15 Appendix B PALAEONTOLOGICAL HERITAGE REPORT

Palaeontological assessment.

PROPOSED PHEZUKOMOYA WIND FARM NEAR NOUPOORT, NORTHERN & EASTERN CAPE

Dr John E. Almond
***Natura Viva* cc**
PO Box 12410 Mill Street
CAPE TOWN 8010, RSA

October 2017

EXECUTIVE SUMMARY

Phezukomoya Wind Farm (Pty) Ltd are proposing to construct the Phezukomoya Wind Energy Facility (WEF) near Noupoort with up to 63 wind turbines and an approximately 15 km long 132 kV grid connection to the Umsobomvu substation. The project area spans the border between the Noupoort District, Northern Cape and Middelburg District, Eastern Cape. Most of the Phezukomoya WEF footprint will be situated in dissected rocky plateau areas underlain by continental sediments of the Katberg Formation (Upper Beaufort Group / Tarkastad Subgroup, Karoo Supergroup) of earliest Triassic age. Latest Permian sediments of the underlying Balfour Formation crop out along the foot of the Katberg escarpment but are generally mantled by a thick apron of colluvium (sandy and gravelly scree, hillwash) and alluvium. Elsewhere in the Main Karoo Basin these sediments have yielded locally abundant vertebrate fossils, large vertebrate burrows, a small range of invertebrate burrows but only rare plant remains. The uppermost Balfour and Katberg Formations preserve an important record of biological and palaeoenvironmental events on land during the catastrophic Permo-Triassic extinction of 252 Ma (million years ago) and subsequent biotic recovery. Several vertebrate fossil localities in the Noupoort area are noted in the scientific literature but only a few fossil remains were recorded during a four-day field assessment of the Phezukomoya WEF and associated powerline. These include fragmentary bones within calcrete breccias as well as several large vertebrate burrows, one with associated disarticulated bones. The paucity of recorded fossil sites here is probably due to (1) the very low exposure levels seen here of overbank mudrocks where most fossils are preserved, and (2) the predominance of amalgamated channel sandstone facies in the upper part of the Katberg Formation building the plateau areas. Scientifically-important fossil remains in the subsurface may well be compromised by the proposed WEF development during the construction phase, notably due to voluminous bedrock excavations for wind turbine footings.

No palaeontological No-Go areas or highly-sensitive fossil sites have been identified within the main WEF development footprint on the Katberg sandstone plateau (Fig. 36). All fossil finds here are assigned a low field rating (Local Resource IIIC) and do not warrant mitigation. A 50 m-radius protective buffer zone is proposed for several vertebrate burrow sites along a stream bed on farm Winterhoek 118 (Field rating Local Resource IIIB). They lie close to the alignment of the Alternative 1 132 kV powerline route which, if chosen, should be moved

slightly to the southeast in this sector to lie outside the proposed buffer zone (See Figs. 38 and 39 herein). Alternative 1 is the least-preferred route option from a heritage viewpoint for this reason, with no preference for either one of the other two route options under consideration.

Excellent exposures of mudrocks of the Palingkloof Member (upper Balfour Formation) that are of geoheritage as well as palaeontological significance because of their proximity to the Permo-Triassic boundary are noted here (red shapes in Figs. 36 & 37). One, lying along the railway line at Carlton Heights (Farms RE/1/1 and 18/1), has featured in several scientific publications while the other, close to Hartebeesthoek homestead on Farm RE/182, is currently unstudied. It is anticipated that neither of these two geosites will be directly impacted by the proposed WEF development.

Due to the low extent, inferred moderate severity and permanent duration of potential palaeontological impacts, the impact significance of the proposed WEF is assessed as *medium (negative)* before mitigation. Confidence levels in this assessment are *medium*, given (1) the extensive palaeontological literature on the Karoo bedrocks concerned weighed against (2) very low levels of bedrock exposure within the study area and (3) the unpredictable distribution of well-preserved fossils.

Given (1) the significant potential for scientifically-valuable fossils being disturbed, damaged or destroyed during the construction phase of the WEF as well as (2) the high level of uncertainty regarding fossil distribution in the subsurface, a precautionary approach to palaeontological mitigation is considered appropriate here. Following discussions with SAHRA (Dr Ragna Redelstorff, Oct. 2017), it is therefore proposed that initially a representative sample (*c*. 10%) of excavations for wind turbine footings be monitored by a professional palaeontologist during the early construction phase. The monitoring protocol should be developed by the palaeontologist appointed in consultation with the developer and SAHRA so as to maximise the palaeontological outcome without interfering unduly with the construction program. On completion of this initial phase of monitoring, a Phase 2 palaeontological report, with recommendations for further specialist monitoring or mitigation (if any), should be submitted by the palaeontologist to SAHRA for comment. This stepwise monitoring approach is recommended because it may well prove impracticable to recognise, record and sample useful fossil material from turbine excavations due to factors such as excessive fragmentation of the bedrock and fossils, obscuring of freshly-excavated bedrock by soil or dust, or safety considerations.

Should the recommended mitigation measures for the construction phase of the WEF development be consistently followed-though, the impact significance would remain *medium* (*negative*) but would entail both positive and negative impacts. Residual negative impacts from inevitable loss of some valuable fossil heritage would be partially offset by an improved palaeontological database for the study region as a direct result of appropriate mitigation.

Given the comparatively small combined footprint of the alternative energy projects in the broader Noupoort region compared with the very extensive outcrop areas of the fossiliferous Balfour and Katberg Formations, the cumulative impact significance of the Phezukomoya WEF is assessed as LOW.

There are no fatal flaws in the proposed WEF project from a palaeontological heritage viewpoint and no objects to authorisation of the development, provided that the recommended mitigation measures are incorporated into the EMPr for this project and fully implemented.

1. PROJECT DESCRIPTION & BRIEF

The proposed 315 MW Phezukomoya WEF would consist of the following infrastructural components:

- Up to 63 wind turbines with a generation capacity between 3 – 5 MW and a rotor diameter of up to 150 m, a hub height of up to 150 m and blade length of up to 75 m;
- Foundations and hardstands associated with the wind turbines;
- Internal access roads of between 8 m (during operation) and 14 m (during construction) wide to each turbine;
- Two 10 000 m^2 on-site switching stations
- Medium voltage underground electrical cables will be laid to transmit electricity generated by the wind turbines to the on-site switching station or substation;
- Overhead medium voltage cables between turbine rows where necessary;
- An on-site substation and OMS area (180 000 m^2) to facilitate stepping up the voltage from medium to high voltage (132 kV) to enable the connection of the WEF to proposed Umsobomvu WEF 132/400 kV Substation, from which the generated power will be fed into the national grid;
- Two medium voltage overhead powerlines (approximately 3 km and 5.6 km in length) connecting the on-site switching stations with the on-site medium voltage/132 kV substation;
- An approximately 16 km 132 kV voltage overhead power line from the on-site substation to the proposed 132/400 kV Umsobomvu Substation where the electricity will be transferred to the national grid;
- A 100 m corridor surrounding Umsobomvu substation so that the grid connection can turn into the substation from any direction;
- A 90 000 m^2 area for batching plant, temporary laydown area and construction compound;
- Temporary infrastructure including a site camp; and a laydown area approximately 7500 m^2 in extent, per turbine.

The total size of the development site is 15 164 hectares. The footprint of the proposed development is estimated to be less than 1% of this area.

Table 8 Infrastructure footprint.

Description	Dimensions		
	Length (m)	Breadth (m)	Area (sqm)
Eskom 400kV Umsobomvu substation	600	600	360000
Phezukomoya medium voltage/132 substation and OMS area	600	300	180000

Construction compound, temporary laydown area and bathcing plant	300	300	90000

The present combined desktop and field-based palaeontological heritage study of the Phezukomoya WEF study area contributes to the comprehensive Heritage Impact Assessment and heritage aspects of the Environmental Management Programme for the project compiled under the aegis of ACO Associates cc, Cape Town (Contact details: Mr Tim Hart, ACO Associates cc. Unit D17, Prime Park, 21 Mocke Road, Diep River, 7800. Tel: 021 706 4104. E-mail: Tim.Hart@aco-associates.com). The EIA process for the project is being co-ordinated by Arcus Consulting, Cape Town (Contact details: Ms Ashlin Bodasig and Ms Anja Albertyn, Arcus Consulting, Cape Town, Office 220 Cube Workspace. Cnr Long Street and Hans Strydom Road, Cape Town 8001. Tel: 021 412 1533. E-mail: phezukomoya@arcusconsulting.co.za).

2. APPROACH TO THE PALAEONTOLOGICAL HERITAGE STUDY

The approach to this palaeontological heritage study is briefly as follows. Fossil bearing rock units occurring within the broader study area are determined from geological maps and satellite images. Known fossil heritage in each rock unit is inventoried from scientific literature, previous assessments of the broader study region, and the author's field experience and palaeontological database. Based on this data as well as field examination of representative exposures of all major sedimentary rock units present, the impact significance of the proposed development is assessed with recommendations for any further studies or mitigation.

In preparing a palaeontological desktop study the potentially fossiliferous rock units (groups, formations *etc*) represented within the study area are determined from geological maps and satellite images. The known fossil heritage within each rock unit is inventoried from the published scientific literature, previous palaeontological impact studies in the same region, and the author's field experience (consultation with professional colleagues as well as examination of institutional fossil collections may play a role here, or later following field assessment during the compilation of the final report). This data is then used to assess the palaeontological sensitivity of each rock unit to development. The likely impact of the proposed development on local fossil heritage is then determined on the basis of (1) the palaeontological sensitivity of the rock units concerned and (2) the nature and scale of the development itself, most significantly the extent of fresh bedrock excavation envisaged. When rock units of moderate to high palaeontological sensitivity are present within the development footprint, a Phase 1 field assessment study by a professional palaeontologist is usually warranted to identify any palaeontological hotspots and make specific recommendations for any monitoring or 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 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 palaeontological collection permits from the relevant heritage management authorities, *i.e.*. ECPHRA for the Eastern Cape (ECPHRA contact details: Mr Sello Mokhanya, 74 Alexander Road, King Williams Town 5600; Email: smokhanya@ecphra.org.za) and SAHRA for the Northern Cape (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). 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.

2.1. Information sources

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

1. A short project description, maps and kmz files kindly provided by ARCUS Consulting and ACO Associates, Cape Town;

2. A review of the relevant satellite images, topographical maps and scientific literature, including published geological maps and accompanying sheet explanations, as well as several previous desktop and field-based palaeontological assessment studies in the broader Noupoort – Middelburg study region (*e.g.* Almond 2011, 2012, 2015, 2017, Butler 2014, 2016 and Gess 2012a, 2012b);

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

4. A four-day palaeontological reconnaissance field assessment of the Phezukomoya WEF project area on 13 to 17 October 2017 by the author and one assistant.

2.2. Assumptions & limitations

The accuracy and reliability of palaeontological specialist studies as components of heritage impact assessments are generally limited by the following constraints:

1. Inadequate database for fossil heritage for much of the RSA, given the large size of the country and the small number of professional palaeontologists carrying out fieldwork here. Most development study areas have never been surveyed by a palaeontologist.

2. Variable accuracy of geological maps which underpin these desktop studies. For large areas of terrain these maps are largely based on aerial photographs alone, without ground-truthing. The maps generally depict only significant ("mappable") bedrock units as well as major areas of superficial "drift" deposits (alluvium, colluvium) but for most regions give little or no idea of the level of bedrock outcrop, depth of superficial cover (soil *etc*), degree of bedrock weathering or levels of small-scale tectonic deformation, such as cleavage. All of these factors may have a major influence on the impact significance of a given development on fossil heritage and can only be reliably assessed in the field.

3. Inadequate sheet explanations for geological maps, with little or no attention paid to palaeontological issues in many cases, including poor locality information.

4. The extensive relevant palaeontological "grey literature" - in the form of unpublished university theses, impact studies and other reports (*e.g*. of commercial mining companies) - that is not readily available for desktop studies.

5. Absence of a comprehensive computerized database of fossil collections in major RSA institutions which can be consulted for impact studies. A Karoo fossil vertebrate database is now accessible for impact study work.

In the case of palaeontological desktop studies without supporting Phase 1 field assessments these limitations may variously lead to either:

(a) *underestimation* of the palaeontological significance of a given study area due to ignorance of significant recorded or unrecorded fossils preserved there, or

(b) *overestimation* of the palaeontological sensitivity of a study area, for example when originally rich fossil assemblages inferred from geological maps have in fact been destroyed by tectonism or weathering, or are buried beneath a thick mantle of unfossiliferous "drift" (soil, alluvium *etc*).

Since most areas of the RSA have not been studied palaeontologically, a palaeontological desktop study usually entails *inferring* the presence of buried fossil heritage within the study area from relevant fossil data collected from similar or the same rock units elsewhere, sometimes at localities far away. Where substantial exposures of bedrocks or potentially fossiliferous superficial sediments are present in the study area, the reliability of a palaeontological impact assessment may be significantly enhanced through field assessment by a professional palaeontologist.

In the case of the Phezukomoya WEF study area near Noupoort in the Northern and Eastern Cape preservation of potentially fossiliferous bedrocks is favoured by the semi-arid climate and sparse vegetation but bedrock exposure is very limited by extensive superficial deposits (sandy soils, scree), especially in areas of low relief such as the plateau areas where the majority of the WEF infrastructure will be placed. Vehicle access to most of the upland plateau areas is currently challenging and very limited.

In practice, approximately two thirds of the fieldwork time was spent traversing the core WEF project area on the Katberg sandstone plateau – uniformly regarded as palaeontologically uninformative due to superficial sediment cover - and perhaps some 10% of time in the powerline project area. However, it is considered that sufficient bedrock and cover sediment exposures were examined during the course of this study to assess the broader palaeontological heritage sensitivity of the study area (See Appendix). Comparatively few academic palaeontological studies or field-based fossil heritage impact studies have been carried out in the region, so any new data from impact studies here are of scientific interest.

2.3. Legislative context for palaeontological assessment studies

The Phezukomoya WEF alternative energy project is located in an area that is underlain by potentially fossiliferous sedimentary rocks of Late Palaeozoic to Mesozoic and younger, Late Tertiary or Quaternary, age (Sections 3 and 4). The construction phase of the proposed development will entail substantial excavations into the superficial sediment cover and locally into the underlying bedrock as well. These include, for example, excavations for the wind turbine foundations, hard standing areas, internal access roads, underground cables, transmission line pylon footings, electrical substations, operations and services workshop area/office building, laydown areas and construction site camp. All these developments may adversely affect potential fossil heritage within the study area by destroying, disturbing or permanently sealing-in fossils at or beneath the surface of the ground that are then no longer available for scientific research or other public good. The operational and decommissioning phases of the wind energy facility are unlikely to involve further adverse impacts on local palaeontological heritage, however.

The present combined desktop and field-based palaeontological heritage study contributes to the consolidated Heritage Assessment for the Phezukomoya WEF project and falls under the South African Heritage Resources Act (Act No. 25 of 1999). It will also inform the Environmental Management Programme for this project.

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

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

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

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

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

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

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

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

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

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

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

(5) When the responsible heritage resources authority has reasonable cause to believe that any activity or development which will destroy, damage or alter any archaeological or palaeontological site is under way, and where no application for a permit has been submitted

and no heritage resources management procedure in terms of section 38 has been followed, it may—

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

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

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

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

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

3. GEOLOGICAL CONTEXT

The Phezukomoya WEF study area is situated in dissected, semi-arid mountainous terrain of the Agter-Renosterberg – Kikvorsberg Ranges which are situated within the Upper Karoo geomorphic province of the RSA (Partridge *et al.* 2010). The core WEF development area where most of the infrastructure will be situated, including wind turbines and access roads, is located on an undulating, grassy sandstone plateau reaching elevations of *c*. 1780 m amsl. on Afrikasberg to the southwest of Noupoort (Figs. 1, 13 & 14). The steep margins of the plateau are incised by several narrow stream valleys reflecting erosional down-cutting during more pluvial periods in the geological past.

The geology of the Noupoort study region is shown on 1: 250 000 sheet 3124 Middelburg (Cole *et al.* 2004) (Fig. 2) and has been briefly described in a previous WEF palaeontological assessment for the Noupoort area by Almond (2012, 2017). Most of the study area, including the core development area, is underlain by Early Triassic (*c*. 250 Ma = million years old) fluvial sediments of the **Katberg Formation** (**TRk**, yellow with red stipple in Fig. 2) which forms the lowermost subunit of the Tarkastad Subgroup (Upper Beaufort Group, Karoo Supergroup). Levels of tectonic deformation in this region are very low, as shown by recorded dips here of only two to three degrees within the Tarkastad Subgroup, with most of the succession being subhorizontal.

Very small outcrop areas of Karoo sediments assigned to the underlying **Adelaide Subgroup** (**Pa**, pale blue in Fig. 2) are mapped in the western foothills of the Kikvorsberg close to the N9 and Noupoort town as well as around the margins of the Afrikasberg (Fig. 3). These older bedrocks belong largely or entirely to the uppermost portion of the **Balfour Formation**, namely the **Palingkloof Member** of Latest Permian to Earliest Triassic age. According to Cole *et al.* (2004) this succession consists largely of reddish mudrocks and has a thickness of only some

20 m or so in the Noupoort area (*e.g.* Carlton Siding). Given their location at the foot of the Katberg escarpment, the Adelaide Subgroup rocks here are largely covered by colluvial debris (gravelly scree, hillwash sands) and are furthermore unlikely to be directly impacted by the Noupoort wind farm development, with the possible exception of a access roads in lowland areas. For these reasons, the Balfour Formation rocks will not be treated in any detail in this study. It should be noted, however, that they are of considerable palaeontological significance elsewhere in the Main Karoo Basin since they record the catastrophic end-Permian mass extinction event and ensuing biotic recovery among continental biotas (*e.g.* Smith & Ward 2001, Smith *et al.* 2002, Retallack *et al.* 2003 and 2006, Ward *et al.* 2005, Smith & Botha 2005, Botha & Smith 2007, Smith & Botha-Brink 2014, Smith *et al.* 2012) (Fig. 38). Good erosion gulley exposures of colour-banded Palingkloof Member mudrocks and thin-bedded sandstones are seen on Hartebeest Hoek 182 (Fig. 4) as well as in the classic exposures close to the railway line at Carlton Heights (Figs. 5 to 7). The Carlton Heights road and railway cuttings, hillslope and gulley exposures (red shale in Fig. 37) have played an important role in on-going geological and palaeontological studies of the continental Permo-Triassic boundary and associated evolutionary events in the Main Karoo Basin (*e.g.* Retallack *et al.* 2003, Gastaldo *et al.* 2005, Ward *et al.* 2005, Gastaldo & Rolerson 2008 and refs. therein). These exposures are therefore considered to be of special geoscientific heritage significance and worthy of special protection (*N.B.* The road cuttings along the N9 at Carlton Heights have been considerably modified by recent road construction).

