PALAEONTOLOGICAL HERITAGE: COMBINED DESKTOP & FIELD-BASED REPORT

PROPOSED DEVELOPMENT OF A 132kV OVERHEAD POWERLINE FOR THE KAREEBOSCH WIND ENERGY FACILITY TO THE EXISITING KOMSBERG MTS, KAROO HOOGLAND LOCAL MUNICIPALITY (NORTHERN CAPE PROVINCE) AND LAINGSBURG LOCAL MUNICIPALITY (WESTERN CAPE PROVINCE)

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EXECUTIVE SUMMARY

The proposed 132kV overhead powerline to connect the authorised Karreebosch Wind Energy Facility (WEF) to the national grid *via* the existing Eskom Komsberg Main Transmission Substation (MTS) will be *c*. 20 km long and will traverse several properties within the Karoo Hoogland Local Municipality (Northern Cape Province) and the Laingsburg Local Municipality (Western Cape Province). Two on-site substation sites and several powerline corridors are currently under consideration.

The grid connection project area is underlain at depth by potentially fossiliferous continental sediments within the lower part of the Abrahamskraal Formation (Lower Beaufort Group / Adelaide Subgroup, Karoo Supergroup) of Middle Permian age. Sparse fossil assemblages in this sector of the Klein-Roggeveldberge region - including extremely rare vertebrate skeletal remains, tetrapod and lungfish burrows, invertebrate traces and vascular plants - are inferred to belong to the *Eodicynodon* Assemblage Zone and contribute to our understanding of the earliest terrestrial biotas that colonised the Main Karoo Basin in Middle Permian times (*c*. 270 Ma / million years ago). The palaeosensitivity of the project area is provisionally rated as High to Very High based on the Lower Beaufort Group bedrocks (SAHRIS website / DFFE screening tool). However, previous field-based palaeontological surveys in the Roggeveld WEF project area have only yielded scrappy plant remains as well as low-diversity trace fossils. With the exception of fragmentary fossil remains of very rare temnospondyl amphibians found on Rietfontein RE/197, close to the powerline Option 1B, additional fossil sites recorded during a recent 2-day palaeontological site visit to the Roggeveld WEF grid connection project area are mostly of low scientific / conservation value and lie outside or on the margins of the grid corridors under investigation. No fossils were recorded within the Late Caenozoic superficial deposits in the region (colluvium, alluvium *etc*). The overall palaeosensitivity of the grid connection project area is inferred to be Low. However, the potential for isolated vertebrate and other fossil finds of high scientific interest – as recorded elsewhere in the Klein-Roggeveldberge region - cannot be completely discounted.

There are no objections on palaeontological grounds to authorisation of the proposed 132 kV powerline and there is no preference on palaeontological heritage grounds for any particular on-site substation site or powerline route option among those currently under consideration. If powerline Option 1B is selected for construction, vertebrate fossil material at or in the vicinity of Locs. 454-456 on Rietfontein RE/197 must be collected by a professional palaeontologist before construction of the powerline (See Appendix 1, Fig. A2). No further specialist palaeontological studies or mitigation are recommended for this electrical infrastructure project. These recommendations and the Chance Fossil Finds Protocol appended to this report (Appendix 2) should be included in the EMPr for the development.

1. INTRODUCTION

It is proposed to construct a 132kV overhead powerline to connect the authorised Karreebosch Wind Energy Facility (WEF) to the national grid *via* the existing Eskom Komsberg Main Transmission Substation (MTS) situated towards the southeast. The proposed powerline will be approximately 20 km long. The overhead line will be a 132kV steel single or double structure with a kingbird conductor (between 15 and 20m in height above ground level). Standard overhead line construction methodology will be employed involving drill holes (typically 2 to 3m in depth), plant poles and a string conductor. It is not envisaged that any substantial excavations or stabilized backfill will be required; however, this will only be verified on site once geotechnical studies have been undertaken at each pole position during the construction phase.

The Kareebosch WEF grid connection project area is situated in the Klein-Roggeveldberge subregion of the Great Karoo, some 40 km north of the small village of Matjiesfontein and *c*. 50 km SSW of Sutherland (Fig. 1). It spans the border between the Karoo Hoogland Local Municipality in the Northern Cape Province and the Laingsburg Local Municipality in the Western Cape Province. Several route options for the grid connection running between an on-site substation (2 site options) and the Komsberg MTS are currently under consideration. The 132kV grid connection corridor options traverse the following properties:

- Wilgebosch Rivier 188 Remainder
- Ekkraal (Nuwekraal) 199 Portion 2
- Klipbanksfontein 198 Portion 1 and Remainder
- Bon Espirange 73 Portion 1 and Remainder
- Rietfontein 197
- Ekkraal (Nuwekraal) 199 Portion 1 and Remainder
- Standvastigheid 210 Portion 2 (Komsberg Substation)

The internal lines from the Karreebosch onsite substation to the Bon Espirange substation will be for Karreebosch WEF, however the line from Bon Espirange substation to the Komsberg substation will be for all three Euronotus projects.

The present combined desktop and field-based palaeontological heritage report contributes to the consolidated Heritage Basic Assessment report for the Kareebosch WEF grid connection that is being compiled by CTS Heritage, Cape Town (Contact details: Ms Jenna Lavin. CTS Heritage. 16 Edison Way, Century City, RSA. Tel: +27 (0)87 073 5739. Cell: +27 (0)83 619 0854. E-mail: info@ctsheritage.com).

2. INFORMATION SOURCES

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

1. A short project outline, maps and kmz files provided by CTS Heritage, Cape Town;

2. A review of the relevant scientific literature, including published geological maps (1: 250 000 geology sheet 3220 Sutherland) and accompanying sheet explanations (*e.g.* Theron 1983);

3. Previous field-based palaeontological heritage studies within the Kareebosch WEF / Komsberg MTS project areas by Miller (2011) and Almond (2014, 2015b) as well as several further desktop and field-based palaeontological assessment studies in the broader Klein-Roggeveldberge region of the Great Karoo by the author and others (See References). It is noted that coverage of upland areas during these earlier field studies was very limited indeed;

3. Examination of relevant topographical maps (*e.g.* 1: 250 000 sheet 3220 Sutherland, 1: 50 000 sheets 3220CD Oliviersberg and 3220DC Swartland) and Google Earth© satellite images;

4. A two-day palaeontological site visit by the author and an experienced assistant during 23-24 and 29 September 2021. Given the generally limited bedrock exposure within the Klein-Roggeveldberge project area as well as access constraints in mountainous terrain, palaeontological fieldwork focused on a representative sample (*c*. 50 localities) of potentially-fossiliferous exposures of bedrock units (especially good Beaufort Group mudrock exposures) as well as of Late Caenozoic alluvial and eluvial deposits close to or within the grid connection corridor route options.

5. The author's previous field experience with the formations concerned and their palaeontological heritage (See References and also reviews of Western and Northern Cape fossil heritage by Almond & Pether 2008a, 2008b respectively).

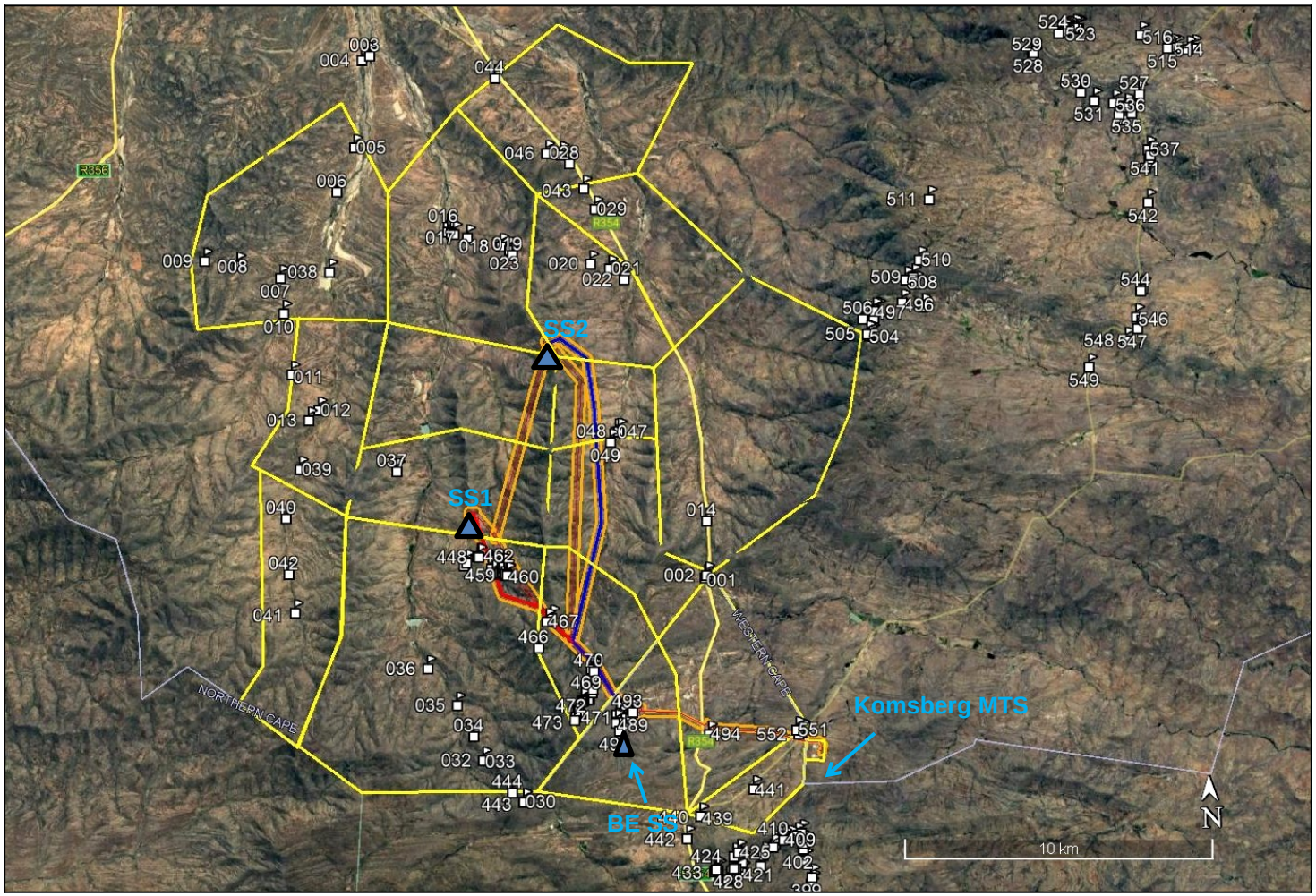


Figure 1: Google Earth© satellite image of the Klein-Roggeveldberge region between Matjiesfontein and Sutherland in the Western and Northern Cape Provinces. The yellow polygons show land parcels concerned in the original Kareebosch WEF project area. Corridor options under consideration for the 132 kV grid connection between the Kareebosch WEF (on-site substation options SS1 & SS2) and the existing Komsberg MTS *via* the existing Eskom Bon Espirange Substation (BE SS) are shown in orange. The blue line shows the currently preferred grid connection route and the red line shows the preferred alternative route. Numbered sites in white indicate representative exposures of potentially fossiliferous bedrocks and superficial sediments examined during palaeontological fieldwork in 2014 (Almond 2014) and 2021 (present report).

Figure 2: View NNW towards the proposed Substation Option 1 site on Klipbanksfontein 198. Note the lack of potentially fossiliferous mudrock exposures in this upland area which is largely mantled by colluvial / eluvial gravels, skeletal soils and *bossieveld* vegetation.

Figure 3: View towards the NW along the powerline route options 1A-1C across Rietfontein 197 showing the dissected mountainous terrain of the Klein-Roggeveldberge with gentle hillslopes and occasional prominent-weathering *kranzes* of sandstone. Otherwise, bedrock exposure is generally very poor in the region, especially regarding the recessive weathering mudrock facies.

Figure 4: Apart from occasional small stream gullies, the Beaufort Group bedrocks underlying most of the hilly terrain in the grid connection project area are mantled by rubbly colluvial or eluvial gravels and skeletal soils as well as karroid *bossieveld* vegetation.

Figure 5: View from the Brakeinde ridge into next valley to the north, Ekkraal 199. Bedrocks are exposed along deeper stream gullies but these will be spanned by the proposed 132 kV powerline. Anticipated impacts along drainage lines will be mainly attributable to any associated new access roads.

Figure 6: View from the SW towards the new Eskom electrical substation on Bon Espirance 73 with an existing powerline heading eastwards towards the Komsberg MTS adjacent to an upgraded access road.

