part of *koppie*. Desert-varnished flaked stone artefacts of black chert common.
272	S27° 23' 06.1" E23° 20' 45.2"	Gently dipping thin-bedded, rusty-brown to pinkish carbonates of Tsineng Fm close to upper contact with BIF. Abundant downwasted black chert from Tsineng Fm. as well as small black sphaerules of ferromanganese ore.
273	S27° 23' 21.6" E23° 20' 44.5"	Numerous large cones of pale grey calc-tufa, including some breccia lenses, attached to cliff of Gamohaan Fm carbonates near large overhang on E face of Kurumankop. Overhangs here have relict stalagmites and stalactites.
274	S27° 23' 16.0" E23° 20' 48.1"	Main overhang eroded into Gamohaan Fm carbonates on E face of Kurumankop. Abundant rock art (incl. stromatolite-like rectangular zigzag pattern typical for the Kurumanheuwels region). Large-scale collapse breccias in front of carbonate escarpment – possible relicts of underground karst caves (*cf* Wonderwerk S of Kuruman).
275	S27° 23' 02.6" E23° 20' 58.9"	Good exposures of Kogelbeen Fm carbonates on lower NE slopes of Kurumankop. Isolated domal stromatolite occurrences. Proposed Field Rating IIIA Local Resource – 50 m buffer zone recommended for future developments.
276	S27° 21' 56.1" E23° 19' 15.9"	Quarry N of R31 on Gamohaan 438. Vertical section through thick (c. 8 m) of rubbly calcrete overlying weathered medium-bedded Campbell Rand carbonate. Also weathered, fractured, calcrete-veined pale, greenish greenstone body – possibly a hypabyssal feeder dyke or sill of Ongeluk Fm volcanics (not mapped) – pale green, speckled, massive, coarse-grained, feldspathic, well-jointed with capping of lateritic soil and platy BIF gravels
277	S27° 22' 14.1" E23° 18' 39.2"	Deep road cutting along R31 through tabular, thin-bedded, rusty-brown BIF – mapped as Danielskuil Fm.
278	S27° 22' 11.0" E23° 18' 10.2"	Orange-brown gravelly to sandy soils, Kalahari thornveld in powerline servitude (not accessible).
279	S27° 22' 22.8" E23° 17' 13.4"	Large quarry into Campbell Rand carbonates (Gamohaan Fm) on lower hillslopes south of Maheane. Horizons of fenestrate microbialites, marker bed of plumose structures visible in upper quarry sector. Lower quarry probably

		excavated into brownish Kogelbeen Fm. carbonates. In general, cut faces of quarry do not show sedimentology and bio-sedimentary structures as well as naturally-weathered slopes. Proposed Field Rating IIIA Local Resource.
280	S27° 21' 19.7" E23° 14' 52.7"	Low R31 road cutting through Danielskuil Fm BIF with irregular bedding, abundant pale yellowish cherty bodies.
281	S27° 20' 19.8" E23° 10' 59.2"	Excavations east of Riries Substation into weathered, crumbly, pale greenish, well-jointed Ongeluk Fm ?lavas (pale green to dark grey-green when fresh). Overlain by calcrete and Kalahari sands.

APPENDIX 2: CHANCE FOSSIL FINDS PROCEDURE: KATHU – KURUMAN - HOTAZEL 132 kV DISTRIBUTION LINE CORRIDORS & SUBSTATIONS		
Province & region:	KURUMAN DISTRICT, NORTHERN CAPE	
Responsible Heritage Management Authority	South African Heritage Resources Agency. Contact details: SAHRA, 111 Harrington Street, Cape Town. PO Box 4637, Cape Town 8000, South Africa. Phone : +27 (0)21 462 4502. Fax: +27 (0)21 462 4509. Web : www.sahra.org.za	
Rock unit(s)	Campbell Rand Subgroup, Asbestos Hills Subgroup, Caenozoic alluvium, calcretes, breccias & calctufa, aeolian sands	
Potential fossils	Stromatolites in carbonate rocks. Mammalian and other vertebrate bones, teeth, horn cores, trace fossils in older alluvium, calc tufa, breccias & calcretes.	
ECO protocol	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.	
	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)	
	3. If feasible to leave fossils *in situ*: Alert Heritage Management 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 Management Authority for work to resume.	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 Management Authority and project palaeontologist (if any) who will advise on any necessary mitigation
	4. If required by Heritage Management Authority, ensure that a suitably-qualified specialist palaeontologist is appointed as soon as possible by the developer.	
	5. Implement any further mitigation measures proposed by the palaeontologist and Heritage Management Authority	
Specialist palaeontologist	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 Management Authority minimum standards.	