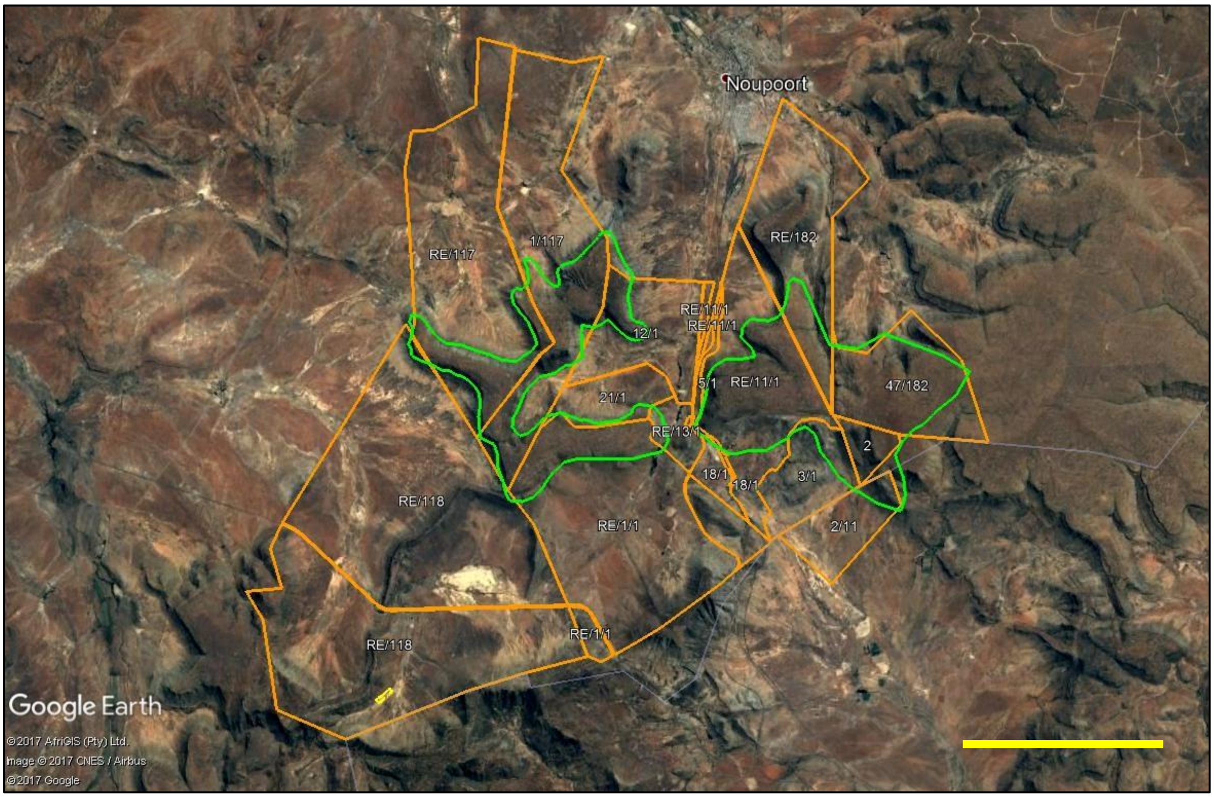

Fig. 1. Google Earth© satellite image of the region to the south of Noupoort showing the study area for the proposed Phezukomoya WEF (orange polygon) as well as an outline of plateau areas where the majority of the WEF infrastructure will be sited (green polygons). Scale bar = 5 km. North towards the top of the image.

The Katberg Formation forms the regionally extensive, sandstone-rich lower portion of the Tarkastad Subgroup (Upper Beaufort Group) that can be traced throughout large areas of the Main Karoo Basin. In the Middelburg sheet area it reaches a maximum thickness of some 400 m, but close to Noupoort thicknesses of 240-260 m are more usual. The predominant sediments are (a) prominent-weathering, pale buff to greyish, tabular or ribbon-shaped sandstones up to 60 m thick (Figs. 8 to 10) that are interbedded with (b) recessive-weathering, reddish or occasionally green-grey mudrocks (Fig. 8). Up to four discrete sandstone packages can be identified within the succession. In the Noupoort area the overall sandstone:mudrock ratio is close to 1:1. Katberg channel sandstones are typically rich in feldspar and lithic grains (*i.e*. lithofeldspathic). They build laterally extensive, tabular, multi-storey units with an erosional base that is often marked by intraformational conglomerates up to one meter or more thick consisting of mudrock pebbles, reworked calcrete nodules and occasional rolled fragments of bone (Figs. 11, 12 & 40). While the basal Katberg succession is often marked by a major cliff-forming sandstone unit, in the Noupoort area there is a transitional relationship with the underlying Adelaide Subgroup that is marked by a broadly upward-thickening series of sandstone sheets (Figs. 3 & 9). The cliff-forming uppermost part of the Katberg Formation in the study area that underlies the plateau areas is composed of amalgamated channel sandstone facies with only a small proportion of overbank mudrocks (Fig. 10). Internally the moderately well-sorted sandstones are variously massive, horizontally-laminated or tabular to trough cross-bedded while heavy mineral laminae occur frequently. Sphaeroidal carbonate concretions up to 10 cm across, sometimes secondarily ferruginised, are common. The predominantly purple-brown Katberg mudrocks are typically massive with horizons of pedocrete nodules (calcretes) and mudcracks but packages of thin-bedded grey-green and purple-brown mudrocks passing up into heterolithic successions of interbedded grey-green fine sandstone and siltstone are also occasionally seen. Mudrock exposure within the study area is very limited indeed due to extensive mantling of these recessive-weathering rocks by superficial sediments (soils, scree, downwasted gravels, hillwash *etc*).

The highland plateau areas that form the great majority of the WEF project area vary from fairly grassy and featureless to rugged terrain with numerous low *kranzes* and pavements of Katberg sandstone (Figs. 13 to 17). Karstic (solution-weathering) features such as polygonal cracks (tessellation / alligator cracking), rock basins (*gnammas*) and rock doughnuts are well-developed on some of the better-exposed sandstone *kranzes* and sandstone pavements in these (*cf* Grab *et al.* 2011) (Figs. 18 & 19). Another interesting feature observed on weathered sandstone surfaces are shallow subcircular to irregular etched depressions generated by epilithic lichens that have been well-studied on younger Clarens Formation feldspathic sandstones in the Golden Gate National Park (*ibid*. and refs. therein) (Fig. 20). The lichen etching appears to postdate the karstic weathering and associated case-hardening and continues to the present day, especially on more shaded, south-facing surfaces.

The Karoo Supergroup sedimentary rocks in the Noupoort study area are extensively intruded by Early Jurassic (183 ± 2 Ma) igneous intrusions of the **Karoo Dolerite Suite** (**Jd**) (Cole *et al.* 2004, Duncan & Marsh 2006) (Fig. 21). The sills and dykes have thermally metamorphosed or baked the adjacent mudrocks and sandstones to resistant-weathering hornfels and quartzite respectively (Figs. 22 & 23).

In most parts of the study area, including both the flatter-lying plateau regions and low-lying *vlaktes* as well as steeper hillslopes, the Permo-Triassic bedrocks are mantled with a variety of **superficial deposits** of probable Late Caenozoic (mostly Quaternary to Recent) age. A wedge-shaped prism or apron of sandy to gravelly colluvium and hillwash mantles the foot of the Katberg escarpment (piedmont fans) (Figs. 23 to 33), while the escarpment slopes themselves are largely obscured by sandstone scree, apart from the thicker, prominent-weathering Katberg channel sandstone bodies (Figs. 9 & 10). Thick sandy to gravelly alluvial deposits are encountered in more major stream valleys at the foot of the Katberg escarpment, where they are often incised by deep erosional *dongas*, while thick sandy alluvium is seen in shallow palaeovalleys on the plateaux (Figs. 25 to 31). Sparse stone artefacts – *some* of which can be assigned to the MSA - embedded within the alluvial deposits constrain their age to the last 300 000 years or so (Mid to Late Pleistocene – Holocene) (Figs. 28 & 31). The Katberg sandstones underlying the buildable plateau areas in the study region are largely overlain by thin, orange-brown sandy soils as well as angular, poorly-sorted gravels of downwasted sandstone (Figs. 14-15) with thicker alluvial sands and gravels in shallow stream valleys, for example those incised along weathered dolerite dykes (Fig. 24). Well-developed Late Caenozioc pedocretes (*e.g.* calcrete) were not encountered during the field study, although modest creamy calcrete is seen locally in the vicinity of dolerite intrusions.

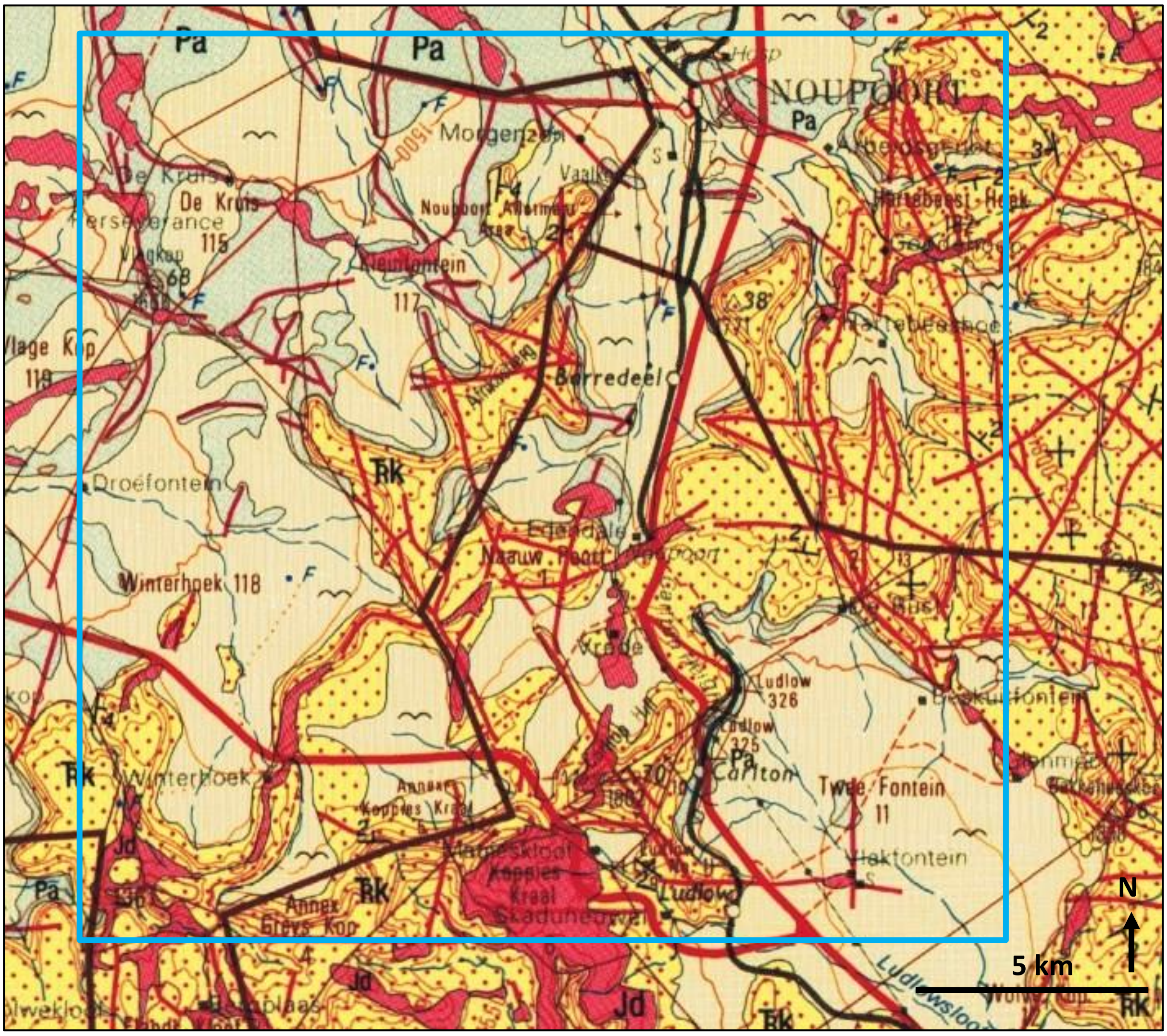

Fig. 2. Extract from 1: 250 000 geology sheet 3124 Middelburg (Council for Geoscience, Pretoria) showing *approximate* outline of the Phezukomoya WEF study area to the south of Noupoort, Northern & Eastern Cape (blue rectangle). The main geological units represented here are:

Pa (pale blue) = Late Permian to Earliest Triassic Adelaide Subgroup (Lower Beaufort Group, Karoo Supergroup)
TRk (yellow with red stipple) = Early Triassic Katberg Formation of the Tarkastad Subgroup (Upper Beaufort Group, Karoo Supergroup)
Jd (red) = Early Jurassic Karoo Dolerite Suite
Pale brown areas with "flying bird"symbol = Quaternary to Recent alluvium

***N.B.* Other Caenozoic superficial deposits such as colluvium (scree *etc*), soils and surface gravels are not depicted here but in fact cover much of the landscape.**

Fig. 3. Extensive streambed exposure of hackly grey-green overbank mudrocks and thin sandstones of the Balfour Formation, Kleinfontein 117 (Loc. 078). North-facing Katberg escarpment of Afrikasberg in the background.

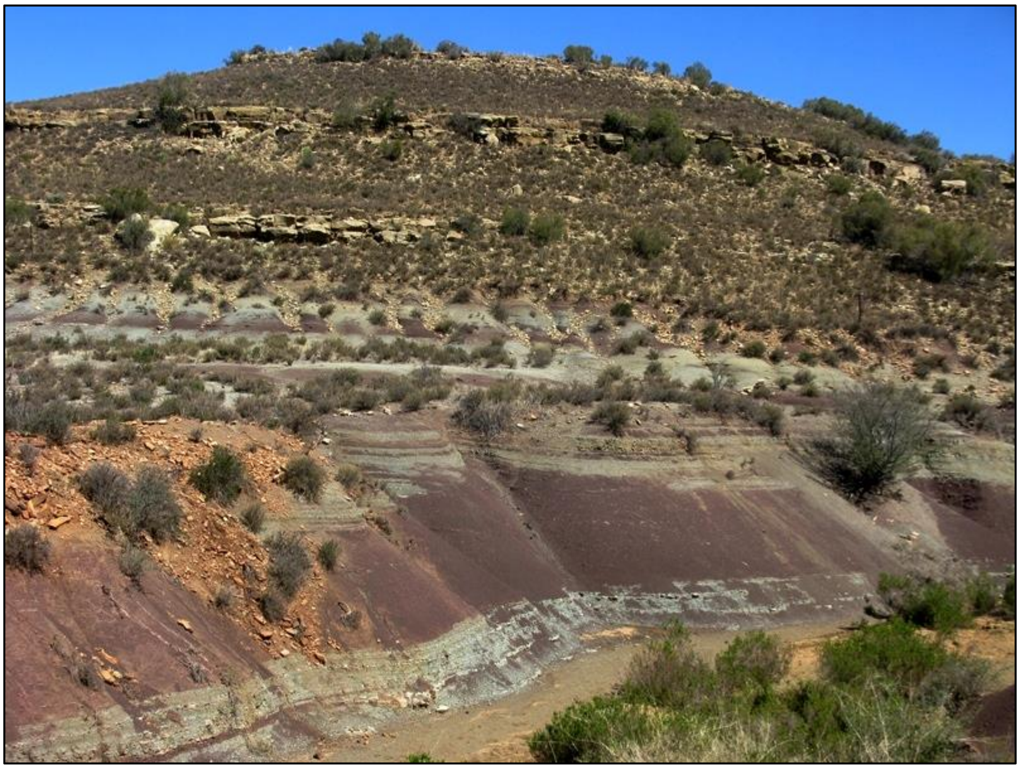

Fig. 4. Excellent erosion gulley and hillslope exposures of colour-banded, predominantly purple-brown overbank mudrocks and thin sandstones of the uppermost Balfour Formation (Palingkloof Member) underlying the prominent-weathering channel sandstones of the Katberg Formation, Hartebeest Hoek 182 (Loc. 073).

Fig. 5. View north-eastwards from Loc. 095 along the Carlton Heights railway line showing good exposures of Palingkloof Member purple-brown mudrocks beneath

basal channel sandstones of the Katberg Formation on Farm 18/1. These exposures are of considerable geoheritage significance.

Fig. 6. Excellent exposure of thin-bedded to laminated purple-brown overbank mudrocks of the Palingkloof Member along the railway line at Carlton Heights, Farm Tweefontein RE11/1 (Loc. 096). These exposures are of considerable geoheritage significance.

Fig. 7. Thin-bedded heterolithic sandstone / mudrock package overlain by thin-bedded purple-brown and grey-green mudocks within the Palingkloof Member, Carlton Heights railway line, Farm 18/1 (Loc. 095). The unit below the prominent-weathering sandstone contains several *possible* vertebrate burrow casts. These exposures are of considerable geoheritage significance.

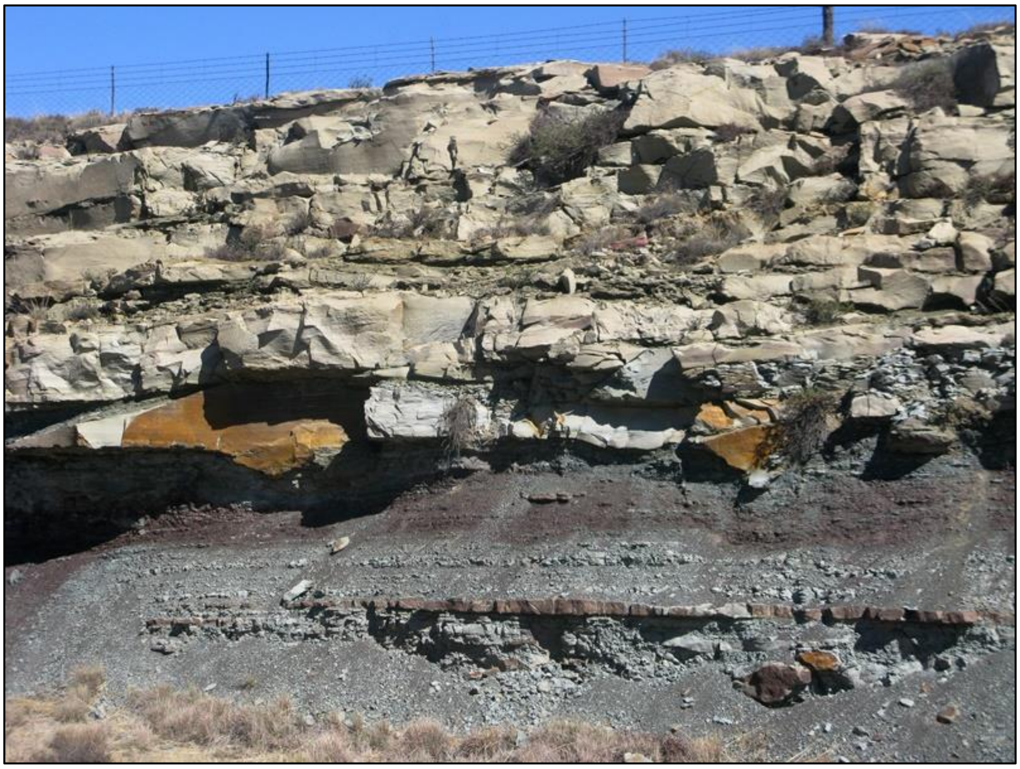

Fig. 8. Package of pale brown, tabular-bedded channel sandstones of the Katberg Formation with markedly gullied base incising colour-banded overbank mudrocks, road cutting along the N10, Farm RE1/1 (Loc. 127).

Fig. 9. Steep north-facing slopes of Afrikasberg, Farm Kleinfontein 1/117, showing prominent-weathering, tabular channel sandstones of the Katberg Formation, mantling of mudrock intervals by greyish sandstone scree and spur built by a steep dolerite dyke on the right.

Fig. 10. View southwards from Loc. 081, Kleinfontein 117, on Afrikasberg showing well-spaced Katberg sandstone packages below and steep cliff of amalgamated sandstones on the skyline, underlying the plateau area.

Fig. 11. Thick, baked and ferruginised basal channel breccia of angular mudclasts and reworked calcrete cropping out near a dolerite dyke on Kleinfontein117 (Loc. 080).

Fig. 12. Well-exposed greyish calcrete basal channel breccia on Kleinfontein 117 (Loc. 081) (Hammer = 27 cm). This unit contains sparse reworked fossil bone (See Fig. **).

Fig. 13. General view towards the west of the upland Katberg sandstone plateau in the eastern sector of the Phezukomoya WEF project area showing general lack of mudrock exposure here (RE/182 in background).

Fig. 14. View across plateau area on RE1/1, in the western sector of the WEF project area, showing areas with very little bedrock exposure mantled by orange-brown sandy soils and grassy vegetation.

Fig. 15. Extensive Katberg sandstone pavement with downwasted sandstone surface gravels, plateau area on Kleinfontein 117 (Loc. 084).

Fig. 16. Karstified Katberg sandstones showing small-scale polygonal alligator cracking, summit plateau of Afrikasberg, Kleinfontein 117 (Loc. 083).

Fig. 17. Prominent-weathering, case-hardened major joints cutting a Katberg sandstone pavement on Farm RE/1/1 (Loc. 102).

Fig. 18. Solution hollow (*gnamma*) in a karstified sandstone pavement, Farm RE/1/1 (Loc. 104).