Figure 7: Extensive streambed and bank exposures of Lower Abrahamskraal Formation sediments just west of the new Eskom substation on Bon Espirance 73. Bedrocks on steep south-facing slopes (cliff in background) are often partially obscured by epilithic lichens.

Figure 8: New wind farm infrastructure on Ekkraal 199, some 2 km west of the new Eskom substation on Bon Espirance 93, showing the substantial area of surface disturbance associated with even small-scale overhead powerlines (middle ground). Sectors of wind turbine access road also require the excavation of major new road cuttings into Abrahamskraal Formation bedrocks.

Figure 9: New road cuttings into maroon mudrocks along the access road to the Eskom substation on Bon Espirance 73. In practice, the recognition, sampling and recording of fossils within freshly-exposed bedrock sections is often highly problematic due to soils / dust cover and fragmentation during excavation.

Figure 10: View eastwards along the recently constructed powerline between the new substation on Bon Espirance 73 and the Komsberg MTS. Bedrock exposure in the low relief terrain here is very limited. Any palaeontological impacts are more likely to be attributable to surface clearance than to excavations for electrical pylon footings.

Figure 11: Occasional good exposures of Abrahamskraal Formation bedrocks are seen in stream gullies incising steep, SE-facing slopes to the NW of Komsberg Substation, as here on the eastern edge of Bon Espirance 73 (Hammer = 30 cm).

3. GEOLOGICAL CONTEXT

The geology of the Karreebosch WEF grid connection project area is covered by 1: 250 000 geology sheet 3220 Sutherland (Council for Geoscience, Pretoria; Theron 1983) (Fig. 12). The grid connection project area is entirely underlain at depth by Middle Permian (Wordian – Capitanian) continental sediments of the **Lower Beaufort Group** (Adelaide Subgroup, Karoo Supergroup). These predominantly fine-grained (muddy to sandy) sediments were deposited in a range of fluvial, alluvial and lacustrine (playa lake) settings within the Main Karoo Basin of South Africa. They are assigned to the lower part of the exceedingly thick **Abrahamskraal Formation** (Pa) at the base of the Lower Beaufort Group succession (Johnson *et al.* 2006, Day and Rubidge 2014, Cole *et al.* 2016 and references therein). In the Kareebosch WEF project area that is situated well to the south of the Great Escarpment the only major dolerite intrusions are a set of laterally persistent, NW-SE trending dykes of the **Karoo Dolerite Suite** that transect the eastern portion of the area. The Lower Beaufort Group bedrocks in the study area are very extensively overlain by **Late Caenozoic superficial deposits** such as scree and other slope deposits (colluvium, eluvium and hillwash), stream alluvium, down-wasted surface gravels, minor calcretes and various, predominantly skeletal soils. These geologically youthful sediments are generally of low palaeontological sensitivity. Levels of bedrock deformation within the project area are generally low. A number of E-W orientated fold axes related to the Permo-Triassic orogeny influence the Palaeozoic bedrocks while locally the finer-grained mudrocks show a well-developed tectonic cleavage.

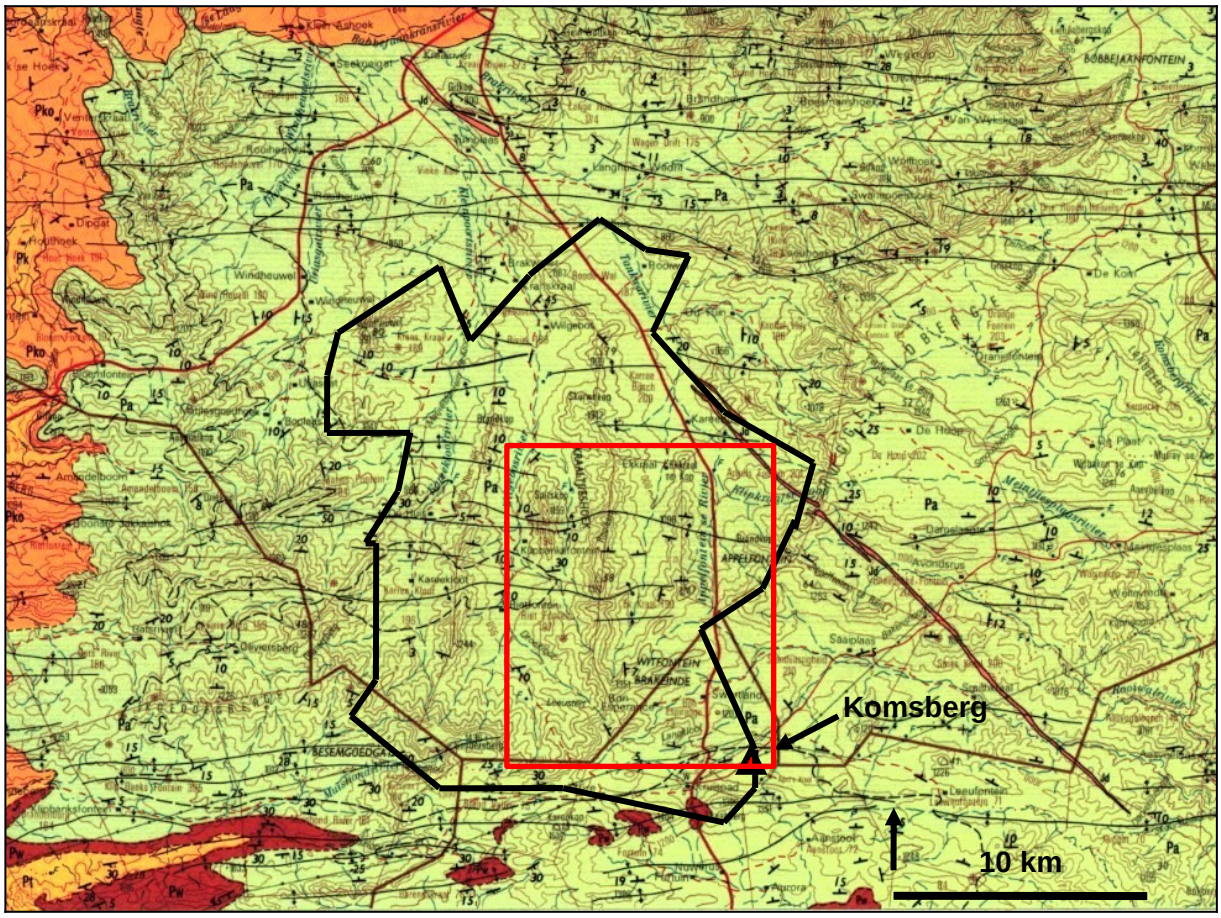
The sedimentology and lithostratigraphy of the Abrahamskraal Formation beds in the Kareebosch WEF project area have been described in some detail in the PIA report for the WEF by Almond (2014; see also Almond 2015f for the Komsberg MTS area). It is inferred that the bedrocks here are restricted to the lower part of the Abrahamskraal Formation, as indicated in the stratigraphic table in Figure 13. This is based on (1) the proximity to outcrops of the underlying deltaic Waterford Formation (uppermost Ecca Group) as well as (2) the presence of dark grey to grey-green mudrock-dominated beds lower in the succession (*e.g.* east of Rietfontein farmstead) with maroon mudrocks only appearing higher in the sequence, and generally at higher elevations, as well as (3) the presence of at least one sandstone-dominated package - possibly the Grootfontein Member of Day & Rubidge (2014) (*e.g.* turbine ridges on Ekkekraal 199, Bon Espirance 73). However, detailed field mapping would be required to confirm or refute this.

The majority of the grid connection project area comprises mountainous terrain with gentle, rocky hillslopes, broad valleys and occasional prominent-weathering, subhorizontal to dipping sandstone *kranzes* (Figs. 2 to 11). Bedrock exposure apart from the thicker channel sandstones is largely limited to stream and erosion gullies as well as the banks and beds of more deeply-incised streams along the valley bottoms. Elsewhere the Beaufort Group beds are obscured by a thin to several meter-thick mantle of rubbly colluvial, eluvial and alluvial deposits (with clasts mainly composed of Beaufort Group wacke, with minor vein quartz) as well as gravelly soils and karroid *bossieveld* vegetation. Near-surface mudrocks are often highly weathered and friable.

Typical features of the Middle Permian continental sediments of the Lower Abrahamskraal Formation within the project are illustrated in Figures 14 to 28 with explanatory figure legends. Episodes of wetter, pluvial and drier, semi-arid palaeoclimates are reflected in the Abrahamskraal sedimentological record. Wetter depositional settings on the ancient floodplain or delta platform are suggested by intervals of dark grey massive to laminated mudrocks with horizons of abundant rusty-brown, large spheroidal to irregular concretions and lenses of diagenetic ferruginous carbonate, ball-and-pillow load structures in crevasse-splay or deltaic sandstones, upward-coarsening sedimentary packages, gradational channel sandstone bases without calcrete-rich basal breccias or gullying, wave-rippled sandstone bed tops with epichnial trace fossils and crinkly microbial mat textures as well as horizons of abundant reedy plant stem casts, sphenophyte (horsetail fern) debris and lungfish burrow casts. More arid palaeoclimatic intervals are indicated by thick packages of maroon mudrocks, palaeosol horizons marked by pale grey, sphaeoidal palaeocalcrete concretions, deep sand-infilled desiccation cracks, abundant gypsum crystal pseudomorphs (“desert roses”) and sharp, gullied channel sandstone bases with well-developed basal channel breccias rich in reworked mudflakes and calcrete glaebules.

It is notable that, with the exception of minor basal channel breccias, the clastic sediments making up the Lower Abrahamskraal bedrocks are predominantly fine-grained, *viz*. claystones, siltstones and fine- to occasionally medium-grained wackes (impure, clay-rich sandstones). This reflects the very low relief of the Mid-Permian Karoo delta platform / distal alluvial floodplain as well as the considerable transport distance from the sediment source area (*i.e.* Cape Fold Belt). The rare occurrence of isolated, large clasts or *lonestones* of exotic rock types (granites / andesites / schists *etc*) within the Beaufort Group bedrocks is therefore of note (*cf* Almond 2010a, 2015e, 2017 and references therein). In some cases, petrified wood has been recorded in association with the lonestones. A single, isolated subrounded cobble of quartzitic schist or gneiss recorded on Rietfontein RE/197 is an interesting example from the present study area (Fig. 47). Plausible explanations as to how such exotic “lonestones” were introduced so far out into the Beaufort Group depository include rocks entangled among the roots of uprooted trees that were transported during major river floods or alternatively downstream ferrying by floating river ice during winter (see discussions in Broom 1912, Jordaan 1990, Loock *et al.,* 1994, p. 190).