Fig. 19. Ring-shaped rock-doughnuts enclosing a central hollow, karstified Katberg sandstone on Farm RE/1/1 (Loc. 106).

Fig. 20. Well-developed lichen weathering of a Katberg sandstone surface on Kleinfontein 117 (Loc. 081) (Scale = *c*. 15 cm).

Fig. 21. Major dolerite intrusion with boulder-sized corestones near Kleinfontein 117 farmstead (Loc. 086).

Fig. 22. ***Krans*** **of tough-weathering hornfels (below) and quartzite (above hammer) baked by a major dolerite intrusion, Farm Winterhoek RE/11 (Loc. 116) (Hammer = 27 cm).**

Fig. 23. Dolerite exposure on Farm Winterhoek RE/118 mantled by colluvial gravels of hornfels eroded from the thermal aureole of the intrusion (Loc. 111) (Hammer = 27 cm).

Fig. 24. Thick gravelly and sandy alluvial deposits *plus* greyish modern soils overlying a weathered dolerite dyke incising the Katberg plateau on Farm RE11/1 (Loc. 091) (Hammer = 27 cm).

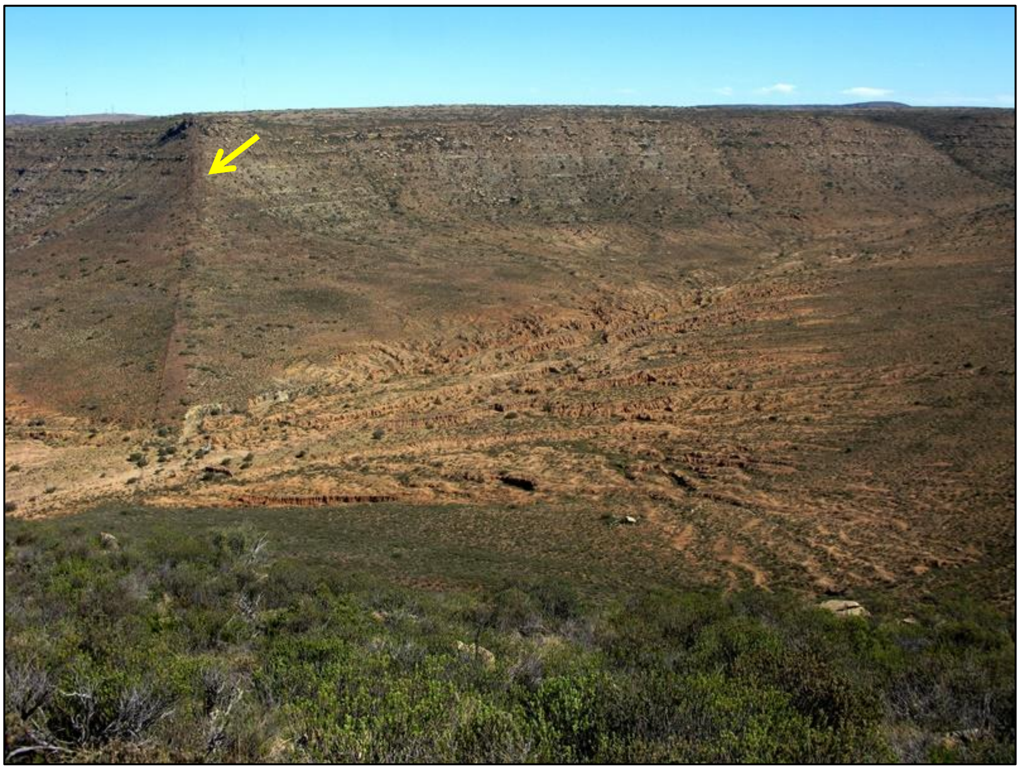

Fig. 25. View southwards into the valley to the south of Afrikasberg (Farm 1/117) showing the valley floor mantled by thick, *donga*-eroded alluvial deposits (See Figs. 26 to 28). A vertical dolerite dyke cuts through the Katberg escarpment towards the left (arrowed).

Fig. 26. *Donga* exposures of thin-bedded, colour-banded Beaufort Group overbank mudrocks sharply incised by sandy and gravelly alluvium with an undulose, erosive base, Farm 1/117 (Loc. 099).

Fig. 27. Well-sorted, massive to bedded sandy alluvium exposed in walls of the donga system seen in Fig. 25 above, Farm 1/117 (Loc. 097) (Hammer = 27 cm). See also following figure.

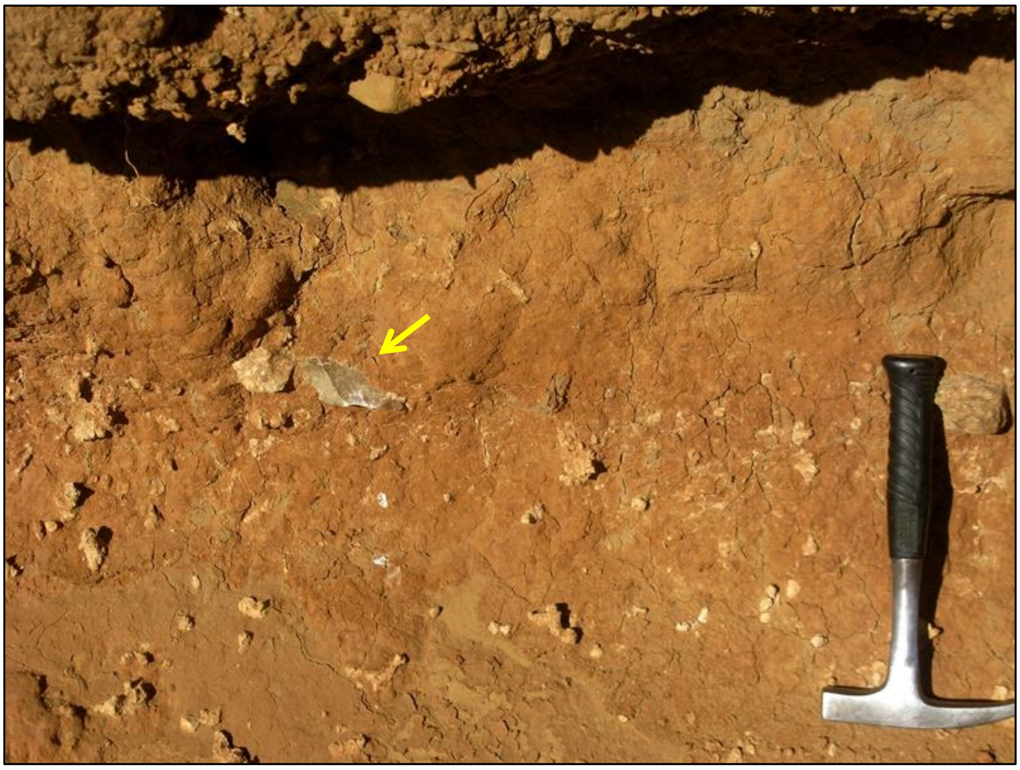

Fig. 28. Close-up of older, well-consolidated, orange-brown sandy alluvium at the base of the succession seen in the previous figure showing calcrete glaebules and possible

calcretised rhizoliths (plant root casts) as well as embedded flaked stone artefacts (arrow) (Hammer = 27 cm) supporting a Pleistocene or younger age.

Fig. 29. Deep *donga* on Winterhoek 118 with a floor of Katberg Formation bedrocks overlain by several meters of well-bedded sandy and gravelly alluvial deposits, downstream of Loc. 123.

Fig. 30. Thick package of coarse, rubbly, sandstone alluvial breccio-conglomerates overlying Katberg bedrocks in donga, Winterhoek 118 (Loc. 121) (Hammer = 27 cm).

Fig. 31. Thick alluvial sands and gravels exposed near the farmstead on Kleinfontein 117 (Loc. 087) (Hammer = 27 cm), with detail of an embedded MSA hornfels flake (exposed length 4 cm) suggesting a depositional age of < 300 000 years.

Fig. 32. Downwasted, boulder-sized, well-rounded quartzite corestones overlying the thermal aureole of a large dolerite intrusion, Farm Winterhoek RE/118 (Loc. 116).

Fig. 33. Angular colluvial gravels of brownish-patinated black hornfels and minor quartzite mantling hillslopes on Farm Winterhoek RE/118 (Farm 111) (Hammer = 27 cm). These gravels are extensively flaked in this area.

4. PALAEONTOLOGICAL HERITAGE

The fossil heritage within each of the major rock units that are represented within the Phezukomoya WEF study area is outlined here, together with a brief account of Beaufort Group fossil records from the Noupoort region itself. Note that a separate account of fossils from the uppermost Adelaide Subgroup (Pa) is not given because the upper part of the Palingkloof Member (Balfour Formation) belongs to the same assemblage zone (*i.e.* the *Lystrosaurus* AZ) as the overlying Katberg Formation. Occasional good exposures of Palingkloof Member (uppermost Balfour Group) bedrocks occur within the broader WEF project area (Fig. 7) and are of considerable geoheritage conservation value.

GPS data for geological and fossil localities mentioned in the text and figure legends are provided separately in the Appendix to this report.

4.1. Fossil heritage in the Katberg Formation and uppermost Adelaide Subgroup

The Katberg Formation is known to host a diverse and palaeontologically important terrestrial fossil biota of Early Triassic (Scythian / Induan - Early Olenekian) age, *i.e.* around 252 million years old (Groenewald & Kitching 1995, Rubidge 2005, Smith *et al.* 2012). The biota is dominated by a range of therapsids ("mammal-like reptiles"), amphibians and other tetrapods, with rare vascular plants and trace fossils, and has been assigned to the ***Lystrosaurus* Assemblage Zone** (**LAZ**). This surprisingly rich fossil assemblage characterizes Early Triassic successions of the upper part of the Palingkloof Member (Adelaide Subgroup) as well as the Katberg Formation. It should also be noted that while the dicynodont *Lystrosaurus* is also recorded from the uppermost beds of the Latest Permian *Dicynodon* Assemblage Zone it only becomes super-abundant in Early Triassic times (*e.g.* Smith & Botha 2005, Botha & Smith 2007 and refs. therein).

Useful illustrated accounts of LAZ fossils are given by Kitching (1977), Keyser and Smith (1977-1978), Groenewald and Kitching (1995), MacRae (1999), Hancox (2000), Smith *et al.* (2002), Cole *et al*. (2004), Rubidge (2005 *plus* refs therein), Damiani *et al.* (2003a), Smith *et al.* (2012) among others. These fossil biotas are of special palaeontological significance in that they document the recovery phase of terrestrial ecosystems following the catastrophic end-Permian Mass Extinction of 252 million years ago (*e.g.* Smith & Botha 2005, Gastaldo *et al.* 2005, Botha & Smith 2007, Smith & Botha-Brink 2014 and refs. therein) (Fig. 38). They also provide interesting insights into the adaptations and taphonomy of terrestrial animals and plants during a particularly stressful, arid phase of Earth history in the Early Triassic.

Key tetrapods in the *Lystrosaurus* Assemblage Zone biota are various species of the medium-sized, shovel-snouted dicynodont *Lystrosaurus* (by far the commonest fossil form in this biozone. contributing up to 95% of fossils found), the small captorhinid parareptile *Procolophon*, the crocodile-like early archosaur *Proterosuchus*, and a wide range of small to large armour-plated "labyrinthodont" amphibians such as *Lydekkerina* (Figs. 34 and 35). Botha and Smith (2007) have charted the ranges of several discrete *Lystrosaurus* species either side of the Permo-Triassic boundary. Also present in the LAZ are several genera of small-bodied true reptiles (*e.g.* owenettids), therocephalians, and early cynodonts (*e.g. Galesaurus, Thrinaxodon*). Animal burrows are attributable to various aquatic and land-living invertebrates, including arthropods (*e.g. Scoyenia* and *Katbergia* scratch burrows), as well as several subgroups of fossorial tetrapods such as cynodonts, procolophonids and even *Lystrosaurus* itself (*e.g.* Groenewald 1991, Groenewald *et al.* 2001, Damiani *et al.* 2003b, Abdala *et al.* 2006, Modesto & Brink 2010, Bordy *et al.* 2009, 2011, Krummeck & Bordy 2016, Bordy & Krummeck 2016, Bordy (Ed.) 2017) (Fig. 39). Vascular plant fossils are generally rare and include petrified wood ("*Dadoxylon*") as well as leaves of glossopterid progymnosperms and arthrophyte ferns (*Schizoneura*, *Phyllotheca*). An important, albeit poorly-preserved, basal Katberg palaeoflora has recently been documented from the Noupoort area (Carlton Heights) by Gastaldo *et al.* (2005). Plant taxa here include sphenopsid axes, dispersed fern pinnules and possible peltasperm (seed fern) reproductive structures. Pebbles of reworked silicified wood of possible post-Devonian age occur within the Katberg sandstones in the proximal outcrop area near East London (Hiller & Stavrakis 1980, Almond unpublished obs.). Between typical fossil assemblages of the *Lystrosaurus* and *Cynognathus* Assemblage Zones lies a possible *Procolophon* Acme Zone characterized by abundant material of procolophonids and of the amphibian *Kestrosaurus* but lacking both *Lystrosaurus* and *Cynognathus* (Hancox 2000 and refs. therein).

Most vertebrate fossils are found in the mudrock facies rather than channel sandstones. Articulated skeletons enclosed by calcareous pedogenic nodules are locally common, while intact procolophonids, dicynodonts and cynodonts have been recorded from burrow infills (Groenewald and Kitching, 1995). Fragmentary rolled bone and teeth (*e.g.* dicynodont tusks) are found in the intraformational calcrete nodule conglomerates at the base of some the channel sandstones. Vertebrate burrows occur within both mudrock and sandstone facies.

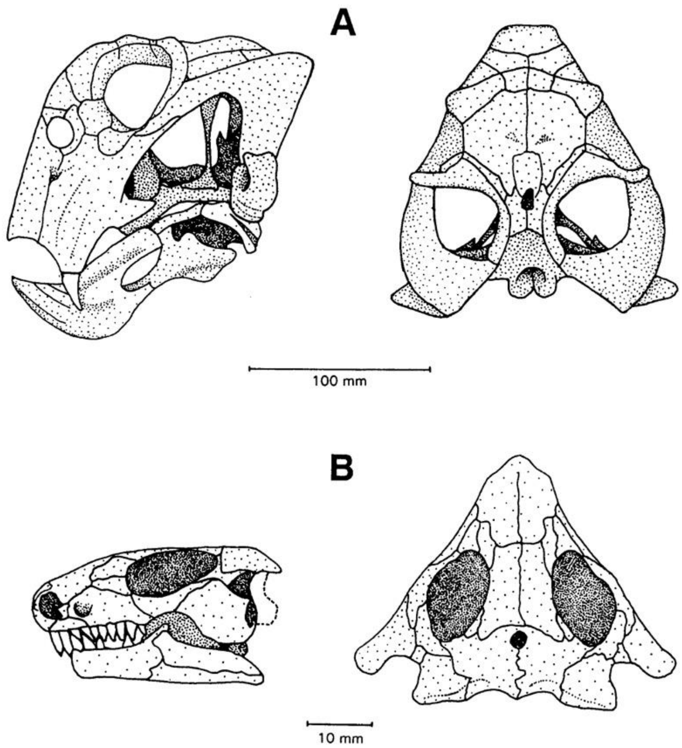

Fig. 34. Skulls of two key tetrapod genera from the Early Triassic *Lystrosaurus* Assemblage Zone of the Main Karoo Basin: the pig-sized dicynodont *Lystrosaurus* (A) and the small primitive reptile *Procolophon* (B) (From Groenewald and Kitching, 1995).

Several Karoo vertebrate fossil sites are reported from the Katberg Formation and underlying rocks in the Middelburg – Noupoort region by Kitching (1977; see Karoo biozonation map in Fig. 36 herein as well as updated Karoo vertebrate fossil site map of Nicolas 2007 abstracted in Fig. 37). For example, Kitching recorded as many as five different species of *Lystrosaurus* from good mountain slope exposures as well as road and railway cuttings in the Carlton Heights area near Noupoort. Abundant lystrosaurids, including three species of the genus, were found at Edenvale and on Noupoort Commonage (*ibid*., pp. 89-100). It is interesting that the spectrum of *Lystrosaurus* species recorded by Kitching (1977) in the Noupoort region – if correctly identified - suggests that Latest Permian beds referable to the *Dicynodon* Assemblage Zone may in fact be present here (*cf.* Botha & Smith 2007). This is supported by a recent search for fossil records from the Noupoort area in the Karoo fossil database at the BPI (Wits University) kindly undertaken by Mr Mike Day. Sites on the farms Naauwport 1, Bergendal 179, New Jakkalsfontein 172 and Carolus Poort 167 have yielded abundant material of *Lystrosaurus* together with *Procolophon*, *Tetracynodon* and a few specimens of *Dicynodon*. An unusually diverse LAZ assemblage has recently been recorded from Barendskraal near Middelburg by Damiani *et al.* (2003a). The spectrum of nine or more tetrapod species found here includes *Lystrosaurus* (albeit with low abundance), therocephalians, archosaurs and several procolophonid reptiles. The poorly-preserved fossil flora recorded by Gastaldo *et al.* (2005) from the basal Katberg at Carlton Heights near Noupoort is of special interest because plant fossils are so rare in this stratigraphic interval. Scrappy compressions of reedy plants within Katberg sandstones were illustrated by Almond (2015) from the Umsobomvu WEF project area southwest of Noupoort.

Sparse, highly-weathered postcranial remains as well as poorly-preserved *Lystrosaurus* skull material was reported just to the SW of Noupoort by Butler (2014). Gess (2012b) recorded locally abundant vertebrate body fossils, including *Lystrosaurus* and a small cynodont, plant stems, vertebrate burrows and *Katbergia* ("roots") on Portion 1 of Naauw Poort Farm 1 located *c*. 11 km south of Noupoort. On farm Blydefontein 168, situated just to the north of the San Krall WEF study area, Almond (2012) recorded fragmentary reworked skeletal remains, including disarticulated skulls, postcrania and teeth (especially dicynodont tusks) within greyish calcrete conglomerates. Some of the fossils were clearly encased in ferruginous pedogenic calcrete *before* they were exhumed and reworked. Overlying massive grey-green siltstones contain rare "bone-bed" concentrations (*e.g. Lystrosaurus* skull and postcrania) and horizons of large ferruginous calcrete nodules representing palaeosols. A small number of, mostly fragmentary, vertebrate fossils were reported from Katberg overbank mudrocks and calcrete breccia beds in the San Kraal WEF study area (Almond 2017) and also the Umsobomvu WEF study area further to the southwest of Noupoort by Almond (2015); they did include one well-articulated lystrosaurid skeleton with associated skull, however.

Low-diversity trace fossil assemblages recorded from Katberg rocks in the Noupoort area – for example south of the Oologspoort road - include locally abundant vertical cyclindrical structures attributed to *Skolithos* in the literature (*e.g.* Almond 2012) but more plausibly interpreted as plant stem casts, as well as small meniscate back-filled burrows ("*Taenidium*").

Numerous examples of the cm-wide subcylindrical invertebrate burrow *Katbergia* were observed by Almond (2012) in fresh road cuttings through the Katberg Formation along the N9 at Carlton Heights and localities further to the SW (Gess 2012, Almond 2015). These distinctive burrows penetrate down through grey-green mudrocks at an oblique angle and show surface scratch markings; they have been tentatively attributed to decapod crustaceans (Gastaldo & Rolerson 2008, Bordy *et al.* 2010). Several much larger, straight, gently-sloping vertebrate burrow casts cutting down through thin-bedded overbank mudrocks within the lower Katberg Formation are recorded from road cuttings on farm Naauw Poort 1 (Almond 2015), while Almond (2017) illustrated an equivocal mudrock-infilled large burrow cast from the lower Katberg Formation in Oorlogspoort.

Fig. 35. Reconstruction of Early Triassic biotas of the *Lystrosaurus* Assemblage Zone (From Benton 2003 *When life nearly died*). Animals illustrated here include the crocodile-like archosaur reptile *Proterosuchus* (top) and below this the dominant, pig-sized dicyndont *Lystrosaurus*, a small predatory therocephalian therapsid (middle left), several small lizard-like reptiles such as procolophonids (middle right), and two large amphibians (bottom). Plants shown here include several ferns and reedy horsetails.