A range of Late Caenozoic cover sediments encountered in the project area are shown in Figures 4 and 29 to 32. An interesting sedimentological feature in the present study area is the frequent occurrence of thin to thick (few dm to several meters), rubbly debris flow deposits (debrites) on lower hillslopes where they are exposed by gullying (Figs. 29 & 32). In this region they are typically pale brown and comprise poorly-sorted angular clasts of wacke suspended within a sandy to gritty or fine gravelly matrix which may show polygonal cracking (perhaps a permafrost feature). The age of the debrites is uncertain, but possibly Quaternary.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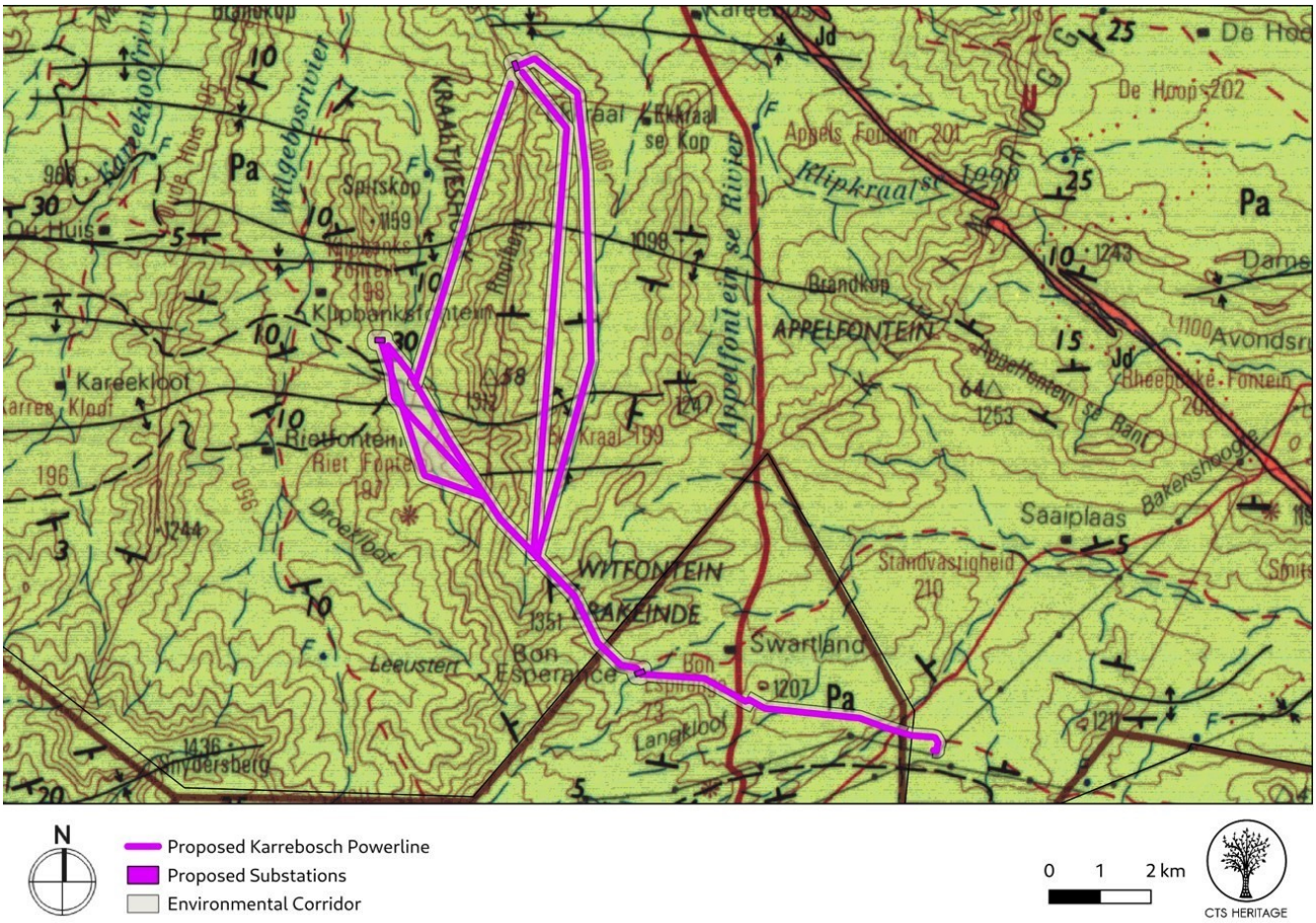

Figure 12. Extract from the 1: 250 000 scale geology sheet 3220 Sutherland (Council for Geoscience, Pretoria, 1999) showing the Karreebosch Wind Farm grid connection project area *c*. 50 km SSW of Sutherland, Northern Cape and Western Cape Provinces (Image prepared by CTS). The project area (here showing all powerline route options under consideration) is entirely underlain by Middle Permian sediments within the lower part of the Abrahamskraal Formation, Lower Beaufort Group / Adelaide Subgroup (Pa, pale green). A narrow NW-SE trending Early Jurassic dolerite dyke of the Karoo Dolerite Suite (Jd, pink) crosses the eastern portion of the WEF area but lies outside the present study area. The black dashed line marks the first appearance of maroon mudrocks within the Abrahamskraal Formation. Note also several W-E trending fold axes as well as a fault line (f-f) mapped within the study area.

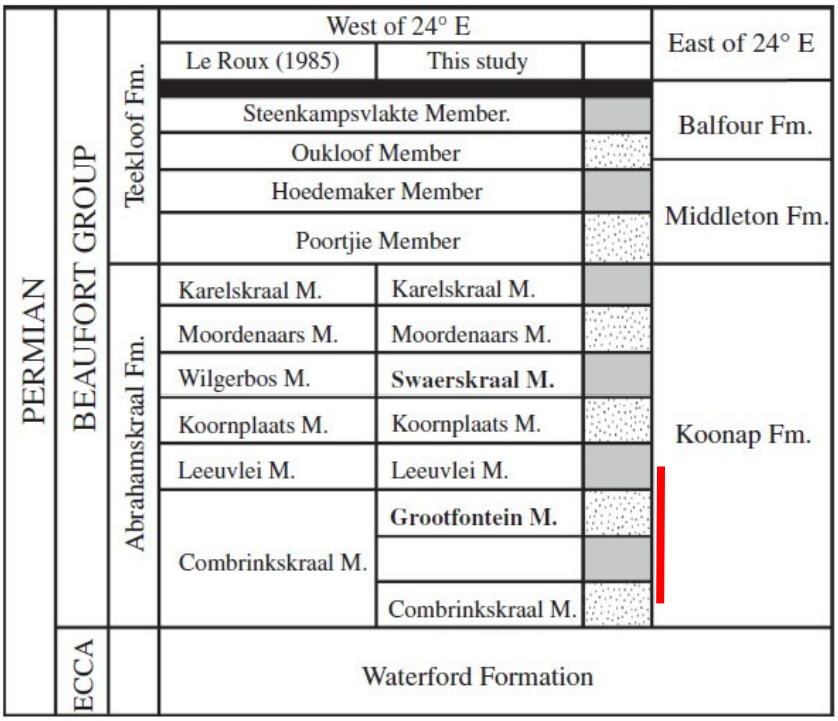

Figure 13: Revised subdivision of the Abrahamskraal Formation by Day and Rubidge (2014). The red bar indicated stratigraphic members that are probably represented within the Kareebosch WEF and grid connection project areas (This requires confirmation through further fieldwork).

Figure 14: Good stream gulley and hillslope exposure of very dark grey siltstones and thin-bedded wackes of the lower Abrahamskraal Formation, Rietfontein 197. They probably belong to the mudrock-dominated interval between the Combrinkskraal and Grootfontein Members (See Figure 13).

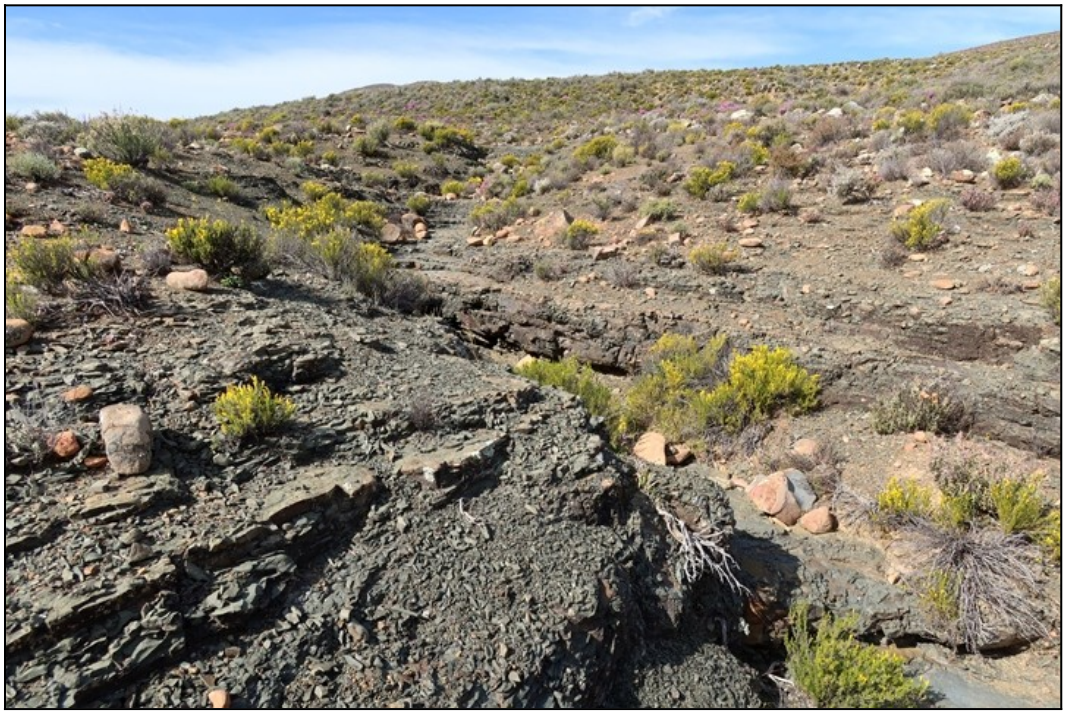

Figure 15: Stream gulley exposure through dark grey mudrocks and thin wackes of the lower Abrahamskraal Formation on Rietfontein 197. These beds contain occasional horizons rich in vascular plant compressions (Figure 46).

Figure 16: Dark overbank lower Abrahamskraal Formation siltstones with load structures overlain by dark grey-green, fine-grained channel wackes with a gradational contact, Rietfontein 197 (Hammer = 30 cm).

Figure 17: Vertically elongate clusters of pale silicified gypsum crystals within massive grey-green mudrocks at the locality illustrated above (Scale in cm). The gypsum pseudomorphs indicate episodes of high evaporation on the otherwise waterlogged floodplain or delta platform.

Figure 18: Horizons of large spheroidal concretions and lenses of diagenetic ferruginous carbonate within the Abrahamskraal overbank mudrocks (Rietfontein 197) suggest protracted waterlogging of the substratum. These larger concretionary bodies are rarely fossiliferous.

Figure 19: Horizons of small, sphaeroidal pedogenic carbonate concretions within Lower Abrahamskraal overbank mudrocks on Rietfontein 197 (Hammer = 30 cm). These brownish-weathering concretions with a greyish, micritic interior mark palaeosols and are a primary focus for vertebrate fossil recording.

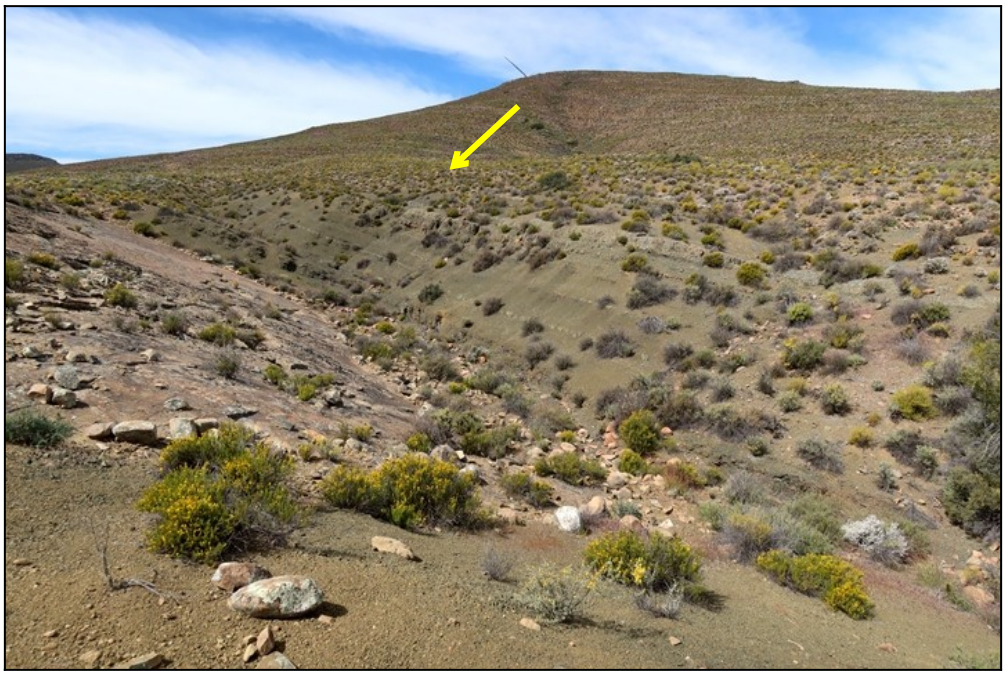

Figure 20: Exceptionally good gully exposure of a thick, grey-green Lower Abrahamskraal Formation mudrock package overlying a well-exposed, wave-rippled sandstone bed top (on LHS), Rietfontein 197. The probable temnospondyl amphibian fossils shown in Figure 37 were recorded in shallow erosion gulley just above the mudrock cliff (arrow).

Figure 21: Detail of the wave-rippled sandstone bed top surface seen in the previous figure, probably situated on the margins of a shallow floodplain pond. The invertebrate traces shown in Figure 43 were recorded from the same locality.

Figure 22: Dark, fine-grained mudrocks of probable lacustrine origin overlying the rippled sandstone surface shown above, here containing horizons of numerous rounded ball-and-pillow structures due to sediment loading within soft, waterlogged bottom sediments (Hammer = 30 cm).

Figure 23: Prominent-weathering, thick tabular channel sandstone body of the Abrahamskraal Formation (possibly the Grootfontein Member package) on Ekkraal 199. The underlying mudrock-dominated succession is rich in maroon mudrocks, as seen in the following two figures.

Figure 24: Series of thin (1-2 m), upward-coarsening cycles of grey-green or purple-brown mudrock capped by brownish-weathering, fine-grained wackes, Ekkraal 199. The thick channel sandstone body at the head of the gulley is shown in the previous figure.