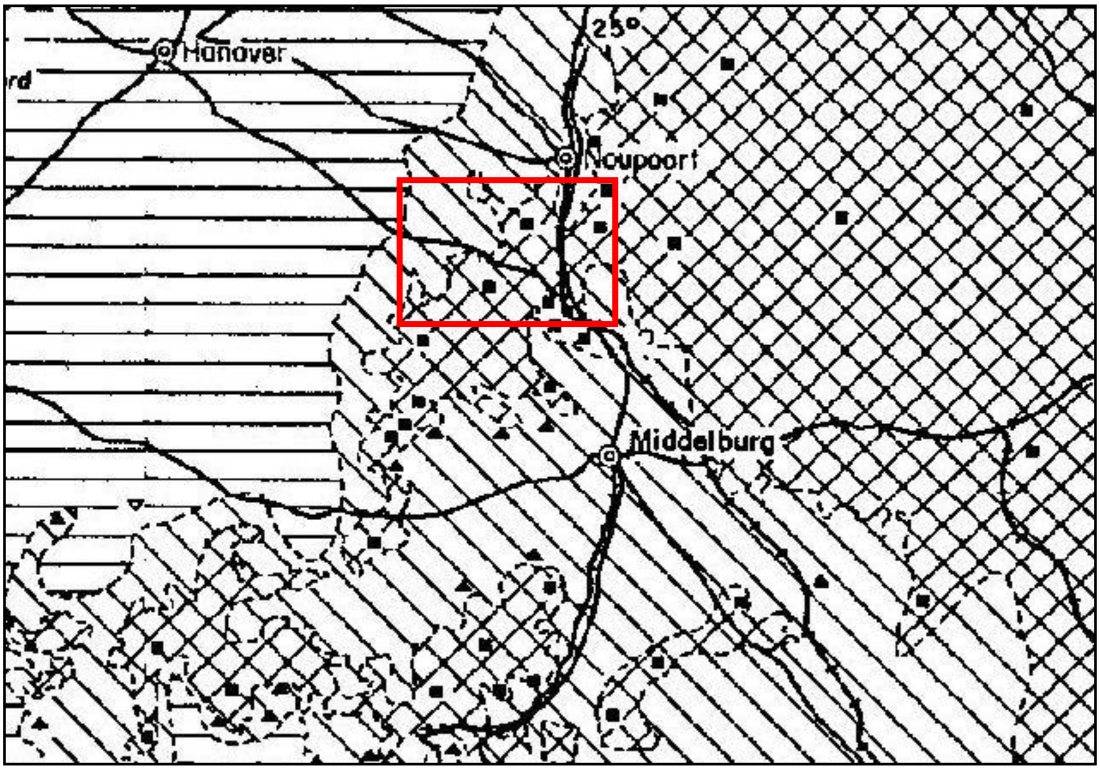

Fig. 36. Fossil zonation map of the Middelburg – Noupoort region showing the occurrence of several vertebrate fossil localities in the area to the south of Noupoort (red rectangle). Black squares here refer to fossils of the Early Triassic *Lystrosaurus* Assemblage Zone (mainly within the Katberg Formation). Triangles to the southwest are *Daptocephalus* (*Dicynodon*) AZ fossils within Late Permian rocks of the Adelaide Subgroup. Figure modified from Karoo biozonation map of Kitching (1977).

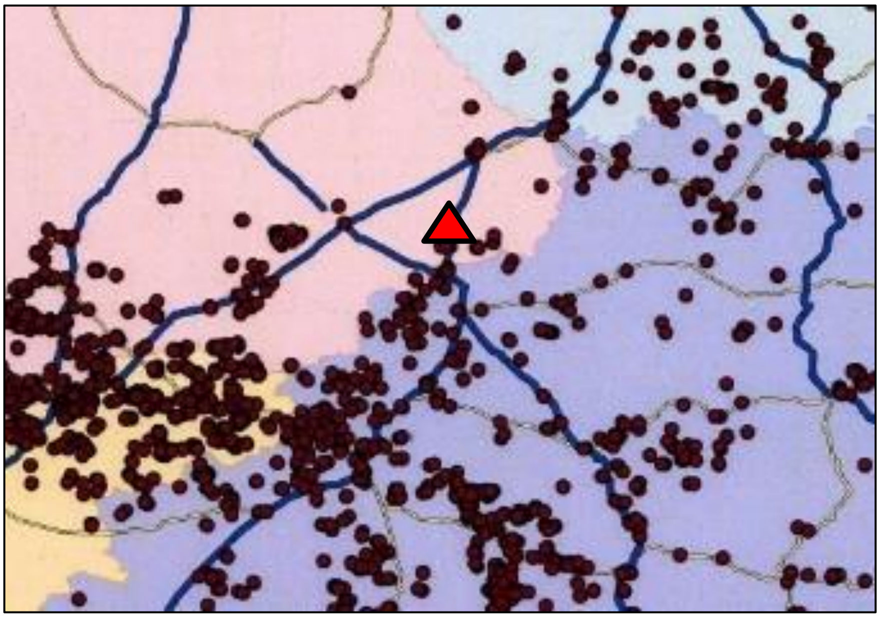

Fig. 37. Map of Beaufort Group vertebrate fossil localities in the vicinity of Noupoort (red triangle), abstracted from Nicolas (2007). Pink – N. Cape. Dark blue – Eastern Cape.

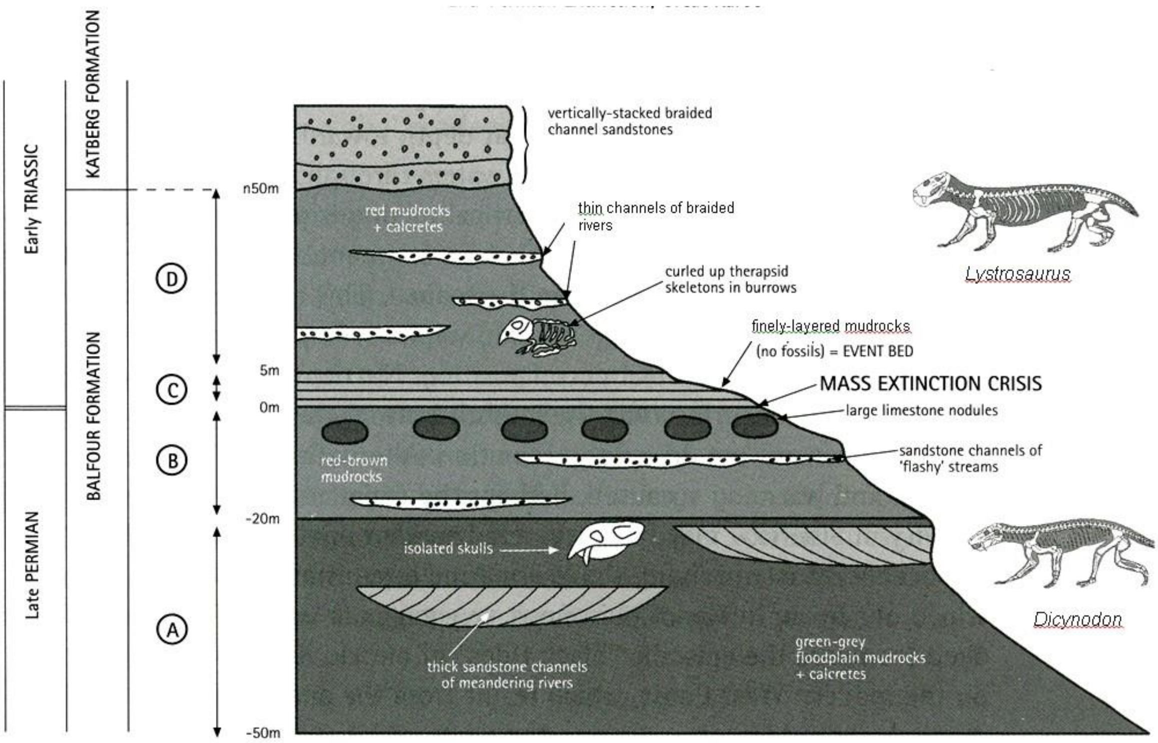

Fig. 38. Highly-simplified stratigraphy of the Beaufort Group spanning the Permo-Triassic boundary and associated mass extinction event of *c*. 252 Ma (million years ago) that has been identified within the upper part of the Balfour Formation (Palingkloof Member).

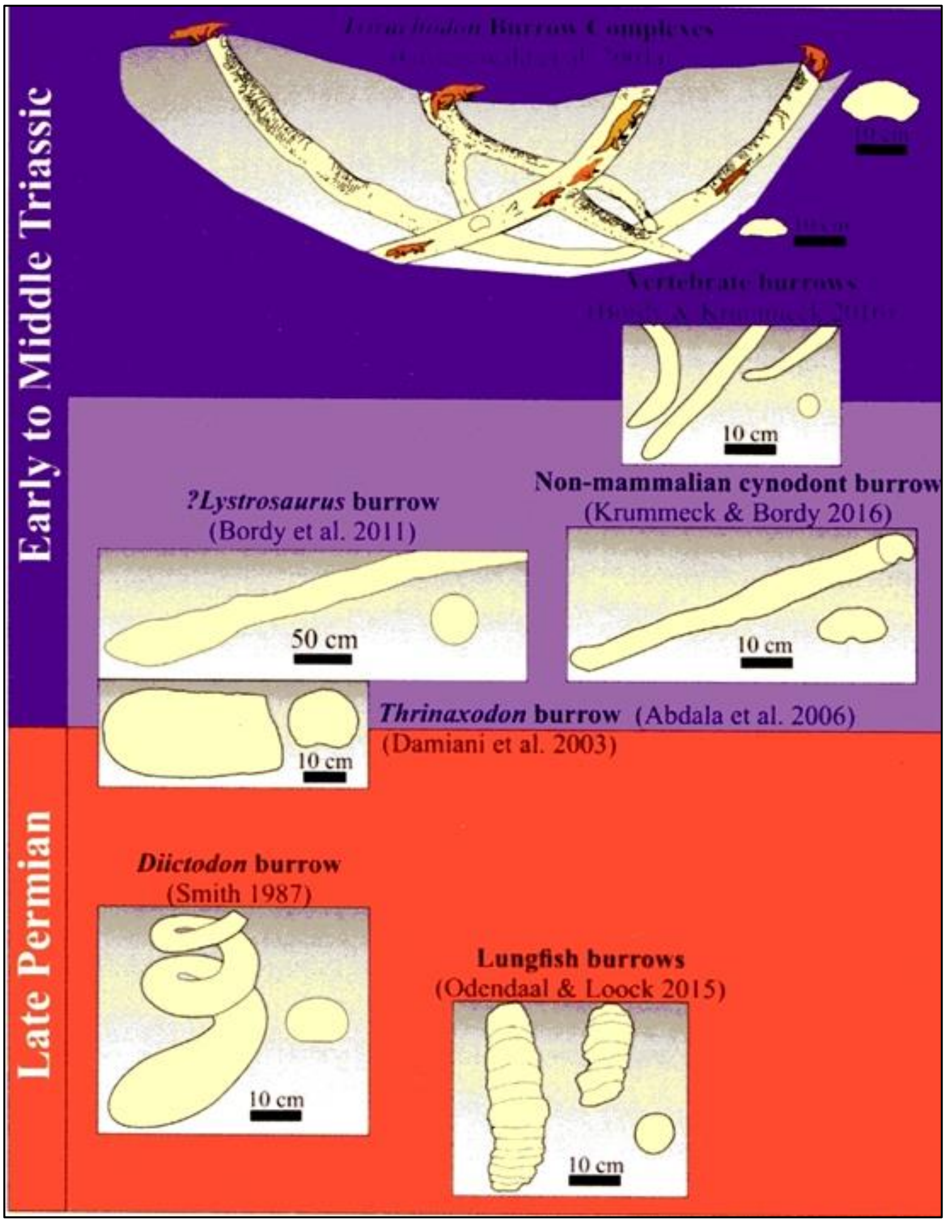

Fig. 39. Diversity of vertebrate burrows encountered within the the Permo-Triassic boundary interval in the Main Karoo Basin, probably in response to highly challenging palaeoenvironmental conditions (*e.g.* seasonal drought or perennial aridity) (From Bordy 2017). It is likely that many of the larger fossil burrows encountered within the Katberg Formation in the present study area were excavated by the super-abundant medium-sized dicynodont *Lystrosaurus*.

4.2. New palaeontological records in the WEF study area

No substantial, well-articulated Karoo vertebrate fossil remains were observed during the present field study of the Phezukomoya WEF study area near Noupoort. Since abundant and diverse vertebrate remains have been recorded from the same stratigraphic units elsewhere in the Main Karoo Basin (see refs. above), this lack of fossil finds is largely attributed to the paucity of overbank mudrock exposures that are the main locus of fossil preservation within the Permo-Triassic sedimentary bedrocks represented here. These mudrocks are only rarely seen along the escarpment areas, and almost never exposed on the sandstone plateaux where most of the WEF infrastructure will be situated (Figs. 9- to 10, 13 to 15).

The great majority of vertebrate body fossils recorded within the WEF project area (satellite map Fig. 36) comprise sparse fragments of bone and teeth – most likely of therapsid affinity , and probably *Lystrosaurus* for the most part. They are found embedded within calcrete nodule breccio-conglomerates that are associated with the bases of major sandstone packages of the Katberg Formation (Fig. 40). These fossils mainly represent disarticulated vertebrate remains lying on the floodplain surface or already embedded within subsurface pedogenic calcrete palaeosols (fossil soils) that were re-exhumed or entrained by floods during episodes of major denudation of the arid Early Triassic landscape. The material is generally taxonomically unidentifiable and of minor scientific interest.

Small-scale invertebrate burrows – most of which can probably be ascribed to the genus *Katbergia* – were recorded at several localities in the Palingkloof Member and lower Katberg Formation (Fig. 35). This form occurs widely in the Permo-Triassic boundary interval (*e.g.* at Carlton Heights) and is not especially conservation-worthy.

The main category of fossils encountered within the Beaufort Group bedrocks are medium to large vertebrate burrows, mostly preserved as sharply-defined sandstone casts within a contrasting mudrock matrix (Figs. 32 to 34). They occur within both the upper Balfour Formation (including the Palingkloof Member) as well as the overlying Katberg Formation and may be attributed to *Lystrosaurus* as well as a range of other tetrapod subgroups. Most of the burrows are straight and subhorzontal to gently inclined, but occasional examples with a possible strongly curved or helical geometry are observed (Fig. 32F). In a few cases, the vertebrate burrow identity is supported by features such as oblique scratch marks on the ventrolateral or even dorsal surface (Figs. 32C-D), a smoothed floor (Fig. 32D), a convex upper surface (majority) or associated vertebrate remains (Figs. 33E-F). Many of the structures, *taken in isolation*, are perhaps ambiguous but their co-occurrence with indubitable burrows supports a similar interpretation. Alternative interpretations – such as loading / dewatering structures, gutter-like erosive channel infills or boudinage structures – are generally unconvincing. The common occurrence of vertebrate burrowing across the Permo-Triassic boundary interval in the Karoo is well-attested by numerous scientific publications (See Bordy 2017 and refs. therein, Fig. 39).

A series of indubitable to poorly-preserved and ambiguous, large vertebrate burrow casts (*c*. 30-60 cm diameter) have been recorded on the farm Winterhoek 118 close to one of the 132 kV grid connection routes for the Phezukomoya WEF (Locs. 119, 120, 122 and 123, Fig. 33; see also satellite maps Figs. 38 and 39). One of the burrow casts is associated with disarticulated postcranial bones (Figs. 33E-F) that *might* belong to the trace-maker. Because of their scientific interest (Field Rating IIIB), it is recommended that the fossil burrow sites be protected by a 50 m-wide buffer zone. The numerous burrows exposed in a N10 road cutting, some of which are illustrated in Fig. 34, lie outside the WEF project area. Burrows in the railway line exposures of the Palingkloof Member at Carlton Heights (Figs. 32E-F) should be protected within the buffer zone proposed for these stratigraphically important bedrock sections (red shape in Fig. 37).

Apart from the Winterhoek 118 vertebrate burrows (Locs. 119, 120, 122 and 123) and Carlton Heights vertebrate burrows (Locs. 095-096 and exposures between) that are assigned a Proposed Field Rating IIIA, all these fossil occurrences belong to categories that have been widely recorded within the extensive Katberg Formation outcrop area of the Main Karoo Basin and do not present obvious unique features. Their palaeontological research and conservation value is therefore assessed as LOW and they are assigned a provisional Field Rating IIIC Local Resource (Appendix 1).

The central Karoo superficial or “drift” deposits have been comparatively neglected in palaeontological terms. However, they 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 from these superficial deposits include non-marine molluscs (bivalves, gastropods), ostrich egg shells, tortoise remains, trace fossils (*e.g.* calcretised termitaria, coprolites, invertebrate burrows), and plant material such as peats or palynomorphs (pollens) in organic-rich alluvial horizons and diatoms in pan sediments. No fossil remains were recorded from the various Late Caenozoic superficial deposits examined during the present field assessment. Occasional embedded stone artefacts are of interest in constraining their age to the Middle Pleistocene or Holocene, *i.e.* the last 300 000 years (Figs. 28 & 31).

Fig. 40. Fragments of reworked bone – largely unidentifiable - embedded within calcrete-rich basal channel breccio-conglomerates of the Katberg Formation with a brown, ferruginous sandy matrix: (A) Unidentified bone, Kleinfontein 117 (Loc. 081), scale in mm; (B) limb bone, *c*. 5 cm long, Farm 1/117 (Loc. 100); (C) Rounded bone (*c*. 3 cm across) with hash of elongate calcretised rhizoliths, Farm RE1/1 (Loc. 108); (D) Small limb bone, scale in cm and mm, Farm RE1/1 (Loc. 108); (E-F) Concentration of bone fragments, largest of which is 2.8 cm long, Farm RE1/1 (Loc. 107).