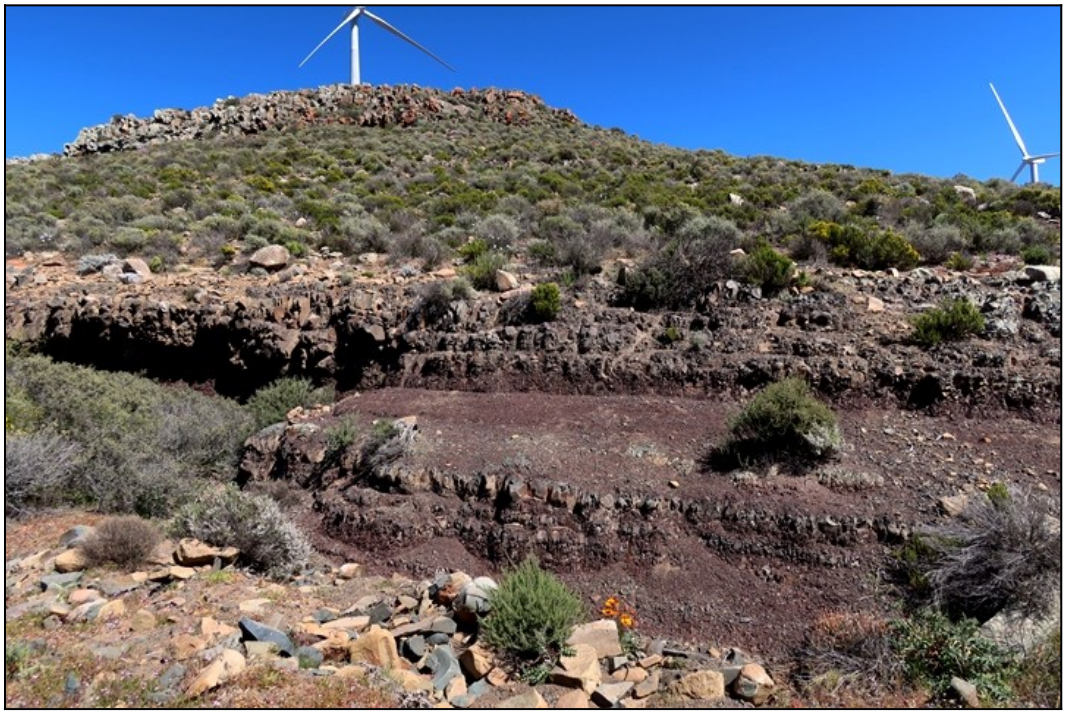

Figure 25: Close-up of upward-coarsening cycles in the same gulley on Ekkraal 199. The maroon mudrocks here may belong to the interval between the Combrinkskraal Member and Grootfontein Member sandstone packages.

Figure 26: Good erosion gulley exposures of Abrahamskraal Formation maroon mudrocks with thin crevasse-splay sandstones on Bon Espirance 73, just NW of the new substation (Hammer = 30 cm). The reddish siltstones and deep, sand-infilled desiccation cracks (arrowed) seen here indicate periods of aridity on the Middle Permian floodplain.

Figure 27: Gulley exposure of Abrahamskraal Formation beds on Bon Espirance 73, less than 1 km west of the the new substation. The pale upper mudrocks show high levels of near-surface weathering which does not favour fossil preservation or recording.

Figure 28: Several stream gullies incising steep hillslopes due west of the new substation on Bon Espirance 73 expose good sections through thin- to medium-bedded sediments of the Abrahamskraal Formation. Mottled mudrocks and wackes here commonly contain casts of reedy plant stems and rarer lungfish burrows, suggesting swampy wetland settings.

Figure 29: Thick rubbly debrite (debris flow deposit) composed of dispersed, "floating" clasts of wacke embedded within a pale brown sandy to fine gravelly matrix, stream bank exposure on Bon Espirance 73 (Hammer -= 30 cm).

Figure 30: Very thick (several meters) wedges of coarse, poorly-sorted colluvial and alluvial deposits have accumulated along valley floors in the project area, seen here on Bon Espirance 73.

Figure 31: Good streambank section through a Late Caenozoic erosional gulley incised up to several meters deep into gently dipping Abrahamskraal Formation bedrocks and infilled with a range of coarse colluvial, alluvial and debrite deposits, Bon Espirance 73.

Figure 32: Gullied hillslopes of crumbly, weathered Abrahamskraal Formation mudrocks near the Komsberg MTS are locally mantled by pale brown, gravelly debris deposits (upper LHS), eastern edge of Bon Espirance 73.

4. PALAEONTOLOGICAL HERITAGE CONTEXT

According to the latest Karoo fossil biozonation maps the lower Abrahamskraal Formation beds in the present study area, located on the south-western margins of the Lower Beaufort Group outcrop area, probably lie within the ***Eodicynodon* Assemblage Zone** of Middle Permian (Wordian) age (*c*. 268-265 Ma) (Lanci *et al.* 2013, Day & Rubidge 2014, Rubidge & Day 2020 and refs. therein) (Fig. 33). However, due to the great scarcity of fossil tetrapod records in the Klein-Roggeveldberge region as a whole, this has yet to be firmly established.

Fossil biotas of the *Eodicynodon* Assemblage Zone have been summarized by Rubidge (1995) and more recently by Smith *et al.* (2012) as well as Rubidge and Day (2020). This Middle Permian biota is characterized by a limited variety of primitive therapsids, most notably the small dicynodont *Eodicynodon* (by far the commonest taxon), very rare large-bodied herbiovorous and carnivorous dinocephalians such as *Tapinocaninus* and anteosaurids, as well as equally rare gorgonopsians and scylacosaurid therocephalians (Fig. 34). The fauna is of considerable palaeobiological significance in that it includes some of the earliest and most primitive examples of several therapsid subgroups recorded anywhere in the world. Associated fossils include disarticulated palaeoniscoid fish and amphibians (rhinesuchid temnospondyls), freshwater bivalves *plus* a small range of invertebrate ichnogenera such as the arthropod trackway *Umfolozia* and various simple horizontal burrows. Vertebrate trace fossils include horizons with subcylindrical sandstone casts of lungfish burrows as well as very occasional tetrapod burrow casts. Records of vascular plants include glossopterid “seed ferns” and the widely occurring sphenophyte ferns *Equisetum* and *Schizoneura* (Anderson & Anderson 1985, Rubidge *et al.* 2000) as well as rare lycopods *cf Cyclodendron* (Almond 2018). Dense assemblages of reedy plant stem casts (commonly mistaken for invertebrate burrows) are common in wetland deposits such as swampy lake and river margins. Petrified wood is apparently - and perhaps surprisingly - absent or very rare in the lower Abrahamskraal Formation, in contrast to the underlying Waterford Formation where well-preserved silicified logs are well-known; it is unclear why this is so. However, large linear drag marks on the tops of channel sandstones that were probably generated by sizeable floating logs have been recorded locally, close to the lower contact with the Waterford Formation (*cf* Almond 2010a).

Vertebrate skeletal fossils – especially identifiable, articulated specimens - tend to be very rare indeed in this biozone (“extremely scarce” according to Rubidge & Day 2020). This is indicated by the fossil chart of Loock *et al.* (1994) as well as the fossil site maps of Keyser & Smith (1977-78) and of Nicolas (2007) (Fig. 35). The fossils are also typically difficult to extract from their resistant rock matrix. They are mainly found within overbank, lake margin mudrocks in association with brownish-weathering pedogenic calcrete nodules or - in the case of the dinocephalians - within or at the base of channel sandstones (Smith *et al.* 2012, Rubidge & Day 2020). Several casts of large (*c*. 15 cm wide), subhorizontal to gently-inclined, straight tetrapod burrows, in one case associated with unidentified, scrappy postcranial and tooth material, are reported by Almond (2016c) from the *Eodicynodon* AZ in the Brandvalley WEF project area situated just southwest of

the present study area. The burrows reported there occur within the sandstone package along the crest of the Klein-Roggeveld Escarpment on Muishond Rivier 161 (possibly the Grootfontein Member of Day & Rubidge 2014). They may represent the oldest known tetrapod burrows reported from the Karoo Supergroup of South Africa (and even perhaps from Gondwana), although this claim remains to be confirmed. Poorly-preserved dinocephalian cranial remains (mainly preserved as moulds) have recently been reported within thick basal channel breccio-conglomerates on the farm Gats Rivier 156 some 30 km west of the present study area (Almond 2020).

These new fossils, in conjunction with spectacularly rich plant-insect Lagerstätte discovered within lacustrine deposits of the underlying Waterford Formation (Middle Permian / Roadian) near Sutherland (Moyo *et al.* 2018, Prevec & Matiwane 2018, Davids *et al.* 2018) as well as well-preserved petrified logs in the same formation, contribute to our understanding of the earliest terrestrial biotas that colonised the Main Karoo Basin in Middle Permian times (*c*. 270 Ma / million years ago).

The diverse Late Caenozoic superficial deposits within the South African interior, including the Great Karoo region, have been comparatively neglected in palaeontological terms. However, sediments associated with ancient drainage systems, springs and pans in particular may occasionally contain important fossil biotas, notably the bones, teeth and horn cores of mammals as well as remains of reptiles like tortoises. Other late Caenozoic fossil biotas that may occur within these superficial deposits include non-marine molluscs (bivalves, gastropods), ostrich egg shells, trace fossils (*e.g.* calcretised termitaria, coprolites, invertebrate burrows, rhizocretions), and plant material such as peats or palynomorphs (pollens) in organic-rich alluvial horizons and diatoms in pan sediments. In Quaternary deposits, fossil remains may be associated with human artefacts such as stone tools and are also of archaeological interest.

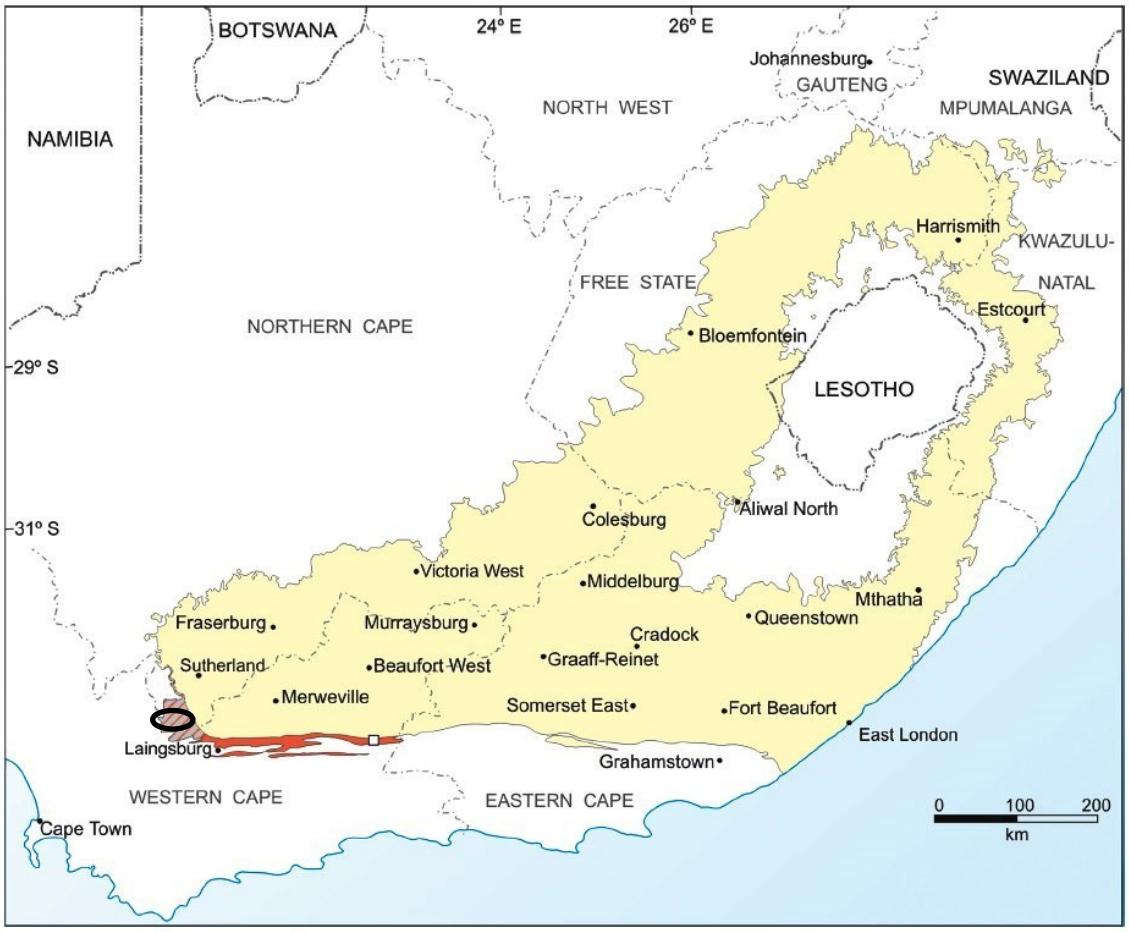

Figure 33: Distribution of the *Eodicynodon* Assemblage Zone (AZ) within the Main Karoo Basin of the RSA (Rubidge & Day 2020). The Kareebosch WEF and grid connection project area (black ellipse) to the NW of Laingsburg falls within the SW corner of the basin (area cross-hatched in red) where fossils of this assemblage zone are suspected to occur but this has not yet been firmly established.