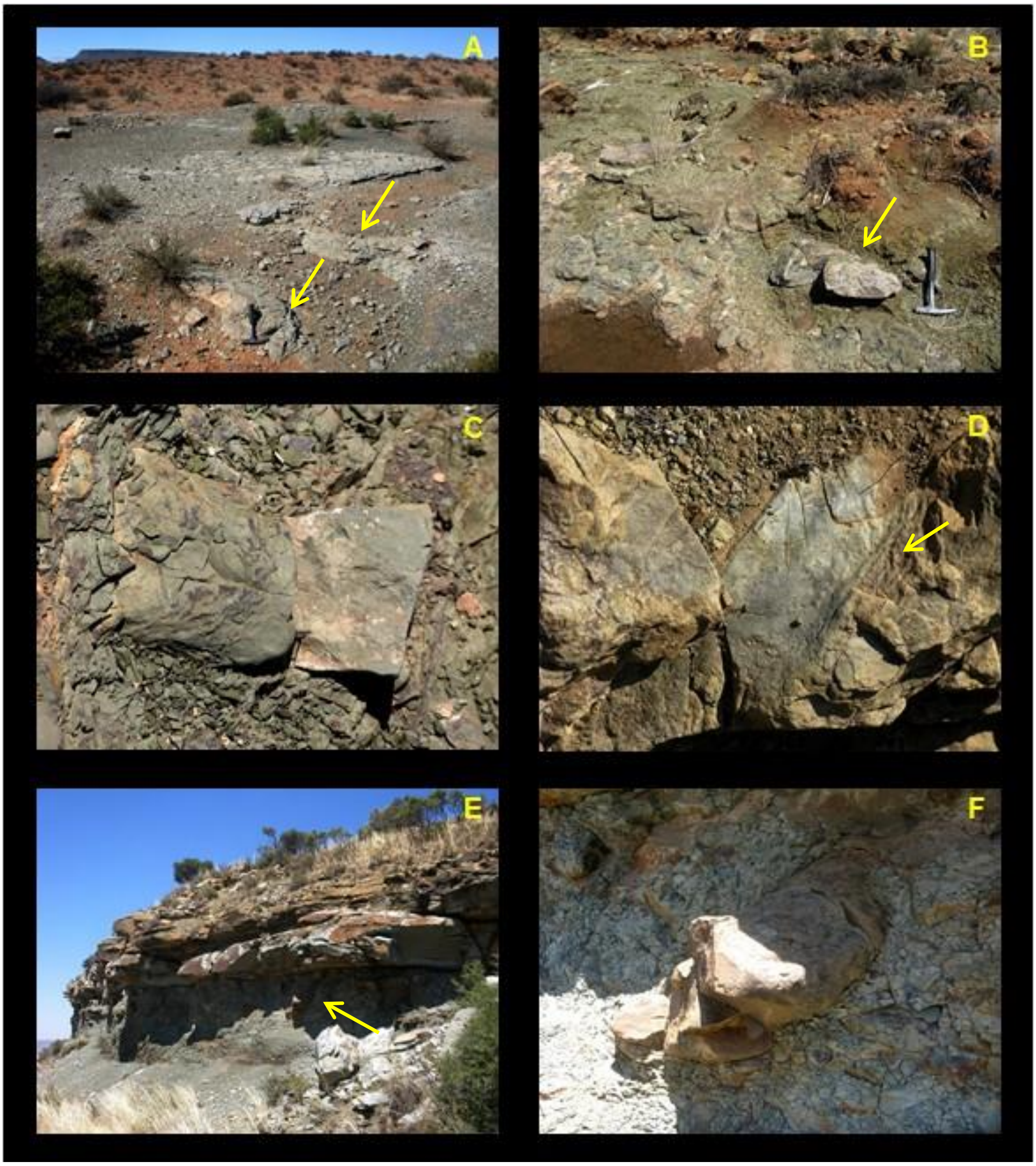

Fig. 32. Medium- to large-sized vertebrate burrows: (A) Subhorizontal to gently-sloping sandstone burrow casts (20-30 cm wide) within the Balfour Formation, borrow pit on Kleinfontein 117 (Loc. 076); (B-C) Horizontal to steeply-inclined burrow casts within the Balfour Formation, stream bed on Kleinfontein 117 (Loc. 078), with oblique scratch marks on the dorsal surface in C; (D) Smoothed floor of a vertebrate burrow (*c*. 10 cm across) flanked by scratch marks (arrowed), lower Katberg Formation on Farm RE/11/1 (Loc. 089); (E-F) Probable vertebrate burrow zone within mudrock package underlying basal Katberg channel sandstone, railway cutting at Carlton Heights, Farm 18/1 (Loc. 095). The large, strongly-curved or possibly helical burrow cast arrowed in E is shown close-up in F.

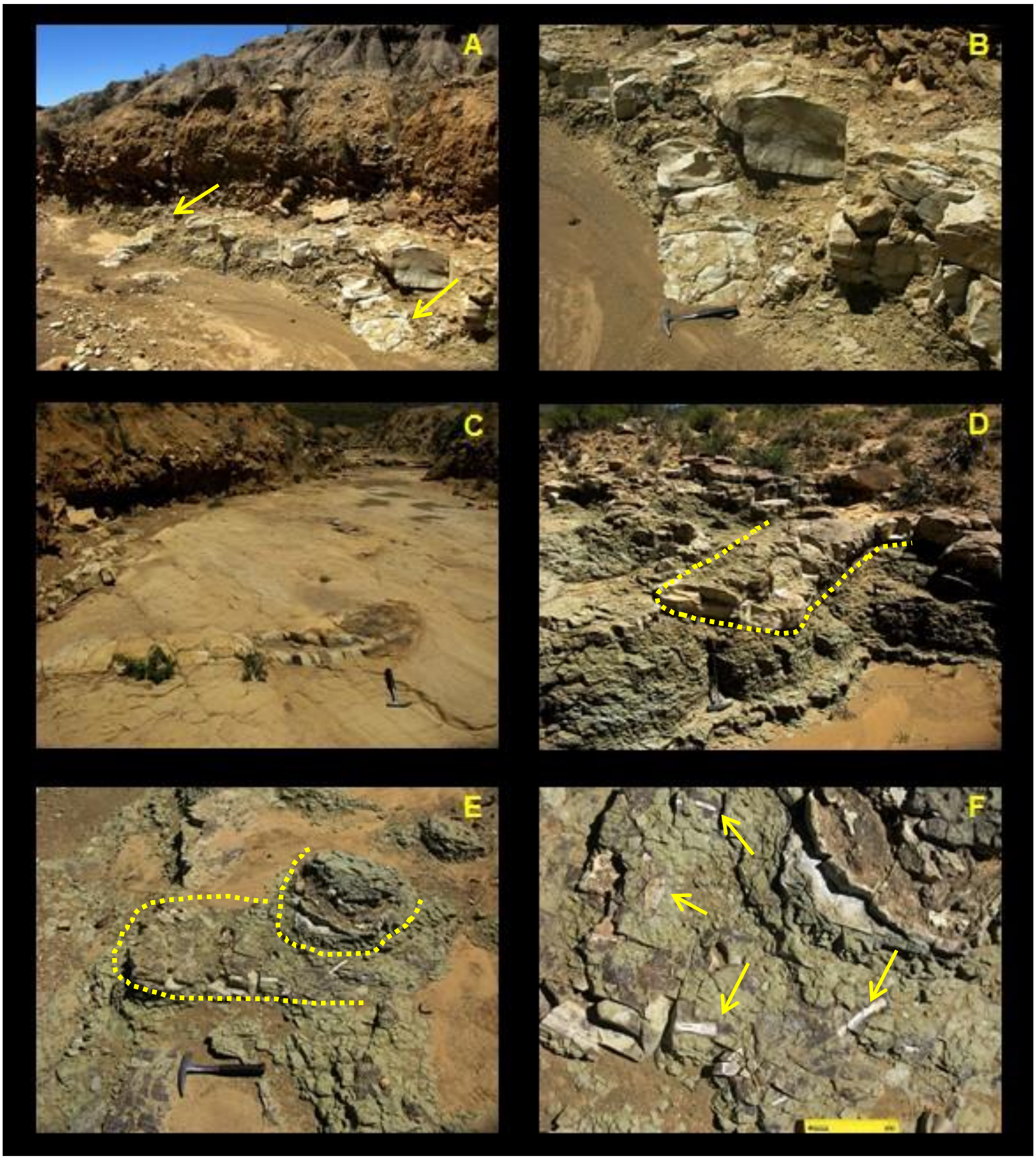

Fig. 33. Large vertebrate burrows within the lower Katberg Formation exposed in the base of a donga on Winterhoek 118 (Hammer = 27 cm): (A-B) Two inclined, 30 cm-wide burrow casts (arrowed) embedded in grey-green mudrock (Loc. 119); (C) Subhorizontal, convex-topped burrow (30-40 cm wide) exposed at the top of a sheet sandstone (Hammer = 27 cm) (Loc. 120); (D) Convex-topped subhorizontal burrow cast with a flattened ellipsoidal cross-section embedded in mudrock (*c*. 60 cm across); (E-F) Two superimposed (or one, curved) vertebrate burrows with associated disarticulated postcranial remains, including limb bones and ribs (arrowed in F), that might belong to the burrow maker or occupier (Loc. 123) (Scale = *c*. 15 cm).

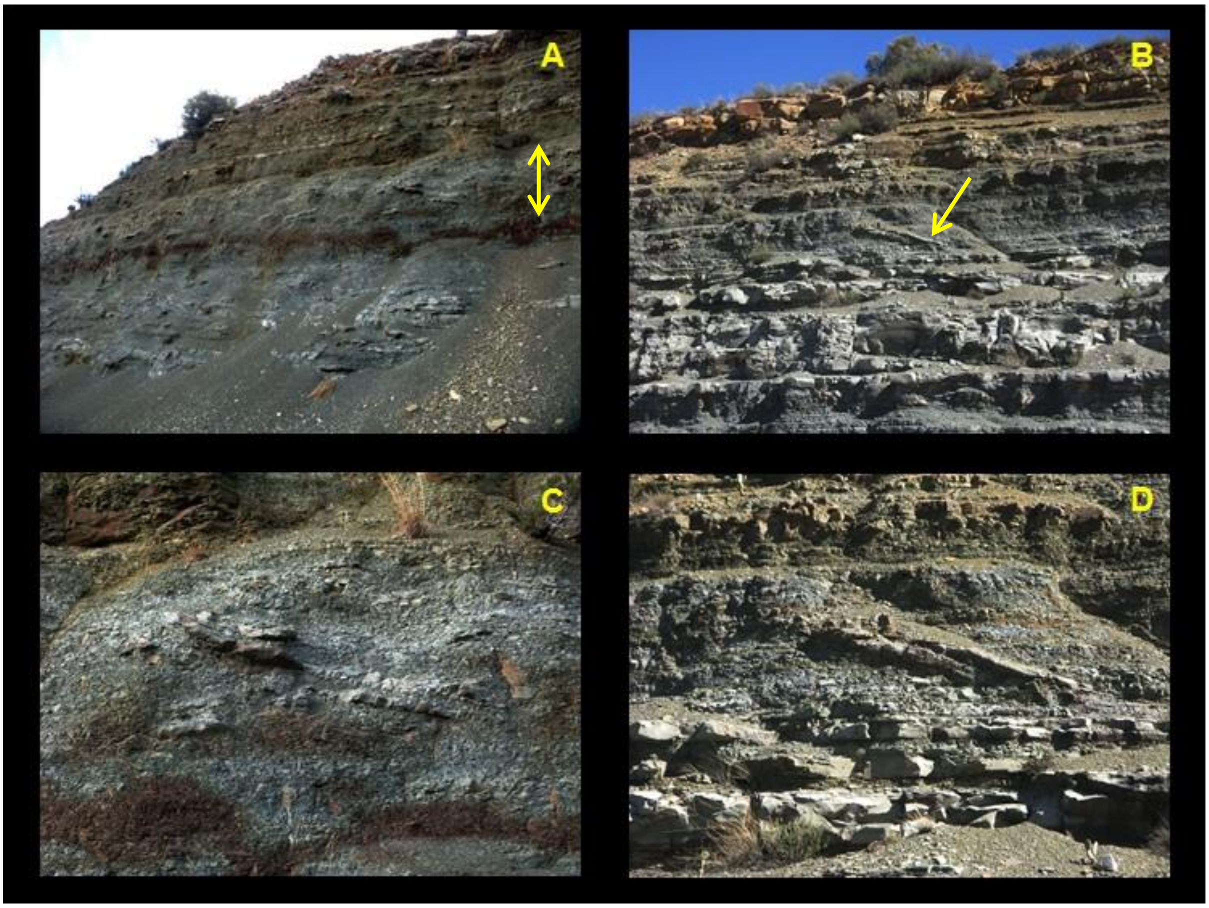

Fig. 34. Extensive N10 road cutting through the lower Katberg Formation some 2 km SE of the WEF project area (Loc. 128). Large, gently-inclined vertebrate burrow casts - mostly inaccessible - occur within thin-bedded overbank mudrocks at more than one stratigraphic horizon. (A-B) show the upper, densely-burrowed unit (arrowed) while close-ups of several burrow casts are seen in (C-D).

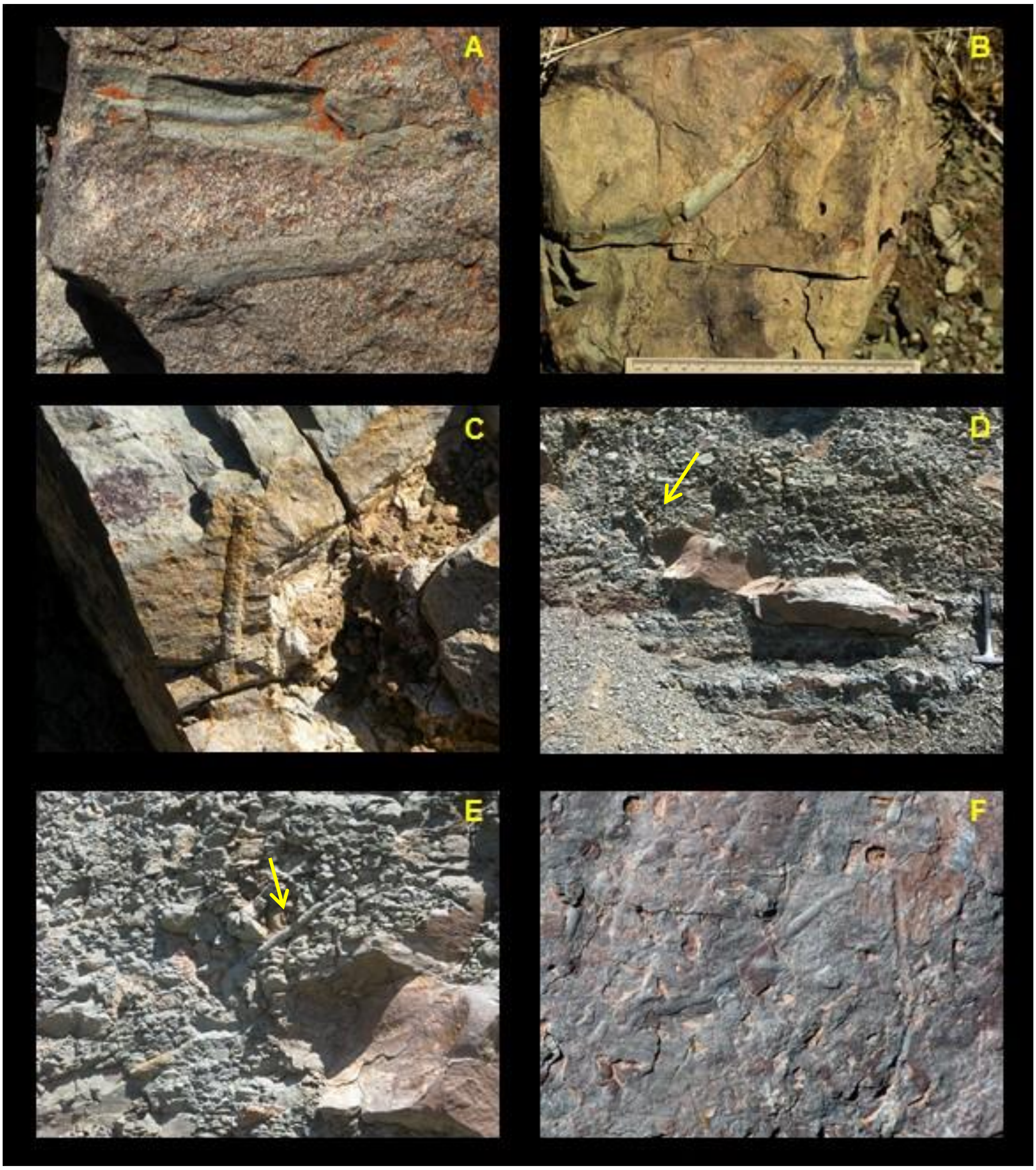

Fig. 35. Invertebrate burrows from the Beaufort Group: (A) Mud-lined or -infilled horizontal burrows (1 cm diam.) within sandstone, Balfour Formation, Kleinfontein 117 (Loc. 075); (B) possible curved, mud-lined *Katbergia* within sandstone (scale in cm and mm), Balfour Formation, Kleinfontein 117 (Loc. 078); (C) probable *Katbergia* (1 cm diam.) in lower Katberg Formation, Farm RE11/1 (Loc. 088); (D-E) Typical oblique *Katbergia* scratch burrow (1 cm diam.) within Palingkloof Member, in close association with a probable large vertebrate burrow cast, Farm 18/1 (Loc. 095) (F) Horizontal and oblique cylindrical burrows (*c.* 0.5 cm across) - possibly *Scoyenia* – in sandstone float block, Balfour Formation, Kleinfontein 117 (Loc. 075);

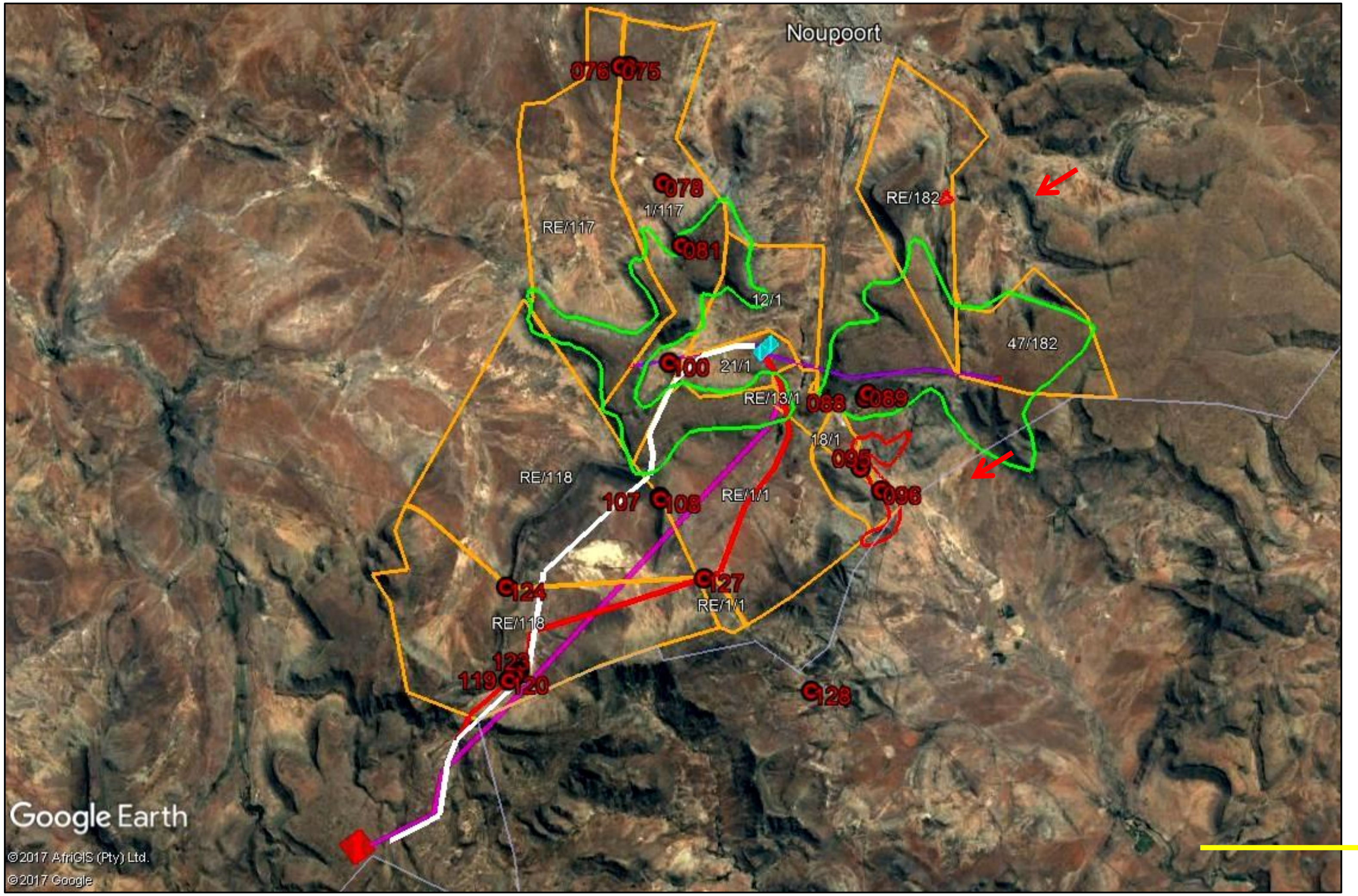

Fig. 36. Google earth© satellite image of the Phezukomoya WEF project area showing numbered new fossil localities in red. The great majority of sites recorded here lie outside the core WEF development areas that are mainly located on the sandstone plateau (green polygons). Good exposures of the Palingkloof Member of the Balfour Formation are outlined in red (arrowed). See Appendix for locality details & brief descriptions. Scale bar = 4 km.

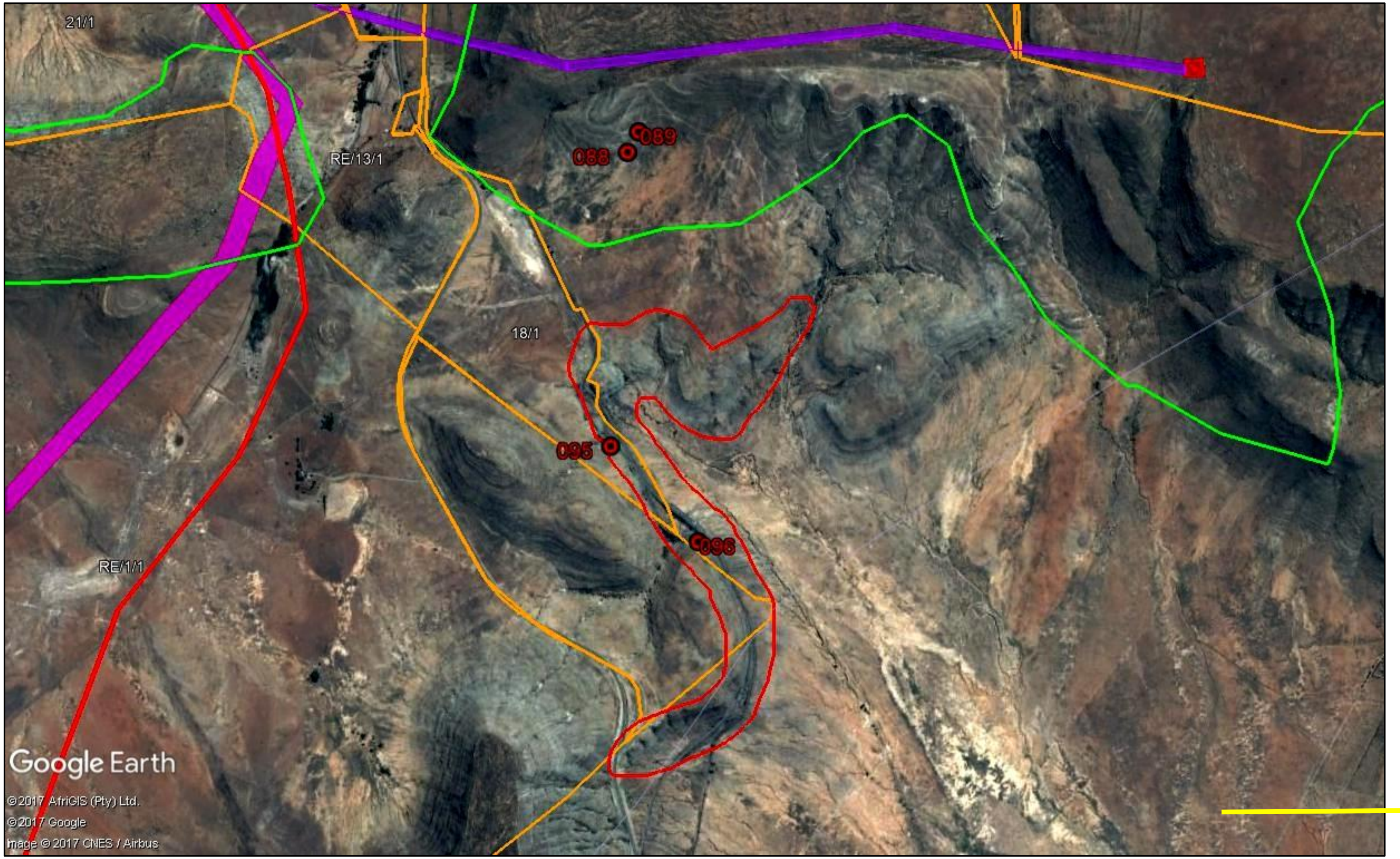

Fig. 37. Satellite image of south-eastern sector of the Phezukomoya project area (orange polygons) showing area with geologically-important exposures of Permo-Triassic boundary rocks at Carlton Heights (red polygon) as well as several numbered fossil localities in the area (red numbers). Scale bar = 1 km.

5. EVALUATION OF IMPACTS ON PALAEONTOLOGICAL HERITAGE

The Phezukomoya WEF study area is located in a region of the Great Karoo that is underlain by potentially fossiliferous sedimentary rocks of Permo-Triassic and younger, Late Tertiary or Quaternary, age (Sections 3 & 4). The construction phase of the proposed wind energy facility will entail substantial excavations into the superficial sediment cover and locally into the underlying bedrock as well. These include, for example, surface clearance and excavations for the wind turbine foundations, laydown and hardstanding areas, internal access roads, underground cables, transmission line pylon footings, electrical substations, operations and services workshop area/office building and construction camps. All these developments may adversely affect potential fossil heritage within the study area by destroying, disturbing or permanently sealing-in fossils preserved at or beneath the surface of the ground that are then no longer available for scientific research or other public good.

The inferred impact of the proposed Phezukomoya WEF on local fossil heritage resources – including the 132 kV grid connection - is briefly evaluated here, based on the system used by ARCUS Consulting. This assessment applies only to the construction phase of the development since further significant impacts on fossil heritage during the planning, operational and decommissioning phases of the facilities are not anticipated.

In general, the destruction, damage or disturbance out of context of fossils preserved at the ground surface or below ground that may occur during construction represents a *negative* impact that is limited to the development footprint (*local / within site boundary*). Such impacts can often be mitigated but cannot be fully rectified or reversed (*i.e. long-term, irreversible*). Most of the sedimentary formations represented within the study area contain fossils of some sort. The pervasive mantle of alluvium, scree and soil covering the vast majority of the potentially-fossiliferous overbank mudrocks within the WEF study area - including the sandstone plateau areas where most of the infrastructure will be situated – is almost certainly largely responsible for the paucity of significant fossil finds here during the present field study. Fossils may be expected in the subsurface and negative impacts at some level on fossil heritage are therefore considered *certain*.

Most fossil occurrences represent taxa that probably occur widely within the study region (*i.e. not unique / irreplaceable*). However, occasional exceptional, scientifically-valuable fossils - such as well-preserved, well-articulated vertebrate skeletons as well as vertebrate burrows - have been recorded in the broader study region around Noupoort. Furthermore, the Beaufort Group bedrock succession underlying the WEF project area records major palaeoecological and evolutionary events across the Permo-Triassic boundary (catastrophic mass extinction event) which are an important focus of ongoing academic studies in Karoo palaeontology. The severity / intensity of anticipated impacts on palaeontological heritage before mitigation is assessed as *moderate (negative)*, given the predicted occurrence of sparse but scientifically-valuable (and potentially *irreplaceable*) fossils in the subsurface within the development footprint. Due to the low extent, moderate severity and permanent duration of potential impacts, the impact significance of the proposed WEF is assessed as *medium (negative)* before mitigation. Confidence levels in this assessment are *medium*, given (1) the extensive palaeontological literature on the Karoo bedrocks concerned weighed against (2) very low levels of bedrock exposure within the study area and (3) the unpredictable distribution of well-preserved fossils in the subsurface.

It should be noted that, should the recommended mitigation measures for the construction phase of the WEF development, as outlined in Section 6 of this report, be consistently followed-though, the impact significance would remain *medium* (*negative*) but would entail both positive and negative impacts. Residual negative impacts from inevitable loss of some valuable fossil heritage would be partially offset by an improved palaeontological database for the study region as a direct result of appropriate mitigation. This is a *positive* outcome because any new, well-recorded and suitably-curated fossil material from this palaeontologically little-known region would constitute a useful addition to our scientific understanding of Karoo Basin fossil heritage.

There are no fatal flaws in the proposed WEF project from a palaeontological heritage viewpoint and no objects to authorisation of the development, provided that the recommended mitigation measures are fully implemented.

5.1. Power line connection to the national grid

The Phezukomoya WEF will be connected to the National Grid *via* a *c*. 15 km-long 132 kV high voltage overhead power line from the on-site switching station to the proposed Umsobomvu substation situated some 23 km southwest of Noupoort (Fig. 38). A preferred powerline route option together with two alternative routes, Alternatives 1 and 2, are briefly assessed here based on palaeontological field experience of the region (adjoining Umsobomvu, San Kraal and Phezukomoya WEF field study areas) as well as recent field examination of short sectors of the powerline corridors.

All three route options traverse similar geological terrain underlain by Beaufort Group bedrocks with occasional elongate, steeply-dipping dolerite intrusions (See geological map, Fig. 2). Apart from the thicker channel sandstones, the Karoo bedrocks are rarely exposed and in low-lying areas are mantled by several meters of, at most, very sparsely-fossiliferous alluvial deposits, such as exposed in areas of deep *donga* erosion and along incised stream beds. With all three power line route options, direct impacts on surface or subsurface fossils as a result of the powerline construction (notably pylon footings, clearance for new access roads) are likely to be similar and minor (low impact significance), especially given the short length of the power line. The proposed sites for the on-site substation, switching station and connecting overhead powerline on the Katberg sandstone plateau within the main WEF project area are unproblematic from a palaeontological view (low impact significance).

As shown in Figs. 38 & 39, the south-western sector of the powerline Alternative 1 passes close to an extensive stream bed exposure of Katberg Formation bedrocks which contain a scientifically interesting assemblage of large fossil vertebrate burrows, at least one of which is associated with disarticulated bones, possibly of the trace-maker. It is recommended that these fossil sites are protected by a 50 m-wide buffer zone (yellow shape) which would then be transgressed by the Alternative 1 powerline route. This is accordingly the least preferred route option on palaeontological heritage grounds. There is no preference between the currently preferred route and the Alternative 2 route. Should the Alternative 1 route be chosen on other grounds, it is recommended that the sector passing close to the fossil sites be moved south-eastwards to run at least 25 m from the stream bed where the fossil vertebrate burrows are exposed.

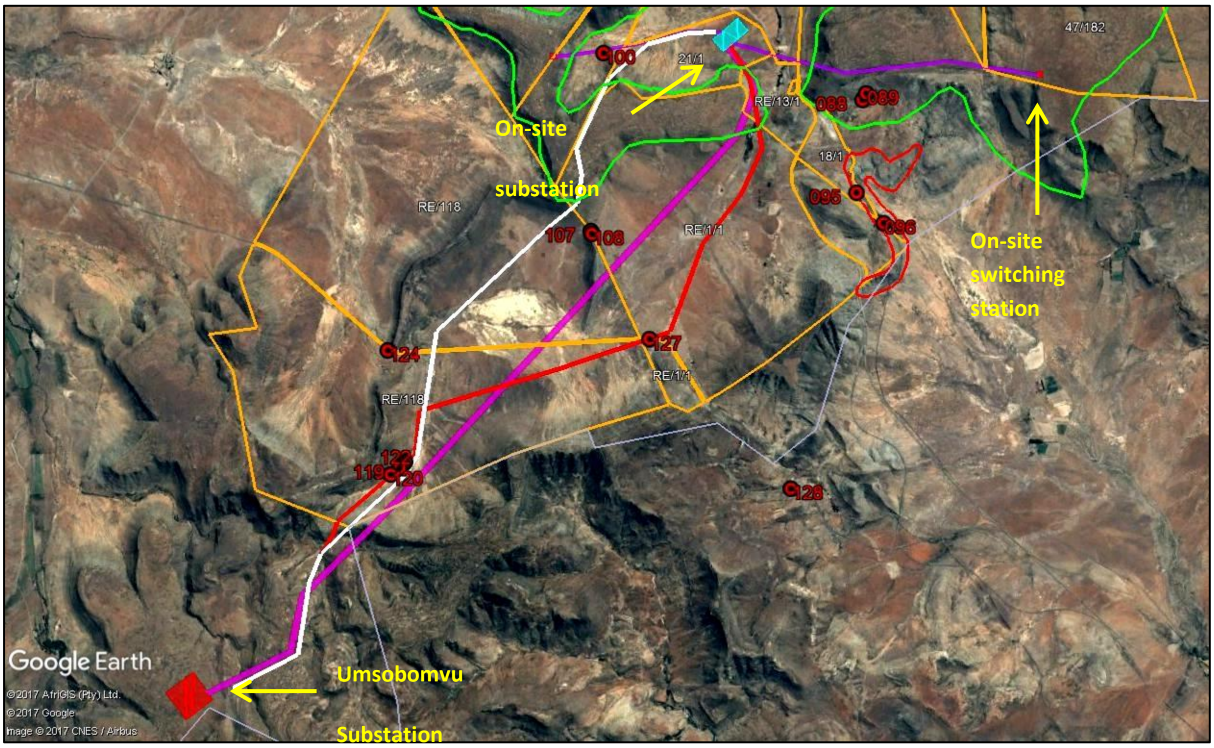

Fig. 38. Google Earth satellite image showing the preferred 132 kV power line connection between the Phezukomoya WEF and the Umsobomvu substation (purple line) as well as two other route options: Alternative 1 (red line) and Alternative 2 (white line).

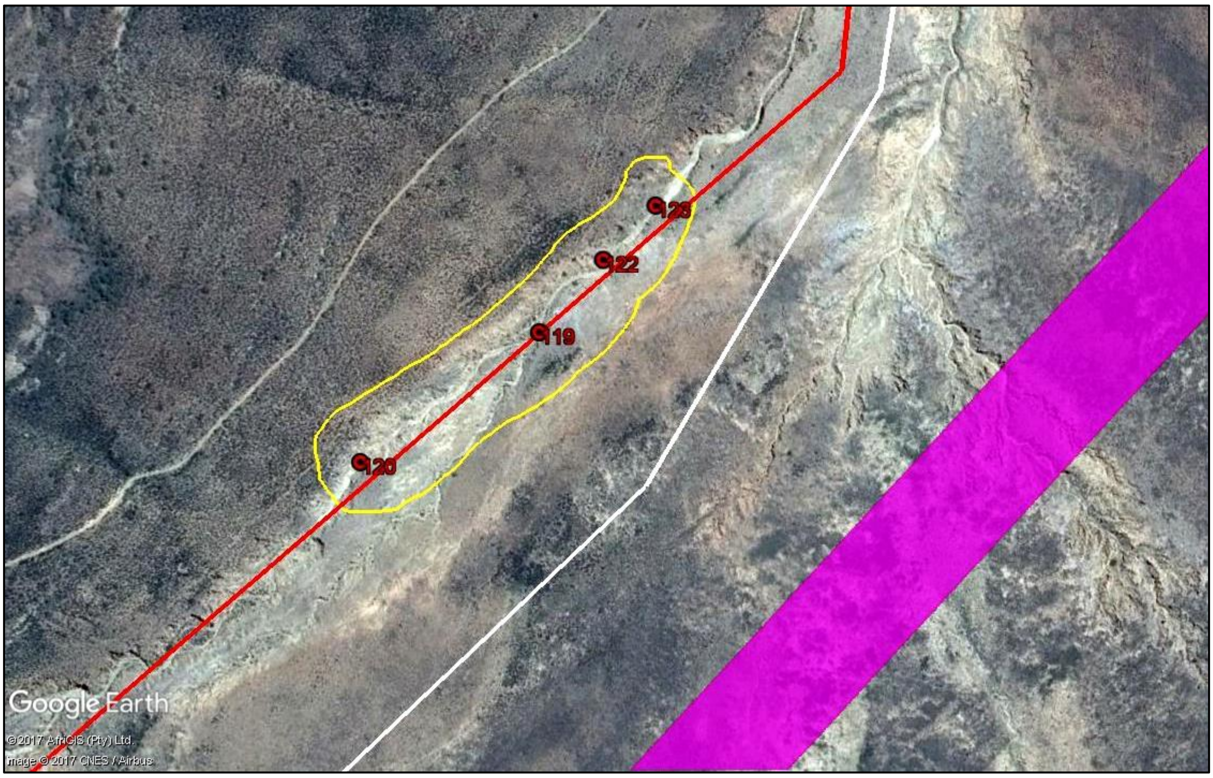

Fig. 39. Detail of the south-western sectors of the 132 kV powerline routes shown in the previous figure. Alternative 1 (red line) passes through the proposed 50 m-radius protective buffer (yellow shape) surrounding several important fossil vertebrate burrow sites in the Katberg Formation that are exposed in a deeply-incised stream bed (Locs. 119-123). Alternative 2 route option – white. Preferred route option – purple.

5.2. Cumulative impact assessment

Previous palaeontological assessments (PIAs) for several proposed or authorized alternative energy projects within a 35 km radius of the Phezukomoya WEF project area have been briefly reviewed (Note that heritage assessments for some projects have been accepted without a PIA; *e.g.* Dida Solar Energy Facility on the farm Rietfontein north of Noupoort). These include field-based assessments for the Noupoort WEF (Almond 2012), the Umsobomvu WEF (Almond 2015), the San Kraal WEF (Almond 2017) as well as several solar projects near Noupoort and Middelburg (Gess 2012a, 2012b), Butler 2016).

In the author's opinion:

- Palaeontological impact significances inferred for these projects that range from low (Noupoort and Umsobomvu WEFs) to medium (San Kraal and Phezukomoya WEFs, Naaupoort 1 solar project) to unassessed reflect different assessment approaches rather than contrasting palaeontological sensitivities and impact levels;

- Meaningful cumulative impact assessments require comprehensive data on *all* major developments within a region, not just those involving alternative energy, as well as an understanding of the extent to which recommended mitigation measures are followed through;

- Trying to assess cumulative impacts on fossil assemblages from different stratigraphic units (in this case, Late Permian fossils from the Adelaide Subgroup and Early Triassic assemblages from the Tarkastad Subgroup) has limited value.

Given the comparatively small combined footprint of the alternative energy projects under consideration compared with the very extensive outcrop areas of the Balfour and Katberg Formations, the cumulative impact significance of the Phezukomoya WEF is assessed as LOW.

6. RECOMMENDATIONS FOR MONITORING AND MITIGATION

Given (1) the significant potential for scientifically-valuable fossils being disturbed, damaged or destroyed during the construction phase of the WEF as well as (2) the high level of uncertainty regarding fossil distribution in the subsurface, a precautionary approach to palaeontological mitigation is considered appropriate here. Following discussions with SAHRA (Dr Ragna Redelstorff, Oct. 2017), it is therefore proposed that initially a representative sample (*c*. 10%) of excavations for wind turbine footings be monitored by a professional palaeontologist during the early construction phase. The monitoring protocol should be developed by the palaeontologist appointed in consultation with the developer and SAHRA so as to maximise the palaeontological outcome without interfering unduly with the construction program. On completion of this initial phase of monitoring, a Phase 2 palaeontological report, with any recommendations for further specialist monitoring or mitigation, should be submitted by the palaeontologist to SAHRA for comment. This stepwise approach is recommended because it may well prove impracticable to recognise record and sample useful fossil material from turbine excavations due to factors such as excessive fragmentation of the bedrock and fossils, obscuring of freshly-excavated bedrock by soil or dust, or safety considerations.

No palaeontological No-Go areas or fossil sites requiring mitigation have been identified within the main WEF development footprint on the Katberg sandstone plateau. In the grid connection study area. Several vertebrate burrows exposed in a stream bed on Farm Winterhoek 118 close to 132 kV power line route Alternative 1 (Fig. 39) should be protected by a 50m-radius buffer zone. Should the Alternative 1 route rather than the currently preferred route be finally chosen, it is recommended that that sector passing close to the fossil sites be moved south-eastwards to run at least 25 m from the stream bed where the fossil burrows are exposed.

In addition to the specialist palaeontological monitoring outlined above, the ECO responsible for the construction phase of the project should be aware of the potential for important fossil finds and the necessity to conserve them for possible professional mitigation (See, for example, Macrae 1999 for a well-illustrated popular account of Karoo fossils). The ECO should monitor all substantial excavations into sedimentary rocks for fossil remains on an on-going basis during the construction phase.

Excellent exposures of mudrocks of the Palingkloof Member (upper Balfour Formation) that are of geoheritage as well as palaeontological significance because of their proximity to the Permo-Triassic boundary are noted here (red shapes in Figs. 36 & 37). One, lying along the railway line at Carlton Heights (Farms RE/1/1 and 18/1), has featured in several scientific publications while the other, close to Hartebeesthoek homestead on Farm RE/182, is currently unstudied. It is anticipated that neither of these two geosites will be directly impacted by the proposed WEF development.