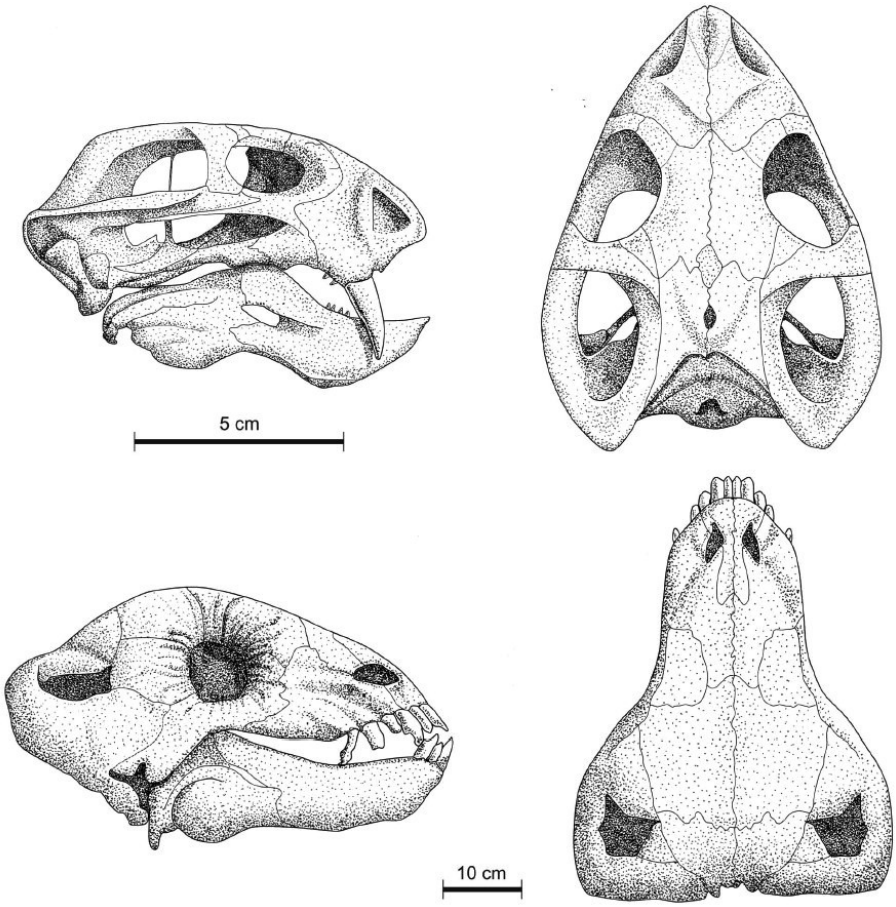

Figure 34: Key tetrapod taxa, both herbivorous therapsids, from the Middle Permian (Wordian) *Eodicynodon* Assemblage Zone of the Main Karoo Basin (from Rubidge & Day 2020). The small-bodied, toothed dicynodont *Eodicynodon* (above) is by far the commonest fossil tetrapod while rhino-sized primitive dinocephalians like *Tapinocaninus* (below) are far rarer. Occasional fossil tetrapod burrow casts in this AZ may be attributable to the former.

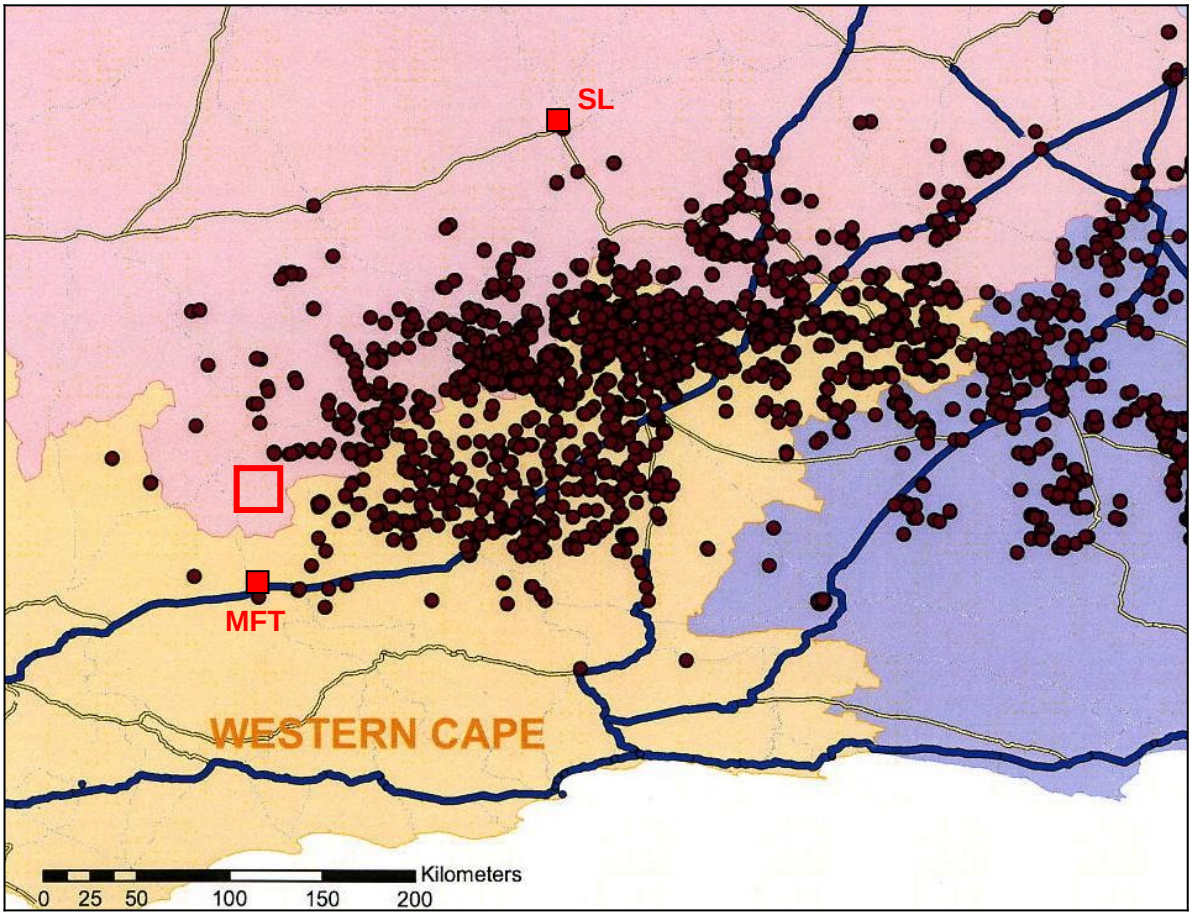

Figure 35: Distribution of recorded vertebrate fossil sites within the south-western portion of the Main Karoo Basin (modified from Nicolas 2007). The approximate location of the Kareebosch WEF and grid connection project area is indicated by the open red square. Note the paucity of known vertebrate fossil sites in this part of the Great Karoo. SL = Sutherland. MFT = Matjiesfontein.

5. RESULTS FROM PALAEONTOLOGICAL SITE VISIT, CONCLUSIONS & RECOMMENDATIONS FOR EMPR

Previous field-based PIA studies in the Kareebosch WEF project area by Miller (2011) and Almond (2014) only yielded sparse records of low diversity invertebrate trace fossil assemblages and scrappy vascular plant remains within the Abrahamskraal Formation bedrocks, with no fossils recorded within the Late Caenozoic superficial sediments. A limited number of new Abrahamskraal Formation fossil sites have been recorded during the recent site visit to the Kareebosch grid connection project area (Figs. 37 to 46). GPS locality details of the new fossil sites (see satellite maps in Appendix 1, Figures A1 & A2) are tabulated in Appendix 1 with a short description and indication of their palaeontological heritage significance (Provisional Field Rating).

Most of the new fossil material from the lower Abrahamskraal Formation comprises low diversity invertebrate trace fossil assemblages (Figs. 41 to 43), sphenophyte (reedy horsetail fern) plant debris (Fig. 46) or stem casts (Figs. 44 & 45) and lungfish burrow casts (Figs. 39 & 40), all of which are associated with swampy wetland habitats on the Middle Permian delta platform or alluvial plain. None of this material is of high scientific or conservation significance while many of the sites lie outside the grid connection project footprint (see satellite map Fig. A1 in Appendix 1), so no mitigation measures are proposed in their regard. No fossil material has been recorded within the Late Caenozoic superficial deposits.

Several small blocks of fossiliferous phosphatic concretion on Rietfontein RE/197 (Locs. 454-456, Figs. 20, 37 & 38) contain probable temnospondyl (amphibian) remains that are of considerable palaeontological interest given their low stratigraphic position within the Abrahamskraal Formation and the rarity of temnospondyl remains in the *Eodicynodon* Assemblage Zone (Prof. Bruce Rubidge, pers. comm., 2021). This material must be collected by a professional palaeontologist before construction of the powerline if Grid Option 1B is selected.

An isolated cobble of extra-basinal metamorphic rock recorded from the Abrahamskraal Fiormation outcrop area on Rietfontein RE/197 (Fig. 47) is potentially of paleobiological significance since such outsized exotic lonestones may have been transported downstream by floods in Middle Permian times, entangled among tree roots. In this case, no fossil wood was recorded in the vicinity of the lonestone site.

Given the very sparse occurrence of recorded fossils of scientific and / or conservation value in the Kareebosch WEF and grid connection project area, and their unpredictable occurrence, it is concluded that the Kareebosch grid connection project area is of LOW palaeosensitivity overall. Impacts on local palaeontological heritage resources due to the construction of the proposed *c*. 20 km long powerline are anticipated to be LOW to VERY LOW and insignificant compared with potential impacts due to construction of the WEF itself. It is noted that surface disturbance associated with any new powerline access roads in mountainous terrain is likely to have greater impact than excavations for electrical pylon footings. The potential for isolated vertebrate fossil finds of high scientific

interest - as occasionally recorded elsewhere in the Klein-Roggeveldberge region - cannot be completely discounted.

There are no objections on palaeontological grounds to authorisation of the proposed 132 kV powerline and there is no preference for any particular on-site substation site or powerline route option among those currently under consideration. If powerline Option 1B is selected for construction, vertebrate fossil material at, or in the vicinity of, Locs. 454-456 on Rietfontein RE/197 must be collected by a professional palaeontologist before construction of the powerline (See Appendix 1, satellite map Fig. A2). No further specialist palaeontological studies or mitigation are recommended for this electrical infrastructure project. These recommendations and the Chance Fossil Finds Protocol appended to this report (Appendix 2) should be included in the EMPr for the development.

5.1. Site Sensitivity Verification

Preliminary palaeosensitivity mapping suggests that the Kareebosch grid connection project area is of potentially of Very High Sensitivity on the basis of the potentially fossiliferous Lower Beaufort Group bedrocks mapped here (*e.g.* SAHRIS / DFFE palaeosensitivity maps, largely based on 1: 250 000 geological mapping; Fig. 36). Previous PIA reports for the Kareebosch WEF / Roggeveld WEF / Komsberg MTS project areas by Miller (2011) and Almond (2014, 2015b) as well as several other PIA reports by the author for renewable energy projects in the Klein-Roggeveldberge region (see References) suggest that scientifically or conservation-worthy fossil remains are, in practice, very scarce and unpredictably distributed here, even where bedrock exposure is locally good. However, a small number of important fossil sites – including exceptionally rare tetrapod skeletal remains, tetrapod burrows, amphibian trackways and swimming trails as well as vascular plant assemblages - have been recorded from the lower Abrahamskraal Formation in the Klein-Roggeveld region as a result of recent PIA field studies, including the recent visit to the Kareebosch WEF grid connection project area. Late Caenozoic superficial deposits (colluvium, alluvium, soils *etc*) that mantle most of the Lower Beaufort Group outcrop area are generally of Low to Very Low sensitivity and so far no fossils have been recorded from these younger deposits in the project area.

Based on combined desktop and field-based palaeontological data an overall LOW palaeosensitivity for the Kareebosch WEF and grid connection project areas is inferred here. However, the potential for isolated vertebrate and other fossil finds of high scientific interest - as occasionally recorded elsewhere in the Klein-Roggeveldberge region - cannot be completely discounted.

As motivated above, the provisional palaeosensitivity mapping for the Kareebosch WEF and associated grid connection corridors, based on the DFFE Screening Tool and SAHRIS website, is *contested* here.

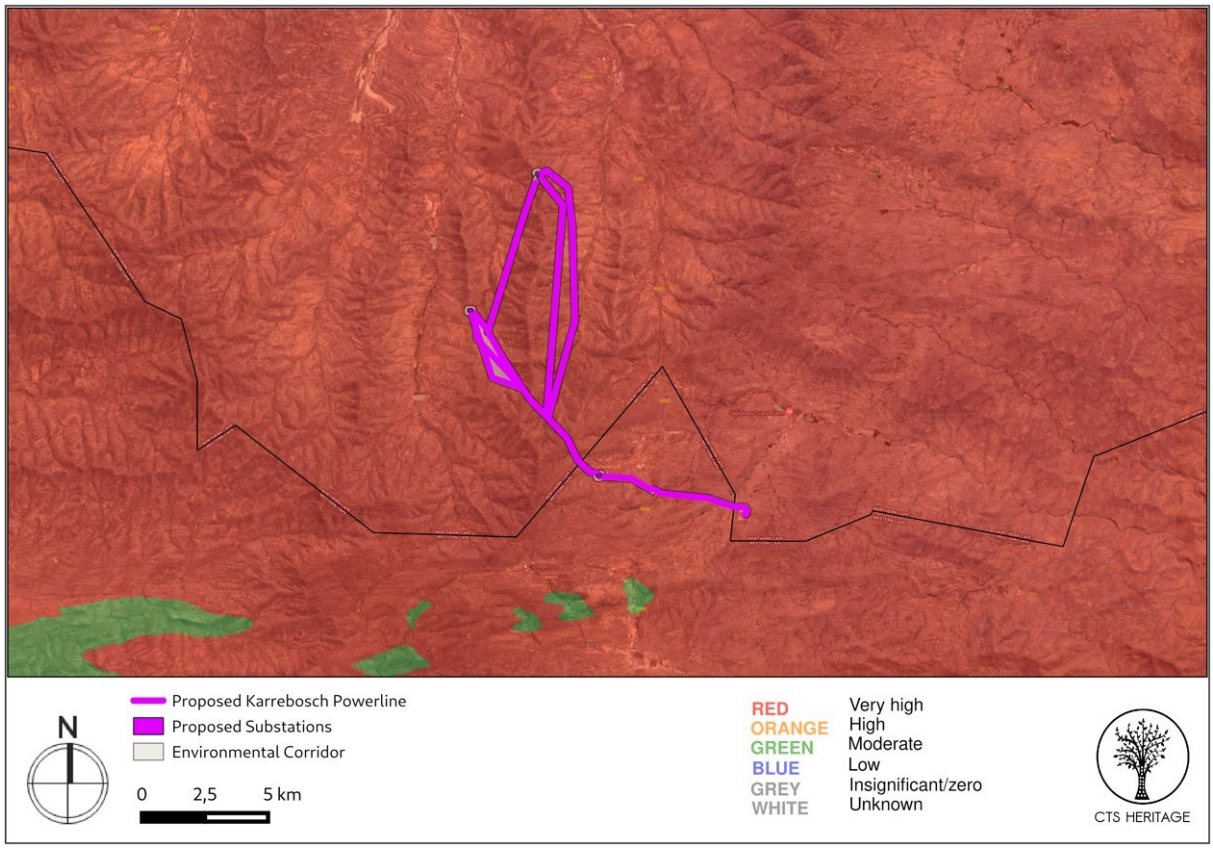

Figure 36: Palaeontological sensitivity map for the Kareebosch WEF grid connection project area (Image prepared by CTS). The provisional Very High Palaeosensitivity inferred on the map is *contested* here; in practice the area is largely of Low Palaeosensitivity, although the potential for rare, isolated occurrences of scientifically important vertebrate and other fossils cannot be discounted.

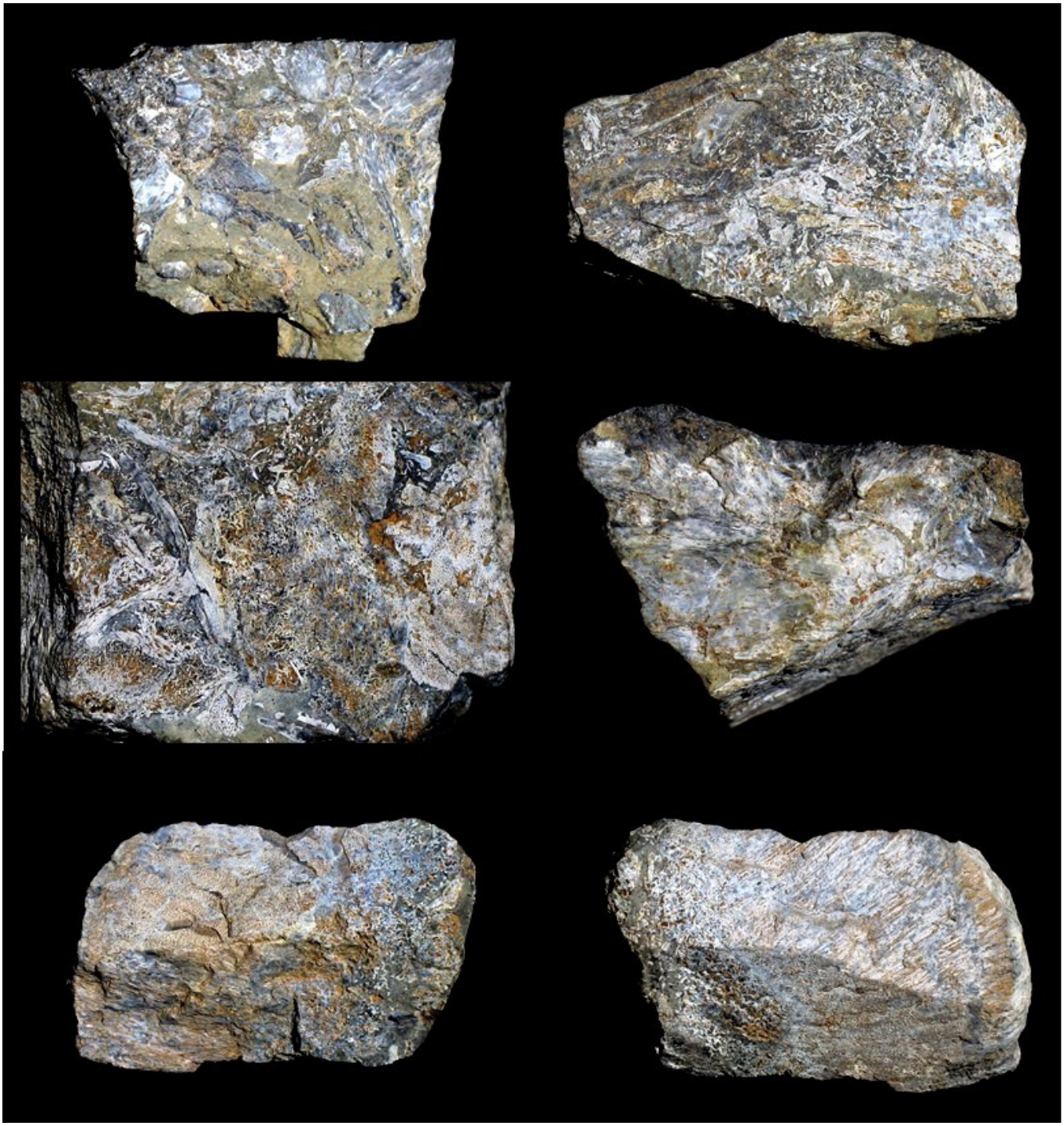

Figure 37: Several small blocky fragments (each *c*. 6 cm in maximum width) of a pale grey phosphatic concretion containing comminuted bone fragments with a dense, cancellous fabric, including possible scutes and teeth. The material probably belongs to a sizeable temnospondyl amphibian and represents one of the very few tetrapod body fossils recorded from the lowermost Abrahamskraal Formation of the Klein-Roggeveldberge region (Rietfontein RE/197, Locs. 454-456). Rare temnospondyl dermal scutes and jaws have been recorded previously from the *Eodicynodon* Assemblage Zone (Rubidge & Day 2020). See Figure 20 for setting of the fossil locality.

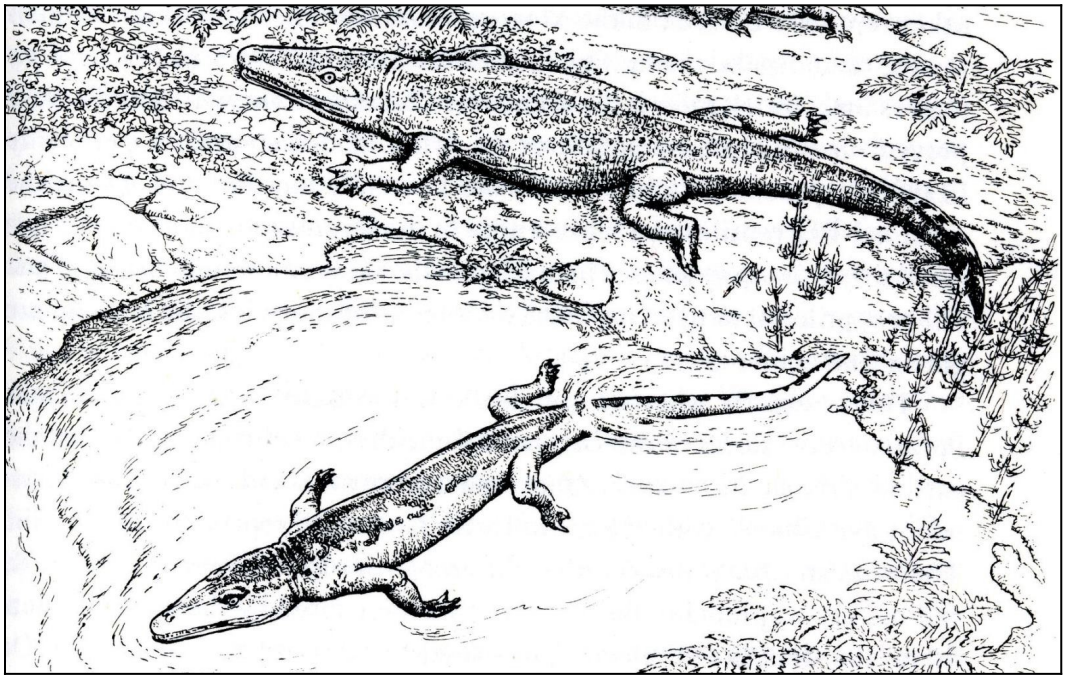

Figure 38: Temnospondyls were an important group of carnivorous, aquatic or amphibious tetrapods in the Permo-Triassic Main Karoo Basin (Modified from Benton 2003 *When life nearly died*). They are related to modern amphibians rather than crocodilian reptiles.

Figure 39: Several sandstone casts of vertical lungfish burrows embedded within crumbly, grey-green mudrocks of probable lacustrine or riverine pond origin (Scale = 15 cm) (Loc. 478, Ekkraal 199).

Figure 40: Two adjacent lungfish burrow casts weathering out to show their subcylindrical geometry (Loc. 478, Ekkraal 199). The largest cast in the assemblage is 9 cm in diameter.