Recommended mitigation of chance fossil finds during the construction phase of the WEF and associated grid connection involves safeguarding of the fossils (preferably *in situ*) by the responsible ECO and reporting of finds to SAHRA for the Northern Cape (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) and to ECPHRA for the Eastern Cape (ECPHRA contact details: Mr Sello Mokhanya, 74 Alexander Road, King Williams Town 5600; Email: smokhanya@ecphra.org.za). Where appropriate, judicious sampling and recording of fossil material and associated geological data by a qualified palaeontologist may be required by the relevant heritage regulatory authorities. Any fossil material collected should be curated within an approved repository (museum / university fossil collection) by a qualified palaeontologist. These recommendations should be included within the Environmental Management Programme for the proposed alternative energy project. Given the internationally recognised value of Karoo fossil heritage (*e.g.* Macrae 1999, McCarthy & Rubidge 2005, Choiniere & Rubidge 2016), the known occurrence of scientifically-valuable fossil material in the Noupoort region, as well as the legal protection of all fossil remains under the National Heritage Resources Act (1999), these mitigation measures are considered to be essential.

7. ACKNOWLEDGEMENTS

Mr Tim Hart of ACO Associates, Cape Town, together with Ms Ashlin Bodasig and Ms Anja Albertyn of Arcus Consulting, Cape Town, are thanked for commissioning this study and for providing the relevant background information. As always, the logistical support and effective assistance of Ms Madelon Tusenius in the field is very much appreciated. Dr Ragna Redelstorff of SAHRA is thanked for helpful discussions regarding mitigation of Karoo WEF projects while Dr Pia Viglietti (Wits University, Johannesburg) kindly shared valuable stratigraphic insights.

8. REFERENCES

ABDALA, F., CISNEROS, J.C. & SMITH, R.M.H. 2006. Faunal aggregation in the Early Triassic Karoo Basin: earliest evidence of shelter-sharing behaviour among tetrapods. Palaios 21, 507-512.

ALMOND, J.E. 2011. Proposed Mainstream wind farm near Noupoort, Pixley ka Seme District Municipality, Northern Cape Province. Palaeontological desktop study, 20 pp. Natura Viva cc, Cape Town.

ALMOND, J.E. 2012. Proposed Mainstream wind farm near Noupoort, Pixley ka Seme District Municipality, Northern Cape. Palaeontological specialist study: combined desktop & field assessment report, 47 pp. Natura Viva cc, Cape Town.

ALMOND, J.E. 2015. Umsobomvu Wind Energy Facility near Middelburg, Pixley ka Seme & Chris Hani District Municipalities, Northern and Eastern Cape. Palaeontological specialist assessment: combined desktop and field-based study, 77 pp. Natura Viva cc, Cape Town.

ALMOND, J.E. 2017. Proposed Mainstream San Kraal WEF near Noupoort, Northern & Eastern Cape. Palaeontological heritage report, 49 pp. Natura Viva cc, Cape Town.

ALMOND, J.E., DE KLERK, W.J. & GESS, R. 2008. Palaeontological heritage of the Eastern Cape. Draft report for SAHRA, 30 pp. Natura Viva cc, Cape Town.

BENTON, M.J. 2003. When life nearly died. The greatest mass extinction of them all, 336 pp. Thames & Hudson, London.

BOK, S.N. 2011. Four potential wind farm sites near Lady Grey, Noupoort, Prieska and Louriesfontein. Geotechnical desktop study, 18 pp. Jeffares & Green (Pty) Ltd.

BORDY, E. M., SZTANÓ, O., RUBIDGE, B.S. AND BUMBY, A. 2009. Tetrapod burrows in the southwestern main Karoo Basin (Lower Katberg Formation, Beaufort Group), South Africa. Extended Abstracts of the 15th Biennial Conference of the Palaeontological Society of Southern Africa. September 11-14, Matjiesfontein, South Africa. Palaeontologia Africana 44, 95-99.

BORDY, E.M., SZTANÓ, O, RUBDIGE, B. & BUMBY, A. 2011. Early Triassic vertebrate burrows from the Katberg Formation of the south-western Karoo Basin, South Africa. Lethaia 44, 33-45.

BORDY, E.M. & KRUMMECK, D.W. 2016. Enigmatic continental burrows from the Early Triassic transition of the Katberg and Burgersdorp Formations in the Main Karoo Basin, South Africa. Palaios 31, 389-403.

BORDY, E.M. 2017 (Ed.). A guide to the ichnology and geology of the main Karoo Basin, South Africa and Lesotho. Field guide, 2nd International Conference on Continental Ichnology, 5-8th October 2017, iv + 73 pp.

BOTHA, J. & SMITH, R.M.H. 2007. *Lystrosaurus* species composition across the Permo-Triassic boundary in the Karoo Basin of South Africa. Lethaia 40, 125-137.

BUTLER, E. 2014. Palaeontological impact assessment for the proposed upgrade of existing water supply infrastructure at Noupoort, Northern Cape Province, 22 pp. Karoo Palaeontology Department, National Museum, Bloemfomtein.

BUTLER, E. 2016. Palaeontological impact assessment of the proposed construction of the 150 MW Noupoort Concentrated Solar Power facility and associated infrastructure o Portion 1 and 4 of the farm Carolus Poort 167 and the Remaining Extent of Farm 207, near Noupoort, Northern Cape. Desktop study, 21 pp. Karoo Palaeontology Department, National Museum, Bloemfontein.

CHOINIERE, J. & RUBIDGE, B. 2016. The Karoo Supergroup. Chapter 14, pp. 95-102 in Anhaeusser, C.R., Viljoen, M.J. & Viljoen, R.P. (Eds.) Africa's top geological sites, 312 pp. Struik Nature, Cape Town.

CLUVER, M.A. 1978. Fossil reptiles of the South African Karoo. 54pp. South African Museum, Cape Town.

COLE, D.I., NEVELING, J., HATTINGH, J., CHEVALLIER, L.P., REDDERING, J.S.V. & BENDER, P.A. 2004. The geology of the Middelburg area. Explanation to 1: 250 000 geology Sheet 3124 Middelburg, 44 pp. Council for Geoscience, Pretoria.

DAMIANI, R., NEVELING, J., MODESTO, S. & YATES, A . 2003a. Barendskraal, a diverse amniote locality from the *Lystrosaurus* Assemblage Zone, Early Triassic of South Africa. Palaeontologia Africana 39, 53-62.

DAMIANI, R., MODESTO, S., YATES, A. & NEVELING, J. 2003b. Earliest evidence for cynodont burrowing. Proceedings of the Royal Society of London B. 270, 1747-1751.

DINGLE, R.V., SIESSER, W.G. & NEWTON, A.R. 1983. Mesozoic and Tertiary geology of southern Africa. viii + 375 pp. Balkema, Rotterdam.

DUNCAN, A.R. & MARSH, J.S. 2006. The Karoo Igneous Province. In: Johnson, M.R., Anhaeusser, C.R. & Thomas, R.J. (Eds.) The geology of South Africa, pp. 501-520. Geological Society of South Africa, Marshalltown.

GASTALDO, R.A., ADENDORFF, R., BAMFORD, M., LABANDEIRA, C.C., NEVELING, J. & SIMS, H. 2005. Taphonomic trends of macrofloral assemblages across the Permian – Triassic boundary, Karoo Basin, South Africa. Palaios 20, 479-497.

GASTALDO, R.A. & ROLERSON, M.W. 2008. *Katbergia* Gen. Nov., a new trace fossil from the Upper Permian and Lower Triassic rocks of the Karoo Basin: implications for palaeoenvironmental conditions at the P/TR extinction event. Palaeontology 51, 215-229.

GESS, R. 2012a. Palaeontological impact assessment for proposed construction of a photovoltaic solar power station near Collett Substation, Middelburg, Eastern Cape., 17 pp. Robert Gess Consulting, Bathurst.

GESS, R. 2012b. Palaeontological impact assessment for proposed establishment of a solar energy facility on Farm Naauport 1 near Noupoort, Eastern Cape, 12 pp plus 1 page Addendum. Robert Gess Consulting, Bathurst.

GRAB, S.W., GOUDIE, A.S., VILES, H.A. & WEBB, N. 2011. Sandstone geomorphology of the Golden Gate Highlands National Park, South Africa, in a global context. Koedoe 53, Art. #985, 14 pages. doi:10.4102/koedoe. v53i1.985

GROENEWALD, G.H. 1991. Burrow casts from the *Lystrosaurus-Procolophon* Assemblage-zone, Karoo Sequence, South Africa. Koedoe 34, 13-22.

GROENEWALD, G.H. & KITCHING, J.W. 1995. Biostratigraphy of the *Lystrosaurus* Assemblage Zone. Pp. 35-39 in RUBIDGE, B.S. (ed.) Biostratigraphy of the Beaufort Group (Karoo Supergroup). South African Committee for Stratigraphy, Biostratigraphic Series No. 1, 46 pp. Council for Geoscience, Pretoria.

GROENEWALD, G.H., WELMAN, J. & MACEACHERN, J.A. 2001. Vertebrate burrow complexes from the Early Triassic *Cynognathus* Zone (Driekoppen Formation, Beaufort Group) of the Main Karoo Basin, South Africa. Palaios 16, 148-160.

HANCOX, P.J. 2000. The continental Triassic of South Africa. Zentralblatt für Geologie und Paläontologie, Teil 1, 1998, 1285-1324.

HAYCOCK, C.A., MASON, T.R. & WATKEYS, M.K. 1994. Early Triassic palaeoenvironments in the eastern Karoo foreland basin, South Africa. Journal of African Earth Sciences 24, 79-94.

HILLER, N. & STAVRAKIS, N. 1980. Distal alluvial fan deposits in the Beaufort Group of the Eastern Cape Province. Transactions of the Geological Society of South Africa 83, 353-360.

HILLER, N. & STAVRAKIS, N. 1984. Permo-Triassic fluvial systems in the southeastern Karoo Basin, South Africa. Palaeogeography, Palaeoclimatology, Palaeoecology 34, 1-21.

JOHNSON, M.R. 1966. The stratigraphy of the Cape and Karoo Systems in the Eastern Cape Province. Unpublished MSc Thesis, Rhodes University, Grahamstown.

JOHNSON, M.R. 1976. Stratigraphy and sedimentology of the Cape and Karoo sequences in the Eastern Cape Province. Unpublished PhD thesis, Rhodes University, Grahamstown, xiv + 335 pp, 1pl.

JOHNSON, M.R., VAN VUUREN, C.J., VISSER, J.N.J., COLE, D.I., DE V. WICKENS, H., CHRISTIE, A.D.M., ROBERTS, D.L. & BRANDL, G. 2006. Sedimentary rocks of the Karoo Supergroup. In: Johnson, M.R., Anhaeusser, C.R. & Thomas, R.J. (Eds.) The geology of South Africa, pp. 461-499. Geological Society of South Africa, Marshalltown.

KEYSER, A.W. & SMITH, R.M.H. 1977-78. Vertebrate biozonation of the Beaufort Group with special reference to the Western Karoo Basin. Annals of the Geological Survey of South Africa 12: 1-36.

KITCHING, J.W. 1977. The distribution of the Karroo vertebrate fauna, with special reference to certain genera and the bearing of this distribution on the zoning of the Beaufort beds. Memoirs of the Bernard Price Institute for Palaeontological Research, University of the Witwatersrand, No. 1, 133 pp (incl. 15 pls).

KLEIN, R.G. 1984. The large mammals of southern Africa: Late Pliocene to Recent. In: Klein, R.G. (Ed.) Southern African prehistory and paleoenvironments, pp 107-146. Balkema, Rotterdam.

KRUMMECK, W.D. & BORDY, E.M. 2017. *Reniformichnus katikatii* (New Ichnogenus and Ichnospecies): continental vertebrate burrows from the Lower Triassic, Main Karoo Basin, South Africa. Ichnos, 1-12.

MACRAE, C. 1999. Life etched in stone. Fossils of South Africa. 305pp. The Geological Society of South Africa, Johannesburg.

MCCARTHY, T. & RUBIDGE, B. 2005. The story of Earth and life: a southern African perspective on a 4.6-billion-year journey. 334pp. Struik, Cape Town.

MODESTO, S.P. & BOTHA-BRINK, J. 2010. A burrow cast with *Lystrosaurus* skeletal remains from the Lower Triassic of South Africa. Palaios 25, 274-281.

NEVELING, J., RUBIDGE, B.S. & HANCOX, P.J. 1999. A lower *Cynognathus* Assemblage Zone fossil from the Katberg Formation (Beaufort Group, South Africa). South African Journal of Science 95, 555-556.

NEVELING, J. 2004. Stratigraphic and sedimentological investigation of the contact between the *Lystrosaurus* and the *Cynognathus* Assemblage Zones (Beaufort Group: Karoo Supergroup). Council for Geoscience, Pretoria, Bulletin, 137, 164pp.

NEVELING, J., HANCOX, P.J. & RUBIDGE, B.S. 2005. Biostratigraphy of the lower Burgersdorp Formation (Beaufort Group; Karoo Supergroup) of South Africa – implications for the stratigraphic ranges of early Triassic tetrapods. Palaeontologia Africana 41, 81-87.

NICOLAS, M.V. 2007. Tetrapod diversity through the Permo-Triassic Beaufort Group (Karoo Supergroup) of South Africa. Unpublished PhD thesis, University of Witwatersrand, Johannesburg.

PARTRIDGE, T.C. & SCOTT, L. 2000. Lakes and pans. In: Partridge, T.C. & Maud, R.R. (Eds.) The Cenozoic of southern Africa, pp.145-161. Oxford University Press, Oxford.

PARTRIDGE, T.C., BOTHA, G.A. & HADDON, I.G. 2006. Cenozoic deposits of the interior. In: Johnson, M.R., Anhaeusser, C.R. & Thomas, R.J. (Eds.) The geology of South Africa, pp. 585-604. Geological Society of South Africa, Marshalltown.

PARTRIDGE, T.C., DOLLAR, E.S.J., MOOLMAN, J. & DOLLAR, L.H. 2010. The geomorphic provinces of South Africa, Lesotho and Swaziland: a physiographic subdivision for earth and environmental scientists. Transactions of the Royal Society of South Africa 65, 1-47.

RETALLACK, G.J., SMITH, R.M.H. & WARD, P.D. 2003. Vertebrate extinction across the Permian-Triassic boundary in the Karoo Basin, South Africa. Geological Society of America Bulletin 115, 1133-1152.

RETALLACK, G.J., METZGER, C.A., GREAVER, T., HOPE JAHREN, A., SMITH, R.M.H. & SHELDON, N.D. 2006. Middle – Late Permian mass extinction on land. GSA Bulletin 118, 1398-1411.

RUBIDGE, B.S. (Ed.) 1995. Biostratigraphy of the Beaufort Group (Karoo Supergroup). South African Committee for Biostratigraphy, Biostratigraphic Series No. 1., 46 pp. Council for Geoscience, Pretoria.

RUBIDGE, B.S. 2005. Re-uniting lost continents – fossil reptiles from the ancient Karoo and their wanderlust. South African Journal of Geology 108: 135-172.

SAHRA 2013. Minimum standards: palaeontological component of heritage impact assessment reports, 15 pp. South African Heritage Resources Agency, Cape Town.

SKEAD, C.J. 1980. Historical mammal incidence in the Cape Province. Volume 1: The Western and Northern Cape, 903pp. Department of Nature and Environmental Conservation, Cape Town.

SMITH, R.H.M. & WARD, P.D. 2001. Pattern of vertebrate extinction across an event bed at the Permian-Triassic boundary in the Karoo Basin of South Africa. Geology 29, 1147-1150.

SMITH, R.M.H., HANCOX, P.J., RUBIDGE, B.S., TURNER, B.R. & CATUNEANU, O. 2002. Mesozoic ecosystems of the Main Karoo Basin: from humid braid plains to arid sand sea. Guidebook 8th International Symposium on Mesozoic Terrestrial Ecosystems, Cape Town, South Africa, 116 pp.

SMITH, R. & BOTHA, J. 2005. The recovery of terrestrial vertebrate diversity in the South African Karoo Basin after the end-Permian extinction. Comptes Rendus Palevol 4, 555-568.

SMITH, R.H.M. & BOTHA-BRINK, J. 2014. Anatomy of a mass extinction: sedimentological and taphonomic evidence for drought-induced die-offs at the Permo-Triassic boundary in the main Karoo Basin, South Africa. Palaeogeography, Palaeoclimatology and Palaeoecology 396, 99–118. http://dx.doi.org/10.1016/j.palaeo.2014.01.002.

SMITH, R., RUBIDGE, B. & VAN DER WALT, M. 2012. Therapsid biodiversity patterns and paleoenvironments of the Karoo Basin, South Africa. Chapter 2 pp. 30-62 in Chinsamy-Turan, A. (Ed.) Forerunners of mammals. Radiation, histology, biology. xv + 330 pp. Indiana University Press, Bloomington & Indianapolis.

STAVRAKIS, N. 1980. Sedimentation of the Katberg Sandstone and adjacent formations in the south-eastern Karoo Basin. Transactions of the Geological Society of South Africa 83, 361-374.

VIGLIETTI, P. 2010. Origin, sedimentology and taphonomy of an Early Triassic *Lystrosaurus* bonebed, Katberg Formation, Karoo Basin, South Africa. Proceedings of the 16th Conference of the Palaeontological Society of Southern Africa, Howick, August 5-8, 111a-111c.

VIGLIETTI. P.A. 2016. Stratigraphy and sedimentary environments of the Late Permian Dicynodon Assemblage Zone (Karoo Supergroup, South Africa) and implications for basin development. Unpublished PhD thesis, Wits, Joburg.

VIGLIETTI, P.A., SMITH, R.M.H., ANGIELCZYK, K.D., KAMMERER, C.F., FRŐBISCH, J. & RUBIDGE, B.S. 2015. The *Daptocephalus* Assemblage Zone (Lopingian), South Africa: Journal of African Earth Sciences 113, 1-12.

VISSER, J.N.J. & DUKAS, B.A. 1979. Upward-fining fluviatile megacycles within the Beaufort Group, north of Graaff-Reinet, Cape Province. Transactions of the Geological Society of South Africa 82, 149-154.

WARD, P.D., BOTHA, J., BUICK, R., DE KOCK, M.O., ERWIN, D.H., GARRISON, G.H., KIRSCHVINK, J.L. & SMITH, R.M.H. 2005. Abrupt and gradual extinction among Late Permian land vertebrates in the Karoo Basin, South Africa. Science 307, 709-714.