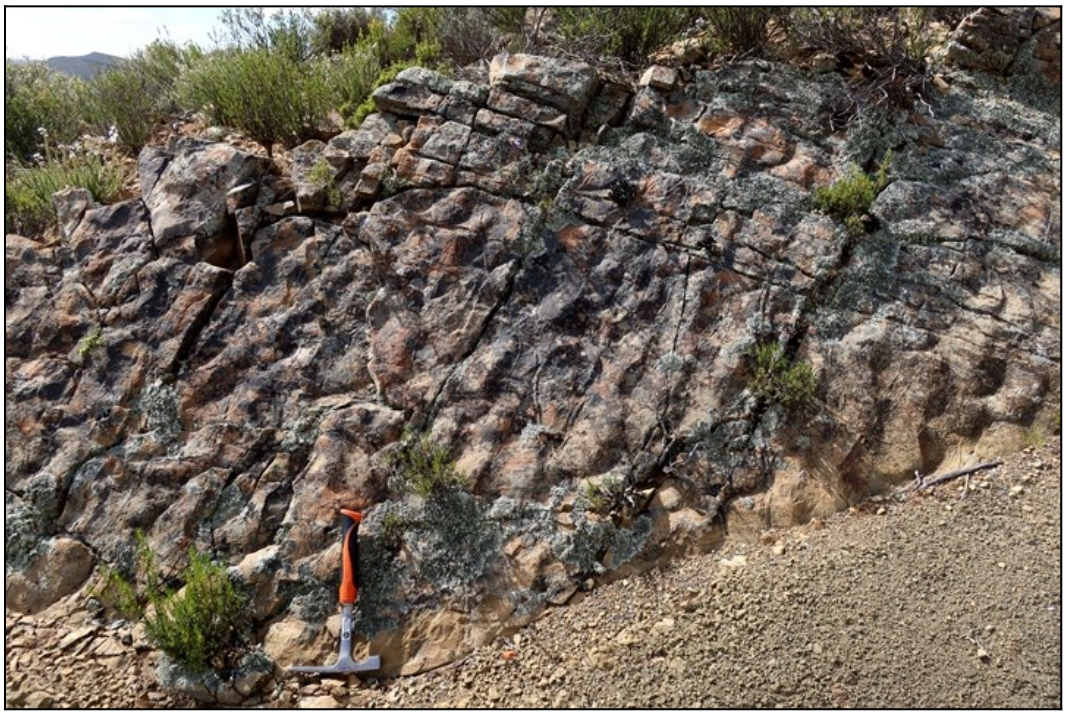

Figure 41: Steeply dipping, current-rippled channel sandstone with sparse epichnial invertebrate burrows (see following figure), Rietfontein RE/197 (Loc. 460) (Hammer = 30 cm).

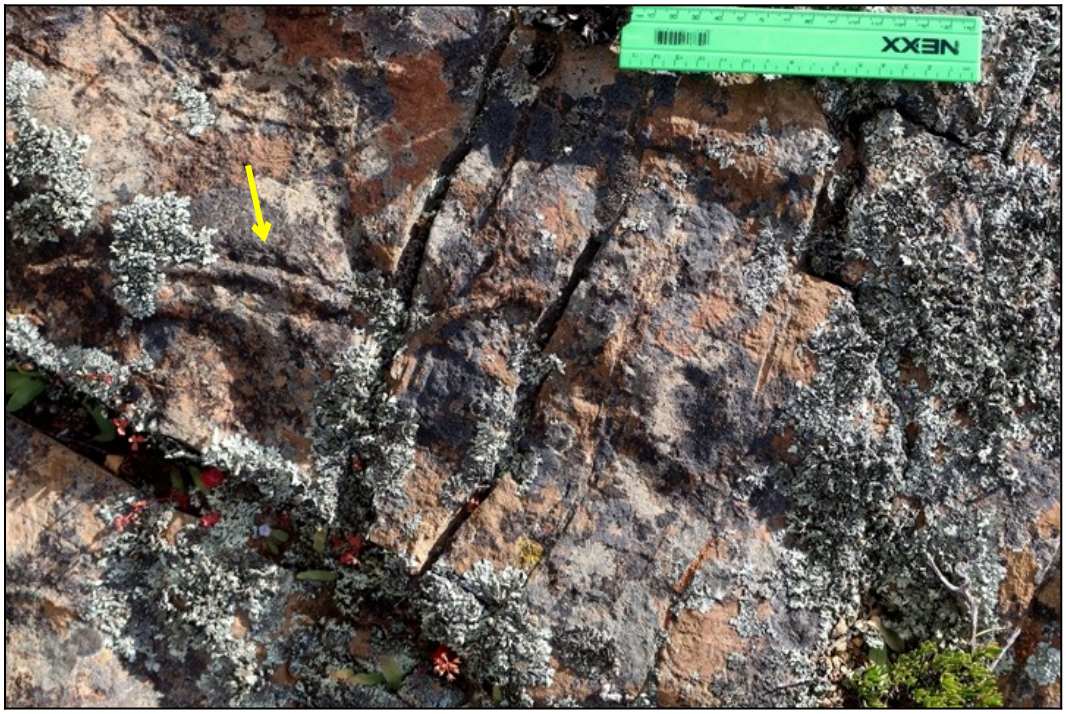

Figure 42: Close-up of one of the epichnial invertebrate burrows (arrowed) shown in the previous figure (Scale in cm).

Figure 43: Rippled sandstone surface with meandering epichnial furrows attributed to burrowing invertebrates in a shallow pond or playa lake setting (Scale in cm and mm), Rietfontein RE/197 (Loc. 453; see Figure 21 for context).

Figure 44: Mottled purple-brown and grey-green siltstone bedding plane containing cm-scale pale rounded sandstone casts, probably of reedy plant stems but possibly invertebrate burrows (scale in cm and mm), Ekkraal 199 (Loc. 484).

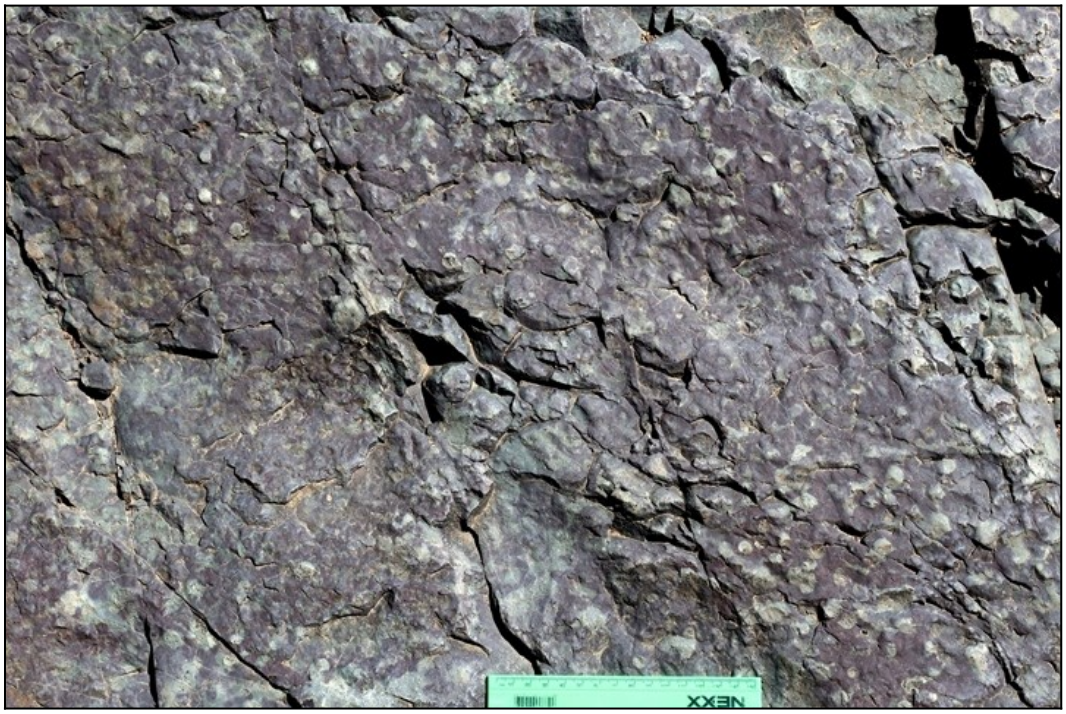

Figure 45: Dense assemblage of probable plant stems casts (*e.g.* equisetaleans) within a grey-green wacke veneered by purple-brown mudrock (Scale = 15 cm), Ekkraal 199 (Loc. 480).

Figure 46: Dense mat of reworked reedy sphenophyte stems (horsetail ferns) preserved as compressions within dark grey siltstones, shallow stream bed exposure on Rietfontein RE/197 (Loc. 463).

Figure 47: Cobble-sized exotic cobble of quartzitic schist or gneiss found in surface float on Rietfontein RE/197 (32 52 31.6 S, 20 29 23.2 E) (scale in cm). Such rare extra-basinal clasts in the Abrahamskraal Formation are potentially of paleobiological significance since they may have been transported downstream from a mountainous source area by floods in Middle Permian times, perhaps entangled among tree roots.

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7. ACKNOWLEDGEMENTS

Ms Jenna Lavin and Mr Nic Wiltshire of CTS Heritage, Cape Town are thanked for commissioning this study as well as for providing the necessary project information and for ably facilitating the field study and subsequent reporting. I am also grateful to Ms Ashlea Strong of WSP in Africa for helpful discussions on grid connection projects in the Karoo. Professor Bruce Rubidge (Wits University, Johannesberg) generously provided helpful input into the palaeontology of the Lower Beaufort Group in the Klein-Roggeveldberge Region. The companionship in the field, substantial palaeontological contributions as well as logistical backup kindly provided by Ms Madelon Tusenius are all highly appreciated, as always.

8. SHORT CV OF 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 the University of Tübingen in Germany, and has carried out palaeontological research in Europe, North America, the Middle East as well as North and South Africa and Madagascar. 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 numerous

palaeontological impact assessments for developments and conservation areas in the Western, Eastern and Northern Cape, Limpopo, Northwest Province, Mpumalanga, Gauteng, KwaZulu-Natal and the Free State under the aegis of his Cape Town-based company *Natura Viva* cc. He has served as a 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, application or appeal in respect of which I was appointed other than fair remuneration for work performed in connection with the activity, application or appeal. There are no circumstances that compromise the objectivity of my performing such work.

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

APPENDIX 1: KAREEBOSCH WEF GRID CONNECTION FOSSIL SITE DATA – SEPTEMBER 2021

All GPS readings were taken in the field using a hand-held Garmin GPSmap 64s instrument. The datum used is WGS 84.

Please note that:

- Locality data for South African fossil sites in *not* for public release, due to conservation concerns.
- The table does *not* represent all potential fossil sites within the project area but only those sites recorded during the field survey. The absence of recorded fossil sites in any area therefore does *not* mean that no fossils are present there.
- The detailed stratigraphic data for each site is provisional and has yet to be confirmed.

Loc.	GPS data	Comments
453	32°52'37.22" S 20°29'19.68" E	Rietfontein RE/197. Extensive exposure of SSE-dipping sandstone bed top with sets of small-scale wave ripples and meandering epichnial invertebrate burrows that were probably generated on the margins of a shallow floodplain pond or playa lake. Sharply overlying grey-green mudrocks show numerous ball-and-pillow load structures. Proposed Field Rating IIIC Local Resource. No mitigation recommended.
454	32°52'37.45" S 20°29'22.32" E	Rietfontein RE/197. Small (c. 6 cm wide), angular block of pale grey phosphatic concretion containing comminuted vertebrate bone and perhaps bony spines or teeth (pearly grey to black). Possibly of bony fish or – more likely - amphibian (*i.e.* temnospondyl) affinity. Block in surface float along shallow drainage line running along top of well-exposed grey-green mudrock package. Proposed Field Rating IIIB Local Resource. This material must be collected by a professional palaeontologist before construction of the powerline if Grid Option 1B is selected.
455	32°52'37.61" S 20°29'21.97" E	As above. Probably part of the same fossiliferous concretion. Proposed Field Rating IIIB Local Resource. This material must be collected by a professional palaeontologist before construction of the powerline if Grid Option 1B is selected.
456	32°52'36.97" S 20°29'23.42" E	As above (2 blocks). Probably part of the same fossiliferous concretion. Proposed Field Rating IIIB Local Resource. This material must be collected by a professional palaeontologist before construction of the powerline if Grid Option 1B is selected.
460	32°52'39.07" S 20°29'29.12" E	Rietfontein RE/197. Hillslope exposure of steeply dipping, SE-facing current-rippled bed top with sparse epichnial invertebrate burrows up to *c*. 2 cm wide, subhorizontal with central convex core (possibly segmented) and shallow marginal grooves. Proposed Field Rating IIIC Local Resource. No mitigation recommended.
463	32°52'31.51" S 20°29'23.81" E	Rietfontein RE/197. Dense mat of reworked reedy sphenophyte stems (horsetail ferns) preserved as compressions within dark grey siltstones, shallow stream bed exposure. Proposed Field Rating IIIC Local Resource. No mitigation recommended.
478	32°54'53.65"	Ekkraal 199. Stream bed and bank exposure of grey-green mudrocks of

	S 20°30'56.37" E	Abrahamskraal Fm with horizon containing several subcylindrical, vertical lungfish burrow casts up to 9 cm in diameter. Proposed Field Rating IIIB Local Resource. No mitigation recommended since site lies outside grid corridor.
480	32°54'52.93" S 20°30'58.94" E	Ekkraal 199. Stream bed exposure of grey-green siltstone or fine-grained wacke covered by purple-brown siltstone veneer and with dense assemblage of rounded traces between 0.5 to 1 cm in diameter – probably reedy plant stem casts (*e.g.* sphenophytes). Proposed Field Rating IIIC Local Resource. No mitigation recommended. Site lies outside grid corridor.
484	32°54'41.76 20°31'10.35" E"S	Ekkraal 199. Stream gulley exposure of mottled grey-green to purple-brown sandstone with assemblage of rounded, oval to irregular sand-infilled casts with reduction haloes, either of plant stems or invertebrate burrows. Proposed Field Rating IIIC Local Resource. No mitigation recommended. Site lies outside grid corridor.
492	32°55'11.03" S 20°31'54.90" E	Bon Espirange 73. Sandstone bed top with possible effaced desiccation crack infills, assemblage of reedy plant stem casts. Proposed Field Rating IIIC Local Resource. No mitigation recommended. Site lies outside grid corridor.

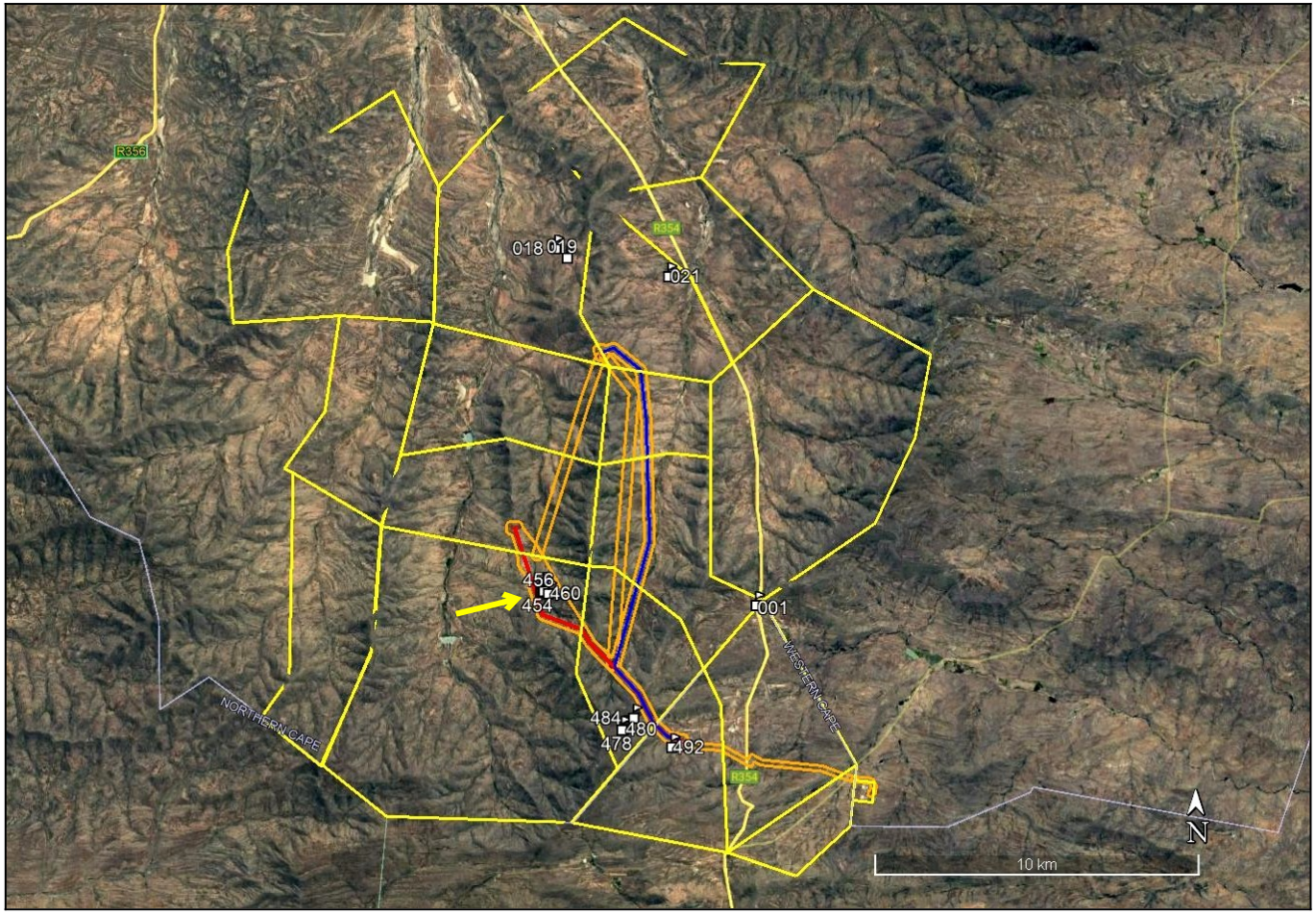

Figure A1: Google Earth© satellite image of the Kareebosch WEF (yellow polygons) and grid connection (orange corridors) project areas (See also Fig.1 for details). The sparse fossil sites recorded during the palaeontological site visit are indicated by the white numbered squares (See table above for details). Several of the fossil sites lie on the margins of, or shortly outside, the powerline corridor options and no mitigation in their regard is recommended here. A small cluster of potentially important vertebrate fossil sites lies close to the powerline option 1B (Locs. 454-456, arrowed; see also Figure A2 below). This material must be collected by a professional palaeontologist before construction of the powerline if Grid Option 1B is selected.

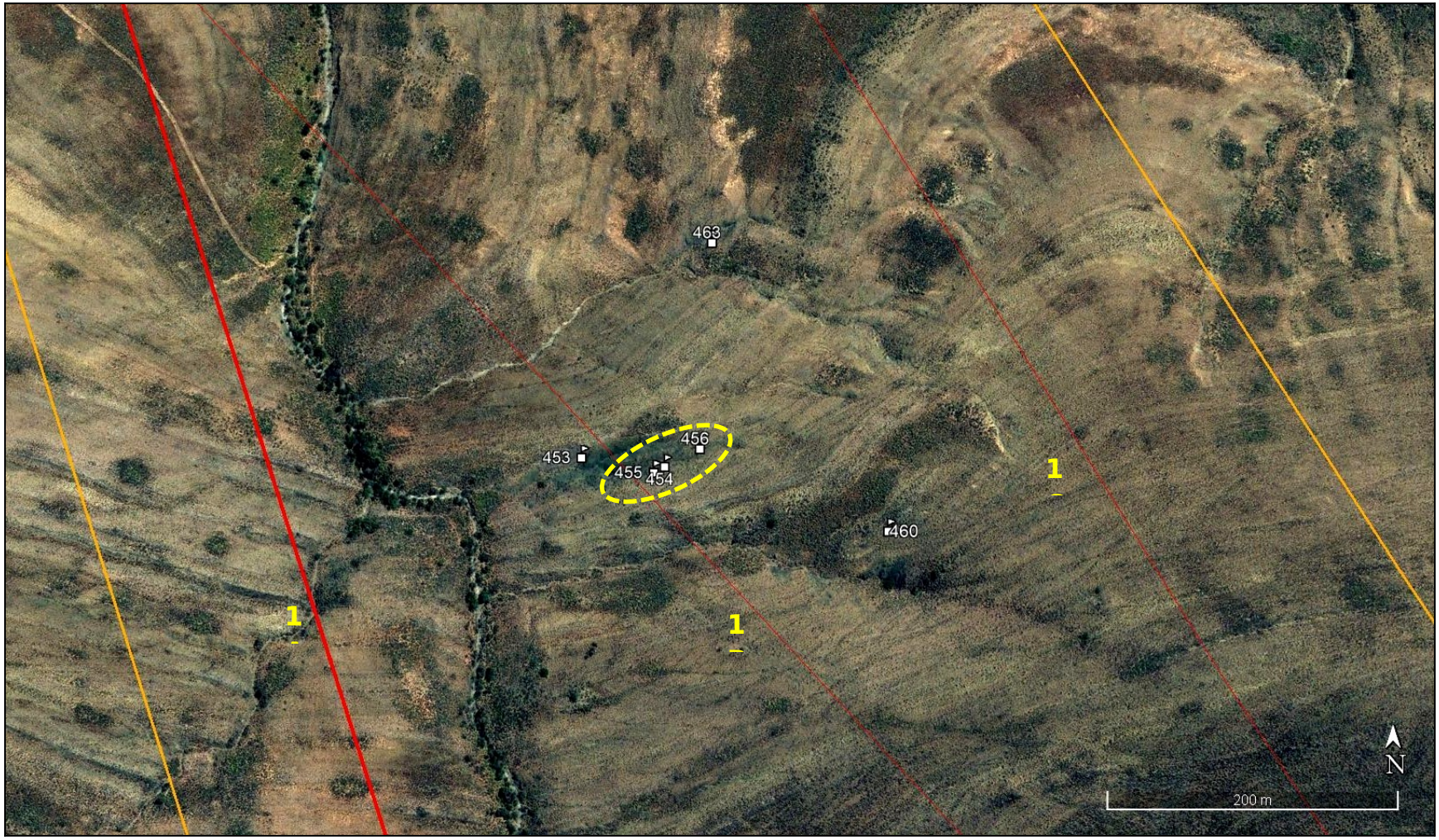

Figure A2: Detail of powerline route options 1A, 1B and 1C on part of Rietfontein RE/197 showing recorded fossil sites. If powerline Option 1B is selected for construction, vertebrate fossil material at or in the vicinity of Locs. 454-456 (yellow dashed ellipse) on Rietfontein RE/197 must be collected by a professional palaeontologist before construction of the powerline.

<table>
<tr><td>Province & region:</td><td colspan="2">Western Cape (Laingsburg Local Municipality) and Northern Cape (Karoo Hoogland Local Municipality)</td></tr>
<tr><td>Responsible Heritage Resources Agency</td><td colspan="2">Heritage Western Cape for the Western Cape (Contact details: Heritage Western Cape. 3rd Floor Protea Assurance Building, 142 Longmarket Street, Green Market Square, Cape Town 8000. Private Bag X9067, Cape Town 8001. Tel: 021 483 5959 Email: ceoheritage@westerncape.gov.za)
SAHRA for the Northern Cape (Contact details: South African Heritage Resources Agency. 111 Harrington Street, Cape Town. PO Box 4637, Cape Town 8000, South Africa. Tel : 021 462 4502).</td></tr>
<tr><td>Rock unit(s)</td><td colspan="2">Abrahamskraal Formation (Lower Beaufort Group, Karoo Supergroup), Late Caenozoic alluvium, colluvium, eluvium</td></tr>
<tr><td>Potential fossils</td><td colspan="2">Fossil vertebrate bones, teeth, large burrow casts, trackways, petrified wood, plant-rich beds in the Abrahamskraal Fm bedrocks.
Fossil mammal bones, teeth, horncores, freshwater molluscs, plant material, calcretised termitaria in Late Caenozoic alluvium.</td></tr>
<tr><td rowspan="4">ECO protocol</td><td colspan="2">1. Once alerted to fossil occurrence(s): alert site foreman, stop work in area immediately (N.B. safety first!), safeguard site with security tape / fence / sand bags if necessary.</td></tr>
<tr><td colspan="2">2. Record key data while fossil remains are still in situ:
• Accurate geographic location – describe and mark on site map / 1: 50 000 map / satellite image / aerial photo
• Context – describe position of fossils within stratigraphy (rock layering), depth below surface
• Photograph fossil(s) in situ with scale, from different angles, including images showing context (e.g. rock layering)</td></tr>
<tr><td>3. If feasible to leave fossils in situ:
Alert Heritage Resources Agency and project palaeontologist (if any) who will advise on any necessary mitigation
Ensure fossil site remains safeguarded until clearance is given by the Heritage Resources Agency for work to resume</td><td>3. If not feasible to leave fossils in situ (emergency procedure only):
Carefully remove fossils, as far as possible still enclosed within the original sedimentary matrix (e.g. entire block of fossiliferous rock)
Photograph fossils against a plain, level background, with scale
Carefully wrap fossils in several layers of newspaper / tissue paper / plastic bags
Safeguard fossils together with locality and collection data (including collector and date) in a box in a safe place for examination by a palaeontologist
Alert Heritage Resources Agency and project palaeontologist (if any) who will advise on any necessary mitigation</td></tr>
<tr><td colspan="2">4. If required by Heritage Resources Agency, ensure that a suitably-qualified specialist palaeontologist is</td></tr>
</table>

	appointed as soon as possible by the developer.
	5. Implement any further mitigation measures proposed by the palaeontologist and Heritage Resources Agency
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 Resources Agency minimum standards.