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

Declaration of Independence

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

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

APPENDIX: GPS LOCALITY DATA

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

Loc. No.	GPS DATA	COMMENTS
072	S31° 13' 10.4" E24° 58' 32.6"	Hartebeest Hoek 182. Extensive gently-sloping hillslope exposures of hackly-weathering purple-brown and grey-green overbank mudrocks – probably upper part of thick latest Permian Palingkloof Member mudrock package (Balfour Fm, Adelaide Subgroup). Horizons of brownish pedogenic calcrete concretions, very thin to thin grey-green crevasse-splay sandstones (heterolithic tops of few m-thick upward-coarsening packages), isolated lenticular sandstone bodies (gully infills or possibly vertebrate burrows – highly equivocal), patches of small-scale wave ripples (playa ponds). Field Rating IIIB Local Resource.
073	S31° 13' 10.7" E24° 58' 27.7"	Hartebeest Hoek 182. Excellent stream gulley exposures of lower part of Palingkloof Member succession showing colour-banded mudrocks and fine, thin-bedded sandstones in vertical profile. Shallow erosional cut-and-fill structures picked out by colour banding. Packages of massive mudrocks passing up into thinly-interbedded sandstone and siltstone couplets. Occasional prominent-weathering thin sandstones (probable crevasse splays) and brownish-weathering palaeocalcrete lenses within coarser grey-green tops of cycles. No large brown pedocrete nodules seen. Field Rating IIIB Local Resource.
074	S31° 12' 35.6" E24° 58' 31.0"	Hartebeest Hoek 182. Extensive area of erosion-gullied, thick alluvial deposits north of farm dam wall. Several m-thick succession of well-bedded, occasionally laminated, brown sandy alluvium with occasional poorly-sorted gravel lenses and horizons. Downwasted coarser gravels at surface.
075	S31° 11' 18.6" E24° 53' 39.0"	Kleinfontein 117. Large shallow roadside borrow pit exposing Balfour Formation dark blue-grey to grey-green, crumbly to hackly mudrocks with lenses and nodular horizons of rusty-brown, ferruginous pedogenic calcrete and diagenetic carbonate concretions / *koffieklip*, large sand-infilled desiccation cracks (or possibly neptunean dykes), veins of Late Caenozoic creamy calcrete. Medium-bedded grey-green channel sandstones. Float blocks of grey-green sandstone with (1) small-scale (c. 5 mm – diameter) cylindrical burrows, horizontal and oblique – probably *Scoyenia* – as well as (2) vague mm-scale, possibly branching intrastratal burrow networks and (3) straight mud-lined or –infilled horizontal burrows up to 1 cm across. Bedrocks partially baked, vuggy, overlain by thick (1-2 m) of orange-brown alluvial sandy soils with minor gravels (*e.g.* angular sandstone, or more patinated hornfels, some flaked, dolerite corestones, Late Caenozoic calcrete). All trace fossils here: proposed Field Rating IIIC Local Resource.
076	S31° 11' 18.7" E24° 53' 46.8"	Kleinfontein 117, eastern side of borrow pit with several probable vertebrate burrow casts of grey-green sandstone, 20-30 cm diameter, compressed ellipsoidal cross-section, horizontal to gently-sloping, straight to gently curved, enclosed in crumbly mudrock of Balfour Formation. Proposed Field Rating IIIC Local Resource.
077	S31° 12' 12.1" E24° 53' 33.2"	Kleinfontein 117. Gulley-eroded alluvium along SW-NE drainage line. Several m-thick orange-brown sandy to silty alluvium with gravel lenses (sandstone, dolerite, calcrete, hornfels clasts with rare pale grey cherty tuff, ostrich egg shell), downwasted surface gravels. No petrified wood seen.
078	S31° 12' 50.6" E24° 54' 14.6"	Kleinfontein 117. Extensive streambed exposure of hackly, grey-green Balfour Fm mudrocks and thin crevasse-splay sandstones exposed by recent floods. Horizons of ferruginous pedogenic calcrete concretions, mudflake intraclast breccias. Small inclined, straight vertebrate burrows exposed as sandstone casts (c. 10 – 20 cm diam.), some with oblique

		scratches on lower lateral surfaces or smoothed floors. Small (cm-diameter), curved, mudrock-cast burrows within baked sandstone may be *Katbergia* but no scratch marks seen on smooth walls. Proposed Field Rating IIIC Local Resource.
079	S31° 13' 23.1" E24° 54' 16.4"	Kleinfontein 117. Mountain pass trackside exposure of rusty-brown ferruginised, thin-bedded Katberg basal calcrete breccia (c. 0.5 m) in vicinity of dolerite dyke
080	S31° 13' 24.6" E24° 54' 18.9"	Kleinfontein 117. Hillslope exposure of baked and ferruginised, thinly-interbedded fine Katberg sandstone and mudflake / calcrete basal breccia (c. 1.5 m), sharply capped by channel sandstone and overlying hornfels. Thin calcrete development associated with dolerite dyke that cuts through Katberg escarpment here.
081	S31° 13' 40.0" E24° 54' 30.2"	Kleinfontein 117. Well-exposed greyish to rusty-brown calcrete basal breccia close to farm track up escarpment containing isolated reworked fossil bone fragment. Proposed Field Rating IIIC Local Resource. Calcrete breccia passes laterally into intercalated sandstone and breccia facies due west. Good examples of lichen etching of sandstone surfaces in vicinity.
082	S31° 14' 45.0" E24° 54' 11.5"	Kleinfontein 117. View southwards from Afrikasberg into valley showing extensive gulley erosion of thick alluvial deposits on valley floor. Good views of Katberg escarpment showing very low levels of mudrock exposure, steep dolerite dyke cutting up through tabular Katberg channel sandstones.
083	S31° 14' 58.0" E24° 53' 17.5"	Kleinfontein 117, summit plateau of Afrikasberg. Karstified Katberg sandstone surfaces (*e.g.* widened joints with case-hardened edges, alligator cracking, solution hollows), downwasted sandstone surface gravels, absence of overbank mudrock exposure, sandy to gravelly soil cover.
084	S31° 15' 45.2" E24° 53' 35.4"	Kleinfontein 117, summit plateau close to southern edge of property. Karstified Katberg sandstone surfaces, downwasted sandstone surface gravels, solution hollows (*gnammas*).
085	S31° 13' 15.8" E24° 54' 14.2"	Kleinfontein 117, foot of Katberg escarpment. Ridge of resistant-weathering pale brown quartzite adjacent to dolerite dyke.
086	S31° 12' 33.1" E24° 52' 47.6"	Kleinfontein 117, major dyke-like dolerite intrusion near homestead. Rubbly corestone exterior.
087	S31° 12' 30.9" E24° 52' 46.7"	Kleinfontein 117. Stream bank exposures of thick (several m) orange-brown sandy alluvium with horizons and lenses of subrounded sandstone pebbles showing current imbrication. Occasional flaked hornfels stone artefacts embedded within alluvium including identifiable MSA (*i.e.* alluvium younger than *c*. 300 000 BP, approximate age of earliest MSA).
088	S31° 15' 42.6" E24° 57' 11.0"	Farm RE11/1. Shallow stream bed exposure of grey-green thin crevasse splay sandstones and overbank mudrocks, probably within lower part of Katberg Fm. Steeply-sloping subcylindrical invertebrate burrow (c. 6 mm diam.) with vague wall scratches – probably *Katbergia*.
089	S31° 15' 39.0" E24° 57' 13.6"	Farm RE11/1. Shallow stream bed exposure of grey-green thin crevasse splay sandstones and overbank mudrocks, probably within lower part of Katberg Fm. Microbial mat textures on flat-laminated sandstone bedding planes. Interbedded, thin-bedded siltstones and sandstones with sand-infilled, wedge-shaped desiccation cracks in vertical section, bedding planes with small-scale wave ripples (playa pond), linguoid current ripples. Incomplete straight vertebrate burrow (c. 10 cm diam.) showing smoothed floor and oblique scratch marks on ventrolateral surface.
090	S31° 15' 25.6" E24° 57' 41.5"	Farm RE11/1. Donga eroded orange-brown sandy alluvial soils on Katberg sandstone plateau close to dolerite dyke. Occasional dolerite corestone lonestones.
091	S31° 15' 28.8" E24° 58' 18.5"	Farm RE11/1. Excellent deep erosion gulley exposures through thick (several m), semi-consolidated sandy to gravelly alluvium mantling floor of stream valley incised into deeply-weathered dolerite dyke (Probably Pleistocene deposits *cf* Masotcheni Fm). Basal coarse, poorly-sorted, angular to subrounded gravels (mainly sandstone clasts, dolerite corestones, some hornfels and MSA artefacts in gritty matrix) overlain by

		several m of orange-brown sands with pebbly gravel lenses and capped by younger coarse angular gravels and greyish modern soils.
092	S31° 15' 38.8" E24° 58' 48.3"	Farm Naau Poort 2. Viewpoint near Katberg plateau edge showing pale brown, closely-spaced to amalgamated tabular channel sandstones towards top of Katberg succession. Thick, steeply-dipping dolerite intrusion with boulder surface, thin apophyses (side veins) cut through Katberg succession with baking of country rocks to form dark, resistant-weathering hornfels.
093	S31° 14' 48.8" E24° 58' 08.4"	Farm RE11/1. Undulating, deeply-dissected grassy to rocky Katberg plateau. No mudrock exposure and low levels of sandstone exposure as well. Channel sandstones best seen along edge of escarpment.
094	S31° 16' 33.8" E24° 57' 02.1"	Farm 18/1. Old abandoned railway cutting through basal Katberg Fm, Carlton Heights. Good vertical sections through basal calcrete breccias (mudflakes, calcrete glaebules), erosive-based, mulit-storey tabular channel sandstones, thin-bedded heterolithic units at top of upward-coarsening overbank or levee packages, grey-green, thin-bedded overbank siltstones.
095	S31° 16' 36.2" E24° 57' 04.9"	Farm 18/1. Steep hillslope and railway cutting exposures of lower Katberg Formation. Sharp, erosive-based channel sandstone, mudflake breccias and medium-bedded heterolithic package underlain by massive, hackly-weathering purple-brown to grey-green siltstones containing several possible, brownish sandstone vertebrate burrow casts (possibly secondarily mineralised by ferruginous carbonate), subhorizontal, gently-sloping to steeply-inclined, curved. Occasional oblique *Katbergia* scratch burrow. Below massive burrowed unit is succession of thinly-interbedded thin tabular sandstones and purple-brown siltstones with occasional purported large vertebrate burrow casts. This is underlain in turn by thick package of apparently massive (possibly thinly-bedded or laminated) crumbly purple-brown mudrock. Exposures of geo-scientific / palaeontological importance – protection within 50 m radius buffer zone recommended. Proposed Field Rating IIIA Local Resource.
096	S31° 16' 54.4" E24° 57' 22.9"	Farm Tweefontein RE11/1. Excellent railway cutting / road / hillslope sections through thick crumbly, purple-brown siltstone package with occasional thin, prominent-weathering, grey-green sandstone interbeds. Upper part (inaccessible) possibly a package of thin-bedded sandstone-siltstone couplets as described within Palingkloof Member (Balfour Fm) extinction zone (*cf* Gastaldo *et al.* 2005, Carlton Heights section in Fig. 9). Capped by more resistant-weathering heterolithic package of grey-green, thin-bedded sandstones and siltstones. Sporadic brown-weathering irregular bodies within lower beds *might* be sandstone casts of vertebrate burrows. Thin sandstone float blocks with sand-infilled mudcracks, possible plant stem casts. Unit overlies package of thin- to medium-bedded tabular sandstones and grey-green silstones. Exposures of geo-scientific / palaeontological importance – protection within 50 m radius buffer zone recommended. Proposed Field Rating IIIA Local Resource.
097	S31° 15' 06.2" E24° 54' 31.0"	Farm 21/1. Thick (several m) orange-brown to brown, well-bedded to massive sandy and gravelly alluvial deposits mantling valley floor exposed in a network of deep dongas. Older more orange-brown, better-consolidated alluvium semi-consolidated with dispersed small calcrete glaebules and locally with elongate calcretised rhizoliths. Occasional embedded flaked quartzite artefacts in this zone. Basal rubbly, angular gravels of poorly-sorted sandstone overlie erosional contact with Balfour Formation mudrocks in stream banks. Bedding plane exposures of Balfour Formation grey-green sandstones along stream bed showing small-scale polygonal fracture, horizons with dispersed sphaeroidal to rounded-irregular diagenetic concretions of rusty-brown, concentrically-laminated ferruginous carbonate (up to c. 10 diameter). Thin-bedded, grey-green / purple-brown colour-banded overbank siltstones.

098	S31° 15' 04.6" E24° 54' 22.6"	Farm 1/117. Lens of clast-supported, well-sorted, upward-fining, horizontally-bedded, fine pebbly alluvial conglomerates exposed in wall of donga. Clasts predominantly of well-rounded to subrounded sandstone.
099	S31° 15' 04.3" E24° 54' 14.9"	Farm 1/117. Good gully wall exposures of thin-bedded, colour-banded overbank siltstones and fin-grained sandstones of Balfour Formation (possibly Palingkloof Member or basal Katberg Fm) with sharp-based, thin-bedded crevasse-splay sandstones in upper part of succession. Deeply incised by cut-and-fill palaeo-gulley deposits of angular sandstone gravels and sandy alluvium. Surface gravels in donga-eroded area mainly of angular downwasted sandstone blocks.
100	S31° 15' 10.0" E24° 54' 15.2"	Farm 1/117. Pale grey calcrete basal breccia within Palingkloof member or basal Katberg Fm. Rounded calcrete glaebules within rusty-brown ferruginous sandy matrix. Sparse dispersed reworked bone fragments. Proposed Field Rating IIIC Local Resource.
101	S31° 15' 44.3" E24° 54' 13.4"	Farm RE/1/1. Karstified sandstone rubble, downwasted platy sandstone gravels (some ferruginised), sandy soils on Katberg plateau.
102	S31° 15' 49.1" E24° 54' 06.0"	Farm RE/1/1. Extensive karstified sandstone pavement cut by well-spaced joints with raised, case-hardened walls separating shallow basins, solution hollows.
103	S31° 15' 53.5" E24° 54' 01.0"	Farm RE/1/1. Extensive karstified sandstone pavement cut by well-spaced joints, low angle tabular cross-bedding, lichen-etched sandstone surfaces.
104	S31° 16' 22.5" E24° 53' 41.7"	Farm RE/1/1. Viewpoint southwards across grid connection route study area in lowlands showing no bedrock exposure. Katberg channel sandstone exposures showing solution hollows (*gnammas*) and lichen weathering.
106	S31° 16' 27.7" E24° 53' 43.6"	Farm RE/1/1. Viewpoint southwards across grid connection route study area in lowlands showing no bedrock exposure. Karstified Katberg channel sandstone exposures showing good examples of solution hollows (*gnammas*) and rock doughnuts (*cf* Grab *et al.* 2011).
107	S31° 16' 53.6" E24° 54' 02.6"	Farm RE/1/1. Small exposure of Katberg grey-green overbank siltstones at N end of ridge-like *koppie*. Thin (few dm) ferruginous, rusty-brown calcrete breccio-conglomerate at base of buff channel sandstone contains dispersed small fragments of reworked bone. Proposed Field Rating IIIC Local Resource.
108	S31° 16' 55.3" E24° 54' 03.2"	Farm RE/1/1. N end of ridge-like *koppie*. Several small fragments of reworked bone and elongate, tubular accrete rhizoliths within clast- to matrix-supported calcrete basal breccia (few dm thick) with matrix of ferruginous sand. Proposed Field Rating IIIC Local Resource. Alluvial sands and downwasted surface gravels in *vlaktes* at foot of *koppie*.
109	S31° 17' 04.9" E24° 55' 11.1"	Farm RE/1/1. Orange-brown sandy alluvial soils with downwasted gravels of patinated hornfels (many flaked), ferruginous sandstone. No fossil wood seen.
110	S31° 17' 05.3" E24° 55' 16.5"	Farm RE/1/1. Pebbly alluvial gravels of dolerite, sandstone, hornfels, quartzite.
111	S31° 18' 03.6" E24° 51' 52.5"	Farm Winterhoek RE/118. Hillslopes east of Winterhoek farmstead with extensive carpet of hornfels and minor quartzite surface gravels showing different levels of surface patination (including abundant flaked artefacts) in vicinity of major dolerite intrusion. Occasional large blocks of quartzite.
112	S31° 18' 05.6" E24° 51' 53.7"	Farm Winterhoek RE/118. Prominent-weathering bed of resistant hornfels, well-jointed, possibly showing local evidence of Stone Age quarrying. Baked sediments here appear to overlie major dolerite body but might also might form part of large xenolith or raft of Beaufort Group country rocks caught up in major dolerite intrusion, or between intrusions.
113	S31° 18' 07.5" E24° 51' 52.8"	Farm Winterhoek RE/118. Quartzite outcrop in vicinity of dolerite intrusion.
115	S31° 18' 03.0" E24° 52' 04.1"	Farm Winterhoek RE/118. Stream bank exposure of thick, pale greyish-brown sandy to gritty alluvium with rubbly basal gravels, overlain by dark grey and orange-brown sandy soils. Sparse dispersed hornfels gravels include several flaked stone artefacts (incl. MSA).

116	S31° 18' 09.7" E24° 51' 59.7"	Farm Winterhoek RE/118. Low cliff of baked tabular-bedded hornfels and quartzite. Surface gravels above of well-rounded Katberg sandstone boulder-sized corestones.
117	S31° 18' 10.2" E24° 52' 01.8"	Farm Winterhoek RE/118. Small exposure of hackly-weathering Katberg overbank mudrocks overlain by colluvial sandstone surface gravels. Latter often moderately well-rounded.
118	S31° 19' 11.7" E24° 51' 25.3"	Farm Winterhoek RE/118. Overhang beneath Katberg Formation channel sandstone. Thin-bedded, interbedded sandstone and grey-green mudrock, mudstone intraclast breccias. Possible boudinage or loading of some sandstone units.
119	S31° 19' 08.0" E24° 51' 46.3"	Winterhoek 118. Stream bed exposure of pale buff Katberg Fm sandstones and grey-green overbank mudrocks showing several well-preserved, gently--sloping, subcylindrical sandstone casts of vertebrate burrows (*c*. 30 cm wide). Proposed Field Rating 111B Local Resource. 50 m-radius buffer zone recommended. Katberg Fm bedrocks are overlain here by thick alluvial succession with coarse gravels at base (*c*. 1 m), brown sandy alluvium above (*c*. 1.5 m) and pale grey modern alluvium (*c*. 1 m) with surface gravels at the top.
120	S31° 19' 11.5" E24° 51' 40.3"	Winterhoek 118. Stream bed exposure of baked Katberg Fm channel or thick crevasse-splay sandstone with probable baked sandstone casts of subhorizontal, large (30-40 cm wide), convex-topped vertebrate burrows exposed on the upper surface. Proposed Field Rating 111B Local Resource. 50 m-radius buffer zone recommended.
121	S31° 19' 13.0" E24° 51' 39.0"	Winterhoek 118. Good stream bank section through thick (> 2 m), coarse cobbly alluvial gravels of angular to subrounded sandstone clasts, poorly-sorted, clast-supported.
122	S31° 19' 06.0" E24° 51' 48.5"	Winterhoek 118. Stream bed exposure of baked, hackly, grey-green Katberg overbank mudrocks with several *probable* sandstone casts of large vertebrate burrows (up to 60 cm diameter, compressed ellipsoidal cross-section, convex tops) – perhaps a warren. Occasional small-scale (1 cm – diam.) *Katbergia* scratch burrows in area. Proposed Field Rating 111B Local Resource. 50 m-radius buffer zone recommended.
123	S31° 19' 04.5" E24° 51' 50.3"	Winterhoek 118. Stream bed exposure of baked Katberg Fm mudrocks with baked sandstone cast of vertebrate burrow(s) and associated, disarticulated skeletal remains – mainly limb bones - of a small-bodied tetrapod (probably therapsid). Proposed Field Rating 111B Local Resource. 50 m-radius buffer zone recommended. Small-scale wave ripple marks, polygonal mudcracks further downstream.
124	S31° 17' 59.1" E24° 51' 40.8"	Winterhoek 118. Extensive N10 tar road cutting through channel as well as possibke crevasse-splay sandstones and tabular-bedded, grey-green overbank mudrocks of the Katberg Formation adjacent to dolerite dyke. Possible sandstone cast of one or more vertebrate burrows (inaccessible). Ungraded due to equivocal status.
125	S31° 17' 51.6" E24° 53' 53.9"	Farm RE/118. Beaufort Group, resistant-weathering baked exposures of interbedded thin sandstones and grey-green siltstones at southern end of N-S trending ridge-like koppie adjacent to dolerite dyke
126	S31° 17' 48.2" E24° 53' 58.0"	Farm RE/118. Thick package of crumbly, purple-brown mudrocks with subordinate thin grey-green sandstones, rusty-brown calcareous concretions - probably within upper part of Palingkloof Member (upper Balfour Fm).
127	S31° 17' 57.7" E24° 54' 40.0"	Farm RE1/1. Extensive N10 tar road cuttings through lower Katberg Formation – good vertical sections though tabular bedded buff channel sandstones with gullied bases, massive to thin-bedded, grey-green and purple-brown overbank mudrocks. *Possible* vertebrate burrows (require confirmation). Ungraded due to equivocal status.
128	S31° 19' 27.8" E24° 56' 13.3"	Extensive N10 road cutting through tabular-bedded lower Katberg Formation channel sandstone, thinly-bedded heterolithic packages and massive to thin-bedded overbank mudrocks c. 2 km SE of WEF project area. Numerous large, gently-inclined vertebrate burrow casts in sandstone (mostly inaccessible) within zone of darker grey-green, thin-bedded

		siltstones (locally purple-brown) between successive channel sandstone packages, especially towards eastern end of road cutting. Some of these burrows may have helical portions. Proposed Field Rating IIIA. In roadside borrow pit just to the west is good example of pale baked quartzitic channel sandstone in contact with major dolerite intrusion.